MURANG'A COUNTY GOVERNMENT

Report of the Technical Committee on Northern Collector Tunnel Project

April 2015

PREAMBLE

Essential part of human development is equity. It will neither be desirable nor sustainable if increases in development are accompanied by rising inequalities … and unsustainable patterns of consumption.” - The Human Development Report (UNDP, 2013)

Northern Collector Tunnel in Context

Kenya increasingly faces the challenge of how to ensure access to adequate water resources for expanding populations and economy whilst maintaining healthy freshwater ecosystems and the vital services they provide. Increasingly common way to distribute water across the landscape is to transfer it from areas with perceived surpluses, to those with shortages[1] by means of inter and intra basin transfer. Water transfer schemes therefore are not entirely a new phenomenon

Inter-basin transfer or trans-basin diversion describe man-made conveyance schemes of water from one river basin where it is available, to another basin where water is less available or could be utilized for a priority human development. Justification for this kind of project has often been their potential economic and social benefits in more heavily populated areas, on the flipside concerns abound over decreased water present and future availability in the source areas and especially from increased water demand.

Be as it may, and since conveyance of water between natural basins are both a subtraction at the source and as an addition at the destination, they may also be seen as controversial due to their scale, costs and environmental or developmental impacts. In legal terms water and riparian rights are affected.

Owing to similar experiences, at national and international levels, it's now increasingly recognised that modifications made to river flows need to be balanced with maintenance of ecological and basic human services depending on the demand and availability of water. The river flows that are required to maintain these services are termed "Reserve Flows" generally defined as the level of in stream flows Compensation Flows necessary to provide for basic human use (domestic, irrigation and commercial) as well as the Environmental Flows required sustaining the river ecosystems. This requirement is more stringent when it comes to inter basin transfers

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Clean and adequate water for all is perhaps the most basic requirement for human survival; however its use has to be based on a strategy for optimal and equitable utilisation of water resources in Murang'a County and to other beneficiaries

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The Murang'a County Government recognises that while inter basin transfer, under certain circumstances, fulfil an important role (for example in supplying drinking water to population centres) the benefits of present large scale transfer scheme and others still on the drawing board is doubtful. In the past, Thika River transfer caused a disproportionate amount of damage in relation to the scheme benefits and social and economic impacts, especially for the donor basin.

[1] *Interbasin water transfers and water shortages, WWF, June 2007*

In the end, efficient management of water is extremely important in Kenya since water resources are very limited. Poor choices today could mean that targeted and local populations continue to suffer from inadequate and unreliable water supply. Allocation of water resources is the function of the Water Resources Management Authority but the right of Murang'a to fair share of water resources must be upheld.

The World Bank in its assessment of Third Nairobi Water Supply in 1989 identified this kind of supply approach as a short-term priority for supplying Nairobi and accordingly recommended that "long-term development plan to eventually provide water to the wider region" this plan and would appropriately include water conservation[2] measures at the destination that can make such water transfers less immediately necessary to alleviate water scarcity, delay their need to be built, or reduce their initial size and cost.

It imperative to note the following relating to NCT and in general of inter basin transfer schemes;

a) Weak governance would appear is symptomatic of inter basin transfer development[3], with poor to non-existent consultation with affected people commonly being witnessed and a lack of consideration at an appropriate management scale. This failure to look at the impacts of the NCT within the river basin management framework considerably elevates the risks of 'collateral damage' from the IBT. Through employing the management model of Integrated River Basin Management, government and society will be much better placed to make well informed decisions in relation to NCT project.
b) Principles of sustainable water resources management though have gained acceptances as means of coping with water scarcity, inequity, pollution and many other water problems and in the process, creating new structures and changing roles and responsibilities. In practice however, water sustainability concept espoused by Integrated Water Resources Management (IWRM) is viewed by many as somewhat nebulous, a catch all phrase lacking a roadmap for implementation. Holistic assessment of water in the context of river basin present the most sensible unit for implementing water management and allocation decisions, arising from the recognition that upstream/ downstream relationship and effects. This case is even more compelling when allocation entails an inter-basin water transfer.
c) The NCT project presents an opportunity to demonstrate commitment to sustainable use of water and Natural resources and to proof actual implementation of IWRM

In particular to:

[2] ***Water conservation*** *encompasses policies, strategies and activities to manage fresh as a sustainable resource, to protect the water environment, and to meet current and future human demand. Population, household size, commercial industrial, agricultural growth and affluence all affect how much water is used and consequently increase pressures on natural water resources*

[3] *Interbasin water transfers and water shortages, WWF , 2007*

- Evaluate NCT project design outputs against water management objectives
- Assess benefits resulting from actions and plans
- Clarify consistency between project activities, outputs, outcomes against development goals and opportunity costs, and
- Ensure and demonstrate legitimacy of action and accountability by all stakeholders

This report provides comprehensive assessment of Northern Collector Tunnel in view of the primary importance of sustainable water supply to Nairobi City but equally important the unalienable rights of the people of Muranga to social-economic equity, statutory and patriotic duty to preserve water catchment and generally the environment.

The report not only highlight the potential negative impacts but suggest good practices, innovative approaches and promising commitments on basis of multi-sectoral and inter-agencies approaches and sustainable responses to water demand.

Finally, in this endeavour the Constitution of Kenya (2010) guarantees every Kenyan under section 42 the right to clean and healthy environment specifically *"to have the environment protected for the benefit of present and future generations through legislative and other measures" particularly those contemplated in Article 69"* appropriately as following;

69. (1) The State shall—

(a) ensure sustainable exploitation, utilisation, management and conservation of the environment and natural resources, and ensure the equitable sharing of the accruing benefits;

(d) encourage public participation in the management, protection and conservation of the environment;

(f) establish systems of environmental impact assessment, environmental audit and monitoring of the environment;

(g) eliminate processes and activities that are likely to endanger the environment; and

(h) utilise the environment and natural resources for the benefit of the people of Kenya.

(2) Every person has a **duty** to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources.

Signed for and on behalf of the Technical Committee:

Eng. Wangai Ndirangu		24/04/2015
Chairman	**Sign**	**Date**
Ms Beatrice N. Kiarie		24/4/2015
Joint Secretary	**Sign**	**Date**
Eng. Gabriel Kamau		24/4/2015
Joint Secretary/ CO, Energy Transport & Infrastructure	**Sign**	**Date**
Eng. Amos Njoroge		24/4/2015
CEC Member, Energy Transport and Infrastructure	**Sign**	**Date**

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Executive Summary

The difference between what we do and what we are capable of doing would suffice to solve most of our problems

A.1 BACKGROUND

a) The Northern Collector Tunnel Phase-I is the second of sequenced projects under Water Supply Master Plan (2012-2035) to Nairobi City and Satellite towns. It is designed to convey 140,000 m^3/day during 90% of the year from Maragua, Irati and Gikigie rivers into Ndakaini Dam in Murang'a County and eventually to Nairobi.

b) The Government of Murang'a appreciates that water is a shared national resource with Nairobi and other counties, under certain circumstances cross basin transfers fulfil an important role, but in case of NCT-1 transfer scheme and others still on the drawing board it is doubtful. Moreover, previous transfer from Thika River caused a disproportionate amount of damage in relation to the scheme benefits and social and economic impacts, especially for the source catchment in Murang'a

c) Efficient management of water is extremely important in Kenya since water resources are very limited. Poor choices today could mean that targeted and local populations continue to suffer from inadequate and unreliable water supply. Allocation outside the County must uphold the right of Murang'a to fair share of water resources

A.2 PROJECT VALIDATION

The Murang'a Leaders Forum convening in Golden Palm Hotel, Makuyu on January 21st 2015 noted that NCT project exerts considerable pressures on water resources and probably disadvantages Murang'a County. The forum resolved to appoint an Independent Technical Committee to examine pertinent issues arising, which include but not limited to ensuring that the project;

i) Does not adversely reduce or affect river flows and levels of the underground water level

ii) Does not result to any adverse ecological or micro-climatic effect on the environment.

iii) Does not adversely affect current and projected water and irrigation demands in the County

iv) Demonstrate in practical terms the benefits to Murang'a County and especially address the water needs of Murang'a people, and finally

v) Clarifies who should control benefits and how it is shared and priced

A.3 FINDINGS OF THE COMMITTEE

A.3.1. Limitation of Consultation process

During EIA consultation, repeatedly in public and other organised forums, the project proponents described an inaccurate situation, and suggested that only flood water will be tapped. The committee observed that;

i) Flood water is generally defined as flows more than Q80 while NCT-1 will abstract over Q95[4], which in the proponents own admission will results to conditions similar to flow during prolonged drought.
ii) Athi Water Services Board disregarded recommendations/caution of their own feasibility studies, indeed the public and stakeholders were not made aware of the precautions

Therefore, consultation process was technically flawed, hence misleading.

A.3.2 Compliance to statutory requirements

Athi Water Services Board awarded contract for construction work in September 2014, yet;

i) NEMA license was granted in February 2015; however conditions set out in the license have not been achieved to the best of information available to Committee.
ii) Application for water abstraction permit is still under process as at April 2015
iii) This action is goes against the provision under Section 42(1) of Environmental Management and Coordination Act and Water Act 27(1).

Consequently, and to this extent the committee finds that;

+ Project activities are in violation of established law
+ The project risks loss of public funds by contractual claims occasioned by delayed site possession or in event statutory authorization is not successful
+ Alternatively, the proponent considers these legal requirement ineffectual and mere formalities

A.3.3 Impacts on flows downstream and Ground water

Assessment of river hydrology finds that NCT-1 will result to significant reduction in downstream flows in the three rivers and unacceptable negative impacts downstream of the intakes;

[4] *Q95 refers normally encountered in dry seasons*

a) Project will have long-term impacts 336,877 people in Murang'a who use the three rivers

b) Combined normal flow (Q80) in the three rivers is 267,800 m^3/day while NCT **average** abstraction is 259,200 m^3/day, implying that NCT project will divert more than 97% of the river flow during 90% of the year

c) The upper catchment of Irati, Maragua and Gikigie contributes 64% of the low during dry season, meaning the downstream region is highly dependent on flows to be diverted for NCT

d) NCT abstraction as currently designed will result to 60% or approximately 216 days every year with zero or extremely low flow downstream.

e) If Reserve Flows are limited to the release of Q95 or even 2xQ95, no investment in flood storage (dam) along the Irati, Gikigie and Maragua Rivers will be possible and any existing systems will no longer be viable

f) Information available to the committee reveal that hydrogeological investigation has not completed however drawings evidence from similar projects tunnelling may result to changes in the underground drainage and drying of springs and river

A.3.4. Impacts on water demand and proposed developed in Murang'a

World Bank appraisal of Third Nairobi Water Supply Project in 1989 observed "*the need to safeguard the interest of the other water users outside the Nairobi area…"*

Water Act (cls 22) prescribe "… the nature and degree of water use authorised by a permit shall be reasonable and beneficial in relation to others uses…" and specifically provide that reserve flow as necessary to sustain basic human needs, ecosystem functions, lawful permitted uses downstream, safeguard existing investment.

a) Water allocation guidelines in first priority over water resources[5] have not been adhered to and existing demand has not been fully accounted.

b) Current water demand in Maragua catchment doesn't accommodate abstraction of river flows lower than Q35 and Q10 in 2030 unless storage is incorporated

c) Should the project proceed as designed ,

[5] *See Prioritisation of Water Allocation for NWMP 2030 in National Water Master Plan 2030 (page EX-15), Water Allocation guidelines (2.3.1)*

i) Only 8600m³/day out of 267,800 m³/day normal flow will remain in the river to cater for 162,543 m³/day of water demand in the Maragua catchment. This will result in serious shortages and possible users conflicts in Murang'a

ii) Existing and planned irrigation schemes will be unfeasible. The annual loss to Murang'a County in foregone irrigation is estimated at Kes 2.3 billion

iii) Intakes to Murang'a Town, Kandara Water Supply will not have sufficient water. Affected areas and centres include_Maragwa Town, Murang'a Town, Kangema, Kahuro, Kangare, Gacharage, Ichichi, Kaharati , Kenol/Makuyu

iv) NCT abstraction will lead to loss of up to 14 MW installed in Wanjii and Mesco HEP stations, in addition will render on-going projects for example Ikumbi minihydro unfeasible.

A.3.5 Ecosystem and Conservation

The conservation of the Aberdare Catchment Area and sustainable utilization of its resources contribute significantly to the local and national economy. Uncontrolled utilization of the Eastern Aberdares ecosystem without conservation will have devastating impacts to large parts of Central and Eastern Kenya and the capital City of Nairobi. Protection of the Abedare Catchment Aberdare is key pillar to realizations of vision 2030 to providing better support to the economic pillar flagship projects

The Committee thus observed;

a) Diversions from Maragua, Irati and Gikigi will result in long-term effects that are both severe and unacceptable. By opting for Q95, project proponents overlooked grave ecological impacts and consequences it portends
b) The Final ESIA Report was less comprehensive than preliminary ESIA and generally circumvented many pertinent issues
c) Meagre 0.074% of project budget is set aside mitigation measures identified in the environment management plan, but mostly none.
d) The NCT will result in 3.7% reduction in the flow reaching Masinga Reservoir and therefore a reduced flow in the Tana River cascade.

A.3.6 Framework for Resources and benefits sharing

The Nairobi Urban Infrastructure Development Strategy NIUPLAN, in the part dealing with water supply emphasized that "...*Water resources and the facilities are located outside Nairobi City. Thus, an agreement of (these) Counties on the development of water supply facilities for Nairobi City is*

indispensable[6]. This was echoed Eng. Michael Ngari, Chief Officer Water, Energy and Natural Resources representing Nairobi City County in Nokras ESIA consultation that the project is.... *not just for Nairobi but for the good of the people in Murang'a*. To that extent, the need for consultation between Murang'a and beneficiaries counties is not in question. However;

a) Project planning has not been demonstrated specific and tangible benefits to the people of Murang'a, nor has there been any consultation with Murang'a taken place to determine nature, size and priority areas of benefit interventions.
b) Murang'a water and sanitation (Kshs.800mi), Gatanga (Kshs.500mi) and Gatango (Khs. 170mi) are not spin off benefits from NCT Phase I, but independent projects with separate budgets under WASSIP-Additional Funding.
c) Despite the NCT abstraction benefiting from soil and water conservation the Murang'a County will remain uncompensated for their effort in this responsibility

A.3.7 Lessons from the past

Drawings lessons from Third Nairobi Water (Ndakaini dam) Project, there is an alarming repeat of principal issues which had led to dismal outcomes;

i) Ineffective and generally inadequate consultation with affected people on critical issues had resulted in resistance and litigation.
ii) Important sub-surface conditions have not been investigated.in particular, it is surprising that geotechnical investigation for project located almost entirely underground had not been exhausted by time Contract was awarded.
iii) Experts review was made after final design by which time their recommendations could not be incorporated, similar, NCT expert and statutory reviews relating to environment and water abstraction.

There is serious doubt on the genuine intent by the proponent to incorporate recommendations of statutory reviews or at least it subjects Government of Kenya to disadvantage owing to potential variation of scope and claims for contractual delays.

[6] Final Draft Report on *Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya pg 8-7, 2014*

A.4 CONCLUSION AND RECOMMENDATIONS

A.4.1 Conclusion

i) The water supply master plan has completely overlooked water needs for Muranga County and other permitted users

ii) The continuing northwards encroachment of rivers in Murang'a for water supply to Nairobi is not sustainable. Both present and future abstractions will critically alter environment and river flows to the detriment of welfare of Murang'a County

iii) Proposed sources in Muranga may last only for the next 15 years up to 2030 while population in Nairobi and Muranga continue to grow. Strategic intervention is required to avert otherwise inevitable future crisis

A.4.2 Consequently the Committee recommends as follows;

A.4.2.1 **Project not to proceed pending revision of NCT design and Masterplan:**

Northern Collector Tunnel and Water Supply Master plan for Nairobi and Satellite Town are re-designed in view of hydrology and successive supply of water demand in Murang'a County explore alternatives sources for Nairobi and ensure measures for efficient water use pursuant to Water Act 32 (b) as perquisite for further new abstractions.

A.4.2.2 NCT to abstract flows level lower than Q50

i) To mitigate the risk of low and zero flow downstream of NCT intakes, the abstraction Minimum Reserve flow shall not be less than Q50

ii) Athi Water Services Board and water supply undertakers in the beneficiary areas cooperate with Murang'a County Government for development of multi-purpose water storage as minimum requirement for any abstraction and continued utilization of water resources in Muranga beyond 2015

iii) Detailed investigation to be undertaken before construction to establish wider changes and impacts on groundwater drainage

iv) Revise intake design to provide upstream by-pass for compensation

A.4.2.3 Statutory approvals and licensing to be completed:

i) The Murang'a County Government petitions NEMA for review of EIA license owing to many pertinent issues still unresolved and flaws in the consultation process

ii) The Murang'a County Government petitions Water Resources Management Authority to object issuance of water abstraction permits until abstraction survey and water demand is validated

A.4.2.4 Full involvement of Murang'a County in design review and project oversight

a) Athi Water services Board and County Government of Muranga establish a Technical Committee to oversee the re-design, implementation of mitigation measures, baseline monitoring during implementation and operations of NCT and Community water project
b) Athi Water services Board to ensure that contract for the construction phase include reference to supervision by the Technical Committee.

A.4.2.5 Soil and Water Conservation Plan to be developed:

i) The proponent to cooperate with Muranga County, Kenya Forest Services, NEMA, Water Resources Management Authority to develop comprehensive watershed management plan complementing existing strategies and to benefit both upstream and downstream

ii) County assembly to enact County laws on water, soil and conservation which at least include conservation or ecosystem services levy

iii) The project activities will upgrade existing and establish regular river monitoring systems for daily reporting of flows

A.4.2.6 Framework of resources and benefits sharing

i) **Formation of Bulk Water Company:** The County Government initiate determined steps to promote the formation of bulk water supply to own and develop bulk water infrastructure in Muranga and to transmit water to users in and outside the County.
ii) **National Law on water and Natural Resources Benefits Sharing:** Urge County legislators in Senate and in Parliament to proactively support fast-track conclusion of the Water Bill in Parliament and the Natural Resources Benefits Sharing Bill in the Senate.

Part I: Overview

Nairobi accounts for about 60% of Kenya's GDP, but the energy, water and some raw materials used to drive economic activities in the City and environs are derived from the Aberdare ecosystem. The conservation of the Aberdare Catchment Area and sustainable utilization of its resources are therefore crucial if Nairobi is to continue with this significant contribution to the National economy

1.1. Project Background

The Northern Collector Tunnel Phase-I is second phase of five phased Water Supply Master Plan for developing new water sources for Nairobi City and Satellite towns prepared by Athi Water Services Board with support from the World Bank and the French Development Agency. The Water Supply Master Plan provides for investment in water supply infrastructure to fulfil short, medium and long term water demand for Nairobi City and 13 Satellite Towns including Kikuyu, Ruiru-Juja, Kiambu, Karuri, Githunguri, Mavoko, Ngong, Ongata Rongai & Kiserian, Thika, Gatundu, Limuru, Tala and Kangundo to 2035. (Figure 1.1-1)

A major component of the planned water supply infrastructure is the Northern Collector pipeline by which Athi Water Services Board (AWSB) proposes to construct river diversion tunnel dubbed the Northern Collector Tunnel to draw water from rivers Irati, Gikigie,and Maragwa to convey approximately 140,000 cubic meters of water per day from the three rivers into Ndakaini Dam to eventually to Nairobi and its satellite towns water for domestic uses.

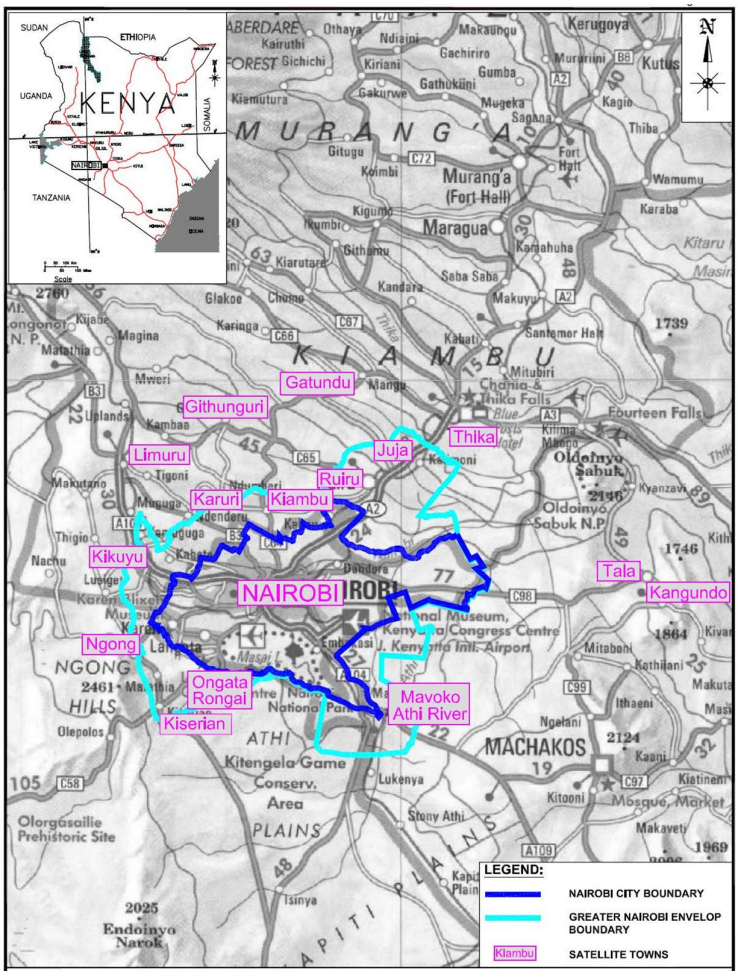

Figure 1.1-1: NCT Benefit areas

The Northern Collector Tunnel (NCT) Phase 1 is intended as new raw water transfer tunnel from Tana and Athi Catchment areas, traversing along the eastern fringe of the Aberdare Conservation Area approximately 60 km north of Nairobi. The tunnel project transfers raw water from intakes at the Maragua, Gikigie and Irati Rivers to an outlet at the Githika River near Makomboki, upstream of the existing Thika Reservoir

This will be followed in the next phase by the subsequent development of the Northern Collector Tunnel Phase 2, diverting water from the South Mathioya, Hembe, Githugi and North Mathioya Rivers, by development of the Northern Collector Tunnel, Phase 2. This will also flow though the Northern Collector Phase I Tunnel.

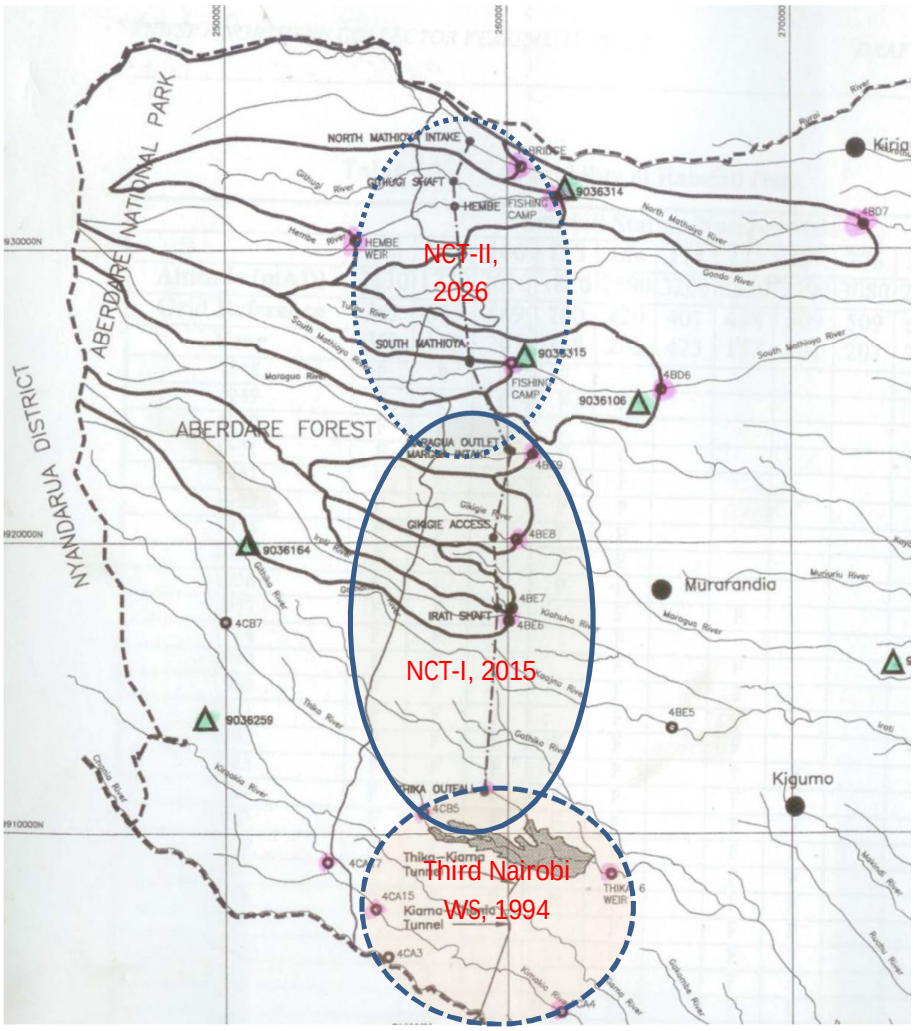

Figure 1.1-2: Sequential River diversion from Murang'a County for Nairobi supply

Based on the conclusions of the preliminary studies for masterplan for water supply to Nairobi and satellite Towns, the objective is to identify and develop sufficient sources of water to meet the demand for water of Nairobi until Year 2030. Previous studies confirmed that Thika Dam was the preferred choice of water for the Third Nairobi Project with a yield of 3.8 m^3/s. The Northern Collector was to constitute an extension of the existing water resource system encompassing Thika Reservoir, Sasumua Dam, and Intakes on the Kimakia, Kiama and Chania Rivers

- **Ph5, 7th Nbi:** Ndarugu Dam 216 MLD 2029
- **Ph4, 6th Nbi:** NC 2 140MLD, 2026
- **Ph3, 5th Nbi**: Maragua Dam 146 MLD, 2020
- **Ph2, 4th Nbi:** Nci 138 MLD and Ground water 64MLD, 2016

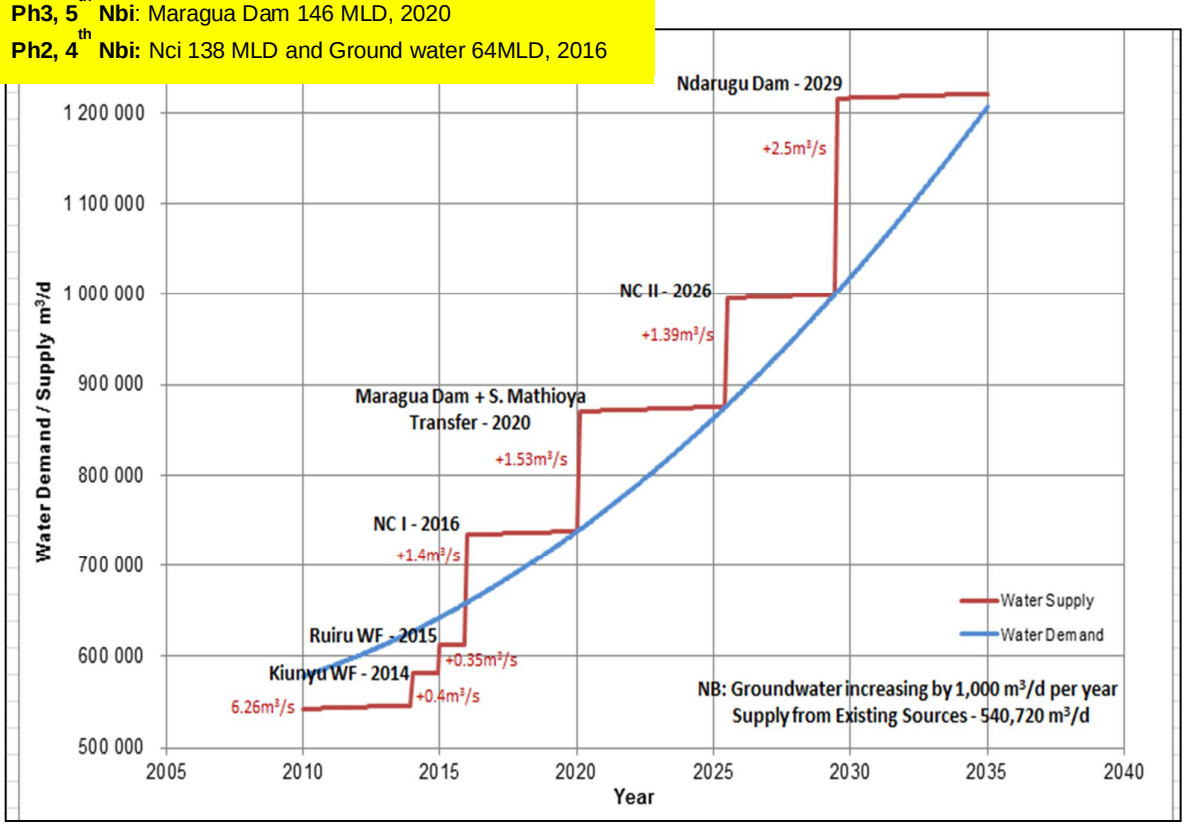

Figure 1.1-3: Sequenced Water Sources Development (Source: Athi Water Services Board)

1.2. Project location and Impacted Areas

The project will affect huge areas traversed or supplied by the three rivers as shown in Figure 1.2-2 and

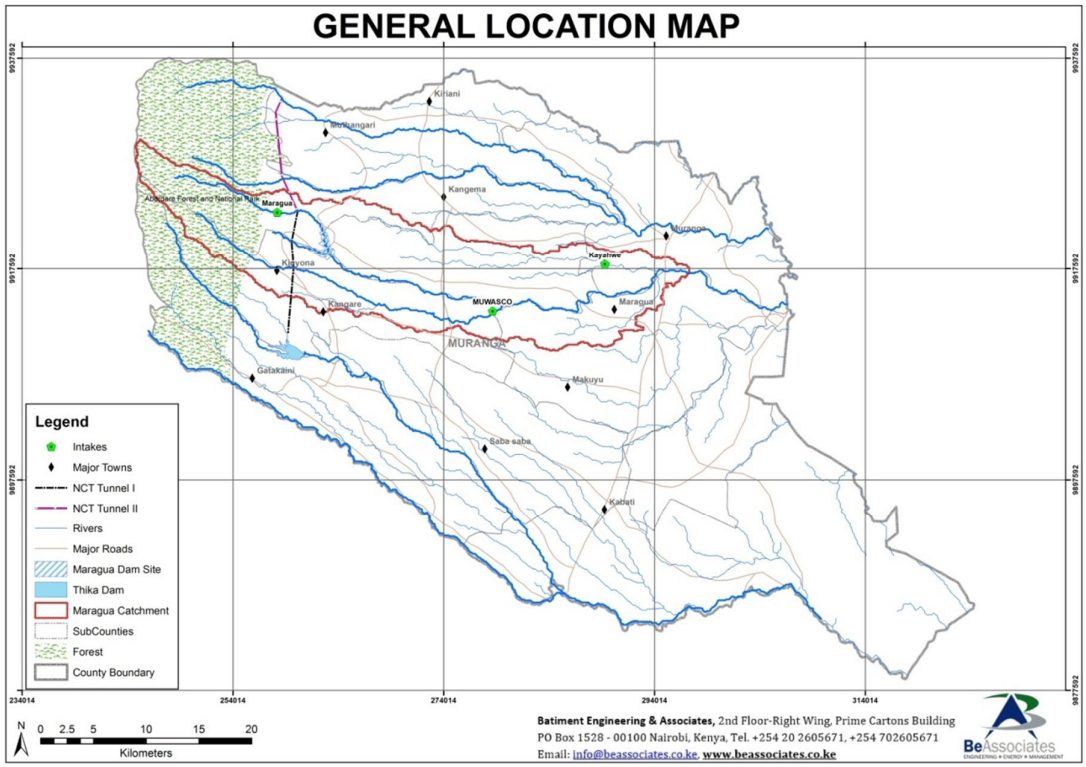

Figure 1.2-1: General Location of NCT Phase I and II

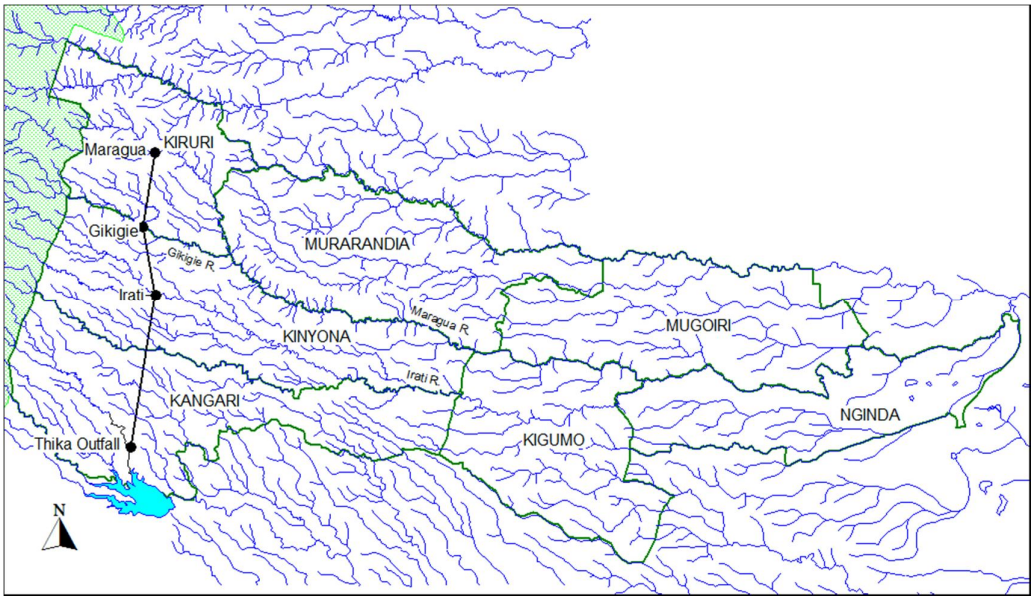

Figure 1.2-2: Locations in upper parts of Murang'a North and South Districts (2009 National Census) through which Maragua, Gikigie and Irati Rivers flow.

1.3. Project Design Validation

Murangá County Assembly through the Committee on Water, Energy, Forestry, Environment, Natural Resources and Cooperative Management was notified of proposed Northern Water Collector Tunnel project being promoted by the Athi Water Water Services Board. In part the project will abstract significant volumes from rivers Gikigie, Irati and Maragua all in Murangá County.

The Murang'a County has no fundamental objection to the project supplying water to Nairobi and appreciates that water is a shared national resource which is equally needed by the residents of Nairobi and its satellite towns as in Muranga. However, in the interest of equitable sharing of natural resources, Muranga County identified pertinent questions relating to the project and which ought to be addressed to ensure that the proposed project will not adversely affect normal water flows and future development plans of the Murang'a County.

The Murang'a Leader Forum convening on January 21st 2015 in Makuyu (Kenol) resolved to appoint of an Independent Technical Committee to authenticate design and issues of proposed project.

1.4. Terms of Reference

Technical Committee was tasked to review pertinent issues which include but not limited to ensuring that the proposed project;

i) Does not adversely reduce or affect river flows and levels of the underground water level
ii) Does not result to any adverse ecological or micro-climatic effect on the environment.
iii) Does not adversely affect current and projected water and irrigation demands in the County
iv) Demonstrate in practical terms the benefits to Murang'a County and especially address the water needs of Murang'a people, and finally
v) Clarify who should control benefits and how it's shared and priced

1.5. Team

The Technical Committee on the Northern Collector Tunnel wsas made of representatives from County and National Government agencies, stakeholders in Murang'a and supported by expert team Batiment Engineering and Associates and Institution of Engineers of Kenya.

	INSTITUTION	REPRESENTATIVE
1.	**County Assembly**	Hon. Joseph Kimani Machiri Hon. Danson Mburu Muchoki Hon. Rebbecca Mwicigi Hon. Mary Waithira Njoroge Hon. Peter Mweri Njoroge Hon. Moses Gachui Mungai
2.	**Murang'a County Government - Executive**	Hon. Amos Njoroge Hon. Muiruri E. Maina Hon. George Kamau Eng. Gabriel Kamau (Secretary) Mr. Patrick Mukuria Mr. Emilio Muchunu Mr. L.G Mwariri Mr. F.W.Muriuki Mr. Anthony Githirwa Mr. Lucy Gicheru Mr. Jeremiah K. Mwirigi Mr. Elijah O. Kinaro Mr Francis M. Kimemia
3.	**Batiment Engineering & Associates Ltd**	Eng. Wangai Ndirangu (Chairman) Dr. Alfred M. Muthee Mr. Eric Akivaga Ms. Catherine Mutwiri Mr. Morris Njagi Dr. Cush Ngozo Ms. Beatrice Nduta (Secretary)
4.	**National Board Irrigation**	Mr. J.G Gitahi
5.	**Kenya Metrological Service**	Mr.Paul G. Murage
6.	**Water Services Regulatory Board**	Ms. Bernadette Njoroge
7.	**IEK**	Eng. Francis W. Ngokonyo

At its inaugural meeting on 12th February 2015 the Committee elected Eng Wangai Ndirangu as Chairman, Eng. Gabriel Kamau and Ms. Beatrice Nduta as joint secretaries to the Committee.

At the same meeting, Committee decided and shared responsibilities to the following Sub-Committees based on the Terms of Reference, members' competence and their availability to serve in their respective capacities.

- Engineering Design and Hydrology
- Environmental and Conservation
- Institutional and legislative issues
- Resources and Benefits sharing
- Policy and oversight
- Independent validation Team of IEK[7]

[7] *Subsequently the Institute of Engineers of Kenya opted to send one representative to join larger committee*

1.6. Methodology of Validation Assessment

The assessment reviewed available document from several sources observing the conclusion form these report. Separately, the team applied independent data for detailed validation analysis of the relationship between land use, water demand and availability. Available hydro climatological data was supplemented by what was available from WRMA and Kenya meteorological services to facilitate determination of situation in wet/dry season at different times and evaluation of trends in rainfall-runoff. The sampling period for hydro climatological data covered period from 1950-2009. The data requirements for the analysis included the following:

- Historical, present and proposed land use data
- Historical discharge data of river gauging stations as close as possible to the abstraction points
- Monthly rainfall data representative of the candidate catchments
- Water abstraction data for the relevant river segments under study

However it need to be clear that the time available for this study was limited and committee review work focused on establishing **reasonable concerns and feasible corrective options** .

The committee made familiarisation visit to the project site, River Kiama and Kimakia which are part of supply system for the Third Nairobi Water project and field visit to Nyambene Hills inMeru County to familiarise with conservation and water supply strategies in water scarce situation.

1.7. Water Demand and Existing Water Supply to Nairobi

1.7.1. Location and Features

Nairobi is the capital and largest city in the Republic of Kenya. It is located close to the Central Highlands region at an average elevation of 1,500 m above sea level. The city of Nairobi now encompasses some 600,000 hectares. The area slopes gently down from west to east with an approximate change in elevation of 300 meters across the city area, drained in the main by the Nairobi River and its many tributaries. The exceptions are the Karen-Langata area and the airport area at Embakasi which are drained by tributaries of the Athi River.

The climate in the Nairobi area is predominantly controlled by its equatorial position and the large scale continental pressure systems and Indian Ocean. However, topography strongly influences the magnitude of the climatic elements and to a lesser extent their seasonal distribution. Nairobi has two distinct wet seasons during April/June and October/December. The average rainfall in the Nairobi area is about 900 mm and the average annual temperature about 20^{o}C.

Nairobi receives its water supply from catchment areas some 50 to 60 km to the north, in the high rainfall area of the Aberdare Mountains. This water is conveyed to Nairobi through pipelines which traverse densely populated rural areas, some of which have inadequate water supplies. In addition, the urban centers around Nairobi (some of which are already supplied from Nairobi's system) will require additional facilities and extended supply. The need to safeguard the interest of the other water users outside the Nairobi area has been evident.

With this in mind, the water demand and the water supply to Nairobi planning require an integrated utilization of the region's water resources to the benefit of Nairobi and the other potential consumers have also been studied as part of Project development. These areas will include the upper Athi catchment and the Thika catchment of the Upper Tana System.

Setting aside short-term priority of supply in the short-term, however, remains for Nairobi Long-term development plan should eventually and necessarily provide water to this wider region.

1.7.2. Existing Water Supply Systems

The water supply to Nairobi is derived from four sources:

i) The first potable water supply to Nairobi was developed by the railway authority between 1900-06 and sourced from water from Kikuyu Springs 18km west of the City, yielding a total of 4,800m3/d (0.056m3/s). In 1921 the water undertaking was bought by NCC from the railway authority, and it is still in operation.

ii) In 1939, an intake on the upper reaches of the Ruiru River with pipeline and treatment work at Kabete was constructed. This source was progressively developed up to 1950 by adding a dam located 25km North of the City and two further pipelines. The system has a safe yield of 21,700m3/d (0.25m3/s)

iii) Between 1952 and 1956 the Sasumua River 60km North of the City was developed by building a dam, treatment works and transmission main. This was further developed between 1960 and 1966 by raising the dam, diverting the flow from other rivers into the reservoir and extending the treatment works twice.

iv) It was apparent in the early 1960's that additional sources would be required and investigations were carried out leading to the implementation of Phase I of the Chania-Kimakia-Thika Project. The works, comprising a diversion weir across the Chania River, pumping

station and raw water main, treatment plant at Ngethu and treated water transmission mains, were commissioned in 1974 increased the water supply capacity to about 130,000 m3 /day. This scheme was followed by Phase II of the Chamia-Kimakia- Thika Project completed in 1985. It employs a gravity feed to Ngethu from a weir intake further upstream at Mwagu, through a tunnel and new raw water main.

The available yields from these sources are summarised in

Table 1.7.2-1: Yield of Existing Water Sources

Source	Yield (m^3/d)	Remarks
Kikuyu Springs	4,800	Existing
Ruiru Dam	21,000	Existing
Sasumua Reservoir	57,000	Existing
Chania River / Mwagu Intake	104,000	Existing
Ndakaini Dam (Thika 6)	225,000	Existing (70 Mm^3 Storage).
Groundwater (Private & NWSC Boreholes)	45,000	Estimated Contribution
Total	**456,800**	

Source: Water Sources Options Review (August 2011)

It should be noted, that present sources on the Chania River (and the Sasumua Dam operated in regulating mode) are basically run-of-river abstractions. The yields are given at 98% reliability levels. About 90% of the water supplied and distributed in Nairobi is conveyed by gravity. The total storage reservoir capacity in the distribution system is 180,900 m^3. While presently total demand marginally outstrip total supply approximates, the demand of the city is not fully met due to an imbalance in the distribution zones; the western part of the city (upper zones) which receives water from the first developed sources, is supplied independently from the eastern part (lower zones), which receives water *from* the later developed Chania source. Due to the demand growth in the upper zones, especially in drought situations, urgent measures are required for the interzonal transfer. The physical losses in the system (primarily in the lower zones) remain very high at about 40% at present.

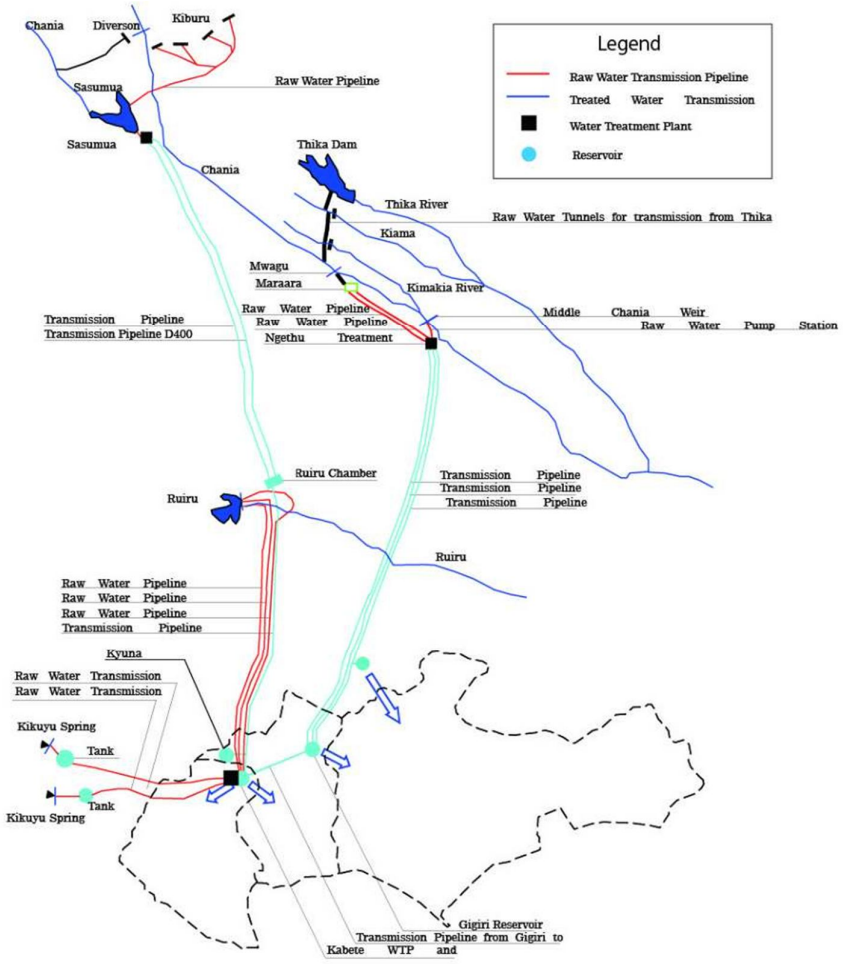

Figure 1.7.2-1: Nairobi Water Supply Outline, (JICA 2013)[8]

1.7.3. Population Projections and Water Demand

Population of Nairobi city was 800,000 in 1980 growing to 3.1 million in 2009[9] accounting for 8.1% of the national population. The current Nairobi population is estimated 1t 3.6 million and is expected to grow further.

