JRIIE Journal of Research Innovation and Implications in Education
Center for Research Implications & Practice

Website:www.jriiejournal.com ISSN 2520-7504 (Online) Vol.8, Iss.4, 2024 (pp. 500 – 520)

Sustainable Abstraction of Water Resource: A Case Study of Kuywa Sub-Catchment in Lake Victoria Basin, Kenya

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Abstract: *Water resource – both surface and groundwater – provides the basis for any significant socio-cultural, economic and ecological development in any region or country of the world whether developed or developing. This owes to its multi-sectoral use in all spheres of development – industrial, urban, agricultural, public as well as domestic and aesthetic purposes. Its availability in the right quality and quantity is thus fundamental at any point in time. The reverse scenario – water scarcity or stress and compromised quality – retards development, a phenomenon usually blamed on bad politics. Far from it! Sufficient supply of clean and safe water to all users calls for safe yield abstraction. This is only possible if all the policy, institutional and legal frameworks in the water sector provided by the Water Act, 2016 are adhered to. The paper thus attempts to examine how safe yield abstraction can be achieved so as to enhance socio-cultural, economic and ecological development. This would translate into sustainable development. The study used surveys, photography, GIS and SPSS to collect and analyze data. Besides, GPS and ADCP were used during field survey. The paper focuses on the Kuywa sub-catchment in Kakamega catchment. The study established that a number of water abstraction points are functional but not protected by the users. The water points are privately, communally and institutionally owned. However, most abstractors do not have permits for operation. Water abstraction faces a number of challenges which need to be addressed for sustainable utilization. The findings are vital for streamlining water abstraction for sustainability.*

Keywords: *Water Abstraction, Safe Yield, Water Right, Water Scarcity, and Water Demand.*

How to cite this work (APA):

Odaro, D. O., Obiri, J. O. & Masika, D. M. (2024). Sustainable abstraction of water resource: A case study of Kuywa Sub-Catchment in lake victoria basin, Kenya. *Journal of Research Innovation and Implications in Education, 8*(4), 500 – 520. **https://doi.org/10.59765/prq759kj.**

1. Introduction

Water resource is quite fundamental for sustence of human life and other ecosystem services. It is both an economic and social good. Howver, due to the ever increasing human populations and economic demand over time and space, water availability and quality has reduced significantly. The world today is faced with a challenge of allocating water between the various human consumptive uses and and the ecological srvices (Zhou et al. 2015). The phenomenon therefore calls for sustainable abstraction of water resource if a balance between the two competing uses has to be achieved.

Unsustainable abstraction of water has been evident world over especially in the developing countries. For example, Kronaveter & Skamir (2009) observe that many regions of the wold withdraw more water than is locally renewable. The global ratio of consumption to renewable resources was 7% in 1990 and is projected to be 9% and 11% in 2025 and 20250 respectively (Kucukmehmetoglu & Gludmann, 2010). It is further projected that by 2030, the global water demand will outsrip supply by 40% (Brears, 2015) while water withdrawal will grow by 17% in the same period (Kenya Water Resources Group, 2016). Sustainable abstractionof water calls for appropriate methods that never impact significantly on the ecological services. This is an imperative since human actions to meet their water needs often alter ecological services to the aquatic ecosystems. For instance, Carolli et al. (2017) observes that water abstractions from rivers do alter the flow regimes of the channels therby impacting significantly on the ecological services.

The rural river basins in developing countries face the problem of increasing demand for freshwater resources due to urbanization, population growth, agricultural production and industrialization. In some of the river basins, the demand already exceeds supply. Many others are yet to reach closure. However, conflicts among competing water users have been observed in many river basins in the developing world. Generally, the demand for water includes both quantity and quality criteria. As the abstraction of water is increased, many water bodies are over exploited and polluted thus leading to water stress and compromised quality respectively. In this context, it has been increasingly difficult for the water managers to design allocation schedules that satisfy the sustainability of water resources, economic efficiency and equity among water users and environmental flow requirements at the same time.

The availability of good quality water is critical for human well being – socio-cultural, economic development - and the environment In fact, it is an indispensable economic driver for indutrial, urban and agriculrural developments as well as public utility (Environment Agency, 2010). Accessibility to clean and safe drinking water is an important ingredient for economic development, especially in developing countries, such as Kenya. It is, however, becoming very difficult to access clean and safe water in many parts of the world, and severe shortages already exist in some societies in sub-Saharan Africa such as Kenya (WWAP, 2009). The global nature of the water problem led to the United Nations (UN) coming up with a number of strategies, including a goal of halving the number of people without access to clean and safe water by 2015 in the Millennium Declaration. The situation is worse in developing countries where water scarcity is compounded by a lack of strong economic structures to combat the shortage. The development and management of water resources remain at the heart of struggle for sustainable human development, growth and poverty reduction as well as ecological sustenance.

In Kenya, water is important for the survival of its citizens and the country's economy depends on the well being of its natural resource base. Some of the major economic sectors like agriculture, tourism and industry are fully dependent on how well the water resources are managed. Similarly, Kenyan cultural and political structures are closely tied to the availability of water resources. However, with an increasing population and expanding industrial and agricultural sectors, demand for water is constantly rising and this poses the challenge of managing and allocating the available water resources in a sustainable and integrated manner. Some of the factors responsible for this situation include improper management of water resources, increased demand from the increasing population, climate change, degradation of catchments, pollution, and misuse of available amounts. To manage these challenges, water sector reforms were introduced through the enactment of the Water Act, 2002 (now Water Act, 2016) which established various institutions and delegation of responsibilities in water resources management and provision of water resources.

Among the institutions established include Water Resources Authority (WRA) for the management of water resources, Water Services Regulatory Board (WASREB) with the mandate of setting standards and regulating the sub-sector, Water Appeal Board (WAB) for adjudicating on water disputes, Water Services Boards (WSBs) with defined areas of operation to efficiently and economically provide water services, Water Services Trust Fund (WSTF) to finance pro-poor investments, Water Services Providers (WSPs) to act as agents in the provision of water and sewerage services utilizing acceptable business principles in their operations and Water Reform Steering Committees (WRSTCs) or Reform Drivers (RDs) to lead in the water sector reforms from time to time. The Ministry of Water and Irrigation (MWI) only oversees the whole water sector through policy formulation, coordination and resource mobilization.

Water resources management in Kenya is put under the responsibility of WRA as stipulated under the Water Act, 2016. WRA has adopted a catchment based management of water resources as a best practice as recognized internationally. In this regard, six catchment areas have been delineated based on six major river basin systems in Kenya. They include: Lake Victoria North Catchment Area, Lake Victoria South Catchment Area, Rift Valley Catchment Area, Athi River Catchment Area Tana River Catchment Area and Ewaso Ng'iro North Catchment Area

The Water Act, 2016 also recognizes the participation of stakeholders in the management of water resources in the country as stipulated in the Integrated Water Resource Management (IWRM) principles. In appreciation of the aforesaid, WRA involves local communities in each micro catchment as major stakeholders. The local communities are organized to form Water Resources User Associations (WRUAs). A

WRUA is an association of water users, riparian land owners or other stakeholders who have formally and voluntarily associated for purposes of cooperatively sharing, managing and conserving a common resource (WRM Rules, 2007). The WRUA usually provides a suitable vehicle around which to mobilize and coordinate the participation of water users in water resource management. WRUAs also ensure that water users participate in decision-making concerning management of water resources in sub-catchment areas. Furthermore, they play an important role in prevention and solving of conflicts over access and use of water resources.

According to Lake Victoria North Catchment Management Strategy in 2007, the population in the catchment faces enormous challenges in the management of the underdeveloped water resources which include but not limited to, catchment degradation, degradation of water resources, irregular water resources assessment and monitoring programme, climate variability, underdevelopment of the available renewable freshwater and competing needs and interests for the diminishing water resources.

Kuywa is one of the micro-catchments in Lake Victoria North (LVN) Catchment Area which has experienced the above challenges. In order to address these issues, WRA in LVN in collaboration with local community, established Kuywa Water Resource Users Association (KUWRUA) to help achieve the aims of catchment management strategy.

1.1 Objectives of the study

The general objective of the study is to establish the nature of water abstraction in Kuywa sub – catchment area with an aim of coming up with practical and realistic ways of achieving safe abstraction for sustainable development. The specific objectives include:

i. To determine the rates of water abstraction in the Kuywa sub – catchment.
ii. To investigate the level of compliance in water abstraction in the Kuywa sub – catchment.
iii. To investigate the potential challenges and threats based on objectives (i) and (ii) above.

