WATER RESOURCES AUTHORITY

WATER RESOURCES SITUATION REPORT

July 2017 to June 2018

AUGUST 2018

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Abbreviations and Acronyms

ABA	Athi Basin Area
ACA	Athi Catchment Area
ACFC	Agro Chemical Food Company
ASAL	Arid and Semi Arid Land
ASDS	Agriculture Sector Development Strategy
BOD	Biochemical Oxygen Demand
CETRAD	Centre for Training and Integrated Research in ASAL Development
ENNBA	Ewaso Ng'iro North Basin Area
ENNCA	Ewaso Ng'iro North Catchment Area
GAWASCO	Garissa Water and Sanitation Company
IMU	Intra Management Unit
ITCZ	Inter Tropical Convergence Zone
IWASCO	Isiolo Water and SanitationCompany
KENSOTER	Kenya Soil Terrain
KWSCRP	Kenya Water Security and Climate Resileince Project
LVNBA	Lake Victoria North Basin Area
LVSBA	Lake Victoria South Basin Area
LVNCA	Lake Victoria North Catchment Area
LVSCA	lake Victoria South Catchment Area
MAM	March-April-May
MCM	Million Cubic Meters
MODIS	Moderate Resolution Imaging Spectroradiometer
MU	Management Unit
NAWASCO	Nanyuki Water and Sanitation Company
NDVI	Normalized Difference Vegetative Index
NYAHUWASCO	Nyahururu Water and Sanitation Company
OND	October-November-December
RUSLE	Revised Universal Soilloss Equation
RVBA	Rift Valley Basin Area
RVCA	Rift Valley Catchment Area
RGS	Regular Gauging Station
TBA	Tana Basin Area
TCA	Tana Catchment Area
TDS	Total Dissolved Solids
TP	Total Phosphorus
TSS	Total Suspended Solids
UPOPs	Unintended Persistent Organic Pollutants
WRA	Water Resources Authority
WRUA	Water Resource Users Association

Excecutive Summary

With the growing population, Kenya faces enormous challenges in the management of its limited water resources. The magnitude of the issues, challenges and the severity of water crisis cut across most sectors of the economy hence, making water resources management a high priority. The available water and the demands vary significantly across the drainage basins with the total demand projected to rise to 21,468MCM/year in the year 2030 against available 26,634MCM/year.

One of the key mandates of Water Resource Authority (WRA) is the regulation of water use to ensure fair and equitable allocation and apportionment of the available water resources. To effectively carry out this mandate, WRA determines the supply in respect to surface and ground water quantity and quality so as to attain efficient and economic use, social equity and environmental sustainability. In addition to water allocation and apportionment, WRA also monitors and assesses water resources, gathers and publishes information on water resources, receives and determines application for water permits and collects water use charges. The water resource situation status in Kenya for the period July 2017 to June 2018 has been analysed based on surface water and ground water quantity, quality and allocation .

Analysis of rainfall across the basins show that more rainfall was received in the period July 2017 to June 2018 than the preceeding year. The high rainfall recorded in the period April to June 2018 caused flooding in several parts of the country. The most affected areas were Lower Gucha-Migori, Sondu and Nyando in Lake Victoria basin, Northern Rift Valley basin at Kainuk and Lower Tana basin at Garissa and Lamu.

A total of 75 surface water regular gauging stations (RGSs) were rehabilitated and 5 automated. Streamflow gauging (discharge measurement) campaigns were done on quarterly basis at the basins and sub basins.

Generally, there was poor performance in achieving the Sustainable Development Goals (SDG) Good Ambient Water Quality Standard target of 80% across the basins mostly due to total phosphorus (5% compliance) and dissolved oxygen. Therefore more emphasis should be placed on better nutrient management in order to comply with ambient quality standards. The compliance to effluent discharge standards by effluent dischargers varied across the regions. Ewaso Ng'iro North basin had the highest regional mean of 61.1% compliance while the lowest was Lake Victoria South basin with 36.1% compliance. A total of 7 new Effluent Discharge Control Plans (EDCP) were developed in LVNCA while the other regions did not develop any.

Ten exploratory wells were drilled in Turkana and Garissa Counties while sixteen sites spread across Isiolo (3) Embu (2), Tharaka Nithi (2), Machakos (2), Turkana (2), Marsabit (2) and Garissa (3) Counties were identified for drilling of exploratory boreholes. Assessment of ground water levels showed stable trends in Athi and Ewaso Ng'iro North basins. However, declining levels were evident in Rift valley basin especially the Rongai Aquifer.

A total of 1,241 new water permits were issued accounting for 88,634,650.97m^3/day. The permits included 1,042 ground water, 239 Surface Water and 2 for effluent discharge.

The high flows experienced during the months of April to June 2018 presented a perfect opportunity for generating peak flow data to update the rating curves. The logging gauging stations, were able to record water levels on hourly basis as they occurred. However, streamflow measurements were not carried out in most of the basins therefore the corresponding critical discharges were not captured.

1 INTRODUCTION

Kenya has a total area of 582,646km^2 square kilometres of which about 97% is land and the remaining 3% is water. Of the land area, approximately 490,000 km^2 (more than 80% of the land area) is classified as arid and semi-arid land (ASAL). The remaining area of about 81,000 km^2 is classified as non-arid and profitably usable lands, sustaining a substantial portion of Kenyan economy and human population. With an estimated population of 39 million in 2009 and a projected population of 52 million by 2030, the country faces enormous challenges in the management of its limited water resources. The challenges are associated with water resources data collection and information generation; water scarcity and variability; water pollution; enforcement of water laws; catchment degradation; and climate change impacts. The magnitude of the issues, challenges and the severity of the water crisis that face Kenya cut across most sectors of the economy; hence, making water resources management a high priority.

The climate of Kenya is primarily influenced by the movement of the Inter Tropical Convergence Zone (ITCZ) and by topographic relief, especially elevation. The rainfall in Kenya is affected by large water bodies like Lake Victoria, complex topography with the Great Rift Valley and high mountains like Mt. Kenya and Mt. Elgon. A relatively wet and narrow tropical belt lies along the Indian Ocean coast. Behind the coastline stretches large areas of semi-arid and arid lands. Kenya generally experiences two seasonal rainfall peaks of long rain (March – May) and short rain (October - December). Mean annual rainfall over the country is 680mm. It varies from about 200 mm in the ASAL zone to about 1,800mm in the humid zone.

Kenya has five major basins namely, Lake Victoria, Rift valley, Athi, Tana and Ewaso Ng'iro North. The largest is Ewaso Ng'iro North with a drainage area of 210,223km^2, i.e 25% of Kenya, followed by Rift Valley with a drainage area of 130,452km^2. Tana, Athi and Lake Victoria basins constitute 126,026km^2, 58,639km^2 and 31,734km^2 respectively. The available surface and ground water yields are shown in Table 1.1 while Table 1.2 presents the water demand in Kenya estimated for the years 2010, 2030 and 2050. The total water demand in 2010 was 3,218MCM/year against available 22,564MCM/year. The demand will rise to

21,468MCM/year in the year 2030 against available 26,634MCM/year. Although there seem to be sufficient water to meet the demand, available water resources in Athi basin barely met the demand in the base year of 2009. As is evident from Tables 1.1 and 1.2, the situation may worsen by the year 2030. Because of human activities and climate variability, water availability in space and time has not been guaranteed in the recent years and hence the need to manage and conserve the resource.

Table 1.1: Available Water Resources by basins *(Units in MCM/yr.)*

Catchment Area	Area (sq.km)	2010	2030	2050
LVNCA	18,374	4,742	5,077	5,595
LVSCA	31,734	4,976	5,937	7,195
RVCA	130,452	2,559	3,147	3,903
ACA	58,639	1,503	1,634	2,043
TCA	126,026	6,533	7,828	7,891
ENNCA	210,226	2,251	3,011	1,810
Total	**575,451**	**22,564**	**26,634**	**28,437**

Source: *National Water Master Plan (NWMP 2030)*

Table 1.2: Water Demand per Region *(Units in MCM/yr.)*

Catchment Area	Area (sq.km)	2010	2030	2050
LVNCA	18,374	228	1,337	1,573
LVSCA	31,734	385	2,953	3,251
RVCA	130,452	357	1,494	1,689
ACA	58,639	1,145	4,586	5,202
TCA	126,026	891	8,241	8,476
ENNCA	210,226	212	2,857	2,950
Total	**575,451**	**3,218**	**21,468**	**23,141**

Source: *National Water Master Plan (NWMP 2030)*

1.1 Overview

Water resources availability determines the patterns of human settlements and socio-economic development. The available water resources in all the basins in Kenya have been assessed in the National Water Master Plan 2030. Table 1.1 gives the projected water resources for the years 2010, 2030 and 2050. The increase in available water resources in the six basins is attributed to the projected increased rainfall due to impacts of climate change.

Surface water is the backbone of hydro-electric power generation, major irrigation schemes and water supplies. This includes the 7 forks hydropower schemes in the Tana River basin, Bura, Mwea, Kano and Perkerra irrigation schemes. The water supplies are for Nairobi, Mombasa, Kisumu, Eldoret, Nakuru and other Urban and Rural Water Supplies. Ground water resources has also played a key role in development of domestic, agricultural, industrial, municipal and rural settlements. It is a major source of water for Mombasa, Nakuru and Nairobi. Most of the drinking water supplies especially in the rural arid areas are sourced from groundwater systems.

The reliability of the water resources for different uses is highly dependent on the physical and chemical composition. Point and non-point water pollution is a key challenge in ensuring accessibility of safe water resources in Kenya. Water Resources Authority (WRA) has an obligation to ensure equitable access to water in the right quality and quantity for the production, environment and basic human needs. This is achieved through water allocation planning, catchment rehabilitation programs and effluent discharge. Different approaches have been employed to achieve this amongst them catchment rehabilitation programs, done in partnership with WRUAs though the implementation of Sub-Catchment Management Plans. Another approach is Effluent discharge Management.

Water resources monitoring is a key factor in water resources management and hence the need to capture the temporal and spatial variation in water resources. For this purpose, Water Resources Authority monitors surface water, climate (specifically rainfall), groundwater, water quality and water use.

1.2 This Report

This report presents the water resource situation status in Kenya for the period July 2017 to June 2018. It outlines the achievements and experiences through analysis of both qualitative and quantitative data. Hydro-meteorological, hydro-geological, water quality and water rights data collected during the period under review have been used and compared with the preceeding year and long term. The analysis has been done based on drainage basins of Lake Victoria North, Lake Vitoria South, Rift

Valley, Tana, Athi and Ewaso Ng'iro North. It should be noted that the terms *basin area* and *catchment area* have been used interchangeably in this report.

1.3 Data Availability

Water resource data is usually collected, digitized and stored in the regional databases. Backups of regional data bases are restored in the national database at WRA headquarters in Nairobi on monthly basis. Analysis is done and used for guiding water resources decision making, determining applications for water among other uses. The WRA hydrological year book provides meta data on available data in WRA data base for each monitoring station and can be viewed in the Water Resources Authority website; www.wra.go.ke.

While the work of developing a knowledge base is on-going, data from the operational stations are being received at the respective regions and sub regional offices. Table 1.3 shows the operational stations, duration of data collection in the six basins and frequency of updating the database while Figure 1.1 gives the summary of data received from each region.

Table 1.3: Operational stations, duration and frequencyof data collection

	Water resources monitoring stations and data submission frequency up to June 2018														
Region	**Operational stations**					**% Data submitted to Database**					**Frequency of update**				
	SW	GW	WQ	RF	EVP	SW	GW	WQ	RF	EVP	SW	GW	WQ	RF	EVP
LVN	24	21	58	3	1	69	48	33	78	100	Monthly	Monthly	quarterly	Monthly	Monthly
LVS	53	12	30	30	19	23	19	35	41	38	Monthly	Monthly	quarterly	Monthly	Monthly
RV	40	33	40	6	2	64	91	77	76	100	Monthly	quarterly	quarterly	Monthly	Monthly
ATHI	33	40	54	29	3	35.10	34	34	36.21	66.67	Monthly	Monthly	quarterly	Monthly	Monthly
TANA	41	18	33	10	2	53.9	0	50	62.5	29.2	Monthly	Monthly	Bi annual	Monthly	Monthly
ENN	31	12	48	12	6	65	29	83	90	14	Monthly	Monthly	quarterly	Monthly	Monthly

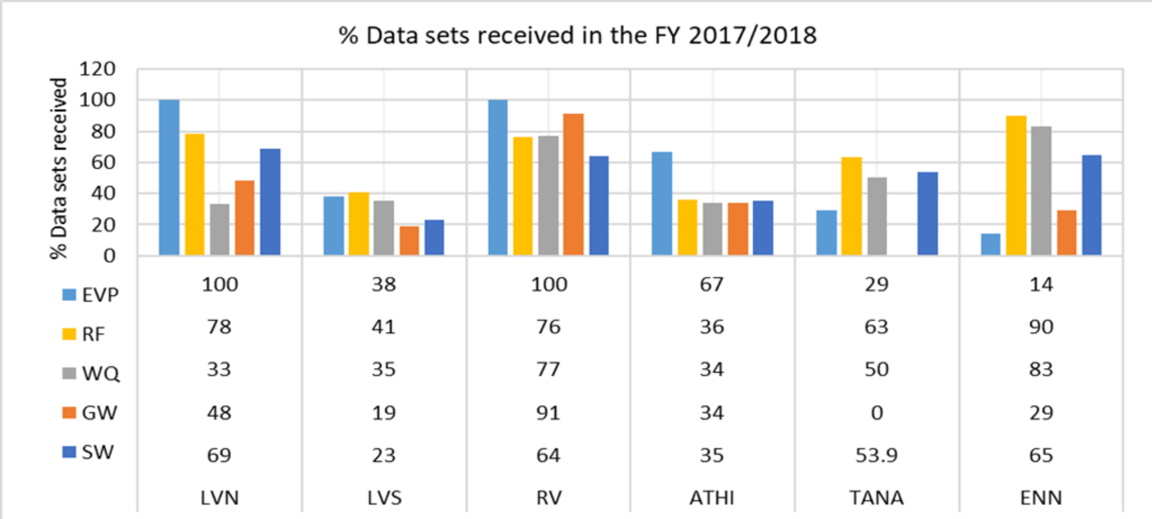


Figure 1.1: Datasets received in the FY 2017/18

2 CLIMATE

2.1 Description of Monitoring Network

Water Resources Authority operates a weather monitoring network comprising rainfall, evaporation and climate stations. During the year under review, 135 out of 260 rainfall stations were operational, 47 of 65 evaporation stations were operational and 18 of 34 climate stations were operational. The regional breakdown is given in the Table 2.1.

Table 2.1: Description of weather monitoring network

	Rainfall	No. Operational	Evaporation	No. Operational	Climate	No. Operational
Athi	47	28	10	5	2	0
ENNCA	26	23	4	2	9	2
LVN	72	30	10	3	5	0
LVS	41	6	20	20	12	12
RVCA	22	18	7	6	4	4
Tana	52	30	14	11	2	0
Total	260	135	65	47	34	18

The weather monitoring stations operated by WRA are strategically located at various parts in the catchments. Data is also obtains data from various stakeholders such as private institutions, government and learning institutions. The data collected from these stations is used for modelling and planning purposes. It is also available to the public at a fee. Figure 2.1 shows the distribution of weather monitoring stations.

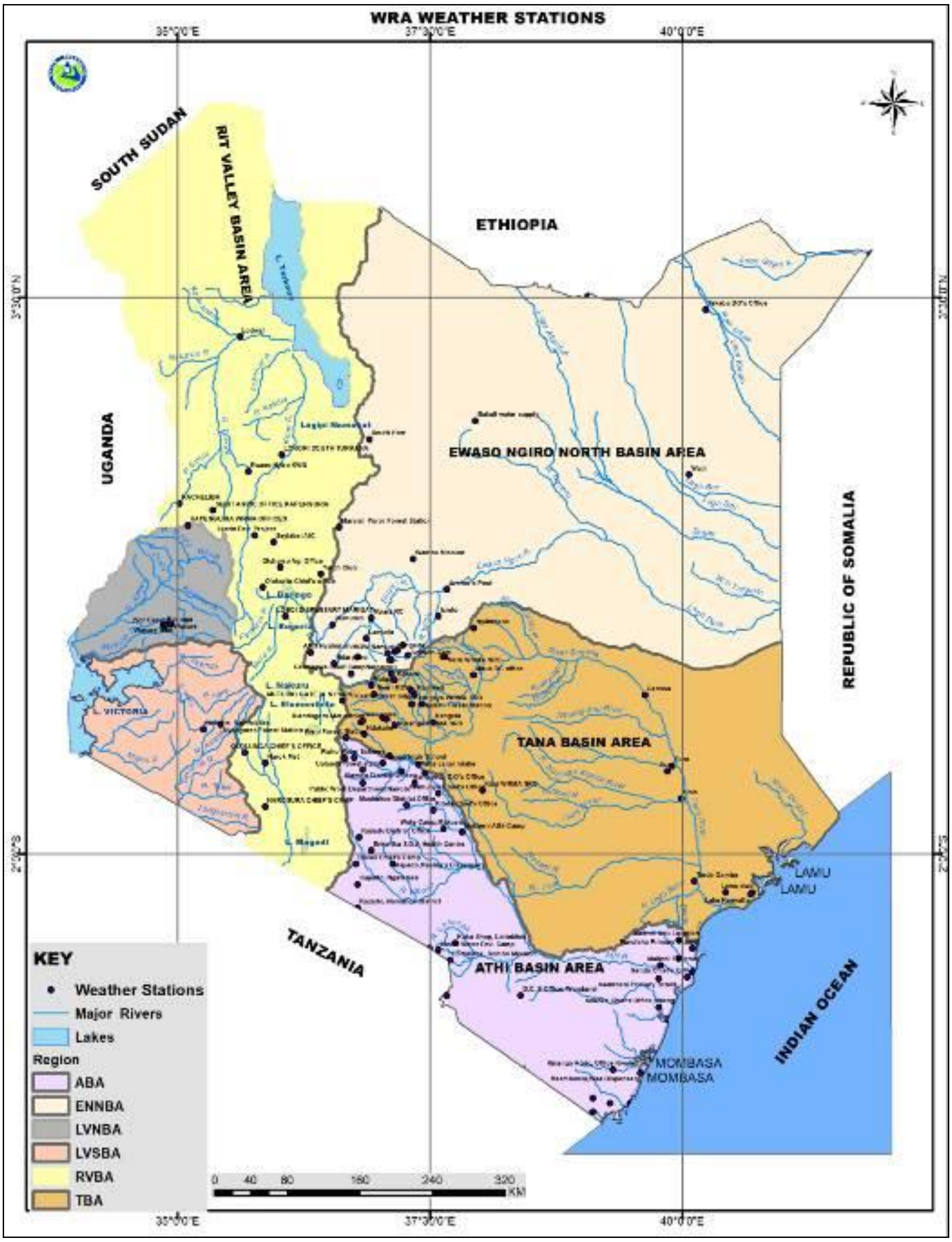


Figure 2.1: Rainfall monitoring network

2.2 Improvements to Network

Climatic monitoring network is frequently affected by vandalism and loss of precision due to ageing. To improve on this and maintain the integrity of data collected, WRA has been regularly maintaining and improving the monitoring network. However, except for the routine maintenance works like clearing of sites, no major improvement was undertaken to the network.

The Ewaso Ng'iro North regional office got into an arrangement with CETRAD to have access link to telemetric weather stations operated by CETRAD. The region and WRA head office therefore receives real time data from Nyambene, Naromuro, Nyahururu, Wamba and Marsabit weather stations.

Before Maintenance | During Maintenance | After Maintenance

Figure 2.2: Maintenance of the Muranga Water Supply Met station (9037109)

2.3 Analysis of Rainfall, Evaporation & Climate

2.3.1 Athi Basin Area

A comparative analysis of rainfall received from six monitoring stations within Athi catchment during the year under review is shown in Figure 2.3.

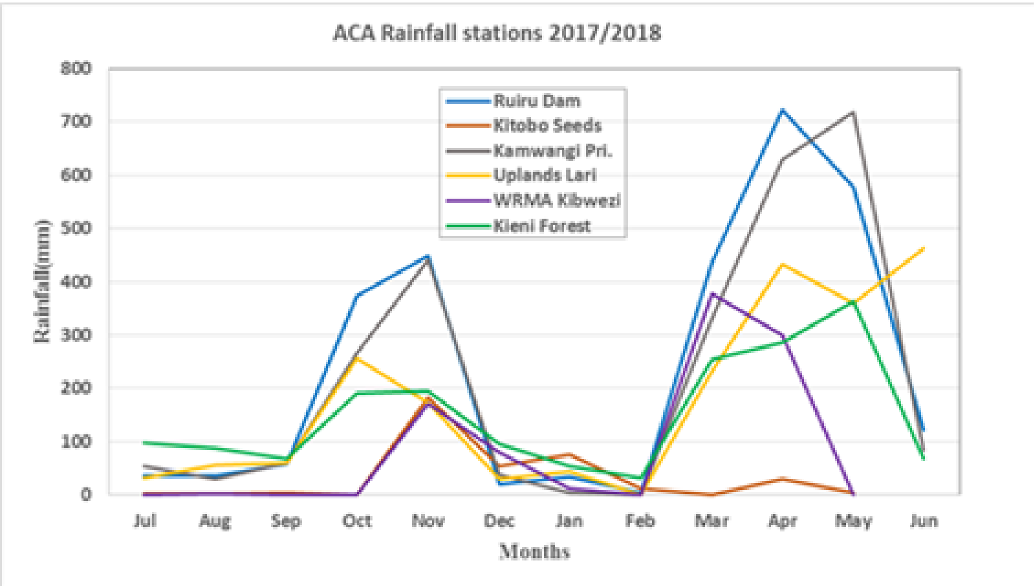


Figure 2.3: Monthly Rainfall totals for selected stations in Athi Basin for FY 2017/18

The rainfall which is bimodal had two peaks in the months of October, November, December (OND) and March, April, May (MAM). The MAM total rainfall for Ruiru Dam and Kamwangi stations was almost twice the Amount received in OND. Koitobo Seeds received very little rainfall in MAM unlike the other stations.

2.3.2 Ewaso Ng'iro North Basin Area

Analysis of rainfall data was dictated by data availability. Only two stations had complete data sets for the period under review, hence analysis was done for the two stations as indicated in Figures 2.4 and 2.5. There was additional data from Cetrad telemetric stations for Nyambene, Archers Post, Naromoru, Wamba and Marsabit were also used. These stations are a good representation of the status in the Ewaso Ng'iro North basin. The rainfall variability and monthly rainfall have been analysed for the five stations.

Rumuruti Sub Met Station

The month of August 2017 received the highest rainfall of 63.3mm while low rainfall of 0mm was recorded in December 2017. The MAM rainfall in the period under review was higher than the previous year.

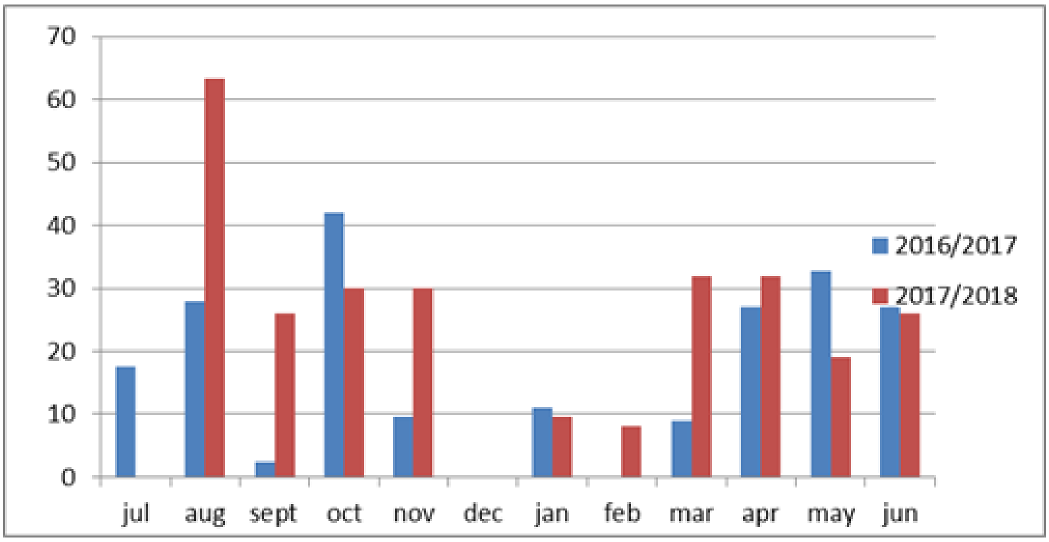


Figure 2.4: Rumuruti Sub-met comparative rainfall for FY 2016/17 and 2017/18

Ndaragwa Rainfall Station

In the year under review only the month of January was below the long-term mean. Compared to 2016/2017 the year had relatively more rains. The month of June recorded the highest rainfall since 1973.