Current population is near to 3.6 million with an annual growth rate of about 3.9%. Nairobi is not only the capital city of Kenya but is also the hub of all business, economic, communication and cultural activities, and the centre of tourism. There are no major secondary centers beside the city center within Nairobi's boundary, but outside the boundary Kiambu, Kajiado, Machakos, host a number of centres North, South and west, respectively. Since urbanization is expanding outside the city boundary absorbing increasing population and economic activities, the condition of the surrounding area has to be considered. Between 1989 to 1999, Nairobi City had grown faster

[8] *Integrated Urban Development Master Plan for the City of Nairobi, JICA, May 2013*
[9] *2009 Kenya Population and Housing Census*

at 4.9% fasters than its environs which grew at 3.0%, but from 1999 to 2009, the environs grew faster as it grew at 4.1% and the city at 3.9%. The 2030 population is projected at between 5.2 million living within the city and 9.6million in the satellite but the later could be as high as 11.5 million depending on development scenario and migration trends[10].

In terms of future development, the rapid growth of overall population and the need for balanced rural-urban growth are among Kenya's most pressing problems, which in turn generate an ever increasing demand for food, housing, employment and social infrastructure facilities. The analysis of the present and future population patterns in Nairobi is extremely important for the definition of urban infrastructure needs.

The assessment of water demand for Nairobi carried out by AWSB with support of WB/AFD in 2010, estimated water demand of core Nairobi City, including non-revenue water would increase up to 1,022,000 m^3/day by 2030. Separately, the Nairobi Integrated Urban Development Master plan over the period 2014-2030 (NIUPLAN, 2014) estimated the demand in 2030 at 864,000 m^3/day.

Table 8.1.10 Summary of Demand Projections and Capacity of Water Supply

Class		2009	2010	2013	2017	2020	2023	2030
Population (capita)	WB		3,250,338		4,0040,325	4,403,791		5,693,457
	ST[1)]	3,138,372		3,601,351			4,677,677	5,212,500
Water Demand (m^3/day)	WB		579,000		672,000	731,000		1,022,000
	ST	576,000		647,000			808,000	864,000
Water loss (%)	WB		53		40	37		37
	ST	39		35			26	20

Source: JICA Study Team (JST) and FSMPNWS
Note : ST (the Study Team)

The water demand projections are comparable until 2023 after which gap opens and overall projected demand by AWSB-WB in 2030 is higher with 158,000 (m3 /day) than of NIUPLAN.

The trend of the demand by WB is in gradual increment almost until 2035 but NUIPLAN demand on the other gradually increases until 2017 and the degree of the increment comes down up to 2030. The principal reason for gap in water demand between these two projects in the assumption on the water loss included in the demands. In the WB study transmission loss and the treatment loss were fixed at situation in July 2012, while JICA study assumed improvement of the distribution loss from 40% in 2010 to 25%. The distribution loss was fixed at 25% in the period 2020 to 2035.

[10] *It is assumed that Nairobi will contain its population growth while its environs should rapidly develop to function as part of the expanding national capital - The Greater Nairobi,*

Conspicuously 17% reduction in current levels of non-revenue water offer an opportunity to raise water supply capacity by volumes equal to supplies envisaged by NCT Phase I, notwithstanding other feasible reuse and efficiency measures

However, Non- Revenue Water remains a challenge to Nairobi Water Company while NCWSC targeted to reduce NRW from 40% in 2010 to 30% by 2014 it actually went up from 37% on 2011 to 39.5% in 2012 and 39.8% in 2013[11]

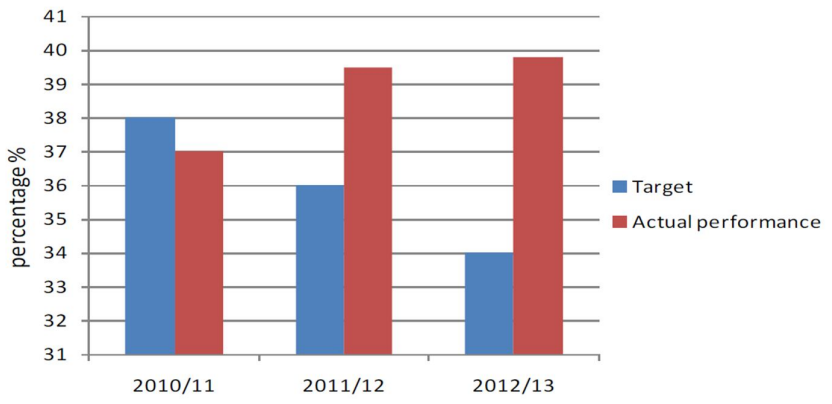

Figure 1.7.3-1: Non-Revenue Water in 2010-13 (source: NWSC)

In order to meet the water supply requirement the master plan recommends five phases of implantation presented in *Table 1.7.3-1*, The phase I of well field development in Kiunyu and Ruiru and the phase II of the northern collector and the water supply system including Ngorongo WTP have been commenced with a fund by WB and AFD.

The phase III of S. Mathioya River transfer, Maragua Dam and Ndunyu Chege WTP is under a planning stage to cover the water demand after 2020

[11] *Nairobi City Water and Sewerage Company Limited Strategic Plan 2014/15 – 2018/19*

Table 1.7.3-1: Proposed Water Sources development under Master plan

Phase	Component	Financer	Completion Year	Planned Capacity (m^3/day)	Status of the Plan as of September 2013
1	Well Field in Kunyu	WB	2014	34,560	
	Well Field in Uriru	WB	2015	30,240	Detailed Design
2	Northern Collector Tunnel Phase I to Thika Dam	WB	2016		
	Ngorongo WTP	AFD	2016	120,960	Detailed Design
3	S. Mathioya Transfer				
	Maragua Dam				
	Ndunyu Chege WTP	-	2020	132,192	Master Plan
4	Northern Collector Tunnel Phase II to Tika Dam	-	2026	120,096	Master Plan
5	Ndarugu Dam				
	Raw Water PS				
	Ndarugu WTP				
	Treated Water PS				
	Kasarani BPS	-	2029	216,000	Master Plan
Total				654,000	

Source: FSMPNWS

The phase IV and V of northern collector second phase and Ndarugu Dam, Ndarugu WTP, three pump stations and pipelines are planned on the basis of the demand projection by WB for 2030 and 2035, respectively.

Although the development includes raw water transmission, water treatment plant and treated water transmission, the distribution network to cover the expanded capacity of water supply has not been included in the proposed plan, thus, plan of the distribution network is considered separately.

> Significantly, the report on Urban Infrastructure Development Strategy (NUIPLAN) prepared in 2014 with support from JICA already noted that ***"water resources and the facilities are located outside Nairobi City. Thus, an agreement of counties on the development of water supply facilities for Nairobi City is indispensable"***[12].

It appears water use in the recipient basin was not fully evaluated prior to the construction of NCT water transfer project. This contributes to the continuation of unsustainable water use practices and, over time, increases the thirst for more water.

[12] *The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya ,Page 8-7*

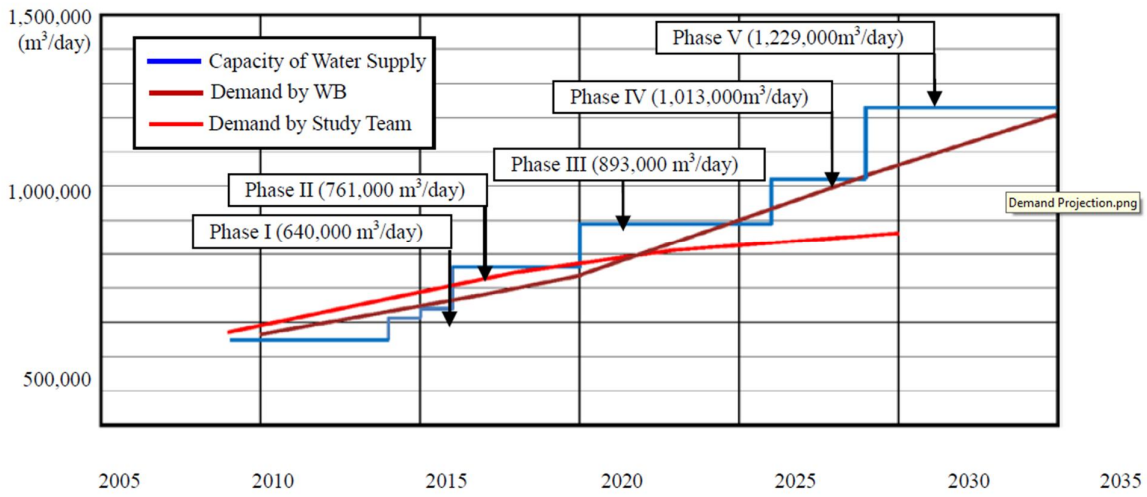

Figure 1.7.3-2: Domestic water demand and supply projection for Nairobi (NIUPLAN, 2013)

The NUIPLAN study concludes, and reasonably so, "*The phase IV and V could be postponed after 2035 subject to the improvement of the water loss. The projected demand with 20% of the water loss will be below the total capacity of the phase I, II and III as presented in Figure 1.7.3-2. Depending on the improvement level of the water loss, the revising the master plan of the development needs to be studied*[13].

Most importantly, comparison of the two reports reveals opportunity to explore alternative investment in different kind of water infrastructure and efficiency measure which conveys equal benefits and optimal use of water.

[13] *Ibid*

1.8. Northern Collector Tunnel Project in the Context of National Development and Water Resources Management

a) Vision 2030

National development blueprint Kenya Vision 2030 outlines strategies to be implemented between 2008 to 2030 for prosperity, thus stimulate;

a) rapid economic growth,
b) just and cohesive and equitable society and ,
c) Clean and secure environment.

The economic and social developments anticipated by Vision 2030 will require more high quality water supplies than at present. On the one hand the economic master plan foresee strategies to enhance social security by raising agricultural productivity and improved universal access to water and sanitation nonetheless balanced with "specific strategies to raise the standards of the country's water resource management, storage and harvesting capability. Specifically, it targets to rehabilitate hydro-meteorological data gathering network and construct multipurpose dams

The Water Catchment Management Initiative protecting sensitive ecological areas among them the Aberdares is key pillar to realizations of vision 2030 , therefore 'Specific strategies will involve promoting environmental conservation in order to provide better support to the economic pillar flagship projects"

b) Environment Management and Coordination Act, 1999

There are several laws and regulations that will govern the implementation of this project at the national level. However the among the prominent legislation that will be evoked is the EMCA 1999. EMCA 1999 was enacted in 2000 to harmonize environmental legislation previously scattered among 77 national laws. As the principal environmental legislation in Kenya, EMCA sets the legal framework for safeguarding entitlement to a clean and healthy environment and its enjoyment for economic, recreational, educational, health, spiritual and cultural purposes.

Section 58 of EMCA requires that an Environmental Impact Assessment precedes all development activities proposed to be implemented in Kenya. This requirement was operationalized by NEMA through its publication of the Guidelines for the Conduct of EIAs and Environmental Audits (Kenya Gazette Supplement No. 56 of 13th June 2003). The framework for environmental assessment in Kenya and a description of types of development that should be subjected to environmental impact

assessment are outlined in Legal Notice 101 and the Second Schedule of EMCA respectively.

c) The Water Act 2002

The National Conference on Integrated Water Resources Management was held in Nairobi in March 2002 conveyed to Kenyans the message that Kenya was facing a water crisis which threatened its very existence and whose reversal would require the participation and support of everybody and every sector that uses water.

This gave birth to Sessional Paper no. 1of 1999 on the National Water Policy on Water Resources Management and Development provides policy direction for the water sector, specially it includes;

- *Preservation, conservation and protection of available water resource;*
- *Sustainable, rational and economical allocation of water resources;*
- *Supplying adequate amounts of water meeting acceptable standards for the various needs;*
- *Ensuring safe wastewater disposal for environmental protection;*
- *Developing a sound and sustainable financial system for effective water resources management, water supply and water borne sewage collection, treatment and disposal.*

The Water Act 2002 forms the principal legislation governing protection and management of water resources in Kenya. This legislation provides diverse safeguards to regulate abstraction and apportionment of water resources for social economic development as follows:

Ownership of Water Resources

Section 3 of the Water Act vests the entire national water resource base to the State, which then authorizes utilization. Abstraction is regulated under Section 25 of the Water Act 2002 with the Water Resource Management Authority (WRMA) assuming responsibility of issuing Water Permits subject to conditions as specified in Sections 27 to 43 and the Second Schedule of the Act. Decisions on the granting of water permits will take account of other existing lawful uses, efficient and beneficial use of water in the public interest, requisite catchment management strategies, potential impact of abstraction on the water resource and other users, quality

considerations, and strategic importance of the proposed water use among other factors.

All the WSBs will be required to request for permission to abstract water from the rivers targeted as intakes by making a formal application to WRMA.

d) Physical Planning Act

This Act provides for the preparation and implementation of physical development plans for connected purposes. It establishes the responsibility for the physical planning at various levels of Government in order to remove uncertainty regarding the responsibility for regional planning. A key provision of the Act is the requirement for Environmental Impact Assessment (EIA).

It provides for a hierarchy of plans in which guidelines are laid down for the future physical development of areas referred to in a specific plan. The intention is that the three-tier order plans, the national development plan, regional development plan, and the local physical development plan should concentrate on broad policy issues.

The Act calls for public participation in the preparation of plans and requires that in preparation of plans proper consideration be given to the potential for socio-economic development needs of the population, the existing planning and future transport needs, the physical factors which may influence orderly development in general and urbanization in particular, and the possible influence of future development upon natural environment.

Part II: Engineering and Hydrology

Competition for diminishing water resources in the country is negatively impacting on socio-economic activities and therefore, contributing to increased poverty. Until now, the water policy has been biased towards water development against water resources management. Consequently, the inadequate attention and under investment in the management of water resources have led to increased degradation of the catchment areas through reduced river flows, increased siltation and pollution. This is raising operation and maintenance, rehabilitation and investment costs to the point of closing down many water schemes - Kenya Country Strategy on Integrated Water Resources Management – Country Strategy on Integrated Water Resources Management, Ministry of Environment and Natural Resources, March 2002

2.1. Introduction

Hydrological analysis is the backbone of all water engineering designs. Such analysis is depended on observed hydrological and meteorological data in the catchment area over a long period. The main objective of this section is to validate the hydrological analysis used in the design of NCT Phase I project. The assessment of surface hydrology in the project area is largely based on desk study, few field visits for validation and spot check verification. The scope is limited to Maragua sub-catchment in Upper Tana catchment area. The focus of this section is therefore on the following:

a) hydrology of Maragua catchment
b) Impacts of tunnel construction on groundwater
c) water demand and county development plans
d) evaluation of hydraulic designs

The observation and conclusion in section had relied on field visits and desk study analysis of the following reports and documents:

i. The Murang'a North and Murang'a South Bulk water supply project report and Appendices
ii. ESIA Report for Murang'a North & South Bulk water supply project
iii. Final Design Report for NCT Phase I by SMEC
iv. Book of Drawings for Tender for NCT Phase I by SMEC
v. ESIA for NCT Phase I by GIBB Africa
vi. CMS for Tana river catchment
vii. SCMP for upper Maragua sub-catchment
viii. Feasibility Study and Master Plan for Developing New Water Sources for Nairobi and Satellite Towns, main report and its Appendices
ix. Feasibility Study And Master Plan For Developing New Water Sources For Nairobi And Satellite Towns, Preliminary EIA for the Selected Scenarios:
x. County Integrated Development Plan
xi. Water Management Rules
xii. Water Allocation guidelines
xiii. Water supply design manual of Kenya (2005)
xiv. Third Nairobi water supply project, Northern collector scheme Feasibility Report by Howard Humphreys
xv. Environmental Appraisal report for Third Nairobi water supply project, Northern collector scheme by Howard Humphreys
xvi. National Water Master Plan 2030 by JICA

2.2. Hydrology of Maragua River Catchment

Maragua catchment is in the Upper Tana catchment. The description of the general hydrology of the eastern slopes of the Aberdare's has well been covered and documented in the reports and need not to be overemphasised. Reference can be made to the reports for general characterisation and description. The eastern slopes plays a big role in describing the hydrology of Murang'a county as a whole where all the rivers that traverse the county begin in the forest from a height of about 3000m above mean sea level as shown in

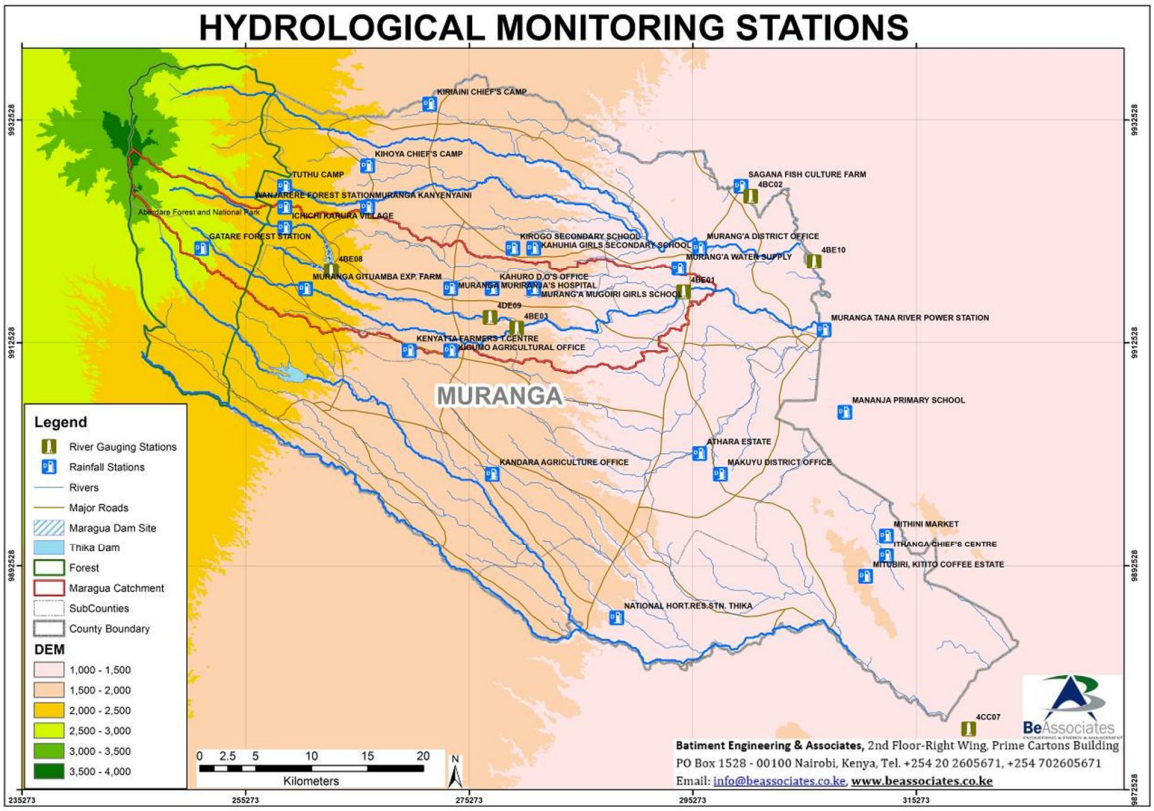

Figure 2-1: Rainfall Stations and Altitude Range

. The county has a good network of rainfall stations and river gauging stations on its rivers. Maragua catchment (4BE1) is approximately 425 km^2 with 4BE3 100km^2(Irati river), and 71km^2 for 4BE09 and 4BE08 (Gikigie and Maragua respectively) forming the sub-catchments that the NCT-I project will directly affect. The combined catchment area upstream of NCT-I intake points forms about 40% of the total Maragua catchment area.

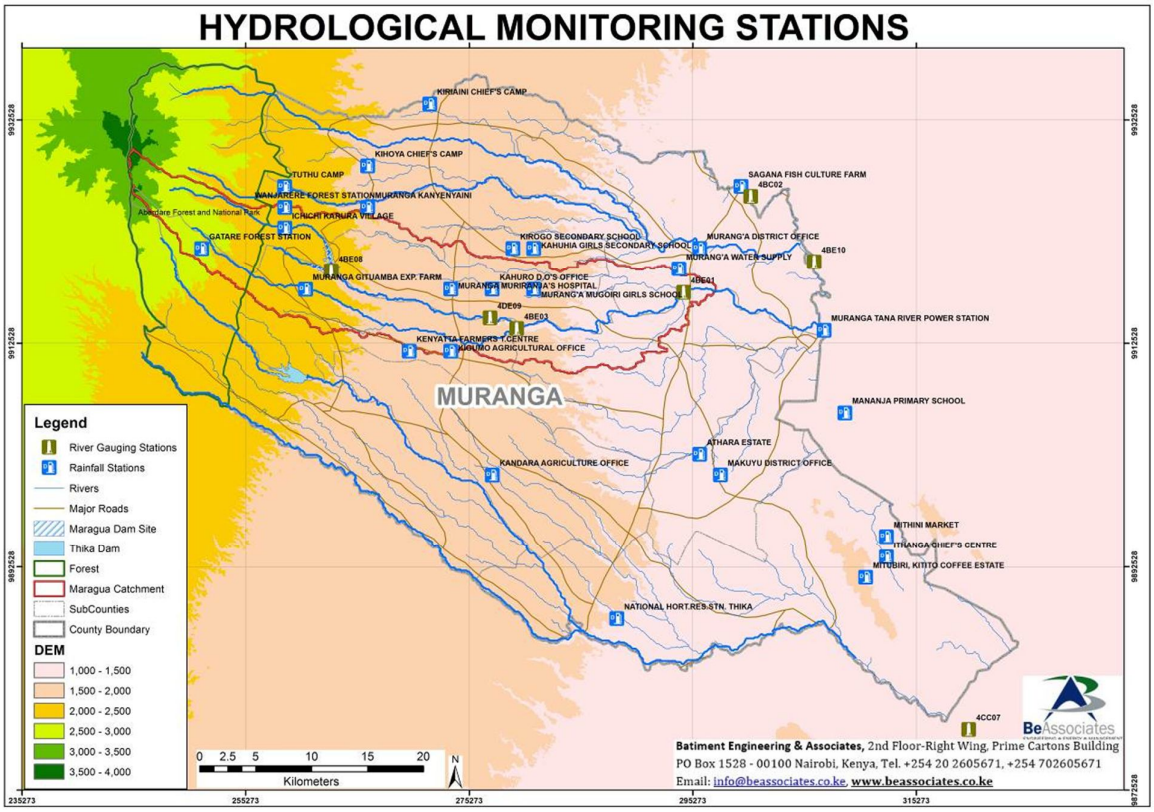

Figure 2-1: Rainfall Stations and Altitude Range

Maragua River catchment is a 'typical' river (as shown in

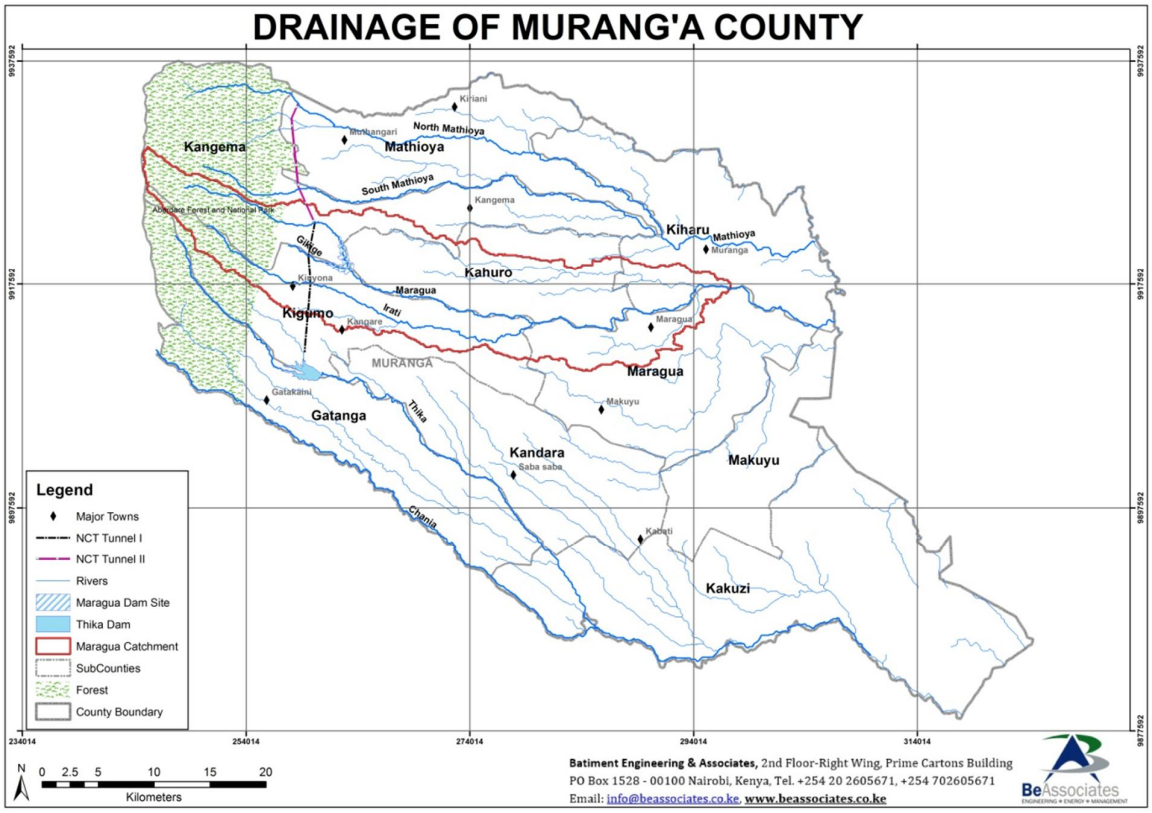

Figure 2-2) of the Eastern Aberdares, rising in the high hills, at over 3,000 m elevation, and then flowing more or less straight down slope to the Tana River (close to the entry of the Tana into the Masinga reservoir) at just below 1,300 m. The catchment area of 425 km^2 is also about 'average'. At the highest reaches, slopes are very steep, mostly >50%. The upper half of the catchment is also steep, with slopes dominantly above 26% and with deeply incised valleys with narrow floors. The lower half of the catchment is more mixed in terms of slope, with significant areas in the 9-25% slope range, and with more level valley floors.

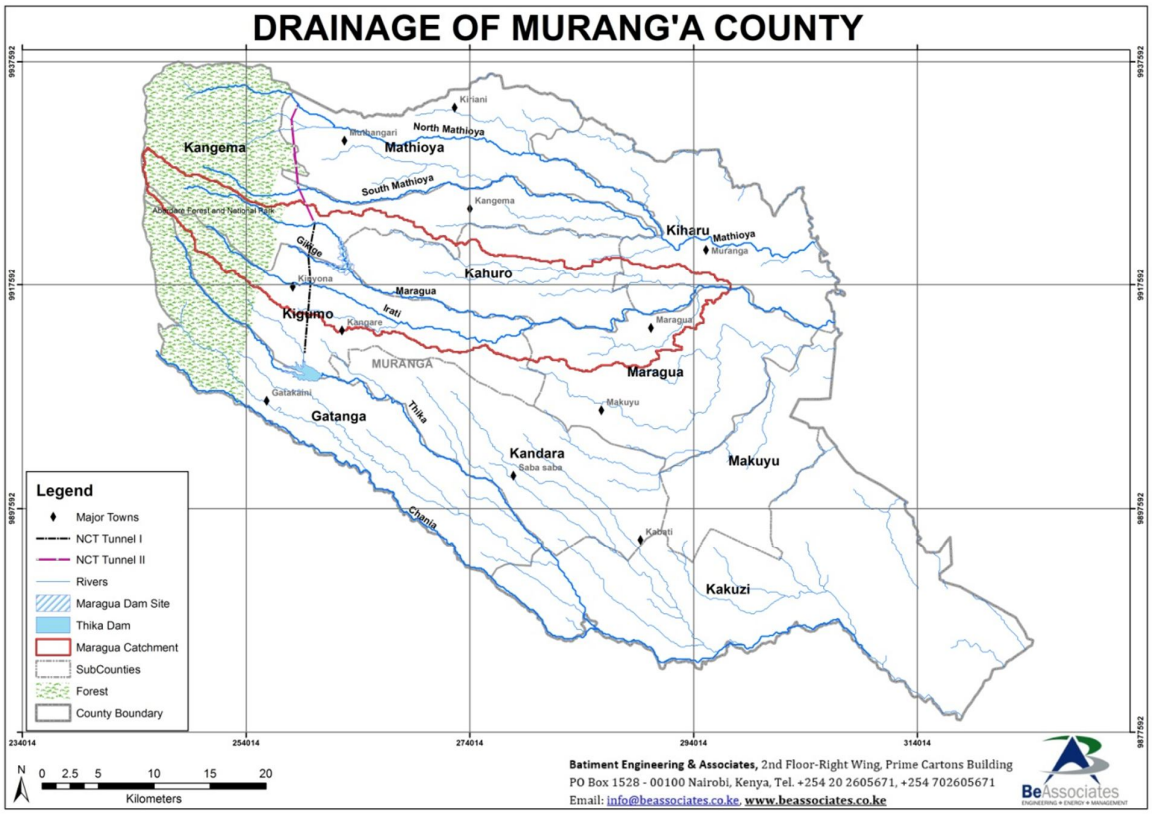

Figure 2-2: River Basins in Murang'a

The upper reaches of the Maragua receive some of the highest rainfalls in the catchment, with average annual rainfall greater than 2,600 mm. Rainfall declines sharply with declining altitude, to below900 mm as the river approaches the Tana River. There is a strong zonation in land use with forest at the highest elevations (>2,400 m), followed by dairy (2,130-2,430 m), tea 1,730-2,130 m), coffee (1,340 – 1,730 m), and then subsistence sunflower-maize cultivation. Due to the 'pinching out' of the catchment at the highest and lowest elevations, most of the catchment falls within the tea, coffee, and subsistence zones.

Studies have established that rivers on the Eastern Aberdare are amongst the most productive in the country, with very high unit runoff and strong baseflow components primarily due to the boggy catchment in the upper parts and forest cover. However due to population and demand dynamics it was important to note that there is significant change in demand for the same non-expanding resource.

Limited river sediment load data suggests that this river has high sediment loads. Gibbs (1959) shows 8 t/ha/yr, and JICA 1.71 t/ha/yr. Atkins estimated that the Mathioya, Maragua and the Saba Saba, together, provide about 21% of the sediment to Masinga. Other observations indicate that the river

emerging from the forest is clear. In its lower reaches the water gets coloured and muddy red-brown. This is especially during the rainy season, when sediment pollution from erosion from farms and dirt roads is highest. This suggests that the sediment comes from stream bank erosion; however, Atkins suggested that there was little stream bank erosion from these rivers coming from the Aberdares.

2.2.1. Stream Flow Analysis

Stream flows are made up of three main components, the quick flows or direct runoff, inter-flows and base flow. The behaviour of this flows indicate the catchment response characteristics to rainfall and the recession time available that provides "storage" in form of interflows and baseflows.

Maragua catchment has primary monitoring station downstream at 4BE01, 6 secondary statins on it has four tributaries, Maragua (4BE9), Gikigie (4BE8), Irati (4BE3, 4BE6, 4BE7) and Kayahwe (4BE4). The total catchment is about 425km^2 and the catchment upstream of NCT I intake are 171km^2.

The mean monthly flows observed at the catchment stations indicates that the upper Maragua catchment produces about 45% of the mean annual flows, 40% of the high flows and 64% of the low flows. This indicates the low flows are highly dependent on the upper catchment.

The high flows are an indication of the quick flows or surface runoff which has a direct correlation with the area of the catchment. Base flow has no direct correlation with the catchment size but the buffering or storage capacity of the catchment. In this case it indicates that during the low flows the upper catchment plays a significant role in flow behaviour during low flows. On average even though the upper catchment is about 40% of the whole catchment it contributes up to than 64% of flows as observed at the catchment observation stations.

Marugua River

Monthly naturalised stream flow series at the

abstraction point used by Egis &MIBP are closely comparable to the studies done by Howard Humphreys. The flow analysis was in filled and extended to the intake points of the NCT Rivers. Howard Humphreys studies have their flow series stretching from 1950 to 1992 (42 years) whereas the flow series derived in the feasibility report by Egis& MIBP is from 1973 to 2010(37 years). These are relatively long enough series to use for hydrological analysis. These series were used to perform yield analysis and reliability analysis of the rivers at the proposed abstraction sites by the consultants in designing for NCT I. The average monthly and average annual flow indices between the two studies are very comparable even though the earlier reports indicates slightly higher average flows than the later studies. This point to a general slight reduction in the average observed flows. Spot flow measurements were done to verify the flow at the nearest gauging stations to the NCT1 intake locations, indicated in

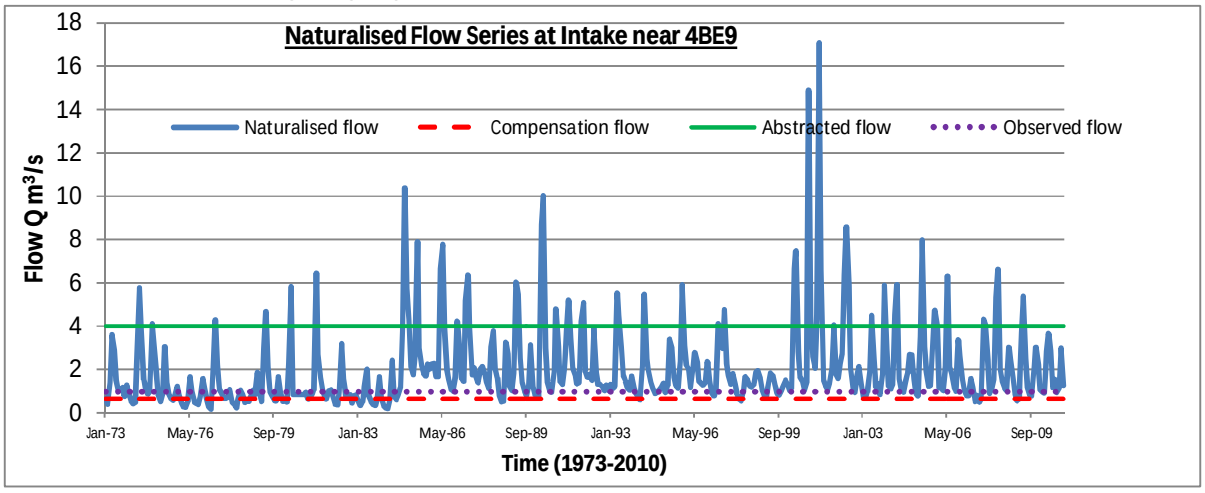

***Figure** 2-3* Observed flow as in **Plate 2-1**and **Plate** *2-2*

The naturalised flow series for Maragua River at the intake point is summarised in **Table 2-1**. The naturalised average annual flow is 2.01m³/s with the highest mean flow occurring in May 4.78m³/s and the lowest mean flow occurring in February and September of 1.00m³/s. The annual average minimum flow is 0.50m³/s with the lowest monthly minimum flow of 0.19m³/s occurring in March and the highest minimum monthly flow 1.05m³/s occurring in May. The annual average maximum monthly flow is 6.49m³/s with the lowest maximum average monthly flow of 17.08m³/s occurring in April and the lowest maximum average monthly flow of 1.73m³/s occurring in September.

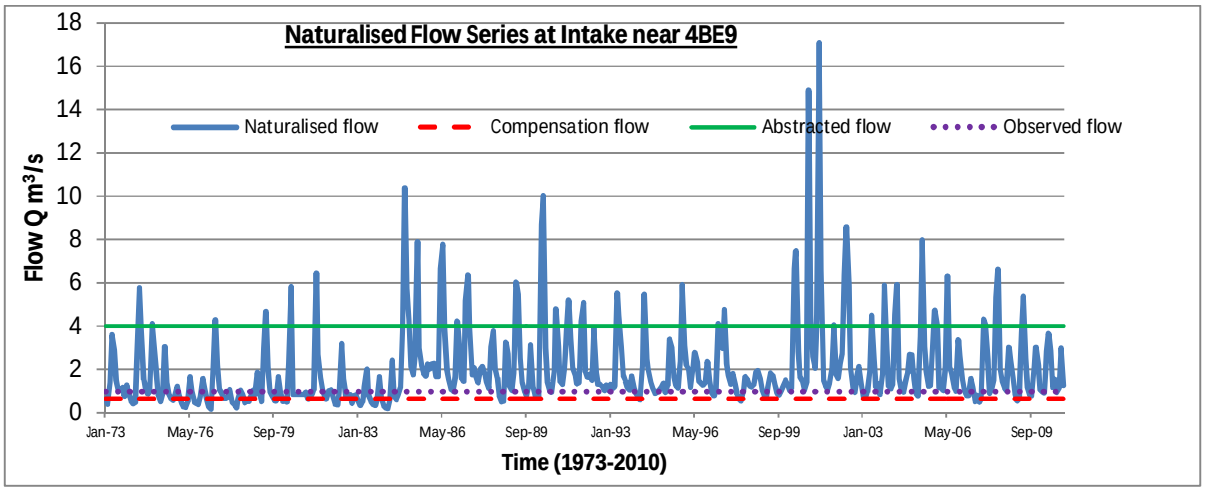

Figure 2-3 is the naturalised flow series at the NCT I intake on Maragua river upstream of gauging station 4BE9. The flow series is an extract from feasibility study report by Egis & MIBP. The flow series compare closely to records obtained from the WRMA sub-regional office in Murang'a.

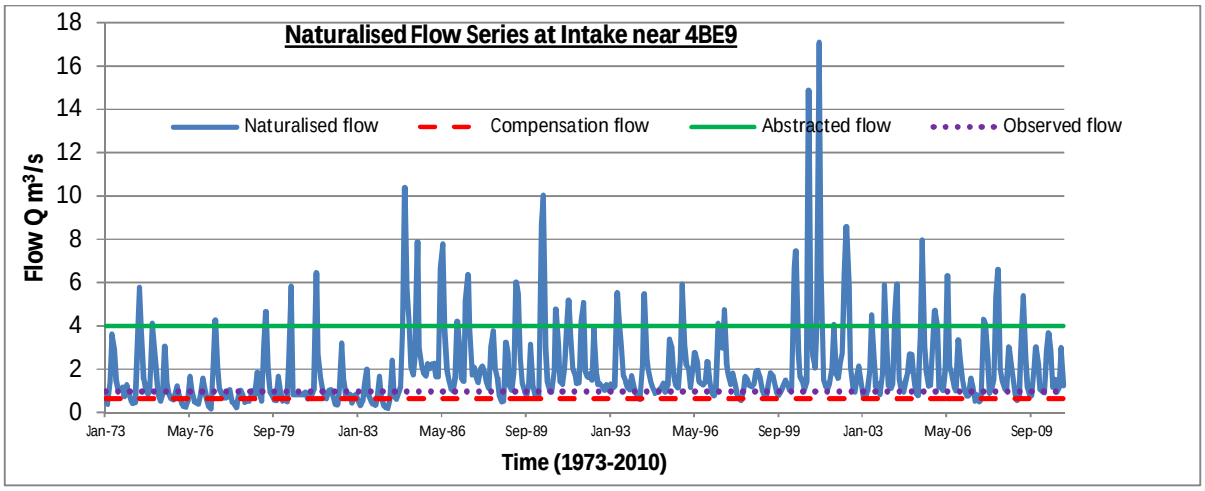

Figure 2-3: Flow Series Analysis at Maragua Intake 4BE9, Source: Northern Collector Feasibility Studies by EGIS BCEOM &MIBP

Plate 2-1and ***Plate*** *2-2* is an indication of the lowest flows during February and March. The flow measured during the spot check on 24th of February 2015 was 0.94m³/s in Maragua River at 4BE9. This is was a value lower than the mean flow in February and March but slightly higher than the minimum monthly mean flow.

Table 2-1: Flow Indices for Maragua at NCT Intake (4BE9)

Month	J	F	M	A	M	J	J	A	S	O	N	D	AAF
Mean	1.29	1.00	1.09	3.44	4.78	2.31	1.44	1.14	1.00	1.55	3.02	2.03	2.01
Min	0.31	0.24	0.19	0.50	1.05	0.53	0.49	0.39	0.36	0.46	0.74	0.70	0.50
Max	4.33	2.30	4.53	17.08	10.04	5.87	4.76	2.25	1.73	4.33	14.90	5.77	6.49

Source: Northern Collector Feasibility Studies by EGIS BCEOM &MIBP

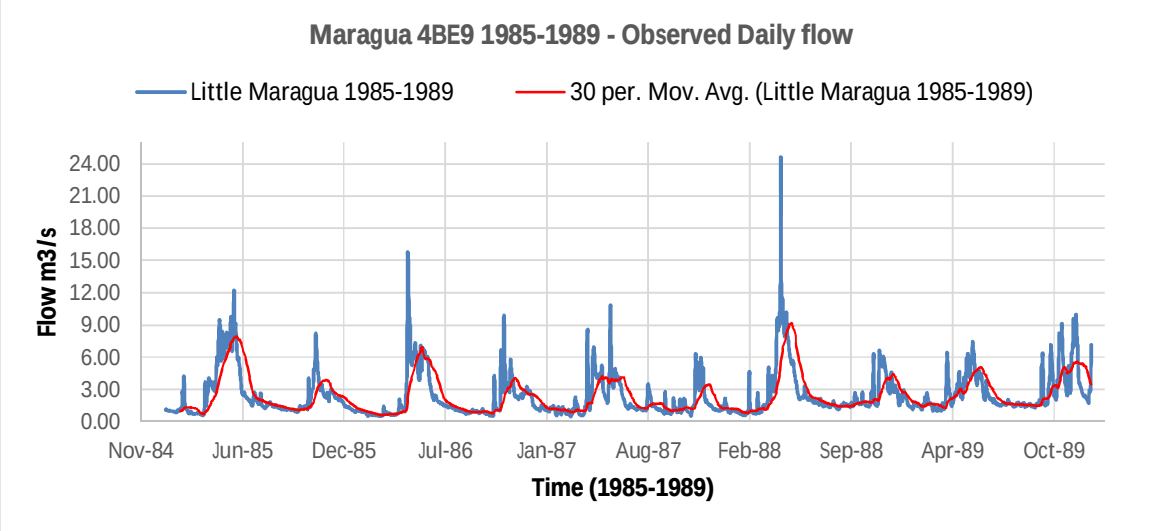

Figure 2-4: Observed Data Obtained from WRMA Sub-Regional Office-Daily flow Series 1985-1989

Plate 2-2: Maragua River near Ichichi observed on 20th March 2015

Comparing the data obtained from WRMA offices and the data simulated in the feasibility studies between 1985 and 1989. It is clear that the monthly averages compare very well and produce a similar trend. The hydrological data therefore used in the design for Maragua River at 4BE9 is comparable and acceptable. The period was selected because it had a complete flow series suitable for comparison and validation purpose.

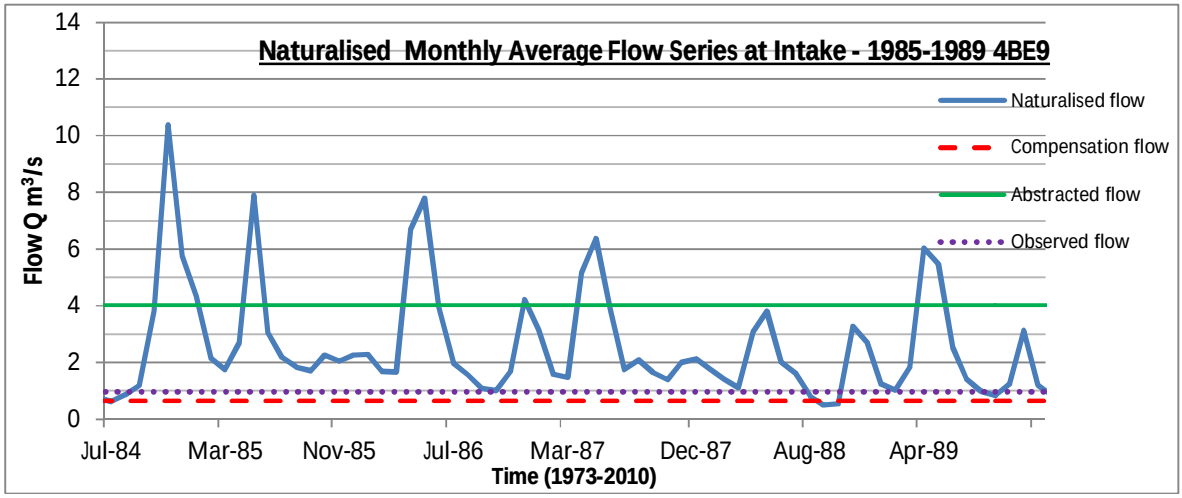

Figure 2-5: Naturalised Monthly Flow Series for Maragua 4BE9 -1985-1989 (Notice Compensation flow against observed seen in plate 2-1 and 2-2

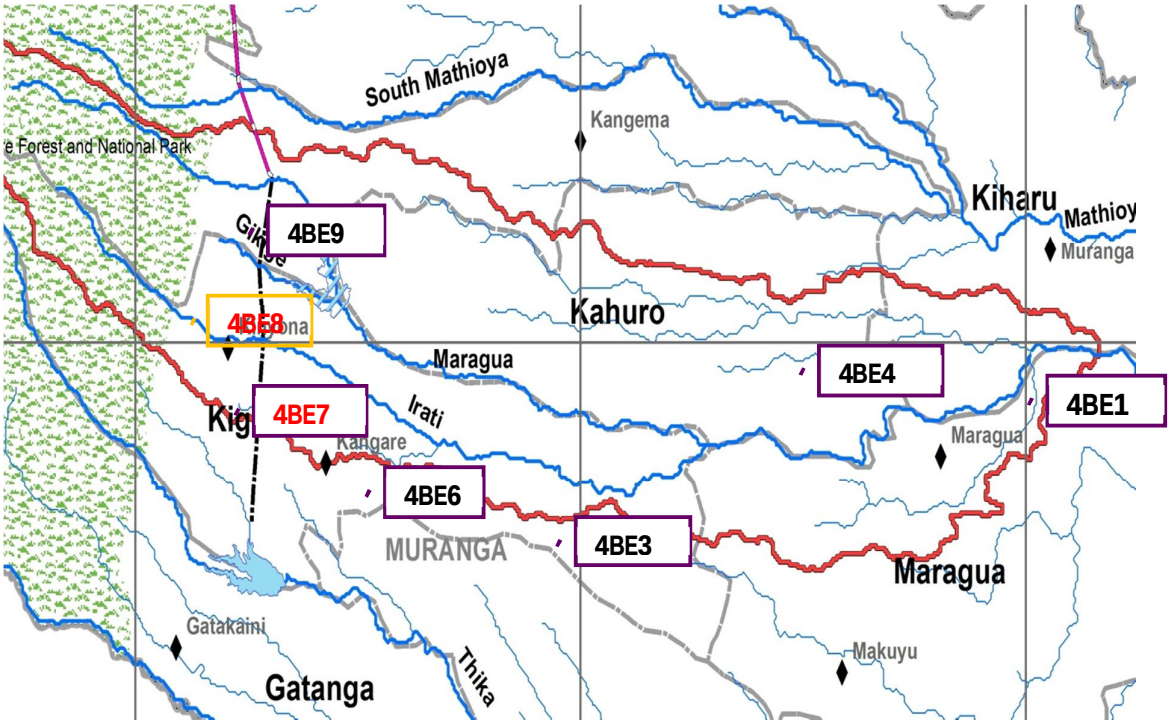

Figure 2-6: River Monitoring Stations in Maragua Catchment

Irati 4BE7

The naturalised flow series for Irati River at the intake point is summarised in **Table 2-2**. The naturalised average annual flow is 1.64m³/s with the highest mean flow occurring in May 4.89m³/s

The spot flow measurement for Irati River taken during field verification was 0.343 m³/s, this corresponds to the naturalised minimum mean annual flow at the intake. The observed flow in the stream downstream at 4BE3 correlates well with the results showing exactly the same pattern of flow. It is important to note that although the station 4BE3 is downstream there is a very little difference in the amount of monthly average flow downstream and upstream at the point of NCT intake. There is an average of 2m³/s in flood peaks. The base flows are even much lower downstream as compared to upstream at the intake during the dry seasons.