1.2 Justification of the study

Kuywa Water Resources User Association (KUWRUA) was formed and registered on
14^{th} December, 2009 by the Registrar of Societies (Number 31142) as a suitable vehicle around which to mobilize and coordinate the participation of water users in water resource management. This is in line with the implementation of Integrated Water Resources Management as defined by the National Water Resource Management Strategy (NWRMS) and LVN Catchment Management Strategy (CMS). The objectives of KUWRUA were to: Improve the quality of water sources by controlling and managing sources of pollution; Reduce conflicts over water arising from illegal water abstractions and over-abstraction for irrigation by enforcing rules on water abstraction and promoting efficient irrigation practices.

Conserve and manage the water resources in the catchment by protecting and rehabilitating water sources such as springs, wetlands and other degraded areas; Discourage planting of high water consuming trees at water sources and support the re-introduction of indigenous trees in the catchment; Minimize soil erosion through soil conservation measures; and Encourage the sustainable use of water for economic gain. In order to implement the activities in the Sub-Catchment Management Plan (SCMP) to as to achieve its objectives, it was found necessary that a baseline survey on water abstraction be undertaken first hence the current study.

1.3 Study Area

The study is based in Kuywa sub – catchment in the Lake Victoria Basin, Kenyan region.

1.3.1 Location and Topography

Kuywa River basin is one of the watersheds within the Lake Victoria North Catchment Area. The entire river system is approximately 97 km long. It is one of the major tributaries of Middle Nzoia basin and traverses five Sub-Counties: Bungoma West, Bungoma South, Bungoma East, Bungoma North and Mt. Elgon. Geographically, the Kuywa catchment is bounded by the following latitude and longitude N 00^0 27' 30'' and 00º 49' 30'' and E 034^0 46' 45'' and 034^0 35' 00'' covering an area of about 344 km^2 (Figure 1a & b). The altitude ranges from 1648 m to 1314 m above sea level (GOK, 2023).

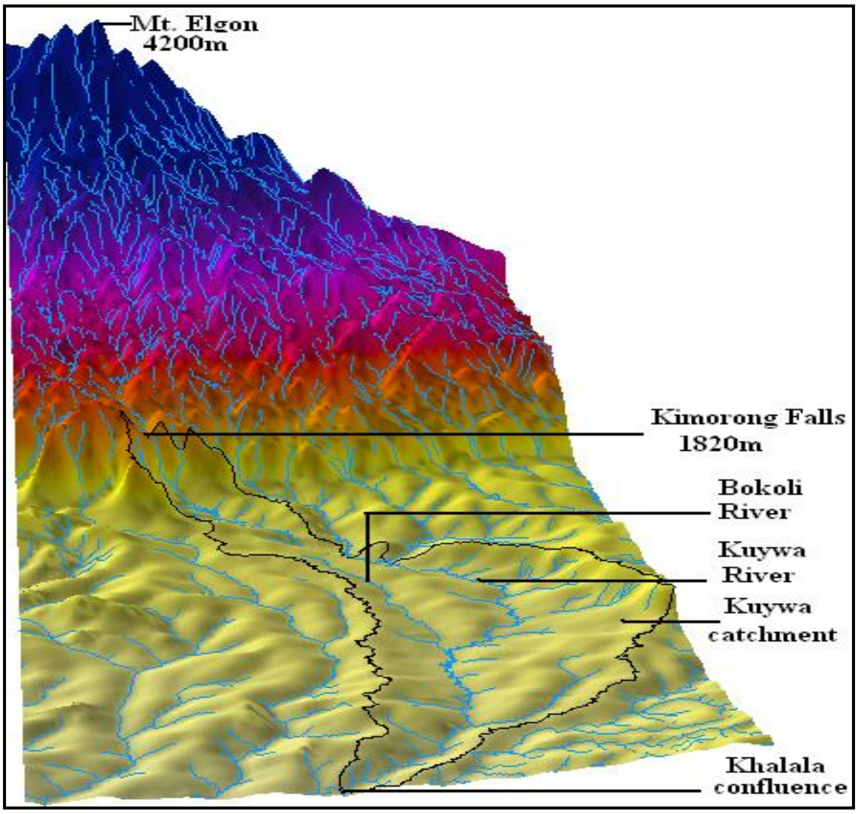

Figure 1a: 3D representation of Kuywa sub-catchment.

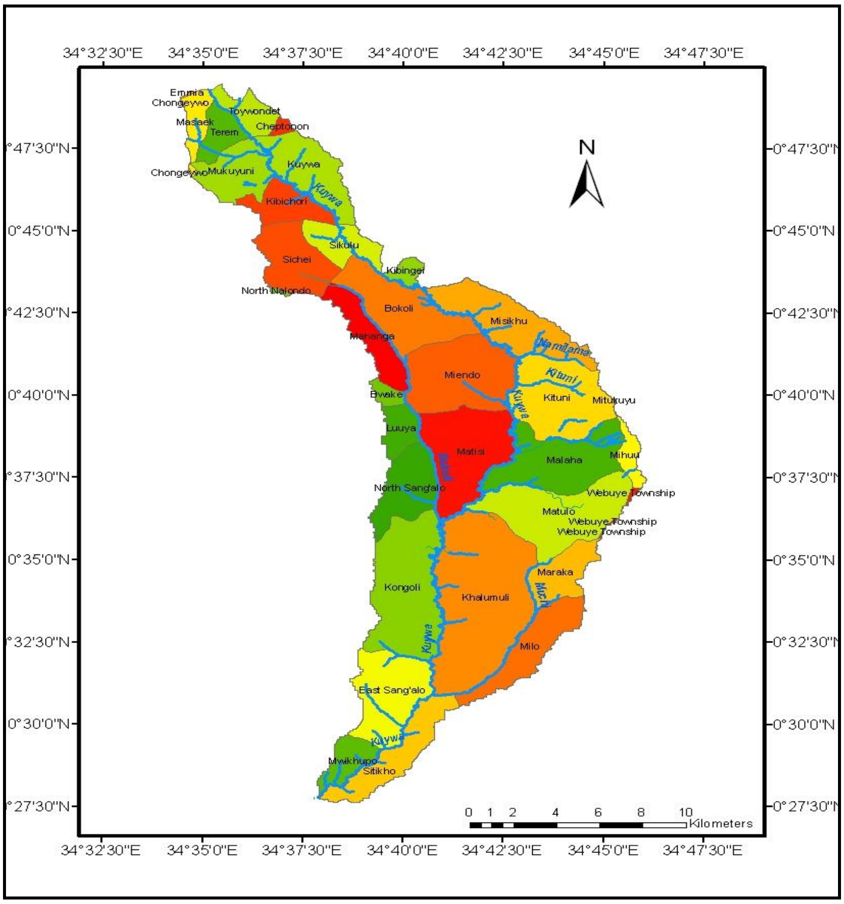

Figure 1b: Kuywa sub-catchment and administrative boundaries.

1.3.2 Hydrology

The catchment drains southwards from Mpakani (at Kimorong falls) in Mt. Elgon through Kuywa - Kibisi confluence all the way into river Nzoia (at Khalala). The tributaries of river Kuywa include Kibisi, Kibingei, Bokoli and Muchi Milo. Others include Samita, Chenjeni, Namawanga Chebukaka, Chebusitati Sitolola and Ndaret streams which join river Kuywa at different points. The catchment also has three (3) major swamps namely Samita, Namakhele and Namawanga.

1.3.3 Climate

The climatic condition of the catchment is humid. The rainfall pattern is bimodal, with the long rain season experienced from March to June and the short rain season is from September to November, while the dry spell from December to February. The mean annual rainfall ranges from 1400-1800 mm and the temperatures from 15^0C to 30^0C (GOK, 2023). The hydro-meteorological network in the watershed comprises two (2) Regular Gauging Stations (1DB01 at Matisi and 1DB03 at Kimorong) and seven (7) miscellaneous River Gauging Station (Kibisi at confluence with Kuywa, Kuywa after confluence with Kibisi, Kibingei at daraja mbili, Bokoli bridge, Kuywa upstream and downstream of Nzoia Sugar Company and Khalala).

1.3.4 Soils and Geology

The geology of the area comprises of metamorphic rocks having a strike of E-W and dipping in the north. These rocks are coarse grained foliated gneisses. In some areas they are covered by young black volcanic soils and ironstones from Mt Elgon eruptions. These soils and ironstones are from weathering of volcanic rocks formed during Mt. Elgon volcanic eruptions.

