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Buffer Zone Plans for Lake Nakuru National Park and for Njoro River in Kenya

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Laurea-ammattikorkeakoulu **Tiivistelmä**
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Kestävän kehityksen ko.

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Suojavyöhykesuunnitelmat Nakuru-järven kansallispuistolle ja Njoro-joelle Keniassa

Vuosi 2010 Sivumäärä 62

Tämä opinnäytetyö koskee Nakuru-järven suojelua Keniassa ja on osa CABULAG-projektia. CABULAG on yhteistyöhanke Kenian Nakurun kunnan sekä Suomen Hämeenlinnan kaupungin kanssa. Projekti on osa pohjoisen ja etelän kuntien yhteistyöohjelmaa. Sitä hallinnoi Suomen kuntaliitto ja se on Suomen ulkoministeriön rahoittama.

Ympäristö on yksi yhteistyön tärkeimmistä kohdealueista. Yksi tavoitteista oli tehdä suojavyöhyke-ehdotus Nakuru-järvelle, jotta sen suojelutaso paranisi. Suojavyöhyke tarkoittaa vihreää aluetta, joka suojelee vettä siihen kohdistuvilta erilaisilta negatiivisilta vaikutuksilta kuten saasteilta ja liikaravinteilta.

CABULAGin suojavyöhykkeeseen kohdistuvissa tavoitteissa mainitaan metsänistutus kotoperäisillä puilla sekä kaupallisesti houkuttelevilla eksoottisilla lajeilla. Vyöhykkeen tulisi myös tarjota paikallisille yhteisöille polttopuuta, puuta rakentamiseen sekä muita materiaaleja. Kuten useissa kehitysmaissa, väkiluvun kasvulla ja jatkuvalla kaupungin laajentumisella on haitallisia vaikutuksia järven ekosysteemiin. Nakuru-järveä uhkaa tänä päivänä mm. maataloudesta, teollisuudesta, jätteistä ja jätevedestä peräisin olevat haitalliset päästöt. Suojelupyrkimyksillä on mahdollista pelastaa Nakuru-järven tärkeä taloudellinen arvo sekä sen luonnon monimuotoisuus.

Tutkimus tehtiin Nakurussa Keniassa lokakuun 2009 ja tammikuun 2010 välisenä aikana. Tutkimuksessa käytettiin kahta eri tutkimusmenetelmää, haastattelua ja havainnointia. Haastattelut pidettiin kolmelle eri yhteistyökumppanille käyttäen kysymyslomaketta apuna. Havainnoinnilla kerättiin tietoa kenttätutkimuksen aikana.

Tuloksena tutkimuksessa syntyi kaksi suojavyöhyke-ehdotusta. Ensimmäinen on Njoro-joelle, joka on yksi viidestä suuresta joesta, jotka laskevat Nakuru-järveen. Joen varsi on pääasiassa maatalousmaata. Toinen ehdotus koskee suojavyöhykettä, joka perustettaisiin kansallispuiston sisälle. Kansallispuiston maa on valtion suojelema ja sen hallinta on uskottu Kenian Wildlife Servicelle.

Suojavyöhyke Njoro-joelle toteutettaisiin yhdessä paikallisten yhteisöjen kanssa varmistaen näin tehokkaammat lopputulokset. Istutetut puut tarjoisivat ruokaa ja materiaaleja paikallisille ihmisille ja heillä olisi myös mahdollisuus tienata tuotteillaan myyntituloja.

Suojavyöhyke kaupungin ja kansallispuiston välillä suojelisi Nakuru-alueen pääasiallista turistikohdetta tuoden tuloja paikallisille asukkaille ja koko Kenialle. Istutushankkeella olisi mahdollisuus myös lisätä tietämystä koskien Nakuru-järven suojelua yhteistyökumppaneiden ja alueen asukkaiden keskuudessa. Molemmat suojavyöhykkeet lisäisivät Nakuru-järven suojelun tasoa ja puiden istutuksella olisi myös positiivisia vaikutuksia kamppailussa ilmastonmuutosta vastaan.

Asiasanat: suojavyöhyke, kansallispuisto, Kenia, järven suojelu

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Abstract

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Buffer Zone Plans for Lake Nakuru National Park and for Njoro River in Kenya

Year 2010 Pages 62

This thesis is about protection of Lake Nakuru in Kenya and is part of the CABULAG cooperation project between the Municipal Council of Nakuru (MCN) in Kenya and the City of Hämeenlinna in Finland. The project works under the North-South Local and Regional Authorities' Cooperation Programme. It is coordinated by the Finnish Association of Local and Regional Authorities (ALFRA) and is financed by the Ministry of Foreign Affairs of Finland.

Environment is one of the main focus areas in cooperation. One of the targets was to make a proposal for a buffer zone for Lake Nakuru to increase its conservation level. A buffer zone means creating a green belt which protects the water from different types of negative impacts like pollution and nutrient loads.

The CABULAG objectives for a buffer zone include reforestation with indigenous trees and commercially attractive exotic species. The zone should also be able to provide sources of fuel wood, construction timber and other materials for local communities. As in many developing countries, the population growth and continuous expansion of the town have a harmful effect on the lake's ecosystem. Lake Nakuru is threatened nowadays by negative impacts caused by agriculture, industry, solid waste and sewage. Through conservation efforts it is possible to save Lake Nakuru's important economical value and natural diversity.

The research was carried out in Nakuru, Kenya, during the period from October 2009 until the end of January 2010. Two data collection methods were used in surveys, interviews and observation. Interviews were held with three main partners and a questionnaire was used as a basis. Information was gathered during the field surveys through observation.

As a result of the research two buffer zone proposals were drawn up. The first is for Njoro river which is one of the five biggest rivers draining into Lake Nakuru. The land along the river is mainly under agriculture. The second proposal is for a buffer zone to be created inside Lake Nakuru National Park (LNNP). The land of the LNNP is protected by the government and its management is entrusted to the Kenyan Wildlife Service (KWS).

The buffer zone for Njoro River would be realized with the participation of local communities in order to ensure more effective results. Planted trees would offer food and materials to the local population and give them the opportunity to earn revenue by selling some of their products.

A buffer zone between the city and the National Park would protect the main tourist site in Nakuru resulting in revenue for local residents and for the whole of Kenya. A planting project would also provide an opportunity to increase knowledge about conservation of Lake Nakuru among stakeholders and catchment residents. Both buffer zones would improve the conservation level in Lake Nakuru and tree planting would also have a positive impact in the battle against global warming.

Key words: buffer zone, National Park, Kenya, lake protection

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1 Introduction

Lakes are dramatic and picturesque features of our landscape and are richly endowed with resource values. They constitute major components of the hydrologic cycle. Lakes sustain human livelihoods, support economic activities, provide habitat for biodiversity and offer important aesthetic values. They also provide buffering capacities against hydrologic and climatic fluctuations, as well as being sinks for inflowing materials collected across their basins. (International Lake Environment Committee Foundation 2005, 3)

Like all ecosystems, water systems are also threatened by ever-increasing human populatons. Overfishing, water pollution, eutrophication, water extraction and many other risks are now daily problems for rivers and lakes everywhere in the world. To avoid draining our vital sources of food and drink and destroying our living environment, and in order to save the recreational value of watercourses, we must act now.

This thesis is about lake protection in Africa. The main target is to make a proposal for a buffer zone for Lake Nakuru National Park in Kenya. As in many developing countries, the population growth and continuous expansion of Nakuru town have a harmful effect on the lake's ecosystem. Through conservation efforts it is possible to save Lake Nakuru's important economical value and natural diversity.

2 Development programmes behind the report

There are two main development programmes behind this report. The proposal for this thesis came from HAMK University of Applied Sciences which cooperates with the Capacity Building For Local Authoritative Governance (CABULAG)-project.

The Nakuru Municipal Council has adopted Agenda 21. The implementation of Agenda 21 is intended to involve action at all levels: international, national, regional and finally at the local level. Agenda 21 is the programme of action which reflects a global consensus towards more integrated policymaking concerning the main issues of development and environment. Nakuru was the first city in Africa to benefit from the programme, with the Municipal Council of Nakuru (MCN) adopting a resolution to develop a Nakuru Strategic Structure Plan (NSSP). The proposals of the NSSP are taken into account in the planning process of the CABULAG-project. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 20.)

2.1 CABULAG project

CABULAG is a cooperation project between the Municipal Council of Nakuru in Kenya and the City of Hämeenlinna in Finland. The project works under the North-South Local and Regional Authorities' Cooperation Programme which is coordinated by the Finnish Association of Local and Regional Authorities (AFLRA) and financed by the Ministry of Foreign Affairs of Finland. The CABULAG project is now in its second phase (2008-2010). The first phase was started in 2005 and was completed in 2007. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 5.)

CABULAG has three components: education, administration and environment. The project is widely implemented through a colleague-to-colleague work methodology, for example work visits, training, sensitization and awareness-raising. The components aim at increasing the capacity of local authority and improving the quality of primary school education and environmental protection and awareness. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 5.)

The need for cooperation between the Municipal Council of Nakuru and the City of Hämeenlinna is derived from several levels, starting with international agreements and ending at the local level. At the United Nations General Assembly held in the year 2000, world leaders prepared a strategy to alleviate poverty in the new millennium. This led to the proposals of the Millennium Development Goals (MDGs) which is a concerted effort to tackle poverty, illiteracy, hunger, safe water access, disease and environmental degradation by the year 2015. The process of achieving the MDGs for most developing countries requires

concerted action by different nations throughout the world. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 13.)

2.2 Nakuru Strategic Structure Plan 2000-2020

The Nakuru Strategic Structure Plan (NSSP) was completed in 1999. It lays out the existing spatial structure of the town. It also identifies key planning sectors and offers a vision of the intended spatial structure, including the institutional mechanisms for its implementation. (McClanahan, T.R. & Young T.P. 1996, 308). The current NSSP is ongoing up to the year 2020. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 20.)

According to the NSSP, it is important that local communities should be part of different planning processes and implementation. CABULAG can use the NSSP in its programme for addressing the problems in Nakuru and making proposals on how to provide solutions to these problems. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 10-13.)

3 Objectives

The objectives of this thesis can be divided into those which are defined in the development programmes, CABULAG and NSSP, and those related to our own learning. This report is made for the MCN and is also the final thesis of a degree programme in Laurea University of Applied Sciences.

3.1 Objectives of the development programmes

The main objectives of CABULAG are set out in its annual report 2009 and are: capacity building of local authorities, the development of the standards and practices for local administration, the improvement of the services provided by local authorities, increasing awareness of issues of democracy and equality in public decision-making, the development of social welfare and poverty reduction, and addressing local and global environmental issues. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 5.)

Environment is one of the main focus areas of the Nakuru-Hämeenlinna international partnership. One of the objectives of the environment component is to create a buffer zone plan for Lake Nakuru National Park, which would also influence the policies. (Municipal Council of Nakuru & City of Hämeenlinna 2010, 19-20.)

According to the CABULAG annual report 2009 the management concept of the buffer zone includes reforestation with indigenous tree species and commercially attractive exotic species. It also gives guidelines for sustainable use of the resources from exploitable areas. The buffer zone should provide more protection to the main touristic sites and natural resources of the Nakuru area, and also at the same time offer sources of fuel wood, construction timber and other materials for local communities. The buffer zone would be important not only when improving the image and landscape of the town but also because it provides an attractive living environment and habitat. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 42.)

CABULAG aims at producing a paper based on the concept plan which includes an implementation strategy. The research involves field surveys, literature studies and finally a buffer zone plan write-up. According to the MCN, the level of knowledge of environmental protection is inadequate and by preparing the plan, the awareness of environmental issues could be increased. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 43.)

Buffer zone activity is supposed to be carried over the three project years (2008-2010). As part of the activity, a management plan based on ecological and social sustainability will be made and discussed together with the MCN authorities and local communities. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 43.)

3.2 Objectives related to my own learning experience

The main objective of my practical work and this barchelor thesis is to protect our beautiful planet and its nature. The second objective is to find out how it is to work on a developing project in a developing country. My ambition for the future is to be involved in international development cooperation and work in a poor country where the people, animals and nature are really in need of help. I also wish to perfect my English and learn to work effectively in different culture zones. I want to increase my understanding of different practices and learn to manage new research methods. I hope that with this project I can make useful proposals for Lake Nakuru’s protection and I can help planet earth on its way towards a more sustainable future.

4 Concept of lake basin management

Lake basin planning is a process consisting of two main steps. The first step is to develop an agreed set of goals for the use of the lake basin. The second step is to find a way to achieve these goals in spite of particular resource constraints and within a specified time frame.

The planning process comprises the following phases:

- establishment of a goal (or a set of goals) agreed by the stakeholders;
- development of alternative strategies for reaching the goal;
- selection of the preferred strategy based on a feasibility assessment;
- implementation of that strategy with mobilization of necessary resources, and;
- refinement of the strategy through monitoring and evaluation.

(International Lake Environment Committee Foundation 2005, 86.)

The development of a lake basin management plan and the identification of different kinds of financing methods for implementing the plan requires the involvement of all stakeholders and institutions concerned (International Lake Environment Committee Foundation 2005, 87).

4.1 Buffer zone

There are many ways of defining a buffer zone. Generally the idea is that a buffer zone is a green belt between the problematic area and the water. This green area is to protect the water from different types of negative impacts like pollution, nutrient loads and sediments. These areas, known also as buffer strips, have long been recognized as critically important for maintaining water quality. The plants used in the buffers can offer varying benefits and are chosen carefully for the purpose.

The buffer zone consists of management zones. The number of these varies between two or three depending how effective the buffer needs to be in order to decrease the negative impacts of the area near the water.