Table 2-2: Flow Indices for Irati at NCT I Intake (4BE6)

Month	J	F	M	A	M	J	J	A	S	O	N	D	AAF
mean	0.93	0.68	0.75	3.07	4.89	1.88	1.03	0.77	0.67	1.00	2.37	1.63	1.64
Min	0.35	0.25	0.21	0.46	0.34	0.24	0.28	0.25	0.19	0.41	0.57	0.55	0.34
Max	4.11	1.67	2.88	10.84	12.96	4.51	4.44	1.6	1.27	3.87	13.73	6.13	5.67

Source: Northern Collector Feasibility Studies by EGIS BCEOM &MIBP

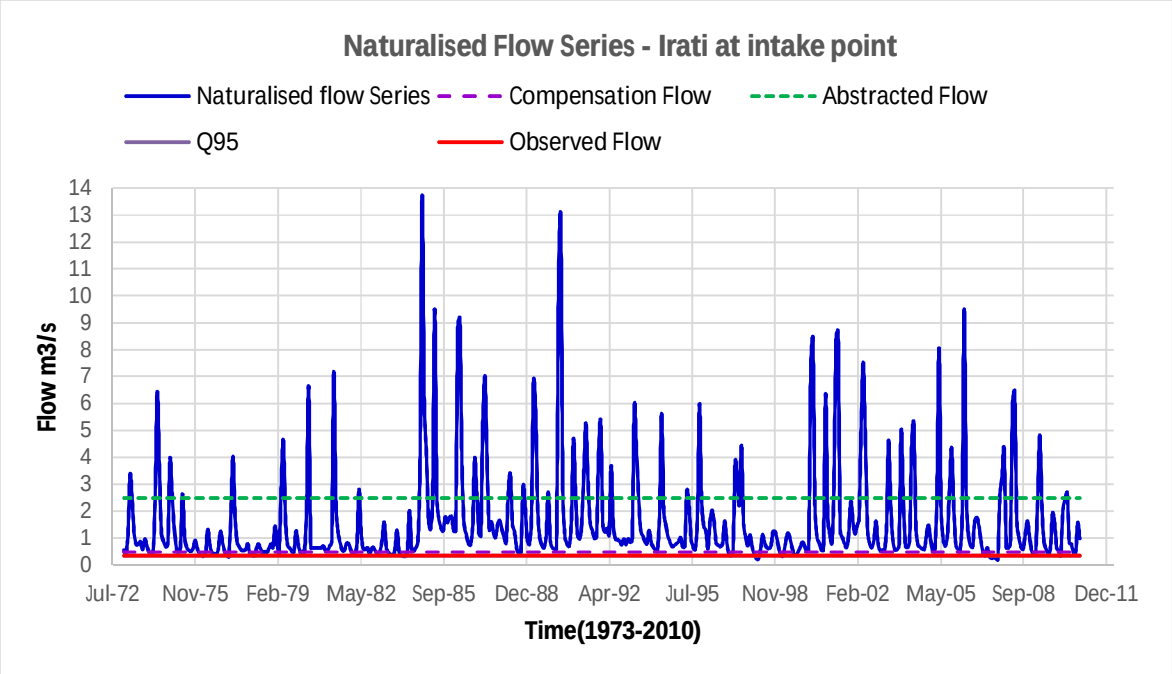

Figure 2-7: Flow Series Analysis at Irati Intake

Plate 2-3: Irati River Just upstream of Intake at 4BE6 20th February 2015 represented as observed trend line in Figure 2-7

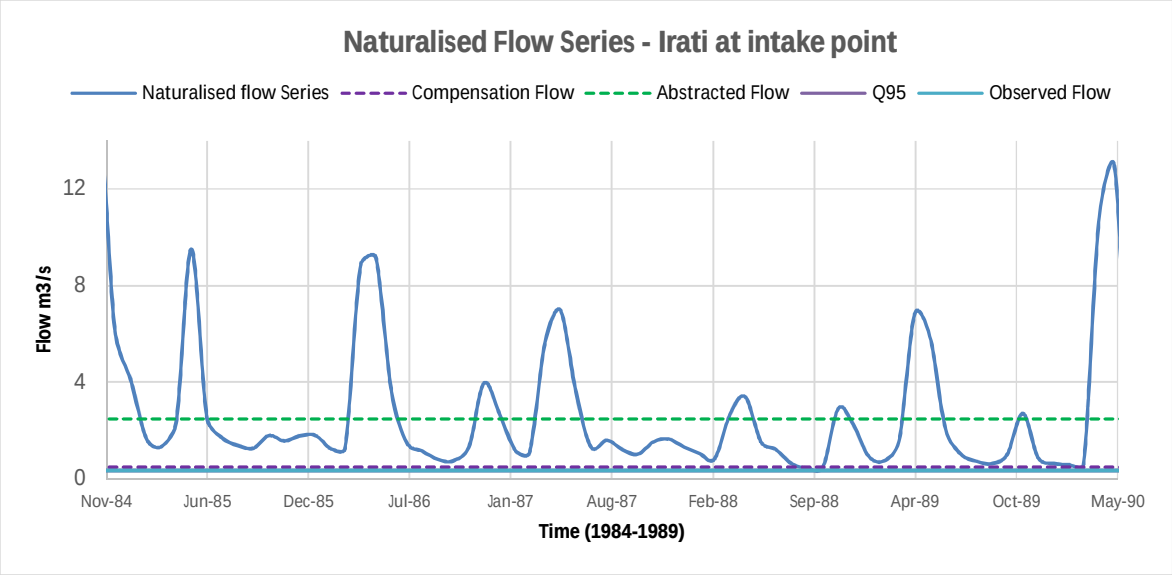

Figure 2-8: Naturalised Flow Series at 4BE6 Irati at NCT Intake 1984-1989

The observed data in is downstream at 4BE3 and the Naturalized flow data is near 4BE7 as illustrated in **Figure 2-8**. *Both show that catchment to have a very quick response time and very low baseflows despite the catchment size at 4BE3 being 170km². This behavior resembles urban areas where water hardly seeps into the ground. This indicates rapid runoff leaving very little baseflows. Thus the flood flow occurs in a very short span of time.*

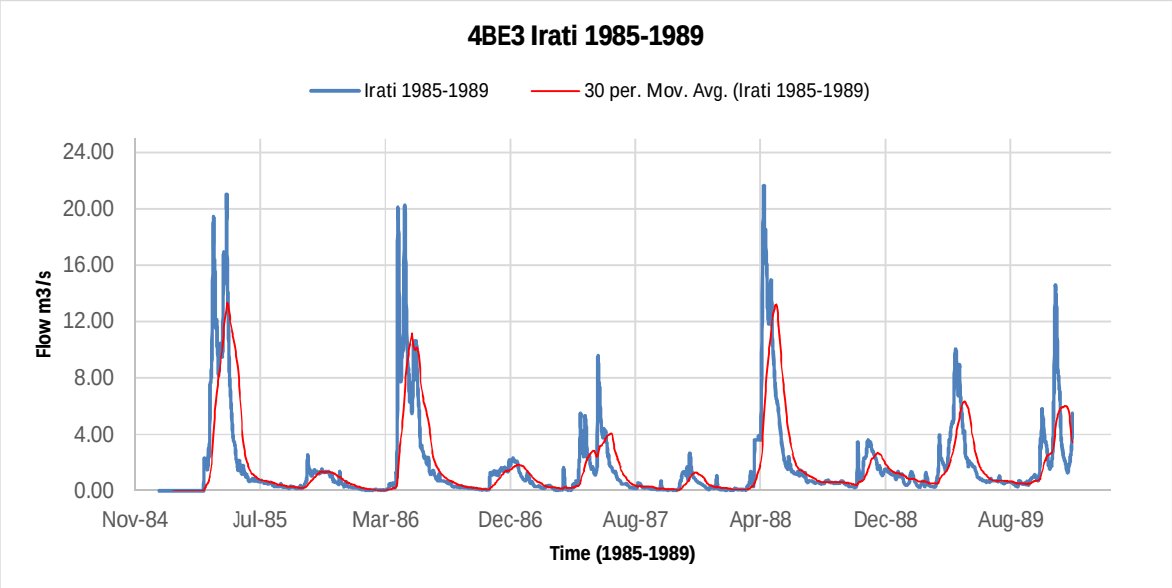

Figure 2-9: Observed Flow at 4BE3 1985-1989 Downstream of Intake

Gikigie 4BE8

The naturalised flow series for Gikigie River at the intake point is summarised in **Table 2-3**. The naturalised average annual flow is 0.61m³/s with the highest mean flow occurring in May 2.13m³/s and the lowest mean flow occurring in February and September of 0.18m³/s. The annual minimum average flow is 0.05m³/s with the lowest minimum monthly flow of 0.01m³/s occurring in March and the highest minimum monthly flow 0.1m³/s occurring in November. The annual maximum average monthly flow is 2.63m³/s with the lowest maximum average monthly flow of 6.30m³/s occurring in April and the lowest maximum average monthly flow of 0.38m³/s occurring in September.

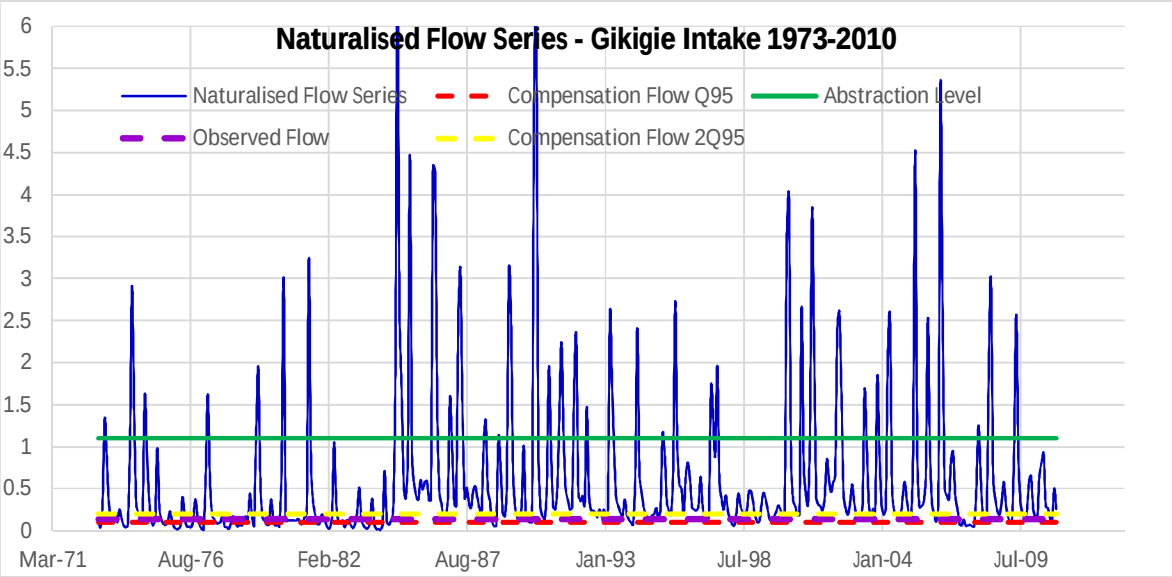

Figure 2-10: Flow Series Analysis at Gikigie Intake

The spot flow measurement conducted during the field trip was 0.136m³/s. This is the flow equivalent to the highest minimum monthly average flow.

Table 2-3: Flow Indices for Gikigie at NCT Intake (4BE8)

Month	J	F	M	A	M	J	J	A	S	O	N	D	AAF
Mean	0.29	0.18	0.20	1.26	2.13	0.73	0.32	0.22	0.18	0.29	0.94	0.56	0.61
Min	0.02	0.02	0.01	0.06	0.06	0.06	0.05	0.03	0.03	0.04	0.10	0.09	0.05
max	1.67	0.58	1.14	5.17	6.30	2.75	1.96	0.57	0.38	1.62	6.75	2.69	2.63

Source: Northern Collector Feasibility Studies by EGIS BCEOM &MIBP

Plate 2-4: Gikigie River Just upstream of Intake at 4BE8 20th February 2015 represented as observed trend line in Figure 2-10. This flow is higher than which is left after NCT-I abstraction

Figure 2-11 and **Figure 2-12** is a comparison of the simulated naturalized flow and the observed flow for period between 1990 and 1994 where there is more consistent observed flow series indicates some disparities in the monthly averages. The simulated flow series seems to indicate a server drought situation in 1992; the observed flow series just indicate depressed flows but not severe drought. The observed flow series indicates a severe drought between September 1991 and March 1992 and yet the simulated flow series indicates normal short rains during this period. The flow series needs further validation.

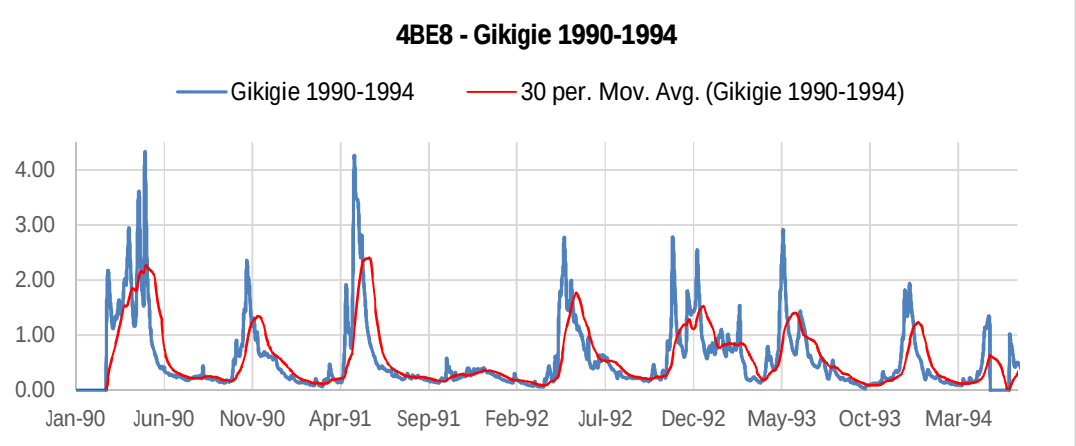

Figure 2-11: Daily Observed Flow Series at 4BE8 1990-1994

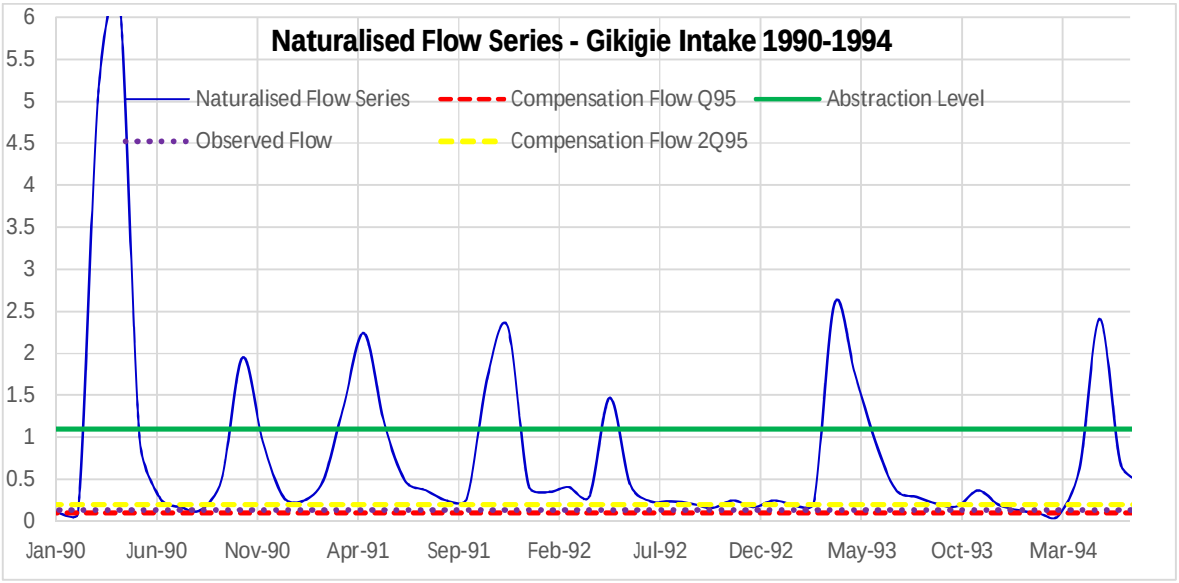

Figure 2-12: Naturalised Monthly flow Series at 4BE8 NCT intake

Observations of Maragua Sub-Catchment 4BE1,

Observation at this station combines entire flows of the Maragua sub-catchment from 1948-1998 and include river flows Gikigie, Maragua, Irati and Kayahwe. The mean monthly flow is highest 35.9 m^3/sec in May and lowest 4.29 m^3/sec in February, while maximum observed flow is highest 97.0 m^3/sec in April and lowest in 10.2 m^3/sec in September. The minimum flow is highest 3.27m^3/sec in April and lowest 1.02 m^3/sec in the month of September.

Table 2-4: Mean monthly (naturalized) flow (m3/s) statistics for Marugua River at 4BE1

Month	J	F	M	A	M	J	J	A	S	O	N	D	AVF
Mean	6.75	4.29	4.97	21.71	35.99	14.18	7.50	5.50	4.55	6.92	16.50	11.33	**11.688**
Max	26.42	12.89	21.59	97.01	90.46	33.58	30.39	11.53	10.27	34.31	90.59	34.51	**41.13**
Min	2.21	1.48	1.24	3.27	2.32	1.63	2.05	1.75	1.02	1.31	2.80	2.87	**2.00**

Source: Northern Collector Feasibility Studies by HH

Table 2-5: Flow Duration Data for 4BE01, Maragua River (1949 – 1998)

Probability of Exceedence	1DayDischarge(m^3/s)	1MonthDischarge(m^3/s)
0.01	85.56	67.49
0.04	47.69	44.32
0.05	41.59	41.47
0.1	26.19	28.51
0.2	14.45	15.61
0.25	11.54	12.38
0.5	5.90	6.50
0.75	3.33	3.63
0.8	2.81	3.16
0.9	1.80	2.12
0.95	1.22	1.54
0.96	1.12	1.41
0.99	0.62	0.75

Source: Detailed Designs and Supervision for Murang'a North and Murang'a South Bulk Water Supply Project, Feasibility review, Design Report I, 2010 by Howard Humphreys

Table 2-6tabulates the flow characteristics based on flow duration curves of NCT Phase I rivers and the catchment observation station at 4BE1. The flow table illustrates the key indices in hydrological regime of the streams and the catchment. The extreme low flows indicate that the NCT I rivers contribute all the base flows in Maragua river. This reduces to 50% contribution during high flows at Q50.

Table 2-6: Characteristic Flows at Proposed Abstraction sites on Northern Collector Phase I

Description	intake River	Flows at proposed intake sites (m^3/s)			
		EFC extreme low flow threshold	Q_{95}	Q_{80}	Q_{50}
NCT -Phase 1	Irati	0.422	0.349	0.531	0.912
	Gikigie	0.089	0.052	0.137	0.295
	Maragua	0.641	0.493	0.843	1.421
Subtotal for NCT-I rivers		**1.152**	**0.894**	**1.511**	**2.628**
Flow at catchment Observation station	**4BE1**	**1.02**	**1.54**	**3.16**	**6.50**

Note: Flows based on 1950-2010 time series calculated at the intake sites. (Source: Northern Collector Feasibility Studies by Howard Humphreys)

2.2.2. Reservoir Hydrology at Thika Dam

Thika Dam is located about 50 km north of Nairobi, close to Ndakaini village and was constructed between 1989 and 1994 under the Third Nairobi Water Supply Project. It is a river regulating reservoir to augment water supply to Nairobi by ensuring adequate flows at Ngethu Treatment works. It collects

water form Thika River and its tributaries. Water from this reservoir is transferred by a series of tunnels into Chania River from which an intake exists for transfer to Ngethu treatments works. The main characteristics of the reservoir are listed in **Table 2-7**.

Table 2-7: Thika Dam Characteristics

Dam Component	Characteristics
Height of the dam	65m
Reservoir water surface	2.8km^2
Full Water Supply Level	2041mAOD
Spillway Crest length	420m
Capacity of reservoir	70millionm^3
Catchment area	75km^2
Tunnel length	340m
Tunnel diameter	3m
Draw-off pipe	1400mmwith6draw-offvalves
Spillway characteristics	H=65m,shaftdiameter:5.5m
Tunnel	Discharge:390m^3/s,length:180m
Emergency spillway	Qmax=120m^3/s
Thika-Kiama tunnel	L=1km,D=2.5m,Q=6m^3/s
Kimakia–Chania tunnel	L=3km,D=2.5m,Q=6m^3/s

Source: Feasibility study and master plan for developing new sources of water for Nairobi and satellite towns–Master Plan Report

Current and Projected Inflows

The record of the inflows and the drawdown at the reservoir are well documented in the Feasibility study and master plan for developing new sources of water for Nairobi and satellite towns–Master Plan Report.

Table 2-8: Mean Monthly Inflows into Thika Dam

Monthly	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAI
Mean	1.43	0.90	0.96	3.90	7.22	3.36	1.81	1.26	0.97	1.33	3.27	2.54	2.41
Minimum	0.44	0.21	0.16	0.61	1.63	0.60	0.84	0.62	0.41	0.50	0.54	0.62	0.60
Maximum	6.10	3.25	4.21	14.20	14.41	8.23	7.47	2.69	2.11	5.77	18.31	8.15	7.91

The average mean annual inflow into the dam is 76MCM, which translates to a storage ratio of about 0.92. The feasibility report by Egis and MIBP concludes the current storage ratio to be 0.86. The records maintained at the dam by Nairobi Water and Sewerage Company (**Figure 2-13**) indicates a very sharp drawdown curve and also a very steep infill curve. This indicates that the dam fills very fast and the dam also draws off at a high rate when it is

supplying water to Ngethu water treatment. This has a profound impact on its buffering capacity which needs to be investigated in details.

Table 2-9: Mean Monthly Inflows into Thika Dam with NCT Phase I

Monthly	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAI
Mean	2.65	1.66	1.91	7.52	12.56	6.51	3.44	2.57	1.91	3.19	7.21	5.23	4.70
Minimum	0.50	0.23	0.16	1.74	2.14	0.60	1.08	0.72	0.59	0.66	1.07	1.27	0.90
Maximum	10.02	6.32	8.56	20.20	20.41	13.71	13.05	5.79	4.98	9.83	24.31	12.71	12.49

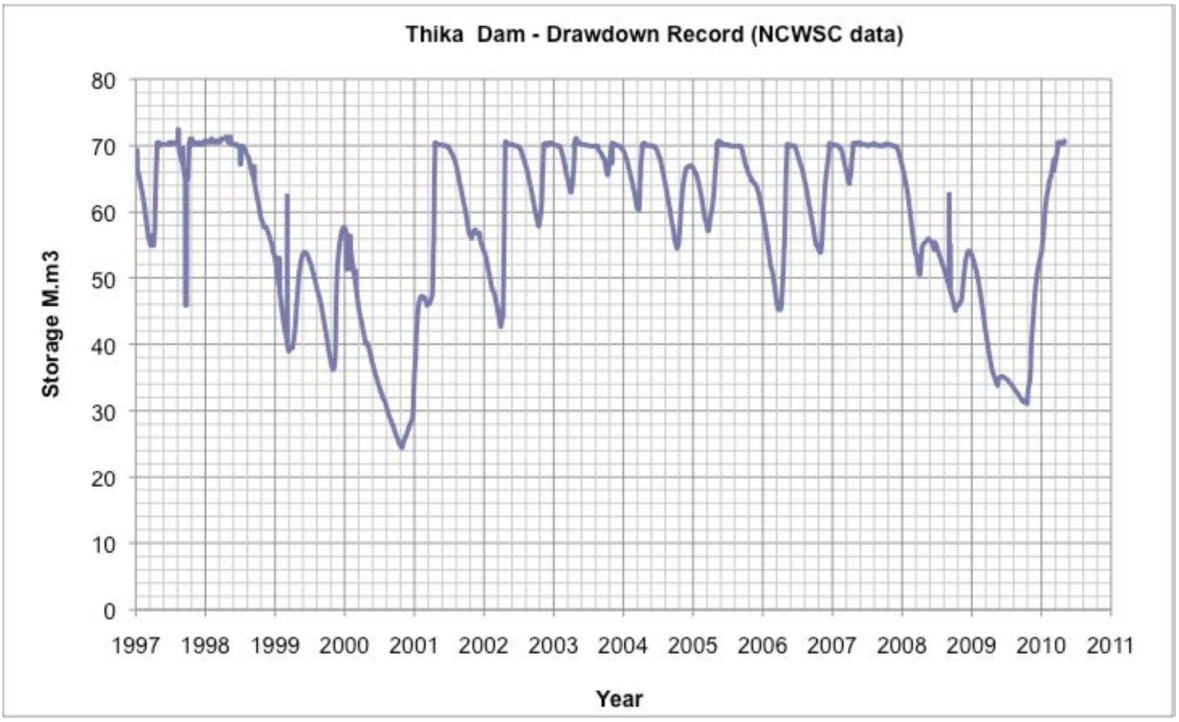

Figure 2-13: Observed Drawdown Record at Thika Dam (NCWSC data)

However, concerning NCT I and II projects, it is seen that there will be an additional yield of between 1.6m³/s to 3.7m³/s. It is notable, however the northern collector scheme reduces the reservoir storage ratio drastically and the study concludes

*"The **buffering capacity of Thika Dam is limited** in case the inflows are increased. The Storage Ratio shows that there is inadequate capacity of the reservoir to buffer any additional inflows. This concurs with previous studies and the necessity of augmenting storage within the system is highlighted."*

The analysis of the drawdown scenario analysis of Thika dam and the filling rate both from observed recording and simulated results agree as shown in **Figure 2-13**, indicates high drawdown and refill rates.

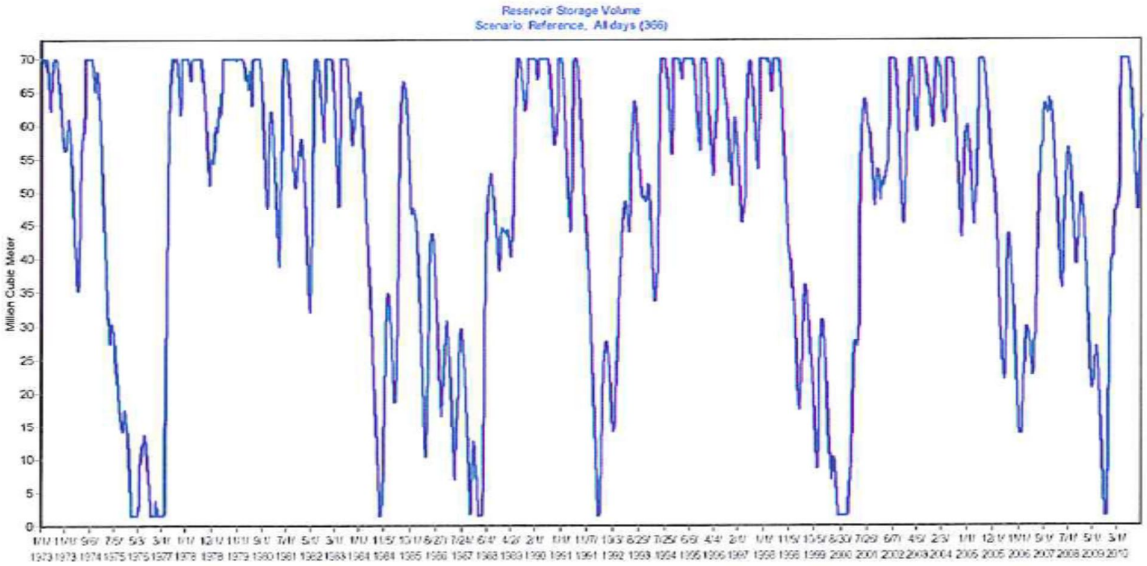

Figure 2-14: Thika Dam Storage Simulation (source EGIS/MIBP)

Thika River is very productive and fills the dam in almost each and every rainy season that is the dam spills twice a year and in a period of less than month. Moreover the dam also draws very fast when almost solely meeting the demand at the Ngethu treatment works. This clearly indicates that the dam cannot sustain higher drawdown rates and if not well supplemented. An in-depth analysis is needed to evaluate its response when flow of 1.6m^3/s and more and the proposed increase drawdown to Kigoro water treatment works to avoid putting the utility of the plant at of risk utilizing only half the capacity. The average current inflows into Thika dam for the two studies on NCT are comparable.

The basic concern is the following:

From the simulation it is not envisioned that the tunnel will deliver the following components of flow to sustain the current scenario:

a. Base flows
b. Normal Flow
c. Flood flow

This arrangement is not sustainable for direct abstraction schemes because it places the system and other users at high risk.

Flood waters from NCT is probably not very useful for the project as the dam fills in 1.5 months and spills for three months during the rainy season; thereafter the scheme is sustained by normal and base flows as indicated in **Figure 2-14**which is collaborated with the observations in the feasibility study that the dam has no buffering capacity and storage should be included in the scheme.

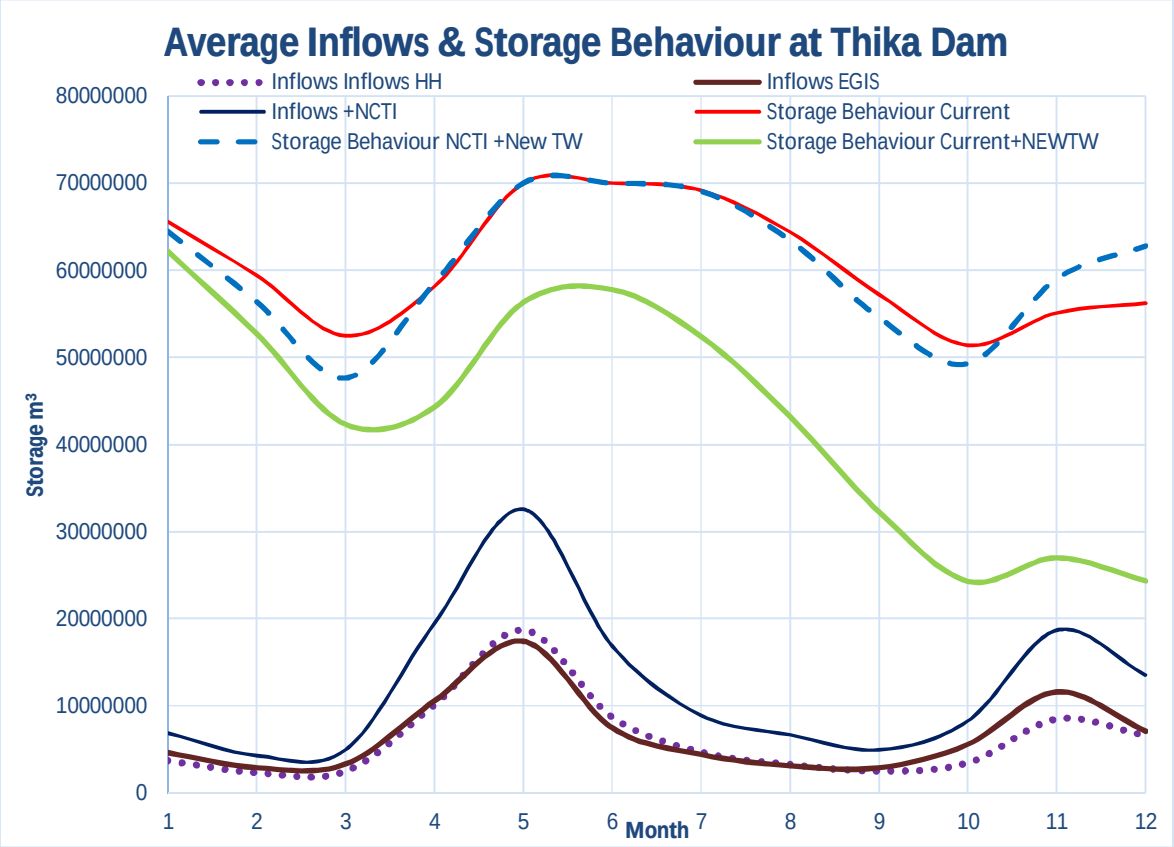

Figure 2-15: Monthly Average Storage Behaviour of Thika Dam

Box 1. Requirement of Additional Storage

The trend in Storage Ratio for Thika Dam with the introduction of NC I and NC II implies that additional storage is required in the System to capture the additional flows from the Water Transfers. If storage is not provided, then the water diverted through the NC System will overwhelm the Thika Dam and simply spill downstream.

Howard Humphreys (1998) briefly investigated possible options for providing additional storage listed below:

- Increasing the capacity of Thika Dam
- A new reservoir downstream of Thika Dam to regulate increased spillage arising because of the Northern Collector operation.
- Reservoirs at one or more of the Northern Collector diversion points to regulate the river flows and hence increase the inflows to the Collector during the dry season.
- Independent reservoirs on one or more of the Northern Collector Rivers but with no connection to the Northern Collector.

Option 1 is not feasible since it has already been established that the Thika Dam embankment cannot be raised any further. Option 2 would be ideal in capturing the spills from Thika Dam. However, more detailed investigations are required to conclude on its feasibility. The same can be said for Option 3. All the intakes for the NC System are located within the Aberdares and therefore impoundment of these rivers at the intake locations will require extensive technical and environmental studies. Therefore, Option 4 remains the most feasible at this stage.

The Chania-Thika Study Supplementary Report by Howard Humphreys (1980) investigated eight potential dam sites to the north of Chania-Thika catchment and recommended provision of storage on Maragua River downstream of the NC diversion site at the confluence with Gikigie River. This is henceforth referred to as Maragua 4 Dam.

The location of the Maragua 4 Dam is appropriate since it allows the option of either sharing the NC II water with Thika Dam or diverting it entirely to Maragua 4 Dam depending on the location of the NC II tunnel outfall.

……

The main outcome of the modelling exercise was the sensitivity of System Yields to IFR, which is consistent with the findings of the earlier studies of Howard Humphreys. Basically, any change in IFR values either in the Existing or Northern Collector System has appreciable changes in the System Yields. Therefore, selection of which scenario to base the Engineering Design of the water infrastructure is critical.

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In addition, the storage capacity of Thika Dam is not adequate to accommodate the additional inflows from the Northern Collector System as shown in Sections 3.5.2 and 3.5.3. Therefore, additional storage within the System is recommended. The most feasible dam site is Maragua 4 Dam which was initially proposed by Howard Humphreys. The Present Study also recommends the same proposal.

Source: FEASIBILITY STUDY AND MASTER PLAN FOR DEVELOPING NEW WATERSOURCES FOR NAIROBI AND SATELLITE TOWNS – MASTER PLAN REPORT…. Page 7-25, 7-26

2.2.3. Rainfall Trend Analysis and Climate Change Scenarios

Climate is often considered to be the driving factor for stream flow. This is normally spatially and seasonally distributed. The climate and specifically rainfall of the Murang'a is heavily influenced by its geographical location, altitude and varying topography as shown in **Figure 2-16**and **Figure 2-17**. The rainfall patterns indicate a bimodal type of rainfall with the highest peaks experienced in April –May and the second low peak in October November. Moreover, there is a drastic fall in the average monthly rainfall received as one moves from the highlands in the Aberdare ranges. The rainfall amount received in the Aberdare's is double the amount received in Murang'a town

as recorded at WRMA offices. There is even and gradual reduction of rainfall and it reduces to one third in Makuyu area.

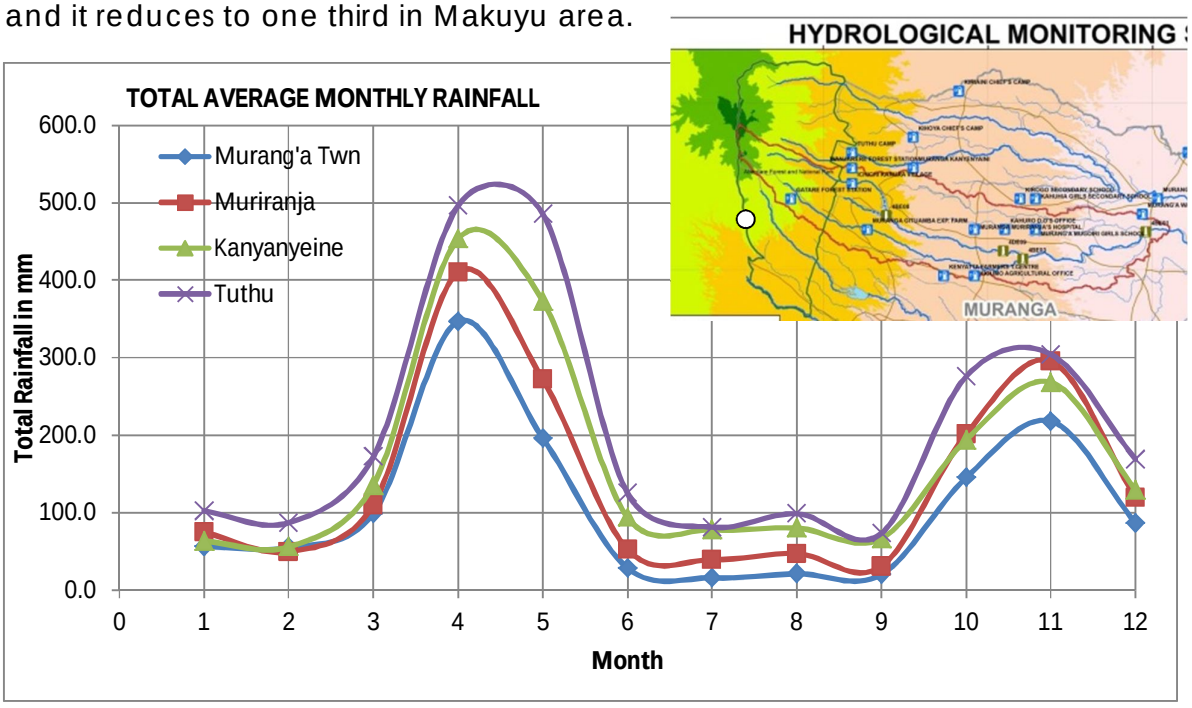


Figure 2-16: Monthly Rainfall Distribution

The annual amount is highly variable ranging from 780mm in the lowland semi-arid rising to 1290 in Murang'a town, 1700mm in Muriranja and finally to 2500mm in Tuthu in the Aberdare's This quick recession in the rainfall received in Murang'a and given the recent trends in the onset and recession of the rainfall seasons it is imperative that irrigated agriculture will continue to gain momentum in the county. This will be widespread in the arid lowlands where there is a low population density and available arable land.

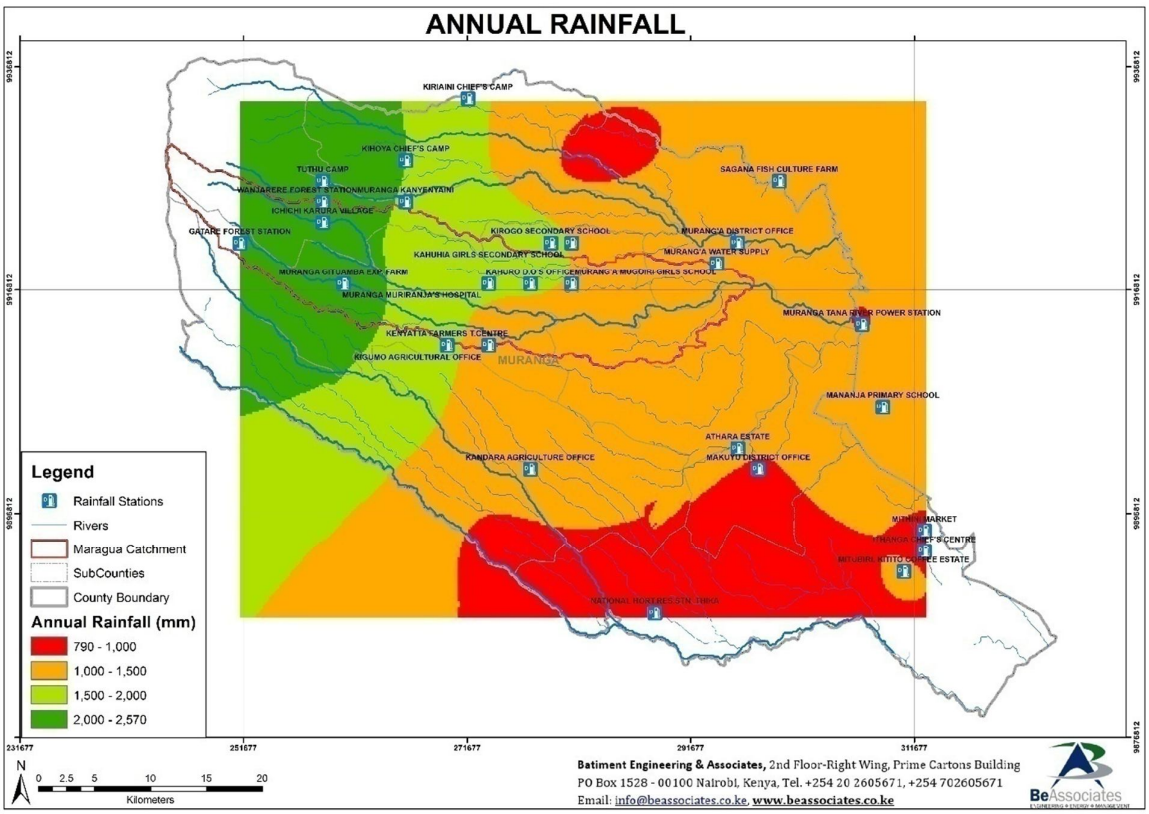


Figure 2-17: Annual Rainfall Distribution

The basin falls within the equatorial trough of the intercontinental convergence zone (I.T.C.Z), with a low pressure cell, where the south easterly and the north easterly trade winds converge, but due to the local differences in elevations, and the continentally, the climate is modified to "modified equatorial climate". This climate is much cooler than the general tropical continental climate or highland subtropical climate and changes with altitude, becoming semi-arid towards the lower reaches of the catchment.

Climate Change versus Climate Variability

Climate Change refers to a change in the state of the climate that persists for an extended period, typically decades or longer (a permanent shift in the normal patterns of climate) while **Climate variability** refers to variations in the mean state of the climate beyond that of individual weather events.

Analysis of the rainfall trend analysis of Muriranja monthly rainfall indicates very little or no change in the monthly averages. However, this does not give information concerning the seasonal behaviour, intensity and duration of the rains being received.

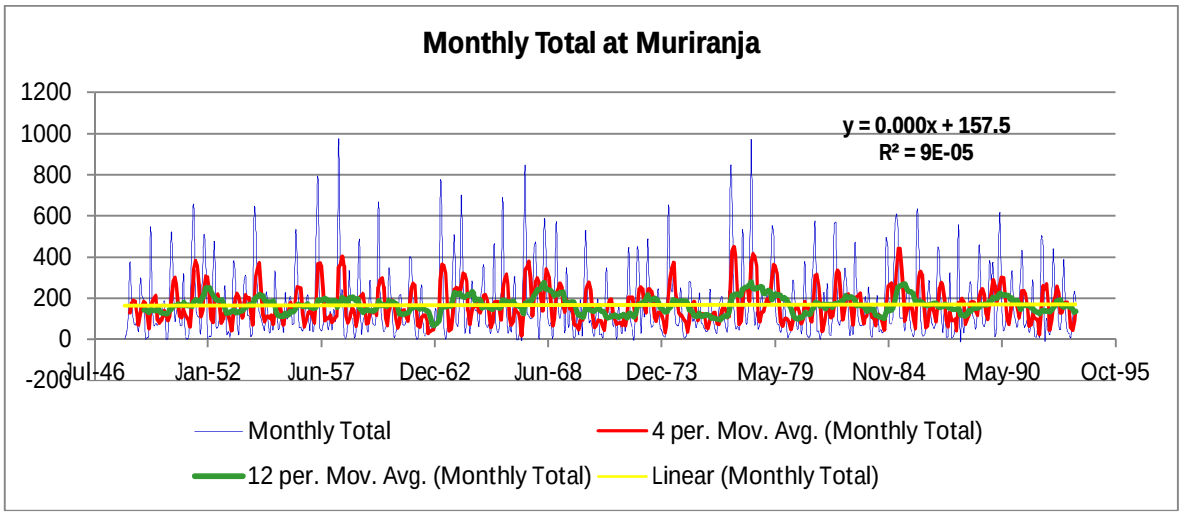


Figure 2-18: Rainfall Trends at Muriranja RGS

Climate Change Models and Projections

Climate models use quantitative methods to simulate interactions and processes in the atmosphere and oceans to study the dynamics of the climate system and provide projections of a future climate.

