FEASIBILITY STUDY AND MASTER PLAN FOR DEVELOPING NEW WATER SOURCES FOR NAIROBI AND SATELLITE TOWNS

PROJECT BRIEF

August 30, 2011

INTRODUCTON

The Project Brief provides a Summary of the Draft Water Source Options Review Report prepared as part of the Feasibility Study and Masterplan for Developing New Water Sources for Nairobi and Satellite Towns. The Feasibility Study and Masterplan have been funded by the Ministry of Water and Irrigation through the Athi Water Services Board, with the support of the World Bank and AFD. This Brief is organized in the following Twelve Sections:

Section 1	Introduction
Section 2	Provides the broad linkages between Kenya's Economy and its Water Resources.
Section 3	Describes the Objectives of the Feasibility Study and Masterplan.
Section 4	Describes the Water Supply Challenges and Opportunities Faced by Nairobi Metropolitan Region.
Section 5	Discusses the Present Situation and Prospects for Nairobi Water Supply.
Section 6	Summarizes Water Demand Projections for Nairobi and Envelop Area.
Section 7	Lists the Water Resources Development Strategy Used.
Section 8	Describes the Development of Scenarios to meet the Short, Medium and Long Term Needs.
Section 9	Discusses the Water Supply Needs for Satellite Towns.
Section 10	Presents the results of the Least Cost Analysis.
Section 11	Describes the Environmental Impacts of the Different Scenarios.
Section 12	Presents the Results of the Multi-Criteria Analysis.

KENYA'S ECONOMY AND WATER RESOURCES

Water plays a key role in the Nation's economy as a resource for urban and rural consumption, for energy generation, for agricultural development, for industrial growth, livestock and tourism development, fisheries, navigation, National Parks and the environment.

Since 1997, the economic growth rate has consistently been lower than the population growth rate. Around the same period, the number of people living below the poverty line and who subsist predominantly on natural resources has increased from 48% in 1994 to 52% in 2000, and to about 56% by 2001. This coincides with a period when investments in water resources development and management have shrunk significantly. In the absence of major changes in the use of natural resource inputs, the disparities in these rates will continue to exert pressure on environmental goods and services, including water resources. Existing resources will have to be used more efficiently to even maintain the same standard of living, let alone meet the country's development goals.

Kenya has a Limited Endowment of Freshwater.

Kenya is classified by the U.N. as a chronically water-scarce country. The country's natural endowment of freshwater is highly limited, with an annual renewable freshwater supply of about 526 m^3 per capita, significantly below the 1,000m^3/capita set as the marker for water scarcity. The current level of development of water resources in Kenya is very low. Only 15% of the renewable fresh water resources (known as the safe yield) has been developed currently. This low level of development means that water supply storage per capita has declined dramatically from 11.4m^3 in 1969 to about 4.3m^3 in 1999 – simply because of population growth and under investment in water resources infrastructure.

Underdeveloped Water Resources

However, the country possesses sufficient water resource to meet demand. A recent study has estimated that, based on current water use efficiencies, the predicted aggregate demand will rise to 5,552 Mm^3 per year in 2020. This would still be within the country's safe yield (8,447Mm^3/yr), although the cost of supplying each additional increment of water is likely to rise steeply as readily accessible sources are progressively tapped.

Declining Budget Allocation for Water Development

As the decline in water storage infrastructure implies, there has been a declining budgetary allocation for water resources development and management in Kenya. Expenditure on water supplies and related services declined from Kshs. 4,249 Million in 1994 to Kshs. 1,765 Million in 2001. The proportion of total funds allocated to water development and water management activities are skewed, with the budget allocation of recurrent costs consuming about 92% of the total budget. Consequently, there have been insufficient funds to properly allocate water, police illegal water extractions, control discharge of wastes into lakes and rivers, protect catchments, and help prevent excessive erosion in headwaters. Water users have taken advantage of these conditions to use water illegally to the detriment of those further downstream.