4.1.1 Definition

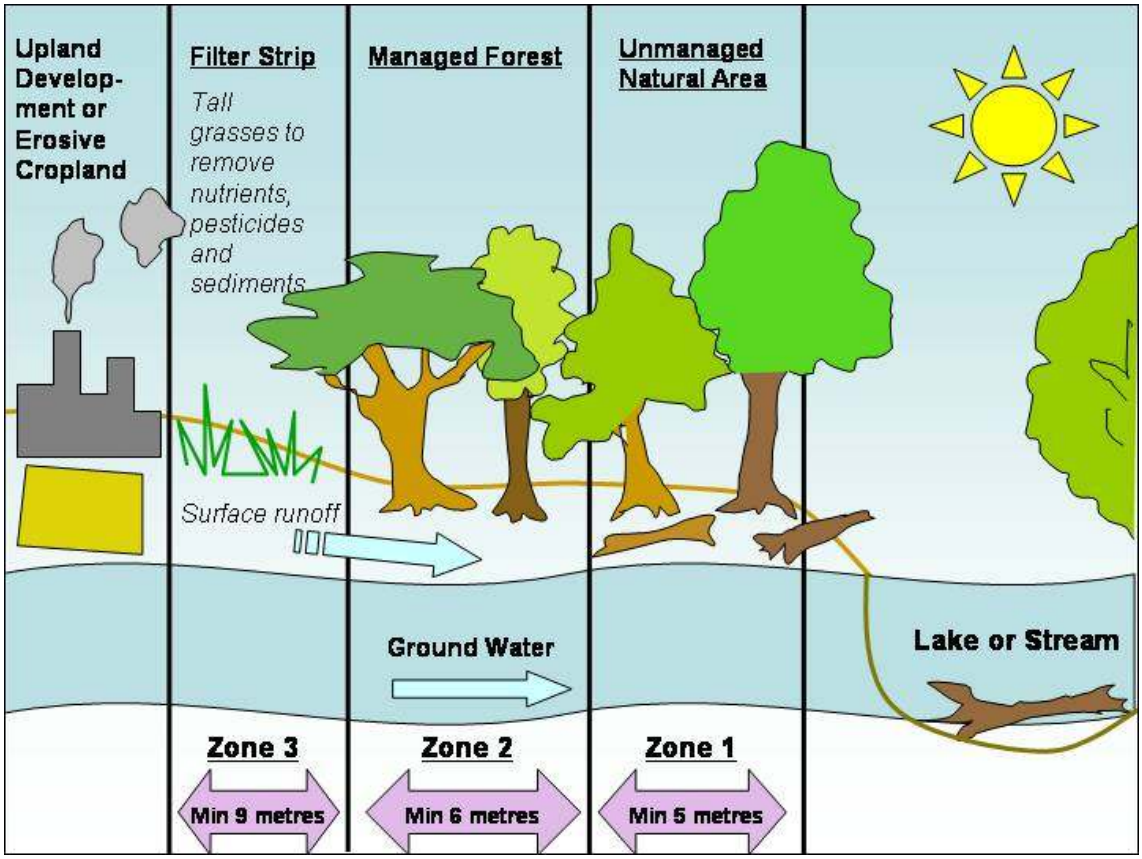
One definition of a buffer zone is found in the Pawtuackaway Lake brochure (2007):

“A Buffer Zone is the strip of vegetation that surrounds wetlands and other bodies of water. It protects the lake from changes in their biological, chemical, and physical properties. A good buffer zone limits runoff into the lake, thereby reducing nutrients and other pollutants entering the water. It also stabilizes soils and stream banks with plant root systems and purifies the water with aquatic vegetation. The buffer zone also provides food, shelter and

shade that improves wildlife habitat and a visually appealing greenbelt and recreational opportunities".

4.1.2 Management zones

One suggestion for management zones in a buffer zone is found in the brochure "Lake and Stream Corridor Owners' Guide for Riparian Buffer Establishment". As a minimum, two management zones are required for all buffers. Also a third zone is required if the buffer is intended to trap sediment, pesticides and nutrients that originate from developed lands, croplands or sparsely vegetated or erosive areas. Picture 1 (Michigan Department of Environmental Quality) shows the management zones in a riparian area.



Picture 1: Management zones illustrated in a riparian area

Zone 1 is contiguous to the water (Picture 1) and contains the trees and shrubs needed to provide shade and insect habitat. For holding soil in place, improving bank stability and maintaining a natural riparian ecology, the multilayered root structures of wood are highly desirable. Within Zone 1 harvesting, livestock grazing or other resource extraction methods should not be permitted. (Michigan Department of Environmental Quality.)

Zone 2 is further inland from the water than Zone 1 and contains trees, shrubs and other vegetation needed to filter runoff to provide uptake of nutrients and pollutants. Zones 1 and 2 provide together a travel fairway and habitat for wildlife in addition to producing shelter, shade from the sun and large quantities of woody debris. Forest management and tree harvesting is permitted as long as the purpose of the zone and its welfare isn't compromised. Tree harvesting and other ways of forest maintenance allow the landowner to maintain the land's value in a productive way while providing water quality benefits at the same time. Livestock should not be permitted in Zone 2. Dominant vegetation should consist of planted or existing trees and shrubs suited to the site and purpose. (Michigan Department of Environmental Quality.)

Zone 3 is on the land side of Zone 2 and consists of a strip of tall grasses or herbaceous cover to spread and filter runoff. Runoff may be transporting sediments, nutrients and pesticides off to urban land, cropland, erosive or sparsely vegetated areas. The establishment of Zone 3 is critical where the control of sediments, nutrients, pesticides or non-point source pollution is necessary, which is the case in urban and agricultural situations. (Michigan Department of Environmental Quality.)

Where soil erosion, nutrient or pesticide pollution is a concern the riparian buffer must consist of Zones 1, 2 and 3. The width (combined) of these zones should be at least 20 metres. Zone 1, beginning at the normal water line or at the upper edge of the active channel, must be at least 5 metres wide measured as a horizontal distance from the water line. Zone 2 extends at least 6 metres landwards from the end of Zone 1. The function of Zone 2 is to act as a zone of nutrient uptake and pesticide and pollutant entrapment. Zone 3 has to extend at least 9 metres upslope from the end of Zone 2. If the slope is steeper than 15% the minimum width of Zone 3 is 12 metres. The listed widths of each zone are the minimum necessary for the buffer zone to work effectively. It is strongly recommended to increase the width of the minimum distances. (Michigan Department of Environmental Quality.)

5 Review of Lake Nakuru and its catchment basin

Lake Nakuru (Kenya, 0°22'S, 36°5'E) is a shallow, alkaline-saline lake lying in a closed hydrologic basin in the eastern African Rift Valley in Kenya (Map 1). The lake is situated 1759m above sea level inside the Lake Nakuru National Park (LNNP). (McClanahan, T.R. & Young T.P. 1996, 299.)

Map 1: Location of Lake Nakuru in Kenya

Lake Nakuru, Picture 2, covers an area of 62km^2. Its mean depth is 2.5m and maximum depth 4.5m. High insolation and an adequate supply of nutrients usually support abundant phytoplankton. Lake Nakuru is a very productive natural ecosystem like most other soda lakes, often featuring the presence of thousands of lesser flamingos which graze the phytoplankton. (McClanahan, T.R. & Young T.P. 1996, 299.)

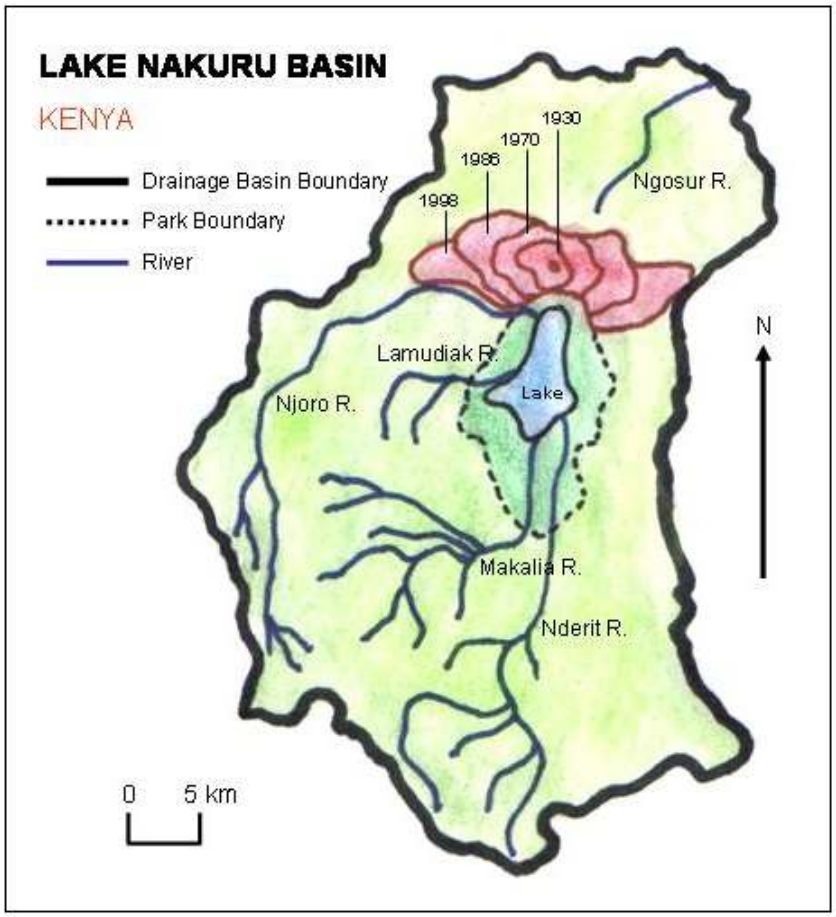
Picture 2: The view over Lake Nakuru from Baboon Cliff (Photo: Nurmi L. 2009)

Lake Nakuru is sensitive to changes in climate which severely affect its depth and salinity over annual and longer time scales with major consequences for the lake's ecology.

Biological communities in shallow soda lakes are vulnerable to even small variations in water balance and salinity. During periods of low rainfall the salinity increases. This also causes changes to the plankton compositions and subsequently a decrease in the flamingo population. (McClanahan etc. 1996, 299.)

5.1 Lake Nakuru catchment basin

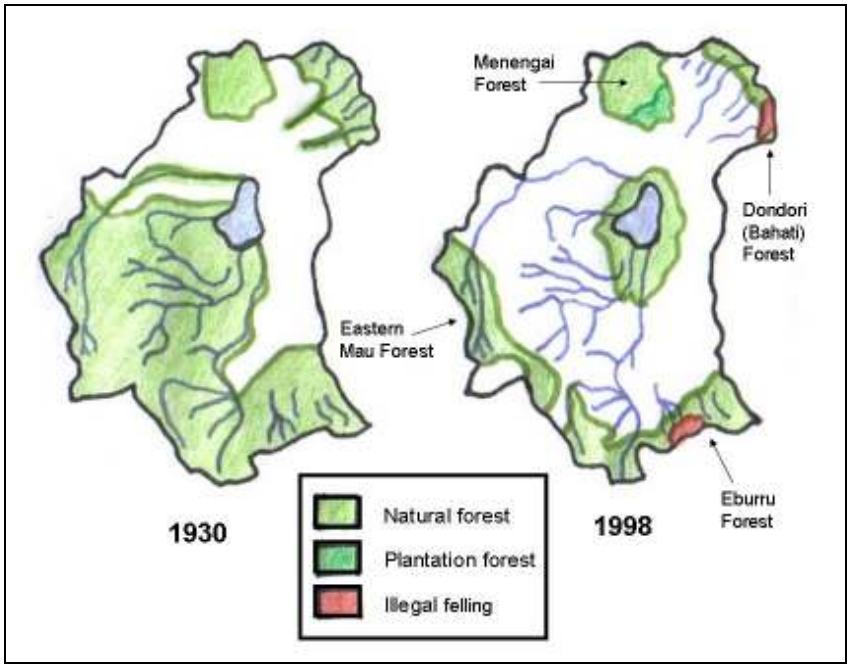
The Lake Nakuru catchment basin is a closed drainage system of 1,800km². At the sump of this catchment basin is the insulated Lake Nakuru National Park. (McClanahan etc. 1996, 299-300.) Over the last 40 years Nakuru city has expanded considerably and, as we see in Picture 3 (McClanahan etc. 1996, 299), now reaches the LNNP boundary on the north side and the Njoro river, which drains straight into the lake, on the west side.



Picture 3: The picture shows the expansion of the city between the years 1930-1998

The Lake Nakuru catchment basin comprises two important forest biodiversity zones; LNNP in the middle and the forests which cover the catchment's upper reaches (Picture 4). Human settlements, with less biodiversity value, are situated between these zones. Inhabitants are

highly dependent both directly and indirectly on the ecological benefits provided by the high biodiversity zones. And conversely, humans have direct and indirect impacts on the ecological stability of the biodiversity-rich areas. (McClanahan etc. 1996, 300.) Picture 4 shows that since 1930 Eastern Mau Forest, Eburru Forest, Dondori forest and Menengai Forest have contracted dramatically (McClanahan etc. 1996, 300). Reduced forest cover seriously affects the environments and ecosystems of lakes



Picture 4: Changes in forest cover in Lake Nakuru Basin 1930-1998

The soil in the catchment area is of volcanic origin and therefore its high porosity, permeability and loose structure lead to erosion, land subsidence and fractures during or after heavy rain. (McClanahan etc. 1996, 299-300.)

Depending on altitude and topography, the Lake Nakuru basin suffers considerable variations in climate. The mean maximum and minimum temperature varies between 10ºC -29ºC. The climate ranges from cold and humid to arid and semi-arid. Mean annual rainfall is approximately 1000mm with peaks in the months of November to December and April to May (State of Environment Report 2009, 11). Mean annual evaporation is 1800 mm. (McClanahan etc. 1996, 301.)

Lake Nakuru is one of the highest lakes in central Kenya. Its altitude has a hydrological effect on its water level. It is an enclosed lake where water loss only takes place through evaporation. Lake Nakuru has minimal underground inflow. Perennial springs along the eastern shoreline contribute only about 0.6 m^3/s to the lake so it is dependent on catchment

supply from 5 seasonal rivers to sustain its water level. Major rivers are Njoro River and Lamudiak River, Makalia River and Djerit River from the southern Mau escarpment, and Ngosorr River from the Bahati Forest (Picture 3). There are also some small streams but these disappear underground. Adding to this, its shallow depth and high evaporation renders the lake a hydrologically-impacted ecosystem. Long drought periods can result in a decline in the lake level. Treated wastewater from Nakuru town also drains into the lake. (McClanahan etc. 1996, 301.)

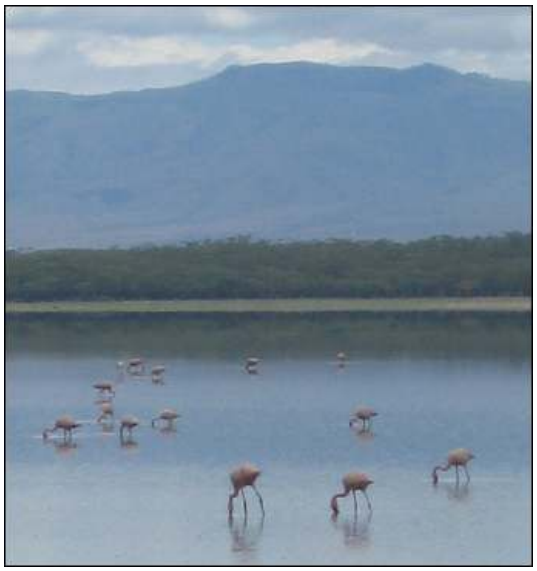
Nakuru town also faces an acute water shortage of about 1000m^3/day. The population increase is putting pressure on the water supply, which comes from boreholes, and is likely to have repercussions on the underground water supply on which Lake Nakuru partially depends. (McClanahan etc. 1996, 303-304.)