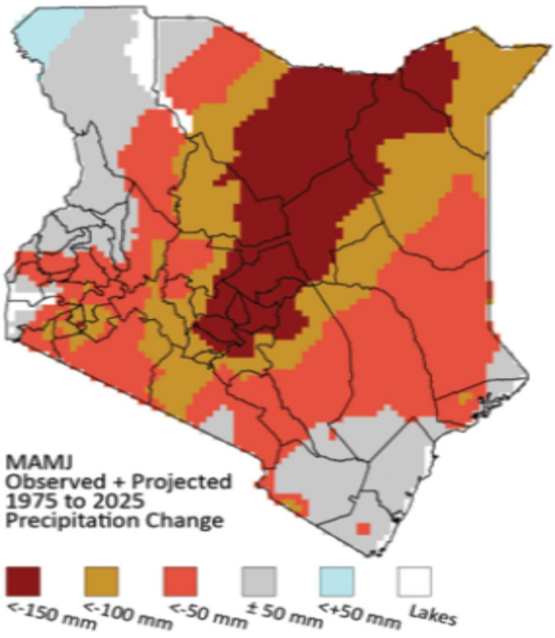


Figure 2-19: Rainfall Change in long Season of MAMJ: (Source: FEWSNET, A Climate Trend Analysis of Kenya—August 2010)

All climate models are based around the planet's energy balance, including incoming energy from the sun and outgoing energy from the Earth's surface. IPCC reports, FEWS NET and other independent studies agree that there is expected increase in surface temperatures and evapotranspiration in central Kenya which covers Murang'a County. The annual trend analysis of rainfall shows no critical change in mean annual rainfall. However, the seasonal trend analysis reveal a different scenario where Murang'a is classified among the regions that may experience a reduction in total rainfall received in the long rains seasons of about 150mm.

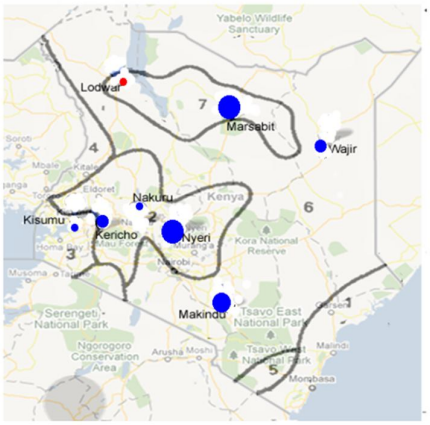


Figure 2-20: Rainfall Changes in MAM

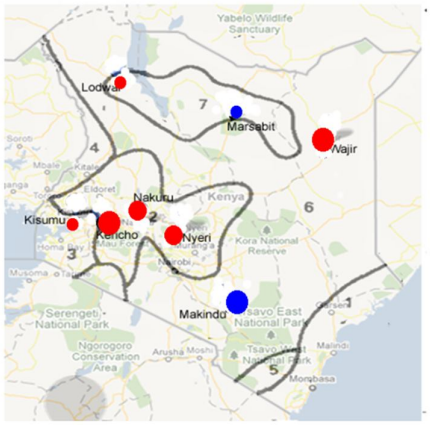


Figure 2-21: Rainfall changes in JJAS

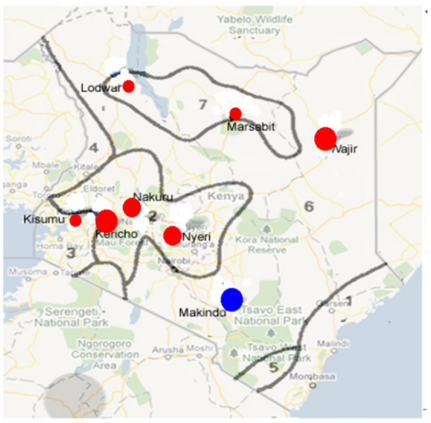
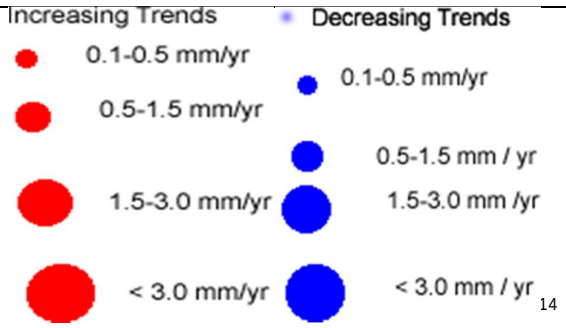


Figure 2-22: Rainfall Changes in OND



(*Source Wangai and Mutuga, 2009*)

Majority of farming activities on the county depend on rain fed agriculture especially subsistence farming. These trends will have profound impacts on small holder farming activities

From the findings of **Building Adaptive Capacity to Climate Change in Kenya** led by UK Met office and WRMA, it's clear that the increase in surface temperature will lead to an increase in evapotranspiration and thus an effect on the crop production.

In addition to substantial rainfall declines in central Kenya, the country also will have warmed substantially during these 50 years. FEWS NET estimates the 1975 to 2025 warming generally will represent more than a 1° Celsius increase in temperature for Kenya, a substantial change in the country's underlying climate. The study concludes that Central Kenya an area that has already

[14] *source Wangai & Mutuga, 2010*

experienced, and will likely continue to experience, substantial and important changes in climate as a result of recent and projected trends in rainfall and temperature.[15]

2.3. Hydrogeology Assessment

Groundwater flow and the associated surface water flow are potential negative factors on underground tunnels. Early detection of environmental impacts on water resources is of significant importance to planning, design and construction of tunnel projects. This can minimize accidents and project delays during construction and more important, it can inform on sustainability of groundwater capacity.

Groundwater studies associated with the design and construction of such a large underground structure should not only focus primarily on methods for controlling water inflow during excavation and keeping the completed structure free of water but also making geotechnical and geological considerations, and hydrological factors relating to surface and groundwater to obtain sound solutions. Methods for minimizing and preventing environmental impact should therefore be planned and made available to support response to predicted impacts prior to tunnel construction.

From the final design report, it has been noted that there is limited available ground investigation hence limited geological and geotechnical information. However, from the regional geology as discussed in the Geological Report of the Kijabe Area (Geological Survey Kenya, 1964) and summarized in the Howard Humphreys Report, the area is composed almost entirely of volcanic rocks and their weathering products. This kind of geo-structure is susceptible to ground water seepage and consequently tunneling would have an impact on the hydrogeological environment in the region.

This review therefore recommends further ground investigation to determine the impact of tunneling excavation on the hydrogeological environment in a regional area around the tunnel and local spring areas all along. The investigation should therefore be conducted in view of simulating groundwater flow pattern in the tunnel area and determining changes in the groundwater flow field due to tunnel construction far away in the surrounding regions.

The important aspects for geological assessment will also impact on the design as the final design report concludes that the appropriate level of Geotechnical Information was not available for Detailed Design and

[15] *A Climate Trend Analysis of Kenya—August 2010, FEWSNET, USGS*

development of Project Construction Contract documentation. The final design went into tendering with an estimated Design as the basis for Contract Documentation. This is an inherently risky approach. This is a project risk to be mitigated by strategies which will be discussed with Athi WSB. It is foreseen that this will have significant impacts on the project costing and other contractual documentation developed on the basis of the results used for final design.

Box 2: Admission of Inadequate Geotechnical Data

1.3 Limitations of the Design

The appropriate level of geotechnical information has not been made available for development of the Detailed Design and Project Construction Contract documentation at the time of preparation of this report. The Consultant has engaged with Athi WSB in an attempt to obtain the relevant information and delay delivery of the Detailed Design in order to enable use of the outstanding information in Detailed Design. However the information is not forthcoming and the Consultant has been instructed that the Detail Design and construction procurement documentation shall proceed on the basis of the available information to date.

The draft design presented here is therefore based on a general estimate of the likely ground conditions along the tunnel route and as such is presented as a draft which may be subject to significant modifications once the appropriate level of geotechnical information is available, in particular with respect to the nature and

SMEC

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As indicated in Box 2, it is clear that geotechnical risks and impacts may not be fully comprehended and detailed geotechnical study is paramount to validate the designs and construction methods proposed

Studies indicate that the cost of delays and impact compensation that can result in inadequate understanding of the environment justify investigations and evaluations of the conditions, as well as establishment of a monitoring system to assess possible impacts. The Study Further notes that the issue of groundwater flow pattern around tunnels is of significant importance to the planning, design and construction of tunnel projects, as tunnel excavation can generate extremely large quantities of inflow, thereby causing potential hazards and project delays. Tunnel construction may alter the groundwater table, recharge, water quality, and groundwater storage or even alter

regional geology and the environment to such an extent that disasters may result. [16]

2.4. Water Demand Analysis and County Development Plans

2.4.1. Population

The population of Murang'a County during the last census stood at 942,581. This is spread in the county which is largely rural. However the clustering is spread more at the centre of the county with the eastern parts close to Aberdare and the lower altitude land towards the west of the county being sparsely populated as indicated in **Figure 2-23**. Population and demographic analysis is the main driver for development planning for all sectors. It is imperative then to have an idea not of the population density and also its spatial spread when planning for water services provision, irrigation and other sectors.

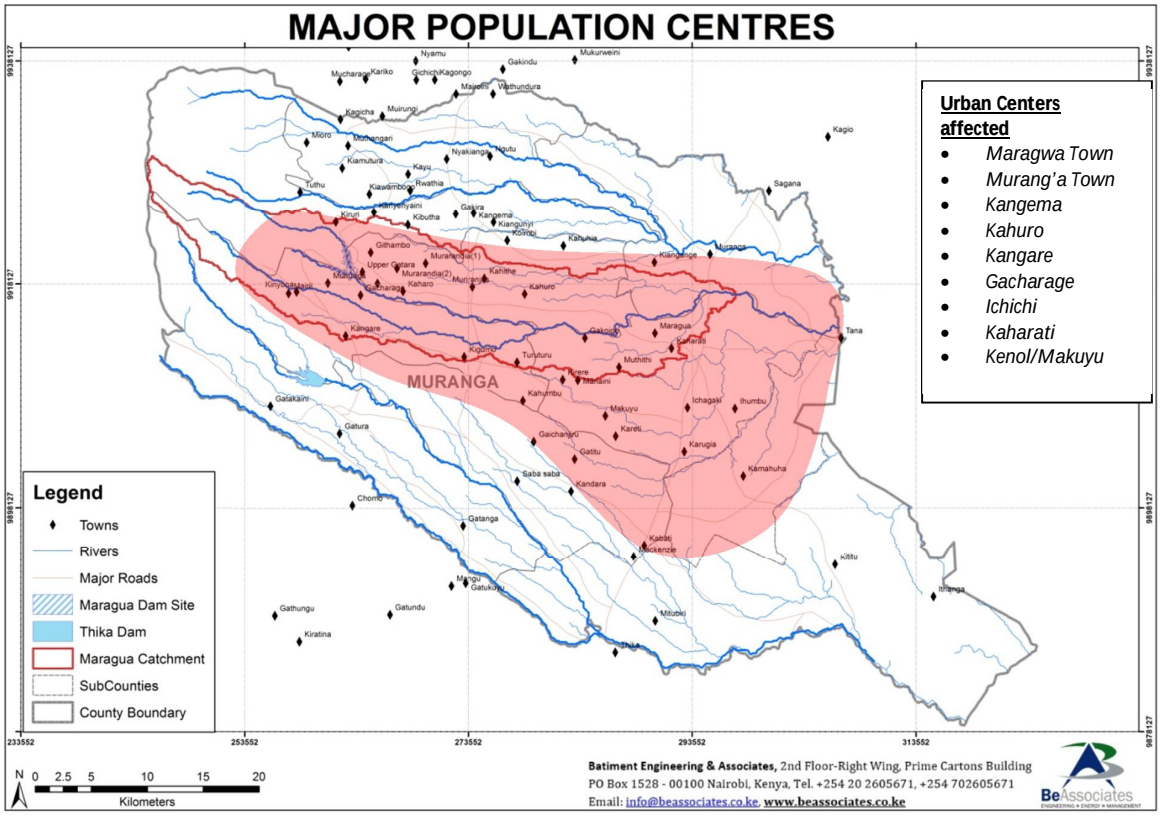

Figure 2-23: Major Population Centers

[16] *Feng-Rong Yang, Cheng-HawLee, Wen-JuiKung, Hsin-FuYeh,(2009) The impact of tunnelling construction on the hydrogeological environment of "Tseng-Wen Reservoir Transbasin Diversion Project" in Taiwan, Journal of Engineering Geology, Elsevier*

Table 2-10: Murang'a County Population

Constituency	2009(Census)		2012(Projections)		2015 (Projections)		2017 (Projections)	
	Pop	Density (Km^2)	Pop	Density (Km^2)	Pop	Density (Km^2)	Pop	Density(Km^2)
Kiharu	181,076	441	183,262	447	185,474	453	186,964	456
Kangema	76,988	443	77,917	449	78,858	454	79,491	458
Mathioya	88,219	251	89,284	254	90,362	257	91,088	259
Kandara	156,663	664	158,554	672	160,468	680	161,757	686
Kigumo	123,766	511	125,260	517	126,772	524	127,791	528
Gatanga	163,597	273	165,572	276	167,571	280	168,917	282
Maragwa	152,272	278	154,110	282	155,971	285	157,224	287
Total	**942,581**	**368**	**953,960**	**373**	**965,477**	**377**	**973,231**	**380**

Source: County Development Planning Office-Murang'a County (2012)

Table 2-11: Population of Urban Centers

Urban centers	Population Projections			
	2009	2012	2015	2017
Murang'a Town	28,775	29,122	29,474	29,711
Maragwa Town	26,374	26,692	27,015	27,232
Makuyu/Kenol Town	44,007	44,538	45,076	45,438
Kiriaini Urban Centre	2,457	2,487	2,517	2,537
Kabati Urban Centre	3,128	3,166	3,204	3,230
Kangari Urban Centre	2,810	2,844	2,878	2,901
Total	107,551	108,849	110,164	111,049

Source: County Development Planning Office, Murang'a, 2012

The total population of people living in urban centres is projected to be 108,849 in 2012. Makuyu/Kenol town has the largest population with 44,538 people followed by Murang'a town with a population of 29,122 people. On urban centres, Kabati has the highest population of 3,166 people followed by Kangari with2, 844people.Kiriainihastheleastpopulationwith2, 487people.

Table 2-12: Population Projection as per water supply scheme area

WATER SUPPLY SCHEME	Area	Census	POPULATION PROJECTION		
	KM^2	2009	2017	2020	2035
		pop	pop	pop	pop
Gatango Scheme (Rural)	84.00	46,517.00	46,891.00	47,032.00	47,742.00

Gaturi Scheme (Rural)	103.00	33,388.00	33,656.00	33,757.00	34,267.00
Mathioya Scheme (Rural)	139.00	59,412.00	59,889.00	60,069.00	60,977.00
Kahuti Scheme (Rural)	332.00	164,368.00	165,688.00	166,186.00	168,698.00
Murang'a Scheme (Rural)	20.00	27,484.00	27,705.00	27,788.00	28,208.00
Gikundi Scheme (Rural)	83.00	15,072.00	15,193.00	15,239.00	15,469.00
Kigumo Scheme (Rural)	296.00	163,497.00	177,114.00	182,508.00	212,044.00
Kandarua Scheme (Rural)	528.00	252,138.00	273,138.00	281,456.00	327,005.00
Gatanga District	250.50	105,600.00	113,856.00	114,395.00	130,276.00
Maragua Ridge Scheme (Rural)	78.00	21,195.00	22,960.00	23,660.00	27,488.00
Makuyu Scheme (Rural)	288.00	83,464.00	90,415.00	93,169.00	108,247.00
Total	**2,201.50**	**972,135.00**	**1,026,505.00**	**1,045,259.00**	**1,160,421.00**

Source: *Feasibility study and master plan for developing new sources of water for Nairobi and satellite towns–Master Plan Report*

The population data presented in **Table** 2-10and **Table** 2-11are comparable with the data used in the feasibility study presented in**Table** 2-12. The feasibility study classified the population according to rural water supply scheme; however it is not clear how the urban centers have been taken care of in the analysis of the population by the feasibility report by Egis &MIBP.

2.4.2. Domestic water Demand

The census report of 2009 and data from the CIDP formed the main source of population data. Table 2.9 shows the population projections per constituency in Murang'a County. The total water demand projected by TWSB in the detailed design and supervision report for Murang'a North and South Bulk water supply scheme. However these projections are based on census report of 1999 of which the current information shows a significant deviation in population as previously estimated.

Data obtained from the county water office indicates that the water demand by the water companies is presented in **Table 2-13** and ***. Table 2-14***for the whole of Murang'a County and in

Table 2-15 for abstractions from Maragua catchment.

Table 2-13: Water Demand per Supply Scheme Area

WATER SUPPLY SCHEME	Area	Water Demand			
	KM²	2010	2017	2020	2035
		(m³/day)	(m³/day)	(m³/day)	(m³/day)
Gatango Scheme (Rural)	84.00	3,991.00	4,034.00	4,046.00	4,107.00
Gaturi Scheme (Rural)	103.00	3,119.00	3,181.00	3,191.00	3,239.00
Mathioya Scheme (Rural)	139.00	5,288.00	5,379.00	5,396.00	5,477.00
Kahuti Scheme (Rural)	332.00	14,315.00	14,545.00	14,588.00	14,809.00
Murang'a Scheme (Rural)	20.00	3,419.00	3,450.00	3,461.00	3,513.00
Gikundi Scheme (Rural)	83.00	1,624.00	1,668.00	1,673.00	1,698.00
Kigumo Scheme (Rural)	296.00	14,171.00	15,198.00	15,661.00	18,196.00
Kandarua Scheme (Rural)	528.00	25,700.00	27,242.00	27,935.00	31,727.00
Gatanga District	250.50	12,920.00	13,535.00	13,812.00	15,316.00
Maragua Ridge Scheme (Rural)	78.00	2,075.00	2,225.00	2,293.00	2,664.00
Makuyu Scheme (Rural)	288.00	8,064.00	8,649.00	8,912.00	10,354.00
Total Water Demand	**2,201.50**	**94,686.00**	**99,106.00**	**100,968.00**	**111,100.00**

Source: *Feasibility study and master plan for developing new sources of water for Nairobi and satellite towns–Master Plan Report*

. Table 2-14: Water Demand per service area of WSP

	NAME OF SCHEME	CURRENT DEMAND m^3/day	DEMAND FOR 2030 m^3/day
1	Gatamathi Water Company	14402	15266
2	Kahuti	18000	19080
3	Gatanga Community Water Scheme	25000	26500
4	MUWASCO	18000	19080
5	Murang'a South	17000	18020
Total		**92,402**	**97946**

Source: Murang'a County Water Office

Comparison of the total water demand for domestic purposes as projected in the feasibility reports and water service companies in their provision areas indicates a desired coverage of about 93% against actual coverage of less than 50%. This indicates that abstraction from water sources would rapidly increase if the water companies were to obtain adequate funding to meet the demand in their area of jurisdiction.

Table 2-15: Existing licensed and actual water abstractions on the Maragua Catchment

Name of WSP	Location of Intake	Licensed Abstraction(m^3/day)	Current Abstraction (m^3/day)
Murang'a Water and Sanitation Company	Irati River	26,000	11,000
Murang'a South Water and Sanitation Company	Maragua River Irati River	53,900	30,000
Kahuti Water and Sanitation Company	Maragua River	9,600	9,600
Murang'a Water and Sanitation Company	Kayahwe River	6,000	4,000
Total		**95,500**	**54,600**

Source: ESIA Final Report of NCT Phase I by GIBB Africa December 2014 and County water office

Maragua catchment supports more than 50% of the water supply schemes in Murang'a County, this includes Kahuti water supply, and Murang'a water Services Company and Murang'a South water Service Company accounting for more than 50% of water supply coverage in Murang'a County.

The water services impact report published by WASREB puts the water supply coverage in Murang'a at about 35% which is much lower than the country average. It is therefore the mandate of murang'a county government under the constitution of Kenya to improve water service coverage to meet the MDGs and other national goals under vision 2030. It is also assumed that an estimated population of 40% use streams for domestic water requirements at 60 L/day per person which gives an additional water requirement of 10280m^3/d in maragua catchment.

2.4.3. Agricultural Water Demand

The National irrigation potential is about 540,000ha of which 205,000ha fall under Tana Basin. The area under irrigation in the country is about 153,800ha but in the Vision 2030 the target is 1.2 million ha.

The irrigation potential of Murang'a County is about 20,000ha of which 5500ha have been identified for irrigation but only 2947ha have been developed. Irrigation in the county should be developed in order to attain food security and employment creation among other benefits. Irrigation is high consumer of water, taking about 70% of the volume of water used. For Murang'a County to exploit the full irrigation potential of 20,000ha it would

require about 1,114,560m^3/day. In order to do so water harvesting, storage and sound management should be enhanced.

Irrigated agriculture should be emphasized in order to mitigate the dismal effects of climate change on crop production. Dams should be constructed in series along the rivers in order to harvest storm water during the rains which would then be used for irrigation development and domestic consumption. This would go a long way towards increasing per capita water availability which currently stands at 647m^3/capita below the UN recommended average of 1000m^3/capita. Other advantages of water harvesting and storage would be

- Replenish the ground water
- Sustain the base flow
- Control flooding

Our National development programme, Vision 2030, aims to increase reliance on irrigated agriculture at a rate of 100,000ha per year in order to attain the 1,000,000ha by the year 2030. A large portion of this area is in Tana and Athi river basins. The largest project being the Galana - Kulalu food security project which covers 1,000,000 acres.

In addition to development of water harvesting, storage and management, protection and conservation of the water resources and the catchment areas should been emphasized.

a) Analysis of current demand per sub-catchment–operational and on-going projects

The information on irrigation water demand was extracted from the County Irrigation Development Strategic Plan prepared in the year 2013. The total current water demand per day is 193,620m^3/day covering 2,947ha. Out of this 1120 ha are in Maragua catchment with a water demand of 43, 372m^3/day as indicated in **Figure 2-24**and **Table 2-17**. The irrigation area at present conditions by type in 2010 was estimated under the following conditions:

a) Large Scale Scheme: Reported areas by the NIB and listed areas based on water permits of WRMA
b) Small Scale Scheme: Identified by DIOs offices under Irrigation and Drainage Department of MWI
c) Private scheme: Identified by the regional offices of the WRMA and estimated area based on water permits granted by the WRMA

For Maragua catchment has irrigation water demand of 43,372m^3/d covering a total area of 1120ha.

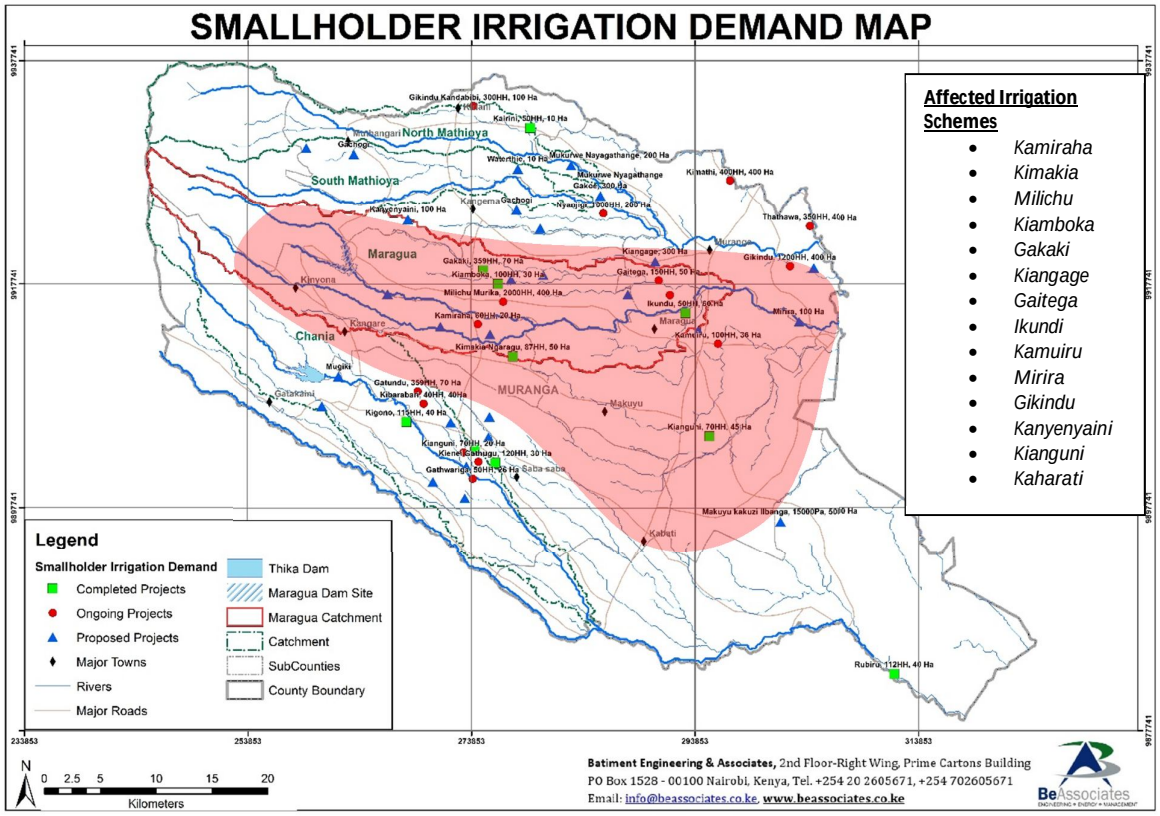

Figure 2-24: Small Holder Irrigation Schemes

Table 2-16: Current Irrigation Demand

S NO	Water Source	Project Name	Water Demand m^3/day	Potential Ha
1	North Mathioya basin	Kairini	864	10
		Gikindu Kandabibi	3456	100
2	South Mathioya basin	Nyanjigi	12873	200
3	Maragua river	Mirichu Murika	16156	400
		Gikindu	6048	400
		Gacharu	2765	80
		Gakaki	6048	70
		Kiamboka	3283	30
		Ikundu	3888	60
		Gaitega	2592	50
4	Sabasaba river	Kimakia Ngaragu	1209	50

		Thangaini	778	20
		Kamuiru	2333	36
		Karathe/Tthara	2938	70
5	Thika river	Gatundu	1728	70
		Kieni Gathugu	2160	33
		Boboti/Kiamande	864	30
		Kianguni	864	20
		Ajibika	32918	50
		Rubiru	2592	40
		Kigono	15638	23
		Riakomo	3110	60
		Kibarabari	2592	40
		Ruchu	1728	25
6	Irati river	Iharu	2592	30
7	Tana river	Thathawa	25920	400
		Kimathi	16243	250
		Githuri	19440	300
	Total		193,620	2947

Water demand per day = 193,620m^3/day covering 2,947ha

b) Projected/future demand per Sub County –proposed projects

These are the projects whose designs have been worked upon and are awaiting implementation funds. The Water demand for the proposed projects is 405,822m^3/day to cover 7,368ha. To be noted is that all the projects described are small holder irrigation projects for subsistence agriculture and very minimal commercial benefit. They are designed to support livelihoods and create employment at the household level where each household will be farming approximates 0.5ha.

Table 2-17: Projected Irrigation Water Demand per Sub-Catchment

S NO	Water Source	Project Name	Water Demand m^3/day	Potential Ha
1	North Mathioya basin	Mukurwe wa Nyagathanga	12874	200
		Mukurwe Mweru	12874	200
		Witeithie	864	10
		Mithanga Gacogi	3024	100
2	South Mathioya basin	Gakoe	12874	300
		Kanyenyaini	6048	100
		Kaihi	3024	120
		Kiangage	12874	300
		Gacaraigu	1814	60
		Kiawanjumbi	5184	20
3	Maragua river	Mirira	3888	100
		Mbagiki	3456	100
		Gakima	3024	50
		Samar	3629	60
		Makuyu/kakuzi/Ithanga	280,627	5000
		Gitiri	605	10
		Kiangochi	12874	200
4	Sabasaba	NA		NA
5	Thika river	Marigu	1209	26
		Mugiki	1728	25
		Mucika	2938	45
		Ndakaini Wanduhi	3456	52
		Gathwariga	1728	26
		Iria Kiriga	1728	24
6	Irati river	Mukigia	1296	20
		Kamukabi-Gatumbi-Gachocho	5184	100
		Kioneki	6480	100
		Kamiraha	518	20
	Total		**405,822**	**7,368**

There are proposed irrigation projects whose field data and the accompanying designs have not been prepared and are estimated to cover 9,685ha and thus exploit the full irrigation potential of the county.

c) *Livestock Demand*

Based on total livestock units (LUS) for Murang'a County as indicated in **Table 2-18**and daily water demand of 80l/LU the total livestock water demand is computed in Table 2-19. The base year is 2009 based on the data collected in the last census report.

Table 2-18: Total Livestock Units in Murang'a County per Water Scheme Area

WATER SUPPLY SCHEME	Area	LIVESTOCK UNITS			
	KM²	2009	2017	2020	2035
Gatango Scheme (Rural)	84.00	9,968.00	10,337.00	10,368.00	10,525.00
Gaturi Scheme (Rural)	103.00	12,237.00	13,138.00	13,177.00	13,376.00
Mathioya Scheme (Rural)	139.00	16,538.00	17,755.00	17,809.00	18,078.00
Kahuti Scheme (Rural)	332.00	39,457.00	42,360.00	42,487.00	43,129.00
Murang'a Scheme (Rural)	20.00	2,341.00	2,513.00	2,520.00	2,558.00
Gikundi Scheme (Rural)	83.00	9,837.00	10,561.00	10,593.00	10,753.00
Kigumo Scheme (Rural)	296.00	35,350.00	38,294.00	39,460.00	45,846.00
Kandara Scheme (Rural)	528.00	131,566.00	135,125.00	136,519.00	144,027.00
Gatanga District	250.50	136,956.00	99,113.00	99,409.00	100,909.00
Maragua Ridge Scheme (Rural)	78.00	9,295.00	10,069.00	10,376.00	12,055.00
Makuyu Scheme (Rural)	288.00	34,477.00	37,348.00	38,485.00	44,714.00
Total Livestock Units (LU)	**2,201.50**	**438,022.00**	**416,613.00**	**421,203.00**	**445,970.00**

Source: *Feasibility study and master plan for developing new sources of water for Nairobi and satellite towns–Master Plan Report*

Table 2-19: Livestock Water Demand Projections

WATER SUPPLY SCHEME	Area	LIVESTOCK WATER DEMAND M³/DAY			
	KM2	2009	2017	2020	2035
Gatango Scheme (Rural)	84	797.44	826.96	829.44	842
Gaturi Scheme (Rural)	103	978.96	1051.04	1054.16	1070.08
Mathioya Scheme (Rural)	139	1323.04	1420.4	1424.72	1446.24
Kahuti Scheme (Rural)	332	3156.56	3388.8	3398.96	3450.32
Murang'a Scheme (Rural)	20	187.28	201.04	201.6	204.64
Gikundi Scheme (Rural)	83	786.96	844.88	847.44	860.24
Kigumo Scheme (Rural)	296	2828	3063.52	3156.8	3667.68
Kandara Scheme (Rural)	528	10525.28	10810	10921.52	11522.16
Gatanga District	250.5	10956.48	7929.04	7952.72	8072.72
Maragua Ridge Scheme (Rural)	78	743.6	805.52	830.08	964.4
Makuyu Scheme (Rural)	288	2758.16	2987.84	3078.8	3577.12
Total Water Demand	**2201.5**	**35,041.76**	**33,329.04**	**33,696.24**	**35,677.6**

The total current livestock demand in maragua catchment is7457 m³/d following the table 2.19.

2.4.4. Hydro-Power Generation

The project area has potential for small hydro's which has not yet been fully exploited. Such is to generate hydropower need to support Tea industry and for household use. It is to be noted that the area has many tea farms and tea drying centers and household in need of power supply. The current permitted water demand for hydro power in Maragua catchment is **1,523,260m³/d.**

Downstream of river Maragua, there are Wanjie and Mesco power stations of 7.4MW and 0.38MW respectively. The Government supports development of small hydro's by continuously collecting hydrological data, enabling dissemination of information on small hydro's and formulation of feed in tariff policy attracting investors.

Establishment of such small hydro's are only viable where river flows are well maintained and the county needs to keep this hydro potential available.

Table 2-20: Major hydro Stations Power Demand

Name	Installed capacity(MW)	River abstracted from	River discharged to	Licensed flow(m³/s)	Rated flow(m³/s)
Wanji	5.4	Mathioya	Maragua	6.25	4.86
Wanji	2.0	Maragua	Maragua	4.26	3.06
Tana (1)	6.4	Maragua	Tana	3.96	Unknown
MESCO	0.4	Maragua	Maragua	3.68	Unknown

NOTE (1): TANA HEP STATION ALSO HAS AN INTAKE ON THE TANA RIVER DRIVING A SEPARATE SET OF TURBINES WITH 8MW INSTALLED CAPACITY.
Source: *TNWSP – Northern Collector Feasibility Study Report by Howard Humphreys, 1998*

Wanjii hydroelectric power plant is located near Murang'a town approximately 90km from Nairobi and comprises four horizontally mounted turbine generators with ratings of 2.7MW each for units 1&2 and 1.0MW each for units 3&4 giving a total installed capacity of 7.4MW. The plant was commissioned in 1950 and utilizes water from Mathioya river to the north of Murang'a via an underground tunnel beneath Murang'a town feeding Units 1&2 and an open channel and penstock from Maragua river feeding Units 3 & 4.

KENGEN has in the recent year embarked on a mission of rehabilitating Wanjii and Mesco power plants which were constructed in the 1950's and 1930's respectively at a huge investment cost. There are other small hyro-power projects in Maragua catchment as highlighted in table 7 which represents existing investments whose sustainability should be guaranteed in water allocation planning.

Table 2-21: Permitted Demand for Hydro Power Stations in the Maragua Basin

NAME OF APPLICANT	Source of Water	Drainage Area	Power (m^3/day)	CLASS OF PERMIT	PURPOSE	REMARKS
KENGEN (Maragua Mesco)	Maragua river	4BE	317,865	D	Power generating 100% returnable	PE
KENGEN (Maragua Furrow B)	Maragua furrow b (river)	4BE	342,363	D	Power generating 100% returnable	PE
KENGEN (Maragua Furrow A)	Maragua furrow a (river)	4BE	317,865	D	Power generating 100% returnable	PE
KENGEN (Wanjii Power Station - Maragua Intake)	Maragua river	4BE	368,181	D	Domestic use &power generating 100% returnable	PE
Francis Ndung'u Nyanjui	Maragua	4BE	470	A	Domestic, general irrigation & industrial	AU
Asa Karanja Solomon	Maragua	4BE	817	C	Domestic, general irrigation & power	AU
Murang'a School For The Deaf	Maragua	4BE	2,862	C	Domestic & power	AU
Murang'a School For The Deaf	Maragua river	4BE	34	A	Domestic & power	AP
Ikumbi Tea Factory Company Limited	Maragua river	4BE	172,800	D	Hydro-power	AU-CW
Total Demand in m^3/day			**1,523,260**			

Source Detailed Design and Supervision for Murang'a North and South Bulk water Supply Design report1

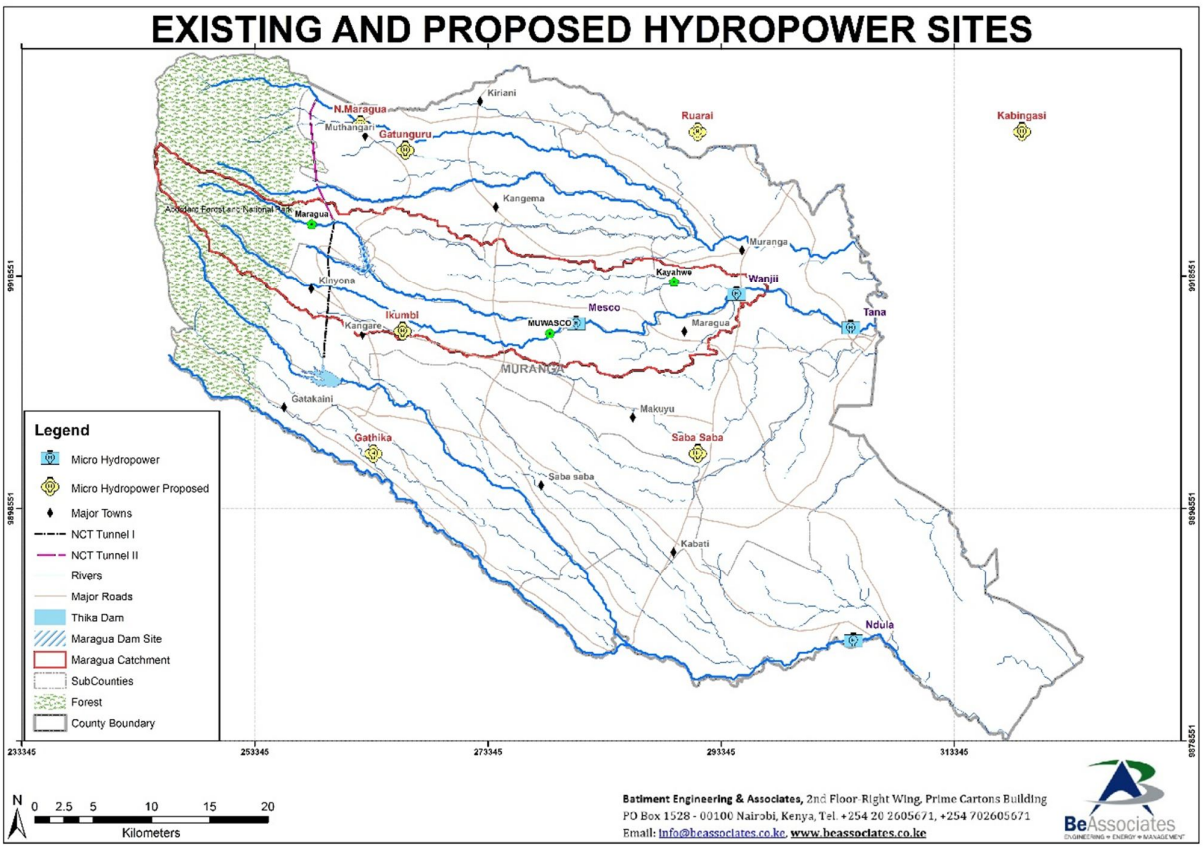

Figure 2-25: Existing and Proposed Hydro Power Plants

It should be noted that the Northern Collector Rivers are all tributaries of the Tana River which is the source for the chain of HEP dams: Masinga, Kamburu, Gitaru, Kindaruma and Kiambere with a total installed capacity of approximately 500MW. Water diverted by the Northern Collector is passed to Nairobi for consumption. However, sewage from Nairobi is discharged to the Athi river. The Northern Collector diversions therefore represent a net loss of water from the Tana River system and therefore a loss of potential hydropower both in the local run-of-river schemes and in the major power stations on the Tana.[17]

2.4.5. Ecological Water Demand

Environmental flows provide the flow regime required for maintaining downstream river ecosystems in a desired state, and for maintaining riverine ecosystems and their benefits. Natural flow variability is one of the most important components of any healthy river. It is not only the amount of water

[17] *TNWSP – Northern Collector Feasibility Study Report by Howard Humphreys, 1998*

in a stream, but its variability that supports species, habitats, and environmental processes. Earlier efforts at defining in-stream flow requirements led to the development and setting of minimum flows. Application of these methods usually resulted in a single fixed minimum flow value, below which water may not be withdrawn for consumptive use.

In practice these minimum flow values are almost always less than optimal. There is a growing international consensus (Hirji and Lintner, 2010)[18] that environmental flows should be described in terms of seasonal low flows, as well as the magnitude, timing and duration of flood events. It is the flow regime that is important, rather than a fixed minimum flow. A full range of natural hydrologic regimes is considered as an essential element for sustaining the riverine environment. It is now also recognised by water resources scientists that *Minimum Flow Standards tend to provide Minimum Protection*.

Four guiding principles about the influence of flow regimes on aquatic biodiversity are recognised.

Principle 1: Flow is a major determinant of physical habitat in streams, which in turn is a major determinant of biological composition.

Principle 2: Aquatic species have evolved life history strategies primarily in direct response to the natural flow regimes.

Principle 3: Maintenance of natural patterns of longitudinal and lateral connectivity is essential to the viability of populations of many riverine species.

Principle 4: Alteration of flow regimes is likely to facilitate the invasion and success of exotic and introduced species in rivers. Increase in exotic species is likely to have a negative impact on indigenous species.

Water management problem solving has now matured from the setting of fixed minimum flows to a recognition of the need to set incremental methods in which the requirement of aquatic habitats are quantified as a function of discharge.

In the absence of detailed long-term ecological studies (which often tend to focus only on individual species) the widely used index for determining minimum Environmental Flow Release (EFR) requirements is the index of natural low flow, Q_{95}. However, release of a constant Q_{95} flow is equivalent to

[18]Rafik Hirji and Stephen F. Lintner (2010) Environnemental Flow Assessments to Conserve Aquatic Ecosystems: World Bank Experience. Washington, DC: The World Bank.

a constant extreme low flow – similar to a constant drought flow. Q_{95} flows are therefore seen as the minimum flow, beyond which abstraction must not occur, and it is strongly recommended that environmental flows should not be defined as constant releases but should be variable in a manner that is similar to the natural hydrograph on a seasonal basis.

2.4.6. Other Downstream Counties

The water from Murang'a County pass through Machakos, Kitui, Tana river among other counties. There are irrigation projects in these counties which require 486,046m^3/day. Apart from the irrigation needs in the downstream counties, there is growing of population centres and development plans to increase water supply coverage. Given that the counties depend on the rivers coming from the eastern Aberdare, it is imperative that they be considered in water development projects for sustainable utilizations.

Table 2-22: Potential Irrigation Demand Downstream

S NO	County	Project name	Potential Ha
1	Machakos	Ndithini	1200
		Muusini/Njukini	120
		Kauthulini	120
2	Kitui	Nguu	120
		Usueni-Wikithuki	5000
3	Tana River	Majengo Kilindini	2000
		Gubatui	100
			8,660

2.4.7. Water Allocation

Water allocation according to WRMA rules should take care of the reserve and the lawful uses as shown in **Table 2-23**. For domestic water supply schemes this is normally allocation of the normal flow as shown in **Table 2-24**. The rules allows for allocation of normal flows for purposes of drinking water supply schemes and for purposes of irrigation which is presumed to tap flood waters, at least a 90 day storage is encouraged.

Table 2-23: WRMA Guidelines on Estimating Normal and Flood Water Available on a Particular Water Source

Methodology for Estimating Normal and Flood Water Available on a particular water course		
Step	**Action**	**Remarks**
1	Develop Flow Duration Curve based on naturalized daily streamflow data	Utilisation of reliable historic records(when abstraction was significantly less than at present) maybe used
		The hydrological records should be representative of the hydrological unit under consideration
2	Extract the Q_{95},$Q_{80}$and Q_{50}values(m^3/day) from the naturalized flow duration curve	
3	The Reserve is not less than the equivalent to the naturalized Q_{95}(m^3/day)	
4	Normal Flow available for allocation (NF) =(Q_{80}-Q_{95})(m^3/day)	This method provides a reasonable estimate on which to base allocation decisions.
5	Normal Water available for allocation toany new application=(Q_{80}- Q_{95})– (Sum of existing allocations from normal flow)(m^3/day)	The existing allocations may include bulk transfers. Existing allocations upstream and downstream should be considered within the boundaries of the hydrological unit
6a	Flood Volume available for allocation(FV) =Area above Q_{80} on the Flow Duration Curve (m^3/year)	This approach makes the assumption that the probability of occurrence overranentire record period is reasonably similar to what might be expected in any one "average "year. This provides an estimate of the Average Flood Volume (m^3/year).
6b	Establish a time series of Annual Flood Volumes (AFV) based on a summation of daily flood volume(DFVi =Qi –Q_{80})where DFV is daily flood volume on day Iand Qi is the actual daily flow on day i. Undertake a frequency analysis to determine the AFV value with 80% reliability (i.e.fails once in 5 years).m^3per year	This is likely to result in avalue that is more conservative than the methodology shown above (6a).
7	Flood Water available for allocation to any new application =FV – (Sum of existing allocations from flood volume) (m^3/year)	All existing allocations should be translated into a volume per year

Source: WRMA Water Allocation Rules

The reserve amount is set at 95% value of the naturalized daily flow duration curve for each river in accordance with WRMA Guidelines for Water Allocation. The probability applied is once in 10years which was determined based on the discussion with WRMA. This criterion has been

discussed in detail by Egis/MIBP feasibility report and suggested that reliability based on actual number of times supply failed is more realistic.

From the discussions on ecological flows and the suggestions in the ESIA report, the environmental flow should be at least Q95 below which no allocations should be done given the significance of the flows in this catchment.

Table 2-24: Prioritisation of Water Allocation

Priority	Water Use
1	Reserve consisting of ecological and basic human needs
2	Existing water uses for domestic, industrial, irrigation and hydropower, and existing inter-basin transfer water (International obligation to allocate water is not considered, because there is no international commitments so far.)
3	New domestic and industrial water uses
4	New livestock, wildlife and inland fishery water uses
5	New irrigation water use
6	New hydro power generation use

Source: JICA Study Team, based on the Guidelines for Water Allocation (First Edition, 2010) and Water Act 2002

2.4.8. Compensation and Potential Impacts Downstream

The aim of flow compensation is to sustain basic human needs, ecosystem functions and lawful permitted uses downstream of the abstraction point. Compensation flows are distinct from environmental flows and are set for purposes such as downstream human uses (e.g. irrigation, livestock, and hydropower, industrial or domestic use). For the NCT project compensation has been set according to the **Table 2-25**shown. It is clear that the proposed compensation flows at the NCTI intake is equivalent to having a sustained low flow or drought condition downstream.

It is important to note that the abstraction level where Q95 is much lower than the low flows that are expected towards the end of the dry season just before the onset of the rainy season.