There is no contradiction in the country being simultaneously water-scarce and able to safely exploit many times in the current water usage. It simply means that not only does Kenya receive one of the world's lowest per capita water replenishment rates each year, but that it has also not developed the limited amount of water available at a time when its population has grown. This, together with the long-term degradation of the existing water resources, makes the country very vulnerable to perturbations in water supply,

particularly from the climate variability, catchment degradation, illegal abstractions, pollution and invasive weeds.

Kenya's water crisis is linked to its three Legacies:

- ***Natural Legacy*** – limited endowment of water and high climate variability. Physical geography has distributed water unevenly - 80 % of Kenya's area consists of arid and semi-arid lands (ASAL), where water is often the limiting constraint to social and economic development.
- ***Management Legacy*** – rapid population growth, demand for most sectoral uses is increasing, water use efficiencies are low, water use conflicts are increasing, pollution is increasing, degradation of water sources is increasing and investment in manmade storage and in the management of water resources has not kept pace with growing needs.
- ***Colonial Legacy*** – Kenya shares over half of its rivers, lakes and aquifers with its neighbours, a legacy of its colonial history. Borders were carved up in European capitals and this has major implications on the utilization, development and management of internationally shared water bodies.

The Vulnerability of Kenya's Economy

Kenya's economy is vulnerable to climate and hydrological variability (floods and drought) and under investments in water resources development. It is held hostage to hydrology and the nation's capacity is inadequate in its ability to deal with either too much water (floods) or too little water (droughts).

The performance of Kenya sectors of the economy is dependent on good management of water resources. Floods and drought impose a heavy toll on the economy. A 2004 World Bank analysis of the economic impact of the 1997-98 El Nino Floods and the 1998-2000 La Nina drought summarize the heavy toll on the economy.

- *It is estimated 11% loss to the GDP from the impact of the 1997/98 El Nino Floods as a result of extensive damage caused in the transport, water, agriculture and health sectors.*
- *It is estimated 16 % loss to the GDP during the two consecutive years of the La Niña drought from 1998-2000, the worst drought on recorded history in Kenya. The key sectors impacted were agriculture, energy, health, livestock and manufacturing.*

Given their regularity, over the long term, floods and droughts are estimated to cost the economy about 2.4 % of the GDP per annum. This is a very serious impact on Kenya's economic performance and competitive edge.

In addition, water resources degradation (resulting from weak allocation of water, increasing pollution, and rapidly degrading catchments and recharge areas) costs Kenya an additional 0.5% of the GDP per annum

The proper management of, and investments in the development of water resources are essential and necessary conditions for growth and poverty alleviation.

The recent and ongoing food crisis and famine, energy crisis, financial and economic crisis as well as increasing concerns over climate change (that will impact precipitation, runoff and water use patterns) will likely add a substantial additional burden to Kenya's water security.

OBJECTIVES OF FEASIBIITY AND MASTER PLAN FOR DEVELOPING NEW WATER SOURCES FOR NAIROBI AND SATELLITE TOWNS

The Nairobi Metropolitan area contributes over 50% of the National GDP. The Government of Kenya has assigned a high political priority to addressing the chronic water supply problems facing the Metropolitan Area and Satellite Towns.

The Ministry of Water and Irrigation through the Athi Water Services Board, with the support of World Bank and the French Development Bank (AFD) has engaged the services of *Consultants - Egis BCEOM International and Mangat, I.B Patel & Partners J.V* to carry out a Feasibility Study and Master Plan for Developing New Water Sources for Nairobi and 13 Satellite Towns. The Masterplan will address the short term, medium term and long term needs for the Metropolitan Area and Satellite Towns.

The initial aim of the Study is to identify a priority strategy to meet the 2017 water demand for which Preliminary Design has to be carried out. A Master Plan to meet the 2035 water demand for Nairobi City and 13 Satellite Towns is to be prepared under the Study.