The soils in Masaek, northern part of Kongeywo and Toywondet sublocations (soil class R1) are developed from tertiary basic rock and are well drained, extremely deep dark reddish brown to dark brown friable and slightly smeary clay with an acid humic topsoil (ando-humic nitisols with humic andosols). In Terem sub-location, northern mukuyuni, eastern Masaek and Central parts of Toywondet sub-locations are found soils of humic nitisols (class R2). These soils are well drained, extremely deep dusky to dark reddish brown, friable clay, with an acid humic topsoil. Eutric nitisols (soil class F1) are developed on colluviums from basic igneous rocks and are well drained, very deep dark reddish brown friable clay. They lie in the northern parts of Kuywa sub-catchment around Mukuyuni, southern part of Toywondet, eastern Cheptonon, southern Masaek and western Kibichori sub-locations.

Ferralic arenosols with ferralo-chromic/orthic livisols (F16) are complex of well drained, deep to very deep, dark reddish brown to dark yellowish brown soils of varying consistence and texture in places gravely and stratified. They lie on the western parts of Misikhu, Mitukuyu, Mihuu, Malaha and Kituni sub-locations. In Kuywa and Kibichori sub-locations lie rhodic ferralsols (UI15) which were developed on biotite gneisses. These soils are well drained, very deep to dark reddish brown, very friable, sandy clay loam to clay. Rhodic ferralsols, partly petroferric phase (UI16) are well drained, moderately deep to very deep friable sandy clay to clay, very petroplinthite on valley side. They are found in most parts of Kongoli, south west Khalumuli, southern parts of Milo, north of East Sanga'alo, northern part of Sitikho and western part of Sichei sub-locations. Orthic to rhodic ferrolsols, partly petroferric phase and iron stones soils (UI20) are well drained, moderately to very deep, dark red to strong brown, friable clay; in many places shallow over petroplinthite. These soils are found in Sikulu, Sichei, Kibingei, Mahanga, northern part of Misikhu, miendo and Matisi; western half of Luuyia, north Sangalo and Kongoli sub-locations; milo, Maraka, and western half of Khalumuli.

Ironstone soils (UI11) are moderately well drained, shallow, brown to dark brown friable sandy clay loam, over petroplinthite (about 30%). These soils dorminate Sitikho, Mwikhupo, East Sang'alo and south east parts of Kongoli sub-locations. Dystric planosols, with pelic vertisols, vertic and humic gleysols and plithic acrisols (B10) are developed on infill mainly from undifferentiated basement system rocks (predominanltly gneisses). These soils are complex of imperfectly drained to poorly drained, very deep, very dark grey to brown, mottled, friable to firm, sandy clay to clay, often abruptly underlying a top soil of friable, sandy clay loam; in some places saline and sodic.in the sub-catchment, the soils run in a north-south strip orientation. The strip runs on the western half of Misikhu, Kituni, Malaha, to Matulo sub-locations. Another strip runs from Sikulu-Sichei sub-locational boundary through mid Bokoli, Miendo, Matisi, Khalumuli and along the divide on the western side in Luuya, Kongoli, North Saangalo to Mahanga sub-locations. Pellic vertisols, partly saline-sodic phase with eutric or vertic gleysols (B9) are poorly drained, very firm, deep, dark greyish brown to black, very fim, slightly calcareous, cracking clay; in many places with saline and sodic deeper subsoil. These soils mainly lie on the western side of Matulo, south west of Malaha and northern central parts of Khalumuli sub-locations.

1.3.5 Land use and agricultural activities

Kuywa micro-catchment is famous for crop and livestock production. The major crops are maize and sugarcane. Other crops include coffee, beans, finger millet, potatoes and groundnuts. The livestock kept by the farmers include both *Zebu* and high grade cattle, goats, sheep, donkeys and poultry. Most farmers practice mixed farming which involves crop farming and livestock rearing. The alternative land use systems being practised by the Kuywa residents include horticulture and brick making.

1.3.6 Demographic Characteristics

Human population in greater Bungoma County has been increasing steadily over the period. The 2019 Population and Housing census indicate that the Kuywa sub-catchment with 28 sub-locations (Table 1) has a population of about 126,725, with an average population density of 547 persons per square kilometer (KNBS, 2019). The most densely populated sub-location is Toywondet with a population density of 702 persons per square kilometre while the least densely populated is Khalumuli with a density of 247 persons per square kilometre.

Table 1: 2019 Demographic characteristics in Kuywa sub - catchment

Sub-location	Population	Area (Km^2)	Population density
Cheptonon	1164	2	583
Toywondet	3500	5	702
Masaek	2446	4	611
Terem	2994	5	595
Kuywa		19	580
Mukuyuni	5498	9	612
Kibingei		17	550
Kibichori	4033	7	577
Sikulu		8	547
Sichei	6968	11	635
Misikhu		33	658
Bokoli	1615	16	521
Mahanga	3654	8	456
Miendo	8031	19	422
Bwake	1070	2	535
Luuya	2087	4	522
Matisi	9874	18	548
Mihuu	1708	3	570
Malaha	9764	17	576
North sangalo	6604	10	662
Matulo	13266	19	699
Khalumuli	9148	37	247
Kongoli	9585	23	417
Maraka	3754	7	535
Milo	4677	10	468
East Sangalo	7123	15	475
Sitikho	5639	11	513
Mwikhupo	2523	5	505

Source: KNBS (2019).

1.3.7 Infrastructural Development

Kuywa Micro-Catchment is accessible and served by tarmac roads, earth roads with the Trans-African Highway and Kenya-Uganda Railway (now Rift Valley Railway) traversing the area. The major roads are Bungoma – Chwele – Kimilili – Kitale road, Kuywa – Kapkateny road, Chepkaka – Mpakani road and Terem – Bokoli road. The area is also served by cattle dips which are a major infrastructural development in the area. The major source of concern is the construction of dips close to water resources where the over-spills and wash off from the dips pollute the water.

2. Literature Review

The amount of water available for abstraction is determined by the amount of water already licenced for abstraction and how much water the environment needs as well as water that cannot, in practice, be used or stored like water that passes during the uncontrolled flooding (Environmrnt Agency, 2010; Speed et al. 2013). Water demand among the various competing sectors or users calls for equitable allocation of the available water resource. This will help to solve conflicts emerging from the competing regions in both upstream and downstream users as well as enhance environmental protection to take care of freshwater dependent ecosystems and protect freshwater services (Speed et al. 2013). Besides, water allocation provides a mechanism for determining who can abstract water, quantity to be abstracted, where, when and for what purpose.

Water allocation provides a means by which water use is regulated through sharing of the water resources among competing users with due regard for the environment, economy and the social well being of the people as dictated by their cultural way of life as explained in the Natural Resource Use Theory by Walter Firey (1961). The regulation aims to achieve equitable allocation of the available water resources for vaious competing needs in a sustainable manner such as the needs of the environment (ecology), economic development, water security, alleviation of water use conflicts as well as commitments made in international treaties and inter-basin water transfers (WRMA, 2008).

Water abstraction for various uses from any source changes the flow regime from the natural state (Ty et al. 2011). Besides, land use changes and climate variability can alter surface and groundwater hydrology while population growth, indusrial and agricultural expansion can modify the patterns of water demand and relative water scarcity (Cutlac & Horbulyk, 2011; Ty et al. 2011). It is imperative that water managers and water policy makers should consider these variables while allocating the available surface water flows to the vaious competing uses in a river basin.

Scarcity of freshwater resources for development activities among the various competing uses has necessitated prioritized allocation system for the resource. While a prioritized allocation is hailed or recommended when full water rights for all, water users cannot be supplied and therefore allows managers to take charge of the water use in a river basin by allocating water in a preferential order that could be based on defined objectives (UN, 2005; Cutlac & Horbulyk, 2011), it is criticized for failure to enforce efficient water use due to the absence of incentive structures, influence of politics, sectoral nature of responsibilities in the implementing agencies, unclear decision making mechanisms, inter-sectoral allocations and inefficient pricing (Weragala, 2010).

Sustainable water abstraction calls for a balance of the amount of water to be abstracted for various purposes and the need to maintain the integrity of the river basin ecosystem thereby achieving safe yield. This balance can be achieved by limiting abstractions and/or requiring discharges from impoundments by adopting the rules of allocation and assessment requirements such as allocating according to the historic observed average flows (Acreman et al. 2008). This rule only applies where there is relatively lower pressure on the available water resources. However, when there is a greater pressure on the available water, more sophisticated rules are adopted where water is allocated differentially from the hydrograph at different times of the year (Speed et al. 2013).