Table 2-25: Comparison of Proposed Compensation Flows

River	Compensation flow provided		Required Compensation flow (ESIA)	Fish habitat requirement (ESIA)	Lowest natural mean flow	Compensation Flow With HEP (m^3/sec)	proposed Compensation (Egis/MIBP)	
Gikigie	Q95	0.100	1.32Q95	0.133	0.18	0.256	2Q95	0.200
Irati	1.4Q95	0.481	2.15Q95	0.989	0.67	0.788	2Q95	0.687
Maragua	Q95	0.645	Q95	0.259	0.98	1.125	2Q95	1.290

Note: HEP=Hydro-electric power stations (these refer to stations in1998)

The yield analysis of the scenario when compensation is at 2Q95 shown to still yield half the project yield that is required if there is no additional storage in the system as shown in the **Table 2-26**.

Table 2-26: Simulated Yields for the Existing System with NCI

Component	Without Operational Rules		With Operational Rules For Thika Dam Only	
	Q95	2xQ95	Q95	2xQ95
Mwagu	**4.80**	**4.80**	**4.80**	**4.80**
Additional Thika Yield	**1.68**	**0.85**	**1.23**	**0.50**

Source: feasibility study and master plan for developing new water sources for Nairobi and satellite towns – master plan report.

The foregoing indicates that the final design of the system did not take into consideration the recommendation of the feasibility reports. It is recommended then that compensation flows should be set at a minimum of 2Q95 for the NCTI projects. This is supported by analysis of the ESIA of the feasibility study in Box 3.

Furthermore the feasibility reports concludes "*The compensation flow requirements will be higher today, thereby reducing the net yield that is available to the Nairobi Water Supply or any other requirements. Hence, future schemes are only sustainable with adequate storage provision from which to supplement yield in low flow periods*[19]."

[19] *Feasibility Study and Master Plan for Developing New Water Sources for Nairobi And Satellite Towns – Master Plan Report, by Egis Bceom International Mangat, I.B. Patel & Partners Volume 1 November 2012.*

Table 2-27: Estimates for Required Minimum Downstream Reserve Flows (m^3/s), NC Phase 1

River	Water Supply Scheme	Design Capacity	Rural & Urban Demand	Other demand	Estimated Compensation Flow	Q_{95}, [1]	Allocated Compensation Flow	Required Reserve Flow
Irati	Kigumo intake i7a	0.144	0.202	0.067	0.401	0.334	0.401	0.74
	Kigumo intake i7b	0.132	0.008					
Gikigie	-	-	-	0.073	0.073	0.101	0.101	0.20
Maragua	Kahuti Ph 4	0.378	0.059	0.073	0.482	0.65	0.65	1.29
	Maragua Ridge	0.017	0.031					

Q_{95} flows based on naturalised 1970-2010 time series estimated at proposed intake sites Source: Water Sources Options Review Report (August 2011).

Table 2-27 indicates the recommended compensation downstream of the abstraction points given the for NCTI rivers in Maragua catchment. The feasibility report further concludes that for the project to meet the target of increasing the yield by 1.6m^3/s, then the tunnel will need to extended northwards so that the demands downstream are maintained and the intended yield is attained.

Box 3: Impact of NCT Abstraction on Downstream River Ecosystems

....These examples from the Irati River illustrate the seasonal nature of natural flows to which all riverine and riparian environments are adapted. They also illustrate how the release of only Q_{95} flows as downstream environmental flows would be similar to long-term drought conditions.

If the release of environmental flows is limited to only Q_{95} flows, without supplementary higher flows, there will be unacceptable negative environmental impacts downstream of the intakes along the Northern Collector tunnel.

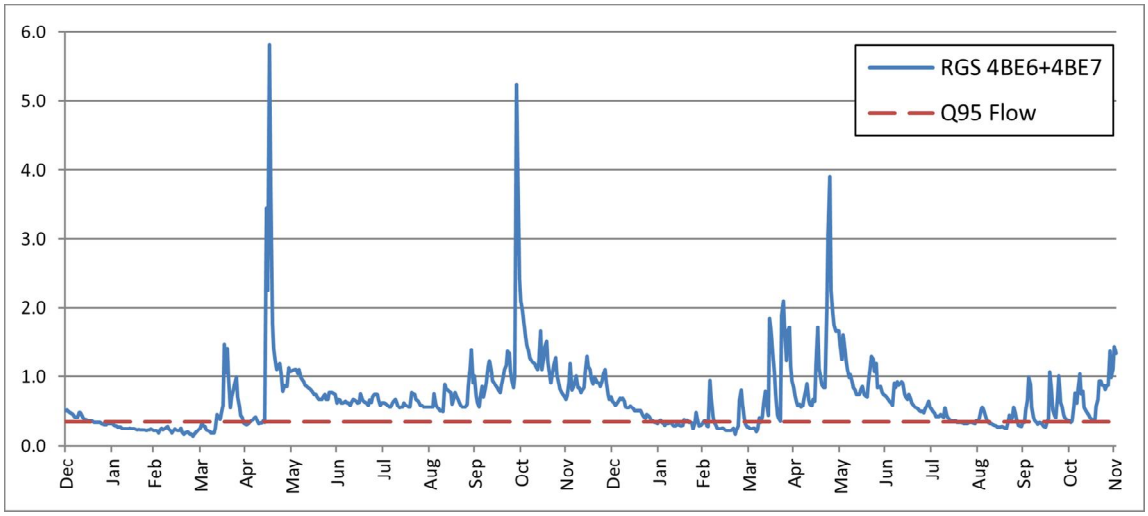

Figure 2-26: Example of flows during a relatively dry period - Irati River 1975-1976 (RGS 4BE6 and 4BE7 combined flows m3/sec)

Source: *Feasibility Study and Master Plan for Developing New Water Sources for Nairobi and Satellite Towns Version 03.... Page 27*

The ESIA prefeasibility report had observed that:

"The abstraction of water at the proposed sites for the Northern Collector Tunnel, Phase 1 will inevitably result in the creation of a relative water scarcity situation downstream of these sites. The following Policy Message and Recommendation from the "Kenya, State of the Environment and Outlook 2010" Report 20 are particularly relevant when considering the requirements for operating rules for downstream Reserve Flows below the abstraction sites "

> ***Policy message:*** *Given the linkages between water and human and environmental health as well as the major sectors of the economy, access to clean and safe water in adequate quantities is a prerequisite for the attainment of Vision 2030. It is therefore vital that measures are urgently instituted to address the water scarcity challenge that the country is currently*

[20] *KENYA State of the Environment and Outlook 2010- Supporting the Delivery of Vision 2030. Summary for Decision Makers, National Environment Management Authority, NEMA (2011)*

grappling with especially in light of the fact that this crisis is projected to rapidly worsen as population increases and climate change and their derivative effects take their toll.

Recommendation: *Ground the concept of integrated water resources management (IWRM) which takes cognizance of the multi-faceted nature of water problems and calls for comprehensive management of water resources based on an ecosystem approach and an appreciation of the needs of the diverse users and the broad range of potential impacts of water use.*

2.4.9. Water Balance

Water balance looks at the supply and demand side of water. This will be based on the aforementioned report which tends to validate the design for NCTI project which in this case affects Maragua catchment.

The water balance should attempt to consider both the licensed and unlicensed water users in the catchment. This can be accurately described by carrying out an abstraction survey. There are also likely to be numerous unlicensed abstractions, and these will all need to be accounted for and included in the formal licensing system. The licensing system and allocation of licenses will need to be modified to take account of the upstream abstraction on these rivers for the Northern Collector tunnel, Phase 1.

Water for agricultural production is largely dependent on rain water. However, there have been increasing instances of crop failures. This has made rain fed agriculture unreliable in many areas. As a result, irrigated agriculture is becoming increasingly important even in areas where irrigation would not have been considered earlier. Together with the increasing population of Nairobi which will require increasing food supplies, this is most likely to result in a demand for increased use of water resources for irrigated agriculture.

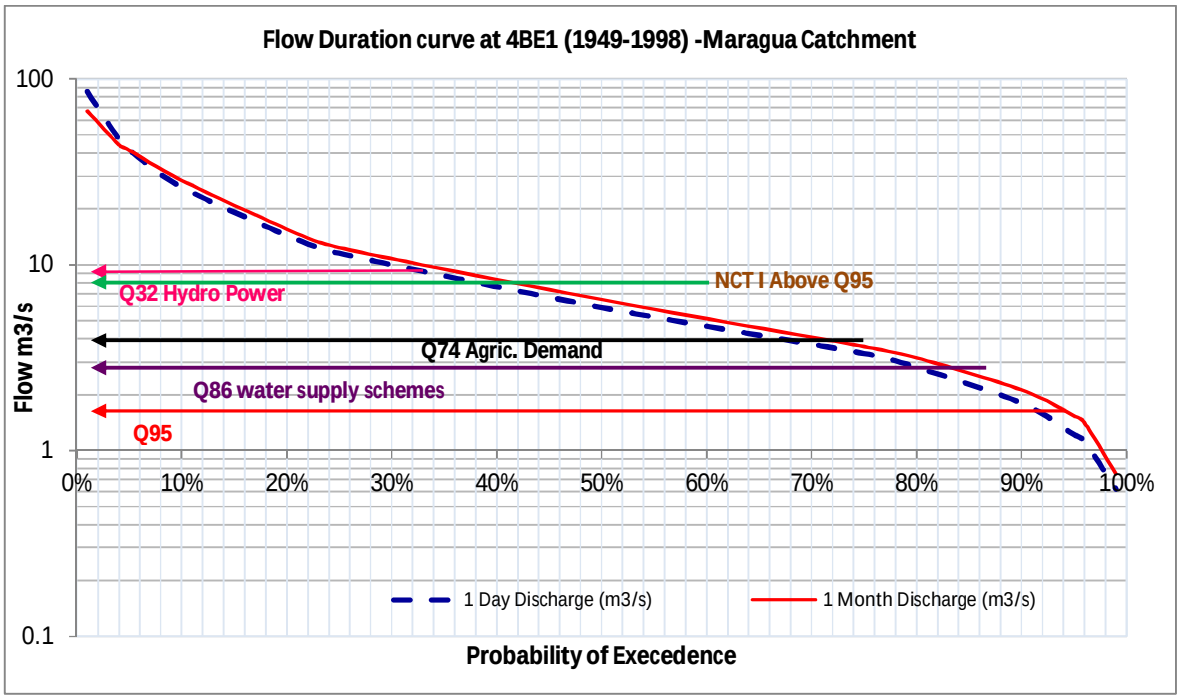

Figure 2-27: Current Water Demand Scenario in Maragua Catchment

The water balance will consider consumptive uses and hydropower needs upstream of the catchment observation station at 4BE1 on Maragua River which takes into account the whole Maragua catchment. **Figure 2-27**indicates that flow of 2.72m^3/s is the mandatory flow that is currently needed at 4BEI to guarantee that environmental and water supply needs in Maragua catchment. To guarantee irrigation demand, a flow of 3.38m^3/s is necessary to be left in the catchment. On the flow duration curve **Figure 2-27**, it is clear that the amount of water NCTI is seeking to abstract at the maximum is equivalent to Q40, even before allocating to other demands. NCTI together with other water supply project demands is will be at an allocation of Q30. This has a potential of drying the river during normal flows where all the demands considered will have no option but to use the flows below Q95 which should be reserved for environmental and ecosystem services of the riverine ecology and basic human needs.

Table 2-28: Summary of Current and Future Water Demand in Maragua Catchment

Water Demand Maragua Catchment (425km²)	Current (m³/d)	2030 (m³/d)
Water Schemes (Permitted Abstractions)	95,500	97,946
Estimated population using streams, Water requirements at 60 L/day per person (m³/day)	10,280	6,168
Livestock Demand (90870 LUS @80L/day)	7, 457	12,722
Irrigation (Permitted by WRMA)	6,121	
Irrigation Demand (Existing Small holder irrigation schemes 1120ha)	43,372	364,953
Sub-Total	**162,730**	**481,789**
Hydropower (Permitted on River Maragua)	1,523,260	1523260
Total	**1,685,803**	**2,005,049**
NCTI	518,400	518,400
Grand Total	**2,204,203**	**2,523,499**

Evaluation of future water demand in year 2030 **Figure 2-28**, a major increase is expected mainly due to increase in irrigation water supply needed to fund the projected development of irrigation schemes by NIB and the County Government. The flow needed in the catchment to satisfy water supply and environmental flow is 2.85m³/s. To satisfy irrigation demand, a flow of 7.07m³/s will be required to be retained in the catchment. This translates to a flow of Q46. This flow can only be useful in Murang'a County if storage is included in the planning for water supply. The scenario indicates that NCTI will be abstracting a flow equivalent to Q40 above Q95. This leaves the catchment with flows below Q95 and above Q40. This will leave the catchment with flows that are not sustainable.

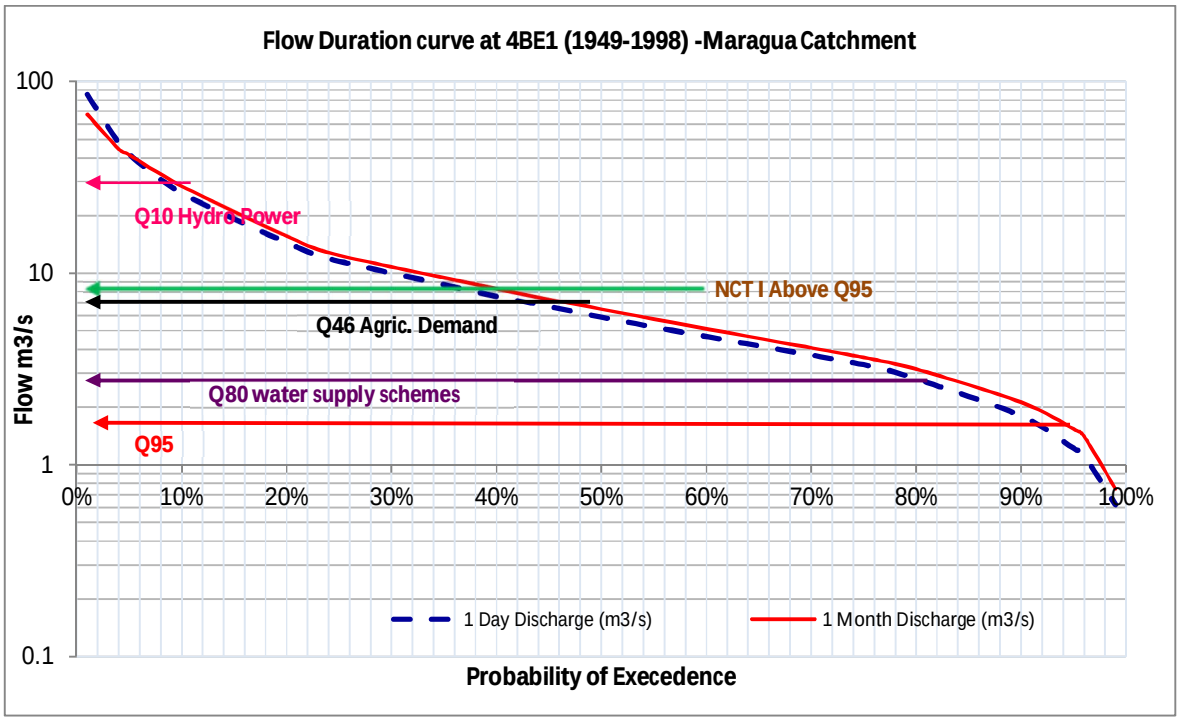

Figure 2-28: Water Scenario in 2030 on FDC curve

Looking at the recommendations of the ESIA report and the water balance of the ESIA report indicated here in **Table 2-29** and **Table 2-30**, it is clear that the water balance did not consider existing water demands downstream and upstream of NCTI abstraction points. Moreover, the report did not consider Maragua catchment of which the three rivers are the main tributaries of the catchment. However, from the water balance in the tables, considering average annual flows, NCTI will be allocated 95% of the total naturalized flows and all the other water schemes and demands will be left with 5% to share among the environment, water supply, basic human needs and ecological demand. This is clearly a scenario that is unacceptable. ,

Table 2-29: Summary flow computations for the Northern Collector Rivers

River	Average annual flow			Compensation flow		Water balance after compensation flow P.a.
	Average annual flow (m^3/sec)	Average annual flow (m^3/day)	Total per year (m^3/year)	(m^3/day)	m^3/year	m^3/year
Maragua	2.01	173,664.8	63,387,652	41,558.4	15,168,816	48,218,836
Gikigie	0.61	52,704	19,236,960	8,726.4	3,285,136	15,951,824
Irati	1.64	141,696	51,719,040	55,728.0	20,340,720	31,378,320
Total	**4.26**	**368,064.8**	**134,343,652**	**106,012.8**	**38,694,672**	**95,648,980**

Source: ESIA final report December 2014.

The average maximum annual flows which was assumed to represent the flooding scenario, indicates that flow of 7.87m³/s will remain in the river after NCTI allocation, however, this is an erroneous way of evaluating the water balance scenario, this is clearly indicated in the FDC curve at 4BE1 which indicates the actual scenario. To establish the flood water, the remains, the analysis ought to have separated the flow components into quick flows (flood water) and slow flows (base flows) after which allocation of flood water and water balance should have been done.

Table 2-30: Comparison of average annual maximum flood flows with the proposed

	Average annual maximum (flood)flow			AWSB maximum weir intake in the design		
	Average annual max flow(m^3/ sec)	Average annual max flow(m^3/ day)	Total per year(m^3/ year)	m^3/sec	m^3/day	m^3/year
Maragua	5.74	495,936	181,016,640	3	259,200	94,608,000
Gikigie	2.6	224,640	81,993,600	1	86,400	31,536,000
Irati	5.53	477,792	174,394,080	2	172,800	63,072,000
Total for three rivers	13.87	1,198,368	437,404,320	6	518,400	189,216,000
Water balance of the flood that will remain in the river after AWSB abstraction				7.87	679,968.0	248,188,320.00

Source: ESIA final report December 2014

2.5. Hydraulic designs and abstraction

2.5.1. General project description

The Northern Collector Tunnel (NCT) Phase 1 is a proposed new raw water transfer tunnel along the eastern fringe of the Aberdare Conservation Area approximately 60km north of Nairobi. The tunnel project will transfer raw water through approximately 11.8km from intakes at the Maragua, Gikigie and Irati Rivers to an outlet at the Githika River near Makomboki trading centre, upstream of the existing Thika Reservoir. The intake points on these rivers are about 5km from the eastern edge of the Aberdare Conservation Area

The principal features of the NCT Phase 1 include the following:

a) River diversion weir and related intake hydraulic structures at Maragua River including:
   - 20m wide, 5m high weir including trench diversion intake
   - 37m long, 4m deep de-silting basin
   - Compensation channel

b) River diversion weir and related intake hydraulic structures at Gikigie River including:
    - 14m wide, 3.3m high weir including trench diversion intake
    - 7m long, 2m deep de-silting basin
    - Compensation channel
c) River diversion weir and related intake hydraulic structures at Irati River including:
    - 20m wide, 4.4m high weir including trench diversion intake
    - 25m long, 2m deep de-silting basin
    - Compensation channel
    - Drop shaft and connection gallery connecting the Irati intake to the main tunnel
d) River outlet at Githika River including:
    - Cut and cover portal outlet from the main tunnel
    - 20m long outfall stilling basin structure

e) Main Northern Collector Tunnel Phase 1 (main tunnel) including portals, excavation, initial support and permanent concrete lining. The tunnel is approximately 11.8km long and of 3m finished internal diameter:
    - Connection adit from Githika tunnel to the main tunnel;
    - Drop Shaft and connection adit at the Irati intake;
    - Access gallery from Kaanja Valley to the main tunnel.

2.5.2. Review of hydraulic design and arrangement

a) Overflow Weirs Designs

The Overflow Weir dimensions are designed for the 100 year flood which is a standard practice as recommended in the Practice Manual for water supply service in Kenya for design of spillways and weirs as a minimum recommended level.

The source of the river was selected and determined to be suitable for domestic water supply abstraction through studies by Howard Humphreys in 1998 and Egis BCEOM and IB Mangat in the Feasibility study and Master plan for developing new water sources for Nairobi and satellite towns. The sources identified for NCT phase I were determined to pass the 96% reliability and yield analysis through the hydrological studies done in the aforementioned studies. WRMA rules for water recommends that domestic water abstraction should be based on normal flows and conversely then should form the basis of checking the reliability of a source and which is a higher threshold than Q96 proposed in the design manual. The summary of the overflow weir design is indicated in

Table 2-31

Table 2-31: Overflow Weir Sizing:

Parameter	MaraguaWeir	GikigieWeir	Irati Weir
Abutment edge radius, r			
Upper limit, r_{max}=0.5Hd	0.720	0.600	0.720
Lower limit, r_{min}=0.15Hd	0.216	0.180	0.216
Provided, r	0.500	0.400	0.500
Abutment contraction coefficient(chart),K_a	0.1	0.1	0.1
Required net length, $L_{req}=L_{ereq}+2(NK_p+K_a)H_e$	19.469	13.441	19.230
Provided net length,L(m)	**20.000**	**14.000**	**20.000**
Provided effective length,	19.712	13.76	19.712
Maximum discharge head over weir during 1 in100yearflood event, H_m(m)	1.80	1.50	1.80
Design head, H_d based on maximum H/H_d= 1.25,(m)	1.44	1.20	1.44
Weir crest height above river bed level, P(m)	**5.0**	**3.3**	**4.4**

Source Final Design Report for the Northern Collector Tunnel Phase I, SMEC December 2013

Other facilities downstream of the weir like the apartment walls, the flow dissipation facilities are of sound engineering design and consideration i.e the choice of the stilling basin and aprons.

b) Intake Trash Rack, Channel

The concept and design of the intake trash rack and channel is based on standard sound engineering practice and design standards that are acceptable locally and globally. The arrangement and design is optimal based on the rating curves and flow surface profile as indicated in the design report by SMEC.

Table 2-32: Intake Weir and Trash Rack

Trench Intake location	Sloping Length of trash rack,L(m)	Inclination,(degrees)	Horizontal breadth of trench, W (m)	Width of trash rack,B (m)
Maragua	1.870	27	1.700	5.600
Gikigie	1.342	27	1.300	2.900
Irati	1.625	27	1.500	4.500

Source Final Design Report for the Northern Collector Tunnel Phase I, SMEC December 2013

c) *Compensation Channel and Fish Passes*

The compensation flows as designed to meet in stream flow requirements are shown in the table 3 below. This has been provided for based on one of the scenario analysis done in the feasibility report by Egis BCEOM/IBMP JV.

Table 2-33: Design Compensation Flows

Name of Intake	Required minimum compensation flow, Q (m^3/sec)	
Maragua	Q_{95}	0.645
Gikigie	Q_{95}	0.100
Irati	$1.4Q_{95}$	0.481

Source Final Design Report for the Northern Collector Tunnel Phase I, SMEC December 2013

The operational requirement of the compensation channel is considered in three phases as follows:

- At low river flows, i.e. not exceeding the required minimum compensation flow$Q<Q_c$), the compensation channel gate is fully open and all flows are permitted through the compensation channel gate under free flow condition. The low flows are not permitted through the diversion intake until the required minimum compensation flow is satisfied.
- At higher river flows, i.e. exceeding required minimum compensation flows but excess not exceeding intake diversion capacity ($Q>Q_c$and $Q-Q_c< Q_d$),the compensation channel gate is partially open to only permit the minimum compensation flow(Q_c) and divert the excess ($Q-Q_c$)to the tunnel intake. The head of water behind the compensation gate contribute to pressure flowt hrough the gate orifice.
- At river flows exceeding the required minimum compensation plus maximum diversion flows (i.e. $Q>Q_c+ Q_d$), the compensation channel gate is fully closed. The excess of diverted flow(i.e. $Q-Q_d$) is passed to the downstream through the main overflow weir, and exceeds the required minimum compensation flow.

Compensation Flows for Ecological (NB not IFR/Reserve) recommended in the ESIA report by GIBB 2014 are shown in **Table 2-34**, which indicate that actually for rainbow trout fish requirement, the compensation flows are not

sufficient for Gikigie and Irati rivers as provided for in the design. This seem to agree with the ESIA report done by Egis BCEOM/IBMP JV and the scenario analysis and recommendation in the feasibility report that suggested that at Q95, the river system will experience a permanent drought situation for most of the times and recommended the release of at least 2Q95 based on preliminary downstream demand analysis.

The water allocation guidelines published by WRMA in 2009 recognise that design criteria proposed by the Ministry of water design manual 2005 for design of a water supply intake, designed to capture or abstract the Q96would be capable of abstracting the entire remaining flow of a river which would violate the requirements of the Reserve.

It is recommended that the design of water supply intakes recognizes the requirements of the Reserve and include adequate storage or alternative sources to ensure that (i)the Reserve is not violated and

- The required supply reliability is achieved.

In effect this means that the design of a water supply intake must be made within the context of:

i. The normal flow available for allocation and
ii. The existing water allocations. In addition, the intake structure should be designed to release the Reserve at all times.

Table 2-34: Recommended Compensation Flows by ESIA

River	Required Compensation flow	Fish habitat requirement	Lowest natural mean flow
Gikigie	1.32Q95	0.133	0.18
Irati	2.15Q95	0.989	0.67
Maragua	Q95	0.259	0.98

Source ESIA on Northern Collector Tunnel Phase I, GIBB Africa December 2014

Comments on the design:

a) The design does not allow low peak flood impacts to be passed downstream which is important for riverine rejuvenation and was an observation made by Preliminary EIA for the Selected Scenario: Nairobi Water Sources, Phases 1 & 2 by Egis BCEOM and IB Mangat version 03 of December 2011

b) The compensation flows are controlled by a weir which converts to an orifice, this can be abused in operation by complete shut off and diversion

c) It is recommended that to guarantee flow downstream, a diversion channel should be made that will not be shared in the same intake works as proposed in the design which can be monitored and operated by in depended operators or designed in such a way that it is in depended of the control structures that allow water into the tunnel.

Fish Passes

The fish pass is intended to provide a migration route for fish which bread upstream or otherwise. The fish ladder is adequate for purposes of design however, the arrangement is not very clear and it needs to be clarified.

Table 2-35: Summary Design for Fish Pass Ladder

Item	Parameter	Maragua Intake	Gikigie Intake	Irati Intake
1	**Weir parameters**			
	Highest headwater level, m.asl	2079.67	2075.20	2114.25
	Lowest tailwater level, m.asl	2073.50	2071.50	2109.50
	Maximum drop height, h_{tot}(m)	6.17	3.70	4.75
2	**Pool Dimensions and hydraulics**			
	Selected pool dimensions for Rainbow trout			
	Pool width, b(1.6-2.0m)	1.60	1.60	1.60
	Minimum water depth, h (0.8-1.0m)	0.8	0.8	0.8
	Length of pool, l_b(2.5-3 m)	2.5	2.5	2.5
	Thickness of partition wall, d(m)	0.15	0.15	0.15
	The surface of the pool bottoms is roughened using river boulders.			
	The cross-walls are to have bottom orifices, and top notches:			
	Clear orifice span,bs (0.4- 0.5 m)	0.50	0.50	0.50
	Clear orifice height, hs(0.3- 0.4m)	0.40	0.40	0.40
	Width of notches, ba(≥0.3m)	0.30	0.30	0.30
	Height of notches,ha (≥0.3m)	0.300	0.300	0.300
	Water level difference in subsequent pools, Δh (Δhmax= 0.2 m)	0.2	0.2	0.2
	Mean water depth, hm= h+Δh/2 (m)	0.900	0.900	0.900
	Slope for pool pass, I =Δh/lb (%)	8.0%	8.0%	8.0%
	Number of pools needed, n=htot/Δh-1	30	17	23
	Discharge through bottom orifice:			
	Flow velocity in orifices, Vs=√(2gΔh) (m/s)	1.98	1.98	1.98

	Assumed discharge coefficient, ψ (0.65 to 0.85)	0.75	0.75	0.75
	Qs=ψ*As*Vs (m3/s)	0.30	0.30	0.30
	Discharge through top notch:			
	Difference in the water level between headwater and tail water, hweirhead=Δh (m)	0.20	0.20	0.20
	Drowned-flow reduction factor, σ	1.00	1.00	1.00
	Assumed discharge coefficient, μ (0.6)	0.60	0.60	0.60
	Qa=2/3*μ*σ*ba*√(2*g)*hweirhead^1.5 (m3/s)	0.05	0.05	0.05
	Total discharge through pool pass, Q=Qs+Qa (m3/s)	0.34	0.34	0.34
	Check: is recommended discharge through fish pass obtained, Qrec (0.2 - 0.5 m3/s)	OK	OK	OK
	Power density, E=ρ*g*Δh*Q/(b*hm* (lb-d)) (W/m3)	200	200	200
	Check: E≤ 200 W/m3?	OK	OK	OK

Source Final Design Report for the Northern Collector Tunnel Phase I, SMEC December 2013

Comments on the design

i. The level of the notches and orifice with respect to the intake weir is not clear, from the proposed drawings for tender it seem to be at a higher level e.g for Maragua about 2079
ii. The operation of the fish pass is not clear from design it seems that it will be dry most of the time i.e. even at normal flows Q80, flow may not flow through the fish pass
iii. The design report and drawings do not elaborate the arrangement and operational structures at the inlet channel and the control of water between the flume and compensation channel

d) De-Silting Basin, Outlet Weir and Tunnel Inlet and Well Drop Structure

The design of the desilting basin as a flume and outlet weir is adequate to transmit the designed for flows as indicated in
Table 2-36.

Table 2-36: Outlet Weir

Parameter	Maragua	Gikigie	Irati
Q=Flow(m^3/s)	3.000	1.000	2.000
C =discharge coefficient, average	0.620	0.620	0.620
g =gravitationalconstant,9.81m/s^2	9.81	9.81	9.81
h_1=Height of the water over the weir, optimized w.r.t weir width(m)	0.642	0.490	0.535
Therefore$_1$=width of the weir, (m)	2.001	1.000	1.750

The feasibly analysis and scenario analysis indicated that they would additional yield at Thika dam with the introduction of NCT I and NCT II into the dam as indicated in **Table 2-37**However the storage ratios goes down dramatically and it is recommended that control structures be put in place at the NCT tunnel intake strictures to avoid a scenario of transferring the flood into the Thika river system outfall at the Thika dam. This is clearly demonstrated in

Table 2-38

Table 2-37: System Yield Analysis

	System Yield(m^3/s)	
Component	**NCI**	**NCI+NCII**
Mwagu	4.80	4.80
Additional ThikaYield	1.40	3.30

Table 2-38: Thika Dam Storage Ratios

Project Phase	MAI(m^3/s)*	MAI(Mm^3/Year)	Storage/MAI
Existing(Thika Dam Natural Inflow)	2.49	78.5	0.87
ThikaDam+NCI	4.96	156	0.44
ThikaDam+NCI+NCII	8.40	265	0.26

*MAI is net of releases for Downstream Users

The consistent reduction of Thika Dam's Storage Ratio after introduction of NCI I and NCII indicate the constrained ability of the reservoir to provide storage for the additional inflow. Therefore, more frequent spills can be expected.

However, these can be partially regulated by providing controls at the River Intakes for NCI and NCII. The incorporation of control structures would effectively reduce the frequent spills expected on Thika dam. It was also observed that the storage capacity of Thika dam cannot be increased and therefore storage in the catchment was the other option of guarantying sustained yield as shown in the recommendations and simulations of the option of Maragua 4 dam in the feasibility report.

e) Tunnel Hydraulic Design

The tunnel hydraulic design has taken into account the anticipated NCII project flows as estimated in the feasibility report by Egis/IBMP JV.

f) Outfall Structures at Githika River

The outfall at Githika River is designed to allow flows from all the NC projects. The flow energy is sufficiently dissipated to allow uniform flow downstream into Thika dam. However, it is not clear what happens at the outfall during rainy seasons when Githika river floods and the tunnel will be delivering design discharge which is a much larger than the average flooding in Githika River.

Part III: Environment and Conservation

Kenya has only five water towers which are faced with severe degradation due to anthropogenic activities. Without their protection and conservation the ecosystem services and water security in the country would worsen having a negative effect on the economic development of Kenya and the living conditions of its population

- *The National Water Policy 2012*

3.1. National Water Resources and the Aberdares Water Tower

3.1.1. National Water Resources Situation

Globally a country is categorized as 'water stressed' if its annual renewable freshwater supplies are between 1,000 and 1,700 cubic meters per capita per annum and 'water scarce' if its renewable freshwater supplies are less than 1,000 cubic meters per capita per annum. Kenya is classified as a water scarce country with an estimated average annual water availability of 500 m^3 per capita. Kenya's neighbours, Uganda and Tanzania have annual per capita renewable water supplies of 2,940 and 2,696 cubic meters per capita respectively. By 2010, Kenya had a renewable freshwater supply of just over 500 m^3 per capita per annum and 235 m^3 by 2020. Kenya is also highly vulnerable to rainfall variability and climate change. Extreme weather events including droughts and floods are becoming more frequent. The country's resilience to droughts is highly compromised by the fact that over 80% of the total surface area is arid and semi-arid land (ASAL). Furthermore, catchment degradation, with impacts on water quality and quantity, and water resources pollution is also impacting negatively on available water resources, and places additional financial and social burden on the population of Kenya compared to other countries that have abundant water resources. Under these circumstances, water should be seen, treated and managed as a scarce resource with social, economic, ecological and political values

a) Present Water Use and Future Water Demands

The present water use estimation and future water demand projection were made for the categories of domestic, industrial, irrigation, livestock, wildlife and inland fisheries uses for subsequent water resources development and management planning. (JICA 2012) The National water master plan has estimated the sectoral water demands as shown in ***Table 3-1***. The estimated demand for 2030 shows that irrigation will account for 84% of demand, while household consumption will account for 12%. The rest of users only account for 4% of demand. The high demand for irrigation is due to the Vision 2030 objective of putting an additional one million hectares under irrigation. Most of irrigation is in the Tana basin and this is linked to water from the Aberdares and Murang'a County

Table 3-1: Present and Future Water Demands by Sub-sector (*Before Water Balance Study)*
(Unit: MCM/year)

Subsector	2010(a)	2030(b)	%	(b)/(a) (%)	2050(c)	(c)/(a) (%)
Domestic	1,186	2,561	12	216	3,657	308
Industrial	125	280	1.3	224	613	490
Irrigation	1,602	18,048	84	1,127	18,048	1,127
Livestock	255	497	2.3	195	710	278
Wildlife	8	8	0.03	100	8	100
Fisheries	42	74	0.4	176	105	250
Total	**3,218**	**21,468**		**667**	**23,141**	**719**

Source: JICA Study Team

b) National Water Balance Scenario

Based on the available water resources and water demands estimated and projected for the years 2010, 2030 and 2050, the balance between the available water resources and water demands was preliminarily determined as in**.**

***Table** 3-2*.

Table 3-2: Available Water Resources and Water Demands by Catchment Area
(Before Water Balance Study)(Unit: MCM/year)

Catchment Area	2010			2030			2050		
	Water Resources (a)	Water Demand (b)	(b)/(a)	Water Resources (c)	Water Demand (d)	(d)/(c)	Water Resources (e)	Water Demand (f)	(f)/(e)
Lake Victoria North	4,742	228	5%	5,077	1,337	26%	5,595	1,573	28%
Lake Victoria South	4,976	385	8%	5,937	2,953	50%	7,195	3,251	45%
Rift Valley	2,559	357	14%	3,147	1,494	47%	3,903	1,689	43%
Athi	1,503	1,145	76%	1,634	4,586	281%	2,043	5,202	255%
Tana	6,533	891	14%	7,828	8,241	105%	7,891	8,476	107%
Ewaso Ng'iro North	2,251	212	9%	3,011	2,857	95%	1,810	2,950	163%
Total	**22,564**	**3,218**	**14%**	**26,634**	**21,468**	**81%**	**28,437**	**23,141**	**81%**

Source: JICA Study Team

It is clear from the estimates in .

*Table 3-2*that Athi catchment area is foreseen to have the highest water deficit because of the concentration of most of kenyas population in this catchment area. Demand is expected to outstrip the resources available in Tana and Athi basin by 2030. Table 3-3 shows the per capita water availability per basin. ACA has a very rapid change and the water situation is accelerating to chronic levels and other options needs to be established. To be noted is that ACA and TCA depend on the Abedares for water. This scenario may change for worse depending on policy and development decisions made these two catchment areas. The current trends in climate indicate a reduction in rainfall and shrinking of the humid and sub humid zones in central Kenya. This works to exacerbate the situation and future outlook.

Table 3-3: Catchment Area per Capita Renewable Water Resources

Catchment Area	2010		2030		2050	
	Population (million)	Per Capita (m^3/c/year)	Population (million)	Per Capita (m^3/c/year)	Population (million)	Per Capita (m^3/c/year)
Lake Victoria North	6.96	855	12.36	503	17.66	400
Lake Victoria South	7.37	959	12.72	618	18.17	503
Rift Valley	4.86	737	7.45	560	10.64	470
Athi	9.79	464	20.54	226	29.33	183
Tana	5.73	2,369	10.37	1,329	14.81	893
Ewaso Ng'iro North	3.82	1,933	4.40	1,735	6.28	989
Whole Country	**38.53**	**1,093**	**67.84**	**653**	**96.89**	**475**

Source: JICA Study Team

Table 3-3 shows that nationally per capita available water will decrease from 1093m^3 in 2010 to 653m^3 in 2030 and to 475m^3 by 2050. The Ewaso Ng'iro and Tana will continue to have per capita availability close to the recommended 1000 m^3 per capita while other basins especially the Athi, when per capita available water resources is calculated by using the renewable surface water resources and sustainable groundwater yield, the results show less availability per capita as shown in the **Table 3-3**. This situation which is close to the current situation shows a drastic per capita decline from 586 m^3 in 2010 to393 m^3 in 2030and 254 m^3 in 2050.

3.1.2. National Water Policy and National Development Targets

The water sector is driven by a number of policy documents, the national water policy, vision 2030 and the national water resources development strategy. . The National Water Policy of 1999 (NWP 1999) set the following specific policy objectives covering four basic areas of water resources management, water supply and sewerage development, institutional arrangement and financing of water sector:

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

Kenya's Vision 2030 policy document aims at transforming Kenya into a newly industrialised, middle-income country providing a high quality of life to all its citizens by the year 2030. Kenya Vision 2030 was based on three pillars – the economic, the social and the political. The Vision for the water and sanitation sector is "to ensure water and improved sanitation availability and access to all by 2030". The national development targets on the water sector in Kenya Vision 2030 are as follows:

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

3.1.3. Significance of the Aberdares Ecosystem

Uncontrolled degradation of the Aberdares ecosystem without conservation will lead to devastating impacts to a large part of Central and Eastern Kenya and the capital City of Nairobi

The Aberdares Conservation Area (ACA) is about 2185 Km^2 comprising the Aberdares National Park (774 Km^2) and the Aberdares Forest Reserves (1411 Km^2). It is located in the counties of Kiambu, Murang'a, Nyandarua and Nyeri. The Aberdares are vital to Kenya as four of seven of Kenya's largest rivers, flowing north, west, east and south, rise in the Aberdares Range. The rivers flow through semi-arid to arid areas providing vital resources to dry ecosystems in such areas as Laikipia district and the Tana basin. They also provide power to the national grid and water to seven major towns – including almost the entire population of Kenya's capital city, Nairobi.

On the foothills and high slopes of the Aberdares, 30 percent of Kenya's tea and 70 percent of its coffee are produced. On its lower slopes, over four million farmers depend on its rich soils and rainfall. Some research show that the Aberdares National Park ANP) alone has over 770 species of vascular plants. The ACA comprises ten vegetation zones with over 270 species of birds. The ecosystem also has 50-60 species of mammals including the black rhino, giant forest hog, wild hog, golden cat, bongo, African elephant, and Columbus monkey among others. These attract about 25,000 – 60,000 tourists annually especially to the famous Treetops and the Ark as well as trout fishing lodges). Thus, the ACA is an important area for conservation and sustainable development. Without the ACA forest cover, topography and climate, the region and indeed the country would not be endowed with the wildlife, industry (including agriculture) and water it currently enjoys. Despite its importance, the ACA had been degraded appreciably particularly in the period between 1990 and 2000. The aerial survey carried out in 2002 identified widespread degradation as evidenced by logging (particularly high-value indigenous trees), over 14,000 charcoal kilns, encroachment, marijuana cultivation, burning, livestock grazing, quarries and landslides

a) *Impacts of climate and Community Observations on Flow Characteristics of Aberdares Rivers*

During a study in 2009/2011 (UNEP, KFS, and Rhino Ark 2011) the community around the Aberdares was asked about their perceptions of flow characteristics of rivers in their respective areas from the 1970s to the most recent times (high, medium, low and scarce flow levels), the responses were as follows:

The majority of the respondents (87%) reported high water levels in the ACA Rivers in the 1970s compared to 9% and 4% who reported medium and low flows respectively. The same trend was reported for the 1990s although the number of respondents reporting high flows was lower 2%

and 6% respectively. The number of respondents reporting high flows reduced to 18% and 16% in the 1990s and 2000s, while the percentage of respondents reporting a trend towards medium and low flows increased Only in Nyeri, Mathioya and Kigumo areas did respondents report increases in river flows in the 2000s. However, this is not supported by rainfall trends in this period. Overall, the percentage of the respondents who did not respond to the question ranged from 20.4% for the 1970s to 8.4% for the 2000s. This trend might imply that most people in the sampled population could not remember past river flow levels 20 to 30 years ago.

b) *Summary of Ecosystem Services from the Aberdares Water*

The Identifiable benefits of the Aberdares include the following: Environmental, Social and Economic studies were estimated as follows:

i. Domestic water supply to populations in Central Kenya, some parts of Rift Valley and downstream Tana which are estimated at an economic value of Kshs.646.6 million
ii. Almost all of Nairobi water supply with an economic value of Kshs.1.465 billion
iii. Irrigation water in Central Province and downstream Tana with an economic value of Kshs.6.3 billion
iv. Contribution of water estimated at 58% of all Tana water which contributes to hydropower generation of 1252 GWh economically valued at Kshs.3.03 billion
v. Irrigation water for L. Naivasha horticulture and floriculture production with an estimated economic value of Kshs.931 million
vi. Irrigation water in the Ewaso Ng'iro basin is valued at Ksh. 76.4 million
vii. Contribution to agriculture in the region with an estimated value of Kshs.21.9 billion in traditional farming areas and excised areas
viii. Contribution to carbon sequestration and soil erosion control with an estimated value of Kshs.2.905 billion
ix. Benefits totaling to Kshs.712 million to forest adjacent communities
x. Contribution to Nyayo Tea Zones, tourism and royalties with an estimated value of Kshs.227 million.
xi. A bio-diversity value estimated at an annual value of Kshs.20 billion.
xii. Incremental water benefits to commercial water users valued at Ksh. 32 billion
xiii. Although many other aesthetic benefits are not quantified, the total annual benefits of products and services was Kshs.38.239 billion while if

the annual biodiversity value is included, the total annual benefits are Kshs.58.239 billion

c) *Aberdares Ecosystem and Integrity of the Water Catchment Areas*

The implications of non-concerted effort in maintenance include:

i. Continued degradation of the ecosystem leading to less downstream benefits to all stakeholders
ii. Nairobi which depends almost 100% on Aberdares water would increasingly be drastically affected by water shortages. As the city accounts for about 50% of GDP (about 1,049,899 million at current prices)
iii. Decrease in electricity supply as Aberdares water account for 58% of hydropower in the Tana system, 40% of national hydropower production and 27% of all electricity produced. The impact would affect industries seriously. For an example, the industrial loss due to 2006 drought industrial loss in Nairobi was estimated at USD1.6 billion (Kshs.128 billion at current exchange rate)
iv. Vision 2030 has one of its pillars as irrigation development in the Tana Basin. Several projects have been proposed and shortage of water from the Aberdares would affect the development goal affecting the progress in self-sufficiency in sugar, rice and other crops.
v. L. Naivasha depends almost 100% for its lucrative floriculture and horticulture industry on the Aberdares. The area accounts for about 50% of floriculture production and at 2008 value of Kshs.40 billion, the loss would be over Kshs.20 billion.
vi. Degradation of the ecosystem would affect the climatic patterns and global warming affecting almost all of Central province agriculture valued at over Kshs.110 billion as well as other agriculture in other areas due to the loss of the carbon sink
vii. Loss of biodiversity in terms of unique flora, fauna and aesthetic value of over Kshs.500 billion.

3.1.4. Future Planning

a) *Coping With Future Water Deficits*

To cope with the future water deficit, the following actions will be required:

a) Water resources development should be promoted to the maximum in order to meet the future water demand as much as possible.

c) Water resources development balanced with the available quantity of water resources should be made.

b) *Avoid Cutting off the Head Waters from Eastern Aberdare Ranges*

The Aberdare streams have very strong baseflows and are also highly productive during the rainy seasons. The impact of cutting off all the streams at the headwaters is costly to the environment and other users downstream.

The impact of the projected future plans on the flows downstream need to be evaluated against the existing benefit and total contribution of the rivers on the eastern slopes of the aberdares to other sectors of the economy as illustrated in the report by UNEP, the value of fencing the Aberdare. The report reports that the ecosystem function of this streams emanating from the Aberdare cannot be overemphasised.

The total value of water from the Aberdare for irrigation in the Tana Basin is Kshs.6.3 bi (USD 97.3 mi).Although some plants are on the Aberdare rivers, it is assumed that the Aberdare rivers which supply 58% of water to the Tana account for a similar amount of electricity (1,252.3Gwh). At Kshs.2.42/Kwh, the value of 1252 Gwh (1.252 bi Kwh) is Kshs.3030.5 billion. The Aberdares account for 40% of all hydropower and 26.5% of all electricity used in Kenya

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c) *Water Demand Efficiency (Ufw/Nrw)*

Efficiency of the technology used in domestic water supply, irrigation need to be relooked at. The future sources of water are going to be in savings made in improved supply and use efficiency and not more abstractions. This is borne from the fact that the water resources are finite whereas population, urbanisation and industrialisation will continue to put an increasing demand on the water resources. It will be imperative therefore to consider integrated water resources management in the light of water management principles that encourage equity, efficiency of use, accessibility, economic, social and ecological functions. It is imperative that the future be planned with this is mind. Efforts should be made to reduce the non- accounted for water by WSPs. For instance Nairobi Water and s=Sewerage Company loses 38.5% of water through UFW. A saving of 18% to the global benchmark of 20% would avail more than 100,000m^3/day of water. WSPs in Murang'a have equally very high UFW some as high as more than 50%.