5.2 Lake Nakuru National Park

Lake Nakuru was declared a conservation area in 1957 and in the year 1961 two-thirds of the lake was designated a bird sanctuary under the Kenya Royal National Parks. It obtained National Park status in 1968 and a northern extension was added to the park in 1974. (Kenya Wildlife Service 2010.) In 1990 the LNNP was designated a Ramsar site (site No. 476) meaning it is an important wetland with great biodiversity significance (McClanahan etc. 1996, 302).

Lake Nakuru National Park occupies an area of 188km^2. It is the second most frequently-visited park in Kenya and offers magnificent flora and fauna. Eleven major ecological habitats are represented there, ranging from the lake and its mud flats and surrounding salt marches, to open and wooded grasslands, dense forest, bush and cliff habitats. (McClanahan etc. 1996, 300.) Within the park, the boundary area next to human settlements is generally open grassland and lacks tree cover except at Lion Hill where shrub vegetation dominates the area close to the park limits.

There are 70 mammal species (including hippo, spotted hyena, leopard, giraffe and white rhino), about 400 bird species (including over 70 species of waterfowl and water-related birds) and over 550 plant species. LNNP is best known for its lesser flamingos, which can be seen grazing in Picture 5, and is said to be an ornithologist’s paradise. Palearctic waders also use the lake during their winter migration. (McClanahan etc. 1996, 300.)



Picture 5: Lesser flamingos use Lake Nakuru for feeding (Photo: Nurmi L. 2009)

LNNP is an excellent source of revenue for the Government of Kenya for a relatively low management cost with approximately 200 000 local and international visitors come to the park every year. This flow of visitors is also important for Nakuru town and its surrounding socio-economic development through activities such as tourism, hotel accommodation, food and curio sales etc. (McClanahan etc. 1996, 300.)

5.3 Lake management

Sustainable development issues have arisen in the Lake Nakuru drainage basin. Various institutions have different roles and responsibilities related to the conservation of Lake Nakuru's environment.

- The Kenya Wildlife Service (KWS) is a government institution entrusted with managing the lake environment. Its mission is to protect the biological diversity in Kenya, working in collaboration with other institutions, to address threats to the lake originating from outside the National Park boundaries.

- World Wide Fund for Nature (WWF) has the Baharini Wildlife Research Station in LNNP. Their target is to generate information that would facilitate the effective management of the lake.

- Wildlife Clubs of Kenya (WCK) has a youth hostel in LNNP and they spread wildlife education in the area.

- The MCN is in charge of urban development, setting trade effluent standards and monitoring. It also collects the waste and manages disposal in designated sites.

- The Ministry of Water Resources Development operates within the lake basin under the Water Act and is responsible for catchment water conservation, water apportionment, pollution control and monitoring.

- The Ministry of Agriculture operates in the catchment basin under The Agriculture Act providing extension services on sustainable agriculture.

- Kenya Agricultural Research Institute (KARI) is responsible for research, capacity building and extension and has been active in reducing agrochemical pollution and siltation, and poverty alleviation in the catchment area.
  (McClanahan etc. 1996, 306-308.)

- The Kenya Forest Service (KFS) is a state corporation which is charged with managing all State forests. It formulates policies and implements guidelines and regulations regarding the management, conservation and utilization of all forest lands in the country (US Forest Service International Programmes 2010). It works under the Forest Act which was created to provide for the establishment, development and sustainable management of forest resources, including their conservation and rational utilization of forest resources for the socio-economic development of the country. According to the Act, forests play a vital role in the stabilization of soils and ground water, thereby also benefiting agricultural activity. Forests also play a crucial role in protecting water catchments in Kenya, including Lake Nakuru's catchment basin, and moderating climate by absorbing greenhouse gases. (Kenya forest sevice 2010.)

5.4 Financing Lake Management

Although financing management and conservation initiatives in the lake basin can be classified into various categories, the system adopted here is consistent with the land tenure system - two categories: government or public land, and private land. Government/public conservation land includes the National Park and the catchment forests, where conservation activities are government funded. Other funding mechanisms include bi/multilateral donor support and private donors. (McClanahan etc. 1996, 304.)

5.5 Laws and regulations

Lake Nakuru is a protected National Park under the Wildlife Act. The other important law concerning Lake Nakuru's protection is The Environmental Management and Coordination Act (EMCA). The EMCA provides a tool to enable the conservation and management of lakes, rivers and wetlands.

5.5.1 Wildlife Act

The Wildlife (Conservation and Management) Act was first adopted in 1976, and amendment in 1989. This suggests a spirited search for ideal legal arrangements for the protection, conservation and management of wildlife in Kenya, and for limiting indiscriminate hunting. The act promotes sustainable development, wise wetland use and implementation of management plans for biodiversity conservation, wetland conservation and national parks and national reserves. (McClanahan etc. 1996, 313.) The regulatory regime requires the Minister to declare that a given area is a national park, natural reserve or a sanctuary. Implementation of the Act is the responsibility of the KWS headed by a Director who may delegate or assign any of his functions under the Act to any officer approved by a Minister. (UNEP 2001, 69.)

Other than the national parks and reserves, the Minister may also declare and gazette an area not exceeding 2.600 acres as a local sanctuary where extraordinary measures of protection are taken regarding species being nurtured for replenishment of stocks. Because the Lake Nakuru ecosystem encompasses the whole Lake Nakuru catchment, the entire Catchment Integrated Management Plan can also rely on the provisions of the Wildlife Act in regard to wildlife conservation and habitat management. (McClanahan etc. 1996, 313.)

There are general penalties for offences under the Act. Those who specifically violate the provisions against entering and residing, hunting, capturing bees or animals or collecting their products, introduction of alien species, disturbing or pursuing animals will be punished by a fine or a prison sentence. (UNEP, 70-72.)

5.5.2 The Environmental Management and Coordination Act

The Environmental Management and Coordination Act (EMCA) of 1999 regulates the overall environmental management in Kenya and consists of the management and control of pollution sources by implementing the Environmental Impact Assessment (EIA) and the Environmental

Audit (EA). The act also requires the NEMA to set the environmental quality standards for water, hazardous wastes, pesticides and toxic substances. (State of Environment Report 2009, 32.)

According to the EMCA in part II: protection of sources of water

> "(1) Every person shall refrain from any act which directly or indirectly causes, or may cause immediate or subsequent water pollution, and it shall be immaterial whether or not the water resource was polluted before the enactment of the Act.
>
> (2) No person shall throw or cause to flow into or near a water resource any liquid, solid or gaseous substance or deposit any such substance in or near it, as to cause pollution.
>
> No person shall:
>
> (a) discharge, any effluent from sewage treatment works, industry or other point sources into the aquatic environment without a valid effluent discharge license issued in accordance with the provisions of the Act.
>
> (b) abstract ground water or carry out any activity near any lakes, rivers, streams, springs and wells that is likely to have any adverse impact on the quantity and quality of the water, without an Environmental Impact Assessment license issued in accordance with the provisions of the Act; or
>
> (c) cultivate or undertake any development activity within a minimum of six meters and a maximum of thirty meters from the highest ever recorded flood level, on either side of a river or stream, and as may be determined by the Authority from time to time".
> (E law 2006.)

Although effective legislation and by-laws already exist, they generally are poorly enforced, resulting in frequent illegal activities which endanger the environment (e.g., uncontrolled sand collection and quarrying along river channels; illegal diversion and damming of streams

and rivers; dumping industrial waste in unapproved areas; cultivation along river bank buffers; illegal conversion of public utility land for private use). (McClanahan etc. 1996, 315.)

6 Nakuru town

Nakuru town is situated in the Great Rift Valley 160 km northwest of Nairobi at 1859 m above sea level. It is surrounded by the Menengai crater to the north, Lake Nakuru to the south, Hyrax Hill to the east and Mau Ridges to the west. (State of Environment Report 2009, 1.) Founded in 1904 as a railway station, it is nowadays the fourth largest city in Kenya after Nairobi, Mombasa and Kisumu. Within this region of Kenya, Nakuru occupies a pre-eminent position in this region of Kenya as the administrative capital of the Rift Valley and as the industrial, commercial and service centre for the surrounding agricultural hinterland. (McClanahan etc. 1996, 302.)

Nakuru was declared a municipality in 1952. At that time the population was only 35,000 people and municipality covered 32km^2 of land. Nowadays Nakuru is severely affected by urbanization and the ever-increasing influx of people migrating from neighbouring rural areas and making Nakuru one of the fastest growing towns in Kenya with a growth rate of nearly 7% per annum. Its population is currently estimated to be 700,000 people and nowadays Nakuru town occupies 290 km^2 of land, which also includes the Lake Nakuru National Park with an area of 188 km^2. (Municipal Council of Nakuru & Town of Hämeenlinna 2009, 6.) To accommodate this massive growth of population, the town's boundaries have been progressively extended.

Land use in Nakuru's development area is dominated by housing (70% of the area). The rest of the land is divided for industry (18%) and transport (2.5%). Nakuru also plays a major role as a transit point for vehicles. Because Nakuru is squeezed between the Menengai Crater to the north and National Park to the south, the urban area tends to spread out towards the east and west. The conflict between the need for urban expansion and the need to protect the lake poses a difficult and complex challenge for sustainable urban development and lake management. (McClanahan etc. 1996, 302-303.) Picture 6 below shows the clear line between the settlement and the natural habitat of the conservation area on the north side of the park. The picture is taken from inside the park.

Picture 6: The line between the settlement and Lake Nakuru National Park is easy to observe on the northern side of the park (Photo: Nurmi L. 2009)

The major economic sectors in Nakuru area are industry, agriculture, commerce, mining, tourism and tertiary services (McClanahan etc. 1996, 303). As part of Nakuru's rapid expansion city also suffers from a high level of unemployment.

6.1 Housing

The housing is provided by the government, private (largest provider) and council. The spatial structure of housing in Nakuru has evolved from racially based differentiation to zoning based on socio-economic status. This also tends to correspond with densities of development (plot coverage rates) with high-income areas generally having low densities while low-income areas have higher densities. (Mbwagwa, R. & Musoga, H. & Michoma, J. & Esho, L. & Mwau, H. & Muthoni, J. & Githire, N. & Osengo, C. & Lateste, M. & Ng'ay, M. & Musyoka, R. & Mutai, P. & Swallah, F. 1999, 47.) These phenomena can be observed in Appendix 1. High income/low-density neigbourhoods are to be found in the northwest, north and east. Middle-income/medium density neigbourhoods are found in the south and northeast. Low-income high density developments are to be found mainly in the south and southwest close to the park boundary and Njoro River.

The above differentiation also tends to correspond with the level and quality of infrastructure facilities within each zone. Most private housing areas, especially low-income, are poorly planned and housing development is haphazard. These areas are poorly served with physical infrastructure and services and lack essential amenities like sewers and electricity (poverty areas can be seen in Appendix 2). This situation has consequences for the lake's ecology. Since quite a large portion of private housing is developed in the rural-urban interface (peri-

urban) areas, the municipal authorities do not provide services. (Mbwagwa, R. etc. 1999, 47-50)

6.2 Land tenure types

Land tenure is the ownership and management of land. The current land tenure in Nakuru falls within two categories, public (council and government) and private. The former two categories are used for municipal and government purposes or leased out for a specified period of time to individuals for various predetermined urban land-use activities. Public land covers the bigger part of the current municipal area. (Mbwagwa, R. etc. 1999, 46.)

Different land tenure types are pinpointed for different land administration procedures and have varying implications on urban planning and development. Traditionally, public land (leased to individuals by the government and municipal authorities) was much more suitable for urban development. Nowadays, especially in recent times, not much of this land is left and therefore is unavailable for lease to private developers. Compulsory acquisition can be seen as the result of this and voluntary based sale/purchase actions as the only method to increase the land for future development of public utilities. (Mbwagwa, R. etc. 1999, 46.)

Private land is available for urban development as leaseholds (public land leased to private individuals) or freeholds. Whereas freehold land is cheaper, the leasehold land is generally more expensive. Much urban development currently takes place on freehold land and this presents at the same time an increasing number of problems related to the control of planning and development. (Mbwagwa, R. etc. 1999, 46.)

Lake Nakuru National Park is owned by the government as can be seen from Appendix 3. On the north side of the National Park, along the Njoro river, land tenure is divided more for public and private landowning. The eastern side of the National Park belongs to the government and on the west side land is for private leasehold by central government, apart from the area where the Njoro treatment installation is situated which belongs to the council. On the southern riverside the land is under private freehold.

7 Lake Nakuru's environmental impacts

There are various pollution sources in the Lake Nakuru catchment such as organic pollution from domestic, livestock, industry and agricultural areas; heavy metal and other chemical pollution from industries and dumping sites; and agricultural chemical and pesticide pollution from agricultural areas.

The ever-increasing human population, poor enforcement of environmental regulations and unsustainable exploitation of natural resources has gradually caused conflict between humans and natural resources. Denaturation and degradation of forestlands, clearing of riverbanks, poor land use planning and urban development and the prevalence of poverty around the LNNP has given rise to the conflict between the catchment's natural resources and the human population. (McClanahan etc. 1996, 305.) Information for these chapters has been collected through documentation, interviews and observation during the field survey.

7.1 Background to the problems: Land use and settlement patterns

Although humans have settled in the catchment basin for tens of thousands of years, the greatest impact on the environment and biodiversity has occurred over the last 40 years when the basin evolved from a sparsely-populated, densely-forested expanse, to a heavily populated area with extensive cultivation and rapid urbanization. This transformation was accompanied by a steep decline in the area's biodiversity. (McClanahan etc. 1996, 304.)

Before Kenya's independence in 1963 cultivation and hunting practices made their mark on the Nakuru landscape but subsequently pressure to allocate land to the landless resulted in additional settlement schemes on the existing large farms. These were sub-divided into smaller, individually-owned parcels of land. As the demand for land increased over the next decade, forest reserves were taken over for human settlement thus destroying the natural protective wooded zone bordering the lake. (McClanahan etc. 1996, 301-302.)

Environmental issues did not form part of the land use planning for the new settlements. By ignoring the soil and slope characteristics, degradation of soil conservation structures constructed during the colonial period and erosion problems on steep slopes occurred. Farmers invested in hybrid seeds, fertilizers and pesticides to boost their crop output. Between 1967 and 1986, more than 400 km^2 of forest and land under natural vegetation in the catchment basin were cleared for settlement reducing the vegetative cover from 47 % to 26 % and in 1986 the total area occupied by farms was 35% of the catchment area. In addition to this, insecure land tenure, low farm prices, droughts and crop pests were aggravating factors leading to a progressive decline in environmental quality in the following years. (McClanahan etc. 1996, 301-302.)