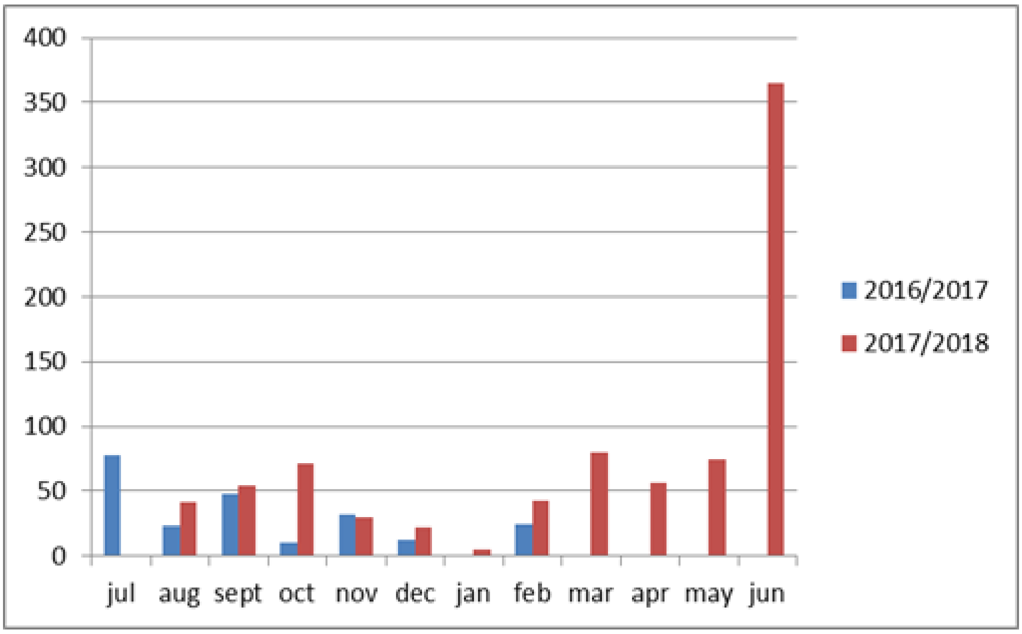


Figure 2.2: Comparatve Rainfall for Ndaragwa Rainfall Station for 2 years

CETRAD Stations

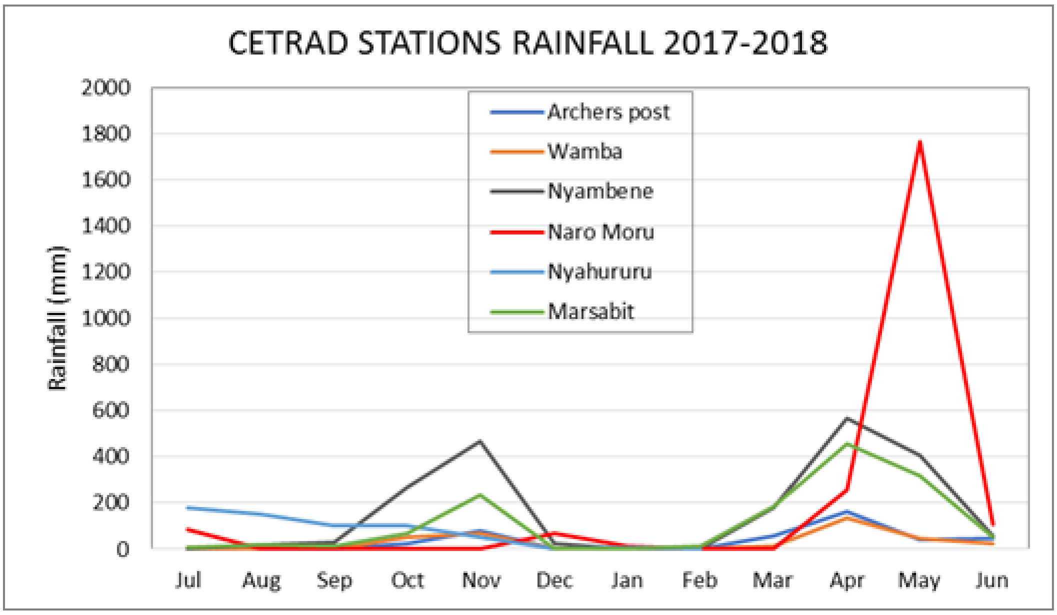


Figure 2.6: Monthly totals for CETRAD Rainfall Stations

The Naromoru Station had exceptionally high rainfall in the month of MAM compared to the other five stations whose peaks for OND and MAM were relatively the same.

2.3.3 Lake Victoria North Basin Area

Lake Victoria North Catchment Area receives bimodal rainfall pattern with long rain season experienced between March and May while short rains come between September and November. The driest months are December, January and February. The amount of rainfall received during the period July 2017 to June 2018 in LVNBA was generally high compared to the same period in July 2016 to June 2017.

Rainfall at Kitale Water Yard Rainfall Station

In January and February 2017 there was more rainfall compared to the same months 2018 while March to May 2018 there more rainfall received in this station than 2017.

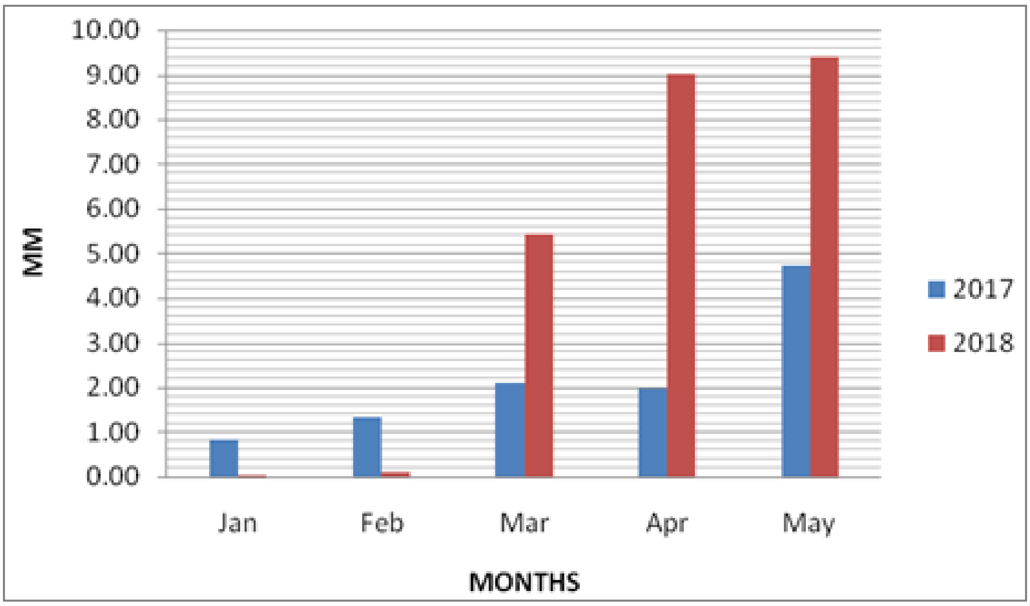


Figure 2.7: Monthly Rainfall at Kitale Water Yard Rainfall Station

Kwangamor Rainfall station in Busia (8934169)

In the financial year 2016/17 the station received a total rainfall of 44.43mm with a mean of 3.42mm while in 2017/18 the station received a total rainfall of 72.22mm. Therefore, there was an increase of 27.79mm translating into 63%. A comparison was done for the months of January to June 2017 and 2018 and the results are displayed in the table below. In the months of January, February and May, 2017 received more rainfall than 2018.

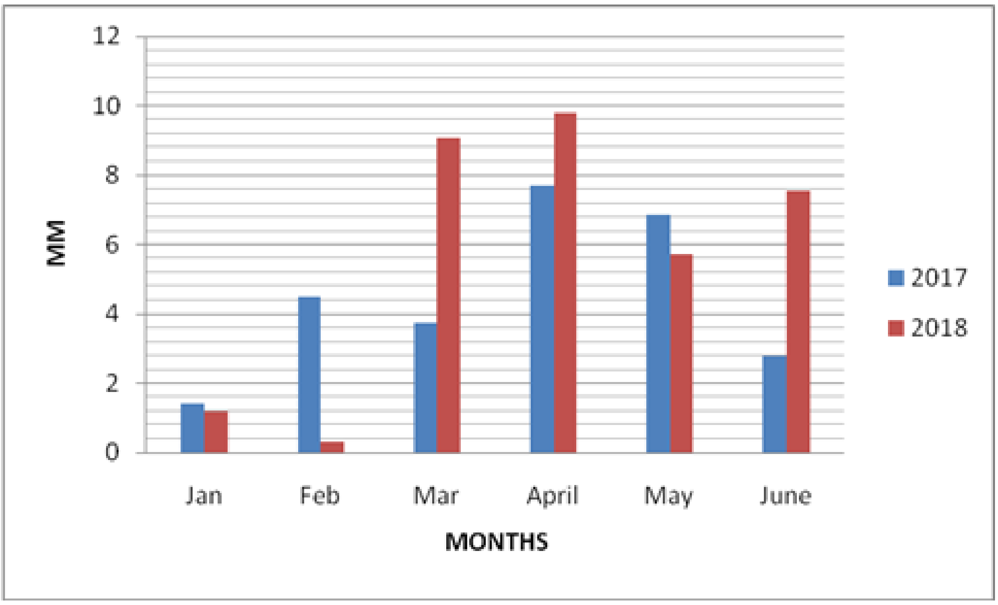


Figure 2.8: Comparative Rainfall for Station 8934169 Kwangamor

2.3.4 Rift Valley Basin Area

Rift valley basin generally received high rainfall especially during the long rains of March to June season. Figure 2.9 shows monthly total precipitation at Kabarnet Water Yard for the period July 2017 to June 2018.

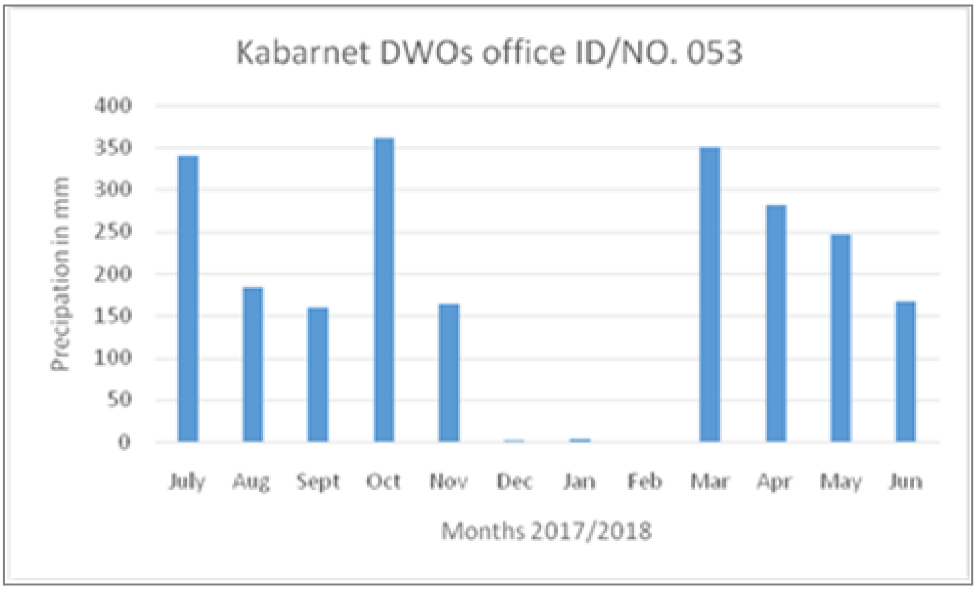


Figure 2.9: Kabarnet Water Yard Rainfall trend

The year was wet with only December, January and February recording less the 150mm of rainfall.

2.3.5 Tana Basin Area

During the Year under review there was alot of rainfall which resulted into floods within the sub-region. Analysis of the period under review compared to the previous years has been analysed.

From Figure 2.10, the rainfall of 1,490mm received during in the FY 2017/ 2018 was higher than the previous three years. The lowest rainfall recorded during these four years was 630mm for the FY 2016/2017.

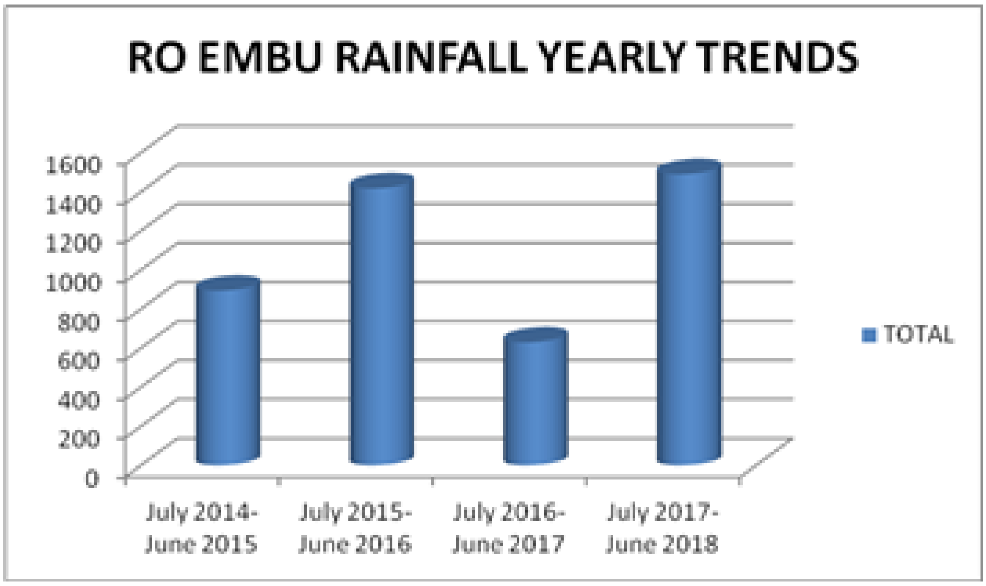


Figure 2.30: Embu RO Office Met Station 4 Yearly Trends

A comparison of total annual rainfall in the last six years at Meru DWO rainfall station is given in Figure 2.11. The year 2018 had the highest rainfall with a total of 878.7mm while 2014 had the lowest total of 304mm. Flash floods were experienced in the months of April and May 2018.

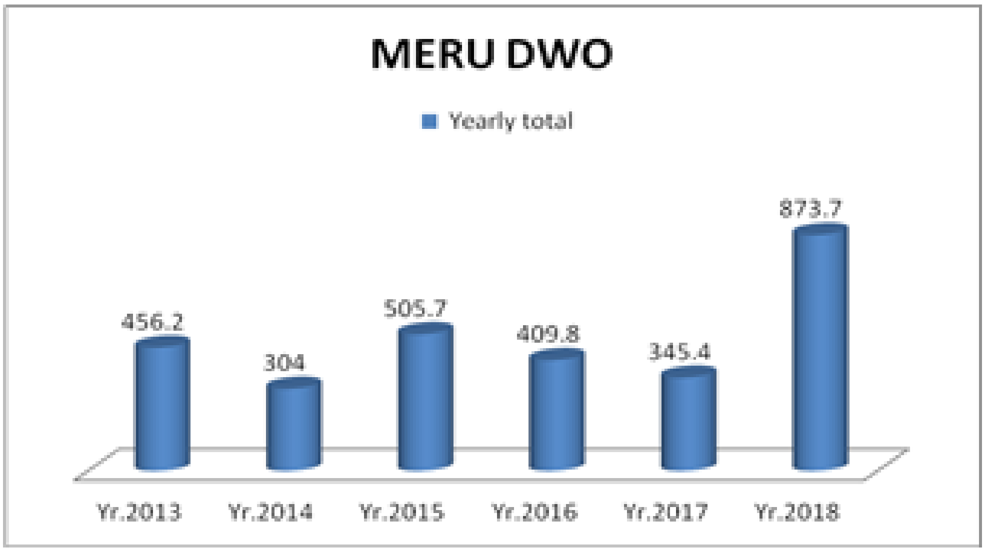


Figure 2.41: Meru DWO Rainfall station- Yearly Trends

Rainfall trends for the last seven years at Murang'a DWO rainfall station are shown in Figure 2.12. The highest rainfall of 3488.8mm was recorded in the period 2017/2018.

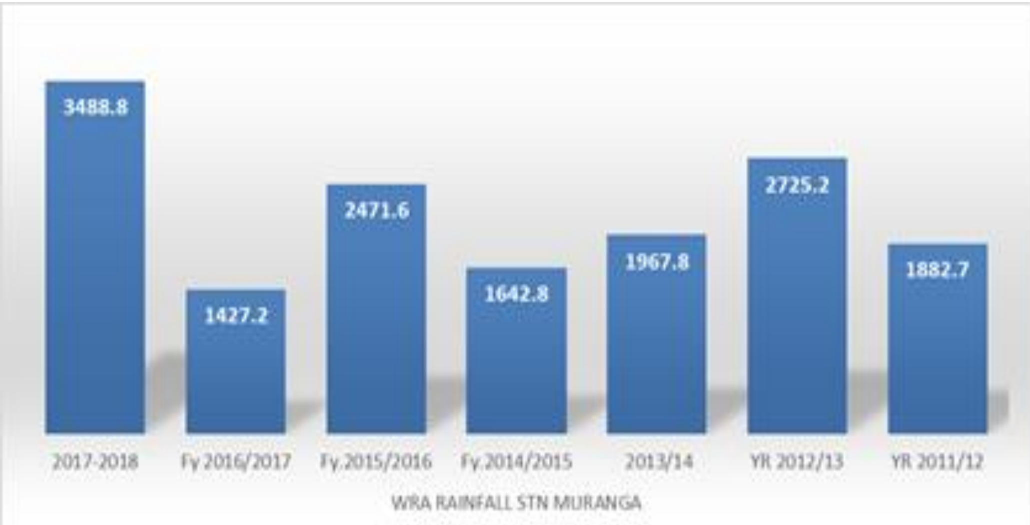


Figure 2.52: Murang'a DWO 9037109 Monthly Rainfall

2.3.6 Lake Victoria South Basin Area

The long-term analysis of rainfall in the catchment was represented by the following sations; Maseno Vet, Ahero, Olenguruone and Bomet w/s.

The rainfall received in Maseno from July 2017 to June 2018 was about 2,920mm, Kipkelion water supply had about 1,608 mm from July 2017 to June 2018. The dry months of the year in the long term are December to February while March to June was wettest period.

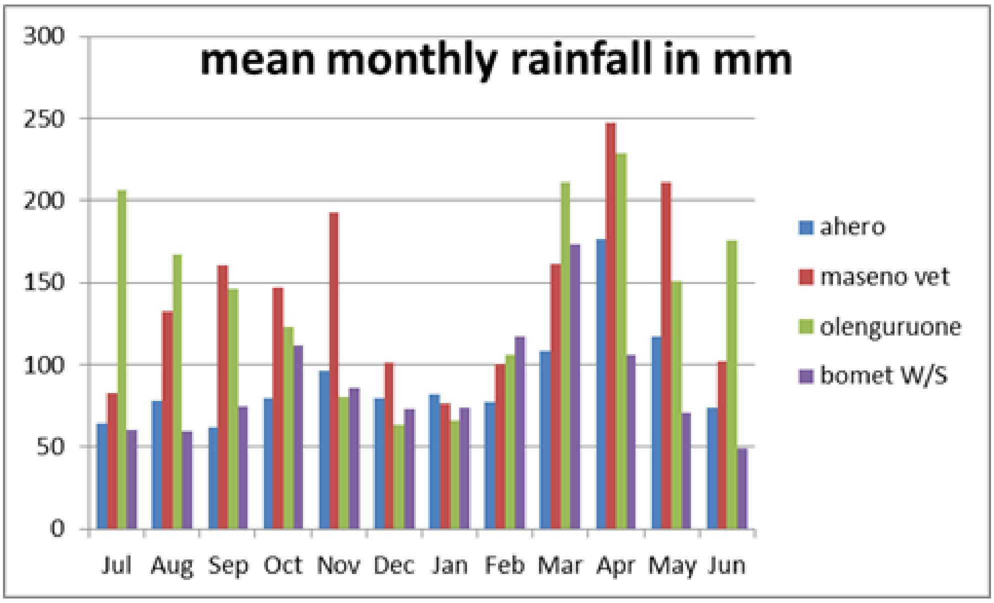


Figure 2.63: Long-term mean rainfall for selected stations in LVB

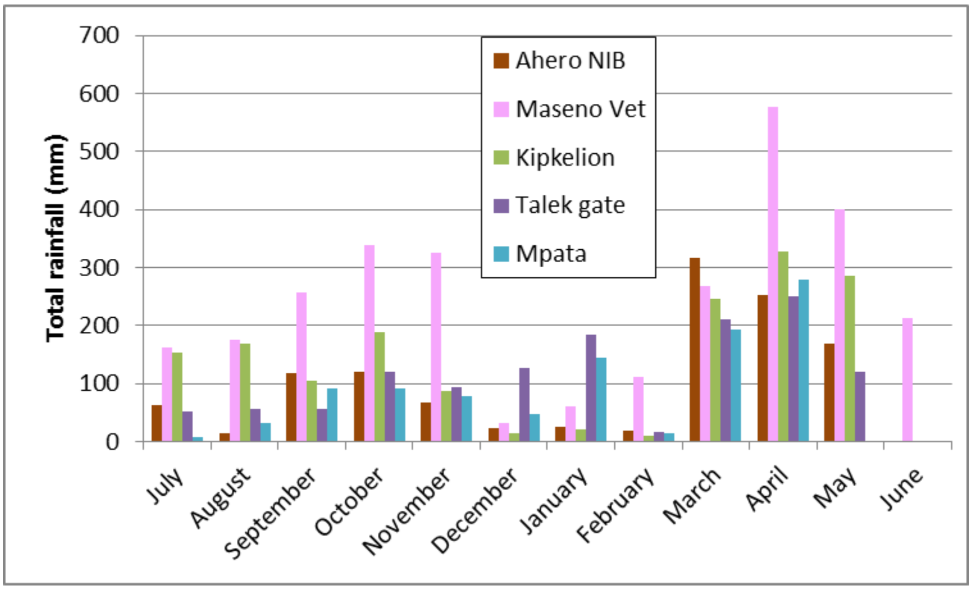


Figure 2.74: Monthly Rainfall during the FY 2017/2018

The year 2017/2018 was relatively wet compared to the long-term average. Maseno and Ahero received more rainfall during the MAM period compared to the long-term. Bomet water supply recorded the lowest rainfall of 20mm.

The total annual rainfall increased over the years for the stations at Ahero, Maseno Vet, and Bomet water supply while Olenguruone station experienced reduction in annual total rainfall until late 70s before the station started recording increasing annual totals with years.

2.4 Comments on Special Events

Lake Victoria South basin had flood cases reported in Nyando, Sondu and Gucha – Migori river basins which resulted in property damages and loss of lives.

Generally, there was increase in precipitation in the Rift valley basin where rift valley lakes levels rose during this period. Floods were experienced in some areas like Kainuk (Malmalte 2B30) which caused collapse of the Kainuk bridge connecting West Pokot and Turkana Counties, Narok where property was destroyed but no deaths were reported.

The effect of high rainfall experienced in Athi basin in the months of April and May had great impact on volumes of water that were recorded in the existing dams. By mid May 2018 most dam reservoirs were over 90% full.

Tana basin experienced severe flash floods in the month of April and May 2018, which generated high volume of runoff in excess of the drainage causing landslides. Several settlement areas in Garissa, Tana River and Lamu were submerged, families displaced, and properties destroyed. Ewaso Ng'iro North had rains spread across most of the basin which resulted in floods in almost all parts of the basin.

2.5 Special Studies

There were no specific special studies carried out in relation to climate. However, two special studies were carried out in Nzoia watershed and Tana basin as enumerated in section 3.7.

3 SURFACE WATER RESOURCES

This section presents an overview of the surface water situation. Description of the surface water monitoring network, analysis of streamflow characteristics, reserve situation and special studies are presented.

3.1 Description of Monitoring Network

The surface water monitoring network is shown in Figure 3.1. There are a total of 223 surface water monitoring stations categorized as National, Management Unit, Intra Management unit and Special Stations. The number of stations and operational status are given in Table 3.1.

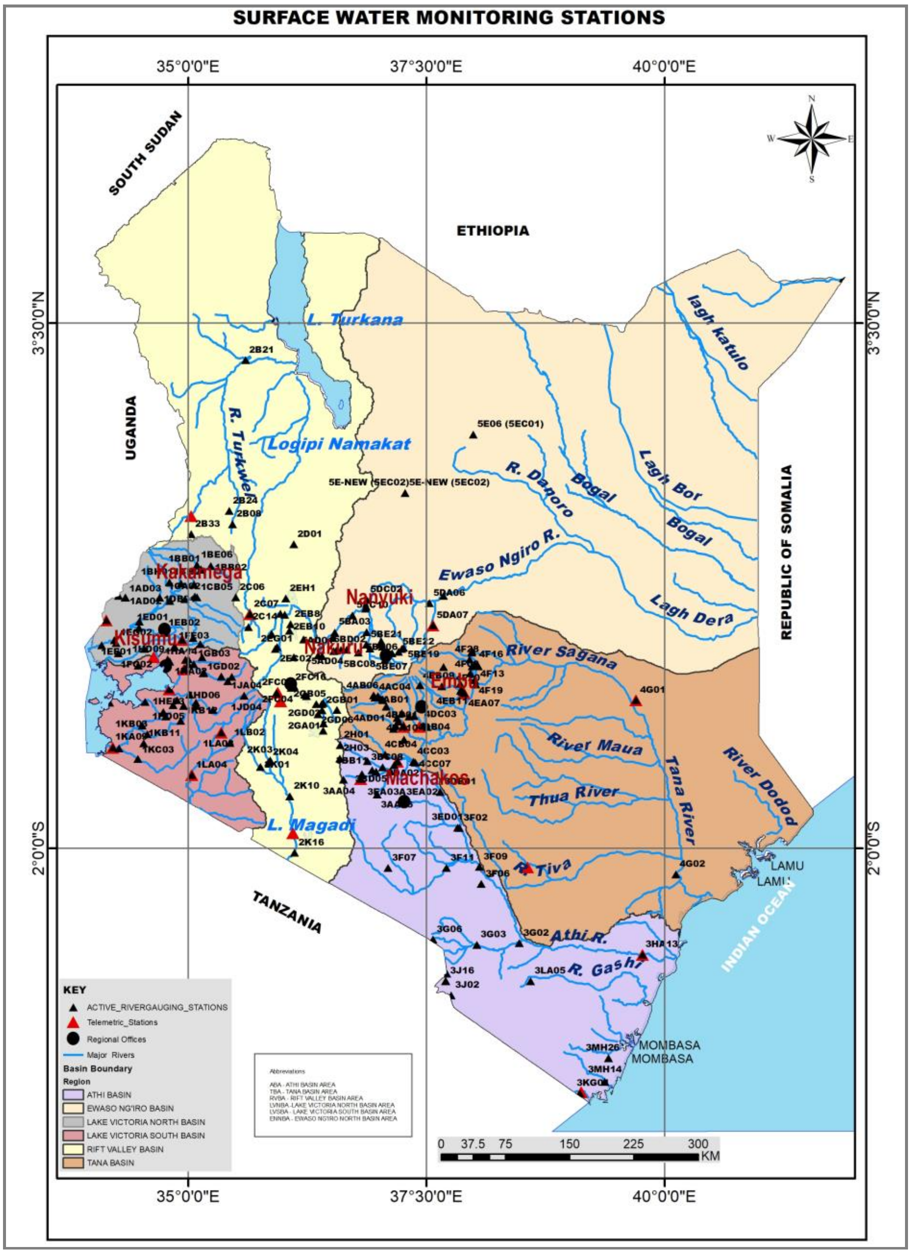


Figure 3.1: Surface Water Monitoring Network

Table 3.1: Monitoring Stations and Operational Status

Region	Category				Total	% Operational
	National	Management Unit	Intra Management Unit	Special		
LVNCA	5	6	10	7	28	**78.6**
LVSCA	5	14	26	2	47	**85**
RVCA	4	8	14	0	26	**61.5**
ACA	3	4	21	3	31	**73**
TCA	1	24	15	15	52	**57.4**
ENNCA	1	5	33	1	40	**72.5**
Total	**22**	**48**	**122**	**31**	**223**	**71.3%**

3.2 Improvements to Network Infrastructure

During the year under review 73 Regular (River) Gauging Stations were rehabilitated and 5 automated in the country.