Domestic water use appliances, water closets needs to be re-evaluated and policies enshrined in the law that makes it mandatory to install water saving

systems and schemes. This could save more than 20% of the current water used in domestic purposes availing huge volumes for other uses.

d) Waste Water Management and Recycling

Water efficiency technologies, recycling technologies should be encouraged as opposed to addition of supplies from new water sources, waste water should be viewed as water sources this could include treatment of waste water, conservation and rehabilitation of rivers like the Nairobi River and Nairobi Dam.

e) Environmental Conservation

The way forward hinges on the two key areas of fence maintenance/overall ecosystem management and control of degradation within the protected area and the farming areas in the downstream areas.

Under the **fence maintenance** and overall management of the ecosystem, the following recommendations are made:

i. A system of payment for environmental services be institutionalized in the MENR and EMCA systems for big beneficiaries like Nairobi City, Kengen, L. Naivasha growers, large scale irrigators and WRMA among others to pay an annual stipulated levy for fence maintenance and control of degradation in the protected area. This can be put in a fund
ii. The water abstraction tariffs and the current levels of royalties should be raised and some portion be allocated for conservation.
iii. Government, especially the Ministry of Finance, be sensitized on the value of Aberdares and the need to empower KFS and KWS to offer more effective management and control of illegal activities. This implies additional budget for ecosystem management.
iv. The community adjacent to the fence be sensitized on the importance of the ecosystem to their livelihoods and the need to be proactive in surveillance and reporting of illegal activities. The CFAs can be sensitized to employ surveillance scouts by encouraging them to contribute some amounts of money monthly.

In **encouraging soil and water conservation in the 2,000km²** of farmland in the Aberdares catchment area, the following can be recommended:

- Capacity building for communities in agro-forestry and forage production to minimize their dependency on protected forestry benefits

- Part of the funds raised under PES system described above be used in empowering the communities in income generating activities e.g. nurseries, apiculture, bamboo cultivation, etc.
- The key beneficiaries build some enabling environment for the communities e.g. road and water infrastructure, social infrastructure and enhancing improvement in agriculture through information
- Major soil and water conservation and afforestation program be developed in the area through a joint donor, government and beneficiary effort.

3.2. Potential Social, Economic and Environmental Impacts of the Tunnel

Clean and adequate water for all is perhaps the most basic requirement for human survival; however its use has to be based on a strategy for optimal and equitable utilisation of water resources in Murang'a County and to other beneficiaries

3.2.1. Affected Rivers

The affected two rivers Irati and Gikigie which are tributaries of the third river Maragwa as shown in **Table 3-4**

Table 3-4: Estimated river lengths between intakes and confluences

River	Length (Km)	Remarks
Gikigie	4.9	Confluence with Maragua River
Irati	30.2	Confluence with Maragua River
Maragua	71.9	Confluence with Tana River
Maragua	61.0	Up to Wanjii Hydropower Reservoir

The average annual flows (m^3/sec) discussed under hydrological analysis and water demand scenario in section II of this report, there are a number of environmental issues that needs to be addressed.

3.2.2. Areas of Concern to Murang'a County

The EIA has identified cumulative impacts which relate to the aggregate of past, present and future actions, and may also arise from additional factors or developments not directly related to the upstream diversion of water via the Northern Collector tunnel to Thika Reservoir. Effects from different

activities may also interact to cause additional effects not initially apparent when considering the individual developments or changes, and there may also be synergistic interaction between different factors. In relation to the Murang'a County concerns the impacts can be summarized as follows:

i) Not to adversely reduce or affect river flows and levels or the underground water level
ii) Not to affect the current and projected water and irrigation schemes in the county
iii) To demonstrate in real terms the benefits to the county and especially address the water needs of Murang'a people and
iv) Not to have any adverse ecological or micro-climatic effect on the environment. These are analysed below based on detailed calculations

a) Downstream Impacts (Concerns 1 & 2)

Downstream impacts include the concerns of reducing river flows and levels or the underground water level which affect current and projected population water needs, livestock needs, irrigation schemes and other economic activities in the county. The cumulative impacts at Maragua 4BE01 is mostly reduced flows.

Reduced flows as a result of diversion of a majority of the flows originating from the Aberdares at Irati, Gikigie and Maragua intakes to the Northern Collector, resulting in:

i) Reduction in the flow reaching Masinga Reservoir and therefore a reduced flow available for hydroelectric power generation,
ii) Some short periods or single days with potentially zero flow or near-zero flow. These periods will normally be preceded and/or followed by further periods with extreme low flow; and
iii) Less flow available for use in existing and future domestic and agricultural activities (e.g. irrigation) in downstream areas. These downstream impacts are not clearly quantified in the study and additional analysis was done to show the magnitude of impacts

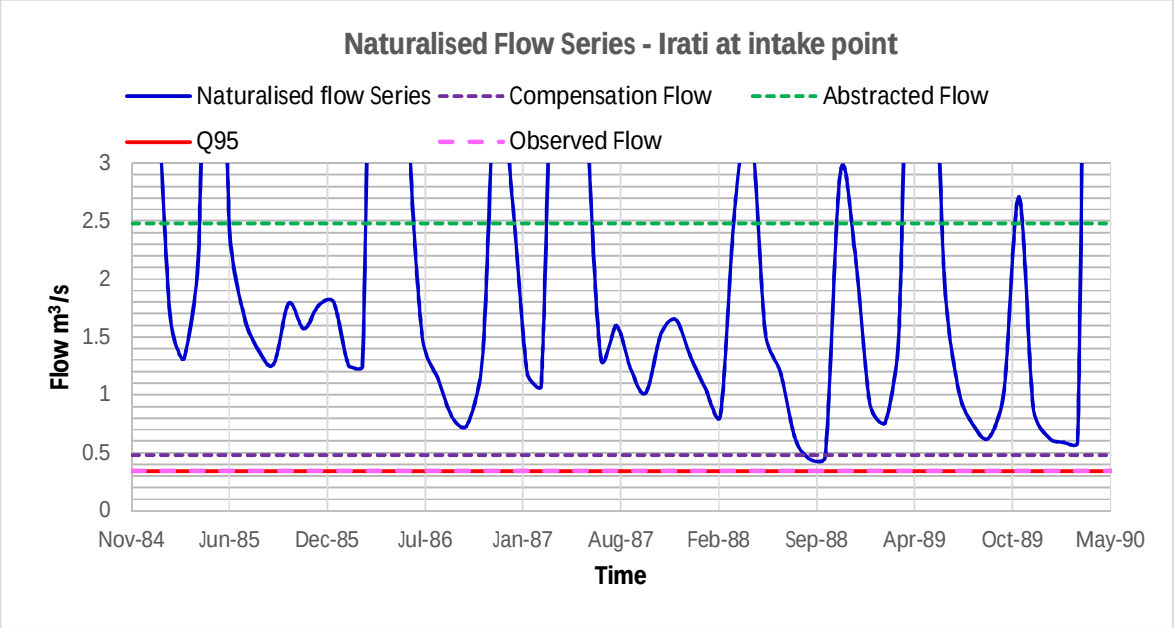


Figure 3-1: Impacts of NCTI Abstraction Downstream

The illustration of **Figure 3-1**, **Figure 3-2**, **Figure 3-3**, and **Figure 3-4** indicate the implications of modified flow downstream of NCTI intake points. It is clear from the illustrations that flow will be impacted and modified in a major way. This is specially so for normal flows which will be reduced to drought flows downstream. There is a risk of having a permanent drought situation downstream of NCTI project as indicated by the modified flow hydrographs. For example between 1972 and 1985, and between 1990 and 1998 at the Maragua intake, the modified flow indicates that there would hardly be any flow above Q95 downstream. The impact of this scenario is dire in respect to the normal flows. The project seems to divert all normal flows and only allow the very minimum flows downstream for other uses.

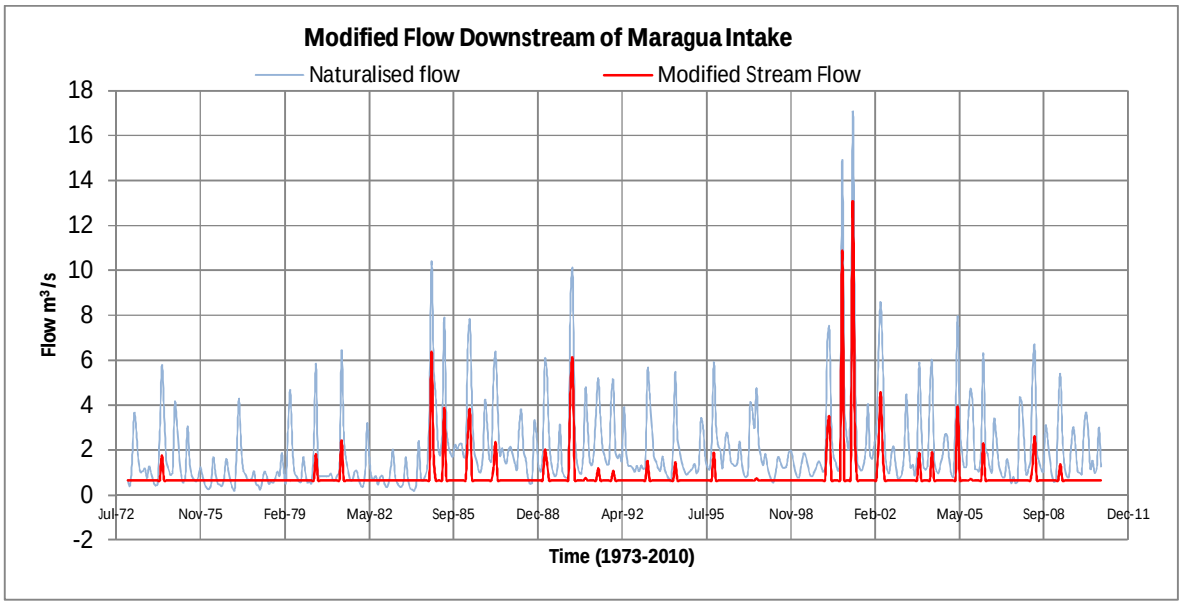


Figure 3-2: Modified Flow Series at Maragua NCTI Intake

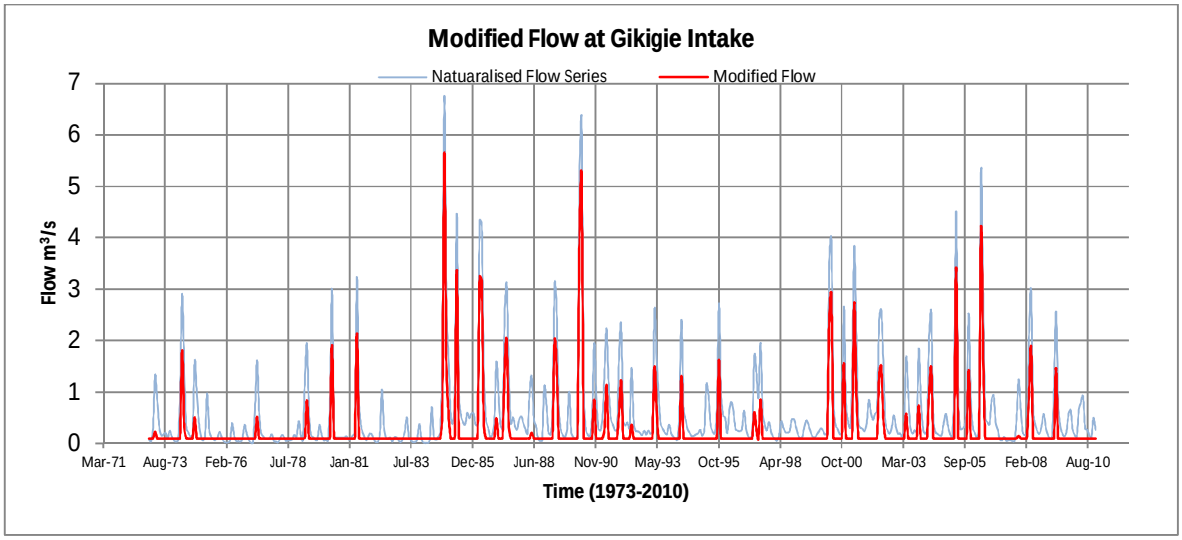


Figure 3-3: Modified Flow Series at Gikigie NCTI Intake

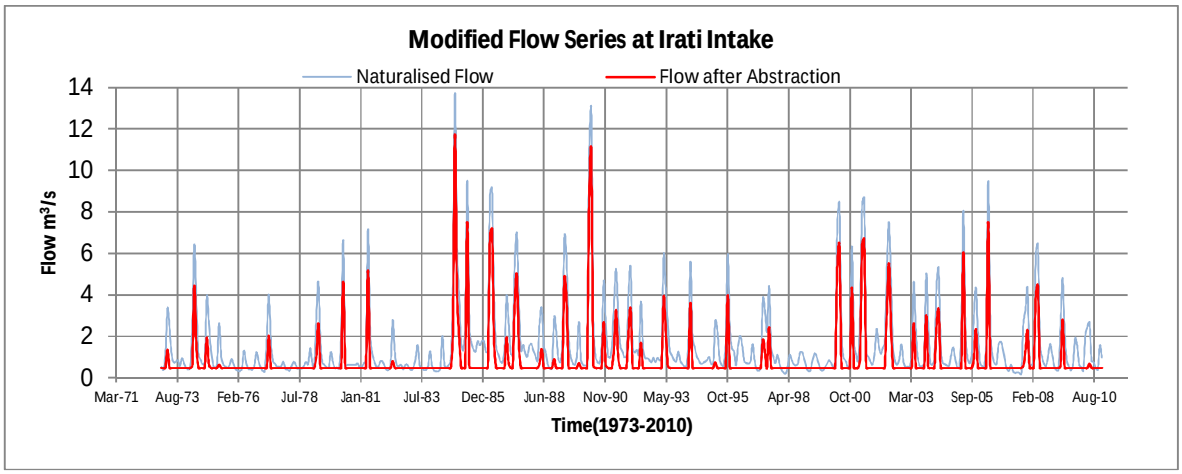


Figure 3-4: Modified Flow Series at Irati NCTI Intake

b) *Impacts on overall Murang'a County water demand*

Murang'a County's water resources are rivers, shallow wells, springs, dams, boreholes and roof catchment. There are 10 permanent rivers, 400 shallow wells, 75 springs, 30 dams and 100 bore holes that supply water for domestic and agricultural use in the county. All these sources supply 60 per cent of the county population with clean and safe drinking water. The county has 27 water supply schemes and about 16 irrigation schemes. Water supply schemes are managed by three different entities. There are some which are managed by the water companies, the department of water and some others are managed by the community members through water project committee. The irrigation schemes, which are managed by the community members, got funding from community own initiatives as well as government and development partners' support. In the county, the mean distance to the nearest water point is three Km with about 29.4per cent of the households taking five to 14 minutes. Water supply schemes such as the Gatanga community water schemes supply water directly to households at reasonable cost. The county will expand the capacity of water schemes to ensure a minimum of 40per cent of the households are directly supplied with water.

Table 3-5: Estimated Total Water Demand in Murang'a County

Category of Demand	MCM/Yr	%	
		No Hydro	With Hydro
Household	28.0	5.3	0.4
Livestock	8.3	1.6	0.1

Irrigation	156.5	29.5	2.2
Other agriculture	330.7	62.4	4.7
Groundwater	6.3	1.2	0.1
Sub-total domestic and agriculture	**530**		
4Hydropower	5147		73.4
Minihydro	1,343		19.1
TOTAL	7020	100	100

The above summary shows that the estimated demand (with no hydro) is about 530MCM with agriculture and irrigation accounting for 92% of demand. In relation to the proposed abstraction, this would be about 10% of demand. However the critical impact is that flood water is the main water for downstream irrigation and abstraction would mean one third of irrigation water demand is abstracted thus affecting proposed irrigation downstream

c) *Impacts on Maragwa River Catchment Area*

Maragwa River Catchment area extends from the eastern Aberdares ranges at 3,620masl to the semi-arid confluence with Sagana River at 1150masl. The catchment covers about 425km^{2}in the constituencies of Kangema, Kigumo Maragwa and some adjoining constituencies. In terms of agro-ecological zones the upper catchment area is the Upper highland/forest Zone with sheep, dairy and vegetable enterprises. This is followed by the Lower highland zone with tea and coffee while in Upper Midland zone is the main Coffee zone and the lower parts are marginal coffee zone/sisal and ranching. The main tributaries of Maragwa River are Kayahwe, Irati, Gikigie and other minor rivers. In terms of basin management it is classified as lower Sagana area under TWSB and is a high livelihood area predominantly with rural populations and in the lower areas there is scarcity of water implying a need for conservation and equitable use and allocation

The hydrological impacts have been outlined in section 2.4. It is clear that if NCT is implemented, Maragua catchment will not have the capacity to meet the following water demands:

a. Domestic
b. Agricultural
c. Hydropower
d. Environmental
e. This is illustrated by the flow duration curve in **Figure 2-27** for current water demands and **Figure 2-28** for future water demand scenario in 2030.

f. As pointed out in the ESIA, the recommended ecological flows will not be met as indicted in **Table 2-34**. This will have an impact of modifying the riverine ecosystem and the channel geomorphology. This was clearly seen on the field visit as indicated in **Plate 3-1**.

3.2.3. Operational Lessons learnt from Third Nairobi Water Project

The third Nairobi water project included water storage in Thika dam, tunnels from the dam to the River Chania outfall with intake and adits on Kiama and Kimakia rivers. During field visits the following operational issues were identified.

i. The compensation flow released downstream is through an orifice on the intake wier. However the flow released especially during normal flows and low flow seasons is the same denying downstream users' water for irrigation, domestic demand. In fact Gatanga Water Company cannot abstract from the three rivers and it has to rely on borehole water for its supply.

ii. The river channel geometry is completely affected with invasive vegetation growing and in some sections hindering flow which pause a hazard during flooding by triggering the river to change its course.

Plate 3-1: Impacts of Minimum compensation downstream of Kiama River

3.2.4. Opportunity cost of water abstracted from Murang'a County to Nairobi

Water is currently abstracted at a rate of KES 0.50/M3 payable to WARMA. Abstracting water from Murang'a to Nairobi has an opportunity cost, or the cost of the alternative use in the county. Analysis above shows that the development of irrigation is a priority area in the county where the potential is estimated at 20,000 hectares and only about a quarter is developed

Analysis of gross margins for rain fed and irrigated agriculture in Murang'a County shows that irrigation creates an increase of 55% in annual crops like bananas and coffee. In bananas the increase is 70% while in passion fruits it is 50%. These two crops are increasingly important in the county and many smallholders are growing them. In horticultural seasonal crops the increases in tomatoes, French beans and kales are 150%, 150% and 97% respectively showing the huge benefits from irrigation. The gross margins and estimated opportunity cost forgone are shown in

Table 3-6

Table 3-6: Opportunity cost of water To Murang'a County

No	Sample enterprise	Gross Margin per Ha. Irrigated	Opportunity cost of water/M^3
1	Bananas	273,418 Kshs./Ha/Yr	24.30
2	Tomatoes	830,565 Kshs./Ha/Season	73.8
3	French Beans	291,000 Kshs./Ha/Season	25.90
4	Passion Fruits	933.937 Kshs./Ha/Yr	83
5	Kales	315,000 Kshs./Ha/Season	28
6	Coffee	402,753 Kshs./Ha/Yr	35.80
Average Annuals		536,703	47.70
Average Seasonal		478855	42.6
Estimated opportunity cost at KES 45/M3			**KES 2.3 Billion/year**

The amount of water to be abstracted from the rivers is about 51.1MCM/year. Assuming water demand for flood water at 11,250m^3/ha this would irrigate 4,542 hectares. This is almost equal to the proposed Kakuzi/Makuyu/Ithanga NIB scheme of 5,000 hectares. Based on per hectare gross margin and irrigation water demand per hectare the opportunity cost of water is as shown in

Table 3-6. It is noted that the opportunity cost varies from KES 24/m^3 in bananas to KES 83/m^3 in passion fruit and averages at KES 47.70/m^3 for annuals and KES 42.60/m^3 for seasonal crops. In general it can be argued that value added water through irrigation is worthy KES 45/m^3 compared to the current abstraction rate of KES 0.50/m^3 of raw water exported to Nairobi. The annual loss to Murang'a County is therefore KES 2.3 billion

a) *To Demonstrate In Real Terms the Benefits to the County and Especially Address the Water Needs of Murang'a People*

The project expects to augment Murang'a water and sanitation (Kshs.800mi), Gatanga (Kshs.500 mi) and Gikigie (Kshs. 170 mi). Other projects indicated under benefit about 250,000-300,000 beneficiaries as shown in the

Table 3-7

Table 3-7: Water projects to be supported by AWSB

Murang'a W/S (Augmentation)		
Project/Component	**Beneficiaries**	**Areas Covered**
Muruka-Kenol-Makuyu Pipeline – 34km	124,000	Muruka Location, Kenol, Makuyu Location, Kabati Sub-location, Gitura Sub-location
Mareira-Sabasaba-Muthithi – 16.5km	46,000	Maragwa Town, Kaharati and Kahumbu locations
Kaharati-Iganjo Pipeline – 6.5km	5,000	From Kaharati to Kamahuha location
Rwathia-Mukangu Pipeline – 27km		Wethaga, Gitie, Kahuti and the surrounding areas
Kayahwe – Kambirwa Pipeline – 12km	15,000	Kambirwa market, Itaru-ini area (by Sagana River), Mirira & Muthigiriri Market
Kahuti II Water Treatment Plant – 4,000m^3/day	Estimates unavailable	Waithaga, Kianderi, Kahuti and another line to serve Mukangu, Gatheru and Gitige
Kiriciiungu Water Treatment Plant - 4,000m^3/day	40,000	Kandara town/Ruchu location
Gatango Water Supply Project		
Gatango intake in the North Mathioya River, laying of 30km of pipelines	Estimates unavailable	Kiru, Kamacharia and Gaturi divisions of Mathioya sub-county
Gatanga Water Supply		
Extension of 8km 8" pipeline from Karangi to Ndakaini	30,000	Wanduhi, Kiriaini, Thare & Mureke
Chomo, Gatura Intakes and Rwagetha Treatment works (300m^3/day)		Kigio, Gakurari, Kirwara, Gatanga, Mabanda and Gatunyu
Treatment works at Karangi (300m^3/day)		Mbugiti, Gatura, Chomo, Rwegetha

The project expects to augment Murang'a water and sanitation (Kshs.800mi), Gatanga (Kshs.500mi) and Gikigie (Kahs. 170mi). This will benefit about 250,000-300,000 beneficiaries: From the analysis of the project it was clear that it was not meant for Murang'a County and what is included as benefits are just Corporate Social Responsibility and other assumed benefits. There was hardly any consideration of any soil and water conservation critical for watershed management. This situation is reminiscent of Ndakaini. Benefits can be both tangible and intangible (in terms that no price has been put for them, as shown in **Table 4-8**

Table 3-8:.Benefits to Murang'a County

Benefits	KES (mi)
Tangible	
Murang'a W/S (augmentation)	800
Gatanga W/S (augmentation)	300
Gatanga W/S (augmentation)	170
Sub-Total	1,270
Intangible (25% of sub-total)	190.5
- Employment opportunities	
- Improved infrastructure	
- Other community benefits	
GRAND TOTAL	**1,460.5**

b) *Not to Have Any Adverse Ecological or Micro-Climatic Effects on Environment*

Negative impacts include hydrological geomorphological changes, temperature water quality, sediment deposition and impacts on aquatic fauna (low water discharge, change in food availability, change in water ferocity, interference with fish movement/passage), impacts of receding water depth on flora, community safety and health, seismic risk and tunnel leaks. In the construction environment and Social Management Plan, these have been identified and allocated mitigation costs as shown in **Table 3-9**

Table 3-9: Mitigation costs

Activities	KES	Activities	KES
Various construction activities	1,000,000	Tunneling works	600,000
Construction camps	2,000,000	Wet season surveys	10,000,000
Diversion wells/fish	800,000	Routine in-flow checks	10,000,000
Oil spills	2,500,000	Changes in riverine flora and fauna	6,000,000
Riverine micro habitat	2,000,000	Liquid waste pollution	1,300,000
Site clearance and earthquakes	1,800,000	Air quality	600,000
Waste handling challenges	1,500,000	Noise nuisance	1,600,000
Liquid waste pollution	1,300,000	Modification of landscape	2,000,000
Air quality	600,000	Noise nuisance	1,600,000
TOTAL	46,800,000		

For a project of this size (KES6.8 billion), putting mitigation costs at KES46.6mi (0.074% of project cost) shows absolute neglect of mitigation. The project does not provide for mitigation measures in soil and water conservation and this is a major shortcoming

In addition to these impacts, there are direct impacts on loss of land above the tunnel (11.8km by 3 metres way leave), and other contractions totaling 18.368 acres (7.436 ha) of which 97.4% is freehold land. This will affect 177

households (657 people) who will require resettlement. In addition, 8 institutions will be affected (Ichichi Secondary School, Ichichi community football pitch, Ichichi, Gikigie and Makomboki primary schools, Nginda tea centre, Makomboki Secondary School and Bible Fellowship Church. These are dealt with in Resettlement Action Plan.

3.3. Environmental Conservation Measures

3.3.1. Aberdares Ecosystem Management

The enormous value of the Aberdares Conservation Area ecosystem to forest margin landscapes, regional, national and global economies and well-being in terms of principally water and biodiversity has been demonstrated. It has also been demonstrated unequivocally that the Aberdares fence has proved to be an effective management tool for protected areas given the largely positive tangible effects throughout. In the devolved government the key counties of Nyandarua, Murang'a, Nyeri and Kiambu need to play a key role. A ten year Aberdares Forest Ecosystem Integrated Management Plan (AFEIMP) has been prepared by the KFS and KWS with financial support from Rhino Ark, KWS, FORREMS and KFS. The core team involved in the development of the management plan included KFS and KWS who in the past had separate management plans in accordance with their respective statutory mandates, Ministry of Water and Irrigation and NEMA. The plan identifies twelve management programmes, namely: (Natural Forests Management, Plantation Development, Habitat Management, Wildlife Management, Tourism Development, Protection and Security, Community Participation in Conservation, Infrastructure and Equipment, Human Resource Development, Research and Monitoring, Water Management and Conservation, and Fence Management

The proposed ABERDARE TRUST proposes 7 trustees out of which four are permanent Founder Trustees comprising Director KFS, Director KWS, Director WRMA, Chairman Rhino ARK or their alternates. In addition, it proposes an independent Chairman appointed by the Founders plus three representatives from Forest Edge Communities elected by the Permanent Members. The community representatives could ideally be drawn from organized groups such as CFAs or the

WRUAs. Considering the process followed in the fence construction and variations in stakeholder consultations, serious consideration should be given in the formation of the ABERDARE TRUST to the following organizations:

i. County Governments of Nyeri, Nyandarua, Murang'a, and Kiambu

ii. Civil society representation (CSO) –**rationale**- representation of non-state actors, who have deep involvement in community activities and engagement of government especially in policy formulation
iii. Nyayo Tea Zone Development Corporation (NTZDC) - **rationale** by their mandate of buffer zone development and management. They provide enormous support in management of the forest margin landscape. They are also important in providing support for a policy on Payment for Environmental Services (PES)
iv. KenGen– **rationale**- highly dependent on ACA to provide more than 70% of the country's hydro-power generation. They are important in providing support for a policy on Payment for Environmental Services (PES)
v. Irrigators downstream and NIB as they are the major users of water
vi. Private Sector Alliance (KEPSA) – **rationale**- represents business and industry interests. They can also contribute to activities in the forest margin landscape and have the potential, like the CSO, of remaining neutral in the management of the fence. They can play a crucial role in providing support for a policy on Payment for Environmental Services (PES)
vii. Water Service Boards – **rationale** – these can act as an important source of pressure to ensure that the ACA is well managed by WRMA and other stakeholders. Considering their outreach and volumes and value of water consumed by their customers, they can form a critical strategic partner to provide support for a policy on Payment for Environmental Services

3.3.2. Watershed Conservation Approaches

Forests and natural ecosystems provide several kinds of environmental services, such as storm protection by mangrove forests, erosion control, pollination of crops, abatement of noise pollution, maintenance of air quality, and scenic beauty. However, not all of these are directly marketable, either because they are not perceived as valuable enough or due to economic and technical constraints as described above. It is useful to note that PES can help in securing only those environmental services for which environmental service users are willing to pay. To date, the four most common services found in developing country PES schemes are:

Carbon sequestration. Forests absorb (or sequester) significant amounts of carbon dioxide from the atmosphere, which helps in mitigating global

warming. Many governments, corporations, and even individuals are willing to pay landowners and communities to adopt land-use practices that promote carbon sequestration.

Watershed protection. Ecosystems such as wetlands and forests regulate hydrological flow and control soil erosion. Better management of agricultural chemicals protects water quality. As clean water becomes scarce and people are more concerned about its quality and quantity, downstream consumers (e.g., hydropower plants, water utilities, irrigators and other downstream farmers, fishermen, and aquaculture.) in some places are willing to pay upstream land users for watershed services.

Biodiversity conservation. A significant proportion of the world's biodiversity exists in tropical forests and other threatened ecosystems, but local people often cannot directly benefit from it. Some agricultural practices are more compatible with local biodiversity than others, and small payments to land users might make them sufficiently profitable to replace practices that destroy biodiversity. Several companies and international non-governmental organizations (NGOs) now support biodiversity conservation through PES.

Scenic beauty. Natural areas provide aesthetic beauty, which is treasured by most human societies. Local land-use practices can enhance or destroy scenic beauty, affecting local quality of life and affecting nature-based tourism opportunities. Tourism companies and even private foundations are paying local farmers or other landowners to preserve this valuable environmental service

3.3.3. Approaches to Watershed Management

A watershed is an area that drains to a common point, making it a useful unit for managing water resources. The key characteristic of watersheds, from a human perspective, is that water generally flows downhill, so that upstream land uses affect downstream conditions through hydrological linkages. All over the world, watershed management efforts aim to influence this upstream-downstream relationship. They do so by encouraging upstream land-use practices that are consistent with maintaining the watershed so that it yields water that is unpolluted, low in sediment, buffered against flash floods, and with minimal fluctuations in dry-season and groundwater flows Local conditions determine what is possible and how best to achieve it. The basic scientific challenge in managing watersheds is to understand how upstream land-use practices affect natural resource conditions downstream, while the basic socioeconomic problem is to encourage people in an upper watershed to adopt those practices even though the benefits will accrue downstream – in other words, how to encourage them to deliver this

environmental service. Watersheds are the focus of a growing number of payments for environmental services (PES) and PES-like arrangements. , The concept behind payments for environmental services is straightforward. Because producers of environmental services are not usually compensated for providing them, they tend to be undersupplied or are not supplied at all. Payment for environmental services (PES) programmes are an effort to "get the incentives right" by sending accurate signals to both providers and users that reflect the real social, environmental and economic benefits that environmental services deliver. It is important to emphasize that payments are only one of the potential tools for increasing the provision of environmental services. Others include information provision, policy reforms to reduce market distortions, command-and control regulations and taxation

Four examples outside Kenya demonstrate what is happening with payment for watershed services and provide some early lessons on the opportunities and pitfalls for further expanding this approach to watershed management.

a) Examples outside Kenya

New York City. In the 1990s, the U.S. Environmental Protection Agency informed the city of New York that it would have to build a filtration plant to ensure clean drinking water supplies. Instead of spending $4 billion to $6 billion on the plant, the city negotiated with landowners in the Catskill-Delaware watershed, the source of much of the city's water, to help them invest in whole-farm plans to reduce pollution. The plan succeeded because it emerged from shared visioning by all parties and because it was possible to develop land-use management approaches that improved farmers' bottom line while also protecting against water pollution. The resulting arrangement helped save more than $1 billion annually for the city by preserving its filtration avoidance permit

Heredia, Costa Rica. Heredia is a city whose municipal water authority serves almost 200,000 people with water that originates in micro-watersheds in the hills above the city. In recent years, the city's water quality has been threatened by changes in the watershed, including deforestation, urban growth, and livestock. In 2000, the water authority initiated a program to pay landowners to conserve and reforest lands in the upper watershed, both to limit further degradation (by eliminating cattle ranching and dairy operations close to the stream) and to rehabilitate degraded areas (through reforestation). To pay for the program, each customer of the water authority is charged a small fee, called the hydrological tariff, attached to the monthly

water bill. Payments to landowners amount to $100 per hectare annually for conservation under a 10-year contract and $1,000 per hectare annually over five years for reforestation. To date there are 23 PES contracts covering about 1,200 hectares. Water consumers pay about $0.05 per cubic meter for the environmental service.

Sumberjaya, Indonesia. In Sumberjaya, the objective of watershed management is to protect against siltation and deliver a consistent flow of water to a run-of-the-river hydroelectric plant at the mouth of the watershed. Most of the 80,000 hectare watershed consists of Protection Forest, a category of government land that is to be protected to preserve watershed functions in support of downstream interests. Most of this area has been deforested and is inhabited by recent migrants who grow coffee on the land as squatters. When the hydroelectric plant was first planned in the early 1990s, the government evicted many farmers based on the belief that their land use would be bad for the power plant. Ultimately the eviction program was ineffective, and in 2000 the government established a new community forestry program in which farmers could remain on the land as long as they grew coffee in a way that was viewed as maintaining the watershed's hydrological function while protecting the remaining natural forest. In this arrangement, secure tenure is the reward for providing the environmental service. Land users form groups that apply jointly for the community forestry permit, which is good initially for a five-year probationary period, followed by a 25-year extendable permit. In Sumberjaya, 10 groups covering several hundred hectares currently benefit from the program, with another 10 groups in the process of obtaining permits. Performance is judged for the group as a whole, which is responsible for policing its members.

Sukhomajri, India. In the village of Sukhomajri in northern India, a program was devised to build small catchment ponds to provide irrigation water to the agricultural lands below. To keep the ponds functional they needed to be protected against siltation that resulted from erosion in the denuded watershed above them. Rehabilitating the watershed required re-vegetation, which in turn depended on eliminating grazing by goats. However, landless people living in the village stood to lose from this arrangement because they had no land to irrigate, and grazing their livestock in the upper watershed was the source of their livelihoods. When the first pond was built, they refused to abandon the upper watershed, and silt quickly filled the pond and eliminated its irrigation capacity. Villagers devised an ingenious mechanism to ensure that all inhabitants gained from protecting the watershed. All farmers were required to pay a fee for using the irrigation water, with the

proceeds shared among all households regardless of whether they farmed. This way even landless people earned income from irrigation, and they agreed to protect the watershed. The village economy was transformed, as stall-fed crossbred dairy cattle replaced grazing goats and local cows, high-value irrigated crops fetched high prices and raised the demand for labor, and the upper watershed became a lush forest.

b) *Green Water Credits/Payment for Environment Services and the Naivasha Example*

In Kenya the payment for environmental services is more pronounced in wildlife/tourism sector, notably the Maasai Mara Game reserve arrangements with Narok County. There is an arrangement of sharing benefits and the Narok County gets over KES 2 billion per year. Possibly this approach can be used for Murang'a County. In relation to water for potential payments, water is categorized as green and blue. Green water is the water held in the soil and available for plants. It is the largest water resource but can only be utilized by plants. Blue water is groundwater and stream flow that can be tapped for use elsewhere for domestic, stock water irrigation, industrial and urban uses.

World Wide Fund for Nature (WWF-Kenya Country office) in partnership with CARE- Kenya has been implementing the phased Equitable Payment for Watershed Services (EPWS) scheme in (reference to water services) within Naivasha basin -Kenya since 2006 (implementation phase commenced in 2008). The PES project goal is *to improve the livelihoods of Targeted households in the Malewa Catchment area by introducing Payment for Watershed Service*. The pro-poor EPWS scheme involves land use transformations by the upstream farmers such as rehabilitation and maintenance of riparian zones, grass strips, terracing along steep slopes, reduction in agro-chemicals use and tree planting to provide downstream users with quality water as environmental services-ES. The aim is to improve water quality, secure livelihoods and habitats for biodiversity and sustainable economic development. The PES scheme is designed to benefit all stakeholders involved; Private-Public sector and local communities to ensure equity and sustainability of the project in the long run.

Naivasha PES project involves watershed services as the main business ES and complements Forest services, Biodiversity and Landscape beauty. The PES design involves two Water Resource Users Associations-WRUAs (Turasha and Wanjohi)representing sellers located in the Turasha and Wanjohi sub-catchments of the Malewa River at the western foothills of the Aberdare

mountains in Kenya -the main catchment area of the Malewa River crucial for both Kenya's horticulture and tourism industry around Lake Naivasha and Nakuru Town. The two WRUAs represent land managers (sellers) while buyers downstream are represented by Lake Naivasha Water Resources Users Association-LANAWRUA. Initially, Naivasha PES initiative started with 565 pilot farmers, the sellers of ecosystem services and buyers primarily Lake Naivasha Growers Group –LNGG members of LANAWRUA (mainly the commercial horticulture business owners) downstream. The PES scheme which started at slow pace has now gained momentum and interest beyond initial expectations. Buyers of ecosystem services have incentivized land managers (communities upstream) for the last three years. In 20th May 2010, 470 Ecosystem Service-ES providers in two WRUAs were rewarded by receiving USD 10, 000 from TANAWRUA and similarly Wanjohi WRUA received Kshs. 438, 815.16 and Upper Turasha WRUA Kshs. 360,909.57 for 504 farmers (Wanjohi 276 and Upper Turasha Kinja 228) during 2011 reward.

The third payment was done on 21st June 2012 when the two WRUAs received Kshs. 1,151,696 for 784 members {including Kshs.132, 496 administrative costs for the two WRUAs 13% of (784*Kshs.1, 300} as incentive from LANAWRUA. Wanjohi WRUA received Kshs. 586,131 for 399 members while Upper Turasha Kinja WRUA received Kshs 565,565 for 385 members. Each farmer's incentive voucher was valued at Kshs. 1,300. The 2012 event attracted more stakeholders; Water Resources Authority (WRMA), UNEP, ICRAF, government line ministries (Water, Agriculture and Livestock), Provincial administration, public schools, buyers and sellers (the two business partners) and the WWF as the main project intermediary.

The Naivasha PES project now at its scale-up phase has attracted 765 farmers/farms (initially 565). Other than Lake Naivasha Growers Group-LNGG as the main buyer; more potential buyers have joined the scheme including Ranchers and other flower companies. Benefits include reduced soil erosion, increasing farm productivity an indicator of improved soil fertility (improved food security), increased income for land owners from different on-farm green enterprises on conserved farms, qualitatively observed increase in water clarity-confirming silt load reduction, community acquired skills and knowledge on good land management practices to protect land and water ecosystems for future sustainable agricultural activities, over 46 ha of land under different soil and water conservation structures. The project is however addressing the challenge by talking to other potential buyers to join the

scheme. Other challenges include degraded public land, complex land tenure system (continuous land sub division) , low capacity of the institutions involved and lack of policy framework governing PES in the country, though PES has been suggested casually in Kenya's March 2012 National Water Policy draft Sec. 6.3 (d).

3.3.4. Watershed and Soil and Water Conservation Programme in the County

In the past, considerable work on SWC has been done by the Government and donor projects. However, currently the onus lies with the County government but due to limited resources, this may not be covered adequately. In the CIDP considerable effort is put on water supply but little emphasis on SWC. Some important aspects related to SWC include: (Advocacy of environmental laws, Increased tree planting, Rehabilitation of dams and wetlands, Water harvesting, Pond construction, Establishment of tree nurseries and Water catchment management in Kimakia area of Gatanga which is a flagship project among others) Despite the inadequacy of funds, the County is addressing some environmental issues within the KES 5-7 billion budget. In total the county has projects as in **Table 3-10**: Some Environmental Related Projects CIDP

Type of Project	Estimated Cost (MI) (2013/14 – 2017/18
Tree seedling nurseries	8
Completion of constituency water pans	144
Mega dams	288
Energy conservation	3
Agroforestry farming system	12
Soil and water conservation	72
Carbon trading projects	25
Bee keeping	12
Total	**564**

This expenditure is impressive but not adequate. What is needed is an integrated project similar to the World Bank and CEF project implemented by ICRAF and KARI in the L. Victoria basin which is aimed at reducing soil erosion and pollution of L. Victoria by promoting farm conservation strategies and local capacity building for integrated agriculture. The project focuses on

100km^2 blocks of land in Nzoia, Yala and Nyando Rivers. In each block, the project work with 8,000-12,000 households. In the case of Murang'a, similar blocks can be defined for the various basins: (i) upstream of tunnel (5,000 farmers), (ii) tea zone areas (10,000 farmers), and coffee areas (20,000 farmers), and lower maize areas (20,000 farmers) giving a total of 45,000 farmers possibly covering 75,000 – 100,000 hectares

3.3.5. WRMA Catchment Management Strategy (CMS)

a) Underlying Principles

The overall responsibility of managing water resources and regulating water resource-use was therefore vested in the Water Resources Management Authority through the Water Act number 8 of 2002. Kenya is a signatory to the Dublin principles that sets out the best practices in Managing Water Resources. These are;

i. Water is a finite, vulnerable and an essential resource which should be managed in an integrated manner- under this WRMA has adopted the River Basin approach to managing water resources
ii. Water resources development and management should be based on a participatory approach, involving all relevant stakeholders- WARMA works harmoniously with the Water Resource Users' Association (WRUAs), Catchment Areas Advisory Committees (CAACs) and the people of Kenya through public consultations.
iii. Women play a central role in the provision; management and safeguarding of water- This have been mainstreamed constitutionally through the 30% gender representation and has been well rooted in the water sector down to the grassroots levels.
iv. Water has an economic value and should be recognized as an economic good, taking into account affordability and equity criteria.-Under this, a minimal tariff for abstraction permits and WARMA is also pursuing the User and polluter pays principle in collaboration with other authorities.

The water use charge has four main water resources management functions;

i. To support WRMA in obtaining accurate data on water use for planning and allocation purposes
ii. Increase water use efficiency. When a cost element is incurred, one is bound to check the possible areas to cut costs. One such area is to reduce wasted water through in efficient systems and methods of use. This increases efficiency in water use
iii. Give effect to the principle that water is an economic good for those who are using it for productive purposes.

iv. Provide the much needed funds to support water resources management functions

b) Catchment Management Strategies (CMS)

In pursuant to Section 15 of the Water Act 2002, the Water Resources Management Authority, in consultation with the public, is responsible for the formulation of Catchment Management Strategies (CMS) for the management, use, development, conservation, protection and control of water resources within each of the six catchment areas in Kenya. The CMS is a tool that describes the framework for the management of the water resources and related land resources in the catchment and it outlines how the concept of Integrated Water Resources Management (IWRM) can be implemented at the catchment level. The strategy provides an opportunity for water resources management institutions and stakeholders to formulate a coherent approach and focus for managing the water resources in a catchment. As such, the CMS is both a process and a framework for management, binding the Authority, the water users, other stakeholders and their representative structures in a social and/or legal union. In addition, the CMS is a comprehensive "business plan" for integrated water resources management focusing on issues, activities, resources, responsibilities, timeframes and institutions required to address the issues effectively and in order of priority. The ultimate aim of a CMS is to facilitate IWRM in a catchment area. The CMS operationalizes the elements of the National Water Resources Management Strategy (NWRMS) and the resource quality objectives (RQOs). Resources Quality Objectives are time-related management goals reflecting a path leading to an agreed future state for the resource as specified by the water resource class.

Functions of CMS

Catchment Characterization information

Such information include: Catchment/sub-catchments areas, drainage pattern, administrative units, topography, geology, land use, agro-ecological zones, soils, vegetation, protected areas (parks, reserves, sanctuaries, riverine). Part of the social system may also be included in catchment characterization, i.e., settlement pattern, population and poverty indices.

Management Approach

In the case CMS, management units have been developed based on ecology, livelihood and

Commercialization. The management approach therefore focuses on the level of importance of each of the three elements. In each unit therefore

aspects to be considered in IWRM include, stakeholder participation, institutional separation of functions, empowerment and gender balance among others.

Water Balance / Reconciliation Strategy

This strategy provides a description of the water balance status within the catchment with respect to availability of the resources and demand. It emphasizes the strategy to safeguard the reserve while meeting future water demands and the options, such as storage or transfers that can be used to mitigate the resource deficits. A hydrogeological assessment is therefore a pre-requisite for water balance in order to establish the quantity and quality of water supply. The assessment includes climate, geology and hydrogeology, boreholes and where relevant shallow wells, current status, abstraction and use, details of past studies, hydrogeological characteristics and analysis (aquifer transmissivity, borehole specific capacities, storage coefficient/specific yield, hydraulic conductivity and sensitivity to external factors), water quality and potential infringement of National standards, the impact of existing activities on aquifer.

Reconciliatory strategy addresses the issues of reconciling supply and demand. The demand aspect include water demand management, which in most cases should receive priority, improved resource management and conservation, the increased use of groundwater, the re-use of water; the management of invasive alien vegetation, the re-allocation of water, the development of surface water resources and the inter-catchment transfer of water and all aspects of conjunctive use. Thus all forms of data on water demand need to acquired giving provision for future plans. These include water demand for domestic, agriculture, livestock, environment, transport, recreation etc.

Water Allocation and Use

The overall guiding strategy for resource allocation is “to allocate the resource in an efficient and transparent manner that is consistent with the availability of the resource, and the needs of the reserve, and promotes social harmony and economic production”. The main instrument to guide water allocation is the Water Allocation Plan (WAP). The WAP is developed through stakeholder participation and it captures the priorities, procedures, and management controls that relate to the sharing of the resources. The principles of WAP are based on Dublin principles as stated above:

Water Resource Protection Strategy

The strategy to control pollution would involve identification of pollutants, classifying them and identifying their sources. Dumping has often been a major point source of pollution; therefore they should be carefully sited and managed. Polluted water has negative impact not only for water for life but also water for environment. Quality of effluent discharges should be controlled. The approach in controlling pollution of water resources should be participatory with all relevant stakeholders given chance to play their role under the coordination of the lead agency. Polluter pays principle could also be considered as a measure to reduce pollution.

Strategy for Catchment Protection and Conservation

Catchment protection and conservation is intended to minimize degradation which may result in reduction in quantity of both surface and ground water resource.. Some of the areas to be conserved or protected include protected areas, groundwater conservation areas, springs, riparian zones, wetlands, farmlands and rangelands. These areas need to be mapped and prioritized in order of severity of degradation and the causes of degradation identified. The stakeholders in relation to conservation areas need to be identified and they should participate in developing plan of action. Where necessary, gazettement may be may be recommended as a measure to ensure protection of prime water catchment areas.