In 1994 the government de-gazetted over 20 000 ha of the Mau forest in the catchment basin for landless forest dwellers. Since then it is estimated that over 30 000 ha of natural and plantation forest have been felled and the land taken for agriculture. Around 30 000 people have migrated into the catchment causing an increasing environmental impact. Despite a ban, felling continues in Mau and Dondori forests. (McClanahan etc. 1996, 302.)

7.2 Solid Waste

As a city, Nakuru is a huge waste producer. The town generates an estimated 250 tons of domestic solid waste per day. About 35-40 % of the garbage is being moved to approved dumping sites which can been seen in Picture 7. (State of Environment Report 2009, 28.) The current dumpsite covers an area of 17ha and is situated on the slopes of the Menengai Crater. It has been in use from 1972 to date. The dumping site is very close to the town centre and residential areas (Appendix 4). The uncollected garbage accumulates in the environment, being eventually deposited in the lake by storm water and wind. (McClanahan etc. 1996, 303.) The site is not equipped with any leachate treatment facility and pollution of groundwater is also a major concern. A study of the leachate from the site in 2001 showed relatively high concentrations of zinc, total chromium, mercury, copper, manganese and nickel. (State of Environment Report 2009, 29.)

Picture 7: The fence which surrounded the Gioto dumping site, an environmental and health hazard, has been destroyed (Photo: Nurmi L. 2009)

The town's first solid waste dumpsite was situated 0.5 km from the northern lake shore. It remained there for several years before it was relocated to the slopes of the Menegai Crater in 1972. Leachate from that landfill drained into the lake and loaded its ecosystem. Now this dumpsite is overgrown with vegetation but contamination is still continuing. (McClanahan etc. 1996, 304.)

7.3 Sewage

About 9000m³ of sewage is generated each day. It is processed in two treatment installations before being discharged into the lake. These use stabilization ponds as a treatment mechanism (Picture 8).

Picture 8: Town Sewage Treatment Installation on the east side of the town was commissioned in 1956 and has a capacity of 6600m³/day (State of Environment Report 2009, 18, 23) (Photo: Nurmi L. 2009)

The sewerage system serves 16.6 km² (26 %) of the town. The system is presented in Appendix 5. Approximately 100 000 residents are living in the sewerage service area but only 30-50 % of them are actually connected to the sewer lines, while the rest are still using on-site wastewater treatment facilities. Approximately 80 % of all the residents in Nakuru town are not connected to the sewerage system. Aside from the low connection rate, frequent clogging of sewer pipes is a major problem (Picture 9), with about 70 % of the sewer pipes having diameters of less than 150 mm. (State of Environment Report 2009, 18.) High density in low-income residential areas fronting the park edge produces large amounts of surface runoff, which discharges pollutants into the park and lake thereby posing a threat to the fragile ecology. Dumping of domestic solid waste along the park edge is also common (Picture 10 & 11). (Mbwagwa, R. etc. 1999, 51.)

Picture 9: Many of the sewers are blocked and overflow during the heavy rain (Photo: Nurmi L. 2009)

Picture 10: People use the drains close to the park to get rid of their washing water and as a dumping site for their garbage (Photo: Nurmi L. 2009)

7.4 Storm water

A lot of storm water is discharged into the lake without prior treatment (McClanahan etc. 1996, 303). During the heavy rains, surface runoff is discharged into the lake through numerous natural drains and through three main drainage channels. Part of it is also discharged to underground reservoirs through normal seepage and through the geological faults. (Mbwagwa, R. etc. 1999, 62.) Storm water is commonly contaminated with effluent

from the houses which are not connected to the sewerage system, garbage and other urban contaminants (oils, heavy metals etc.), which add to the pollution load and eutrophication of the lake (Picture 10 & 11) (International Lake Environment Committee Foundation 2005, 20). This problem can be especially observed next to low-income residential areas.

Picture 11: Polluted water discharges straight into the park without prior treatment on the eastern side of the town (Photo: Nurmi L. 2009)

Table 1 below shows the mean value of water quality of the storm water drainage channel during 2005-2008. The quality of surface water was 123 mg/l of BOD, and 280 mg/l of COD, as mean values during the years from 2006 to 2008. These values show that the surface water is polluted, similar to raw sewerage. This is mainly due to domestic wastewater from the houses which are not connected to the sewerage system. Moreover, leaking or overflowing sewerage from the clogged pipes flows into the surface drainages. (State of Environment Report 2009, 20.)

Sampling Point	pH	TSS	NH4-N	TKN	T-P	BOD	COD
	-	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Stormwater Drainage Channel	7.6	105	13	20	7	123	280

Table 1: The table shows the mean value of water quality of the storm water drainage channel during 2005-2008 (State of Environment Report 2009, 20.)

7.5 Industrial pollution

Nakuru is still undergoing rapid growth and industrialization. There are approximately 60-70 factories in Nakuru. The major industries are textile, food processing, pyrethrum, chemical, battery, tanning, seed coating and paint. (State of Environment Report 2009, 2.) The effect

on water quality is very diversified, depending on the type of industry products fabricated and chemicals used. Industrial wastes can contain heavy metals, PCBs, dioxins and furans, BOD, lead, copper, mercury, zinc, cadmium, chromium, nickel, DDT, dieldrin and gamma BHC and other toxic chemicals (McClanahan etc. 1996, 312). An Appendix 6 of land use shows the location of industrial activities in Nakuru Town. Industry is concentrated on the east and west sides of the Business District Center (BDC).

Industrialization in Nakuru started in the early 1970s without any thought being given to the impacts of industry on the ecology of the land or the lake, and no effort made to leave out industries that might cause serious environmental problems. A fungicide factory was built in the town and operated for a year before its negative impacts on the environment and its potential for polluting were understood. After this the factory was relocated to another part of the country. (McClanahan etc. 1996 304.) Pre-treatment of industrial waste is a major concern and some factories still exceed the stipulated values of water quality (State of Environment Report 2009, 21).

From 1993 to 1997, a large number of birds died at Lake Nakuru. High concentration of toxins (up to 9 different metals in excess amounts) were found in their bodies (McClanahan etc. 1996, 310).

7.6 Agriculture

Runoff originating from nonpoint sources is a major challenge in environment conservation and is typical in areas where the land is used for agriculture. The difficulty in controlling nonpoint sources is that sources cannot be readily identified. Nonpoint sources usually become more of a problem with increased development and changes in land use within the basin. Changes lead to increased generation of sediment, nutrients (primarily nitrogen and phosphorus) and agrochemicals. The associated destruction of wetlands and riparian areas reduces the basin’s ability to filter these pollutants before they reach the lake. (International Lake Environment Committee Foundation 2005, 62.)

7.6.1 Eutrophication

Soils have only a limited capacity to absorb nutrients used to increase crop production. The nutrients which are not taken up by the soil/plant system leach into the surface and are carried into the lake by runoff resulting in water quality problems related to eutrophication. In addition the amount of organic nitrogen from animal waste also increases due to high livestock densities. (Kira, T. & Jorgensen, S.E. & Ondok, J.P. & Priban, K. & Kvet, J. & Piczynska, E. & Löffler, H. & Straskraba, M. & Herodek, S. 1990, 121.)

Picture 12: The land used for farming close to the Njoro River on the west side of the city (Photo: Nurmi L. 2009)

Nutrients from agriculture commonly originate from soil erosion. Increases in nutrient levels in the lake are associated with algal outbreaks and growth of aquatic weeds. Expansion of the vegetation resulted by eutrophication can contribute to siltation and can decrease the area of open water. It can also result in reduced oxygen levels. (International Lake Environment Committee Foundation 2005, 20.)

Nutrient enrichment is a large-scale problem in Lake Nakuru. It results in reduced productivity of the lake's natural primary producer *Arthospira fusiformis* and frequent occurrence of toxic blue-green algae blooms. This phenomenon easily leads to desertion of the lake by lesser flamingos (McClanahan etc. 1996, 312). Appendix 1 shows that on the south side of Njoro river all land is used for agriculture. Also on the north side of LNNP a large amount of land next to the river line is used for farming (Picture 12).

7.6.2 Chemicals

Agro-chemical pollution comes from agricultural activities in rural land use. Farmers who settle in the catchment area above the lake can cause problems because agro-chemical residues (for example from fertilizers, pesticides or herbicides) are carried through runoff into the lake. (International Lake Environment Committee Foundation 2005, 20.)

Chemicals, both industrial and agricultural, cause deterioration in the water quality of the lake and its streams and expose human and animal populations to pesticide residues and other potentially dangerous leachates. Chemicals can also affect aquatic food chains. Some

long-life chemicals can persist in lake sediments for extended periods of time. (International Lake Environment Committee Foundation 2005, 20.)

7.7 Alterations in hydrological balance

Deforestation, agriculture and urbanization exert effects that alter the hydrological balance of the catchment area. The destruction of forests in the Lake Nakuru catchment basin not only has consequences for the biodiversity they support but also cumulative impacts on the catchment hydrology. Many springs have dried up causing higher peak discharges in rivers. This affects seasonality in stream flows and significant declines in stable yields of wells and boreholes. (McClanahan etc. 1996, 301.)

In recent years the lake has suffered long droughts and also wide variations in water levels between the dry and wet seasons. Dry river conditions are shown in Picture 13. It's suspected that this is caused by increasing watershed land conversion to intensive crop production and urbanization. Both reduce the capacity of soils to absorb water, recharge ground waters and thus increase seasonal flooding. As the demand for water and abstraction rates increase, the capability of the catchment to harvest and hold the rainwater appears to be diminishing. (McClanahan etc. 1996, 301.)

Picture 13: Njoro river flows during rainfall (Photo: Nurmi L. 2009)

There are over 350 registered and unregulated water intakes for domestic, irrigation and factory use along the upstream parts of the rivers. Adding to this, 156 registered and a few unregistered boreholes are under exploitation in the catchment. (McClanahan etc. 1996, 301.)

7.8 Erosion and dust

The extent of erosion problems depends on local climate, soil characteristics, land vegetation, topography, water utilization and management, land uses and intensity of human activities. Also road building accelerates the erosion, if care is not taken to reduce it (Kira, T. etc. 1990, 13). The threat of erosion and sediment input often originates from poor land use and riparian management in lake basins (International Lake Environment Committee Foundation 2005, 20).

In Nakuru, the erosion is often caused by short heavy rainfalls. These occur typically in the afternoon and are mainly convective (McClanahan etc. 1996, 301). Accelerated soil erosion in Nakuru catchment basin causes losses in farm productivity and income and, in turn, leads people to overexploit the natural resources (McClanahan etc. 1996, 312). Erosion and sediment transport also act as carriers of nutrients and other pollutants.

The destruction of forests in the Nakuru basin also has its consequences. When forest cover bonding the soil in a lake basin is destroyed, the result is usually an increase in land erosion and sediment transport, which in turn leads to reduced lake water quality which limits the penetration of light into the water column. (International Lake Environment Committee Foundation 2005, 20.)

The production of excess dust during dry seasons and pollution dustfall from the town's industrial activities also largely disadvantages the lake and the park (Mbwagwa, R. etc. 1999, 112).

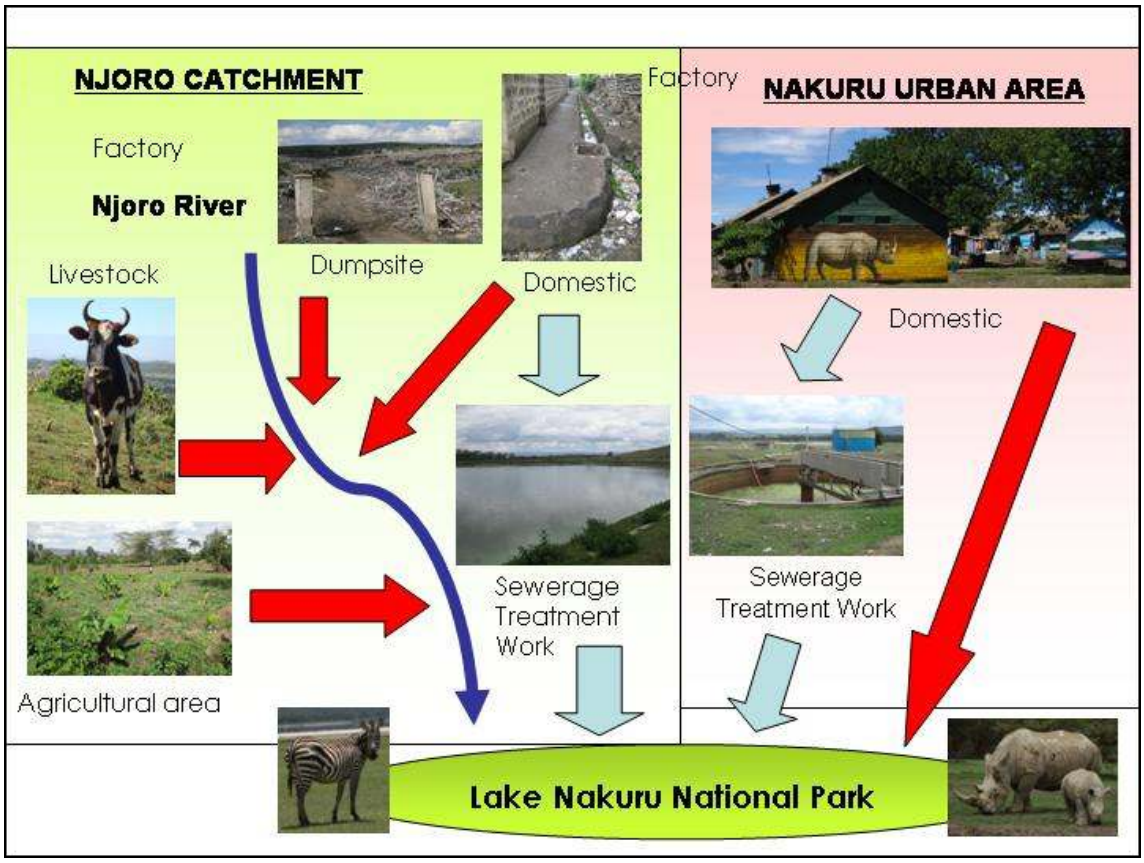
7.9 Other problems related to Lake Nakuru's catchment management

The single most serious health challenge in Kenya is the HIV/AIDS epidemic. It also has an impact on lake management, because time, efforts and other resources originally allocated for improving livelihoods and conservation are now being used for health protection programmes (McClanahan etc. 1996, 303-304).