The list of the Satellite Towns as per the Request for Proposal (RFP) is given in Table E1 below and their locations with respect to Nairobi City are shown in *Figure E1 on Page 5.*

Table E: List of Satellite Towns

No.	Satellite Town	District
1	Kikuyu	Kikuyu
2	Ruiru-Juja	Ruiru and Thika West
3	Kiambu	Kiambu East
4	Karuri	Kiambu East (Kiambaa)
5	Githunguri	Githunguri
6	Mavoko Municipality (Athi River)	Machakos
7	Ngong Township	Kajiado North
8	Ongata Rongai	Kajiado North
9	Thika	Thika West
10	Gatundu	Gatundu
11	Limuru	Kiambu West
12	Lari (Uplands and Kimende)	Lari
13	Tala-Kangundo	Kangundo

Some of the Satellite Towns are located within the vicinity of Nairobi City Boundary and should apparently be considered as part of the Greater Nairobi, and thus within the “Effective Envelop of the Nairobi Water Demand”. The population growth is occurring not only within the Municipal Boundaries but is also infilling all the land available between the Satellite Towns and the Nairobi City Boundary. The present trends in physical development, i.e. population growth, optimum housing densities, infrastructure development and the Study of Kenya Government Vision 2030 Strategy, have all been considered in ascertaining the “Effective Envelop of Nairobi Water Demand”.

Table E2 below shows the Satellite Towns considered to be within the Effective Envelop of Nairobi Water Demand.

Table E: List of Satellite Towns within the Effective Envelop of Nairobi Water Demand

No.	Satellite Town	District
1	Kikuyu	Kikuyu
2	Ruiru-Juja	Ruiru and Thika West
3	Kiambu	Kiambu East
4	Karuri	Kiambu East (Kiambaa)
5	Mavoko Municipality (Athi River)	Machakos
6	Ngong Township	Kajiado North
7	Ongata Rongai	Kajiado North

Figure E1

WATER SUPPLY CHALLENGES AND OPPORTUNITIES FACED BY NAIROBI METROPOLITAN REGION

- Investments in water supply infrastructure have lagged since 1994 with the completion of the Nairobi Water Supply Project Phase 3 Project and the demand in the Nairobi Metropolitan area now far outstrips supply.
- Nairobi, the Capital City and economic hub of Kenya, contributes over 50% of the GDP.
- The City, which has been in existence for about 100 years, has grown from a settlement of 25km^2 to the current 684km^2. Nairobi City is divided into eight administrative divisions namely Kibera, Dagoretti, Pumwani, Central, Embakasi, Kasarani, Westlands and Makadara.
- Nairobi is also an important regional centre for trade, commerce, and regional integration. The City has an estimated resident population of 3 million people and an estimated daytime population of around 6 million people. The current population of the AWSB area (the City and surrounding Districts of Thika, Gatundu, Ruiru, Gatanga, Kiambu East, Kiambu West, Lari and Kikuyu Districts) served by the Athi Water Service Board (AWSB) is estimated to be 5 million people and it is projected to increase to 8 million by the year 2030.
- The Government has emphasized the need for developing the Nairobi region into a world class commercial center. This will require basic and reliable water supply and sewerage facilities, solid waste collection and disposal and transport infrastructure. Improving water security for the Nairobi Metropolitan Region is a high government priority.
- The City and its Satellite Towns still face large water supply deficits, which have been magnified during the past two years of drought. Chronic water shortages are common in many parts of the City. This has made supply unreliable and increased water rationing, the high price paid by consumers for water from vendors, the time spent queuing for water, and increase in incidences of water borne diseases.

The main issues facing the Nairobi Water Supply System are:

1. Lack of water resources
2. Low pressures in the network
3. Not enough pipe work/distribution capacity
4. Leakage in distribution reticulation
5. Deteriorating status of pipes (corrosion and old age)
6. Tracking of illegal connections
7. Lack of adequate coverage of consumers
8. Leakage in housing connections
9. Vandalism of controls at appurtenances (air valves, hydrants, sectional valves, zonal meters)
10. Proper management of rationing
11. Maintenance and quick response to attend to pumping mains

The following factors are adding to the current Nairobi water crisis:

- Reduced inflows into Thika Dam
- Dilapidated and undersized water distribution infrastructure which has large physical losses (UfW)
- 15 year time lag and delay in new investment in water storage for the City
- High population growth without proportional development of service infrastructure
- Inadequate attention to groundwater development and management as part of the solution to the City's water supply