Institutional Development Support Strategy

The institutional framework is one of the most important aspects of IWRM since it determines the effectiveness of policy implementation. Institutions are important as they provide a forum for stakeholder participation among water users and other interested persons before policies relating to the management and use of water resources are implemented. Co-operative governance (i.e. liaison and integration of planning between government departments, district and local authorities in governing a common resource) needs to be factored into the overall integrated water resources management arena to ensure a compounded benefit to all users in the catchment. The Water Resources Management Authority (WRMA) has already established its formal institutions, namely the Board, National and regional offices and Catchment Area Advisory Committees (CAACs) The establishment of the Water Resources Users Associations (WRUAs) is less formal and is a continuous process.. These institutions liaise with other governmental and nongovernmental institutions in co-operate governance of water resources.

Water Infrastructure Development and Management Strategy

Storage development is seen as an important option in the management of water resources in the Kenya, particularly with respect to making water available for beneficial use, improving reliability of water supplies and river flows, and for mitigating the effects of floods. Storage development provides a way of harnessing water resources during periods of excess (rainy seasons) and making the water available during periods of water deficit (dry seasons). This is seen as key in the fight to reduce poverty as it increases the water available for productive purposes e.g. irrigation, which with effective management can play an important role in improving agricultural production given that 80% of Kenya is arid or semi-arid. Water storage can be considered both for surface and groundwater. Surface water takes the form of tanks, reservoirs, pans, and dams. Groundwater storage development takes the form of augmented groundwater recharge

Strategy for Rights Based Approach

Over time water users have often violated permit conditions and abstracted more water to the extent of drying up the resources. This is common practice by large commercial farmers and has in a number of cases led to conflict over water use. The right based approach ensures that the disadvantaged groups including the environment have access to water. These groups usually use minimum water only to meet their basic needs. Such needs include domestic, livestock and health among others. Environmental needs for water include, reserve water to sustain aquatic life and water to meet wildlife water demands. Furthermore due consideration should also be given to poverty, gender, rights and governance and HIV/AIDS.

Climate Change Adaptation (CCA) in the WRMA

The inclusion of Climate Change Adaptation (CCA) in the WRMA catchment management strategies is in line with the National Climate Change Action Plan, which proposes, inter alia: i) Mainstreaming of CCA into all water resource management plans and actions; ii) Water conservation efforts including reduction of degradation of the main water towers and rehabilitation and restoration of all water catchments; iii) Carrying out effective trans-boundary water resources management and iv) Carrying out water resources assessment, documentation and dissemination of necessary information to stakeholders.

The key Climate Change Adaptation issues in TCA are:- i) Changes in rainfall patterns ii) Changes in river regimes (high flows have high peaks and short durations, low flows are lower and broader) iii) Frequency and magnitude of extreme weather conditions iv) Inadequate capacity for adaptation and resilience v) Impacts of climate change to water resource infrastructure

investments (RGS Destruction, siltation, high water losses from dams vi) Inadequate data for modeling, creating scenarios and early warning system vii) Progressive drying up of ox-bow lakes in the Tana delta. The key to effective community based adaptation to climate change is proper utilization of weather and climate information (which needs to be communicated in a meaningful way and in a timely manner). At the local level; WRUA members who are directly affected need to prepare and adapt to the impacts of climate change through:

i) Mainstreaming Climate change adaptation projects in the SCMPs and implementing them with a view to developing a climate change resilient community and
ii) Use the already developed climate change adaptation guidelines to inform project planning

Livelihood Enhancement

The Livelihood Enhancement component provides investments in community projects, and provides a demand driven window of funding for livelihood investments .This is done through the provision of Livelihood Micro Grants, which is an additional element within the WDC framework. Groups who are members of a WRUA are able to make an application for a livelihood enhancement project. This application will be endorsed by the WRUA for funding. Once funds are received, the project will be implemented by the group under the supervision of the WRUA. The target group for the livelihood enhancement are members of WRUAs located within the catchment area who are interested in receiving small grants to invest in their own income generating projects or projects which have a beneficial impact on the management of the natural resources base. WRMA provides quality assurance.

Monitoring and Information Management Strategy

Good planning and management of the water resources requires a good understanding of the available water resources and the needs for water. The water resources assessment aims at improving this knowledge of the resources and the needs. The process involves taking a holistic view of monitoring the water resources and information acquisition. Monitoring should identify the pertinent parameters of the hydrological cycle, assess the water availability spatially and temporally and evaluate the present and future water demands against the available resource. The understanding and consideration of the terrestrial and aquatic ecosystems and their interactions and land use impacts is an essential element of the assessment. A good water resources assessment needs to be based on physical and

socioeconomic data. This requires routine measurement from a network of hydrological monitoring stations with a sufficient frequency to allow the assessment to extract the required information. Socio-economic aspects must include analysis of user behaviour, the potential effects of demand management, etc. Water resources assessment for IWRM must put hydrology in a wider context and considers social and economic development issues such as urban growth and changing land use

3.3.6. Need for a Soil and Water Conservation (SWC) Programme for Murang'a County

a) *Objective and Justification*

The objective of soil and water conservation in Murang'a County should be

> *"To supply clean and adequate water to current and future population in the county for its domestic, agricultural and irrigation needs and to sell surpluses to other users"*

This can be done through payments for environmental services or in the case of water in terms of green water credits (GWC). Normally soil and water conservation projects funded by the public sector are the key mechanism.

b) *Up-stream Conservers*

Green water credits are a mechanism for payment of land users for specified water management activities. GWC also addresses MDG-1 to eradicate extreme poverty and MDG-7 to ensure environmental stability. It combats poverty by enhancing people's resilience to external shocks by enabling them to build assets (water) resources, stable soils, and reliability in crop yields. In environmental stability, it enables improved land and water management that benefits water users downstream, enhance habitats, reduce siltation of reservoirs and protect infrastructure from floods. At source water has been treated as common property so there is no incentive for sustainable management. Depending on SWC, the amount of water that infiltrated the soil can be increased threefold. The key managers of water are farmers but their usefulness is unrecognized and unrewarded. With GWC, this market failure can be remedied through payment by downstream beneficiaries to upstream land manager for the water management services they provide.

c) *Costs and Benefits for Downstream Water Users*

Improved SWC in upstream areas have the following benefits: (Improved water transmission (more water per unit of rainfall), Improved water quality,

buffering of above-average rainfall event, Reduction in extent and severity of soil erosion, reduced sedimentation of reservoirs and waterways and Stability of slope). Willingness to pay in the case hydropower depends on high volume transmission, security of supply and control of siltation, while in the case of municipalities it depends on quantity/quality and security of supply. A study done on the potential of SWC in the upper Tana Basin in 2007 (GWC Report 3) noted that depending on management crop, rainfall and local soil and terrain, green water management will:

- Abate sediment input to Masinga reservoir by 22-72 percent (03 – 2.5mi tonnes per year)
- Increase groundwater recharge from cropland by 4-57% (16-160mm/year) a potential gain of 160-1,600m^3/ha
- Cut damaging run-off by 22-66%
- Reduce unproductive evaporation of water from soil surface by up to 15% (50mm/year) a water gain of 500m^3/ha/year.

3.3.7. Approaches to Soil and Water Conservation

Two approaches can be identified:

(i) Augmenting the Aberdares Conservation area, and
(ii) Programme of soil and water conservation in areas above and below the proposed tunnel.

a) Augmenting the Aberdares Conservation Area (ACA)

As discussed in Chapter 3, the Aberdares as a whole is an important water tower for Central, Rift Valley, Eastern, Coast Province and Nairobi. Its conservation should therefore be treated as a national issue. Rhino Ark and partners in a period of 20 years constructed the 400km fence at a cost of KED400 million. This fence requires maintenance costs estimated at KES50 million/year. However, for the Aberdares Conservation efforts, no mitigation costs are included. It is proposed that AWSB should allocate KES 5 million annually to be managed jointly with Rhino Ark and KFS for maintenance of the fence component.

b) Programme of Soil and Water Conservation in Areas Above and Below the Proposed Tunnel.

Technologies used in SWC

Depending on the agro-ecological zone, slope, topology of soils and rainfall patterns, various SWC technologies can be used including; contour bunds, grass strips, gully plugging, stone bunds, tied ridges, compositing/mulching, percolation ponds and contour trenches, water harvesting ponds, road and roof water harvesting, spring protection, farm forestry and conservation

agriculture among many more. The impacts of some of these SWC technologies is as summarized in **Table 3-11**

Table 3-11: Some cases of soil loss and run-off reduction

Type	Soil loss reduction t/ha	Soil loss reduction (%)	Run-off reduction % of rainfall	Run-off reduction %
Zero tillage	22	88	25	83
Terrace	122	68	6	60
Check dam	70	39	18	38
Trash lines	90	90	45	64
Fanya juu	9	82	30	60
Road run-off management	10	40	30	80
Gravellia trees	2	30	5	13
Water harvesting	7	90	38	84
River bed reclamation	7	58	40	67
Gully reclamation	609	100	50	83
Pasture management	2	67	12	60
Stream bank stabilization	190	95	45	56
Stone bunds	8	80	30	75
Small bench terraces	40	76	29	62
Average	45	76	29	62

It is noted that the highest reduction in soil loss is by gully reclamation (609MT/ha) stream bank stabilization (190MT/ha) terraces (122MT/ha), while the average for the various technologies is 45MT/ha which is 76% reduction in soil loss and 62% reduction in runoff. Tea and coffee are the major cash crops while maize is the major food crop in the county. In terms of SWC and green water management systems for these crops, the potential systems are as summarized in table 3.16.

Table 3-12: Green Water Management Systems

AEZ	Crop	Management Package	% Reduction on run-off evaporation and erosion
I	Tea	• Grass contour strips • Mulch & weeding young tea	50% run-off reduction 75% erosion reduction 40% evaporation reduction
II+III	Coffee	• Grass contour strips • Mulch and weeding	50% runoff reduction 75% erosion reduction 40% evaporation reduction
II-IV	Maize	• Grass contour strip	50% runoff reduction 75% erosion reduction

It is noted that depending on the green water system, the reduction in runoff is 50% of baseline and erosion reduction is 75% while in terms of reduction in evaporation is about 40%. Another benefit is recharge of the groundwater which in maize is about 26-42%, in tea 6%-15% and coffee 4-12%.

Costs of SWC Measure

The costs vary by type of method and slope. The estimated construction and maintenance costs for various technologies are shown in table 3.17

Table 3-13: Average costs in KES/ha at USD = KES 90

	Soil bunds	Stone bunds	Fanya Juu	Grass strips	Farm Forestry	Tied ridges	Mulching
Construction	13,250	28,350	47,340	1,890	14,400	2,700	9,000
Maintenance	2,520	2,520	2,520	360	2,520	2,520	-

Tentative Estimate of SWC Project

Analysis was made for the project components of capacity building, tree seedlings nurseries, Aberdares fence maintenance, stabilization of riparian systems, Ndakaini catchment area including Kimakia forest, support to farmers in upstream of tunnel, and soil conservation measures in tea coffee and maize zones.

a) .**Capacity Building:** 29 officers at divisions trained and motorcycles provided, 4500 farmers trained and environmental hotspots in each division mapped

b) **Tree Nurseries in Divisions:** Each division should establish a nursery for agro-forestry trees and fruit trees which will serve as training for farmers and supply of seedlings. It is estimated that each nursery will cost KES 300,000 and will be self-sustaining though sale of seedlings.

c) **Maintenance of 40km of Aberdares Fence**: 40km at an estimated annual maintenance cost of Kshs.125,000 per km totalling KES 5 million

d) **Stabilization of Riparian Systems:** Murang'a has 10 permanent rivers and 70 springs. Using the assumption that the average main river length is 30km and springs is an average 5km, the calculation of the riparian system (assuming 2 metres on each side).The estimated riparian area is 13000 ha at KES 1500/ha.

e) **Ndakaini Riparian Area:** The Ndakaini ecosystem is viewed as consisting of four sub-components. The ***Thika river catchment area*** includes the upper catchment areas mostly forested area of the Aberdares, the dairy-tea zone in the dam area, the coffee area in downstream of the dam and the Thika-Chania confluence dominated by horticultural farming. ***The reservoir catchment area*** is estimated at 4444 ha with over 97% covered by bamboo, indigenous/plantation forests, herbaceous and bush cover. ***The reservoir area*** is the area surrounding the dam and impoundment. This was initially set at 717 ha affecting 975 people and finally the ***impoundment area*** which is that area upstream from the dam which is flooded. This is estimated at 305 ha of impoundment and 45ha of shoreline. .The potential lead group is the Ndakaini Dam Environmental Conservation Association (NDEKA), a community-based organization which brings together residents of Ndakaini and Makomboki sub-locations who have a common concern for conserving the dam resource.. There are over 200 groups with over 6000 members. CFAs close to Kinakia dealing with IGAs like forest non-timber products, water, bee keeping, environment, bamboo utilization and eco-tourism. There The estimated conservation costs are as follows: (Ndakaini area conservation – KES 10 million, Support to Ndeka- 10 million, Kimakia forest Catchment- 20 million and Support to CFAs at KES 25000/group- 5million)

f) **Upstream of Tunnel:** In Murang'a County:, There are community forests associations involved in grazing/grass cutting, fishing, water conservation, bee keeping, environment, tree nurseries. There are about 1,700 farmers were involved in about 50 CFAs. These CFAs can be identified and promoted in starting IGAs e.g. (Tree nurseries,

Environment conservation, Bee keeping, and others) Additional cases may include of stone/soil bunds (500ha) Fanya juu (200 ha) , grass strips (1,000ha) and riparian protection (200ha) .

g) **Tea Area:** Potential environmental hotspots may be 10,000 ha which can be improved by grass contour strips and shade trees at a cost of KES 2,000/ha

h) **Coffee Zone:** Assuming 20,000 ha of hotspots with 15,000ha requiring fanya juu at KES 43,340/ha and 9,000ha of grass contour strips at KES 2,000/ha

i) **Maize**: Assuming about 50,000 ha are hot spots, requiring grass contour strips at KES 2,000/ha

The estimates of costs are tentative and can only be affirmed by detailed project preparation which AWSB should finance. The proposed projects are in addition to those proposed by Murang'a County. The tentative identification of projects and costs is as presented **Table 3-14**

Table 3-14: Summary of project costs

	Activity	Estimated costs (KES Mi)
1	Capacity building	149.34
2.	Division tree nurseries	8.70
3.	Aberdares fence maintenance	5.0
4.	Stabilization of riparian systems	19.5
5.	Ndakaini catchment	45.0
6.	Upstream of tunnel	20
7.	Tea area	20
8.	Coffee areas	61.34
9.	Maize areas	100.00
	Sub-Total	428.88
10	Misc. (20%)	85.776
	TOTAL	**514.656**

3.4. Economic Analysis Impacts

There Is No Free Lunch

a) Water allocation

The current criteria of allocating water among competing users do not include an evaluation in terms of the social and economic impacts on the economy. Water allocation on a "first come, first serve" basis is impractical under conditions of water scarcity. Strategies for water allocation are important to avoid over allocation in areas where even little practical opportunity for reallocation may be possible. Using water efficiently involves making choices aimed at ensuring that sectors or individuals are allocated water according to their contribution to the growth of the economy. Essentially, water should be allocated to high value uses, taking into account the economic, financial and social impacts of the projects on the community and entire economy. Economic principals require that sectors or individual users be charged for water at a rate equal to the full economic cost of water. The full economic cost of water is a summation of the full supply cost, opportunity cost, economic and environmental externalities.

On the other hand, for reasons of equity, public health and amenity a minimum amount of water should be provided at low unit prices to meet the needs of the poor (basic human needs). For higher units of consumption, a progressive tariff structure ought to be used i.e. charging a higher rate for higher units of consumption. Establishing the Principle of Economic Value of Water is central in determining the water footprint on different sectors of the economy. Until recently, water management has been characterized by a supply management approach. Water demand has been established on an *ad hoc* basis and solutions designed to meet this demand. Economic, social and environmental impacts of water management may be devastating. Flood damage, drought, degradation of water resources through pollution, over-extraction of groundwater, etc have economic costs. The social costs of poor water resources management include water use conflicts, costs accruing to downstream water users as well as impacts on the poor. Environmental costs generally are pervasive because water itself is an integral part of the environment on one hand and determines environmental sustainability on the other. Aquatic environmental degradation generates both economic and social costs.

b) Cost-Benefit Analysis (CBA) of the Project

The NCT project was not meant for Murang'a County and what is included as benefits are just Corporate Social Responsibility and other assumed benefits. There was hardly any consideration of any soil and water conservation critical for watershed management. This situation is reminiscent of Ndakaini.

Benefits to Murang'a County

Benefits can be both tangible and intangible (in terms that no price has been put for them) For Murang'a County these were KES 1,460.5 million as shown in table 3.7 above.

Costs

The single most important cost element is the water loss from the county at the rate of 140,000m^3/day or (51.1mi m^3/year. At the extraction rate of 0.50 KES/m^3 this would be KES25.55mi However, this is not a good measure as exporting raw water affects value addition activities like irrigation, agriculture/livestock, and hydropower, among others. We consider these to have a value addition of KES 45/M. Therefore, the real cost is the opportunity cost forgone in irrigation calculated at KES 2,299.5mi at KES45/m^3.

c) *Scenario in Economic Analysis*

The analysis of seven scenario is based on the following assumptions.

i. Discount rate of 8%
ii. Time span of 25 years
iii. Benefits calculated as proposed funding of three water projects plus 25% of other benefits
iv. Two SWC projects at start of Tunnel 1 and 2
v. Agricultural benefits of SWC calculated at 50% of SWC project costs
vi. Costs are basically the loss to Murang'a by assuming a rate of KES 0.50/M^3 , KES 0.75/M^3 KES 1.0/M^3 and a market value added rate of KES 45/M^3
vii. Adding existing Ndakaini water at value added rate

The summary of economic Analysis shows that the critical area in the analysis is the cost of water. Water is abstracted at a ridiculously low rate and sold at near market price, since the benefits of selling water accrue to NWSC it is a cost to the county. From the proposed project the only tangible benefits are the costs for augmentation of the three projects. The county can get additional benefits if the project proponents included an additional project on soil and water conservation. The CBA as described above shows the following results

SUMMARY OF CBA
➢ Considering only the augmentation costs as benefits to the county and water abstracted at KES 0.50/M³ the BCR is 0.78:1 implying that the county gets 22% less in benefits
➢ Considering the augmentation costs as benefits to the county and water abstracted at KES 0.50/M³ plus SWC and associated benefits the BCR is 1i.6:1 showing the impacts of SWC
➢ Considering only the augmentation costs as benefits to the county and water abstracted at KES 0.75/M³ the BCR is 1.5:1
➢ Considering the augmentation costs as benefits to the county and water abstracted at KES 0.75/M³ and SWC and benefits, the BCR is 07.7:1 implying
➢ Considering only the augmentation costs as benefits to the county and water abstracted at KES 1.0/M³ the BCR improves to 1.14:1 implying that the county gets 14% more in benefits
➢ Considering only the augmentation costs as benefits to the county and water abstracted at KES 1.00/M³and adding SWC and agricultural benefits the BCR is 5.8:1 implying SWC is critical in this type of project
➢ Introduction of water at KES 45.00/M³t0 the above scenario lowers the BCR to 0.4:1, however without the SWC benefits the BCR is even lower at),02:1
➢ Introducing the NCT II at the same water abstraction level as NCT I and adding A second Phase SWC only improves the BCR to 0.09:1. Similarly adding the existing Ndakaini water lowers the BCR to.0.05:1

In conclusion it is noted that as long as water is abstracted at source at low costs and sold to consumers at a higher price the benefits to the county will always be insignificant

3.5. Critical Appraisal of ESIA

3.5.1. *Public Discussion and Participation:*

EIA has become an important instrument for ensuring environmental sustainability, social safeguard– to identify, avoid, and mitigate the potential negative environmental impacts associated with project implementation and operations. One major strength and outstanding feature is increased public discussion and participation. However, in this instance public consultation progressed upon inaccurate information[21]. AWSB continually asserted that NCT will draw from flood extreme flood water but according to Kenya's Water Allocation Criteria [22] and common definition, normal flow is defined as Q80 while Q95 criteria adopted by AWSB is indeed extreme low flow.

[21]Northern Collector Tunnel Phase 1 Environment and Social Impact Assessment Study Report, December 2014 Item sn 7, 8, 11 page 6-11
[22]Water Resources Management Authority- Water Allocation Guidelines (Table)

Community Supply Schemes (page 7-28) are cited as project benefits to Murang'a County were. Erroneously presented spin benefits of NCT Phase I, yet there are independent projects with separatebudgets under the financing agreement (*see Annex I*). The project proponents withheld material information instead adopted carrot and stick approach.

Moreover, some projects are classified as CSR, example in Gatanga yet the fall within AWSB mandated ares, thus AWSB are obligated to develop water supply infrastructure

It is noted the Construction Contract was awarded in September 2014 while the EIA report was completed in December 2014 and licence was issued in February 2015. It is doubtful there was ever really chance to included suggested mitigation measures in the project design.

Table 3-15: Analysis of stakeholders Concerns and mitigation action taken

Impacts	Proposed Mitigation	Comment
Reduce water levels and impact on the cascades downstream in Tana River, especially the Wanjii and Mesco HEP stations	None	- Report draw example of Ndula Hydro- Power Station which had to be closed down due to over abstraction - Wanjii and Mesco HEP are licensed abstractions and NCT may results in up to 15MWhydro power generation losses - Ikumbi Mini Hydro presently under development will be adversely affected, probably not operate
Disruption of ground water systems[23]	- Any shallow wells and boreholes affected by the project will need to be re-established when identified during the project operation; - AWSB has proposed projects to supply piped water to the area covered by the project	The mitigation measures do not address core impacts
Project location prone to landslide, tunnelling may at times deploy explosives and aggravate landslide hazards and tremors.	- Review of specialist geotechnical analysis conducted on the project area….. - Geotechnical monitoring will be undertaken through	- Appropriate level of geotechnical information has not been made available for development of the Detailed Design and Project Construction[24]

[23] The Final ESIA Report (section 7.3.5) observes that "tunnelling activities may lead to alterations of underground drainage and fracture flow. During the drilling, water inrushes may occur at fracture zones. Studies have shown that tunnels can lead to drying up of springs and streams leading to severe socio-economic and ecological effects such as the total disappearance of fish, amphibians and aquatic invertebrates in the dry stream sections. Several streams and rivers will be crossed by the tunnel

[24] Final Design Report Northern Collector Tunnel Phase-1 Page 3-7

Some severe damages including collapse of tunnel structures may occur in adverse situations.	Excavation Performance Review (EPR) system to continuously monitor the Geotechnical stability during the construction phase	- Risky for project work and workmen to be employed in the project - Excavation Performance Review (EPR) not captured in the Final design report.
The flow of water to users Downstream will reduce	The proposed project will abstract the flood water flows only. The intake infrastructure is designed in a way that ensures the gates close upon lower levels than flood flows;	Project draws all flows higher than Q95 which is extreme equivalent to extended drought flow levels
Catchment protection and Conservation;	Catchment management by AWSB will be highly recommended during the construction and operation phases of the proposed project;	No Budget provided in BoQ
Reduced water levels downstream that may lead to water conflicts between down stream	AWSB will undertake Water Abstraction Survey in partnership with WRMA	- No Budget provided in BoQ for construction phase - Cost of post-project compliance monitoring pass on to WRMA
Damage to roads in the area.	Contractor signs an agreement with the community to ensure that roads will be reinstated and or improved will be considered in the ESMP	- No evidence that agreements been signed - Budget provide – Kshs 2 Million

3.5.2. Comparisons of Preliminary and Final EIAS on Key Issues

The National Policy on Water (1999) has the following policy statements relevant to EIAs of water projects:

i. Preserve, conserve and protect available water resources and allocate it in a sustainable rational and economic way.
ii. A stage has been reached where freshwater issues often become the limiting factor for sustainable development and often result in conflicts among various competing sectors.
iii. The construction of major water projects (e.g. dam schemes, irrigated agriculture, flood control scheme and water transfer schemes, etc) while having positive impacts are also known to have negative impacts on the environment and human life.
iv. The solution to these problems (negative impacts) lies in adopting a multi-objective approach and incorporating a comprehensive environmental impact assessment. Every project's adverse impact on the environment and the necessary measures that need to be taken to mitigate these effects should be clearly defined. In particular, the upstream and downstream environmental impacts

of the project should be examined and the results taken into account during the planning and design stage.

The conclusions are based on how the two EIAs address the issue of conservation, downstream impacts and mitigation as stipulated in the Water Policy (1999). Issues of comparison include:

(i) construction and operational impacts and mitigation,
(ii) downstream hydrology,
(iii) water demand in Murang'a, and
(iv) Catchment management. As shown in **Table 3-16**.

Table 3-16: Comparisons of preliminary and final EIAs on key issues

	FINAL ESIA	PRELIMINARY ESIA
1.	**GENERAL FOCUS OF ANALYSIS**	
	• The analysis is focused on the tunnel zone and specifically on supply of water to Nairobi	• The analysis assumes a holistic approach looking at both the needs of Murang'a and Nairobi.
2.	**CONSTRUCTION/OPERATIONS IMPACTS AND MITIGATION**	
	• Are clearly addressed and additional mitigation costs allocated	• Clearly addressed and mitigation issues suggested but no cost allocation
3.	**DOWNSTREAM HYDROLOGY**	
	• Addressed with a fixed Q9s in relation to Nairobi supply while downstream impacts are casually mentioned in cumulative impacts.	• Critically addressed in all rivers with a conclusion that 2 X Q9s is required to satisfy downstream compensatory flows downstream
4	**ESTIMATION OF WATER DEMAND FOR MURANG'A**	
	• No overall water demand done but there is an assumption that augmenting current WSPs and adding new wider pipes will meet demand. However, demand for other economic activities not addressed	• No overall water demand is addressed but the assumption is put that 2Q9s will meet domestic and other economic activities. It specifically notes that reduced flows would have drastic effects on downstream uses.
5	**WATER CATCHMENT MANAGEMENT/CONSERVATION**	
	• Mentions the need for riparian and Aberdares conservation but does not allocate any mitigation costs.	• Argues for riparian areas conservation, upstream and downstream conservation and management, although no mitigation costs are allocated.

Based on the above observations the sustainability of the project depends on:

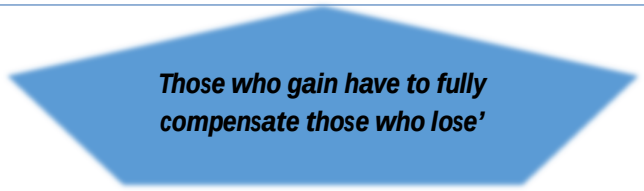
i. Addressing the downstream hydrology in relation to water demand for human consumption and other economic activities to mitigate against future conflicts.
ii. A comprehensive watershed management strategy (upstream, downstream and riparian areas stabilization) to meet the water policy objective of preserve, conserve available water resources and allocate in a sustainable and rational and economic way.
iii. Considering that water is scarce and that in its utilization there are losers and gainers (Murang'a County as a loser and Nairobi as a gainer), possibly use the policy decision based on Potential Pareto

Superiority, i.e. 'those who gain have to fully compensate those who lose'.

3.6. Summary Observations

A rule in making decisions on utilization of natural resources

> We don't own the water resources; we have borrowed them from future generations
> In Welfare economics the decision making rule is the policy decision based on Potential Pareto Superiority criterion. '.



Several observations have been made as follows

3.6.1. General Observations

i. Water in Kenya is a scarce commodity and relevant institutions should consider reviewing water abstraction rates to reflect the scarcity of water
ii. The Project put very little emphasis on water shed conservation, The Aberdares which is intricately tied with water in Murang'a and supply to Nairobi should be considered as a priority area for conservation by water user beneficiaries
iii. Murang'a County residents are not adequately supplied with clean water to the MDG stipulated level and the county should put this as a priority before considering supplying external beneficiaries
iv. Water supply and demand situation were not adequately covered. The analysis should have noted that the lower parts of the county are ASALs and need water for irrigation. In addition to household consumption needs the water related activities kike irrigation and mini hydro power potentials should be given more emphasis instead of the casual comments the report. Overall the report did not consider downstream users.

3.6.2. Northern Collector Tunnel 1

The following observations are made about the tunnel:

i. The overriding justification was cost-effectiveness vis-a-vis other alternatives considered especially the pumping costs in relation to water supply from a dam in lower areas of the county

ii. Considering the existing Ndakaini system and the proposed tunnel and extensions it will mean all major rivers in the county will be tapped at source putting the county at risk in meeting domestic water needs and for other activities
iii. The concept of tapping water resources at Q95 is particularly risky in respect to compensatory flows downstream and may curtail any future water-related economic activities. The preliminary EIA argued strongly against this
iv. The proposed development, as in the case of Ndakaini puts very little or no emphasis on watershed conservation both upstream or downstream
v. With the ever looming shadow of climate change and inadequate geotechnical information, not only the rainwater may be affected but also underground aquifers' which can be ruptured during drilling affecting springs and boreholes
vi. Measured in terms of BCA the benefits of the tunnel to Murang'a County are insignificant and the project can be considered as exploiting resources in one county to enrich another

3.6.3. Potential Decision outcomes

These are considered at two options

a) No to Construction of the Tunnel and Implications

A: Nairobi and Environs

i. Nairobi and environs will experience water shortages but this will prompt them to put in place water use efficiency measures by recovering the 30% water loss (almost 162,000m^3/day which is equivalent to the tunnel supply) and explore other options like Mavoko dam
ii. With decreasing fuel prices Nairobi can explore other options like a dam in the lower part of the county instead of putting too much emphasis on gravity flow

B: Murang'a County

i. Murang'a County can develop a programme to be a bulk water provider and supply Nairobi
ii. The so called flood water can be value added by utilizing it in irrigation and hydropower development to benefit the people of Murang'a County

b) Yes to Construction of the Tunnel and Implications

A: Nairobi and Environs

i. This will benefit Nairobi and environs but there will be no impetus to improving water use efficiency especially if abstraction rates remain low
ii. There will be no urgent need to explore other alternatives

B: Murang'a County

i. Murang'a County will lose about KES 2.3 billion in value added water annually due to opportunity costs forgone in irrigation development
ii. Benefits sharing as proposed in the Bill can increase the benefits, but the level at which these benefits are calculated needs to be decided. If the abstraction rates are low the benefits will be insignificant
iii. Murang'a County to insist on additional Water projects within the county and a comprehensive soil and water conservation project to cover the whole county
iv. Murang'a County can levy a specified fee to all water users for development of the water sector and facilitate exploitation of any farther resources beyond Ndakaini to ensure sustainability of the precious water resources
v. Murang'a County to immediately create a Murang'a County Watershed Conservation Fund in which the county and beneficiaries

During public disclosure meeting held at Nokras Hotel, several good points were raised and if had been heeded may have given different results.

The ESIA is important to provide data, information and knowledge for informed decision making on the design and operations and environmental management noting that "Preliminary environmental issues were reviewed at the Master Plan Level but the ESIA is expected to provide details on these issues **- Dr. Rafik Hirji: -World Bank**

Note: The ESIA report was complete in December 2014 while the project awarded in September 2015 by which time it was considerably late to incorporate a number of mitigation measures

AWSB is committed to dialogue for healthy discussions and feedback to inspire progress for the good of all stakeholders. **Peter Kungu: - Chairman AWSB**

Environmental issues take a long time to manifest hence it is important to conduct ESIA so as to identify the impacts early enough and plan to manage them - **Eng. Robert Gakubia CEO WASREB**

The Project was not just for Nairobi but for the good of the people in Murang'a; It's important to remember the lessons learnt from Ndakaini Dam which led to the need for development of a community water supply for Murang'a. - Eng. Michael Ngari- **Chief Officer Water, Energy and Natural Resources; Nairobi City County Government**

put funds for payment of environmental services/green water credits for watershed conservation

A compromise between the two ends is considered viable and is thus recommended

Finally, the draft Environmental management plan[25] form good basis to review the project impacts and mitigation while all the issues raised therein are important, the table below emphasis few areas of utmost priority.

Table 3-17: Summary of Critical EMP issues

Issue of Concerns		**Action, Surveys or Data required**
Monitoring of water resources	- Adaptive water management needs reliable and comprehensive data on which to base decision making. - These data should cover not just daily hydrological characteristics, but also indicators of water use and abstraction and water quality	- Upgrade existing and establish new river gauges for monitoring flows. River flow gauges spaced at not more than 10 km intervals downstream of the intake weirs and upstream of Masinga Reservoir. - Establish systems for daily reporting of these data to a central system.
Monitoring of water use and abstraction	Monitoring of downstream water use by communities and industries is required. i. Household use ii. Agricultural use iii. Industrial/commercial use	- Up-to-date information on all abstractions from the rivers, including both licensed and unlicensed abstractions for all uses. - Obtain data on volumes of water required as well as monthly or seasonal changes in requirements, and methods of abstraction.
Rural Water Supplies	Consideration should be given to ensure that all communities traversed by the pipelines are fully provided with piped water supplies, as a priority.	Provide adequate local, rural and urban water supplies along pipeline routes

[25]See annex VI

Issue of Concerns		Action, Surveys or Data required
Data for monitoring aquatic and riparian fauna	Monitoring for the EMP requires a set of accurate and comprehensive baseline data on which to base subsequent surveys, compare changes, and determine required actions. Where possible, surveys should include involvement of personnel from the National Museum.	- Surveys of aquatic fauna, including fish species in the rivers and in Thika Reservoir. - Surveys in the riparian zone of bird species and population numbers.
Technical committee	A technical committee, including environmental assessment personnel, needs to be established with the remit to assess any damage caused and assess required compensation or mitigation measures during construction and operational phases.	- Establish technical committee and review the collection of baseline monitoring data. - Ensure that contracts for the construction phase include reference to supervision by the technical committee. - Ensure that all local communities are fully aware of the details of upcoming activities.
Technical committee	- Continue the technical committee and review the collection of baseline monitoring data. - Ensure that the technical committee is able to review information from continued environmental monitoring activities as well as all ongoing construction activities.	All involved Authorities and Construction management
Access Roads to NC tunnel access sites	Road maintenance to be carried out on a regular basis to ensure continued access for all local services. Road maintenance should make maximum use of material excavated from the tunnel.	Administrative
Hydrogeology	Tunnelling may result in changes to underground drainage as a result of underground fractures. This will require detailed investigation during construction. The wider impacts of changes in underground drainage on groundwater resources will also need to be investigated, and suitable mitigation measures developed and implemented.	Data collection , monitoring and Construction management

.

Part IV: Framework for Resources and Benefits Sharing

Our water, Our life, our livelihood

National Campaign, *Conference on Policy and Integrated Water Resources Development* Mbagathi March 2002

4.1. Economic and Financial Sustainability of Water Resources use in Murang'a County[26]

This section presents an Integrated Water Development Planning (WaDeP) model of Murang'a County that assesses the economic sustainability of the use of water resources in areas that will be affected by the Northern Collector Tunnel (NCT) in the next 30 years. It also employs a scenario planning to assess the most financially sustainable funding sources for water investments in Murang'a County.

4.1.1. Economic Sustainability of Water Resources Use in Murang'a County

This study integrates a hydrological Vulnerability-Capability Assessment (VCA+) alongside a satisfactorily developed and applied benefit-cost analytical model (BCA) constructed under three scenarios of rainfall fluctuation in Murang'a County using the WaDeP water planning tool (Luwesi et al., 2012).

a) Key Assumptions of the Model

The WaDeP prediction model was used to develop and test options for matching water supply and water demand both upstream and downstream and assessing different options for utilising water surplus and optimizing water sufficiency for unmet demand in case of implementation of the NCT in Murang'a. The VCA+ and BCA were based upon unprobabilistic hydrological and financial mathematical models using linear programming, which was

[26] Documents consulted include

i. AWSB. (2012). Feasibility Report for water Supply Masterplan to Nairobi and Satellite Towns
ii. GoK. (2009). Government of Kenya Strategic Investment Plan - Dams' Construction (Unpublished).
iii. JICA and GoK (2013). The Development of the National Water Master Plan 2030 (Final Draft). Nairobi: Nippon Koei Co., Ltd.
iv. Luwesi, C.N., Shisanya, C.A. and Obando, J.A. (2012). Warming and Greening - The Dilemma Facing Green Water Economy under Changing Micro-Climatic Conditions in Muooni Catchment (Machakos, Kenya). Lambert Academic Publishing, Saarbrüken.
v. Luwesi, CN (éd.)(2011). "Innovative Ways in Financing the Water Sector". Final Report of the bfz /SWAP–WaterCap Training Workshops held in Mombasa (Kenya) from 7 to 11 November 2011 (Available at:www.watercap.org/ reports).
vi. Murang'a County Government. (2014). Murang'a County First County Integrated Development Plan 2013-2017. Republic of Kenya, Government Print, Nairobi.
vii. Ragab, R. and Hamdy, A. (2004). Water Management Strategies to Combat Drought in the Semiarid Regions. Available online at URL: http://ressources.ciheam.org/om/pdf/b47/05002266.pdf.
viii. TWSB. (2010). Detailed Design and Supervision for Murang'a North and Murang'a South Bulk Water Supply Project - Design Report Part 1: Feasibility Review. Document No. 10330-FR-C-001/1. Consultant: Howard Humphreys (East Africa) Ltd Consulting Engineers. Tana Water Services Board (TWSB), Nyeri.

embedded in the WeDaP system. The model assumed that the NCT would affect different areas along the NCT and downstream demand nodes (sub-counties), notably Kigumo, Kiharu, Kahuro, Murang'a South, Mathioya, Kangema, Kandara and Gatanga. However, Phase I of the NCT would the whole of Maragua Catchment estimated to of about 425 km^2 , which is an asylum to about a third (1/3) of the Murang'a County population. However, out of this population, about half of it will be severely affected, especially those living in the semi-arid areas of Makuyu and Kakuzi in Murang'a South Sub-County (also known as Maragwa) while Mathioya sub-county (normal areas) and Ithanga in Gatanga Sub-County (Arid areas) would be directly affected by Phase II of the NCT, owing to their dependence on the stream flow from the Grand Maragua, North and South Mathioya Rivers for drinking and food production. This report focuses on Phase I of the NCT implementation along the 3 major tributaries of the Grand Maragua River, which is Small Maragua, Irati and Gikigie streams. Compared to the available groundwater resources, these streams were considered to be the most reliable sources of water for the selected areas in Maragwa Sub-County.

b) Model Description and Scenario Planning

Figure 4-1provides a synopsis design similar to the WaDeP water planning model adopted from Ragab and Hamdy (2004). The prediction model built scenarios in terms of "what if" propositions for different levels of catchment development and water use options, to enable the design of contingency plans under risk and uncertainty. The study considered three (3) plausible scenarios on future developments of water resources and supplies in the selected area of Murang'a County by the year 2045. These encompassed "normal", "very dry" and "fairly wet" conditions assed from the river flows using mean flows (mean Q), the 99^{th} percentile flow (Q99) and the 95^{th} percentile flow (Q25) predicted by AWSB (2012). The "very dry" and "fairly wet" scenarios used a water supply turnover ratio computed from the predicted median flow (Q50).

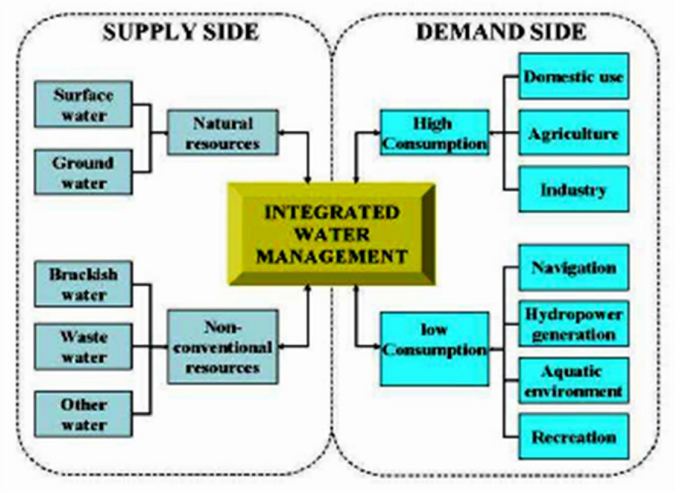


Figure 4-1: Integrated Water Development Planning Approach (Ragab and Hamdy, 2004)

These scenarios were dependable on the predicted hydrological, climatological and socio-economic conditions prevailing in Maragwa area. Regarding water demands, one or more of the following six (6) assumptions were to be maintained or expand at any time:

(i) "Business-As-Usual" (a status quo scenario);
(ii) implementation of an Environmental Reserve Flow (EFR);
(iii) irrigation expansion;
(iv) High population growth;
(v) high urbanization; and
(vi) low economic growth. Water supplies and demands as well as cost and revenues for their supply were computed from each scenario to unveil the economic sustainability of water resources use in Murang'a County with a special focus on Murang'a South Sub-County (or Maragwa).

c) Projected Socio-Economic and Hydrological Conditions in Maragwa

As said above, the projection of water resources and demands was based on simulated demographic and economic developments from the year 2015 to 2045 in the Maragwa area. This simulation also considered the size of the area, its income size and growth, population size and demographic growth, number of households and size of household, expected level of urbanization (**Table 4-1**). It shall be noted that the unit of cost for water supply under "normal" scenario of 10.11 Ksh and the one for demand (11.39 Ksh) were imputed from the average shadow price of raw water treated and/or distributed in Murang'a County by 5 major Water Service providers (WSPs), namely Murang'a, Murang'a South, Kahuti, Gatamathi and Gatanga Water

and Sanitation Companies (WASCO). This unit cost comprised a fix variable cost of 20% and an operating variable cost of 80%.

Table 4-1: Projected Demographic and Economic Developments in Maragwa By 2045

Variables	2015	2045
Gross Domestic Product (GDP) per capita (KSH)	32,159.70	27,475.14
Population (Number of People)	155,978.20	175,952.18
Number of Households	38,994.55	43,988.04
Household Size (Number of People)	4.00	4.00
Average Income per household (KSH)	128,638.78	109,900.56
Annual Population Growth Rate (%)	0.40	0.40
Income Growth Rate (%)	- 0.52	- 0.52
Cost of water supply under "normal" scenario(KSH/m^3)	10.11	11.20
Cost of water demand under "normal" scenario (KSH/m^3)	11.39	14.79
Level of urbanization (from 1 and 99%)	1.22	2.84
Average Water Supply turnover ratio under "Very dry" scenario (Q99/Q50)	0.44	0.37
Cost of water supply under "Very dry" scenario (KSH/m^3)	23.64	30.64
Cost of water demand under "Very dry" scenario (KSH/m^3)	26.63	40.46
Average Water Supply turnover ratio under "Fairly wet" scenario (Q25/Q50)	1.90	1.90
Cost of water supply under "Fairly wet" scenario (KSH/m^3)	2.85	3.16
Cost of water demand under "Fairly wet" scenario (KSH/m^3)	6.12	7.94

Owing to the fact that water services in both rural and urban areas are highly dependable on catchment hydrological conditions, the computed average shadow prices for raw water supply and demand were adjusted under "Very dry" and "Fairly wet" scenarios using the average water supply turnover ratio for each scenario. **Table 4-2**presents the predicted hydrological flows that served as the basis for the computation of the turnover ratio for each supply node. The mean flow (Q) in Table 2 was taken into consideration to simulate the water supply under "Business as Usual" scenario. To simulate the worst drought and mild flood in Maragwa the Q99 and Q25 flows were useful indicators of the "Very dry" and "Fairly Wet" hydrological conditions of the area, respectively. Water abstraction by the NCT (Phase I) was estimated based on the predicted Q95 flow of each tributary of the Grand Maragua. its s assummedn that Maragwa stakeholders complemented these surface water resources with a spoonful underground water resource. Finally, the

current water supply volume by WSPs in Maragwa amounted to 17,000 m^3 / day (**Table** 4-3).

Table 4-2: Predicted River Flows in the Grand Maragwa Catchment (m3/s)

River / Tributary	Q99	Q95	Q50	Q25	Mean Q
Small Maragwa Stream	0.621	0.704	1.719	2.899	2.467
Irati Stream	0.154	0.279	0.777	1.447	1.358
Gikigie Stream	0.051	0.101	0.338	0.722	0.693
Grand Maragwa River Flow	***1.453***	***2.417***	***7.030***	***13.099***	***12.132***

Source: Compiled from AWSB (2012) and TWSB (2010)

Table 4-3: Estimated annual water resources volumes in Maragua catchment area (000,000 m3)

Water Source	"Very Dry" Scenario		"Normal" Scenario		"Fairly Wet" Scenario	
	2015	*2045*	*2015*	*2045*	*2015*	*2045*
Small Maragua	26.9	19.6	75.5	64.5	127.4	108.8
Irati	32.8	23.9	41.6	35.5	77.4	66.2
Gikigie	10.3	2.2	21.2	18.1	68.6	38.7
Groundwater	0.2	0.1	0.3	0.3	1.1	1.1
Total	***70.2***	***45.8***	***138.6***	***118.4***	***274.5***	***214.8***
WSPs current supply	6.1	6.1	6.1	6.1	6.1	6.1
Projected NCT abstractions	14.8	10.8	33.2	28.4	58.9	50.3

Water demands for then above water resources in Maragwa area were prioritized according to the orders specified in **Table 4-4**. Agriculture was given the highest priority to enable catering for the current, ongoing and proposed irrigation projects in Maragwa over an area of 1,610 hectares. The model estimated daily water abstracted by households, schools, health centres local industries and farms either through existing water projects (WSPs) or directly from the rivers. The approach used was basically after the National Water Master Plan 2030 (JICA and GoK, 2013) and the First County Integrated Development Plan (Murang'a County Government, 2014).