3.2.1 Lake Victoria North Basin Area

There were nine stations rehabilitated in the region. These were Edzawa 1FF03, Yala 1FE02, Malakisi 1AD02, Nzoia 1BB01, Nzoia 1DA02, Nzoia 1DD01, Isiukhu 1EB02, Sio 1AH01 and Yala 1FG02. Construction of logger house at Yala River 1FG02 earmarked for upgrading to telemetry under the capital project was completed and installation of the equipment done.

The Yala River RGS 1FG02 is situated at the Bondo Water Supply Intake at the road crossing for Siaya Bond Road approximately 15 km for Siaya Town. This is a National station but it had not been upgraded and was only having manual gauges. The station was assessed in February 2017 for the purpose of upgrading. A Recorder house was constructed in August 2017 and the equipment installed on 17th September 2017. The equipment consists of a water level, rainfall and temperature sensors. Data is logged on hourly basis and transmitted to the server once every 24 hours.

Figure 3.2: Recorder house and Equipment at RGS 1FG02 Yala River

Figure 3.3: Rehabilitated RGSs 1AD02 Malakisi (left) and 1DA01 Nzoia at Webuye (right)

3.2.2 Lake Victoria South Basin Area

Ten RGS were rehabilitated. These included Nyando 1GD07, Awach Seme 1HB05, Gucha- Migori 1KB05, Ainamutua 1GB03.Nyamasaria 1HA11, Migori 1KC03, Gucha Macalder 1KB01A, 1LA03, Kipsonoi 1JF08, Yurith 1JD03, Kimugu 1JC03.

3.2.3 Rift Valley Basin Area

In the reporting period (FY 2017/18) 16 no stations were rehabilitated. Seven stations were rehabilitated in upper and lower turkwell Sub-Regions in collaboration with Tullow oil Ltd. One station was established though it was later washed away. Upgrading of Kerio 2C07 through installation of telemetric data logger which was started in the last FY was completed in the year.

3.2.4 Tana Basin Area

In Tana basin, the site cross sectional survey and topographical survey was carried out by JICA Team in collaboration with WRA. Two Cross sectional surveys and fixing of station benchmarks for 6 monitoring stations were carried out for 4CC08

Thika, 4BE1 R. Maragua, 4DD2 . Thiba, 4F10. Kathita, 4BE10 Tana Rukanga and 4BE1 Maragua.

Thirteen RGSs were rehabilitated including Tana Rukanga 4BE10, Thiba 4DD2, Kathita4F10, Rupingazi 4DC6II, Rupingazi4DC3, Thingithu 4F17, Thangatha 4F08, Mutonga 4EA6, URA 4F09, Amboni 4AB06, Maragua 4EB1, Garissa 4G01 and Garsen 4GO2.

Six stations were Upgraded to Telemetry in Upper Tana for Monitoring sasumua and Ndakaini system. These were Thika 4CB05, Thika 4CB07, Ndakaini dam -Chania outfall canal, Ndakaini dam-Kiama canal, Sasumua dam -Chania canal to sasumua River, Sasumua dam -Kiburu canal to sasumua dam and Sasumua dam -Kiburu canal to sasumua dam. Other stations upgraded to telemetry were Thiba 4DD02 and Mutonga 4EA06.

4BE10 Tana Rukanga rehabilitation in conjunction JICA team.

4F10 Kathita rehabilitated and installed with telemetry

Logger at Chania canal of Sasumua dam.

Figure 3.4: Rehabilitation of RGSs 4BE10 Tana at Rukanga (left) and 4F10 Kathita(middle) and Chania Canal (right)

3.2.5 Tana Basin Area

During the period under review 10No. regular gauging stations were rehabilitated. The stations were 5DA01 Isiolo, 5ED01 Ewaso Ng'iro, 5BC02 Naro Moru, 5DA01

Ngare nything, 5BE05 Teleswani, 5AD01 Mutara, 5AB02 Pesi, 5BD02 Suguroi, 5BE22 Sirmon and 5AC10 Ewaso Narok.

3.3 Improvements to Data Quality

The upgrading of stations to automatic logging and telemetric transmission has ensured that accurate and timely data is captured. The automatic stations are configured to record data on hourly basis and transmit to a server which can be access via web-based portal. This stations would however require regular maintenance and prompt battery charging/replacement to avoid losing data.

Gauging campaigns are done to validate and improve rating equations. The gauging plan for the regions entails sustained discharge measurement at the newly installed or rehabilitated stations in order to develop and/or improve the rating curves. This was done quarterly by the regions but the data needs to be entered in the database for updating of the rating curves. Monitoring stations were maintained across the regions as follows; Lake Victoria North basin carried out maintenance at 10 stations while Tana basin monitored 30 RGSs. Special gauging campaigns were carried out in Athis basin by EGIS consulting firm at Umba River 3KG01, Mwena River, Ramisi River 3KB1, Pemba/Manolo 3MH, Mwache River and Chigutu River.

Figure 3.5: RGS Assessment: left and Centre 1EF01, Nzoia at Ruambwa and 1HA01Sio River respectively

3.4 Assessment of Surface Water Resources

This section analyses river flows in selected stations for the period July 2017 to June 2018.

3.4.1 Lake Victoria South Basin Area

Assessment of stream flows was a challenge because very few data sheets were received from gauge readers. Therefore, data from only nineteen stations, RGS

1LA04 Marai,1LA07 Sand River, 1LA08 Talek, 1LA03 Nyangores, 1LB02 Amala in Mara River basin, 1JA02 Kiptiget 1JG04 Sondu in Sondu River basin, 1GB05 Ainamutua, 1GB06A Mbogo, 1GC06 Kipchorian,1GD02 Nyando, 1GD07 Nyando in Nyando River basin, 1HA14 Awach - Kajulu,1HA11 Nyamasaria in Nyamasaria basin, 1HA01 Great Oroba , 1HD05 Awach Kasipul, 1HD06 Eaka Kioge in Tende Kibuon basin, 1HE02 Mogusii in Tende basin and 1KB12 Gucha in Gucha Migori basin were analysed.

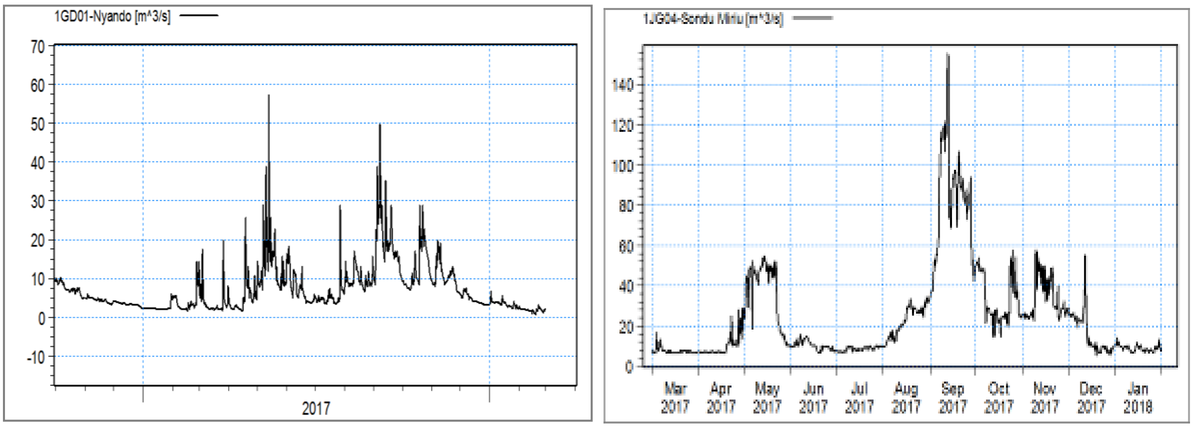


Figure 3.6: Streamflow hydrographs for Nyando 1GD03 and Sondu river 1JG04

3.4.2 Lake Victoria North Basin Area

Stream flow analysis for FY 2017-18 was dictated by data availability. Six stations were analysed, i.e. Malakisi River 1AB01 and Nzoia River 1DA02. 1BB01 Nzoia River. The analysis show that there was more flow in the year 2018 compared to 2017 at all Rivers monitored.

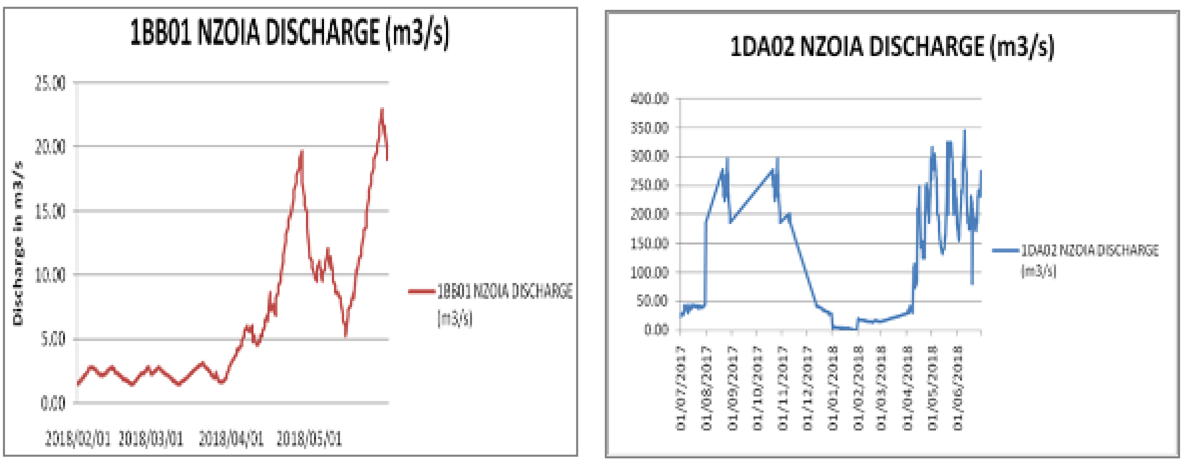


Figure 3.7: Streamflow variability at Nzoia river 1BB01 and 1DA02

The discharge at Nzoia River 1BB01 increased gradually with a peak of 19.66m3/s on 28th April 2018 which was followed by a drastic reduction with the lowest of 5.23m3/s.Nzoia River 1DA02 recorded two peak flows during the year under review of 296.30m³/s in August 2017, and 336.12m³/s was recorded in 10/6/2018.

3.4.3 Tana Basin Area

Analysis of water level hydrographs at Tana River 4G01 at Garissa and 4G02 at Garsen between the months of April and june 2018 shows that there was a steady rise at the beginning of the period and that the water level was maintained well above 3.5m which is the flood level threshold.

Figure 3.8: Water level hydrograph at Tana river 4G01 and 4G02

3.4.4 Ewaso Ng'iro North Basin Area

The four sub basins analysed depicted almost similar stream flow characteristics throughout the year. Among the three stations in the upper sub basin, Equator River had the highest flow recorded in the month of May 2018 which is contrary to long term mean and previous year 2016/17. This could be attributed to the extra ordinary rains experienced in the upper reaches at the onset of long rain period which extended to the month of June.

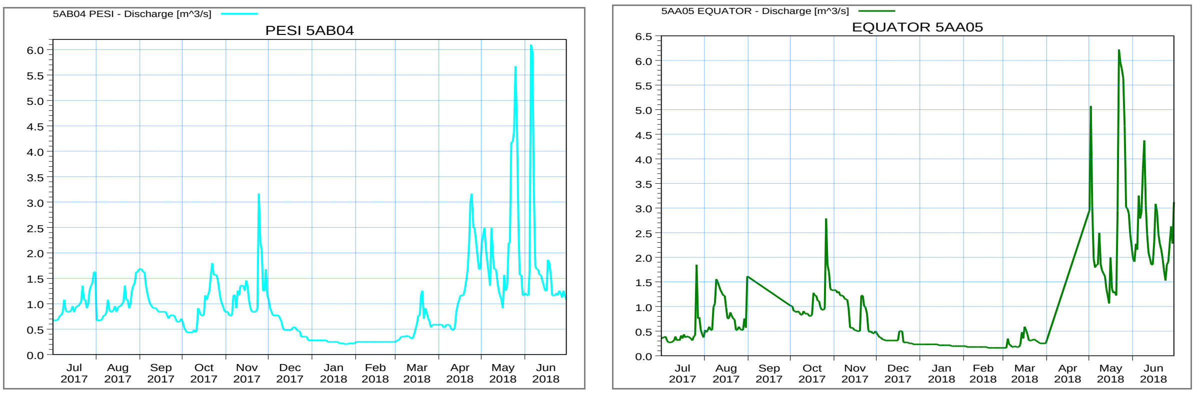


Figure 3.9: Streamflow variability at Pesi River 5AB04 and Equator River 5AA05

Pesi River had many months having flows more than the long term mean and the previous year. In all the months the mean monthly flows in the period under review for Ewaso Narok River was more than the long term mean and the previous year 2016/2017 .The flows as observed gradually increased at the start of the period and rapidly to the end of the review period.

Temporal comparisons of flow for the year under review with the previous year at the four RGS in the Engare Narok Melghis catchment that is Pesi, Mutara, Equator and Ewaso Narok indicate increase in flow towards the end of the period. This could be as a result of the MAM rains in the sub catchment. The situation could be considered as stable compared to previous season.

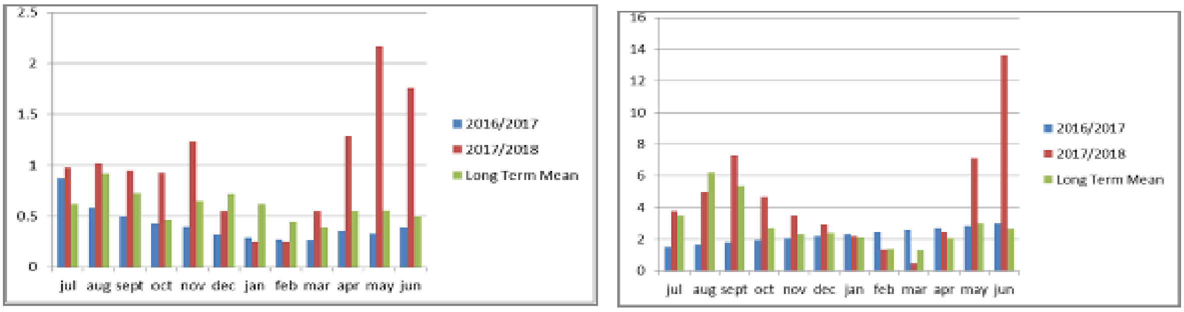


Figure 3.10: Comparison of long term mean flows vs monthly mean flows for FYs 2016/2017 and 2017/2018 at Pesi River 5AB04 (left) and Ewaso Narok River 5AC15 (right)

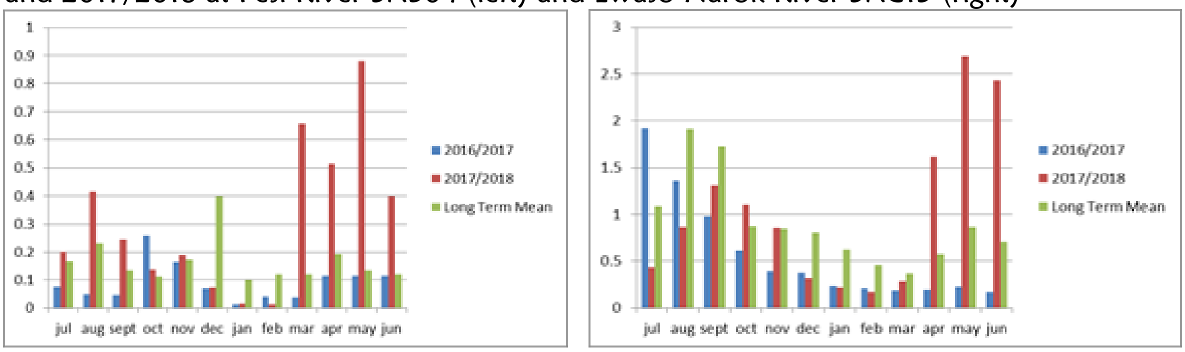


Figure 3.11: Comparison of long term mean flows vs monthly mean flows for FYs 2016/2017 and 2017/2018 at Mutara River 5AD04 (left) and Equator River 5AA05 (right)

For Mutara and Equator Rivers, the period under review had more flows in all months than the long term mean except in three months only.Comparing to 2016/17 the flows were more in almost all the months. The months of April, May, June and October in the year under review had more monthly mean flow than the long term mean. The general observation is that the flows for 2017/18 were more than the previous year.

3.5 Comments on Special Events

3.5.1 Flooding

Flooding was experienced throughout the country during the months of April to June 2018. A highlight of flooding situation at the basin level is outlined:

Lake Victoria North Basin Area

Like many parts of Kenya, Lake Victoria North Catchment Area experienced floods during the months of April to June 2018.The prolonged floods caused drastic increase in stream flows and ground water levels. The self-cleansing capacities of the rivers were also enhanced due to high dilution rates. The floods led to adequate water in terms of quantity to certify all human and ecological needs but in some cases the water quality was compromised Lake Victoria North Catchment Area is one of the most flood prone catchments within the Republic of Kenya. The rivers that usually cause the greatest havoc are Nzoia and Yala. There are other numerous smaller rivers that contribute to flooding mostly in the low-lying areas. A summary of the flood situation as a consequence of the rainfall experienced during the March-April-May-June season at sub regional levels in LVNCA was as follows.

1. Elgon-Cherang'any Sub-Region

The floods that were experienced in most parts of the country due to heavy rainfall however occurred in just a few areas of the Elgon-Cherang'any Sub-Region. The water levels remained within the banks of most rivers. The worst flood case experienced within Malakisi River Sub-catchment was when the river burst its banks by mid-March 2018 causing significant losses. Some floods were also experienced within Nzoia River Sub-Catchment in Kuburengu Lukhoba and Maraka when the river burst its banks after the water level at Nzoia 1DA02 flood monitoring station rose beyond 2.7m (which indicates 'alarm' flood level). The losses were however insignificant. In Namanjala area within Sabwani Sub-catchment which is the most flood prone area in the Sub-Region, the water levels remained within Sabwani river banks.

Flash floods were experienced within Malakisi river sub-catchment in mid-March for two days duration (15^{th} and 16^{th}) after the river burst its banks following a heavy down pour. The flood inundation depth was 1.2m. The floods are exacerbated by catchment degradation and siltation of the dams that were meant to mitigate against the menace i.e. Bukokholo, Butonge and Bitonge. Among the most affected areas were, Malakisi, Matisi (Sirisia Sub-county) and Kengatuyi, Kakoli, Aboloi and Kocholia (Teso North Sub-county). The losses incurred during the floods include; Destruction of maize and beans farms, loss of livestock, temporary displacement, houses being submerged and destruction of RGS station: 1AD02 at Kocholia. Figure 3.12 illustrates the flood menace.

Figure 3.12: Flooding at Kocholia: *Left*- Damaged gauge 1DA02 on Malakisi River. *Middle*-Level of water during the flood at Kocholia. *Right*-One of the maize farms destroyed by flood

2. Lower Nzoia-Yala (Siaya) Sub region

There are three major rivers in Lower Nzoia-Yala namely Nzoia, Yala and Sio. The flood situation was monitored at the three National stations and is shown in Table 3.2.

Table 3.2: Flood situation in Siaya Sub region

Name of River	RGS No.	Situation
Nzoia at Rwambwa	1EF01	The flood waters were contained within the dykes and the level fell gradually.
Yala at Bondo	1FG02	The Level had risen to 4.40m by 17th April. By 18th April the level had reduced to 4.35m.
Sio at Mundika	1AH01	The level had risen to 2.40m on 17/04/2018. By 18th it had reduced to 1.96m

Flooding was reported on the downstream reaches of River Yala where it broke its banks and almost got into some farmlands. The dyke along Yala River bordering Dominion Farms was breached and consequently some flow was diverted into the farms cutting off communication with the nearby Youth Training Centre and Dominion Academy. Approximately 800 acres of maize, banana and vegetable plantations were submerged and the crops destroyed. The floods displaced over 10 households from the two villages of Yimbo and Bungu. Some of the victims were accommodated by relatives while others camped at a temporary evacuation centre at Margo on the left bank of the river which could only be accessed by boat.

The remaining portions of the dyke seemed to be considerably weakened and likely to breach in case the rains continued, thereby threatening further the Dominion Farms and the nearby villages.

Figure 3.13: Flooding in Lower Nzoia: *Left*-Breached Dyke at Dominion. *Middle*-Flood flow into the farms. *Right* - Diverted river flow

Despite the fact that River Nzoia at Rwambwa broke its banks the floods remained confined within the dykes. The same situation was experienced at Sio River where the inundation was contained within the flood plain.Flood monitoring and conveyance of early warning to downstream communities was done in an integrated manner involving Water Resources Authority, Kenya Meteorological Department (KMD), WRUA's and other stakeholders.

Rift Valley Basin Area

Floods occurred in some areas like Kacheliba, Narok, Naivasha Karagita and Kainuk where bridge was destroyed. Properties were also destroyed in towns like Narok and Naivasha.

Athi Basin Area

There has been reported cases of flood during the fourth quarter especially in Lumi, Nolturesh and Rombo river systems due to heavy rain being experienced in the area. Athi 3DA2 busted banks and a gauge height of 8.6m recorded. Some of the flood affected areas in our catchments require reclamation.

Tana Basin Area

During the period under review, there were heavy rains in Meru, Kitui and Mwingi that resulted in massive flooding in Garissa and Tana River Counties. The flooding resulted in damage to infrastructure and displacement of populations. In Garissa County, the damages due to flooding were quantified as 2 submersible pumps at the GAWASCO intake lost, 42m length of 6" diameter rising mains at Ziwani borehole site washed away, 3km of distribution network ranging from 6" to ¾" diameter washed away, 4 boreholes at Ziwani submerged, old sewerage system blocked, causing backflow of sewage, about 1400 pit latrines collapsed, ponds for new effluent treatment plant submerged and water supplies along the Tana river either submerged, pumps washed away or made inaccessible.

Figure 3.14: Flooding in lower Tana: *Left*- community relocating at Garsen. *Middle*-Flood surveillance team at Salama location in Garissa farms. *Right* – RGS 4G04 water level above 6m

Normal to above normal rainfall episodes were experienced in the upper parts of the basin. This caused floods at different parts of the basin. At Riagicuna village of Kirinyaga East Sub County, depressed site experienced oozing of Sub surface water way after the rains had subsided. The water filled the swamp and streamed to the nearby farms destroying crops and feeder roads.

Figure 3.15: Flooding in Upper Tana: *Left*- Flooded parts of Murang'a town. *Middle*- Thiguku village in Kerugoya. *Right* – Evacuation site for Thiguku flood victims

3.5.2 Violation of the Reserve

Violation of the reserve was reported in Ewaso Ng'iro North basin. The 5DA sub catchment (Isiolo, Ngare Ndare, Ngare Nything, Marania rivers) experienced depressed discharge compared to the long-term discharge. The water resource status was in the "Alert" state at the start of the period but deteriorated to "Alarm" by early March 2016. Incidences of reserve violation were experienced with the rivers drying up completely at some points.

In the four-sub basins where analysis of flow was carried out they experienced depressed discharge in the months of Dec, Jan and Feb compared to the long-term discharge. During those months incidences of reserve violation were experienced with the rivers drying up completely at some points. The water resource status improved rapidly due to the early onset of long rain season. At the end of the review period the water situation in the catchment could be considered to be stable.

3.6 Special Studies

There were two studies carried out on flood mapping for Tana basin and erosion risk mapping for Nzoia watershed.