Unsustainable or excessive water abstraction often results into increased water use, lack of sufficient knowledge about water resources and lack of coordination in water resources management in the basin leading to water deficits downstream thereby affecting development therein (Mutiga et al. 2010). It is therefore important to balance or match the water requirements for the various competing uses or sectors in the basisn with the available water resources so as to achieve both economic and environmental or ecological sustainability.

The site or location of abstraction points is equally critical for water availability for different competing uses. According to Postel et al. (1996), municipal and industrial activities should be located upstream of agricultural projects so as to ensure sufficient water availability downstream since return flows for these uses are about 90% of the initial abstractions. That reverse scenario may be counter-productive since evapotranspiration from agriculture consumes between 50% and 80% of the abstractions depending on the type of crops grown, climate and irrigation efficiency (Postel et al. 1996).

3. Methodology

A number of methodologies were used to collect data. Appropriate tools for data collection were developed and utilized. To ensure that all the requirements and information needed as per the study objectives were captured, the mapping exercise was planned and executed as illustrated below.

3.1 Pilot Survey

Reconnaissance survey was carried out prior to the main field research. The purpose of the survey was to familiarize with the study area and current situation on the ground in order to identify the potential respondents – both water resources users and stakeholders – to be used in the sampling frame. During the exercise, informal interviews were conducted. Besides, structured questionnaires or schedules to be used in the main field research were tested and reviewed. The responsibilities and roles of each research team were clarified.

3.2 Sampling Procedure

The study used two (2) techniques namely simple random sampling and purposive sampling. The first technique targeted the community members who abstract water within the sub-catchment while the latter technique targeted the KUWRUA members and specified stakeholders such as water resource use regulators.

3.3 Field Data Collection

The field phase was carried out by the researchers and their assistants accompanied by the KUWRUA representatives. Three (3) teams, each covering its own area, were in place to undertake the survey. Each team was equipped with a set of questionnaire papers, a GPS device, a bucket, stop watch and measuring tape. During the field visit, contacts were made with individuals and the management of the various water projects. The target was to map out and collect attribute information regarding water abstraction points in Kuywa sub-catchment.

The geographical coordinates of the water points were recorded using hand held GPS sets for geo-referencing. The GPS coordinates were taken directly at the points of abstraction. The longitude and latitude were taken in UTM coordinates and the altitude in meters above mean sea level (a.m.s.l) using the Arc 1960 datum. Attribute information were gathered through consultations and discussions with water points management, individual owners or other relevant respondents using the generated questionnaire. A standard questionnaire guided the survey team on which details to take from the abstraction points. The questionnaire contained parametres such as owner, GPS coordinates, permit, authorized abstraction, measuring devices, status of abstraction works, surrounding activities, storage facilities and actual abstraction assessment. Photography was also used to pictorially document the nature and status of existing water points.

Discharge measurements at the springs and other abstraction points without measuring devices were done using 20 or 5 litre jerricans together with a stop watch. Flow measurements in the rivers were carried out using an ADCP or current meter for those rivers with a reasonable flow while the float method was applied for streams that had very low flows.

Abstraction assessment was the most challenging part of the survey exercise. This was so because of the different methods used to measure flow from the different sources i.e springs, rivers and groundwater aquifers. The average daily abstraction was easily calculated for abstraction points where measuring devices were installed. However, for cases where measuring devices were not installed two approaches were used to do the abstraction assessment namely the supply and demand based approaches.

The supply based method was done using flow measurements in open stream or volumetric measurement in piped systems (including protected springs). The volumetric method measures the outflow of water from a pipe for a certain time period using a bucket with a known volume. The time it takes to fill the bucket gives the capacity of the gravity pipe or pump in volume per time. This value multiplied by the total usage time per day gives the actual amount abstracted per day.

The demand based approach assesses the demand of water for irrigation, livestock or domestic. In the case of irrigation, the area under irrigation was multiplied by the standard water requirement of 60 m^3/day/ha. For more precise calculations, irrigation method, crop type and weather conditions are needed. The water requirements for livestock were assessed using standard requirement. Every Livestock Unit (LU) requires 50 litres per day. One LU is equivalent to one (1) grade cow, three (3) indigenous cows, fifteen (15) sheep or goats or five (5) donkeys. The water requirements for domestic use were assessed by considering the number of persons per household and determining the consumption rate per day.

3.4 Data Analysis and Presentation

After the field survey, the collected data were coded and data entry using MS Excel and SPSS (version 29) was done. Analysis was then carried out and this involved organizing the data collected using the GPS sets and the questionnaire into manageable database that enabled the link between spatial and attribute information. Using ArcGIS software version 9.3, the GIS layers were created and generated into maps. The findings of the study have been presented in the form of figures, tables, charts, maps and graphs. The study used qualitative techniques in data analysis since the methods tended to be strong in terms of validity (Babbie, 1986; Medina, 1998).

4. Results and Discussion

This section presents the findings of the study, which have been discussed in various sub-sections as detailed below. The findings have been presented according to the study objectives.

4.1 Drainage System

A map of Kuywa sub-catchment (Fig. 2) shows the basin boundary, drainage pattern, regular and miscellaneous gauging stations, market centres and other relevant features. The upper parts of the Kuywa basin is drained by Rivers Kibingei and Kibisi while the middle part is drained by a number of small streams. The lower part is drained by river Bokoli and Muchi Milo together with a number of other small tributaries.

For purposes of effective management of the Kuywa basin, the larger Kuywa is divided into three (3) zones namely A, B and C, with each zone consisting of a management team. Zone A extends from Mpakani area, close to the foot of Kimorong falls to the confluence of Rivers Kuywa and Kibisi. Zone B stretches from this confluence to the railway line while zone C extends to the point where Kuywa river discharges into Nzoia river (Khalala area).

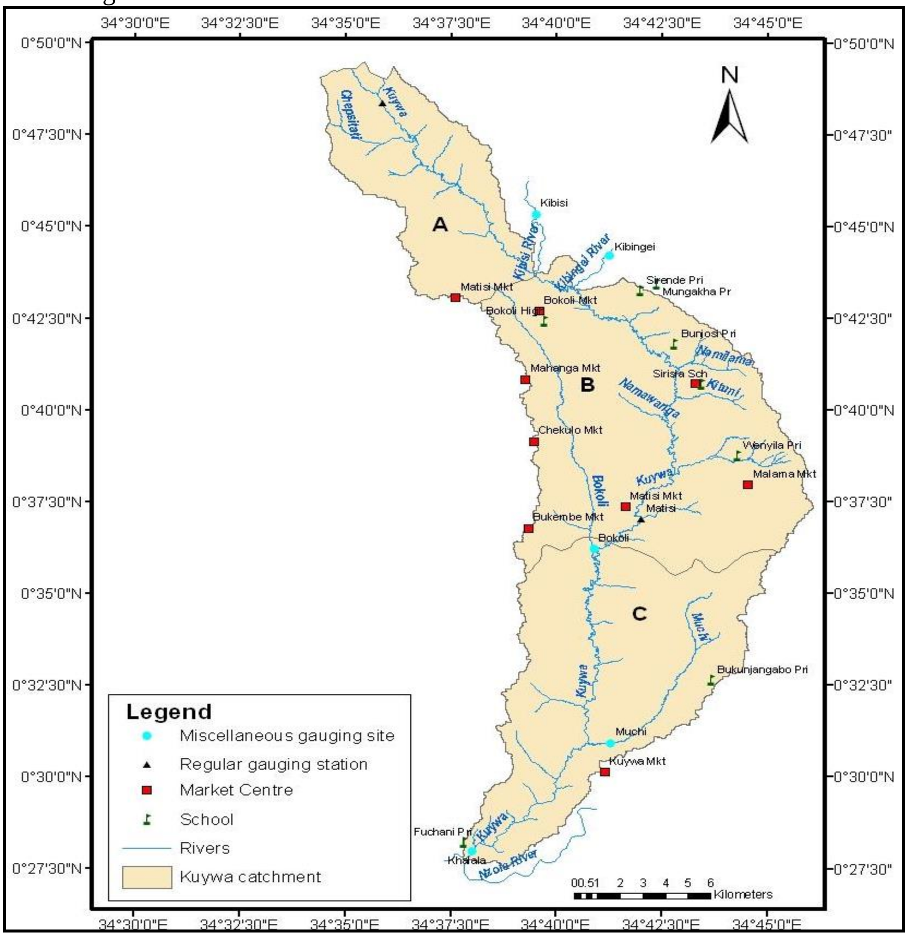

Figure 2:Kuywa sub-catchment base map.