Table 4-4: Water Demand Sites and Allocation Priorities in Maragua Area

Variable	2015	2045
Domestic urban water demand (priority ranging from 1 to 99)	10.0	10.0
Domestic rural water demand (priority ranging from 1 to 99)	5.0	5.0
Industrial water demand (priority ranging from 1 to 99)	20.0	20.0

Agricultural water demand (priority ranging from 1 to 99)	60.0	60.0
Transmission links from supply and resource sites to demand sites (%)	5.0	5.0
Demand site monthly share variation (%)	9.4	9.4
Demand sites loss rate (%)	30.0	30.0

Accordingly, Water for basic human needs (Domestic use) was calculated as a product of the population by 20 litres/person/day in rural areas, and by 50 litres/person/day in urban areas. Water for industrial use was allocated 15% of water use in urban areas. Livestock water consumption ratio for semi-arid areas was estimated to 18 m^3 per Livestock Unit (LU) per year comprising ½ head of grade cow, 1½ indigenous cows, 7½ sheep / goats, 2½ donkeys and 1 head of camel. Water allocation for wildlife was estimated in two steps: (1) water for big mammals (i.e. Elephant, zebra, wildebeest, kudu, warthog, and buffalo) representing 50% water allocation per LU per year (that is 9 m^3); and (2) water for small mammals (i.e. Giraffe, gazelle, gerenuk, impala, hartebeest, topi, eland, oryx, ostrich) representing 25% (that is 4.5 m^3). To compute agricultural water demand the model used consumptive water use in farming based on the potential evapotranspirations estimated to about 10,240 m^3 per hectare in Murang'a County.

Table 4-5summarizes the results of these computations for the year 2015 and 2045.

Table 4-5: Simulated water demand volumes for Maragwa area (000,000 m³/annum)

Water Use	"Very Dry" Scenario		"Normal" Scenario		"Fairly Wet" Scenario	
	2015	*2045*	*2015*	*2045*	*2015*	*2045*
Rural domestic use	0.9	1.0	0.9	1.0	0.9	1.6
Urban domestic use	0.6	1.1	0.6	1.1	0.6	0.7
Industrial use	0.1	0.2	0.1	0.2	0.1	0.2
Livestock use	0.008	0.014	0.008	0.014	0.008	0.014
Wildlife use	0.004	0.004	0.004	0.004	0.004	0.004
Agricultural use	39.0	51.5	16.7	18.8	8.8	9.9
Total Use	***40.6***	***53.8***	***18.3***	***21.1***	***10.4***	***12.4***

d) Economic Opportunities and Risks Arising from Water Use in Maragwa

The projections presented above clearly demonstrate that though currently plentiful, water resources in Maragwa area are facing fast growing demands with population growth, the urbanization level and the changing hydro-climatic conditions in different catchment areas. These high water demands will certainly be challenged in the near future by the decreasing river flows and groundwater resources as well as water demands and supplies outside the Maragua catchment, including the NCT project (**Figure 4-2**).

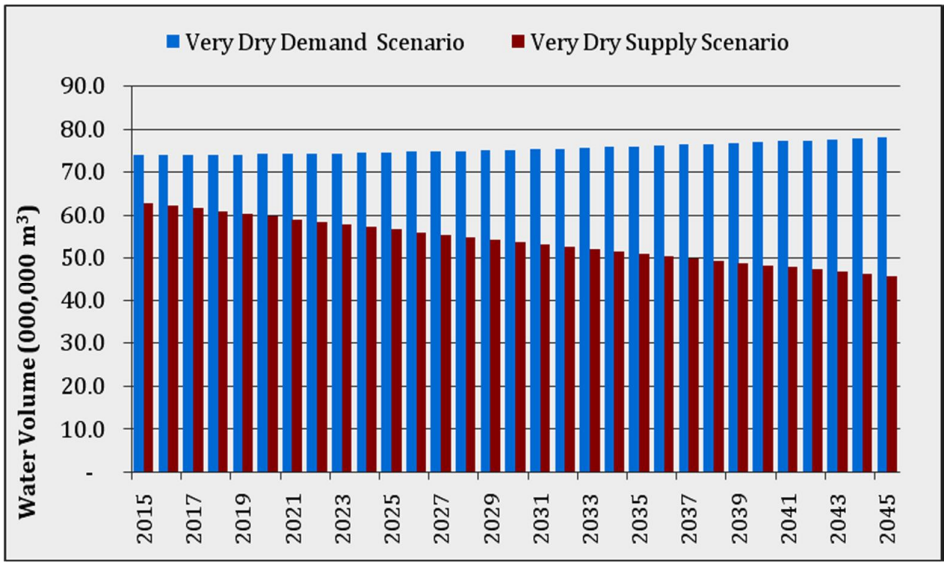


Figure 4-2: Water balance in Maragwa area under very dry conditions after NCT implementation

Implementation of the NCT may exacerbate drought conditions in Maragua catchtment, thus leading to water deficits of about 25 to 65% of the required water demand in Maragwa area by the year 2045. These risky conditions may be supplanted by other economic risks and opportunities arising from such water uses, which are presented and discussed below under each scenario.

First, there is a high risk of competition between the corridor other water uses in the catchment under the "Normal" and "Very dry" hydro-climatic conditions. In effect, the projected NCT abstractions were computed based on the Q95 flow for each tributary of the Grand Maragua River under a "business as usual" scenario. The latter was adjusted according to the water supply turnover ratio under the "Very dry" and "Fairly wet" scenario as illustrated by **Table 4-6**.

Table 4-6: Projected Annual Water Abstractions along the NCT in Maragua Catchment Area (000,000 M³)

Water Source	"Very Dry" Scenario		"Normal" Scenario		"Fairly Wet" Scenario	
	2015	*2045*	*2015*	*2045*	*2015*	*2045*
Small Maragua	7.6	5.6	21.6	18.4	36.4	31.1
Irati	6.7	4.9	8.5	7.3	15.9	13.6
Gikigie	0.4	0.3	3.1	2.6	6.6	5.6
Total	***14.8***	***10.8***	***33.2***	***28.4***	***58.9***	***50.3***

This table reveals that to attain its designed capacity of 142,000 m³/day, the NCT needs "Fairly wet" conditions in each catchment, with a reliability of at least 90%. Yet the chance for such conditions to occur has been established to 25% only by hydrologists. Thence, the NCT would compete with the local demands under a "normal" scenario, thus resulting in millions of Shillings of opportunity costs that Murang'a County would likely bear, if no compensation mechanism would be established. The NCT would be an unfair project under "Very dry" scenario because it would worsen the already existing drought and escalate its shortage costs to billions of Shillings. Therefore, the "Fairly wet" or flooding scenario is the only feasible option for the implementation of the NCT in Murang'a County.

The building of the NCT would result into several opportunities for Murang'a people under conditions floods since it will reduce the high costs of saving massive water surplus ranging from 15 to 25 times the required water demand (Figure 4.2-3).

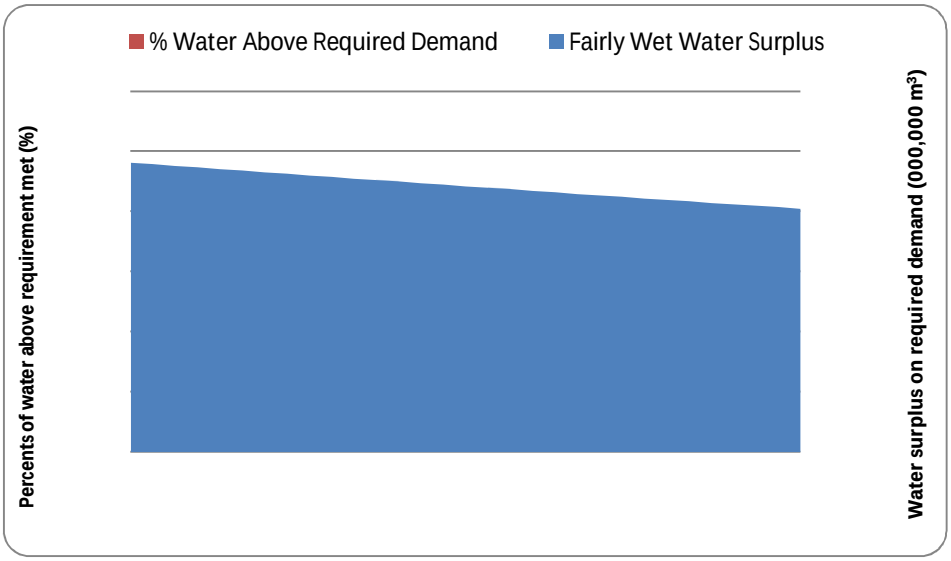


Figure 4-3: Water surplus on demand requirement in Maragua under "Fairly Wet" Scenario

This storm water generally wreaks havoc, destroying properties and lives where no adequate storages and protections exist. The transfer of part of this floodwater would save billions of Shillings to the County Government, which it could have used to build huge water pans, weirs, dams and hydropower plants as well as massive irrigation schemes and water based recreational centres. Besides, the NCT offers a platform for negotiations and benefits sharing between Murang'a County and the neighbouring Capital City of Nairobi, which are the main user of waters from Ndakaini Dam and the potential NCT user. This co-operation will be healthy for both counties since it

may results in an exchange of interflows in terms of water treatment and distribution, funds for catchment conservation and further investments in Nairobi and Murang'a County, respectively. The following sub section translates these opportunity, shortage and saving costs of water use in Maragwa area in monetary terms.

i. Costs and Benefits for Water Development in Maragwa

A cost-benefit analysis was needed to study the feasibility of water projects in Murang'a County under the current socio-economic conditions. The development of water surpluses through viable investments in water storages and other infrastructure for the protection of properties and life as well as irrigation schemes and water based recreational centres will require massive funding. This money may be raised from the sale of bulk raw water to the neighbouring counties at the demand cost or through water treatment. However, this last option is more contingent and requires careful computation of costs and benefits. **Table 4-7**provides a detailed calculation for investing in the water balance yielded in Murang'a South (Maragwa) under any scenario for the benefit of the people of Murang'a.

Table 4-7: Projected Benefits from Water Balance Development in Murang'a South

	Horizon 2015			Horizon 2045		
	Very dry	Normal	Fairly Wet	Very dry	Normal	Fairly Wet
Water Balance (000,000 m^3)	22.2	120.4	240.8	-8.0	97.4	202.4
Water Balance with EFR/NCT (000,000 m^3)	-11.1	48.7	113.2	-32.3	36.1	93.3
Annual Investment Share (000,000 Ksh)	343.4	343.4	343.4	382.7	382.7	382.7
NCT Water Cost (000,000 Ksh)	350.6	335.6	167.7	331.8	317.6	159.0
Total Water Cost (000,000 Ksh)	2,445.0	1,627.7	1,133.1	3,601.9	1,479.4	1,112.4
Total revenue (000,000 Ksh)	354.0	332.6	883.9	193.1	320.4	964.2
Benefit (OM model) (000,000 Ksh)	-508.9	-498.7	224.9	-819.6	- 466.7	287.1
Benefit (OM/OC model) (000,000 Ksh)	-2,091.0	-1,295.1	-249.3	-3,795.0	-1,159.0	-148.2

To develop its water resources by the year 2045, Murang'a South Sub-county needs an investment of Ksh. 10.3 billion, which can be scaled up over a period of 30 years with a share of 343.4 million p.a. This water investment was based on the cost of constructing 2 large dams of the size of Chemususu in Koibatek (Baringo County) estimated to Ksh. 4.9 billion per dam (GoK, 2009; Luwesi, 2011). These dams will contain the volume of water balance

computed under the "Normal" scenario and part of the "Fairly wet" scenario, if an Environmental Flow Reserve (EFR) and the NCT water abstraction are included.

Under a "Fairly wet" scenario, the water balance amounted to 113.2 and 93.3 million m^3 for the year 2015 and 2045, respectively. This water surplus would incur total water supply costs of 1.13 and 1.11 billion Shillings in 2015 and 2045, respectively. The cost of saving NCT water would have amounted to 167.7 and 159 million Shillings in 2015 and 2045, respectively. This water business would result into a financial benefit (O&M model) of 224.9 and 287.1 million Shillings in 2015 and 2045, respectively. However, the saving costs of the massive water surplus will burden the economic profit (O&M+CS model) to close to a loss of 249.3 and 148.2 million Shillings in 2015 and 2045, respectively.

Under a "normal" scenario, the water balance was estimated to 36.1 and 48.7 million m^3 for 2015 and 2045, respectively. This water surplus would incur total water supply costs of 1.63 and 1.48 billion Shillings in 2015 and 2045, respectively. The opportunity cost arising from the NCT water would amount to 335.6 and 317.6 million Shillings in 2015 and 2045, respectively. The financial benefit (O&M model) would amount to a loss of 498.7 and 466.7 million Shillings in 2015 and 2045, respectively. If added to this benefit, the opportunity costs would increase this loss to 498.7 and 466.7 million Shillings in 2015 and 2045, respectively.

Under the "Very dry" scenario the water balance would be catastrophic and could not allow taking an EFR neither an NCT allocation. Hence, the catchment would result into a water surplus in 2015 amounting to 22.2 million m^3 with unmet demands of 8.0 million m^3 in 2045. The water surplus recorded in 2015 would incur total water supply costs of 2.5 billion Shillings with a shortage cost arising from the NCT water of 350.6 million Shillings. In such circumstances, the financial benefit (O&M model) would be a loss of 508.9 million Shillings, while the economic profit (O&M+CS model) would result into a total loss of 2.1 billion Shillings in the year 2015.

To ensure sustainable water supply in Murang'a and neighboring counties, the County Government needs to introduce innovative economic instruments and financial mechanisms for pricing water and protecting its resources without withstanding the key principles of equitable sharing of benefits, efficient water supply and economic use of natural resources. The following sub-section suggests financially sustainable ways for investing in water resource development in Murang'a County.

4.1.1. Financial Strategy for Sustainable Water Development in Murang'a County

a) Key Assumptions of the Financial Strategy

Murang'a County is in dire need of financially sustainable water investments to upscale its water use and reduce the massive opportunity and saving costs. Though being a burden to its water economy, The Northern Collector Tunnel (NCT) may provide various opportunities for Murang'a County Government to venture into water business. This study narrowed down to three possible options, which were found financially sustainable water investments by the committee of expert. These included: (1) the creation of bulk water company to manage the NCT water; (2) the institution of a water conservation fund to cater for expenses of watershed and water towers rehabilitation; and (3) the introduction of a water levy per unit of water abstracted in Murang'a and transferred in other counties. While looking at the three options, the following assumptions would be critical for the success of the water development strategy:

(1) There will be a political goodwill among interested parties in the forthcoming deal;

(2) Funds availability will not be a hindrance to the projects;

(3) Trained staff and other human resources and capacities will be adequately available;

(4) There will be a constant flow of water to sustain current and future demands; and

(5) The economic environment in Murang'a and Nairobi Counties will be conducive for water business.

b) Bulk Water Company

There are two major bulk water businesses in Kenya, which supply bulk treated water to Mombasa City and Mavoko. There were thus calls for the creation of a bulk [raw] water company, fully owned by Murang'a County Government, and to be registered with the KRA, WASREB and other State agencies. The company will be fully mandated to: (1) Manage bulk water at source through conservation of the water catchment; (2) Abstract and sell bulk water to distributors and retailers; (3) Raise fund for development and maintenance of infrastructure; (4) Assure major water users and irrigation schemes of the County's Government protection; (5) Ensure Equitable distribution of water resources across the county. The Administration of such a company will be done by a Board of seven (7) Directors representing all the

major shareholders, including the National Government, Murang'a County Government and Nairobi County Government.

As noted under sub-section 4.2.5, an initial investment of Ksh.10.3 billion is needed to construct 2 large dams worth Ksh. 4.9 billion each, of the size of Chemususu in Koibatek (Baringo County) and cover initial administrative costs (GoK, 2009; Luwesi, 2011). Table 4.3-1 suggests an accounting of the future operational costs to be incurred by the Bulk Water Company.

Table 4-8: Projected Operational Costs and Pricing of the Bulk Water Company

	Ksh. 10.3B raised through Public Grant	Ksh. 10.3B raised through Loan repayable over 15 years at 8% interest p.a.)
Expenditure		
Personnel	37,213,395	37,213,395
Administration	24,917,067	24,917,067
Operations	41,297,151	41,297,151
Maintenance	1,852,158	1,852,158
Regulatory Levy	5,431,614	5,431,614
Conservation cost	433,500,000	433,500,000
Loan repayment for capital		215,707,500
Total Expenditure	***544,211,385***	***759,918,885***
Revenue		
Volume sold	41,170,000	41,170,000
Unit Cost	14.8	23.6
Total Revenue	**609,316,000**	**971,612,000**
Benefits		
Total Benefits	**65,104,615**	**211,693,115**

It was hypothesized that operational costs incurred by Mombasa Bulk Water Company will guide bulk water pricing in Murang'a County. The latter will represent a third of operational costs of Mombasa Bulk Water Company. Funds will be raised either through a public grant from the National Government and development partners or through a loan repayable over a

period of 15 years to buy out the NCT infrastructure. This initial investment fund will be repaid through cost recovery. This will require adequate pricing of water services and management of the production.

Henceforth, the Murang'a Bulk Water Company expects to charge Ksh. 14.8/m^3 if accorded a public grant, and Ksh. 23.6 if the fund would be raised through a loan repayable over 15 years. In any case, the company expects to yield a volume of water equal to the projected volume to be transferred through the NCT under a "normal" scenario, which is equal to 48,000,000 m^3 p.a. This water will be distributed as follows:

(1) Distribution within Murang'a County: 6,830,000 m^3 per annum
(2) Transfer to other counties: 41,170,000m^3 per annum

It shall be noted that there are many factors that may impede the implementation of such a project. The following have been identified as major limitations for the existence of the Bulk Water Company: (1) lack of adequate funding; (2) enormous tasks at inception; (3) insufficient managerial capacity to run the company; (4) lack of political goodwill from the national government; (5) conflicting mandates with the existing institutions in the water sector; (6) hostile national political environment; and (7) possible future political interference to the company mandate at the county level.

C) Ecosystem Services Fund

When faced with challenges of implementing the bulk water company project, the Murang'a County Government may resort for a water conservation fund to be created by an act of Murang'a County Assembly and adopted by the executive for implementation. The idea of a water conservation fund was prompted by the inadequate funding of the water catchments conservation in Murang'a County. Moreover, there is shortage of staff dealing with soil and water conservation, owing to limited training opportunities. Besides, the encroachment of the riparian zones by farmers has raised alarm on community capability to monitor and manage environmental activities, besides the weak enforcement of the EMCA, Forest Act and the WRMA Water Rules. Therefore, the new fund will solely be set aside for implementing water development projects such as: (1) Afforestation and reforestation of public and private lands, including the Aberdares' forest rehabilitation; (2) Soil conservation measures along the riparian zone; (3) Community water conservation demonstration projects; (4) School soil and water education projects; (5) Information campaigns on capturing, harvesting, storing and using rainwater; and (6) other similar projects.

Will be eligible for the fund, any applicant (private or public) having a water and soil conservation component in its daily business. These encompass: (1) Municipal and urban public institutions in charge of education, environment, agriculture, health care and water infrastructure, etc.; (2) Non-profit making corporations ventured in the above businesses; (3) Rural water supply schemes (self-help groups or community water projects); (4) sub county water offices (former DWOs); and (5) other water and soil conservationists.

The fund will be managed by a board of nine (9) members appointed by the Murang'a County Government. The latter will be mandated to: (1) mobilize resources and raise adequate funding; (2) finance development and maintenance of infrastructure; (3) finance and manage conservation activities in the county; (4) build the capacity of communities in the riparian areas; (5) ensure continued availability of the commodity; and (6) Initiate and sustain environmental conservation activism.

A total amount of Ksh. 1.2 billion scalable in 4 years was estimated to cater for both *in situ* conservation for the affected area (Rehabilitation activities) and capacity building (through awareness creation and information sharing) of the communities in Murang'a County at large. With an annual cost of 306 million, the County Government expects to raise a water charge of Ksh. 6.8/ m^3 over the projected 45,000,000 m^3 to be yielded by the NCT. The following steps have been recommended for the smooth implementation of this conservation strategy: (1) a Draft forest policy based on the Forest Management Planning (Zoning) ecosystem approach; (2) stakeholders involvement consultative meeting; (3) Promotion of forestry and extension services; (4) Promotion of dryland forestry; (5) catchment rehabilitation through reforestation and afforestation; (6) Private sector industrial plantation forest development; and (7) Institutional transformation.

Without withstanding the importance of this conservation fund, the following limitations have been pointed out by the committee of experts: (1) The enactment of the fund may be in contravention of the EMCA, Forest Act and WRMA Water Rules; (2) Financing projects may be inadequate to effectively implement planned activities; (3) The fund may not have adequate staffing and other human resources; (4) There may be possible political interference and lack of political goodwill. In such a circumstance, the County Government may resort to enforce a water levy.

D) County Environmental Mitigation Levy

Murang'a County Government may introduce a royalty payable for the mitigation of natural disasters within the county. This levy will be enacted by the County Assembly and be used to ensure sustainability of water use

through the conservation of water catchment areas and equitable allocation of water supply among competing uses. The County Government shall appoint a committee of three (3) members to oversee, allocate and account for the funds raised for proper utilization. This committee will comprise three major stakeholders interested in the trans boundary water transfer, namely: (1) ministry of environment and natural resources; (2) Murang'a County Government; and (3) a representative of environmental conservation groups (WRUAs, CFAs and others) registered under the ministry of culture and social services. The water levy was estimated to Ksh. 7.8/ m^3 based on the expected water shortage costs (of Ksh.350.6 million p.a.) arising from the implementation of the NCT as computed earlier (see Table 7) and the projected water volume (of 48,000,000 m^3 p.a.). Nonetheless, the institution of this levy may be seen as an additional burden to the water users since they already contribute similar charges to WRMA and WASREB. Hence, a bulk water company implementing an Ecosystem Services Fund (ESF) would be the best alternative.

4.1. Legal and Institutional analysis

4.1.1. Introduction and Background on the Northern Collector Tunnel

i. **MURANG'A County** is endowed with water resources namely, (in relation to NCT water services infrastructural project), the watercourses of Maragua, Gikigie and Irati.

ii. The Athi Water Services Board (AWSB) is a state corporation incorporated by the Government of Kenya by mandate of the Water Act 2002, and licensed in water services and sanitation infrastructure management, development and improvement functions by the Water Services Regulatory Board (WASREB). AWSB has been vested with bulk water management mandates by the Water Act 2002. AWSB manages water services and infrastructure development in Murang'a County within Gatanga sub-county and Thika dam.

iii. Tana Water Services Board (TWSB), is also a state corporation, which is key in Murang'a County, as it is licensed under the Water Act in water services and sanitation infrastructure management, development and improvement functions of Murang'a County by the Water Services Regulatory Board (WASREB), (except for Gatanga sub-county which is under the mandate of AWSB).

iv. The NCT is a project of AWSB to be built in Murang'a County atvarious tributary points of Maragua and Gikigie and Irati rivers in the villages, locations of Murang'a County to an outlet at the Githika River, all water to flow downstream to the existing Ndakaini Dam in Gatanga Sub-County.

The following are the legal aspects relating to the NCT Project.

4.1.2. Licence for Provision of Water Services

i. TWSB is licensed within the attached Murang'a County gazetted area

ii. AWSB mandate is within the attached area gazetted *Gazette Notice No of 2003. (Note that a*longside AWSB are other four water services Boards (WSB) in the country, as per G*azette Notice* no. 1714 of 12th March 2004

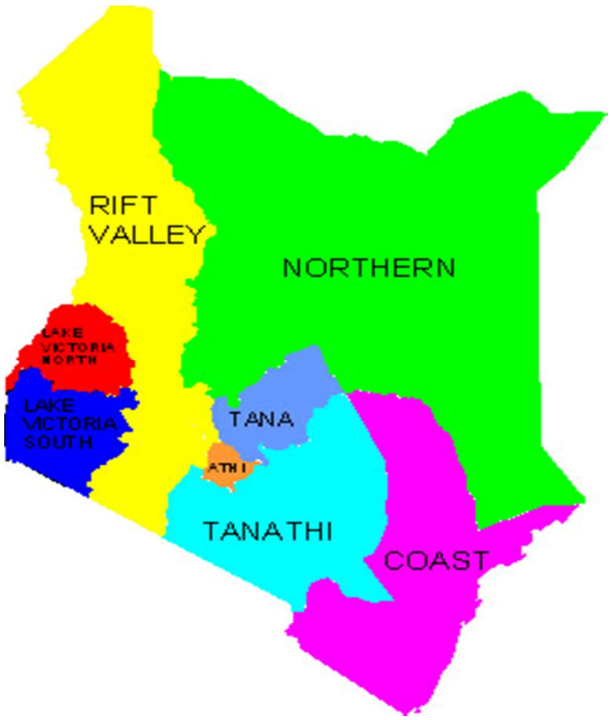


Figure 4-4: Jurisdiction map of Water Services Board- Gazette Notice no. 1714 of 12th March 2004

iii. The Water Act 2002 requires that the services boards (AWSB and TWSB in this respect) in turn to engage water services providers as agents, namely companies, to undertake provision of water and sewerage services within a defined area and based on water services provision agreement.

iv. The proposed development of infrastructure and delivery of water and sanitation services within the mandated areas by water services boards are required to be approved, incorporated in the projected development planning of each WSB, in order for the licence to be issued.

v. Section 57(6) and section 107 of the Water Act also requires that public consultation process and review of project proposals made be undertaken. Any person opposed to the issuance of the Licence may object in writing to WASREB and even appeal to the Tribunal against the issuance of the Licence.

vi. TWSB has a current licence, and the proposed NCT infrastructure development in Murang'a County is within its area of jurisdiction (as per gazetted map) but these developments were not proposed or incorporated in the TWSB Business Plan. Reports on consultations with AWSB and WASREB and consents to undertake the Project inside TWSB jurisdiction do not exist.

vii. Currently AWSB has a ten (10) year licence. WASREB issued the current Licence to AWSB in 2009 for 10 years up to year 2019

viii. AWSB 10 year Business Plan – Planned Financial & Infrastructural Improvements are attached to the Licence (*Note - NCT infrastructural works are not in the Business Plan of its licence).* NCT was later incorporated as a Project later in the reviewed AWSB strategic plan.

ix. A consultation process and agreement with the TWSB which is mandated in water services in the areas of tapping water by NCT was not conducted.

x. When the Murang'a County Government was established, a County government and Murang'a people public consultation process on the NCT was not conducted by AWSB. Hence consultation process and request for approval with the MCG on the NCT was not undertaken by relevant government agencies.

xi. It is therefore correct to state that consultations were not conducted and approvals were not given for the NCT be undertaken by AWSB in areas beyond their jurisdiction, that is, inside the villages, sub-counties and County of Murang'a, before and after the County government was established.

4.1.3. Construction of Northern Collector Tunnel - NCT project of Athi Water Services Board (out of AWSB area of jurisdiction/area of mandate)

i. The gazetted area of jurisdiction of AWSB as per map is upto Gatanga, and not in all areas of Murang'a.

ii. The NCT is beyond the jurisdiction of AWSB. It has no jurisdiction in Murang'a areas where the 3 watercourses traverse and the points where the water is to be tapped. Consultations and the consent of the Tana Water Services Board and Murang'a CG is a prerequisite to the project commissioning.

iii. Most of the areas to be excavated are in community land under the MCG mandate on behalf of communities under Article 63 of the Constitution.

iv. Based on the existing World Bank Northern Collector Tunnel - NCT project documents, Nairobi Water Company shall manage the Northern Collector Tunnel from source, i.e. Bulk water of the Gikigie, Maragua, and Irati rivers shall drain into Ndakaini dam.

v. Murang'a County Government is evaluating the NCT project to assess its impacts on Murang'a water resources and the water supply needs of Murang'a County. In this respect MCG shall

make submission to the Water Resources Management Authority on the proposed permits for water intakes by AWSB from the three watercourses of Murang'a County.

4.1.4. Murang'a County Water Demand Requirements

i. Technical survey reports indicate that only about 32% of residents of Murang'a County have clean drinking water.
ii. The rest of the population uses untreated water from streams (50%), wells (23%) and other sources (11%). This implies that there is a great need for piping clean water to over 200000 households. The county is developing a Master Plan to expand the capacity of water schemes to ensure a minimum of 40% of the households are directly supplied with water.
iii. The existing five water companies are undertaking a study for strategic planning to enable them to meet the water and sanitation demand needs of Murang'a County.
iv. MCG has priority of use of its water resources in accordance with the principles of sustainable utilisation and intergeneration equity.

4.1.5. Constitution Mandates of Murang'a County Government

i. With the promulgation of the Constitution, devolution, and establishment of the Murang'a County Government (MCG), the Constitution in the 4th Schedule PART 2 mandates the County governments as follows: -
    a) MCG has obligations to plan and provide water and sanitation services to its people - Schedule 4 Part 2 Clause11 b.
    b) Other functions include - Clause 10 on implementation of policies on natural resources and environmental conservation including soil and water conservation and forestry, storm water management.
ii. Therefore the constitution of Kenya has transferred vital roles to the County governments by allocating them with mandates water and sanitation infrastructural works and services. MCG has therefore prepared the MURANG'A WATER BILL
iii. In respect of the role of County governments soil and water conservation and forestry means that vital aspects of water resources protection and management vest in the County governments.

iv. The NCT project report and AWSB action has ignored the current mandates of the Murang'a County government and its water service's needs, and the tender for construction of the Northern Water Collection Tunnel has already been awarded to Chinese company known as China Ghezouba Construction Company limited.

4.1.6. Jurisdictional Mandates of Murang'a County Government in Water/catchment resources Conservation

i. Within the Aberderes ranges there are other watershed counties and linking the three watercourses with Murang'a is Nyandarua.

ii. Riparian Counties in which the watercourses flow has the jurisdiction and duty as the riparian county to be concerned about and be involved in: -

a) Reasonable and sustainable utilisation of water resources firstly for the needs of Murang'a people and its environment and the extension of uses to other jurisdictions.

b) To protect water resources from threats of adverse effects, or changes in the conditions of the watercourse and environment, economy and wellbeing of Murang'a county, its people and its environment,

c) Measures for the prevention, control and reduction of pollution, and measures to abate acidification and eutrophication of water resources.

d) Management of water resources and bulk water of Murang'a County.

e) Joint cooperation is essential by riparian counties for the above conservation activities (Aberderes range watershed counties) together with the national government authorities

f) The application of the Precautionary Principle – to take action to avoid potential impact and continuous assessment of action which might cause release of hazardous substances into the water resources

g) The Polluter Pays – the costs of prevention, control, and reduction measures shall be borne by the polluter

h) Water resources shall be managed so that the needs of the present generation are met without compromising the ability of future generations to meet their own needs – intergeneration equity.

i) Payment for environmental services being the cost of conservation and protection of the watercourse system from the

source to non- source areas shall be borne by the beneficiaries of the water resources. MCG to establish a trust fund mechanism

j) Undertake data and measurements on basic and economic uses of water resources – household – water and sanitation, agriculture for joint planned measures.

4.1.7. Strategies for management of Water Conservation areas as stipulated in the Water Act and Water Resources Rules, 2002.

Include: -

i. Strict conditions and measures to prevent pollution using Environmental Impact Assessment and Audits (EIA)
ii. Ecosystem management approach hence including soil and water conservation, sustainable utilisation, forestry and biodiversity management, uses of water – agriculture and livestock, household uses amongst others for efficient apportioning of water use demands and considering the priority of use.
iii. Additional measures to prevent pollution of ground waters
iv. Define water quality objectives and criteria – e.g. set emission limits for discharges from point sources into the surface waters.
v. Also establish programs for training of communities in conservation and monitoring the conditions of water resources.
vi. It is expected that WRUAs are to be more empowered and work with the County government

Question - Who is currently undertaking these functions?

i. The functions are currently conducted by the Water Resources Management Authority – WRMA.
ii. WRMA lacks capacity in term of facilities and equipment including staff and vehicles to patrol and manage the entire large areas of Tana catchment.
iii. The Constitution has hence devolved mandates and provided MGC with most of the WRMA functions.
iv. MCG shall liaise with WRMA to plan and promote the protection of catchment areas and establish zones protection zones.

4.1.8. The Issuance of a Permit for Water Withdrawal from the Watercourses

i. WRMA issues permits and charges for water abstraction for the categories of user stipulated in the Rules Category of Permits – ABCD.
ii. AWSB has applied for a category D permit for the Northern Collector Tunnel. The details are contained in the permit application.
iii. The issuance of a permit requires public consultation processes and MCG has been invited to participate in the process.
iv. It is recommended by this report that MCG opposes the issuance of the permit for the following reasons: -
    a) The water demand needs of MCG for its uses described in reports cannot be met if further withdrawal of water is made to fill into Thika dam.
    b) The engineering reports indicate that collecting more water and storing it at Thika dam may cause an overflow.
    c) The filling in of NCT water into Thika dam has not taken into consideration a **contingency fund** and **emergency** measures, including funds.
    d) It means that Murang'a County shall bear the burden of contingency and emergency.
    e) The application for a permit comes after the contractor is already on site whereas it should be applied for before the commissioning of works, hence in breach of Section 27
v. TWSB and MCG has mandate to develop the proposed works and water intakes in the County and not AWSB the applicant.
vi. The EIA licence has recently been issued based on misinformation and in disregard of the findings of consultants who reviewed the project proposal.

4.1.9. The Constitution on functions of the National Government

i. The national government has water resources functions which are currently delegated to WRMA.
ii. The 4th Schedule No.2 states 'the use of international waters and water resources' (*not clear and subject to interpretation).*
iii. However 4th Schedule No. 22 states that the national government has management mandates in – 'Protection of the environment and natural resources with a view to establishing a durable and sustainable system of development including.....(c) water

protection, securing sufficient residual water, hydraulic engineering and safety of dams'.

iv. The 5th schedule on devolved government requires transition to county government management within three (3) years. It is therefore expected by the County governments that the CIC will have completed the mechanisms including draft legislation for handover to County governments.

4.1.10. Water Law Principles

The guiding principles in water course management for consideration by Murang'a County Government: -

i. Water resources shall be managed as a whole from source to non-source points based on agreement on planned measures.
ii. Planned Measures shall be undertaken by all parties to include-
    a) Control of Pollution (use of best available technology) – measures to prevent control and reduce the release of hazardous substances in to the water, abate eutrophication and acidification of water resources.
    b) Require ecological sound and rational water management
    c) Conservation and restoration of the ecosystem
iii. Agreement on equitable and reasonable utilization and cooperation for all users (Identify the Users) and apportionment
iv. Application of the precautionary principle, the polluter pays principle
v. Impacts of human activity, the physical origin of which is situated wholly or in part within areas of jurisdiction of different parties. In this case the water originates from the Aberderes mountain range.
vi. Such effects on environment include effect on human health and safety, flora, fauna, soil air water climate landscape and other physical structures or the interaction among these factors, effects on the cultural heritage and socio economic conditions resulting from alterations to those factors.

4.1.11. Principles of Cooperation –

i. The Constitution – '*County governments shall consult and cooperate in a manner that respects the functional and institutional integrity of national and county governments and the constitutional status'.*
ii. It is expected that AWSB & Nairobi County Government shall cooperate on the basis of sovereign equality of counties, territorial

integrity, and mutual benefit in order to obtain optimal utilisation of resources by Murang'a County and other Counties (Nairobi) and adequate protection of the watercourses.

iii. Joint cooperation – between the riparian counties and the beneficiary county.

iv. Therefore joint cooperation measures can be undertaken by Murang'a, and Nairobi County governments to be extended to Nyandarua based on recommendations in the technical reports.

4.1.12. MCG on Obligation to Negotiate & Consult

i. Information sharing and decision making on the proposed Northern Collector Tunnel (NCT) is essential.

ii. MCG has initiated negotiations with the Ministry of Water, Wildlife and Natural Resources, Athi Water Services Board, the Nairobi County government, in good faith in accordance with the Constitutional provisions PART V, Article 189, which enables inter-governmental cooperation, liaison and exchange of information, and in case of any dispute to make every reasonable effort to settle disputes through alternative mechanisms including negotiation, mediation and arbitration, with a view to achieving amicable agreement.

iii. Noting that MCG has a vital role in facilitating communities and in catchment management (as the riparian county) custodian/ trustee government of the systems within whose jurisdiction the assets are situated.

4.1.13. Bulk Water

i. It is quite clear that Murang'a endowed with bulk water. Bulk water requires management through a private investment framework as stipulated in the Water Act 2002, Section 66 supports this mandate.

ii. It has been recommended by the technical team that MCG incorporates a Bulk Water Supply Company.

4.1.14. Pending Bills in Parliament & Senate & Law Review

The Murang'a County government and its leaders in Parliament and the Senate to examine the pending Bills in Parliament and the Senate, amongst them the following:-

i. The Water Bill
ii. The Forest Bill
iii. The Climate Change Bill
iv. Natural Resources (Benefit Sharing) Bill

v. Community Land Bill, and
vi. Lobby for inclusion of mandates of the County government and its people in decision making in a collaborative process
vii. Accountability of national institutions to County government
viii. Equitable share of Benefits of the resources transferred to other Counties
ix. Payment for Environmental Services PES and devolution of Trust Funds to County Level managed by the County and its people as the real trustees of its resources
x. County government to draft its own Bill for conservation of its water resources and biodiversity.

Conclusion and Recommendations

There are two things none can stop; Truth and an idea whose time come has come.

5.1. Conclusions

The Technical Committee assessment concludes that the question of water transfer from Murang'a is a subject of varied analysis and comments. At the sometime it is an action that is required to ensure continuous supply of water to Murang'a *as well as to Nairobi and satellite Towns. It is imperative that* downstream water demand is analysed alongside any other considerations and put in place appropriate institutional structure and coordination mechanisms to enable water resources is shared in a beneficial, amicable and sustainable manner

An appraisal of Third Nairobi Water supply Project by the World Bank in 1989[27] noted that;

> *"Nairobi receives its water supply from catchment areas some 50 to60 km to the north .... Through pipelines which traverse densely populated rural areas, which have inadequate water supplies. In addition, the urban centres around Nairobi which are already supplied from Nairobi's system) will require additional facilities and extended supply. The need to safeguard the interest of the other water users outside the Nairobi area has been evident. With this in mind, the water demand and the water supply facilities required for an integrated utilization of the region's water resources to the benefit of Nairobi and the other potential consumers have to be studied as part of Project preparation. This area covers approximately 7,500 km2 and comprises the whole of the upper Athi catchment and the Thika catchment of the Upper Tana System."*

5.2. Hydrology and river flows

Following the review of design and hydrology and in view of the information that was availed to the review team, the following conclusion and recommendations are made:

a) Conclusions

i. Water demand analysis was not conducted during the final design but according to analysis it far outstrips the available resources in Maragua catchment for direct abstraction and thus the compensation downstream is not adequate and will disadvantage lawful abstraction downstream and Murang'a county in developing its development plans

[27] *Staff Appraisal Report, Third Nairobi Water Supply Project,July 6, 1989*

ii. Thika dam has a very low buffering capacity with the introduction of NCT inflows the buffering capacity reduces to a storage ration of less than 40%. The Feasibility report by Egis &MIBP JV recommended that flow control structures into the NCT tunnel should have valves to avoid transfer of flooding to Thika dam, this is not clear how it has been implemented
iii. Operational challenges occur when the compensation channel is lumped together with the intake weir.
iv. Geotechnical work was not conclusively done to enable detailed design of the tunnel for tendering purposes and the project runs at a risk of excessive flow from underground water during construction and impacting on the regional hydrogeology
v. To meet Murang'a county current and future demand as envisioned in its development plans, storage has to be incorporated in the design.
vi. Maragua Catchment is strategic to national and regional development goals including hydro power production and abstractions from the catchment needs to have a wider stakeholder involvement

b) Recommendations

In view of the review of the designs and concept of the NCTI project and the comments of Murang'a County government, the following is recommended

i. The compensation flows should be increased to at least Q80, preferably Q50
ii. compensation flow should be diverted upstream of the intake works
iii. An abstraction survey should be conducted to determine the water abstraction scenario downstream of the catchment because the system is very sensitive to compensation flows
iv. Incorporate storage in revising the design to allow for integrated water resources management and use.
v. Continuous Monitoring of the abstraction by NCT and all other abstractions should be done
vi. Detailed Groundwater and geotechnical survey should be carried out because the cost of this task far out ways the risks during and after construction

5.3. Environment and Conservation

It has been demonstrated in the preceding sections that the planned abstraction of river waters flowing from the Aberdare to provide new water sources for Nairobi will inevitably have significant impacts on flows downstream of the intake sites.

The Kenya Water Act (2002) reinforces the principle of maintaining environmental flows in river systems and reserve flow in order to satisfy basic human needs for all people who are or may be supplied from the water resource; and (b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource, and therefore;

a) Conclusions

i. Addressing the downstream hydrology in relation to water demand for human consumption and other economic activities is required to mitigate against future conflicts.
ii. A comprehensive watershed management strategy (upstream, downstream and riparian areas stabilization) to meet the water policy objective of preserve, conserve available water resources and allocate in a sustainable and rational and economic way.
iii. Considering that water is scarce and that in its utilization there is need to avoid losers and gainers scenario (where Nairobi and its surroundings is perceived to gain at the expense of Murang'a County), possibly use the policy decision based on concepts of Potential Pareto Superiority, users pay and payment for ecosystem services

b) Recommendations

i. Murang'a County to develop a bulk water provision service to Nairobi and other willing users.
ii. Evaluate mechanism and infrastructure development to share flood water for irrigation and hydropower development in Murang'a County
iii. Murang'a County to insist on the re-design of the project abstraction so as to address the downstream hydrology in relation to water demand for human consumption and other economic activities to mitigate against future conflicts

iv. The NCT project to include comprehensive soil and water conservation project covering the whole catchment
v. Explore legislative measures to enhance benefits sharing;
    - As envisaged in the proposed draft law in Senate
    - County legislation to levy a specified fee water and soil conservation
vi. Murang'a County to immediately create a Murang'a County Watershed Conservation Fund in which the county and beneficiaries put funds for payment of environmental services/green water credits for watershed conservation
vii. Project will;
    - Carry out surveys to create a comprehensive up-to-date baseline of the aquatic and riparian communities from which to monitor changes and potential impacts on these communities
    - establish as system of Regular monitoring and daily reporting of land use and land cover changes, a series new river gauges upstream in the intake and downstream at not more than 10km upstream up to month of Masinga dam

5.4. Framework for Resources and benefits sharing

a) Conclusion

i) Murang'a County is richly water resources endowment but largely unutilized for beneficial gain of its residents

ii) The Northern Collector Tunnel (NCT) is an illustration of needs to careful planning and develops water resources to satisfy the competing needs of local population and in the neighboring Counties.

iii) Transferring water outside the source catchments in Maragua may be seem appealing on the surface but especially during wet session but under normal conditions and more so during drought , it could have enormous consequences in opportunity and shortage costs

iv) The gazetted area of jurisdiction of AWSB as per map is upto Gatanga, and not in all areas of Murang'a.

v) Based on the existing World Bank Northern Collector Tunnel - NCT project documents, Nairobi Water Company shall manage the Northern Collector Tunnel from source, i.e. Bulk water of the Gikigie, Maragua, and Irati rivers shall drain into Ndakaini dam. The TWSB and MCG has mandate to develop the proposed works and water intakes in the County and not AWSB the applicant or Nairobi Water Company

vi) The constitution of Kenya has transferred vital roles to the County governments by allocating them with mandates water and sanitation infrastructural works and services.

vii) Consultations were not conducted and approvals were not given for the NCT be undertaken by AWSB in areas beyond their jurisdiction, that is, inside the villages, sub-counties and County of Murang'a, before and after the County government was established.

viii) The NCT project report and AWSB action has ignored the current mandates of the Murang'a County government and its water service's needs. In this respect MCG shall make submission to the Water Resources Management Authority on the proposed permits for water intakes by AWSB from the three watercourses of Murang'a County.

ix) MCG has priority of use of its water resources in accordance with the principles of sustainable utilisation and intergeneration equity.

x) In respect of the role of County governments soil and water conservation and forestry means that vital aspects of water resources protection and management vest in the County governments.

xi) The EIA licence has recently been issued based on misinformation and in disregard of the findings of consultants who reviewed the project proposal.

xii) However 4th Schedule No. 22 states that the national government has management mandates in – 'Protection of the environment and natural resources with a view to establishing a durable and sustainable system of development including.....(c) water protection, securing sufficient residual water, hydraulic engineering and safety of dams' but there incapacity by WRMA is due lack of facilities and equipment including staff and vehicles to patrol and manage the entire large areas of Tana catchment.

b) Recommendations

i) Murang'a County Government raise investment in water resource development, in order fairly mitigate seasonal water shortages, conserve flood water and environment

ii) Create an entity to autonomously and exclusively ensure continued water security. An estimated investment is about ksh.10.3 billion

iii) Establish and run bulk water supply service at current supply cost of Kes 23.6 per m^3.

iv) Create a contingency/ emergency fund to support residents adversely affected by the project through disaster and/or interrupted

v) It is recommended by this report that MCG opposes the issuance of the permit for the following reasons: -

a) The water demand needs of MCG for its uses described in reports cannot be met if further withdrawal of water is made to fill into Thika dam.

b) The engineering reports indicate that collecting more water and storing it at Thika dam may cause an overflow.

c) The filling in of NCT water into Thika dam has not taken into consideration a contingency fund and emergency measures, including funds.

d) It means that Murang'a County shall bear the burden of contingency and emergency.

e) The application for a permit comes after the contractor is already on site whereas it should be applied for before the commissioning of works, hence in breach of Section 27

vi) The project contributes to enhanced capacity for watershed monitoring by providing management facilities and equipment to manage Maragua and Tana catchment.

vii) The Murang'a County government and its leaders in Parliament and the Senate to examine the pending Bills in Parliament and the Senate, amongst them the following:-

a) The Water Bill
b) The Forest Bill
c) The Climate Change Bill
d) Natural Resources (Benefit Sharing) Bill
e) Community Land Bill, and
f) Lobby for inclusion of mandates of the County government and its people in decision making in a collaborative process
g) Accountability of national institutions to County government
h) Equitable share of Benefits of the resources transferred to other Counties
i) Payment for Environmental Services PES and devolution of Trust Funds to County Level managed by the County and its people as the real trustees of its resources
j) County government to draft its own Bill for conservation of its water resources and biodiversity.

Annexes

Annex I: AWSB-WaSSIP AF Project
Annex II: AWSB Letter on Response to Clarifications
Annex III: Third Nairobi Water Project Completion Report (extract)
Annex VI: EIA licence
Annex V: EMP EIGIS& MIBP
Annex VI: Final ESIA STUDY REPORT NCT Ph-1- Summary of Stakeholder issues
Annex VII: Environmental and Social Management Plan - ESIA STUDY REPORT NCT PHASE 1
Annex VI- Mathioya River Permit Details