Poverty also has an impact on lake management. In the rural areas there are differences in annual farm income among households and this has a harmful impact on conservation efforts in the catchment area. A high percentage of households have no off-farm income, so the consequence of this is a high rate of exploitation and dependence on the basin's natural resources. This might accelerate basin degradation. (McClanahan etc. 1996, 304.)

7.10 Water pollution mechanism

As mentioned earlier, there are many sources of pollution in the Nakuru catchment area and Picture 14 below shows the pollution pathways. The picture has been made using the information gathered during the field surveys. On the west side of the city in Njoro catchment area the main sources of pollution are agriculture, livestock, the Gioto dumpsite, industrial activities and domestic waste. Pesticides, fertilizers, leachate, solid waste, domestic sewage etc. are discharged into the Njoro river which drains into the park without pre-treatment. The lack of a sewerage system and low-income housing along the riverline are also aggravating factors. Along the riverline there are numerous little plots for cultivation. Even though the riverline is owned by the government and protected by laws people still cultivate there. It is difficult to control the farming because of the numerous subdivisions of land and the large populations of people who use that land. The river and the adjacent agricultural land do not have any buffer zones so the plots reach the riverbank and increase the pollution load of the river water. Dumpsite and industrial activities pollute the river water through surface runoff.



Picture 14: This shows the pollution pathway from pollution sources reaching the lake in the Nakuru urban area and the Njoro river catchment

On the very eastern side of the urban area, dirty water flows into the park without prior treatment through many drains and pipes. The east side has a low-income settlement next to the park boundary and the pollution comes mainly from domestic water use. In that area houses are constructed very close to the boundary line. People use the drains to get rid of their sewage (washing water) and as a dumping site for their garbage. In many places the garbage has blocked the pipes. In some places the dirty water smells like raw sewage.

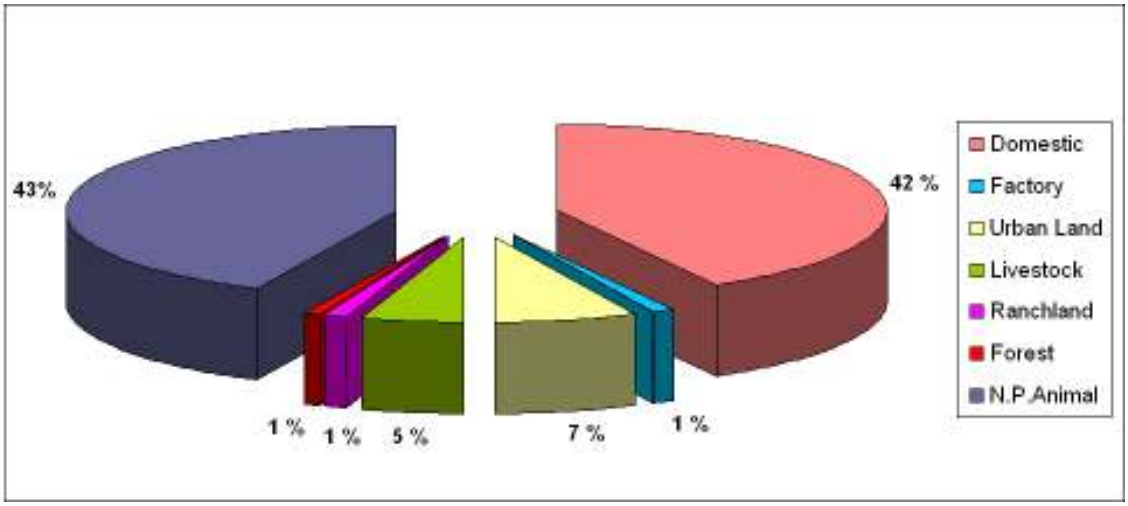


Figure 1: The ratio of pollution load of each sector in 2008 (State of Environment Report 2009, 23.)

Figure 1 above shows the ratio of pollution load of each sector in 2008 in the Lake Nakuru catchment. Regarding the pollution load generation of each source, approximately 40 % is from natural bases (mostly from the animals in the National Park) while about 60 % is from human activities. The domestic sector occupied 42 % of the total pollution load and 7 % of pollution comes from urban land. Factory, forest and ranchland are minor factors while livestock has a heavier impact. The pollution load from domestic and urban areas is increasing due to population growth and expansion of urban areas.(State of Environment Report 2009, 23.)

7.11 Reduction of Lake stresses

The vast majority of problems originate from activities on the land surrounding the lake. Therefore, management of the lake means management of its drainage basin (International Lake Environment Committee Foundation 2005, 3).

Nonpoint-source problems, particularly sediments, nutrients and agro-chemicals from agricultural and forestry land uses, can be tackled through reforestation (replacing destroyed forests) and afforestation (planting forests where they did not exist before), creating buffer zones and other catchment protection activities (International Lake Environment Committee Foundation 2005, 62).

In view of all the threats to the biodiversity of the Lake Nakuru area , the main challenges according to McClanahan etc. 1996, confronting the lake management include:

- "maintaining the vitality and integrity of the catchment,
- restoring maximum groundcover in the catchment,
- restoring the water balance and quality of the catchment through better land use practices - sustainable water management
- entrenching the conservation ethic among catchment residents
- promoting sustained conservation
- monitoring the biodiversity in order to evaluate progress and identify new threats" (McClanahan etc. 1996, 305.)

8 Research progress

Methods of data collection are represented in the following chapters. The research was carried out using qualitative methods. Facilities, time schedules and co-operation partners are also shown.

8.1 Data collection methods

Qualitative methods are usually more flexible than quantitative methods. Qualitative methods allow greater spontaneity and adaption of the interaction between the researcher and the subject under research. In quantitative methods questions asked are very strict and put to each participant in the same way. On the other hand, in qualitative methods questions are usually asked "open-ended" and not necessarily in the same way for each participant. With open-ended questions participants are free to answer in their own words and these answers tend to be more complex than simply "yes" or "no" –types of answers. (Mack, N. & Woodsong, G. & MacQueen K. & Guest, G. & Namey, E. 2005, 3-4.)

It should also be noted that in qualitative methods the relationship between the researcher and the participant is usually not as formal as in quantitative methods. The participants have chance to respond more elaborately and they also have a greater sense of detail than in a typical case with quantitative methods. In turn, researchers have the opportunity to respond

immediately to what participants say by tailoring subsequent questions to information the participant has provided. (Mack, N. etc. 2005, 4.)

8.1.1 Observation

The observation method is used to describe a setting, the activities that occurred, the people who were there, and the meaning of what was seen. Usually the observation method involves direct contact with the target under research but it can also be done by using photography or video recordings and/or audio tapes. The means of observation is chosen in relation to the purpose of the research and the information sought. (The International Development Research Center 2010.)

Direct observation helps to develop a deeper understanding of issues handled, problems and practices. Researchers should use all of their senses to describe the setting in a physical environment. This method consists of systematically observing and documenting the subject being researched in its natural setting. Researchers should remain silent observers and should not interact in any way with the subject of research or the situation. (The International Development Research Center 2010.)

In this research direct observation was used as one of the data collection methods. Photography was a common tool during the research. Observation took place over several days, on foot and by motorbike. Environmental problems, housing and other structures were easy to document by using this method.

8.1.2 Interviews

Interviews are used to help the researcher gather people's opinions, values and experiences. There are numerous kinds of interviews, for many different purposes, with varying forms and durations. In general, the main idea in interviews is to ask people a selection of questions on a particular topic. (The International Development Research Center 2010.)

Interview methods used in this research were informal conversation and semi-structured interviews. Informal conversation is a flexible interview method and in this research was used without any strict subject order. Questions or answers emerged from the natural flow of conversation. The disadvantage of this method is that the conversation can take an unwanted direction and it took many interviews to collect all information necessary for the research. (The International Development Research Center 2010.)

Semi-structured interviews constitute a stricter method and are based on a straight list of questions and topics, which acts as a guide for the interview. (The International Development Research Center 2010.) Semi-structured interviews were prepared in advance for this research. The questions can be seen in Appendix 7 and they were put to three interviewees: Bernard Kuloba, Daniel Kamau Mbugua and John Mwangi Kahiga.

8.2 Facilities

During the research many facilities were used. Cameras and mobile phones were essential to the project. Photographs helped to visualize environmental problems related to Lake Nakuru and were taken during the field survey. Mobile phones helped keep contact with working partners. Computers and Internet were also used, more in Finland because of the uncertain internet connections offered in the local African cyber cafes. Motorbikes were extremely useful for the field survey along the park boundary. A simple notebook was used during the interviews for taking notes.

8.3 Co-operation partners

The main partners during the project were MCN, KFS, KWS and CABULAG. The MCN arranged the meetings with organizations and people in the KFS and the KWS and also gave informative help and advice concerning the buffer zones. In the MCN the working partners were Sammy Knige Kimani, Nora Mulani, Daniel Kamau Mbugua and Samuel Natha. Mr Kimani had the role of introducing the project to the KFS and the KWS, and the Public Health Officer Nora Mulama worked as an assistant. She also arranged some field trips and supplied informative books. A field trip was carried out with Daniel Kamau Mbugua and Samuel Natha. Salomon Mbuguah from the MCN supplied some good maps for the project.

In the KFS the main co-operation partner was John Mwangi Kahiga who greatly supported the work. Many field surveys were carried out with him and he supplied a motorbike for the purpose. In the KWS the adviser was Bernard Kuloba. Several interviews and conversations were held with him during the progression of the work. A meeting also took place with Senior Warden Lydia Kisoyan from the KWS. In CABULAG the contact person was Heidi Piilola to whom the work progress was reported. In Appendix 8 there is a table of the main partners and their roles and activities in their organizations. They can also be considered as stakeholders in the buffer zone process.

8.4 Time schedule

The field reserch was done in Nakuru, Kenya, during the period from the middle of October 2009 till the end of January 2010. Documentation was also collected in Finland before and after the African visit at the beginning of October 2009 and February 2010-March 2010. The report will be published after the evaluation in Spring 2010, given to CABULAG and sended to MCN.

9 Results

Proposals to reduce environmentally harmful impacts outside and inside the park boundaries to protect Lake Nakuru are introduced in the following chapters. The results have been collected through documentation, interviews and observation during the field survey. Two main proposals are in chapter 9.1 “Creating a buffer zone for Njoro River” and chapter 9.2 “Creating a buffer zone inside the Lake Nakuru National Park”. Some other proposals are also introduced briefly at the end.

9.1 Creating a buffer zone for Njoro River

Even though the Njoro riverline is owned by the County Council and there should be a defined buffer area, the land now is heavily cultivated. Pesticides and fertilizers drain into the river, and the dumpsite uphill has its negative impact on the quality of the water. Creating a buffer zone for Njoro River would be extremely beneficial both to the water quality which flows into the park and to the local people economically. To obtain the best result, the buffer zone should start from the edge of the river valley on both sides and end on the water line/river bank. To minimize all the negative impacts, the buffer zone should start from the boundary of the park and continue 3-4 km up river.

The preferable trees and shrubs for purifying the runoff are indigenous species that enrich nature. The species introduced below have been chosen by using the information gathered through inteviews with John Mwangi Kahiga. Kahiga’s ideas and the knowledge helped also to draw the picture 15.

Tree species, such as Acacias *(Acacia spps*), Cussonia *(Cussonia Spicata),* Fever Tree *(Acacia Xanthophloea)* and Fig *(Ficus spps)* are suitable for the zone this being their natural habitat. Cussonia and Fig supply beehives, carvings, medicine and fodder, while the Fever Tree offers,

charcoal, firewood, fodder and medicine. Cussonia is suitable for nitrogen fixation, river and sand stabilization.

Suitable shrubs to plant on the river zone are for example: *Rhus Natalensis, Mauriciaus Thorn* and Bamboo. *Mauriciaus Thorn* is very thick and has spikes. Due to this it has the capacity to act as a hedge to prevent access to the riverline both by domestic animals and humans. Bamboo is very dense and a good species to purify the water. It also provides building materials and food.

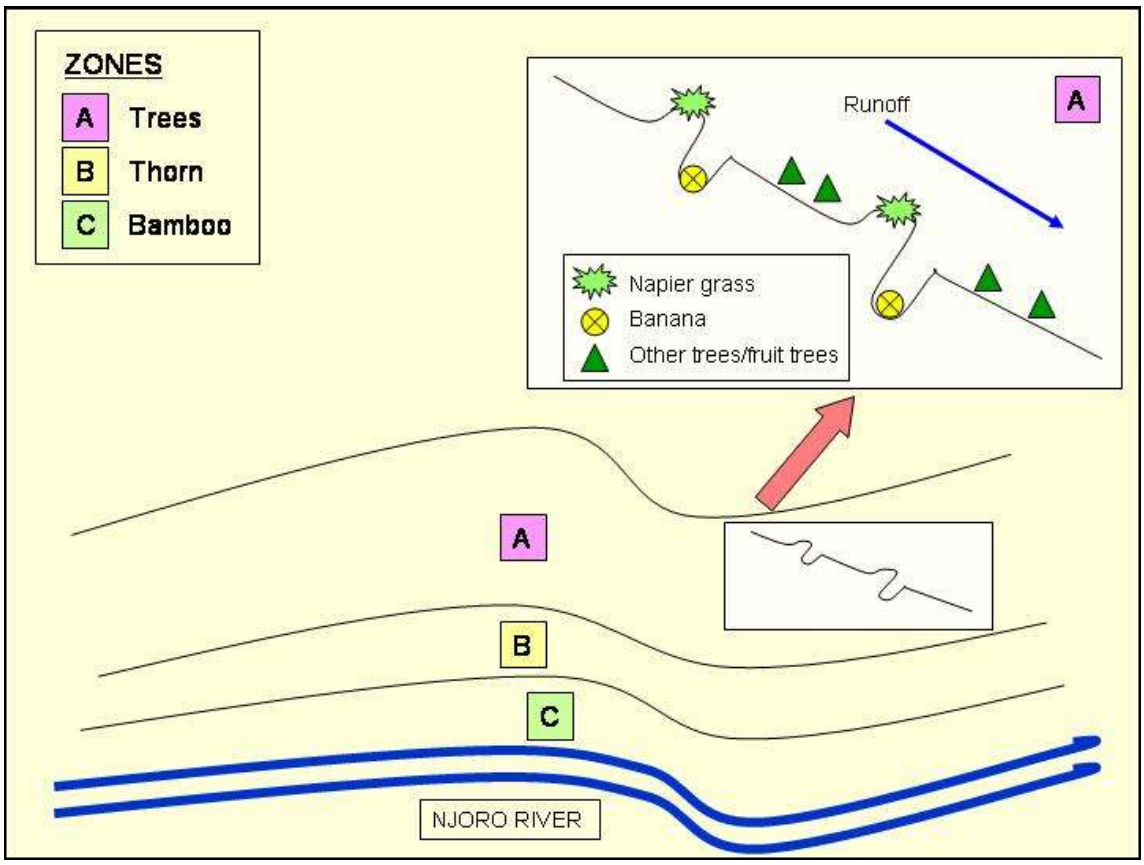
Exotic fruit trees can be considered as an excellent option together with local tree species because they usually have more rapid growth rates (leading to quicker soil stabilization) and greater marketability. Avocado and banana are very marketable plants and could generate income for local people. Guava *(Psidium Guajava)* and Loquat *(Eriobotrya Japonica)* are good species for domestic use.