3.6.1 Flood Mapping for Lower Tana basin

During the March to May season, Kenya experienced rainfall above normal as reported by Kenya Met Department. These rains resulted in flooding in various parts of the country with at least 32 counties affected by the floods. Regional Centre for Mapping of Resources for Development (RCMRD) utilized the telemetric data shared by WRA on water levels to generate information on flooding.

Various tools and data were used to give some status update on the flooding menace in Kenya. Some of the information are of global extent while others have been developed locally under the SERVIR Eastern & Southern Africa project. Apart from the tools, satellite images were used to show the area/extent of flooding in some of the locations. A Near Real Time (NRT) tool with a spatial resolution of 1km and temporal scale of 3 hours was used to give information on riverine flooding.

Tana River was the worst hit by flooding where the whole of Tana Delta was flooded. Figure 3.16 shows the flood extent developed for specific dates. GLOFAS developed by EU (http://www.globalfloods.eu/glofas-forecasting/) was also used to capture the surging water on Tana River as depicted in Figure 3.17 showing the river flows for 28th April 2018.

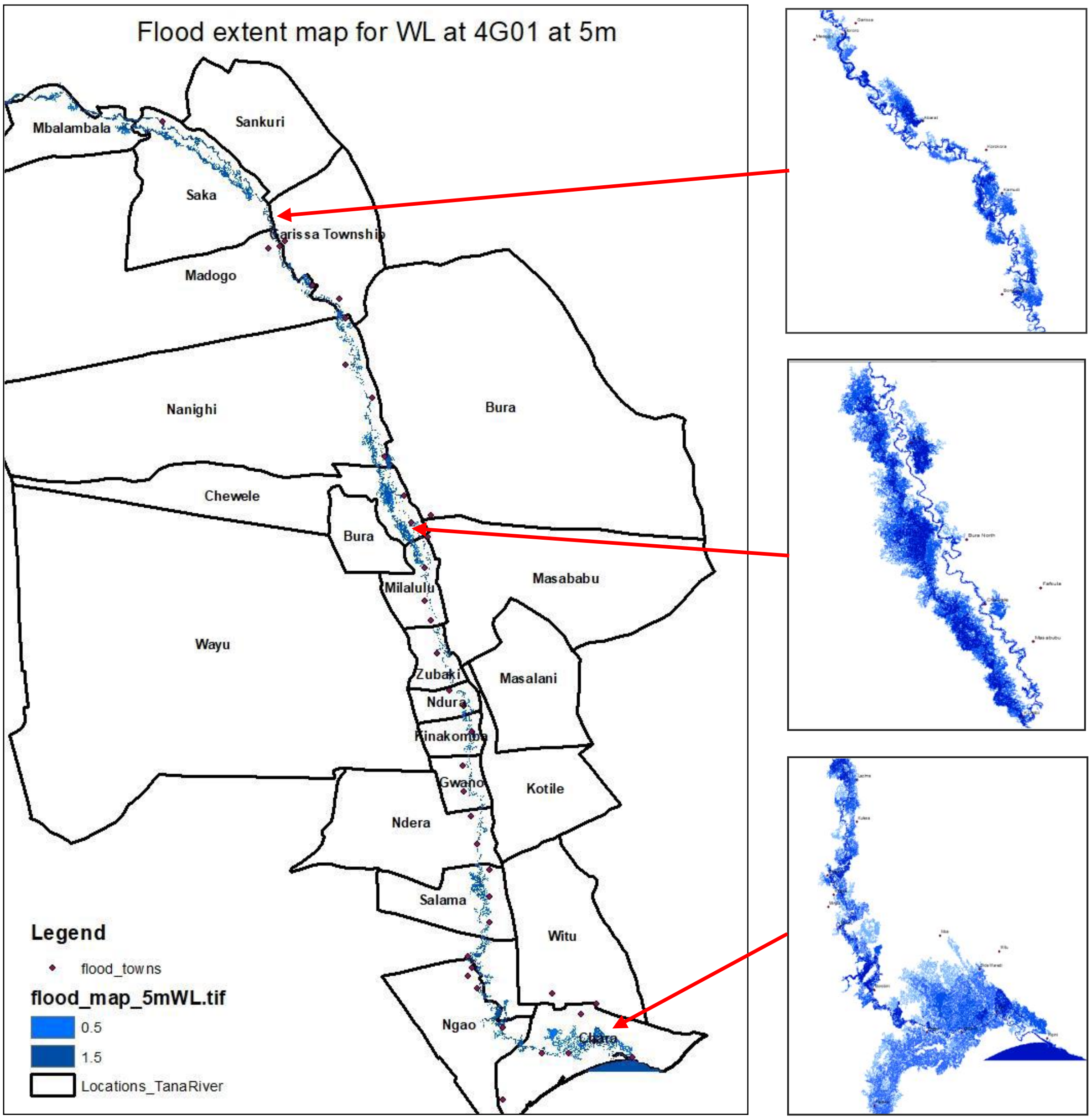


Figure 3.16: Flood map generated using the online flood tool, zoomed in sections along the Tana delta overlaid and the flood plains

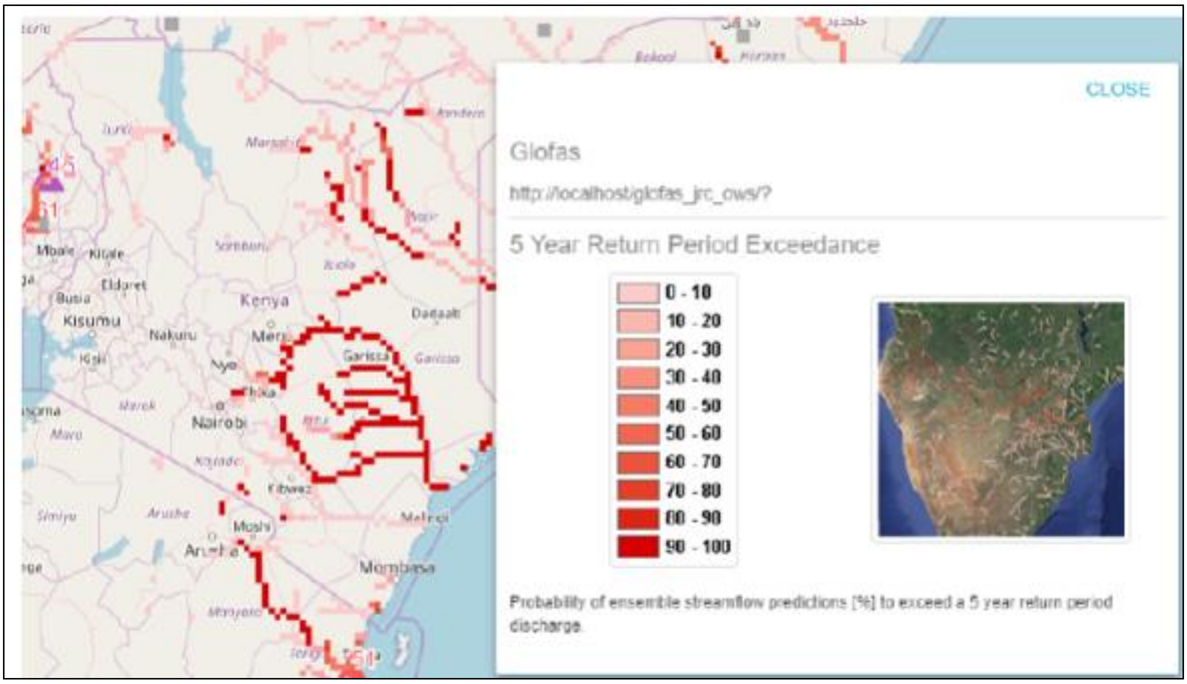


Figure 3.17: High streamflow recorded over Tana River on 28th April 2018 by GLOFAS tool

The methods or products used clearly depicted the likelihood of flooding where rainfall was seen to increase over the region, followed by swelling river discharges as indicated in Figure 3.16. Flood maps have also been generated using water level data from WRA and the maps clearly showed that most of the towns along the flood plain were likely to be flooded if the river water level of 3.5m is surpassed. This was emphasized more by the satellite images that captured most of the flood waters during the period.

The information generated was for the sole purpose of assessing the areas affected. However, more validation would be required by using local knowledge especially of the extent of flooding (areas flooded and the depths of flooding) for an impact based analysis.

3.6.2 Erosion Risk Mapping for Nzoia Watershed

As part of the program and the first initiative under the Kenya Water Security and Climate Resilience Project (KWSCRP), the lower Nzoia Irrigation Scheme has been developed. It is a flagship project of the Kenya Agricultural Sector Development Strategy (ASDS) and of Kenya Vision 2030. The overall goal of this project is to support farmers by working towards food and economic security as well as increasing climate resilience. The Nzoia River will serve as a water source for the scheme where 4,043 hectares will be irrigated.

High sediment load of the Nzoia River poses a risk to the proposed irrigation scheme. Sediment deposition along the canals and other infrastructure increase maintenance costs to the administrators of the scheme. In order to ensure sustainability of the project, a sub-component targeting reduction of the sediment load from upstream of the intake was included in the project.

A physiographic study was carried out in January 2018 for the Nzoia River Basin to model erosion generation within the catchment in order to identify major erosion hotspots. The study also prioritized Water Resource User Associations (WRUAs) in the Nzoia Basin in terms of the sedimentation risk they pose to the Lower Irrigation Scheme.

Figure 3.18: Gullies within Mid Nzoia (left) and Nzoia River downstream of Musanda Bridge (right)

Figure 3.19: Upper Nzoia Watershed

Objectives and Scope of the Study

The study aimed at achieving the following:

i) Characterize the Nzoia watershed and identify erosion hotspots within it. An erosion yield map be generated for the whole basin with a color ramp showing the variation in erosion yield for the basin. The units of measurement are tons/ha/year.

ii) Prioritize implementation of soil and water conservation activities in the watershed. This would be done by identifying and ranking the sedimentation risk each of the WRUAs poses to the Lower Nzoia Irrigation scheme.

The study summarized the results of a desk study that was carried out by the LVNCA counterpart staff that were trained on the use of Revised Universal Soil Loss Equation (RUSLE) model to generate erosion yield for the Nzoia Basin. Ground truthing of identified erosion hotspots was not carried out and would be highly encouraged before the adoption of this study as a guide for activity implementation.

The study results (WRUA ranking) was based purely on the sedimentation risk they pose to the Lower Nzoia Irrigation Scheme. This was determined using a sedimentation risk index that only considered erosion yield potential of the WRUA as well as its distance from the intake of the proposed Lower Nzoia Irrigation Scheme. Further analysis may be proposed to refine the ranking based on the WRUAs' current statuses.

Methodology

In order to successfully complete the assignment, two approaches were applied by the study team to map out erosion hotspots within the Nzoia Basin i.e.

i) ***Vegetation Delineation:*** Remote sensed vegetation cover images were processed for the Nzoia River basin and overlaid on top of the slope maps for the area. Areas with high slopes and low vegetation cover were deemed at more risk to erosion and mapped as hotspots.

ii) ***Revised Universal Soil Loss Equation (RUSLE):*** was applied for the Nzoia Basin using remote sensed data. Major inputs included TAMSAT satellite rainfall data, KENSOTER soil map for Kenya and, Normalised Difference Vegetative Index (NDVI) data obtained from MODIS.

Results

Erosion yields in Nzoia watershed ranged from 0 to 22,7675ton/ha/yr. Areas around Mt. Elgon, Cherang'any and Northern parts of Nandi Hills have yields in excess of 800ton/ha/yr. The downstream parts generally have low erosion yields (0-500ton/ha/yr) with patches of erosion hotspots around Ruambwa, Butere, Ugunja and Mumias. The maximum, minimum and average erosion yields computed for each sub catchment show higher mean and maximum values in the upper parts of the catchment. All the sub catchments yield a substantial amount of sediments ranging from 10.22ton/ha/year to 701.65ton/ha/year.

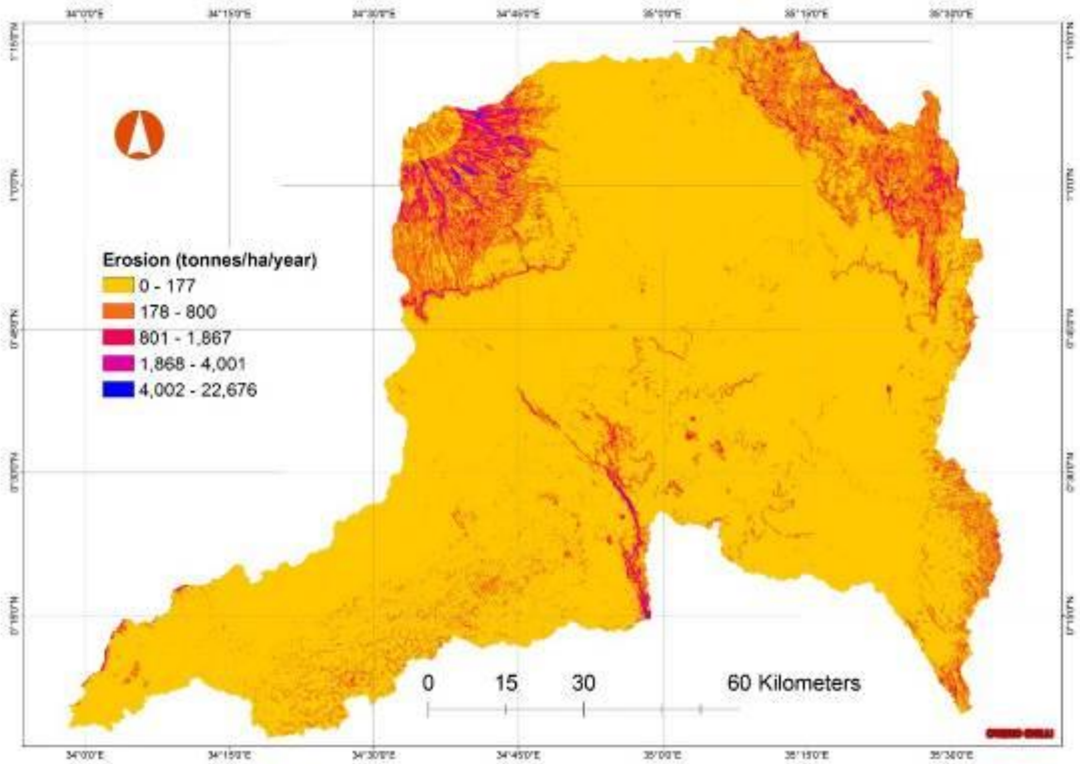


Figure 3.20: Erosion yields in Nzoia watershed

Ninety five (95) sub catchments were ranked based on their sediment contribution to the lower Nzoia irrigation scheme using their mean erosion rate and distance from the intake. It was assumed that the sub-catchments closer to the irrigation site and have larger mean soil erosion rate will contribute most of the sediment to the reservoir. Hence Sediment Risk index was calculated by multiplying the mean erosion rate by inverse distance, i.e

Sediment Risk Index = Mean Erosion rate × 1/Distance from Irrigation site

Soil loss/erosion statistics (minimum, maximum, mean, and total) was obtained from the RUSLE map. Map of the 95 sub-catchments and their respective risk ranking was generated together with a matrix of the sub catchments showing the sediment risk index, max erosion yield, minimum erosion yield, mean erosion yield and standard Deviations.

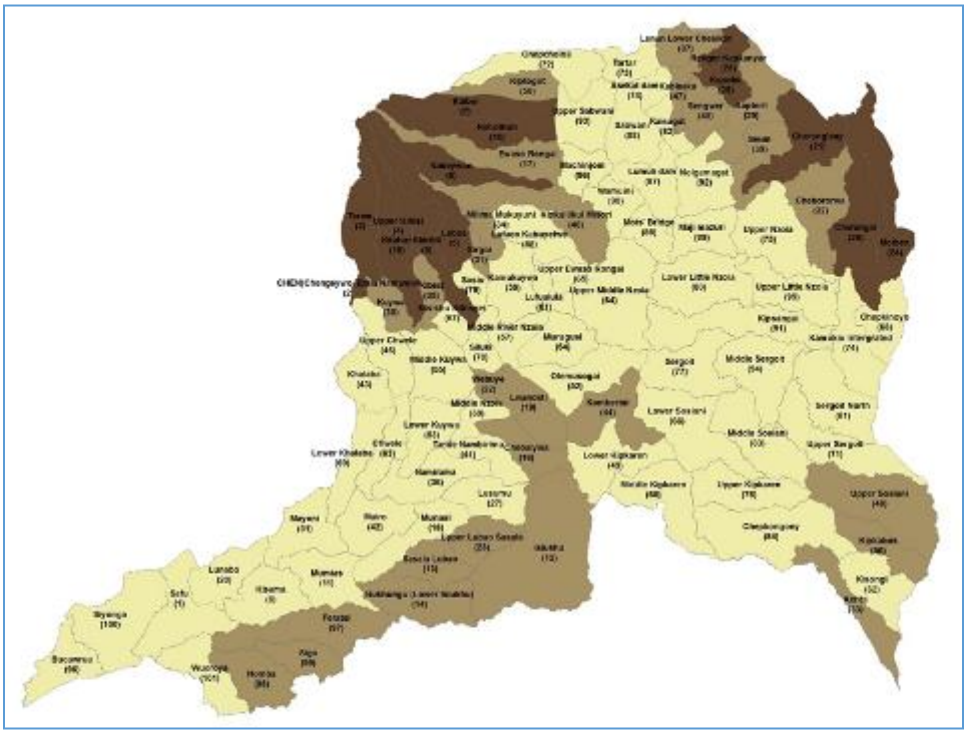


Figure 3.21: Sediment Risk WRUA ranking in Nzoia Watershed

Conclusions

Based on the erosion risk modelling and vegetation delineation, the following conclusions were made:

i. All the sub catchments in Nzoia watershed have potential to generate sediments.

ii. The upper catchment including parts of Mt. Elgon and Cherang'any hills have higher average erosion yields. The higher erosion yields seem to be dictated by the steep slopes.

iii. The sub catchments in close proximity to the irrigation project pose more sediment risk because the soil generated from these catchments are likely to reach the irrigation intake. Although the upper catchments have higher erosion yields, the sediments are likely to settle before settling settle before reaching the site.

Recommendations

i. Further study needs to be carried out on transfer of sediments generated in the upper catchment to establish whether they reach the irrigation intake point.
ii. A study on RUSLE factors (i.e L- Factor and R-Factor) should be done to establish the correct constants (equations) for this region. This would give more reliable results compared to those in this study which relied on factors established for other regions (i.e Europe, USA, Ethiopia).
iii. This study used the RUSLE to generate erosion yield for the Nzoia Basin. Ground truthing of identified erosion hotspots would be highly encouraged before the adoption of this study as a guide for activity implementation.

4 SURFACE WATER QUALITY

Water quality refers to the chemical, biological and physical characteristic of a water resource. It is influenced by both natural and human activities. Water quality management is a challenge due to a number of factors including industrial developments, development of urban centres especially unplanned urban settlements, poor agricultural practises like riverbank cultivation, across the contour farming amongst others.

4.1 Description of Monitoring Network

Water resources Authority has a total of 260 water quality monitoring stations distributed within the river basin areas. These stations are adopted from the surface water Regular Gauging Stations (RGSs) and classified as National, Management Unit (MU), Intra Management Unit (IMU) and Special. National Stations are those considered to be of national importance if affected by natural and anthropogenic activities. Management Unit stations monitors impact at the basin level while IMU monitors the impacts at the sub basin level. Special stations are for monitoring special studies.

Table 4.1 shows the surface water quality monitoring stations per region and classification. The largest proportion of the stations are the IMU constituting 55% of the total number while the National Stations constitute 7%. Furthermore, a total of 13No. Station are automated, 10 in TCA and 3 in LVSCA.

Table 4.1: Surface water monitoring stations used as water quality monitoring stations

Regions	National	MU	Intra-MU	Special	Others	Total
LVNCA	5	16	17	2		40
LVSCA	6	15	26	2		49
RVCA	4	5	13	0		22
TCA	1	26	25	13	3	68
ACA	3	6	32	3		44
ENNCA	1	5	30	4		40
Total	**20**	**73**	**143**	**24**	**3**	**260**
Percentage (%)	**7**	**28**	**55**	**9**	**1**	**100**

4.1.1 Non point pollution monitoring

Non point pollution occurs when rainfall wash over land, farmland, roadways, urban and suburban residential areas. The 260 stations mentioned in section 4.1 are used for monitoring the non-point pollution.

The proportion of the station monitored at least once ranged from 50 % (LVSCA) to 92 % (RVCA) with national mean of 72.17 %.

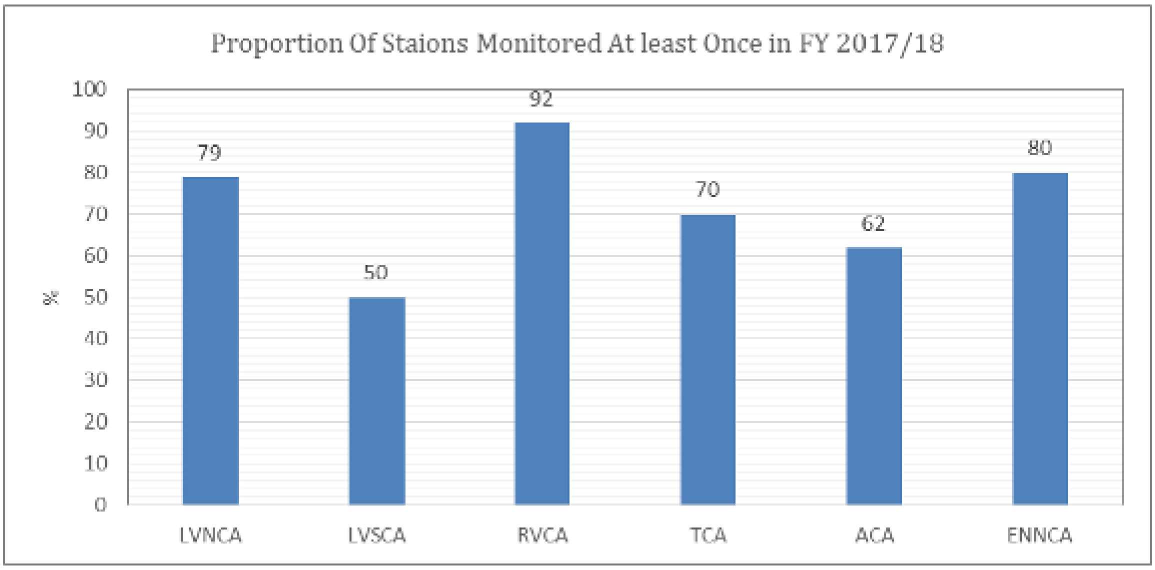


Figure 4.1: Proportion of water quality monitoring stations monitored at least once in FY 2017-18

Nationally, a total of 682 data sets were collected for the financial year 2017/18. The data sets varied across the regions and the quarters. Table 4.2 shows details of the datasets collected for the year 2017-18. Regionally, ACA catchment and LVSCA had the highest and least data collected at 135 and 57 respectively. Similarly, the highest datasets were collected in quarter 2 and 3 respectively.

Table 4.2: Data collected across the region for the FY 2017-18

Regions	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual Total
LVNCA	22	44	10	15	91
LVSCA	16	11	3	14	44
RVCA	37	49	12	12	110
TCA	75	66	3	4	148
ACA	33	30	52	42	157
ENNCA	21	55	27	29	132
National	**204**	**255**	**107**	**116**	**682**

An average of 10 Parameters were monitored across the regions during the period under review. As shown in Figure 4.2 ENNCA region monitored the highest number of parameters in comparison to others while on the other hand ACA had the least.

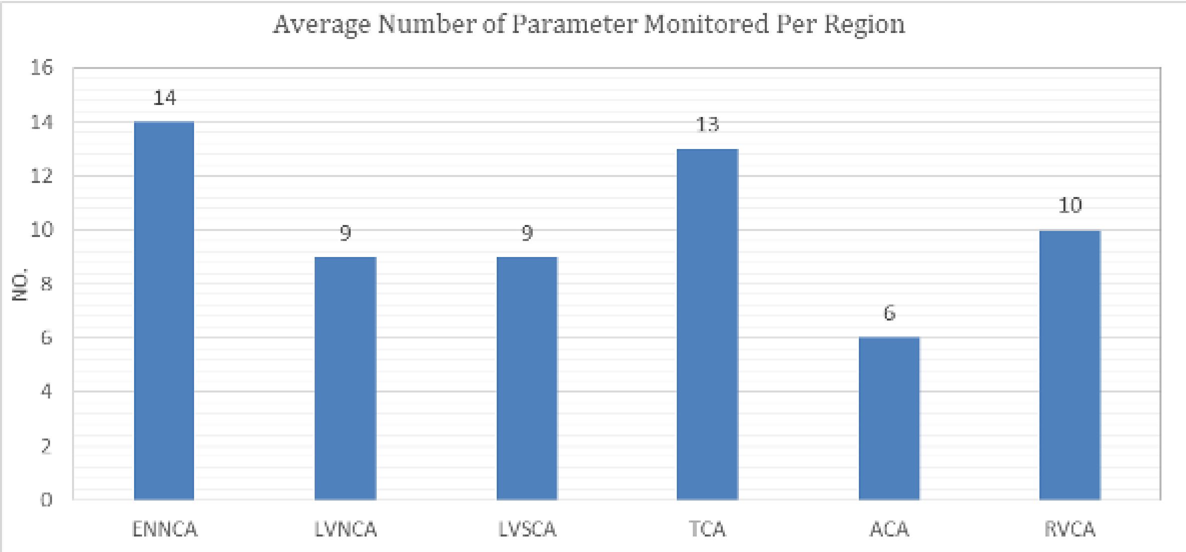


Figure 4.2: Average number of surface water quality parameters monitored

The frequencies of the parameters that were monitored is given in Figure 4.3. The parameters that had the highest and least frequency were conductivity (96%) and Total Nitrogen (TN), Sodium (Na) and 4HrPV (1%) respectively.