4.2 Water Abstraction Points

A total of 305 water abstraction points were identified and mapped during the survey. These include 159 shallow wells, 121 springs, 17 boreholes and 8 river abstractions. Figure 3 summarizes the proportions of water points mapped. The figure indicates that shallow wells are the most prevalent (52%) followed by springs (39%), boreholes (6%) and river abstractions (3%). Mount Elgon region and Kuywa basin act as recharge areas for most of the water sources in this catchment. Many households have undertaken private interventions in water supply by sinking wells in their compounds due to the distances from the springs and also because of the high water table in the study area.

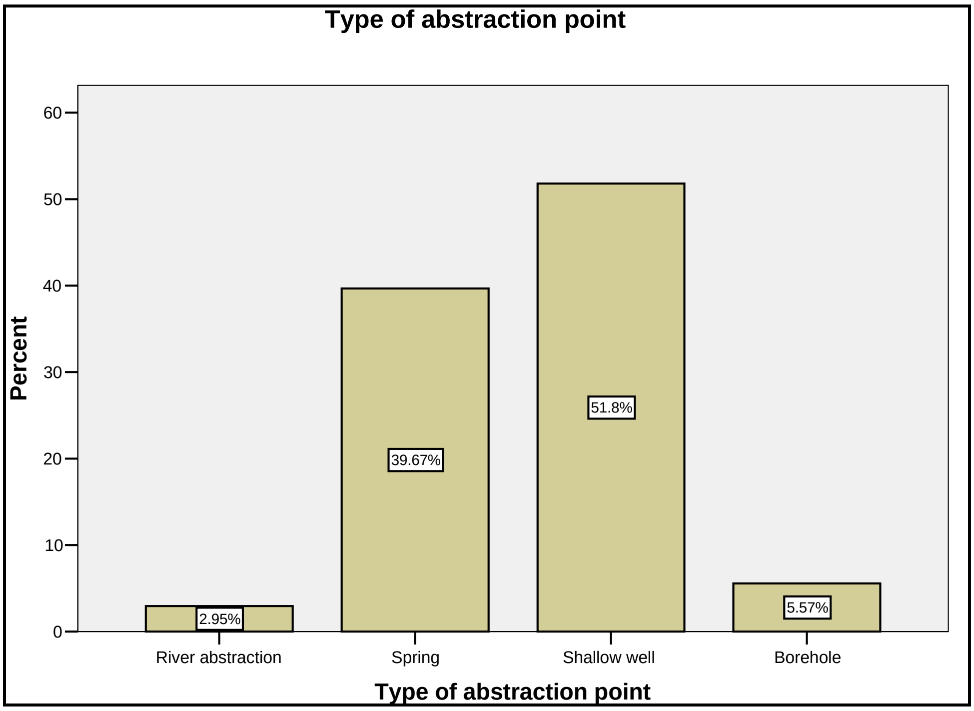

Figure 3: Distribution of water points in the study area.

The spatial distribution of water abstraction points in the study area was presented in form of GIS maps. The collected spatial information was generated into layers and then overlaid to create the maps. From the generated maps, it was noted that there is fair spatial distribution of water points in the whole study area (Fig. 4). However, in terms of the various water sources, springs are the most well spatially distributed (Fig. 6) while shallow wells show skewed spatial distribution (Fig. 5) with the northern and southern parts of the study area having more shallow wells compared to the central parts of the sub - catchment. The river system is such that most streams flow from the north towards the south, influenced by the geological controls manifested in form of valleys and depressions in the area.

A number of reasons may be attributed to the observed spatial distribution. First, the higher grounds act as a catchment and recharge area for a number of perennial streams originating from the upper part. The sources of these streams are manifested as springs which then feed the streams in the study area. Shallow wells are concentrated in the upper and lower parts of the catchment where the population is fairly high while the area is characterised by high water table. The upper part of zone ‘C’ is characterised by few water abstraction point sources due to the fact that it is mainly covered by Nzoia Sugar Company cane nucleus estate. Since most springs are concentrated on the slopes of river valleys, the nature of terrain, distance from the springs and the slippery grounds make fetching water from those springs a tedious exercise. Therefore, the population in most parts of the study area have made concerted efforts to seek for alternative water sources, hence the many shallow wells that have been sunk to supply water for livestock and domestic purposes.

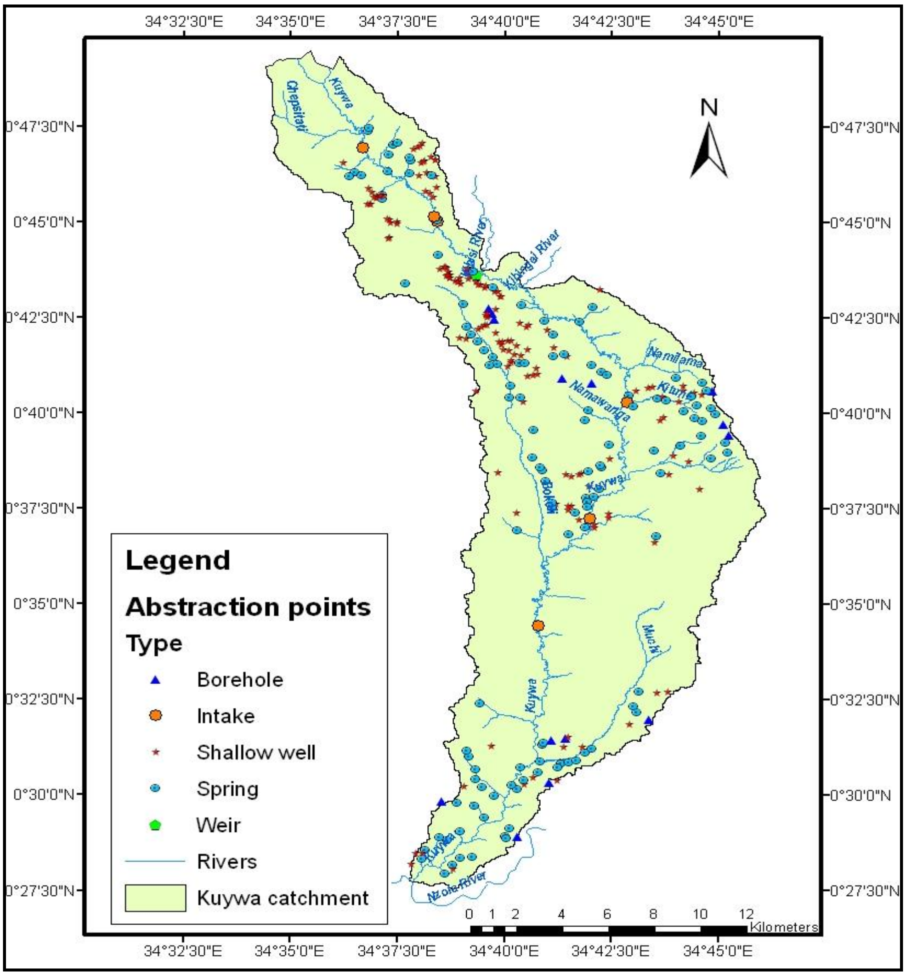

Figure 4: Spatial distribution of abstraction points in Kuywa sub-catchment.

Figure 5: Spatial distribution of shallow wells in Kuywa sub-catchment.