9.1.1 Cropping and Planting Plan

Seedlings are easy to get in Kenya and there are many tree nurseries. CABULAG has its own tree nursery next to the eastern sewage plant and a demonstration tree nursery at the Town Hall site.

Before starting to plant the trees, the slope of the river valley needs to be terraced to capture the water (see Picture 15). Zone A is the cropping zone where the farmer will get direct benefits while zones B and C are there to improve the river water quality. Zone A should be 15 metres wide, zone B 5 and zone C 10 metres. But if the riverside is wider than 30 metres, farmers should duplicate zone A.

In zone A there should be two trenches for bananas (60 cm wide and 60 cm deep) which will contain the runoff water. Alongside these trenches the most beneficial cultivated plant is banana because it needs ample water to grow well. Above the banana rows it is advisable to plant some napier grass *(Pennisetun Purpureum).* It has the capacity to hold the soil together and prevent runoff and erosion. It can also be used as forage grass for livestock and as a silage. On the terraces below the banana rows it is advisable to plant indigenous trees and exotic fruit trees, in consultation with the farmers, as agroforestry fruit trees. *Mauricias Thorn* should be planted in zone B to protect the riverbank and prevent access. Bamboo is ideal for planting on the water line (zone C) for purifying purposes. With the interaction of these three zones the runoff should be clean when it reaches the river. Fertilizers are not necessary when using this cultivation method.



Picture 15: Buffer zone plan for Njoro River

9.1.2 Preliminary plan for estimated costs

To minimize the costs and to involve the local people in actions concerning their plots, farmers will plant their own seedlings with the advice of professionals from NEMA, Forestry and Agriculture. The planting action itself will last for three days. Planting is divided into three sessions: the first day for pegging (identifying the planting spots), the second day for pitting and the third day for planting the seedlings. Appendix 9 shows the calculation of estimated costs.

9.1.3 Evaluation

In developing countries there is always a risk in tree planting when the land use policy is not well implemented. People can prioritize crop farming rather than tree farming and thus continue using the land for cultivation for food production and revenue by selling their crops. Co-operation and negotiating with farmers rather than forcing them to change their farming habits has better results. Holding discussions and meetings with farmers and asking what tree species they would prefer for intercropping leads to better results in conservation. It is

important to make them understand that intercropping will give multiple final products economically. Mature trees will give multiple benefits i.e construction materials, firewood and, from fruit trees, improved food security with surplus earning revenue. To ensure that farmers can harvest fruits as soon as possible (approx. after three years growth), it is best to use grafted seedlings.

Along Njoro River there are many quarries. To get the best conservation results for the area there is a need to implement quarrying policies and ban illegal quarries. To minimize tree felling it would be necessary to contact the National Environment Management Authority (NEMA) and the Kenya Forest Service (KFS) who enforce the law and make tree exploitation illegal in some specific areas.

The buffer zone along the Njoro River will interpret the objectives of CABULAG. Tree species used for planting are indigenous and commercially viable exotic trees. The buffer zone is a source of fuel wood, construction timber and other local industry materials for communities and offers a green area for recreation/aesthetic purposes and a better living environment.

Table 2 shows how the SWOT-analysis has been used as an aid in evaluating the results, advantages and disadvantages of the buffer zone along the Njoro River. The SWOT-analysis describes the strengths, weaknesses, opportunities and threats related to the chosen issue. The topics for the SWOT-analysis has been collected by using the information gathered during the field survey and interviews.

Strengthts	Weaknesses
-Better land use practices will improve the quality of the water which runs into the lake -Vegetation helps to restore maximum groundcover in the catchment -Seedlings are easy to obtain -Participation of local communities will ensure more effective results -Trees will offer food and other materials -No need for fertilizers by using this method -Tree planting has a positive impact in the battle against global warming	-Lack of knowledge among the local people on how to take care of seedlings -Lack of funds -Weak land policy
Opportunities	**Threats**
-Green areas offer better living environments -Local communities will earn some revenue -Increased knowledge of conservation among local people	-Illegal quarries -Crop farming will continue -Lack of tending after tree planting

Table 2: SWOT-analysis for the buffer Zone on Njoro riverbank (Nurmi L. 2009)

9.2 Creating the buffer zone inside the Lake Nakuru National Park

A buffer zone outside the park next to the boundaries between human habitation and the National Park is not possible even if this was the MCN's initial idea when starting this research. There is no space anywhere for the buffer zone because the area next to the boundary is highly settled. The only open area outside the park is the fire line which goes around the park to protect both the settlement and the park from the risk of fire. In that line it could be possible to plant some species which are suitable to protect the spread of fire and good for buffer purposes. However the line is very narrow, about 6 metres, so the buffer effect would not be efficient enough.

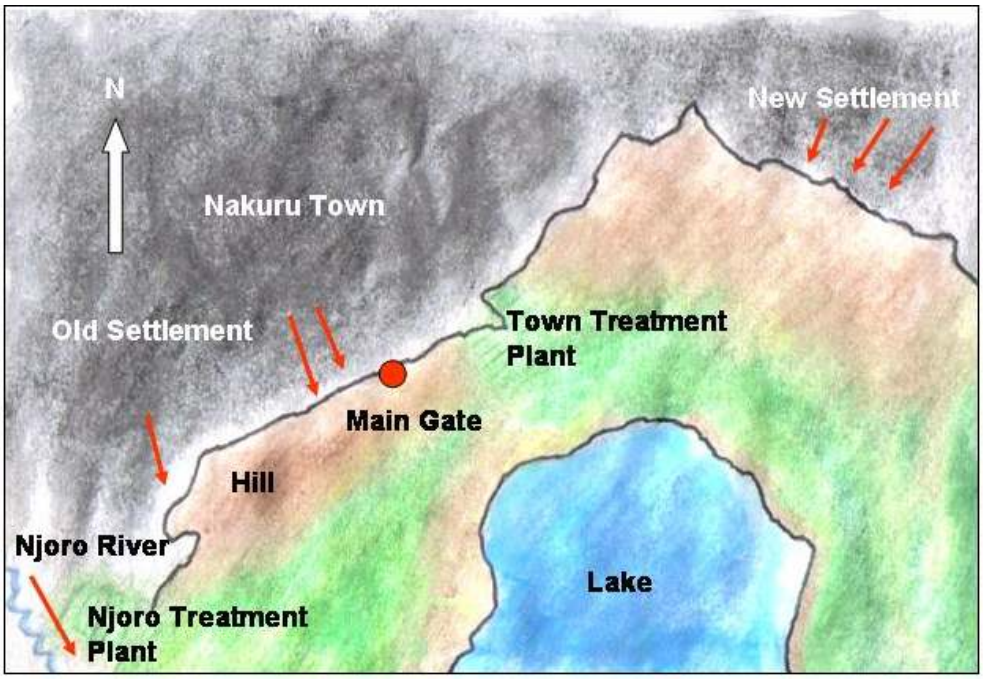
Creating a buffer zone inside the park is one important option when trying to decrease the pollution load entering the lake. Excessive pollution loads of both sewage and solid waste

were observed next to the boundaries during the survey especially in low income areas. The National Park land is owned by the government and is thus highly protected. Even though there is a fence on the north side (partly electric, partly ordinary barbed wire) goat grazing was observed inside the park close to the borderline. The fence was partly broken in some places (Picture 16). To protect the park from misuse, fencing should be repaired.

Picture 16: The park fence is broken in many places close to the town's treatment plant (Photo: Nurmi L. 2009)

Trees planted inside the park must be indigenous and of the same ecological zone to avoid a negative impact on nature and vegetation in the National Park. They also need to be tolerant of drought conditions because of the dry soil type. When creating the buffer zone tree coverage should be increased at least in critical areas for the purpose of purifying runoff water where it flows through the surface drains into the park without prior treatment (See Pictures 17 and 18 where critical points are marked with red arrows). If possible and to better maximize the positive effect, the buffer zone would be a green belt inside the park along its northern boundary where the town has a harmful impact, starting from the new settlement on the east side and ending at Race Course Hill (Picture 18).

As well as having a purifying role the thick planted vegetation strip would block the view of the city and vice versa. The purpose of this measure has a recreational meaning and value. When inside the park, the feeling of being close to nature is enhanced when the settlement is out of sight. The buffer's third function is that the green zone along the park fence would act as a dust buffer. The proposed width for the buffer zone is 20 metres.



Picture 17: According to a field survey, this image shows the critical points where dirty water discharges into the National Park

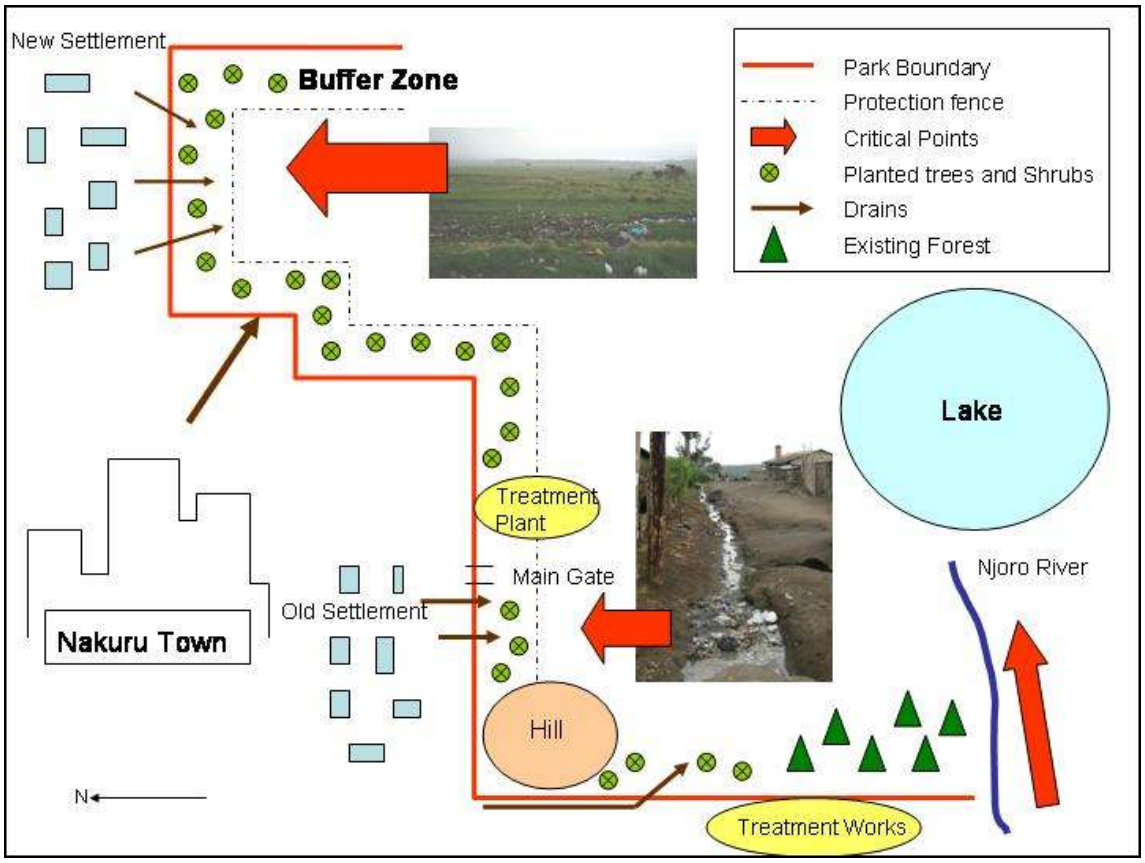
9.2.1 Planting plan for the green belt

The buffer zone will consist of trees and shrubs. The best trees to plant in the buffer zone are acacias. They are big enough to shield the view of the settlement and at the same time can adapt to this kind of ecosystem. It is also recommended that there should be no fruit trees since fruits will attract monkeys too close to the boundary and on the other side of the fence creating conflict with the residents. Neither should the trees be planted too close to the town sewerage plant ponds because the latter need a special micro climate to operate properly and too much shade affects the purifying process. Some shrub species should be avoided because they can attract rhinos to graze too close to the settlement. Suitable shrub species to plant for water filtering and purifying process are for example *Grewia similas* and *Rhus natalensis*. The species introduced above have been chosen by using the information gathered through inteviews with Bernard Kuloba.

The risk inside the park is that animals, especially buffaloes, destroy the seedlings. To achieve the best results, seedlings must be protected. Single seedling protection is not enough to protect the seedlings from wild animals so the solution is to build a temporary fence (Picture 18) to protect planted areas and remove it when the seedlings are mature enough to survive on their own. Fencing and planting should be in four phases (four years), because of ecological and economical aspects: it is advisable not to block a large area at one

time since animals need considerable space for grazing. Using the same fence from one phase to the next will cut costs.

Acacias must be planted densely, because the soil inside the park is a volcanic ash type and gets very dry. Some seedlings may suffer from drought. Watering is necessary until the seedlings are well established. Planting is best carried out during the heavy rain season (April-June) in Nakuru. Security against wild animals must be provided when planting.



Picture 18: A map of the buffer zone inside the park boundaries

9.2.2 Evaluation

The buffer zone inside the park will meet the objectives of CABULAG when it comes to reforestation with indigenous tree species. It will also provide additional protection to the main tourist site and offers a green area. But some CABULAG objectives for the buffer zone cannot be met. The buffer zone will be located inside the park which is gazetted land where it is not possible to plant commercially attractive exotic trees. Neither can the zone provide a

source of fuel wood, construction timber and other materials for local communities, because tree cutting and harvesting is illegal in National Parks.