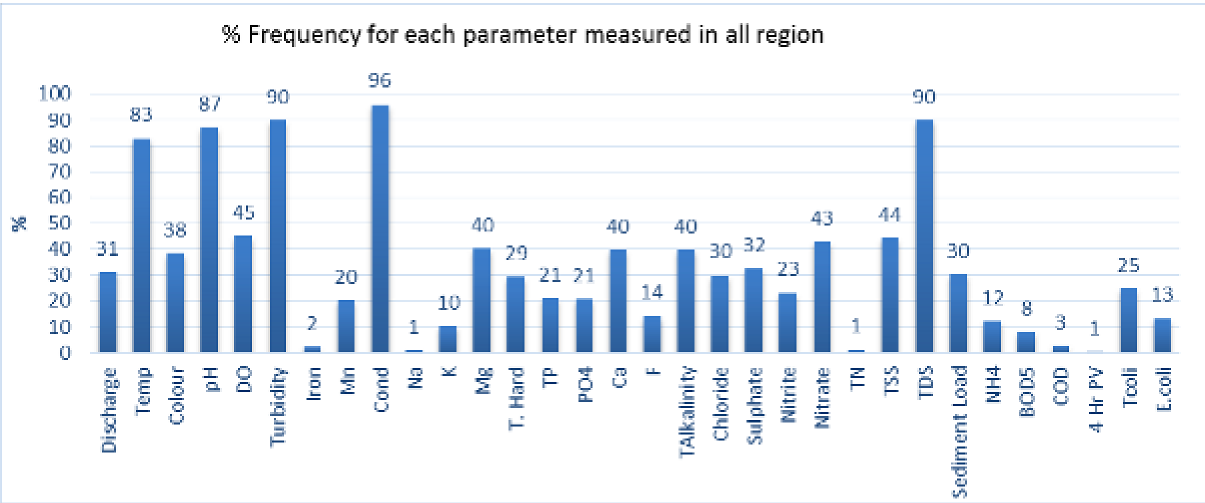


Figure 4.3: The frequencies of parameters monitored nationally in FY 2017-18

4.2 Instrumentation

During this reporting period 4 equipments were bought under GIZ/ Mashav project; 3 Multi parameter and 1Colorimeter.

4.3 Improvements to Network Infrastructure

During this reporting period, the following activities were carried out to improve the network infrastructure:

a. Under the Kenya Water Security and Climate Resilience Project (KWSCRP) the entire water quality monitoring network was reviewed with objective of making it optimal. The reviewed network is to be implemented in the 2018/19 financial year,
b. Moreover, Lake Victoria South Catchment Area (LVSCA) did establish 1No station at River Nyando at Chemilil and Awasi Bridge for measuring the impact of Muhoroni Sugar Factory. This was done under the Mashav project,
c. Also under Unintended Persistent Organic Pollutants (UPOPs) projects, some of the monitoring stations were adopted for UPOPs monitoring.

4.4 Improvements to Data Quality

In this reporting period, the following were carried out to improve and ensure that data quality was optimal:

a. Calibration of equipment at Central Water Testing Laboratory by KEBS,
b. Improving the capacity of water quality officers through 2 No. of training on water quality management that were carried out at Kisumu and Nakuru for water quality officer's staff.
c. 4No. Equipment bought; 3No. Multi parameter and 1No. Colorimeter were bought under GIZ/ Mashav project 3. 1No. Effluent monitoring station established for River Nyando at Chemilil-Awasi Bridge to monitor impact Muhoroni Sugar Factory.

4.5 Assessment of Surface Water Quality

4.5.1 Non-Point Source Pollution

For this report, assessment of the surface water status was based on;

i) Regional average of the stations that complied with ambient water quality standard. The proportion of station that complied ambient water quality standard was first calculated and then average for the region was calculated as per the equation 4.5.1 and 4.5.2 respectively.

$$S = (\sum_{i=1}^{n} \mathrm{pi})/N \text{.................................} 4.5.1$$

Where S is the % compliance of the station that was monitored. P is the parameter that complied with the standards. N is the total number of parameters analyzed.

$$R = \frac{\sum_{i=1}^{n} \mathrm{Si}}{N} \text{...} 4.5.2$$

Where R is the regional average % compliance for the stations monitored. S is the % compliance of the station that was monitored. N is the total number of stations analyzed.

ii) Proportion of the stations in region that complied Sustainable Development Goal 6.3 good ambient water quality target of 80%. This was calculated first with equation 4.6.1 and then then the proportion of station with S> 80% for each region was calculated using equation 4.5.3

$$x = \frac{\sum_{i=1}^{n} \mathrm{Yi}}{N} \text{...} 4.5.3$$

Where x is the proportion of stations whose compliance was greater than 80%. Y is the stations whose % compliance to ambient water quality standard was > 80%. N is the total number of stations analyzed in a region.

Ambient water quality refers to the natural quality of water resources and represent the combination of natural activities within the aquatic system. Deviation from this conditions usually leads to disruption of essential aquatic ecosystem services such as fisheries and provision of water for drinking and other human uses.

In this assessment the following parameters were used in calculation of the compliance to ambient water quality;

a. PH is a measure of acidity or alkalinity. Eco toxicological studies have shown that optimal range for aquatic life is 6.5 to 9. Therefore 6.5 to 9 is the range considered as good ambient water quality standard for this assessment and it was measured in 87% of all station monitored (Figure 4.3).
b. Conductivity/TDS is measure of dissolve substance in water. For this assessment, good ambient water quality standard is considered to be

<700μS/cm (Conductivity) or <500mg/l (TDS) since many Eco toxicological studies have shown values above them leads to poor egg formation, reproduction and growth of aquatic organism(. To add this these parameters was well covered in all the monitored station at 96% and 90% frequencies for conductivity and TDS respectively (Figure 4.3).

c. Dissolved oxygen is essential for aquatic life. From Eco toxicological studies values <6mg/l can disrupt growth, reproduction and can even lead to death. Therefore, in this assessment 6mg/l is the lower limit for good ambient water quality. Only 45% of station monitored measured this parameter (Figure 4-2.3).
d. Total phosphorous: Phosphorous is essential nutrient for aquatic plants and many studies shows it's normally the limiting nutrient. However, in excess amount of 0.05mg/l (used as the ambient water quality standard) studies have shown that it leads to unbalanced aquatic ecosystem due to excessive growth of plants such as algae (eutrophication). Algae have been known lead death due toxicity and depletion of oxygen. It was measured in 21% of the monitored stations. (Figure 4-2.3).
e. Total Nitrogen: Similar to phosphorous it is an essential nutrient but in excess of 1mg/l(standard used) studies has shown to lead to eutrophication and consequently toxicity and death due to oxygen depletion.

4.5.1.1 Findings/Results

The results of the assessment is presented Figures 4.4, 4.5, 4.6. Lake Victoria South Catchment Area (LVSCA), Lake Victoria North Catchment Area (LVNCA), Ewaso Ngiro North Catchment Area (ENNCA) and Tana Catchment Area (TCA) were analyzed since their monitoring stations had at least 3 of the 5 parameters mentioned above.

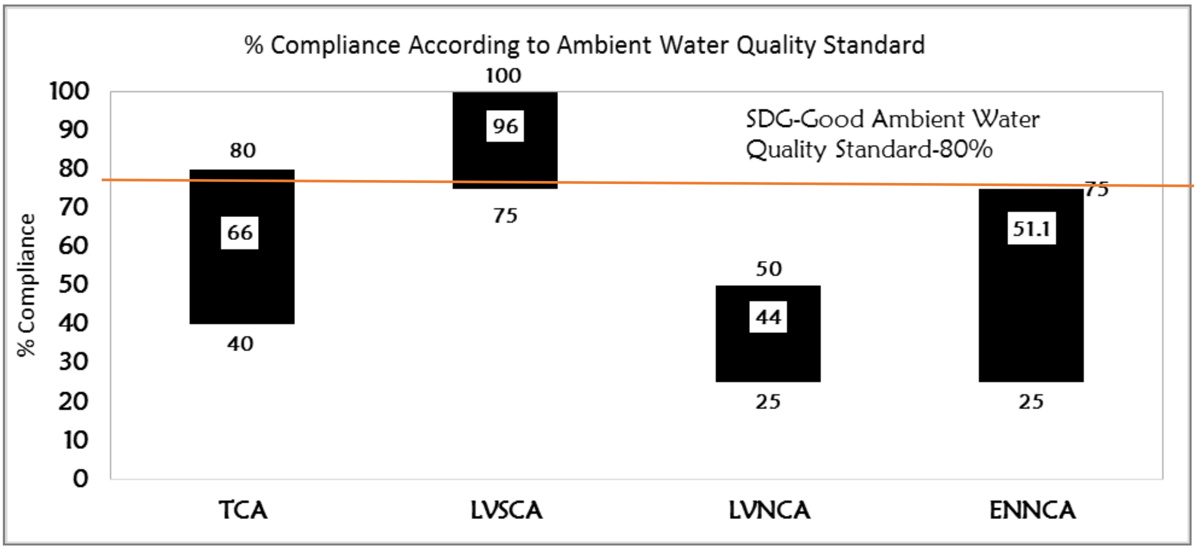


Figure 4.4: The ranges and mean (white values) performance in compliance of the station in each region to ambient water quality standards. The maximum value are on the top and minimum value on the bottom

Compliance ranged from 25 to 100 % across all regions with a national mean of 60%. LVSCA region had the highest mean to compliance of ambient water quality while LVNCA had the least at 44%.

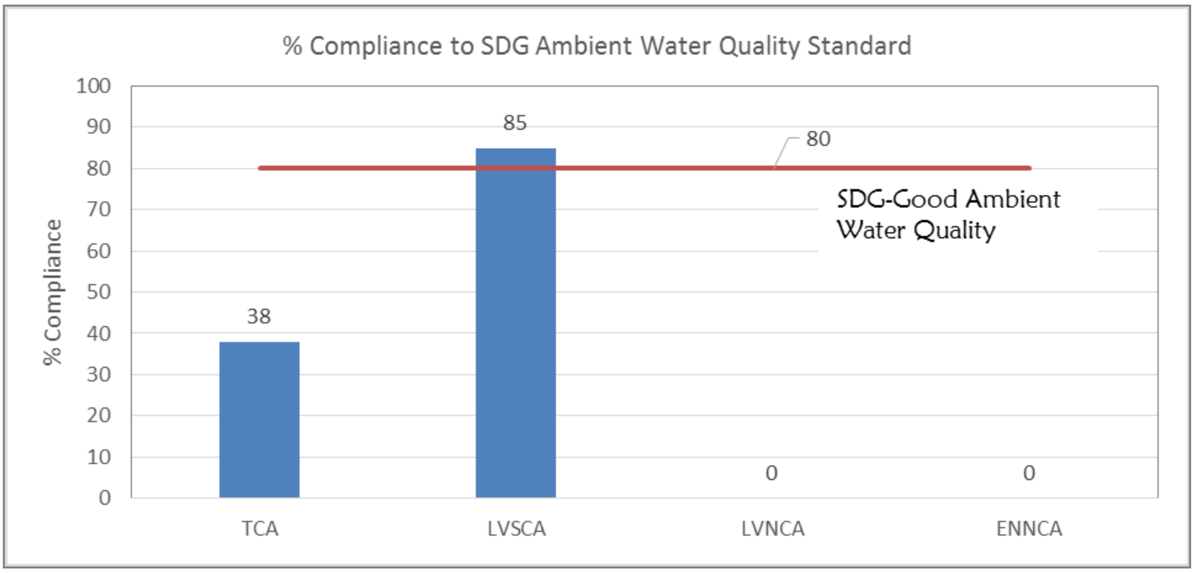


Figure 4.5: Compliance of the stations in each region to SDG ambient water quality standard target of ≥ 80%

Generally, there was poor performance in achieving the SDG Good Ambient Water Quality Standard target of 80% across the regions. LVSCA had the highest proportion of monitored stations achieving this target at 85% (That is 85% of its station had a compliance of ≥ 80%) while LVNCA & ENNCA did not have any station achieving this target.

This poor performance was mainly due to non-compliance to ambient water quality standard for total phosphorous and dissolved oxygen as shown in Figure 4.6. Nationally, the parameter with least compliance is total phosphorous at 5%. Conductivity on the other hand was complied with in all the monitored station. Therefore the emphasis should be on better nutrient management in order to comply with ambient quality standards.

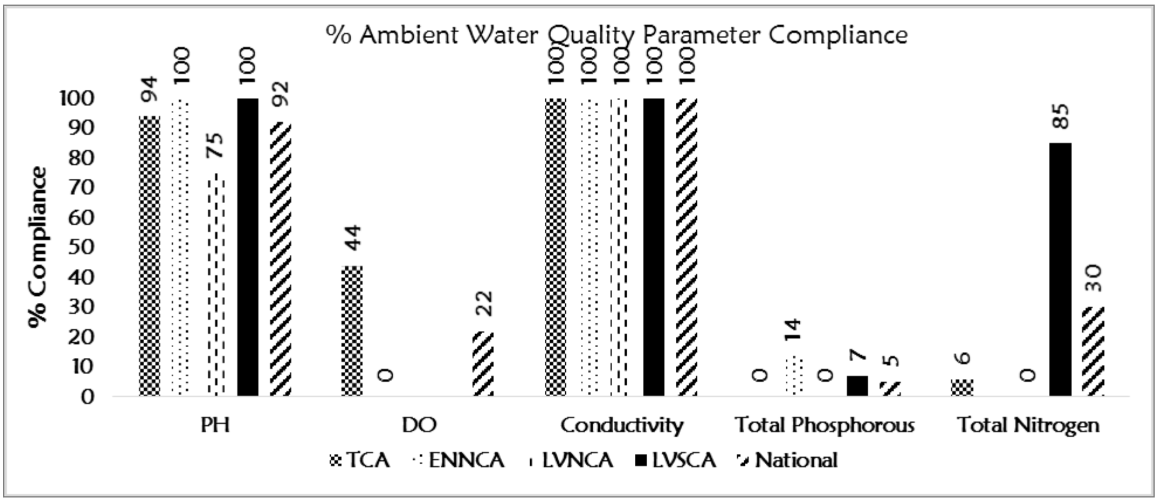


Figure 4.6: The frequencies of parameters monitored nationally in FY 2017-18 that complied with good ambient water quality

4.5.2 Point Source Pollution

A total of 102 data set was collected during the financial year 2017/18. Fifty five percent of the were collected by LVNCA while TCA had the least.

Only one permit was issued nationally in LVNCA. A further one is under processing in LVSCA while 6 authorizations were issued in LVNCA.

A total of 7No. new Effluent Discharge Control Plans (EDCP) were developed across the regions. Majority of these were from LVNCA (7No.). The other regions, TCA, RVCA & ACA did not develop any new EDCP.

Table 4.3: Data collected across the region for the FY 2017-18

Regions	Total Number of Data collected	New Permit Issued	New EDCP
LVNCA	56	1(+ 6No. other authorization under processing)	4
LVSCA	15	0(1 permit pending- under processing)	1
RVCA	11	0	0
TCA	1		
ACA	11	0	0
ENNCA	8	0	2
National	102	1	7

4.5.2.1 Assessment of Point Source Pollution

The assessment was done by compiling the proportion of the parameter that complied with effluent discharge into water resources standards as per schedule 3 of Water Resources Management Rules (WRM) 2007 Rules. Regions performance was calculated as the average of the compliance of its effluent dischargers. A minimum of 4 parameters was required for these calculation. Only in ENNCA, LVSCA & LVNCA regions that met this criteria where pH, Total Dissolved Solid(TDS),Total Suspended Solids(TSS),Total Phosphorous(TP),Biochemical Oxygen Demand(BOD) & Chemical Oxygen Demand(COD) were analyzed. Athi Catchment Area and Tana Catchment Area monitored one station each and measured only pH and TDS.

National Outlook

The compliance to effluent discharge standards as per Schedule 3 by effluent dischargers varied across the regions.

The best performance was in LVNCA at 88.3% (Butali and West Kenya Sugar) while the least was recorded in both LVNCA and LVSCA at 16.7 %(Figure 4.5.2.1). ENNCA had the highest region mean at 61.1% while the lowest was LVSCA at 36.1%.

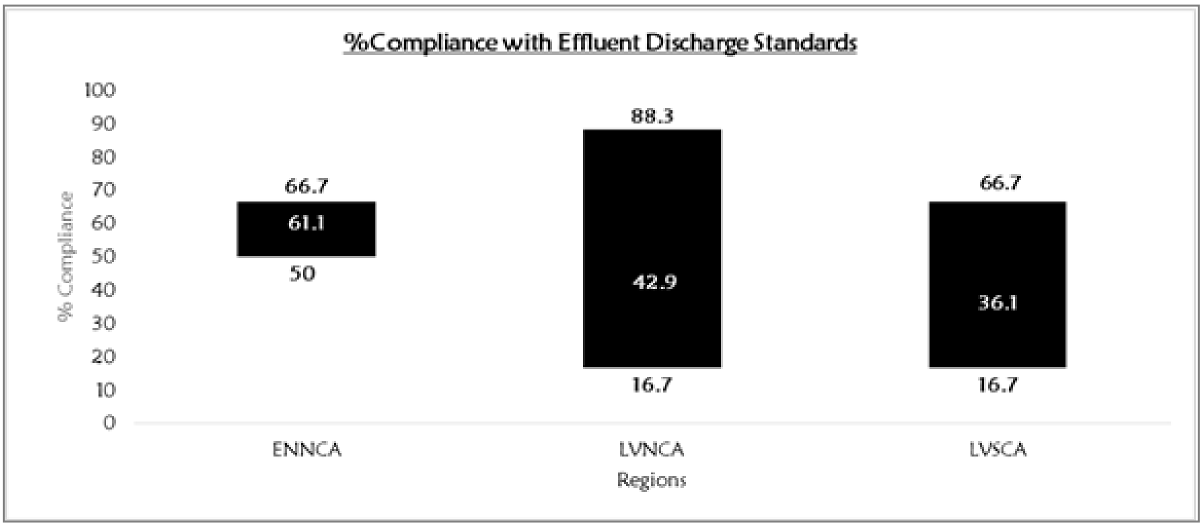


Figure 4.7: Compliance of the Effluent Dischargers to Effluent discharge Standards into water resources (WRM Rules 2007 Schedule 3)

The National mean was 46.7 % which is still low was mainly contributed by poor performance in compliance by COD parameter. Most of the effluent dischargers, i.e 86% did not meet this standards. However, TDS in the effluents from most of the dischargers monitored were within the required standards.

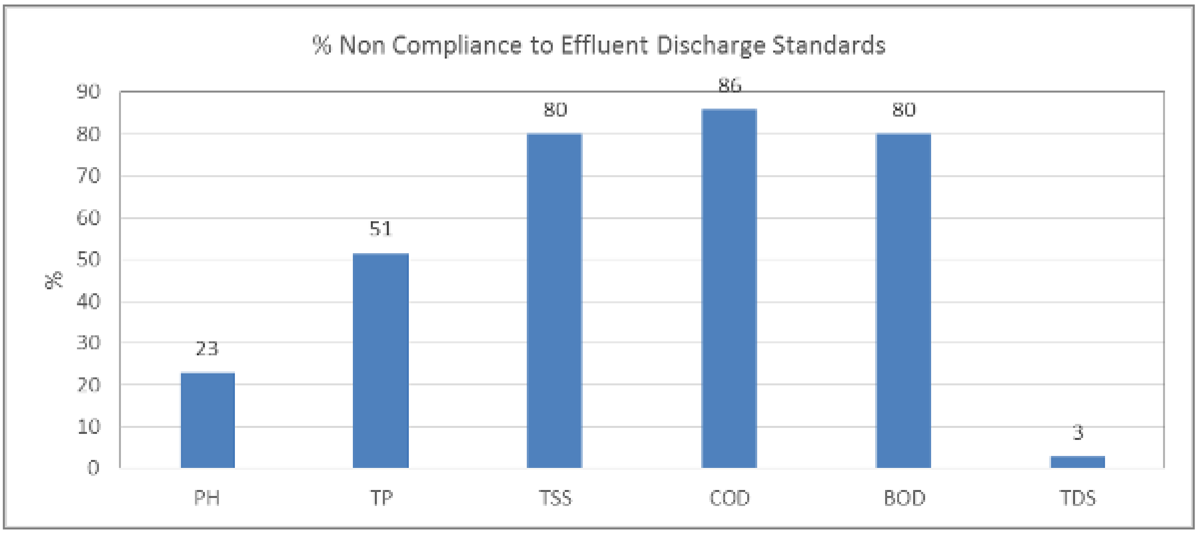


Figure 4.8: National non-compliance of parameters to the effluent discharge standards

Lake Victoria North Basin Area

The mean compliance to effluent discharge standard for LVNBA was 42.9%. Table 4.4 summaries the compliance performance for the different effluent categories in this region. From this table, Sugar and Dairy recorded the best (88.3%) and least (27.1%) performance respectively in complying with the standards.

On one hand, COD seems to be the problematic parameter in terms of compliance across all the sector. On the other hand, TDS had the best performance in terms of compliance to the standards. These two observation are similar to the national one.

Table 4.4: Characteristic of the effluent discharges in LVNB region

Effluent Categories	Average Mean (%)	Highest	Lowest	Parameter Performance	
				Best	Worst
Sugar	83.3	Butali & West Sugar (88.3%)		PH, TSS, TDS, TP & BOD (100%)	COD (96%)
Municipal	41.7	Bidii WWTP (66.7%)	Machinjoni, ELDOWAS-Boundary, Kapsabet (33.3%)	PH &TDS (100%)	COD &BOD (0%)
Dairy	27.1	Moi Bridge & Lelchege (33.3%)	KCC-Kitale (16.7%)	TDS (100%)	COD, TSS, TP & BOD (0%)
Flower	54.7	Zena Roses-Asai Farm & Equator Flowers (66.7%)	Maji Mazuri Flower (33.3%)	TDS (100%)	COD (0%)
Coffee	33.7	Khachonge(66.7%)	Endebes&Kabisi(16.7 %)	TDS (100%)	TSS & COD (0%)
Institutions	40	O'Lessos TTI & Moi University (50%)	Mosoroit TTC, University EA Baratom, University of Eldoret (33.3%)	PH & TDS (100%)	BOD&COD (0%)

Lake Victoria South Basin Area

The mean compliance was 36.1% where the highest and lowest was recorded in Nyalenda Ponds (66.7%) and ACFC (16.7%) respectively.

All the dischargers monitored did not comply with TSS and BOD discharge standards. PH & TDS (83.3%) were complied with at all the monitored dischargers with the exception ACFC effluent.

Ewaso Ng'iro North Basin Area

The % compliance to effluent discharge standards ranged from 50 % (IWASCO) to 66.7 %(NYAHUWASCO & NAWASCO) with a mean of 61.1%. Similar to other regions, PH & TDS were complied with all dischargers while TSS, BOD & COD (0%) were not. To add to this Phosphorous removal by these systems was very good as they meet the required standards.

4.6 Comments on Special Events

Table 4.5 gives a summary of key special events that occurred in this reporting financial year 2017/18. The majority of these key events that took place were cholera outbreaks were reported in LVSBA, LVNBA and TBA due to high rainfall. Other notable major event was the pollution of Likii River by sewerage sludge from Mt. Kenya Hotel in Nanyuki. They were issued wit orders and did correct the situation, and continual monitoring show improved water quality.

Table 4.5: Special Events that occurred across the region for the FY 2017-18

Region	Qtr 1	Qtr 2	Qtr 3	Qtr 4
LVNCA		Pollution of river kivavywa by butali sugar reported at national environmental conservation committee	Cholera outbreak in kakamega town	
LVSCA	Cholera outbreak at kodiaga due to contaminated water of river saka by poor sewerage treatment by the same prison		Lielango river contamination by kibos sugar. Order given and compliance monitoring is continually done monthly	
RVCA	Pollution by soniam flower farm reported and matter handled	River njoro and lake nakuru clean up		
TCA			Cholera outbreak in garissa and tana river county	
ACA				
ENNCA			Pollution of river likii by fairmont mt. Kenya hotel. Order was given and pollution clean-up and compliance monitoring done	

4.7 Special Studies

Annex 1 gives a summary of special and capital projects carried during this financial year. From the Table 4.7, majority of the studies were Abstraction and Pollution Survey (APS) were done (13No.). 10No. of these were carried out in TBA by WRUA funded under Upper Tana Natural Resource Management Project and the remaining 3No. were done under the capital project in LVSBA and LVNBA regions.

Other notable studies included; Siyonga Water Abstraction Plan and under Athi River Restoration Project-Point Source Pollution awareness held, mapping and marking pollution and riparian encroachment in Nairobi River Basin were done. From the mapping and marking of the pollution points and riparian encroachment the following were observed

a. 10No. Premises that encroached riparian were marked for demolition and given orders.
b. Major pollution points were identified along Dandora dumping site, slums (Korogocho, Kiambio e.t.c) and along major markets (Gikomba and Korogocho soko mjinga).

5 GROUNDWATER RESOURCES

This section outlines the achievements and experiences by WRA in the management of groundwater resources during the period 1st July 2017 to 30th June 2018. Several activities were carried out to enhance the groundwater knowledge in terms of amounts abstracted and characterization of aquifers as well as conservation of groundwater catchment areas. Chief among this is groundwater data monitoring that has been done over the last decade while incorporating new stations.

5.1 Description of Monitoring Network

The types of aquifers and the monitoring network are shown in Table 5.1. There are a total of 140 monitoring stations across the country.