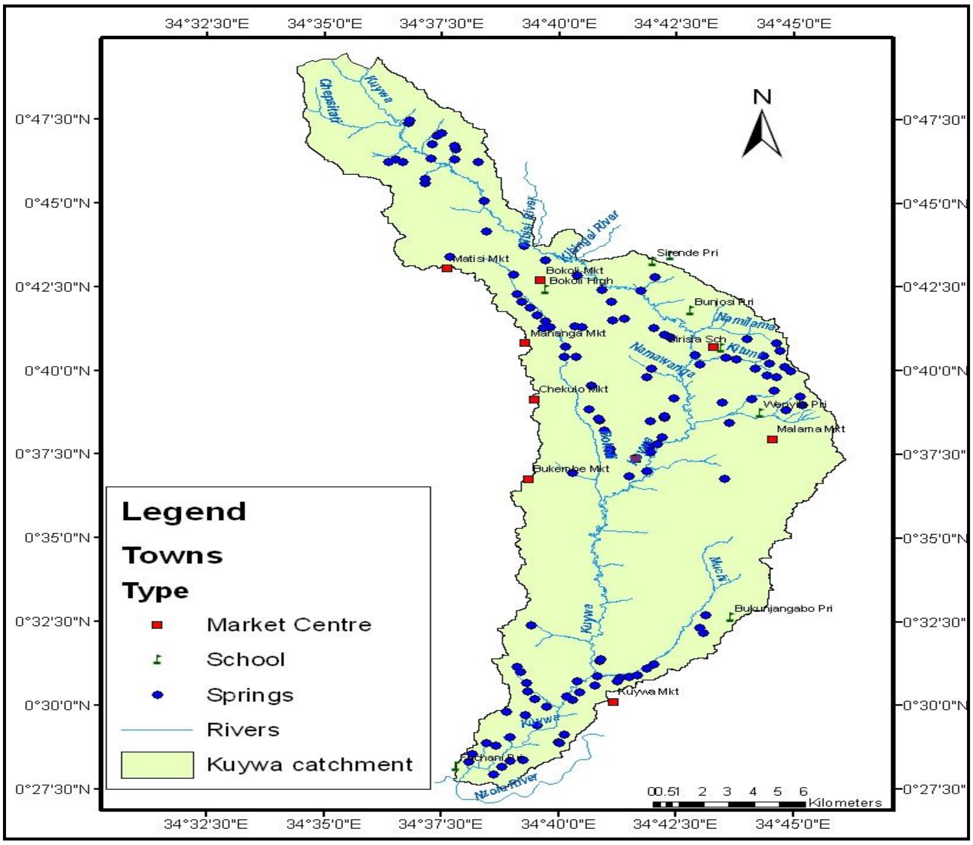

Figure 6: Spatial distribution of springs in Kuywa sub-catchment.

4.3 Ownership and Access to Water

Points

The onwership of the water points fall under three (3) categories, namely private, communal or group and institutional. Individual persons have sunk their own boreholes in the homesteads while shallow wells and springs belong to the community. Institutions such as schools, churches and health facilities have their own boreholes. Besides, there are also water supply agents such as Nzoia Water and Sewerage Company (NZOWASCO) and Nzoia Sugar Company. Most of these water points, particularly the springs, lacked proper management committees to run them. Therefore there were no lead persons and/or committees to take responsibility or spearhead any corrective measures in case of water point failures or breakdown. Public access to privately owned water points is dependent upon the willingness of the owner to provide water freely or at a cost. Access to the institutional water points is also restricted.

The problem of management of the water abstraction points established in the study area is attributed to the communal or common ownership of the resources. Under this regime, a resource is free for all and thus liable to overexploitation, pollution, damage or depletion. This is because the benefits of exploitation accrue to individuals, each of whom is motivated to maximise his/her own use of the resource, while the costs of exploitation – management – are distributed between all those to whom the resource is available – community. The water points are therefore common property and their management is at risk as explained by Garret Hardin in his work *The Tragedy of the Commons* in 1968 and further revised in 1998. Private property regime is thus encouraged for sustainable abstraction of the water points.

4.4 Operation, Protection and Construction Status of Water Points

During the study, it was established that majority (96%) of the water points were fully functional. However, the different types of water points were characterised by different operational status as working, closed or under construction (Fig 7). In terms of protection, most of the water points were protected. For example, 96% of the visited springs were operational and out of these only 87% were protected while 13% were unprotected. Similarly, the construction status of the shallow wells indicated that 68% of the wells are unlined inside hence prone to silting up and collapsing walls and majority (81%) of these wells are poorly covered at the top using plank woods or iron sheets. The few wells (19%) that were covered with concrete slabs are themselves not professionally done. However, there are indications of deliberate attempts or effort to protect them.

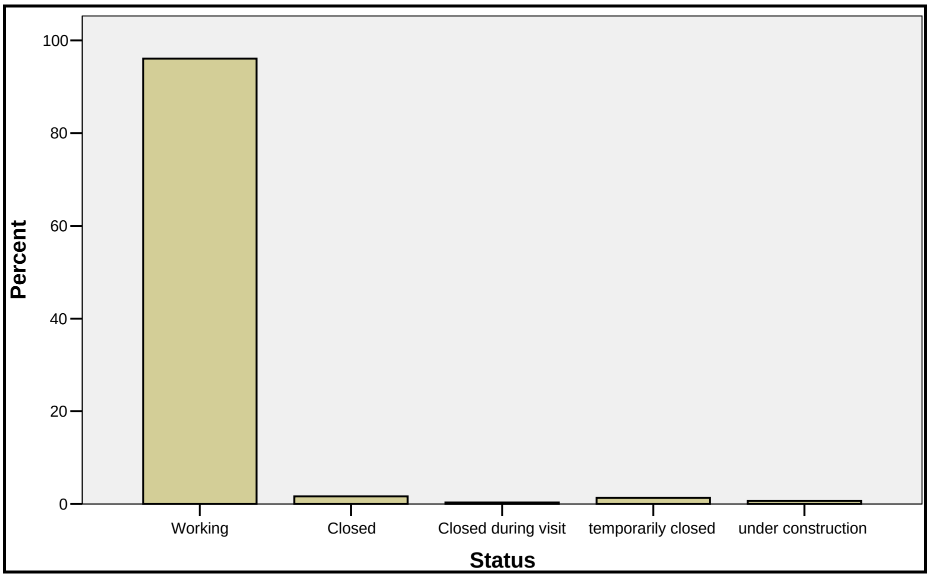

Figure 7: Operational status of the water sources.

4.5 Discharge Measurement

From the existing data, the computed average discharge measurements at Kimorong (1DB03) indicate that the amount of water entering Kuywa river is 106,775 m^3/day while the instantaneous discharge measurement carried out during the study period gave a value of 1,106,352 m^3/day (Table 2). From the miscellaneous stations at Kibisi and Kibingei, the computed average discharges yielded 91,214 m^3/day and 70,142 m^3/day respectively. The total contribution of the above rivers together with the flow from the upstream is captured at Matisi (1DB01) where it is computed as 402,786 m^3/day. Further downstream at Khalala (at point of discharge into River Nzoia), the total flow from Kuywa river is computed as 642, 834 m^3/day. This includes contributions from Rivers Bokoli and Muchi Milo. The measured high instantaneous discharge values for the various points on River Kuywa and its tributaries are a reflection of the high flows during the study period. The locations of the gauging stations (1DB03) and (1DB01) are shown in Fig 8.

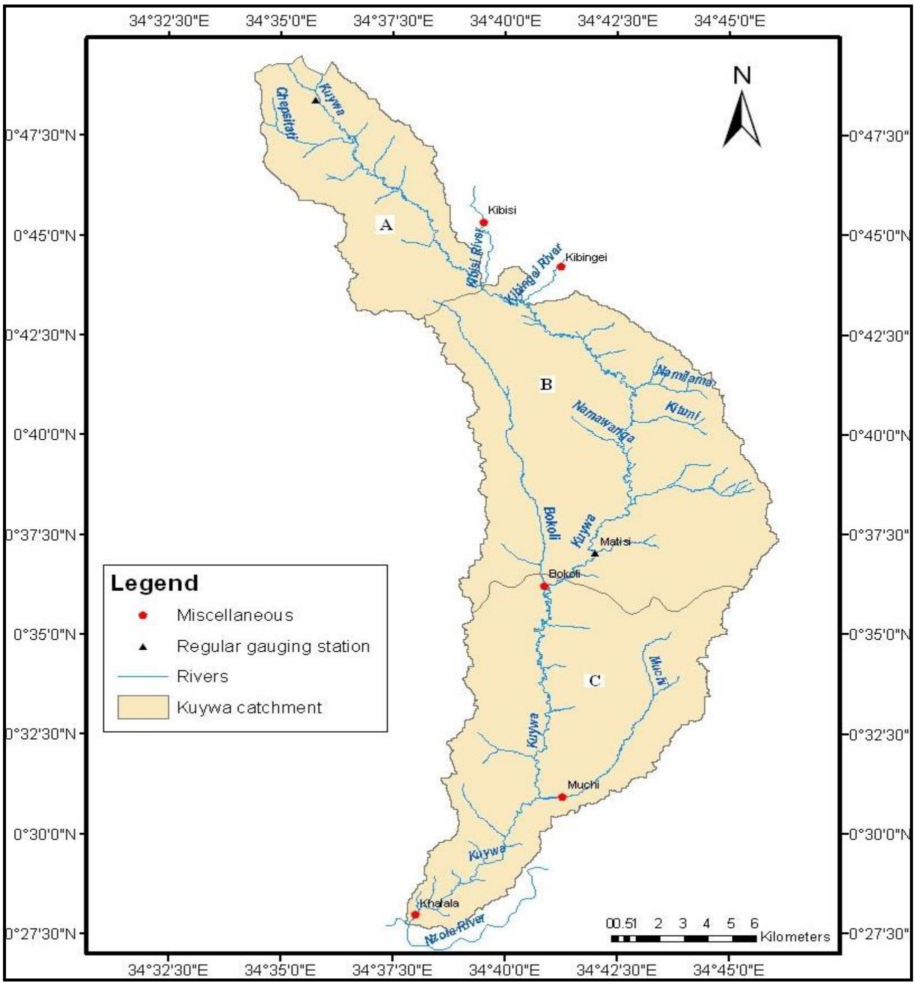

Figure 8: Locations of gauging stations (1DB01 and 1DB03) and miscellaneous discharge measurement points.