If the buffer zone for the National Park is created, it will have a very positive impact on the nature, local people and for the whole of Kenya. The conservation level in Lake Nakuru National Park will increase through more sustainable water management and the project could increase the knowledge of conservation issues among stakeholders and catchment residents. It will also maintain the tourist inflow to the area and support local business activities. The Park's pure natural habitat would continue to attract visitors and bring in revenue from park fees now and in the future. Tree planting also has a positive impact in the battle against climate change. Below Table 3 shows the SWOT-analysis for the buffer zone inside the National Park. The topics for the SWOT-analysis has been collected by using the information gathered during the field survey and interviews

Strengths	Weaknesses
-Better conservation and water management level in Lake Nakuru National Park -Green belt will block view of settlement -Decreasing negative impact of dust -Seedlings are easy to obtain -Tree planting has a positive impact in the battle against global warming	-Lack of money/funds -Lack of time -Lack of effectiveness
Opportunities	**Threats**
-Increasing the knowledge of conservation issues among stakeholders and among catchment residents -Protecting the main tourist site in Nakuru resulting in revenue for residents	-Seedlings might suffer from drought -Lack of tending after planting -Animals can destroy the seedlings -Illegal tree cutting and grazing

Table 3: SWOT-analysis describes the strengths, weaknesses, opportunities and threats of the buffer zone (Nurmi L. 2009)

9.3 Digging the drains to irrigate the fields

On the west side of town in the Njoro River area, there are wide open drains where the surface runoff flows directly into the Njoro River. It carries the water into the park without prior treatment. Pesticides, fertilizers, solid waste and wastewater pollute the water in the drains. To prevent this contaminated water getting into the river, surface runoff should be harvested and directed towards the crop fields. This can be done by digging cut-off drains in the field for irrigation and directing the water there by blocking the main drain temporarily. Banana for example would be a good species to plant in those cut-off drains. Once in the field, the water then infiltrates into the ground, is filtered and ends up in the lake as groundwater.

9.4 Rehabilitation of the drains and pipes

One option could be to plant some trees and shrubs on the borders of the drains which lead straight into the park without prior treatment. The roots of the trees and shrubs could filter the dirty water. There are some good species for purifying polluted water. Close to the houses it is necessary to use species which are not too big because the roots cause damage to buildings. Expanding the sewerage and storm water drainage system(s), cleaning and rehabilitating broken pipes, increasing the number of connections to the sewerage system and also developing adequate measures to stop surface draining and pollution into the lake, will have large-scale positive impacts on Lake Nakuru conservation.

10 Final words

The period of the research took altogether about eight months. The research itself progressed without major problems and the schedule remained much as planned. The project has been of great educational value to me and gave me the opportunity to develop the skills that I was looking for in Africa. I believe that taking part in this project has given me the experience to enable me to work in challenging circumstances in the future. My enthusiasm towards this line of work increased greatly during the survey, and I believe that this will be my chosen field of activity for my future career. I also understood that big projects like this need teamwork involving motivated people in order to be successful. For this reason I especially want to thank Thomas Bernatt, who greatly supported my research in Africa and shared an unforgettable trip with me, and Maggy Bernatt for her help with my English. I hope that this research report will help protect Lake Nakuru National Park in the future so that people from all over the world can continue enjoying this astonishing feature of Kenya’s natural heritage.

Picture 19: Lake Nakuru has an impressive recreational value

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Pictures, figures, tables and maps

Appendixies

Appendix 1

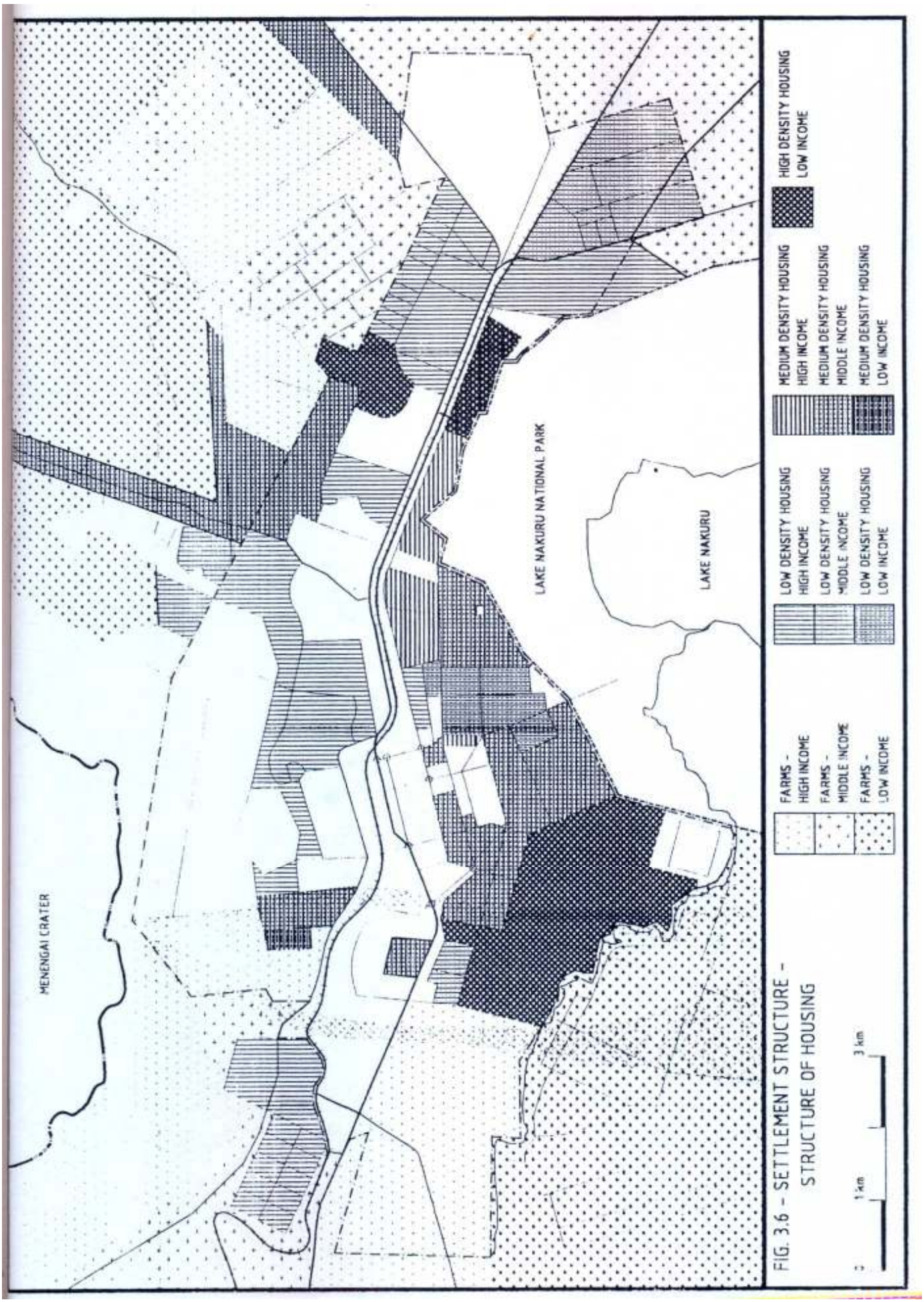
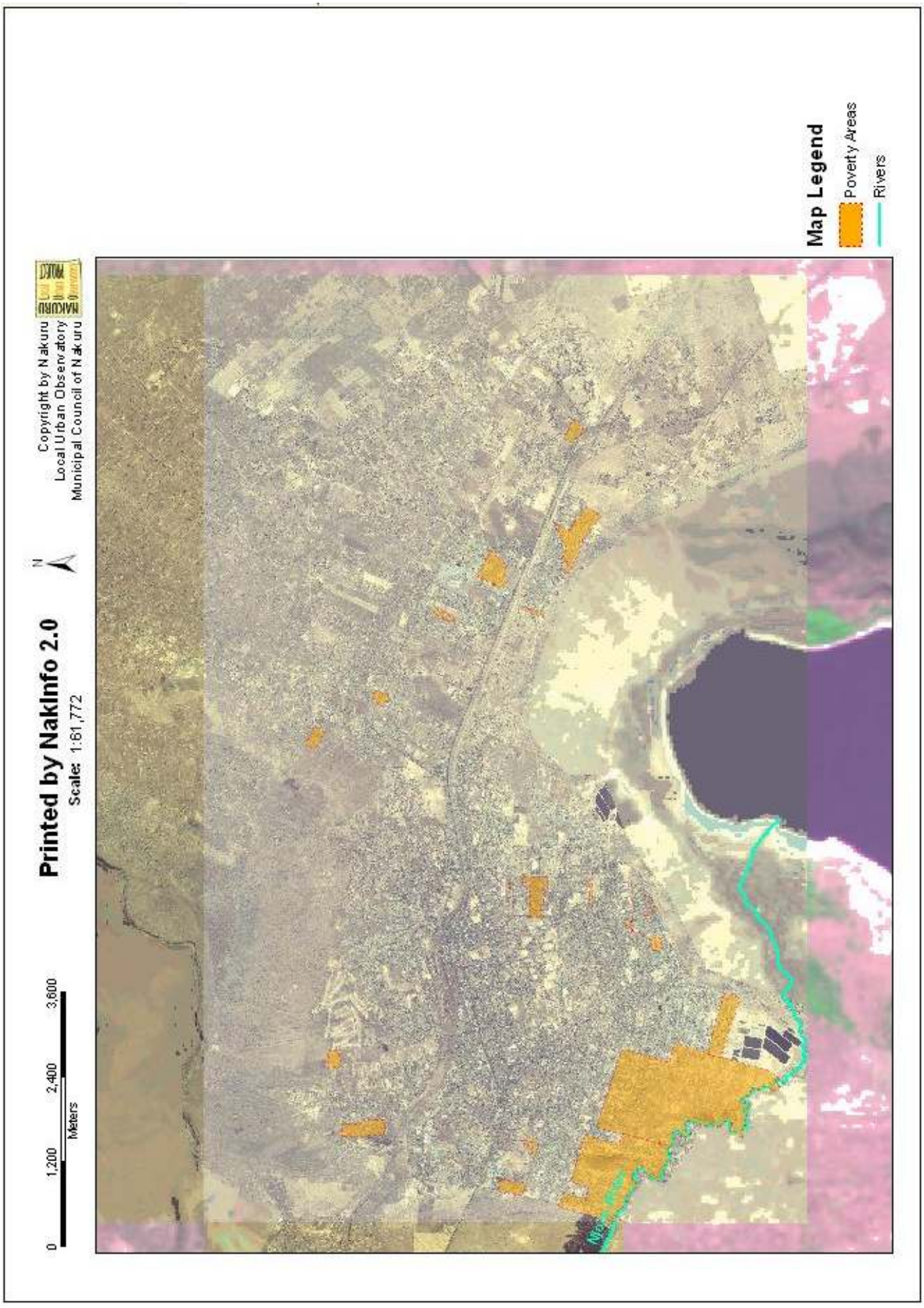


FIG. 3.6 - SETTLEMENT STRUCTURE - STRUCTURE OF HOUSING

Appendix 2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Local Urban Observatory
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Appendix 3

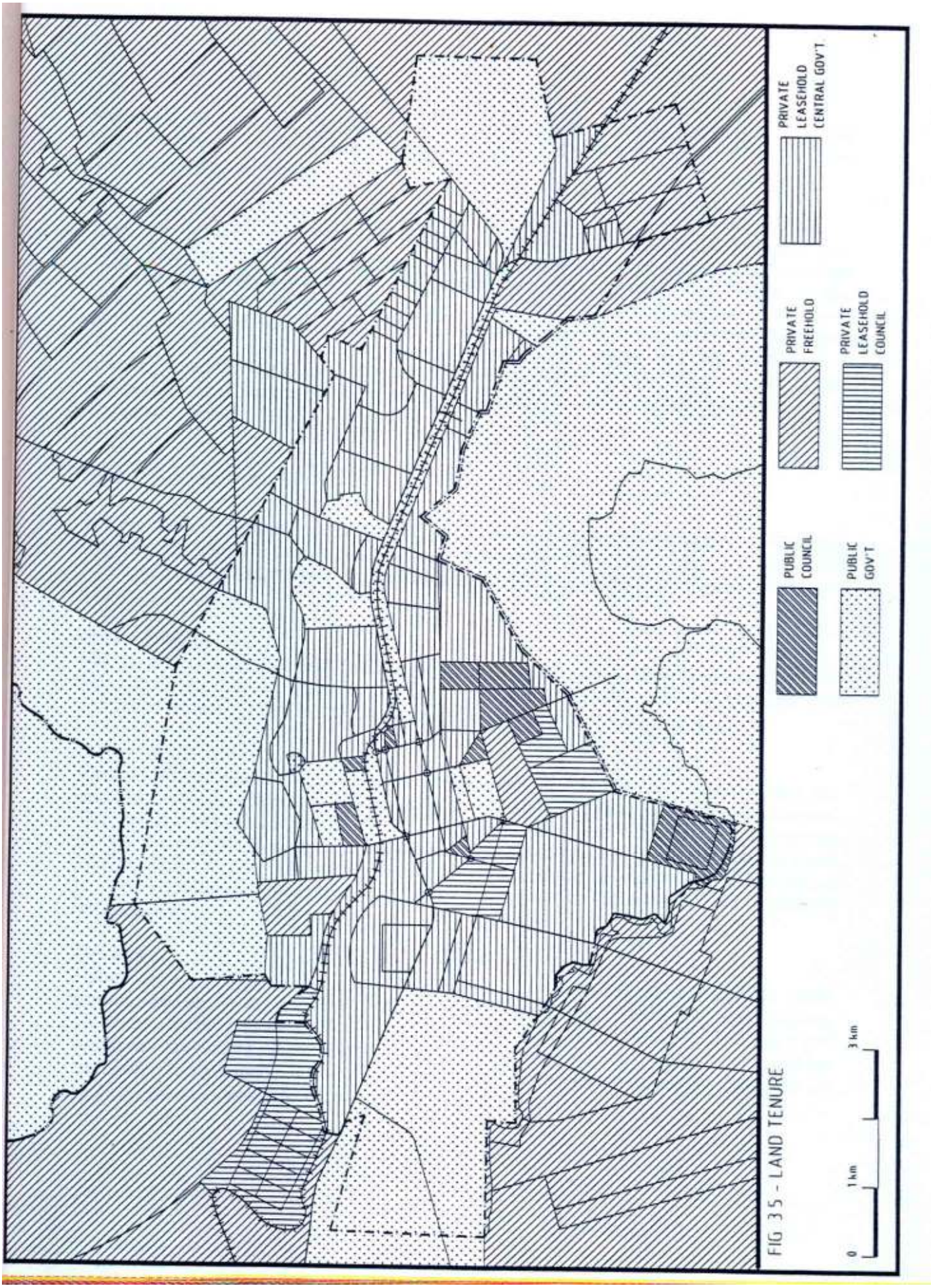
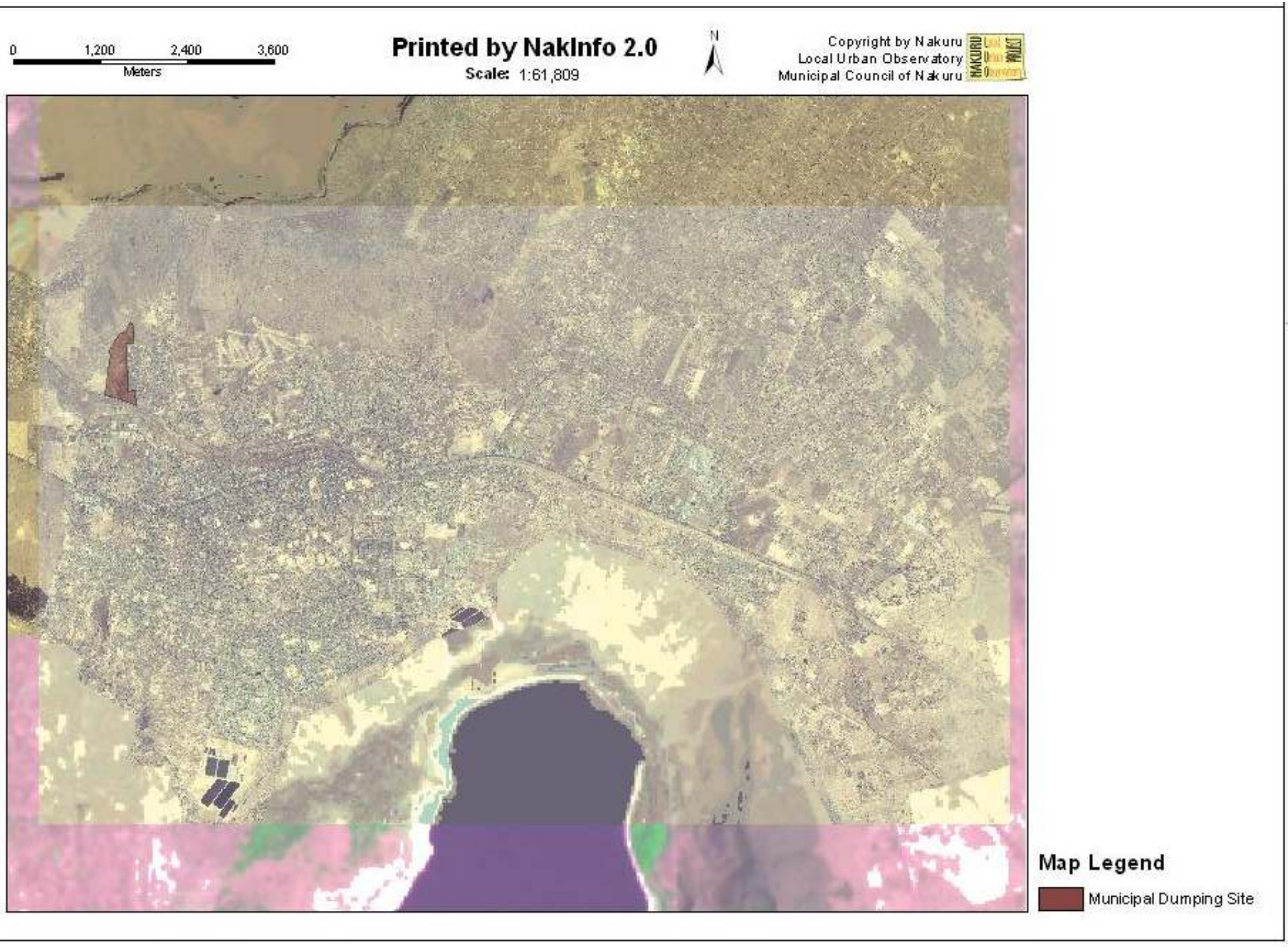