Table 5.1: Description of the Monitoring Network

	Strategic	Major	Minor	Special	Total	% Operational
Athi	4	20	11	3	40	
ENNCA	5	3	4	0	12	75
LVN	0	6	7	6	19	100
LVS					18	
RVCA	8	12	11	2	33	
Tana	7	6	5	0	18	43.9
Total					**140**	

In the Tana Catchment area, out of the 41 monitoring wells a total of eighteen (18) stations were monitored in the year and were from Lower Tana, Tiva/Tyaa and Kathita/Mutonga subcatchments. From the monitored stations only three (3) stations in Tiva/Tyaa had complete data. The others had many gaps making it difficult for interpolation and extrapolation. Forty (40 No.) boreholes have been operated as Groundwater monitoring stations as source of water levels and water quality data in Athi Catchment Area. However, only 24 No. have been able to provide data during the FY 2016/17.

In ENNCA and the other regions the routine data collection is as evidenced in Annex 2 (annexed to demonstrate monitoring stations within the year and the stations in each WRA Catchment Area.)

Figure 5.1 shows the groundwater monitoring network on the aquifer map of Kenya. The monitoring objective currently is largely for groundwater levels.

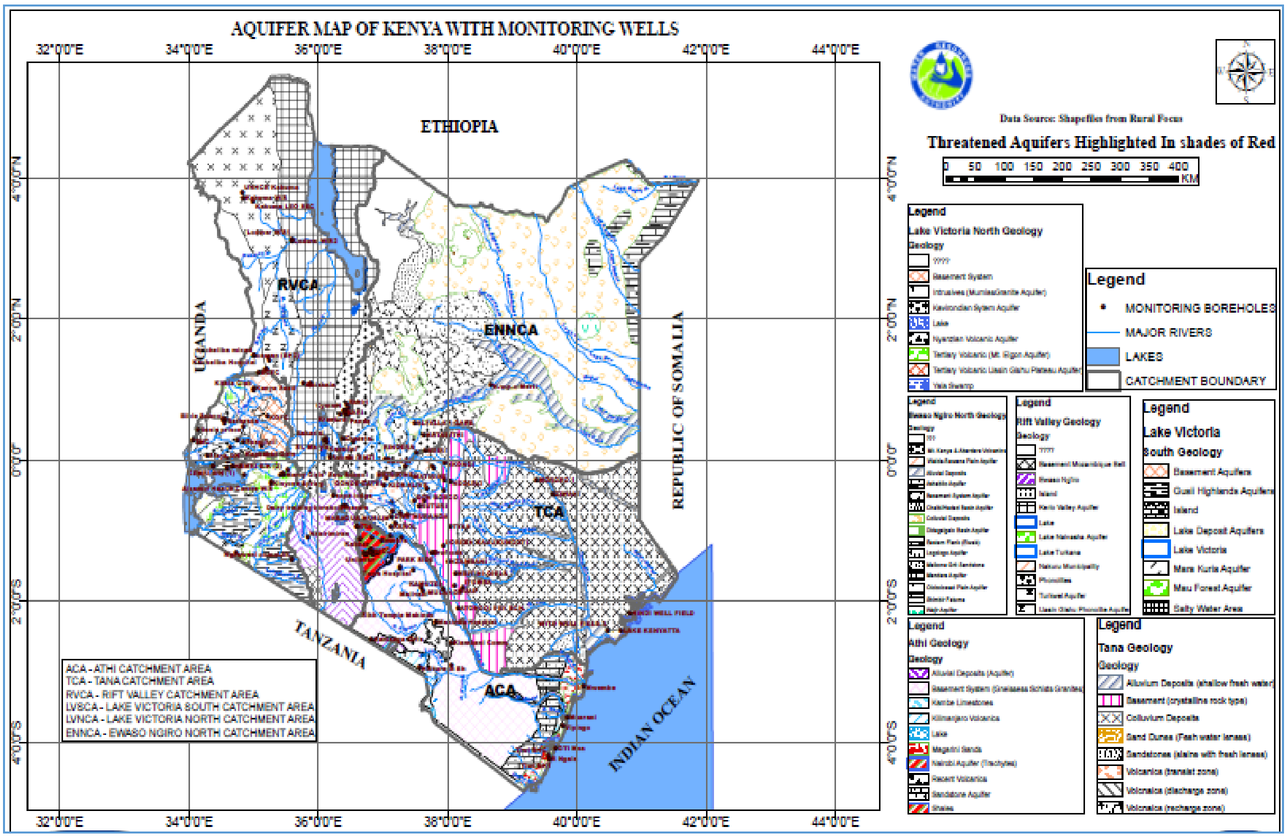


Figure 5.1: Aquifers within the six catchment areas and the monitoring boreholes network

5.2 Instrumentation expected at each type of station

Most of the current groundwater monitoring stations are mostly production boreholes used for water supply to institutions or individuals. The instrumentation in production boreholes in order to facilitate for possible data collection is usually an airline piezometer. There are few stations like the Kreative Roses monitoring well that had been giving telemetric data which was only operational for a short time.

Several other stations are fitted with the automatic data loggers which are the instruments expected for every groundwater monitoring station. Within ENNCA, there are only two stations with data loggers namely Lolmarick and Backlit. Within the RVCA, Kabatini dedicated well and Rongai Dedicated wells are equipped data loggers and are occasionally downloaded for water levels data. Within ACA however, most of the data loggers dropped into the boreholes due to corrosion of the cable holders. This has led to loss of the opportunity to collect groundwater. The data loggers need to be reinstalled.

5.3 Improvements to Network Infrastructure

Water resources data acquisition and management is one of the WRA's strategic objectives geared towards sustainable water resources management. Improvement of monitoring networks is aimed at ensuring reliable data is acquired to enable planning, development and management of water resources.

Improvement to the groundwater monitoring networks is planned through drilling of dedicated monitoring boreholes. Equally wherever there is opportunity, memorandum of understanding with owners of production boreholes in crucial aquifers.

In the year under review within Rift Valley basin there were 6 new monitoring stations that were proposed to be established and rehabilitated. Five are yet to be established while one station was installed with an Automatic logger at Kreative Flowers.

Athi basin proposed additional stations targeting existing/abandoned boreholes with an aim of using them as monitoring stations and to expand their monitoring network. 15 existing boreholes have already been identified and awaiting discussion with the respective owners.

Through support from Kenya Water Security Programme, 25 dedicated monitoring boreholes shall be drilled within the Nairobi Aquifer Suite, Tiwi Aquifer and Lamu Sand Dunes Aquifer. Evaluations for the contractors has already been conducted and drilling shall commence very soon.

5.4 Assessment of Groundwater

Identification of sites for drilling of exploratory boreholes were carried for aquifers within various counties including; Isiolo (3) Embu (2), Tharaka Nithi (2), Machakos (2) Aquifers. Turkana (2), Marsabit (2) and Garissa (3) Counties. The assessment identified 16 No. sites whose drilling will commence in July, 2018. These exploratory boreholes will help in understanding the geology, nature of aquifers and their thicknesses, potential, aquifer characteristics and the groundwater quality. This goes a long way in groundwater resources characterisation, allocation and management.

5.4.1 Water Level

Ground water levels have been measured in boreholes that are distributed in the various aquifers across the catchment areas. The groundwater monitoring targets collecting static water levels and water samples quality analysis from the boreholes.

During the year under review, water levels were measured from some boreholes within the monitoring networks in each catchment. Water level trends for the operational groundwater monitored stations in meters from above mean sea level for the year have been presented.

Within the Ewaso Nyiro North basin, the groundwater level was consistently taken from four monitoring stations. The trends have been relatively stable during the year depicting a balance between abstraction and recharge as illustrated in Figure 5.2 below.

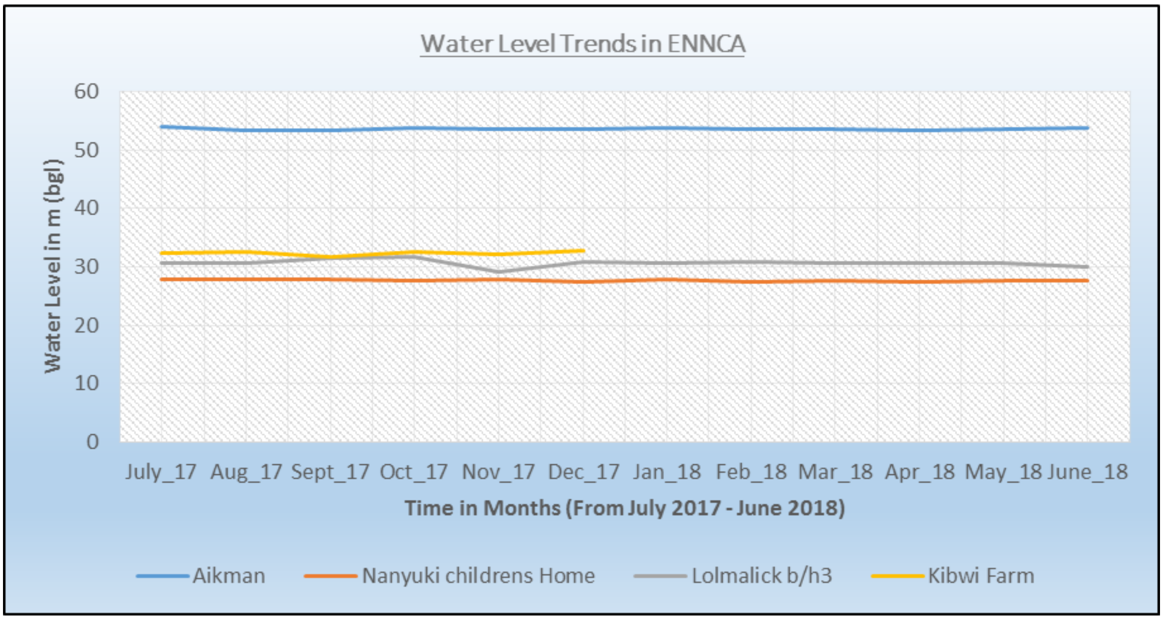


Figure 5.2: Noticeable Trends for four stations within ENNB

Four boreholes were used to show the trends in water levels within the Tana Catchment Area. Below are the water level trends for the operational groundwater monitored stations in meters from above mean sea level for the year.

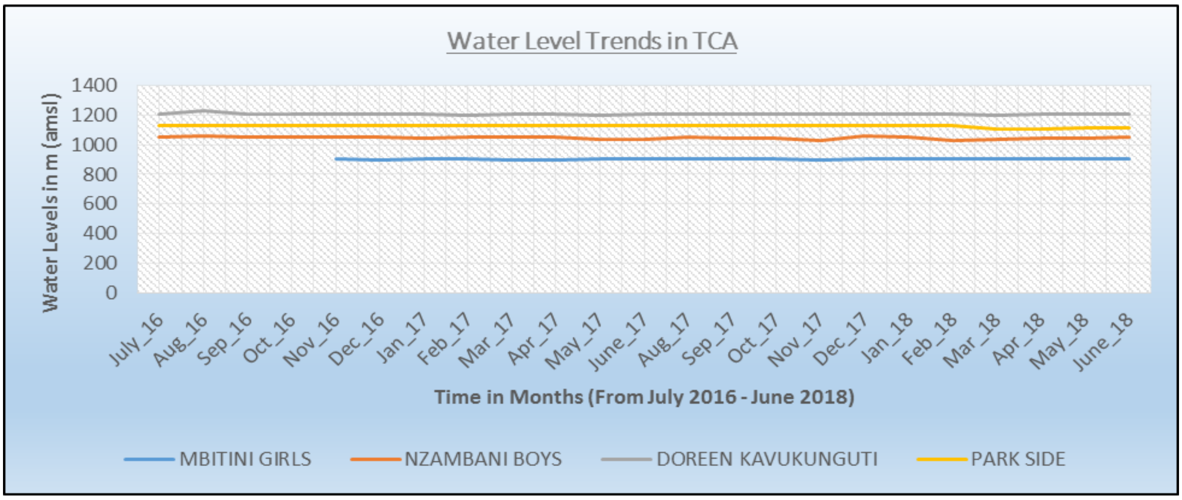


Figure 5.3: Noticeable Trends for four stations within Tana basin

Figure 5.3 shows the four stations monitoring the basement aquifer in Tana basin i.e. Doreen, Mbitini Girls, Parkside Hotel and Nzambani Boys exhibit a more-or-less stable condition.

In Rift Valley basin, the water levels were used to gauge the variation with seasons and time with respect to recharge due to precipitation. The graph below shows the water level variation in three boreholes lacted around Nakuru; Kabatini borehole, Baharini borehole and the St Mary's borehole.

Declining water level trend were observed in the Rongai special aquifer. This is attributed to:

- Changes in land use around the area, hence increasing surface runoff and reducing infiltration.
- Reduced rainfall in the area affecting the groundwater recharge.

In Naivasha area, the water levels are indicated in the graph below. The decline in water level in Panda farm count be attributed to over-abstraction by the farmer for irrigation purposes.

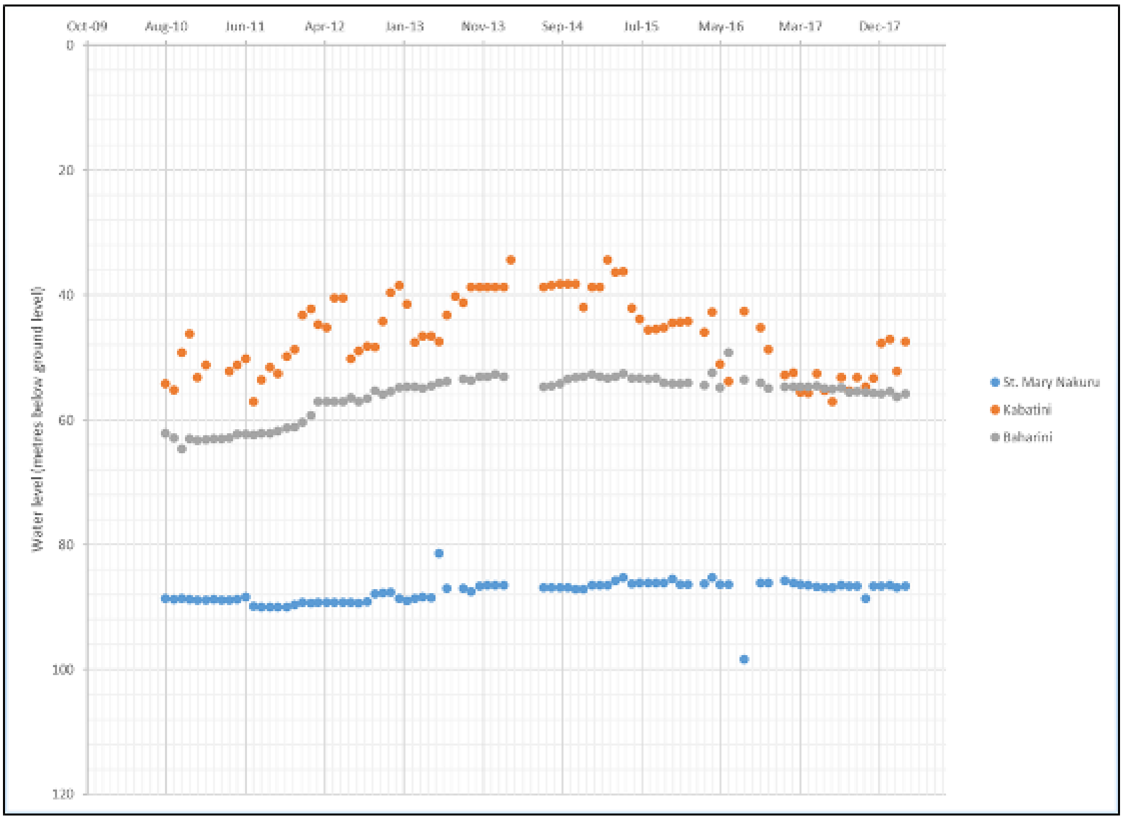


Figure 5.4: Noticeable Trends within Nakuru Monitoring boreholes

Water level trend is expected to give an overview of the general behaviour of the aquifer and responses to various occurrences either natural or anthropogenic. A few boreholes have been selected to depict water level trends in respective parts of the region as presented in the foregoing.

The Kabatini aquifer (Kabatini borehole) shows a recharge peaking in the year 2014, before declining. Kabatini aquifer is the major water supply supplying Nakuru town. An aquifer management plan is hereby proposed.

The Athi Catchment Area aquifers are diverse and its only justified to analyse the groundwater level trend on individual aquifers.

Nairobi Aquifer Suite

This Aquifer is found within Nairobi area and Upper Athi sub-Regions areas. The water level trends in boreholes within the aquifer zones are shown in Figures 5.5, 5.6, 5.7 and 5.8.

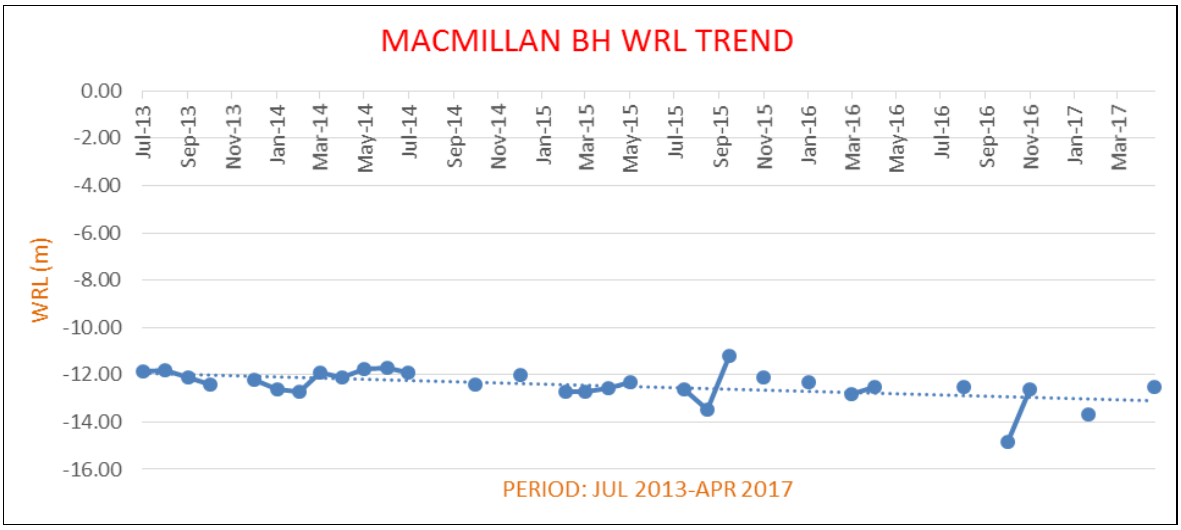


Figure 5.5: Water Rest Level Trends at McMillan Borehole

Macmillan borehole represents water level trend in upper Athi zone (3BC to 3DA) covering Ruiru, Juja and Donyo Sabuk. Available data for the last two years portrays declining levels within the Upper Athi sub-basins of the Nairobi Suite Volcanic formations. This can be attributed to high dependency on ground water resource in the area and high rates of abstractions. In the year under review, the available data is for one quarter only in the months of October and November 2016 with October giving the lowest level ever recorded at 14.84m bgl compared with other records.

Nairobi area Sub-basin Drainage areas 3AA to 3BB

These covers the areas of Limuru, Kikuyu, Nairobi City, Karen, Ruai, Athi River and Kitengela areas. Kabete water Supply, Riverside, Unilever, Kenya Poly Men's Hostels, Technical University and Jorgen boreholes represents water level trends for Nairobi Aquifer Zone (3AA to 3BB) covering the areas of Westlands, Limuru, Kikuyu, Nairobi City, Karen, Ruai, Athi River and Kitengela areas. Water levels in the City Centre and Westlands areas have been on the decline as depicted by the two boreholes Lorgen and Riverside. This can probably be attributed to increased abstractions and reliance on ground water source within the City CBD and Westlands areas.

Kabete water Supply borehole may be relied on to provide trends on recharge from lateral inflows from the Limuru-Rironi area. The water levels depicts continuous fluctuations with an almost constant trend despite many abstractions in Kabete and Nairobi City environs. There seems to a balance between discharge and recharge in the area which cannot be sustained as more boreholes are drilled eventually increasing the abstraction rate.

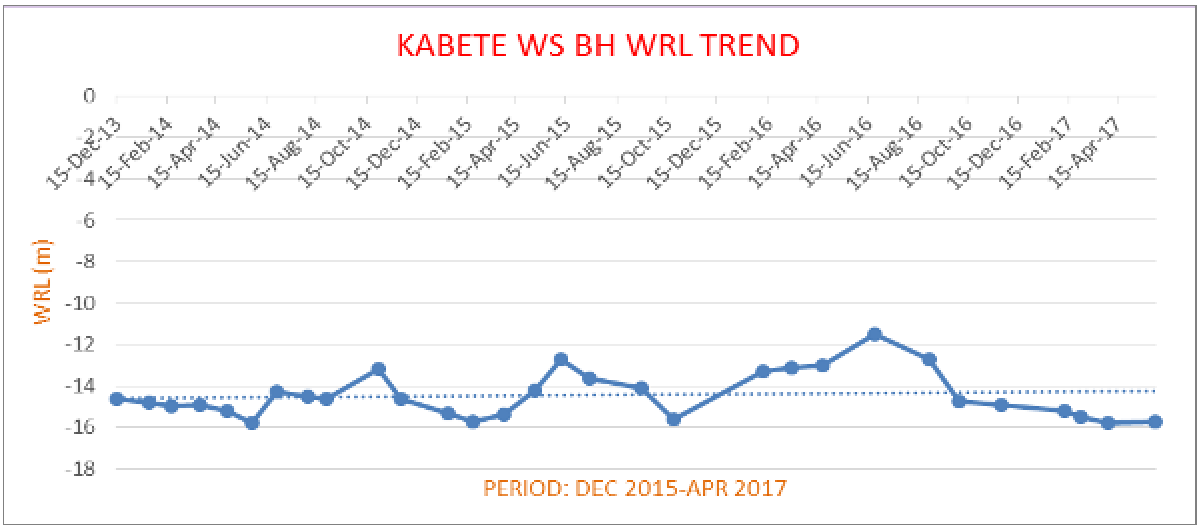


Figure 5.6: Water Rest Level Trends at Kabete WS Borehole

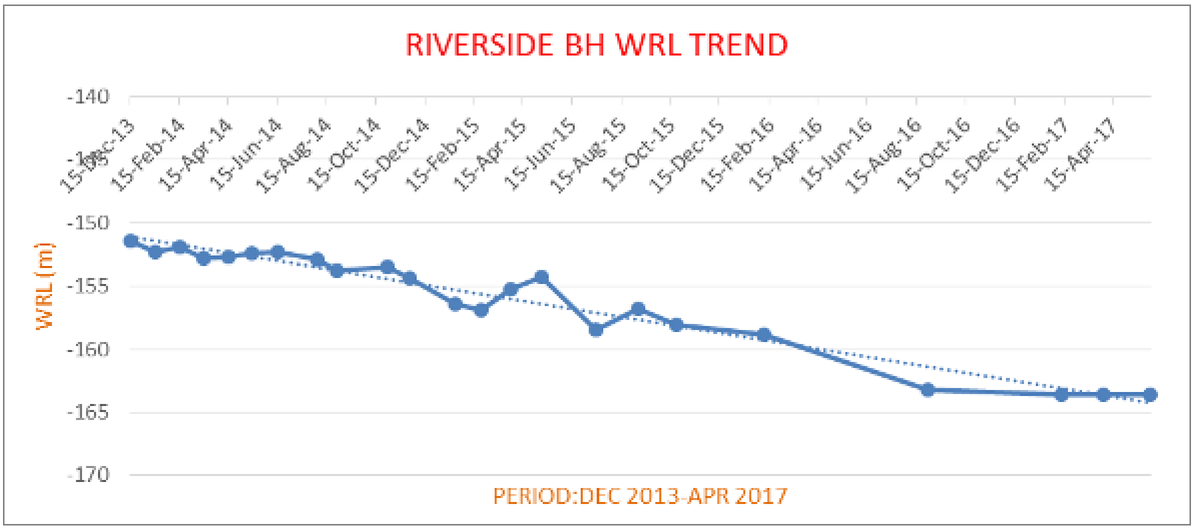


Figure 5.7: Water Rest Level Trends at Riverside Borehole

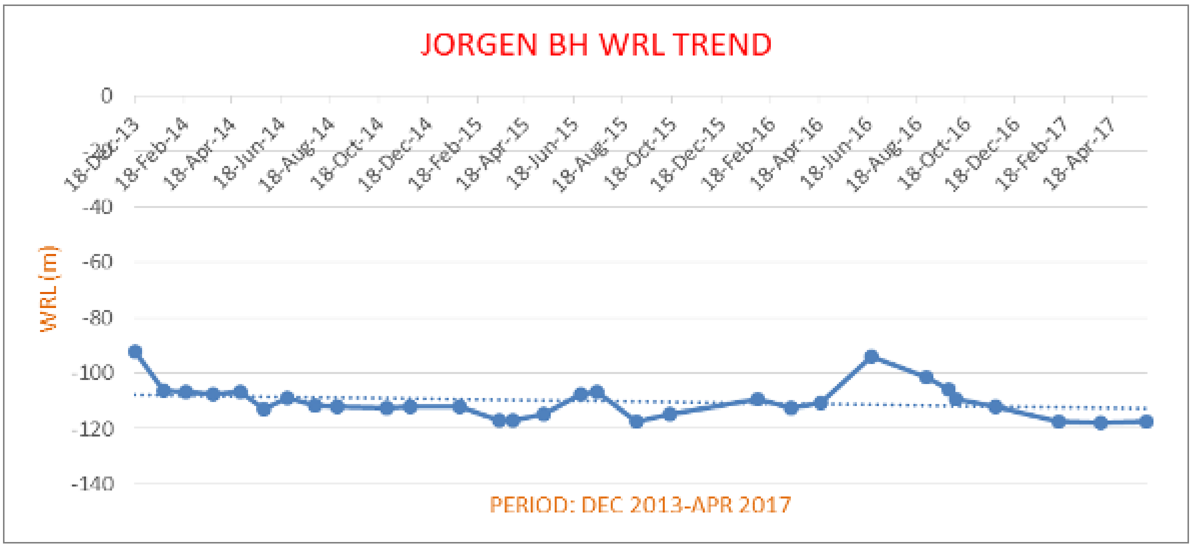


Figure 5.8: Water Rest Level Trends at Jorgen Borehole

An enhanced number of monitoring stations equipped with automatic data loggers can give real time data which will reflect the actual scenario of the aquifer behaviour hence avail reliable data to enable modelling for future predictions and management.