Table 2: Average andInstanteneous discharge measurements on River Kuywa and its tributaries

Discharge measurement point	Instantaneous discharges (m^3/day)	Average discharges (m^3/day)
Kimorong	2,798,496	106,775
Kibisi	1,106352	91,214
Kibingei	498,528	70,142
Matisi	4,978,368	402,786
Bokoli	461,376	32,001
Muchi Milo	317,952	-
Khalala	6,489,504	642,834
Total	**16,650,576**	**1,345,752**

4.6 Abstraction Amounts

The amount of water abstracted varies with the type of water point, the pattern of water availability, mode of abstraction, water use and the number of people using the water point or source. In the case of springs and shallow hand dugwells, the study estimated the amount abstracted by taking into consideration the number of people in each household using the water point and the number of 20 litre jerricans each user draws per day. For cases where it was not feasible to establish due to variations, an average was used based on the provided range.

Figure 9 show that more water is abstracted from the rivers followed by spring sources. The boreholes and shallow hand dugwells recorded low abstraction volumes. The study recorded eight (8) major abstractions from the river whose total abstraction amounted to 5,492 m^3/day. This accounts for 0.9% of all the water available in River Kuywa.

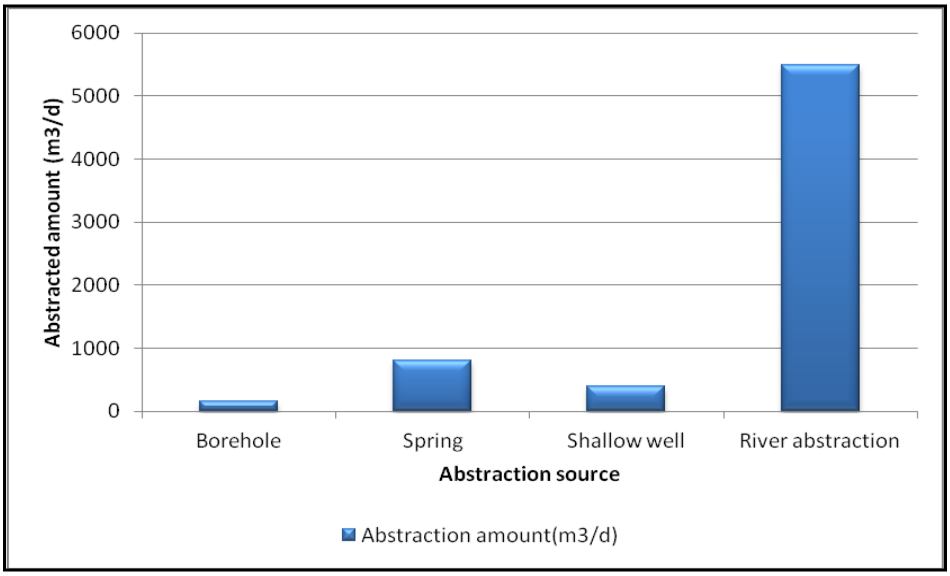

Figure 9: Amount of water abstracted from different water sources.

4.7 Compliance Status

At every abstraction point, it was asked whether the abstraction had an authorization to construct and/or a permit to abstract water. An authorization allows an abstractor to build or construct the abstraction works while a permit is then issued to allow the abstractor to draw and use the water after inspection of the works by WRA. The inspection is meant to ensure that the abstractor complied with the construction details. Such a permit is valid for a 5-year period after which renewal is required.

4.7.1 Permit Coverage

According to WRA LVN Water Rights Officer, not all abstractions require to seek for authorization to construct works or permit to abstract water. Water points such as shallow hand dugwells and protected springs from which water is drawn from the source manually do not need to apply for permitting or follow the permitting process unless WRA finds it necessary. For these cases, all one needs to do is to notify WRA office of their intention to construct such works. With this understanding therefore, only the permit status for those sources that involved piped installations, mechanical pumping or drawing water from the river through furrows or canals were considered in this analysis.

4.7.2 Permit Compliance

Each abstraction point with a permit is allocated or authorized a certain amount of water that it can abstract per day. The study has established that four (4) abstractions from boreholes have authorizations to construct works, one (1) abstraction by NZOWASCO has a valid permit, two (2) abstractions by Kuywa Irrigation Scheme and Teremi Secondary School have applied for a permit, one (1) abstraction by Nzoia Sugar Company has applied for renewal of the permit and twelve (12) abstractions are illegal (Table 3).

Table 3: Authorization/Permit Compliance Status

Name of water source	Northing	Easting	Altitude (m)	Type	P/Auth No	Amount authorized	Purpose	Remarks
Bokoli BH	0.7078	34.66279	1547	Borehole	WRMA/LVN /BH/132	18m^3/day	Domestic	Issued with an Authorization
Bokoli Hosp BH	0.71039	34.66180	1554	Borehole	-	-	Domestic	Not Registered
Bukholi Dip Bh	0.48177	34.67199	1423	Borehole	-	-	Domestic	Not Registered
Wamangoli Pry School	0.62265	34.70723	1452	Borehole	WRMA/LVN CA/B/H/261	15m^3	Domestic	Authorization
Rehema Childrem Home	0.57506	34.65186	1481	Borehole	WRMA/LVN CA/B/H/259	16m^3	Domestic	Authorization
Kimima BH	0.67643	34.74797	1693	Borehole	-	-	Domestic	Not Registered
Kuywa FSK BH	0.50565	34.68425	1431	Borehole	-	-	Domestic	Not Registered
Lugulu GHS BH	0.65720	34.75432	1684	Borehole		20m^3/day	Domestic	Issued with a permit
Lugulu Hosp. BH	0.66176	34.75190	1693	Borehole	-	-	Domestic	Not Registered
Mangana BH	0.52477	34.69071	1451	Borehole	-	-	Domestic	Not Registered
Milo Hosp BH	0.53299	34.72294	1486	Borehole	-	-	Domestic	Not Registered
Mufule Poly BH	0.49716	34.64269	1454	Borehole	-	-	Domestic	Not Registered
Machakha BH	0.68218	34.68935	1526	Borehole	WRMA/LVN CA/BH/323	20m^3/day	Domestic	Authorization
Namawanga BH	0.67983	34.70076	1511	Borehole	-	-	Domestic	Not Registered
Namikela BH	0.52383	34.68521	1437	Borehole	-	-	Domestic	Not Registered
Salim Binale BH	0.71249	34.66079	1545	Borehole	WRMA/LVN CA/BH/392	20m^3/day	Domestic	Permit expires 2015
Kituni Coffee Factory	0.67121	34.71461	1467	Intake			Industrial	Permit expired
Kuywa Irrigation	0.75025	34.64067	1543	Intake	-	500m^3	Irrigation	Permit still under process
Nakayonjo Coffee Factory	0.7823	34.61138	1577	Intake	13639		Industrial	Permit expired
Chenjeni coffee factory	0.72248	34.65922	1533	Intake	22447		Industrial	Permit expired
Matisi W/S	0.62002	34.70025	1450	Intake	WRMA/LVN CA/56	7000m^3	Public	Expiring in 2016
Nzoia Suga Co. ltd	0.57355	34.68008	1454	Intake	18127	4283m^3/day	Industrial	Permit expired 2009, have applied for renewal
Chepsitati	0.78553	34.59281	1668	Diversion				
Teremi Intake	0.75250	34.63949	1549	Intake	-	-	Domestic	Applied for water permit
Chalicha S/p	0.53964	34.65739	1462	Spring	-	-	Domestic	Not Registered
Murono S/p	0.48116	34.66750	1415	Spring	-	-	Domestic	Not Registered

4. 7.3 Measurement Compliance

According to Water Resources Management Rules (2007), each abstraction point falling in permit class B, C or D must have a measuring device at the point of abstraction. The device measures the level of abstraction as directed or permited by WRA. Those abstractions that fall in class A do not need a measuring device unless WRA finds it necessary. The study established that 84% of the abstraction points fall in the permit class B, 16% fall in class C and none falls in classes A and D (Table 4). This implies that all abstraction points in the Kuywa sub-catchment must have measuring devices. However, only five (5) abstractors have installed measuring devices. They include Bokoli Sub-County Hospital (borehole), Milo Sub-County Hospital (borehole), Mufule Community Water Supply (borehole), Matisi Water Supply (river abstraction) and Nzoia Sugar Company (river abstraction).