FIG 35 - LAND TENURE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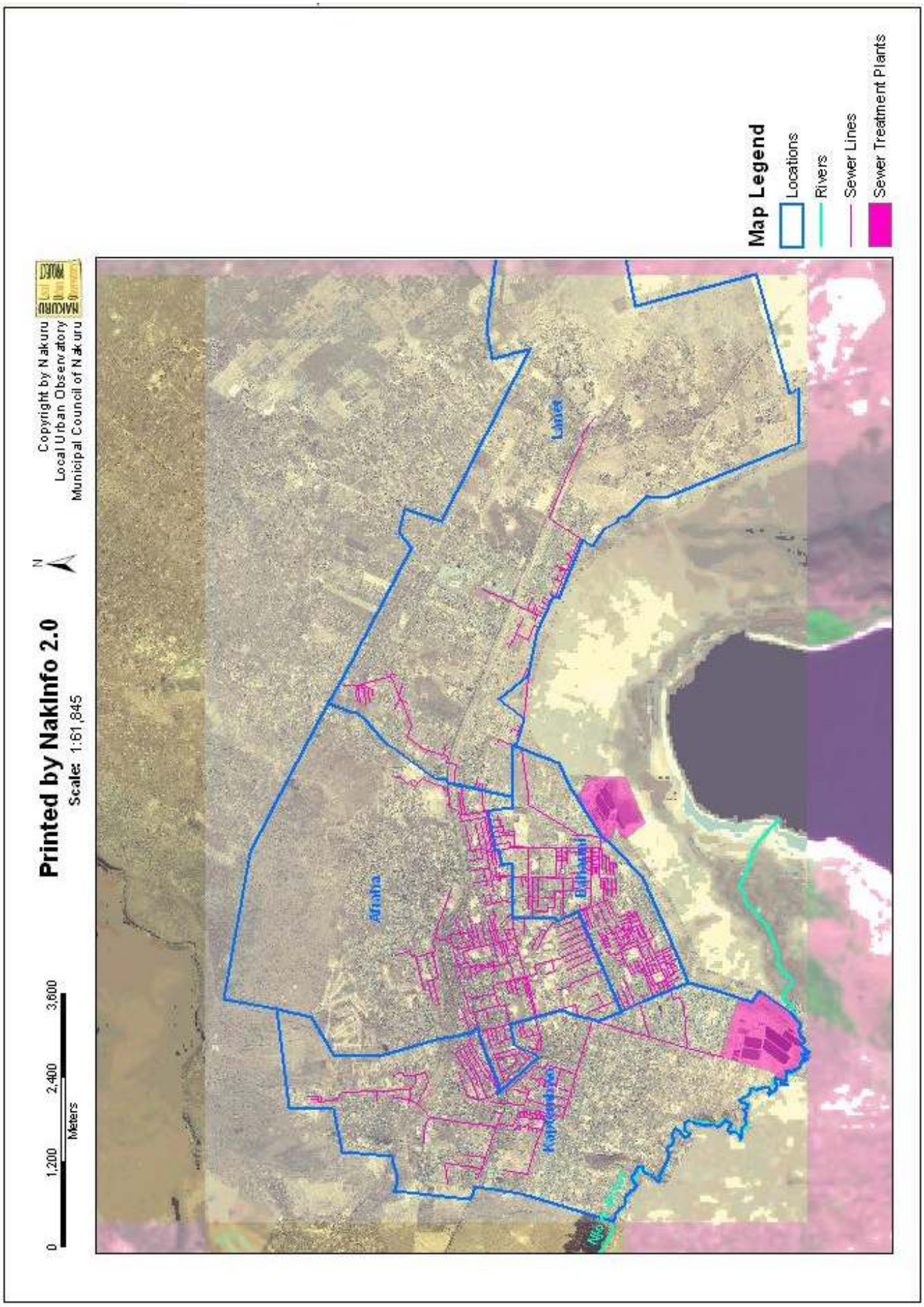
Map Legend
Municipal Dumping Site

Appendix 5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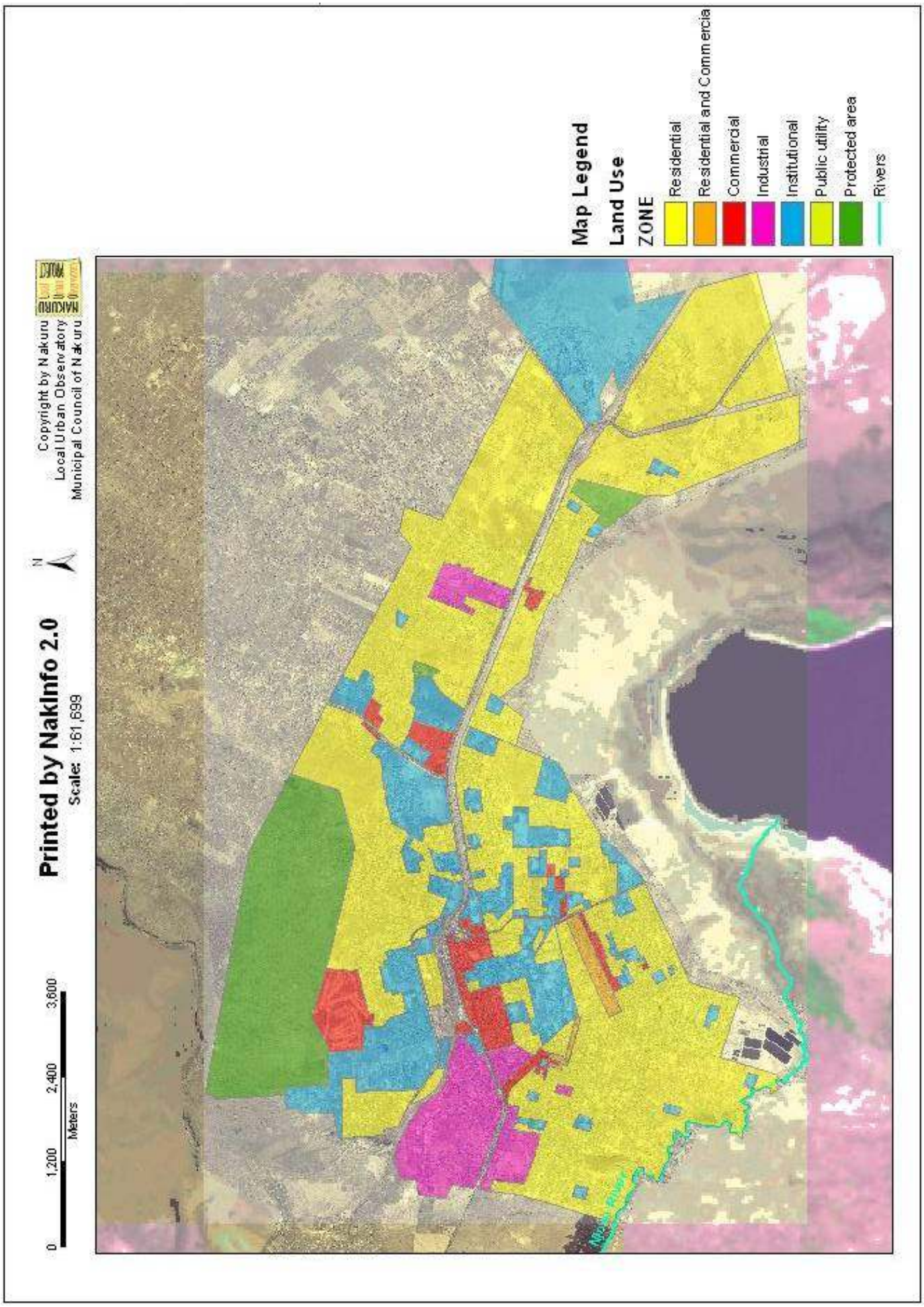
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Appendix 7

Questionnaire

Forest centre:

1. Buffer outside the settlement:

a) Which tree species would be good to plant close to Lake Nakuru NP boundaries?
b) Why these species?
c) Which shrub species would be good to plant for buffer zone purposes (filter the runoff or some other benefit)?
d) How densely do you need to plant the trees?

2. Buffer inside the settlement:

a) Which species are good to plant in yards?
b) What can they be used for?
c) What other benefits do they offer?
d) How densely do you plant them?

3. General information:

a) How long is the period of growth before the tree serves its purpose?
b) What are the threats for seedlings after planting (in the middle and outside the settlement)?
c) How to manage the seedlings after planting (what does it need, costs)?
d) Do you have a tree nursery?

Tree nursery:

1. Capacity:

a) How many seedlings do you plan to produce per year?
b) For how many seedlings would you have the capacity?
c) How many people are needed to take care of them?
d) What do you need to grow seedlings (equipment: tools, soil, bags, water..)?
e) What is your budget per year, what are the costs?

2. Tree species:

a) Which tree species have you chosen and why?
b) What can they be used for?
c) Where are you going to plant them?

3. Seeds:

a) Where do you get the seeds?
b) Is it difficult to get the seeds?
c) How much do the seeds cost?

4. Planting:

a) How much time does it take before the seedling is ready for planting?
b) How much does one ready-to-plant seedling cost?
c) How do the seedlings need to be taken care of after planting?

Appendix 8

Co-operation partners

Bernard Kuloba Kenyan Wildlife Service (KWS) –Research Scientist-Lake Nakuru Park Activities: Ecological monitoring, species inventory and environmental impact assessments Location: Lake Nakuru Main Gate Email: bkuloba@kws.go.ke
John Mwangi Kahiga KFS -Forester Menengai Activities: Forest management (conservation, protection, establishment, community integration) and administration (office and staff) Location: Menengai Forest Centre E-mail: kahigamjohn@yahoo.com Tree nursery
Daniel Kamau Mbugua MCN and Samuel Njatha MCN -Parks Supervisors Activities: Tree planting, landskaping etc. other gardening activities Location: Old Town Hall of Municipal Council of Nakuru Tree nursery

Appendix 9

Estimated costs for buffer zone for Njoro River when the average plot is 50 m

Digging the lines and making the terraces: 10m = 100Ksh 50m = 500Ksh x 2 lines/plot = 1000Ksh	Napier grass cuttings: =500Ksh/plot	Trees: 20Ksh/tree seedling 10 seedlings/line x 2 lines =20Ksh x 20 pieces =400Ksh	Bananas: 100Ksh/each 10 seedlings/line x 2 lines =100Ksh x 20 pieces =2000Ksh
Fruit trees: 100Ksh each 10 pieces in each bed x2 lines =2000Ksh	Thorn: 10 Ksh/each 10 pieces/plot = 100Ksh	Bamboo: 150 Ksh/each 10pieces/plot =1500Ksh	Transport/farmer: One trip with a truck → 2000Ksh/ 200 seedlings 2000Ksh:200= 10Ksh/seedling 10x20 seedlings/species =value/species/farmer 200Ksh 3 (trees, bananas, fruit trees) x200Ksh+ 10seedlings(thorn) x 10Ksh =700Ksh
Total: 1000Khs + 500khs + 400Ksh + 2000Ksh + 2000Ksh +100Ksh + 1500 +700Ksh =8200Ksh/plot/farmer ~80€ 1km=400plots=32000€			
Extra costs divided for all plots/farmers: Supervisor 1200Ksh/day 3 persons needed(NEMA, Forestry, Agriculture)= 3600Ksh x 3 days= 10800Ksh Truck hire 6000-8000Ksh/day			