It is recommended that abstraction within Nairobi City be controlled and adherence to permit conditions enforced accordingly including sealing off of shallow aquifers above 100m depth in all the upcoming boreholes. Also gazettement of Kikuyu Aquifer GCA will go a long way in improving recharge of the Nairobi Aquifer Suite.

Again establishment of the proposed dedicated monitoring boreholes will be good and reliable avenue for gathering real time data to inform on the true scenarios of the Nairobi aquifer behaviour and subsequent ground water management precautions.

Coastal sediments

These are to be found within the Coastal Athi Sub-Region. Two boreholes, Mwembe Tayari and TIWI have been chosen to represent the coastal region water levels.

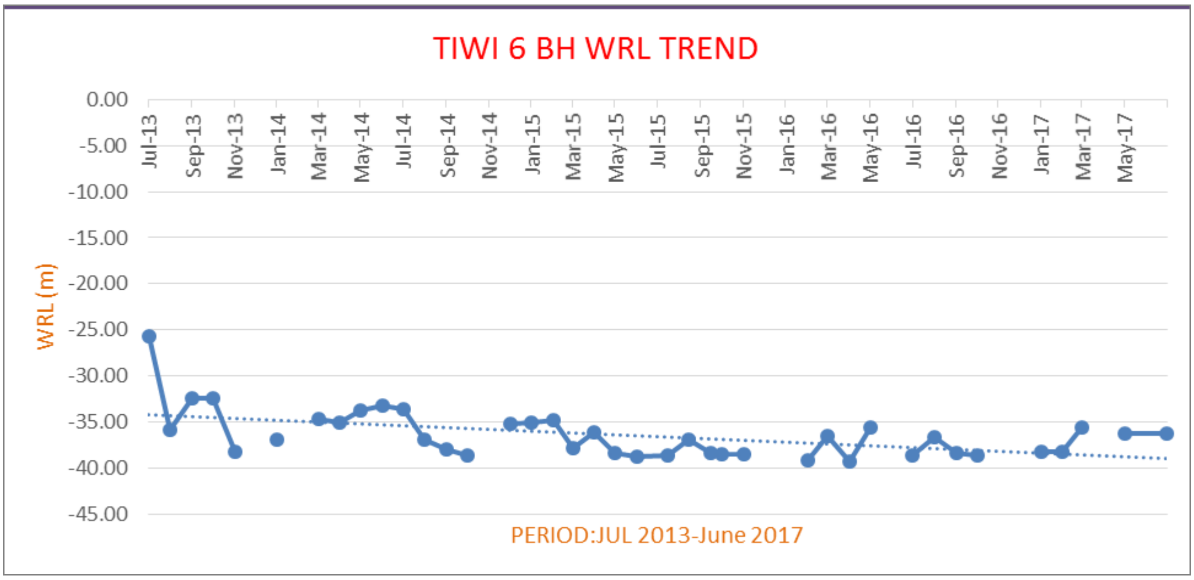


Figure 5.9: Water Rest Level Trends at Tiwi 6 Borehole

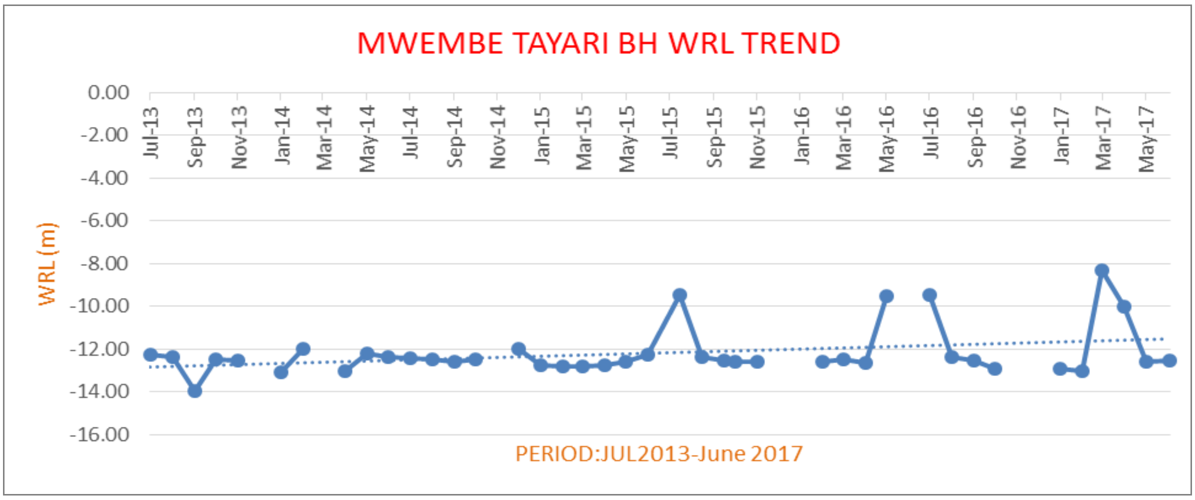


Figure 5.10: Water Rest Level Trends at Mwembe Tayari Borehole

Along the coastal strip, though water level data is not consistent, ground water levels have fluctuated over time as depicted by the trends from TIWI 6 and Mwembe Tayari boreholes. These seasonal fluctuations can be attributed to several factors among them:

i. Daily variations in water table resulting from evapotranspiration from the surrounding environment
ii. Prolonged dry spell resulting to reduced recharge in the aquifers
iii. Continuous pumping/discharges from wells in the surrounding e.g. CWSB wells in TIWI area
iv. Response to tidal currents

v. Effects of barometric pressure on confined aquifers due to vibratory motions caused by loading from heavy trucks, trains and also earth tremors

vi. Improved recharge around TIWI area as a result of the on-going rainfall along the coastal area.

Athi Basement

These are to be found within Machakos Makueni and Kajiado areas where Tawa Hospital, Bishop Kioko Hospital and Nzueni boreholes were occasionally monitored. However, data collected were very inconsistent as the boreholes have inconsistently been pumped or airlines were faulty. Therefore no reliable trends could be deduced.

Chyulu Volcanics

These are found within Tsavo west National Park extending to Emali Makindu and Kibwezi areas. Three monitoring boreholes have been established within Makindu, Kibwezi and Kambu areas. The three boreholes namely PCEA, Makindu Hopsital and Kiambani have a lot of data gaps and therefore no water level trends could be depicted.

Kilimanjaro Volcanics

These are found within Loitokitok area of Nolturesh – Lumi Sub-Region. The Nolturesh monitoring station depicts a true scenario of the aquifer since this BH is normally not in use and hence does not need time to recover before monitoring is commenced. Its trend since the year 2014 is presented in Figure 5.11 below.

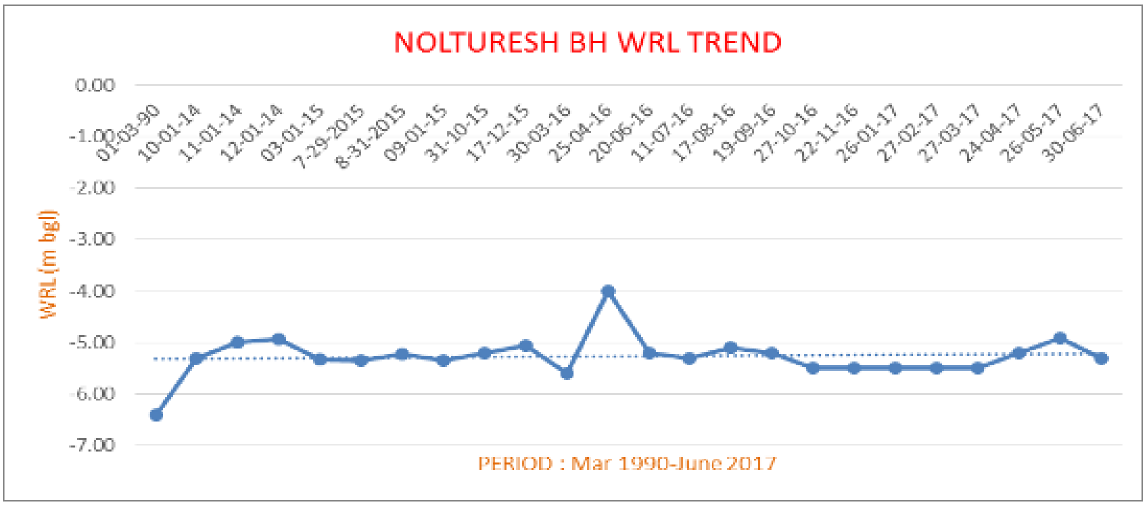


Figure 5.11: Water Rest Level Trends at Mwembe Tayari Borehole

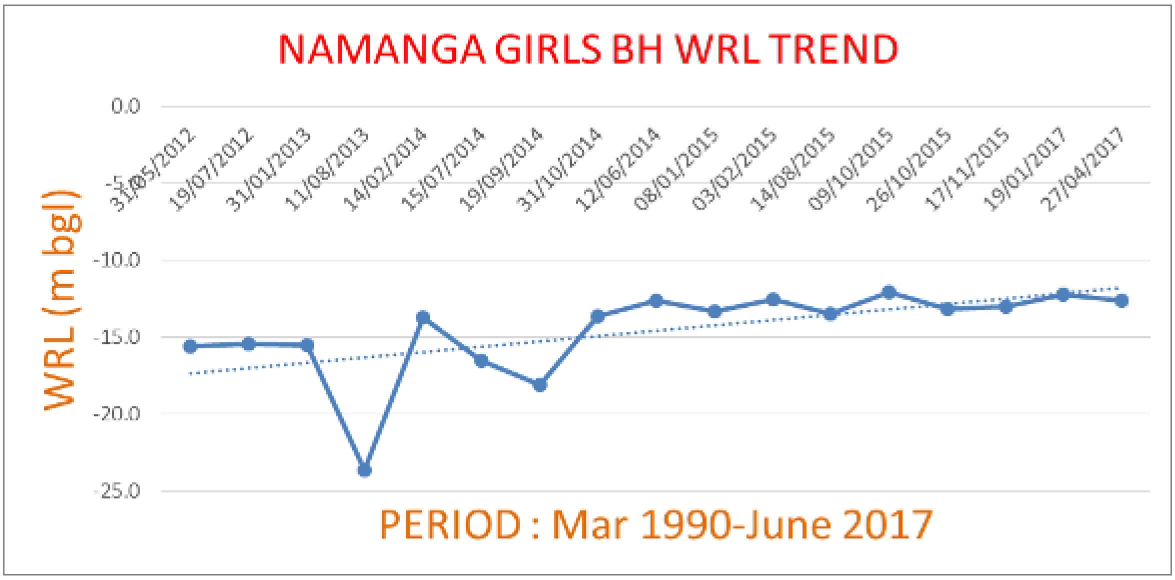


Figure 5.12: Water Rest Level Trends at Namanga Borehole

The Nolturesh monitoring station offers a true scenario of the aquifer since this borehole is normally not in use. The WRL has fluctuated over time but the trends remains almost constant over the years from 1990 to 2017. In the last one year, levels have shown fluctuations from a low of 5.50m in October 2016 bgl to a high of 4.92m bgl in May 2017. However, the trend have been relatively constant.

In Namanga area, levels have been on an increasing trend over time between 2012 and 2017. In the last one-year data availability is scanty to infer a true scenario.

5.5 Comments on Special Events

During the year under review, special events included the study of Kikuyu Springs and Lamu ground water conservation area. Launching of ground water database was also done.

5.5.1 Kikuyu Groundwater Conservation Area

A study commissioned by Water Resources Authority in 2010 to quantify mean annual recharge to the recharge zone of the Kikuyu Springs among other objectives. In undertaking the study, abstraction data was obtained from the water service providers and community water supplies. By this, the total annual recharge were found to amount to 13.2 MCM against an abstraction of 6.7 MCM from boreholes and 2.3 MCM abstracted from Kikuyu Springs discharge. This showed an increase in abstraction of nearly 350% in the last 30 years, and presented that up to 68% of the annual recharge is abstracted. A Catchment Management Plan was proposed and which WRA has been implementing since 2012.

The Water Resources Authority therefore having found that the Kikuyu Springs aquifer is under threat in view of the lack of a reserve declared for the aquifer. The Water Resources Authority through the management guidelines has put in certain measures including the gazettement as a groundwater recharge area to safeguard the Kikuyu Springs and by extension the Nairobi aquifer that supply water to the Nairobi City.

In the year under review the following was achieved.

1. The request for area to be gazetted as a groundwater conservation area was forwarded to the Ministry of Water and Sanitation.
2. Delineation of Ondiri and Manguo Swamps was undertaken
3. Installation of two tanks within the catchment area was undertaken at tow schools under Bathi WRUA in Kibagare and Kamahia. 2500 trees were also planted in the Bathi River Riaparian Land.

5.5.2 Lamu Groundwater Conservation Area

Following the completion of the scientific study that determined the boundary of the proposed groundwater conservation area (GCA), the area has since been delineated, surveyed and mapped. A Scientific report on the Lamu Catchment Area report by Kuria, Z (2008) seeking among other things to give the status of the sand dunes aquifer, indicated that there was already sea water intrusion into the fresh water zone and the wells have been reported to have dried. The Lamu Sand dunes aquifer is therefore threatened as a result of detrimental anthropogenic activities. Its vulnerability is very high as a result of these activities and due to its natural geological characteristics that predispose it if not checked to irreversible degradation. Owing to the extra water demand occasioned by other water sources drying up like in the drought experienced in 2017, the aquifer is experiencing stress. Due to the vulnerability of the aquifer, WRA has deemed it necessary there is need to put into place measures in the form of a management plan drawn as per the Water Act 2016.

The goals of the Management Plan are to ensure aquifer protection and conservation as well as sustainable use of the resources.

A valuation exercise for the Lamu GCA was undertaken between 17th and 27th January 2017 and a draft report for compensation estimate prepared. Development and ratification of the management guidelines and conservation plan schedules was also done.

5.5.3 Borehole Database

Several activities were undertaken towards development of the borehole database:

1. Digitisation of the borehole completion records hard copy records is ongoing at the Ministry of Water and Irrigation. Over 1000 records were digitised with GiZ support.

2. The WRMA borehole database application developed by Rural Focus under the Turkana Marsabit Study was completed. The WRMA BH database was rolled out in March 2018. Water Resources Authority has engaged casuals to digitize over 22000 records and populate it in the WRA Borehole database. More than 3000 records were populated in the borehole database by the end of June 2018.

3. WRA together with Ministry of Water have reviewed the 4 documents on codes of practice for groundwater between 25th February 2018 and 2nd March 2018. The review was to synchronise the documents to current practices and legislation. This is meant to be shared with the groundwater sector stakeholders especially drillers, hydrogeologists and county governments among others. A popular version on the drilling process has been developed to inform groundwater users seeking for authorization and permitting from WRA.

   A consequent workshop to share the documents with stakeholders was held on 28th March 2018 at the Crowne Plaza Hotel. The documents have now incorporated the comments from stakeholders. There was an appeal for the drillers to submit borehole completion records to WRA during the workshop.

5.6 Special Studies

5.6.1 Drilling of Exploratory Wells

The drilling of exploratory wells at the Turkana-Marsabit aquifers were done. For Marsabit Aquifer, 5 exploratory wells were drilled and works completed as per the contract in Laisamis, Kargi and Awaiye and El-adi , the remaining work entails drilling of the last borehole at Loiyangalani.

For the Turkana Aquifer, 5 Exploratory wells were also been completed as per the contract in Loperot, Lokichar , Lopur, Meyan and Kapsor.

In Garissa on the other hand, drilling of 5 No. exploratory boreholes were completed as well as per the contract in Abdisemed, Hagarbul, Hagarjareer and Welkajof. One borehole at Barazaben is on going.

During the year under review, ten (10 No.) exploratory well sites were assessed as shown in Table 5.1. Procurement of the drilling contractors was almost complete as at 30th June 2018.

Table 5.2: Assessed exploratory wells

	Locality	Village	Depth(m)
Lot 1	Isiolo South	Biki	450
Lot 1	Isiolo South	Hawaye	350
Lot 1	Isiolo North	Saret	450
Lot 2	Embu 1-Kiritiri	Karia Dispensary	350
Lot 2	Embu 2- Siakago	Riandu Secondary School	350
Lot 3	Tana River	Haroresa Village	450
Lot 4	Machakos	Isinya	350
Lot 4	Machakos	Lukenya	250
Lot 5	Tharaka Nithi	Kamacibi	450
Lot 5	Tharaka Nithi	Ciakariga	250

5.7 Challenges and Opportunities in collection of groundwater data

i. Production boreholes

Most of the boreholes operated as monitoring stations are privately-owned production boreholes for water supply purposes. In such cases to obtain good and reliable data, water pumping need to be stopped for at least 24 hours before the water levels are taken. This has not been possible and groundwater monitoring has been a big challenge. The time laps between the pumping stoppage and the level measurement is not consistent hence leading to inconsistent and unreliable data for decision making.

ii. Inconsistent Data

There is lack of long term data for comparison purposes therefore compromising the quality of the analysis.

iii. Logistical constraints

Groundwater monitoring has faced logistical support and limited resources. Several sub-region offices have not been able to undertake monitoring due to logistical challenges.

iv. Faulty tools

- Two automated stations have been abandoned due to faulty data loggers. Re-installation is recommended.
- There has been a problem of availability of Dippers.

v. Low number of Personnel

The low number of groundwater personnel has hampered the smooth undertaking of ground water activities at the sub regional offices. Some offices totally lack groundwater officers hence no ground water monitoring could be done.

6 WATER USE

Water use is regulated through permitting. Water allocation is dependent on availability of water in the water body. Applications are received at the sub regional offices and evaluated by the Regional Technical Evaluation Committee (TEC). Classes C and D applications are further evaluated by the National TEC. The applications that are recommended for approval are issued with authorizations to construct works. Once the works are completed, permits to abstract water are issued.

6.1 Permits

During the 2017/18 Financial Year a total of 1,281 permits were issued. Out of the which 1,084 were new permits while the rest were renewal of old permits.

The total permits processed through Permit Database (PDB) as at 30th June 2018 are 5,893.

6.1.1 Type of permits issued

The new permits issued in the financial year were as follows:

- 1,042 Groundwater
- 239 Surface Water
- 2 Effluent Discharge

6.2 Water Use

The number of applications, authorizations and permits in the permit database as at the end of June 2018 as presented in Table 6.1.

Table 6.1: Number of Applications, Authorizations, Permits in the Permit Database

Region	Hydro. Units	No. of New Applications	Current Authorization Status			Current Permit Status		
			Valid	Expired	Cancelled	Valid	Expired	Cancelled
LVN	36	218	226	610	0	627	89	0
LVS	29	359	212	761	0	200	66	0
RVC	33	452	511	1811	0	756	178	0
ATHI	32	921	2572	9845	0	2877	405	0
TANA	45	354	38	1130	0	601	383	0
ENNCA	29	30	226	884	13	479	122	8
Total	**204**	**2636**	**3786**	**15041**	**13**	**5540**	**1243**	**8**

There is need to correct the wrong hydrological units, 6AA and 6AB in the PDB appearing under Lake Victoria South region.

There were 2,636 new applications as at the end of June 2018. Athi region had the highest number of applications yet to be processed followed by Rift valley and Lake Victoria South respectively. ENNCA had the lowest number of new applications.

There were 3,786 valid authorizations against 15,041 expired ones. Athi had the highest number of valid authorizations followed by Rift Valley while LVSCA and ENNCA tie in the third place.

The highest number of expired authorizations were also from Athi, followed by Rift and Tana respectively while LVN had the least number of expired authorizations followed by LVS and ENNCA.

Only ENNCA region had cancelled authorizations. There were 5,540 valid permits against 1,243 expired ones. Athi had the highest number of valid permits, followed by Rift Valley and LVN. Athi had the highest number of expired permits followed by Tana and Rift Valley. LVS had the lowest no. of expired permits followed by LVN and Rift Valley respectively.

The final transactions Status by month between July 2017 and June 2018 are shown in Annex 4.

During the year under review, a total of 4,289 applications were handled at various offices in different levels as follows:

- 795 new applications received within the financial year, awaiting issuance
- 3,978 authorizations were processed within the Financial Year
- 235 authorizations extended
- 1,241 new permits issued
- 353 old permits renewed
- 10 Permits transferred
- 36 permits varied
- 155 applications deferred
- 52 applications rejected
- No permit was cancelled during the year under review

24 Sub regions had installed 1,563 meters in the permit database.

- 194 are for surface water abstractions
- 1,369 are for groundwater abstractions
- Kisii, and Mandera have not installed any meter in the system.
- All the sub regions in Rift Valley and Athi have installed meters and entered them in the PDB.

- Athi has the highest no. of meters installed followed by Rift valley and ENNCA respectively.
- LVS has installed the least no. of meters

Table 6.2: Permit Processing Performance (Ageing Analysis)

Category of Permit	Pending Applications < 30 days	Pending Applications 30 - 90 days	Pending Applications 90 - 120 days	Pending Applications 120-180 days	Pending Applications > 180 days	Average Permit Processing Time(days)
Cat A	0	10	6	8	88	1153
Cat B	14	326	79	82	575	1255
Cat C	2	11	3	7	67	1495
Cat D	0	2	6	8	121	1499
Total	16	349	94	105	851	5402

Table 6.3: Monthly Water Abstracted Between July-2017 and June-2018

	SW	GW	Total
July-2017	0	0	**0**
August-2017	0	0	**0**
September-2017	0	0	**0**
October-2017	0	0	**0**
November-2017	0	0	**0**
December-2017	0	0	**0**
January-2018	0	0	**0**
February-2018	0	857	**857**
March-2018	0	0	**0**
April-2018	0	0	**0**
May-2018	0	0	**0**
June-2018	0	0	**0**
Average	**0.00**	**71.42**	**71.42**

Water use data is presented in Table 6.6 according to the categories per subregion.

- ENNCA has authorized the highest volumes in category A, and Athi the least volumes
- Tana has authorized category B volumes followed by Athi. LVS authorized the least volumes
- Tana has authorized highest volumes in category C, followed by LVS and LVN authorized the least
- Tana has authorized the highest volumes in category D followed by LVS. ENNCA has the least volumes
- In summary the highest volumes of water have been authorized by Tana, followed by LVN and Athi.
- Authorized volumes include all application status at permit level

Table 6.4: Water use by permit category

AUTHORIZED WATER USE (m^3/d)					
	CATEGORY				TOTAL
REGION	A	B	C	D	
LVN	2057.33	22532.77	9301.09	297871.58	331762.77
LVS	1812.34	6126.65	32321.73	2812769.81	2853030.53
RVC	1341.84	22455.09	59788.23	2133918.77	2217503.93
ATHI	986.7	69759.02	180959.29	545201.01	796906.02
TANA	2017.6	376574.345	347977.64	81361487.46	82088057.045
ENNCA	8168.06	43889.69	99583.19	195749.73	347390.67
Total	**16,383.87**	**54,1337.57**	**72,9931.17**	**87,346998.36**	**88,634650.97**

6.3 Special Studies

Abstraction data collection and will be reported in subsequent reports.

7 EMERGING ISSUES

In order to accurately analyse the surface water situation, it is necessary that good quality data is used. As such, periodical discharge measurement and assessment/inspection of the hydrometric stations is necessary. The discharge data is used to update the rating equations while inspection of stations keep the gauge readers on check to ensure accurate water level data is recorded daily. The high flows experienced during the months of April to June 2018 presented a perfect opportunity for gauging high streamflows to updated the rating curves. However, this did not happen in most of the basins and the events were not captured. With the automation of the gauging stations, it will be possible to capture all events as they occur.