Table 4: Status of measuring devices compliance

	Name	Abstraction Class	Type of Abstaction	Status	Detailed Status
1		B			
2		B	Borehole	Closed Working	No measuring device installed
3		B	Borehole	Working	No measuring device installed
4	Kimima BH	B	Borehole	Working	No measuring device installed
5	Bokoli Friends Secondary shool	B	Borehole	Closed during visit	No measuring device installed
6	Namawanga Girls School	B	Borehole	Working	No measuring device installed
7	Namachakha	B	Borehole		Measuring device installed
8	Polytechnic Salim wamalwa binale	B	Borehole	Closed Working	No measuring device installed
9	Bokoli sub. district hospital	B	Borehole	Working	
10	Lugulu Girls BH	B	Borehole		No measuring device installed
11	Lugulu Mission Hospital BH	B	Borehole	Under construction	No measuring device installed
12	Lumonya friends School Friends School Kuywa	B	Borehole	Working	N/A
13	Milo Subdistrict Hospital	B	Borehole	Temporarily closed Working	Measuring device installed
14	Mufule Community water supply	B	Borehole		Measuring device installed
15	Chebukaka Girls Secondary B/H	B C	River	Working Temporarily closed	
16	Chepsitati stream	C	River	Working	No measuring device installed
17	Teremi High School	C	River River	Working	No measuring device installed
18	Kuywa irrigation	B			
19	Nzoia Sugar Company	B	Spring	Working	No measuring device installed
20	Chalicha Spring Murono Spring	B	Spring River	Working Working	No measuring device installed,
21	Kituni Coffee Factory Chenjeni Coffee Factory	B	River	Working	Measuring device installed
22	Nakayonjo Coffee	C	River	Working	
23	Factory Matisi Water Supply	B	River	Working	No measuring device installed
24	Milo Subdistrict Hospital	B	Borehole	Working	No measuring device installed
25	Rehema Childrens' home	B	Borehole	Working	No measuring device installed

No measuring device installed, Pump fitted
No measuring device installed
Measuring device installed
Measuring device installed
No measuring device installed

4.8 Challenges and Threats

The study revealed several challenges and threats that emanate from each type of water abstraction point in the sub-catchment. These challenges and threats need to be addressed because the available water varies in quantity, quality and reliability. Besides, the challenges and threats pose myriad social, health and environmental problems and risks as discussed in the succeeding sections.

4.8.1 Protection of Water Points

Water abstraction sources should be protected by conserving the vegetation in their catchment to maintain their ecological integrity. Similarly, they are supposed to be fenced, grassed and indigenous trees planted around to control erosion and subsequent siltation. However, in the study area, it was established that the water catchment areas are cultivated and left bare. As a result, a few cases of drying up of springs during dry season were reported. Some water points are improperly protected which exposes them to possible pollution or contamination through surface run off and siltation. Proper protection is required to maintain water quality. Some springs were reportedly abandoned due to poor workmanship during construction and management. Some of the water points are protected. For instance, shallow wells are covered using concrete slabs or wooden planks. The latter is however ineffective in controlling dust and runoff water from entering the wells. This posed a potential health hazard to the consumers.

4.8.2 Water Quality

Water quality plays a major role in the prevention of water borne and water related diseases. An assessment to understand people's view about the water they use revealed that majority of the water points, particularly the spring sources, are rated clean which illustrates the reliability of the available water for human consumption. This perhaps explains in part why many respondents do not treat their water before use. Only a few do treat their water by boiling or by chemical treatment using Lifestraw kit and Water Guard. This is despite the fact that some water points are improperly protected and are therefore prone to pollution or contamination through runoff and dust even if they have clean groundwater abstracted from them.

4.8 3 Ownership of Water Points

Apart from the privately owned water points, the common water sources - particularly spring sources - do not seem to have clear ownership or persons or committees taking responsibilities. Most of the so-called group-owned water points lack effective management committees hence poses a management challenge. In fact, none is directly concerned with the management of the water points despite the benefits derived from the resource. Tragedy of the Commons thus results, which leads to overexploitation, pollution, damage and even depletion of the resource in question.

4.8.4 Mode of Abstraction

Most of the abstraction methods are manual. For example, most abstractors use rope and bucket. This method, however, has far reaching implications on water access and quality considering who fetches the water. To ensure that everyone accesses water without challenges, there is need to invest in more friendly drawing systems such as powered pumping or hand pumps and developing gravity schemes from the spring sources located on higher elevations or grounds.

4.8.5 Maintenance of Water Points

The quality of management for several privately and group managed water points is not up to standard. This is because they are poorly maintained and lack adequate protection, which is likely to affect the quality of the water provided. Effective protection is necessary in order to maintain water quality and check possible accidents such as slippage into open or partially covered wells during water collection. Therefore, the community needs to be sensitized on water sources management and protection to avoid contamination, possible disease outbreaks and accidents.

4.8.6 Proximity of Latrines to Water Points

The siting of pit latrines relative to water sources, particularly shallow wells, is a matter of concern in the study area. Some wells are located in the same compound with the same or at lower elevation than pit latrines without consideration of minimum safe distance. Health protection demands that sources of microbiological contamination are located sufficiently far from drinking water sources as to minimize or eliminate health risks (WHO, 1999). This may compromise water quality through underground seepage. Thus, sensitizing the community on the need to have latrines for sewage disposal – especially the households which do not have latrines - and the best location of latrines in relation to the wells is crucial. Moreover, an investigation on the influence of latrines location on water quality would better inform the awareness creation process.

5. Conclusion and Recommendations

5.1 Conclusion

The study shows the existence of varied types of water points in the sub-catchment namely piped systems, wells, boreholes, springs, rivers and undeveloped water holes but with skewed spatial distribution. Most of the springs are concentrated along the slopes of the river valleys where recharge is manifested while most shallow wells are located in the northern and southern parts of the study area due to high water table. Although the water points in the study area supply clean water to a fair proportion of the population for multiple uses such as domestic, livestock watering and irrigation, most of them do not possess abstraction permits and are not metered as required by law.

The water points derive their water from ground and surface sources. While surface sources are relatively easier for all to collect, the ground sources use manual drawing systems that may be challenging to majority of the users. In addition, one has to travel to the water point to collect water due to lack of distribution systems. Private intervention in water development has taken place as evidenced by the prevalence of privately owned water points.

There are numerous options to be considered in ensuring that the entire population in the sub-catchment has access to adequate supply of clean and safe water. They include seeking for more water projects that will ease the cost burden, enhancing water distribution systems in order to reach every corner of the sub-catchment, enhancing management, ensuring effective protection of water points, and taking advantage of the larger rivers in the sub-catchment to develop new water supply systems.

5.2 Recommendations

The study therefore recommends the following measures and strategies in order to ensure continuous access and use of adequate, clean and safe water resource in the Kuywa sub-catcment.

1. Equipping and building capacity of the KUWRUA management team to be able to assess the water situation in terms of quality and qunatity, mobilize and sensitize the people on the best practices for water use and management as well as raising revenue for enhancing water resources development. The practices include planting grass and trees around the water sources and on riparian land as a remedial measure of countering erosion and the subsequent siltation as well as constructing water collection and livestock watering points within the Kuywa sub-catchment.

2. Installing Regular Gauging Stations (RGS) on Rivers Kibisi, Kibingei and Bokoli to monitor the discharge over time to enable determination of environmental flows and apportionment. This will be supplemented by investing in water supply systems to take advantage of the perennially flowing water from the numerous springs as well as promoting rainwater and flood runoff harvesting for both present and future domestic, agricultural, public and other uses.

3. Undertaking a study to determine the potential of aquifer recharge rates in order to guide the regulation on spacing and depth of shallow wells and boreholes within the sub-catchment and even beyond.

4. Investing in more friendly water drawing systems to ensure that women and children can also access water with ease as well as investing in more public water points to supply affordable water to all with minimal cost especially to take care of the financially disadvantaged groups Investing in more public water points to supply affordable water to all with minimal cost especially to take care of the financially disadvantaged groups. This will enhance water storage and distribution to reduce distances travelled in search of water.

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