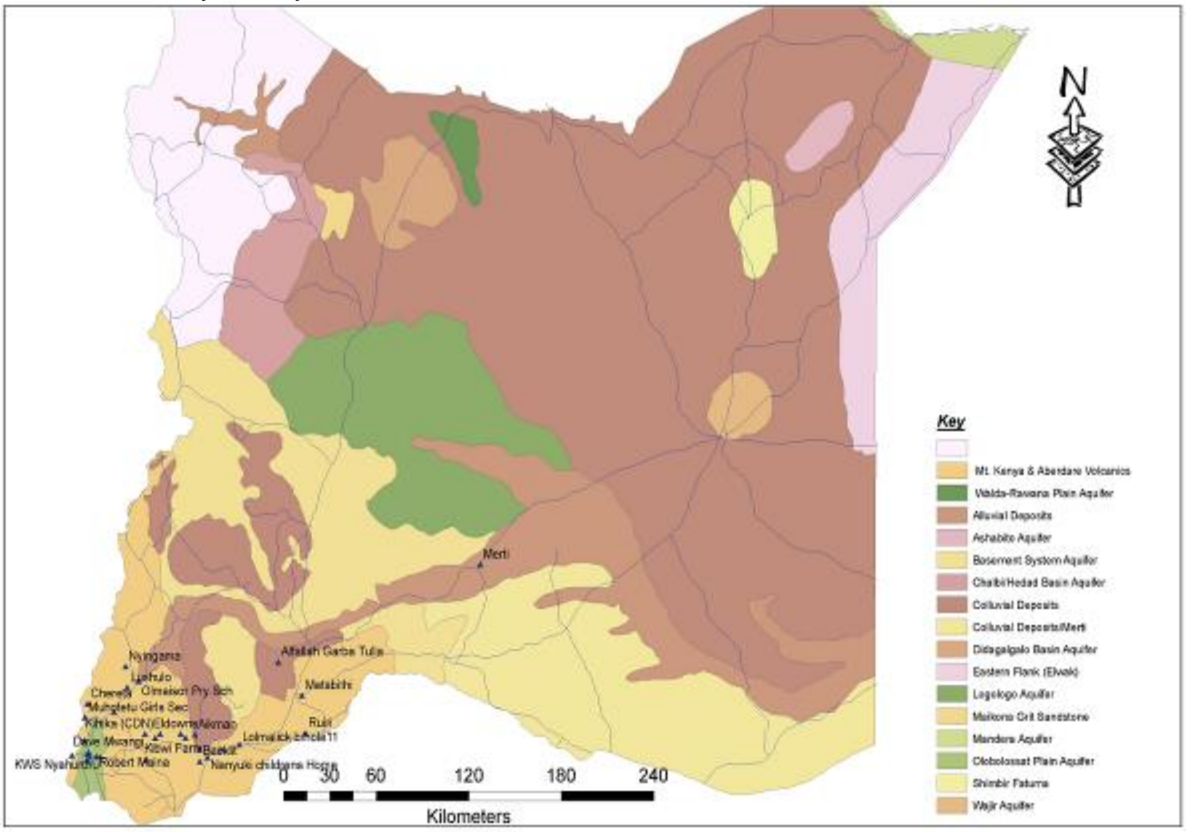
ANNEXES

Annex 1: Special studies and capital projects done in 2017/18 financial year

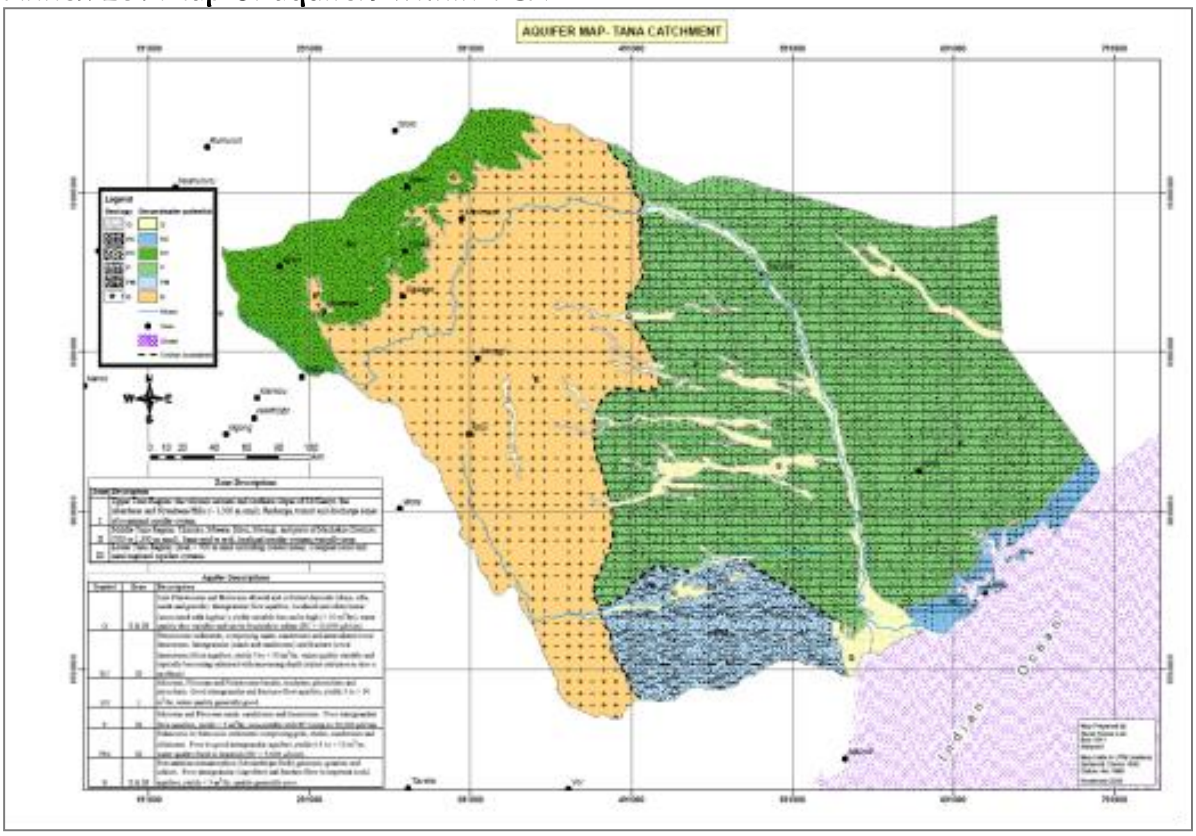
Region	Parameter	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual summary
Lvnca	Special studies done					1. 14no. Water abstraction & pollution survey 2. 1no. Water allocation plan. 3. Point source pollution awareness held, mapping and marking pollution and riparian encroachment under the arrp
	Capital projects done	Siyonga water allocation plan done		Chwele abstraction and pollution survey done		
Lvsca	Special studies done		Timbilil water abstraction & pollution survey			
	Capital projects done		Yurith water abstraction & pollution survey			
Rvca	Special studies done			10no. Water abstraction & pollution survey by wrua under upper tana natural resource project (ruguti, tungu, lower thanatu, gura, south mathiaya, chania, middle kathita, aura, kamuga mutonga and kithina)		
	Capital projects done					
Tca	Special studies done					
	Capital projects done					
Aca	Special studies done					

Region	Parameter	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Annual summary
	Capital projects done	Athi river restoration project; Mapping of pollution sources and riparian encroachment along nairobi river basin	Athi river restoration project; Marking the proscribed structures and activities on riparian land targeting nairobi river basin rivers: nairobi, mbagathi, kirichwa kubwa, kirichwa ndogo and ngong		Athi river restoration project; Held point source pollution effluent dischargers awareness and cognition of best practices on effluent discharge control plan at east africa foundry, ruaraka attended by ruaraka business community, danish embassy, wra and other key stakeholders	
Ennca	Special studies done					
	Capital projects done					

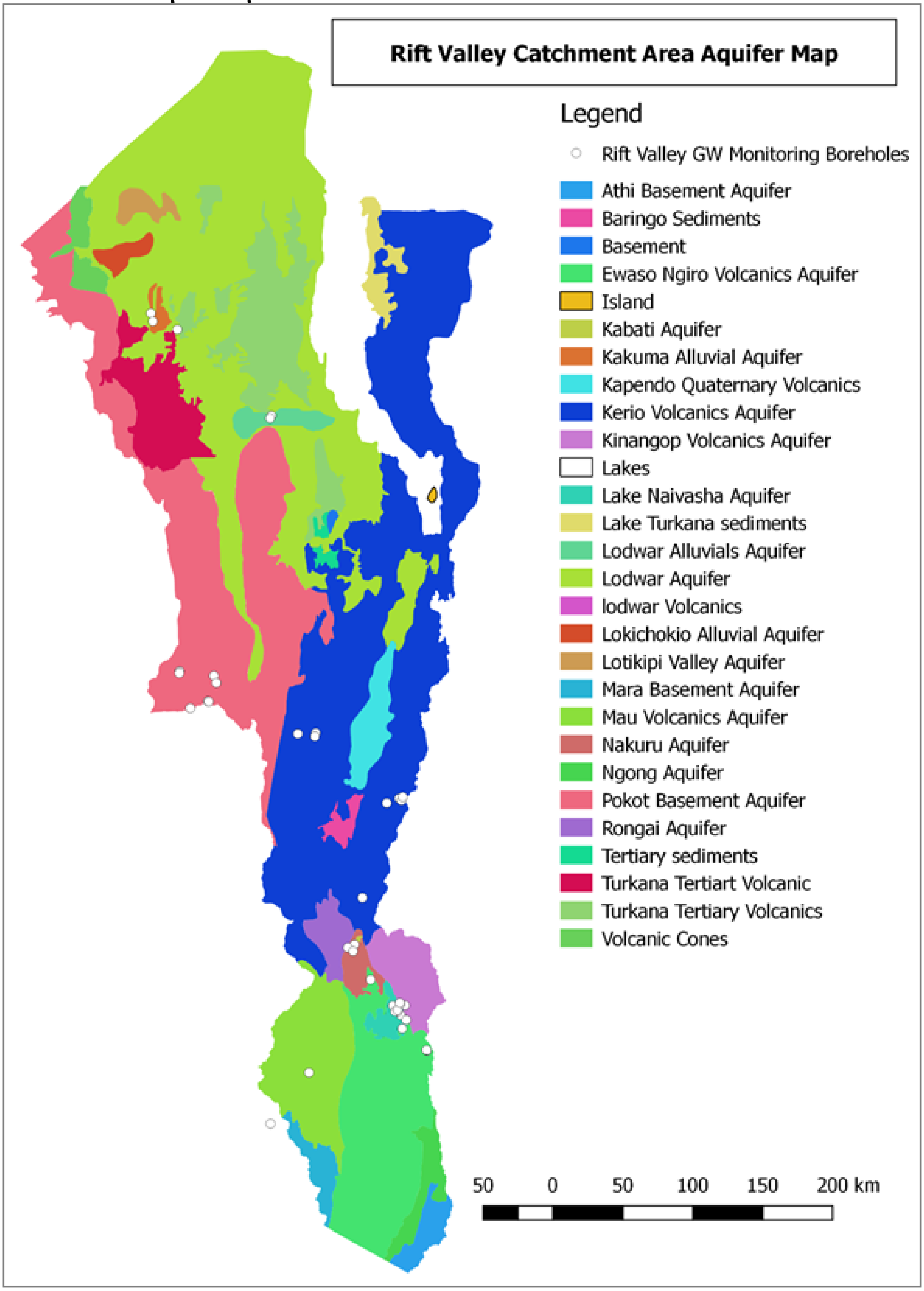
Annex 2A: Map of aquifers within ENNCA



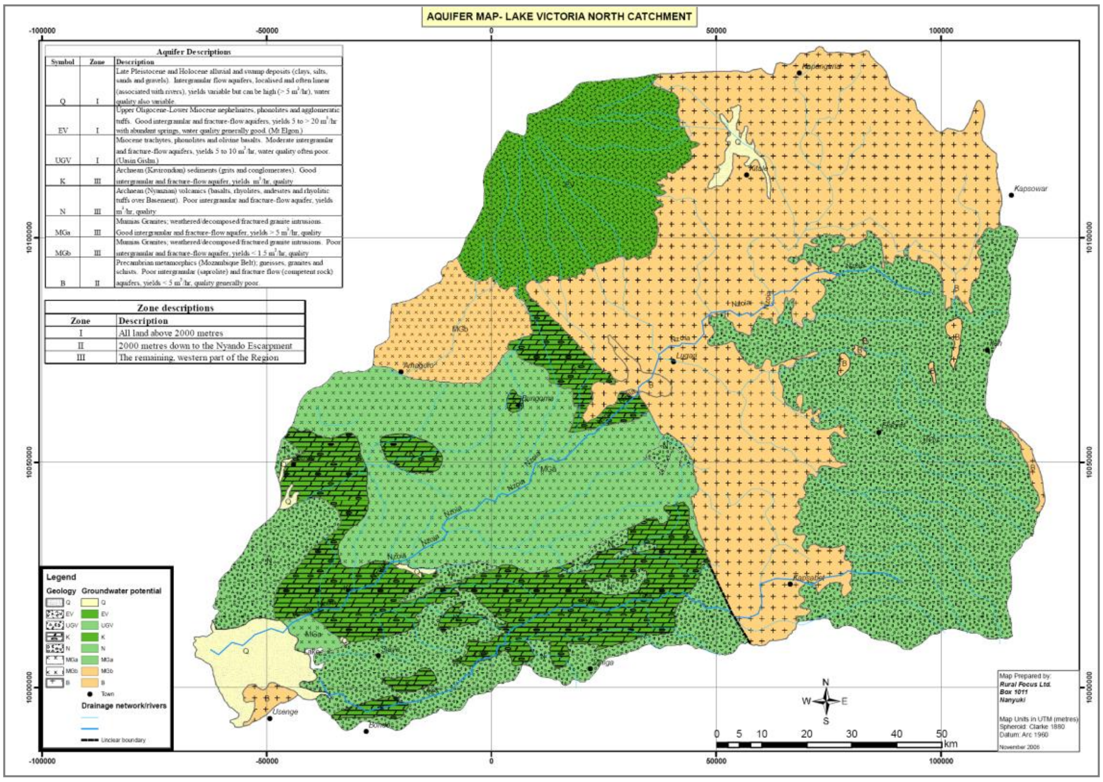
Annex 2B: Map of aquifers within TCA



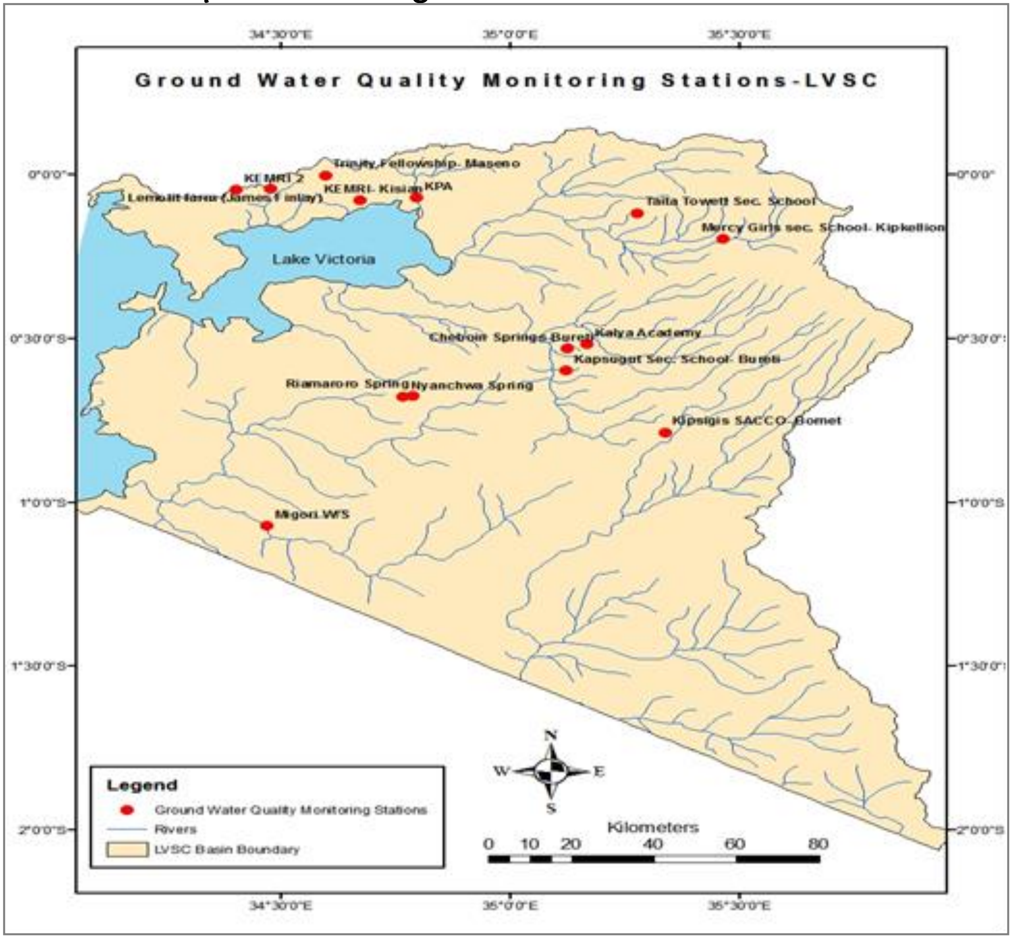
Annex 2C: Map of aquifers within RVCA



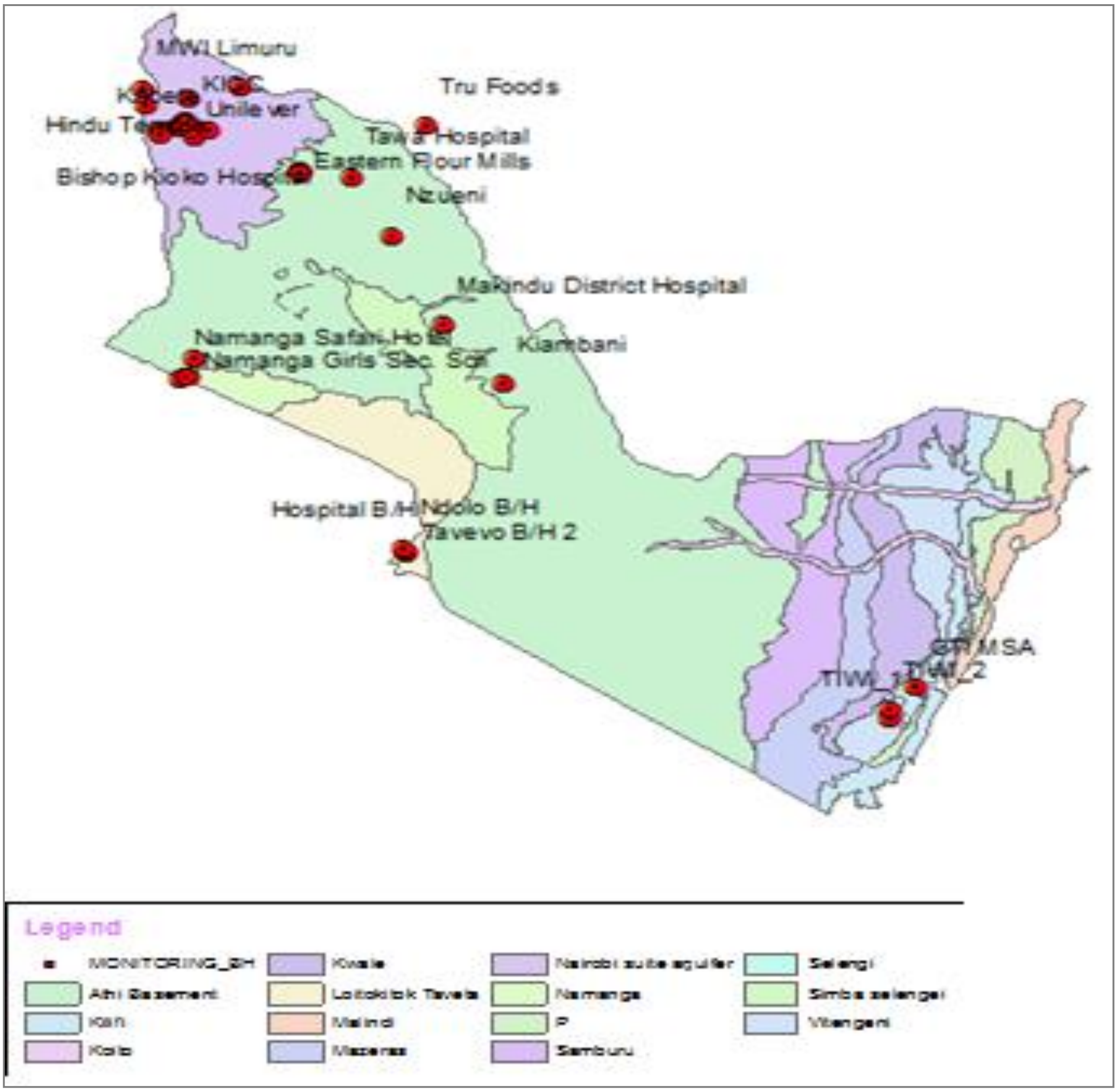
Annex 2D: Map of aquifers within LVNCA



Annex 2E: Map of Monitoring boreholes within LVSCA



Annex 2F: Map of Monitoring boreholes within ACA



Annex 3A: Ground Water Monitoring Stations in aquifers within ENNCA

Name	C- No	Aquifer	Class
Aikman	C-12826	Basement	Poor Aquifer
Backlit	c-241	Timau aquifer	Strategic Aquifer
Nanyuki childrens Home	C-11934	Mt. Kenya aquifer	Major Aquifer
Lolmalick b/h3	c-11311	Timau aquifer	Strategic Aquifer
Kibwi Farm	C -861	Basement	Poor Aquifer
Primarosa 1	C-14,058	Ol Bolossat	Strategic Aquifer
Tabor Hill 2	C-13662	Ol Bolossat	Strategic Aquifer
Kihingo Dispensary	C-12803	Aberdares	major Aquifer
Chereta	C-13345	Basement	Poor Aquifer
Familia Takatifu		Basement	Poor Aquifer
RUIRI	C-8974	Mt. Kenya	Major Aquifer
Matabithi		Timau aquifer	Strategic Aquifer
Kargi			

Annex 3B: Ground Water Monitoring Stations in aquifers within RVCA

Aquifer	Aquifer Classification
Mara basement aquifer	Poor
Nakuru aquifer	Strategic
Lodwar aquifer	Special
Pokot basement aquifer	Poor
Kakuma alluvial aquifer	Special
Lokichokio alluvial aquifer	Major
Lotikipi valley aquifer	Minor
Lodwar alluvials aquifer	Special
Lake turkana sediments	Poor
Kerio volcanics aquifer	Poor
Ngong aquifer	Major
Rongai aquifer	Special
Mau volcanics aquifer	Major
Ewaso ngiro volcanics aquifer	Minor
Lake naivasha aquifer	Strategic
Kinangop volcanics aquifer	Poor
Kabati aquifer	Strategic
Athi basement aquifer	Minor
Turkana tertiart volcanic	Poor
Baringo sediments	Special
Kapendo quaternary volcanics	Poor
Lodwar aquifer	Special
Lodwar volcanics	Special
Turkana tertiary volcanics	Poor
Turkana tertiary volcanics	Poor
Turkana tertiary volcanics	Poor
Turkana tertiary volcanics	Poor
Turkana tertiary volcanics	Poor
Turkana tertiary volcanics	Poor
Kerio tertiary sediments	Poor
Turkana tertiary volcanics	Poor
Turkana tertiary sediments	Minor
Basement	Poor

Annex 3C: Ground Water Monitoring Stations in aquifers within LVNCA

Station	Name	Aquifer Type	Importance	Aquifer Name
1	KEMRI - Kisian	Alluvium, tertiary Phonolites and Lake sediments	Major	Winam
2	Maseno trinity Fellowship	Nyanzian basalt	Strategic	Maseno
3	KPA- Kisumu	Alluvium, tertiary Phonolites and Lake sediments	major	Winam
7	Mercy Girls Sec. School	Tertiary volcanics	Minor	Kipkelion
8	Lelach Spring	Tertiary volcanics	Minor	Sotik
9	Riamaroro Spring	Bukoban System	Major	Kisii
10	Nyanchwa Springs	Bukoban System	Major	Kisii
11	Withur Community W/P			Winam
12	Ndori Water Project			Ndori
13	Taita Towett Sec. School			Kipkelion
14	Kapsogut Sec. School			Bureti
15	Kipsigis SACCO-Bomet			Bomet
16	Kinyose Spring			
17	KESREF			Winam
18	Kalya Academy			Kericho

Annex 4: Final PDB Transactions Report

Month/ Year	Application Received	Authorisation Issued	Authorisation Extensions	Permits Transfer	Permits Variation	Applications deferred	Applications rejected	Permits Issued	Permits Renewal	Permits Cancellation	Total
July-17	29	363	24	0	1	3	2	276	50	0	748
Aug-17	13	341	27	0	4	4	2	87	29	0	507
Sept-17	24	408	27	3	3	5	13	121	43	0	647
Oct-17	15	311	14	0	3	8	5	89	32	0	477
Nov-17	19	267	24	0	5	3	7	141	39	0	505
Dec-17	21	324	7	0	1	3	4	57	18	0	435
Jan-18	82	284	15	1	5	9	3	94	25	0	518
Feb-18	51	277	24	0	5	97	1	68	39	0	562
Mar-18	70	513	33	3	6	4	2	106	33	0	770
Apr-18	63	276	9	1	1	5	2	89	27	0	473
May-18	197	267	11	1	1	8	6	25	5	0	521
Jun-18	211	347	20	1	1	6	5	88	13	0	692
Total	**795**	**3,978**	**235**	**10**	**36**	**155**	**52**	**1,241**	**353**	**0**	**6,855**

Annex 5: List of Meters

List of Meters as at end of June 2018				
Region	**SRO**	**SW**	**GW**	**Total**
LVN	ELD	10	28	38
	KTL	1	8	9
	SYA	2	17	19
LVS	KCO	3	3	6
	KSI	0	0	0
	KSM	7	4	11
RVC	KAB	2	34	36
	KAP	0	1	1
	LOD	0	11	11
	NSA	26	184	210
	NAR	2	0	2
ATHI	KBU	15	67	82
	KBZ	19	63	82
	LTK	0	8	8
	MSA	0	118	118
	NRB	2	545	547
TANA	GSA	0	5	5
	KRG	11	17	28
	KTI	2	57	59
	MRG	9	27	36
	MRU	13	5	18
ENNCA	ISL	11	17	28
	MAE	0	0	0
	MIT	1	55	56
	NUK	41	54	95
	RUM	17	41	58
Total		194	1369	1563