Groundwater

Unlike surface water sources, problems associated with Groundwater are as follows:

- Groundwater development is largely unplanned and not strictly regulated.
- The data available suggests that for each well that is registered, there maybe 2-3 other wells that have not been registered.
- Some boreholes have high fluoride levels ranging from 5 to 11 mg/l, which are above the WHO drinking water quality standards of 1.5-2.5 mg/l.
- In addition, there is no systematic monitoring of groundwater levels or quality.
- there is ample evidence to suggest that aquifer water levels are declining rapidly in some 'hotspots'
- No comprehensive map to properly delineate the Nairobi aquifer, its characteristics and determine the safe yield has been prepared.

The above issues therefore limit the ability of the authorities to sustainably manage this important source of water.

Hypothesis on underground fractured bedrock systems suggests that there may be a good ground water potential in Nairobi area that could result in high yielding wells of above 2,000m^3/d per well.

PRESENT SITUATION AND PROSPECTS FOR NAIROBI WATER SUPPLY

1) Surface Water Sources

The main source for water supply for Nairobi is the Eastern Aberdare Rivers within the Aberdare Conservation Area (ACA). The ACA includes the Aberdare National Park and the gazetted Forest Reserves that surround the National Park. These areas are all under Government protection through Kenya Wildlife Service (KWS) and Kenya Forest Service (KFS). These areas are not subject to catchment degradation through settlement and forest clearance, as has been recorded in other national forests, notably the Mau Forest. It can reasonably be assumed that the "protected area" status will not only be maintained by the Government, but will be strengthened, hence the sustainability of the surface water sources arising from the ACA is assured under current Government policy, subject to control of permitted abstractions.

The Existing Water Sources for Nairobi Water Supply are as follows:

Table E: Yield of Existing Water Sources

Source	Yield (m^3/d)	Yield (m^3/s)	Remarks
Sasumua Reservoir	56,000	0.65	Existing
Chania River / Mwagu Intake	104,000	1.20	Existing
Ruiru Reservoir	21,000	0.24	Existing
Kikuyu Springs	4,000	0.05	Existing
Ndakaini Dam (Thika 6 +kiama + Kimakia)	225,000	2.60	Existing (70 Mm^3 Storage).
Total Available Yield	**410,000m^3/d**	**4.74m^3/s**	

The total abstractions for Ngethu Treatment Works is 5.13m^3/d (443,232m^3/d), over a simulated period of time. Figure E2 on page 10 shows the existing Sources and Transmission Routes to Nairobi City.

2) Groundwater

The groundwater contributions to Nairobi Water Supply for both domestic, commercial or industrial purpose via public, private or individual boreholes and wells was considered to be about 45,000 m^3/day with a potential to grow by 1,000 m^3/day per year till the 2035 horizon.

Two New Wellfields in Kiunyu (Thika) and Ruiru have been identified with potential yields of 0.4m^3/s (34,560m^3/d) and 0.35m^3/s (30,240m^3/d) respectively. Test boreholes to be drilled to confirm these yields.

The yields from the proposed surface water and ground water sources are given in Table E4 below.

Table E: Proposed Potential New Water Sources

Source	Yield (m^3/d)	Yield (m^3/s)	Remarks
Proposed Groundwater Wellfields in Kiunyu & Ruiru	64,800	0.75	
Proposed Northern Collector – Phase I	138,240	1.6	Diversion and transfer from Irati, Gikigie and Maragua Rivers
Proposed Northern Collector – Phase II	151,200	1.75	Diversion and transfer from South Mathioya, Hembe, Githugi & North

			Mathioya Rivers
Proposed Maragua 4 Reservoir	45,792	0.53	the yield of Maragua Dam is dependent on cross basin transfer and varies for different Scenarios
Proposed Ndarugu 1 Reservoir	397,440	4.60	With Chania - Komu River Transfer, (300 Mm³ Storage).
Total Potential Yield	**797,472 m^3/d**	**9.23m^3/s**	

3) Other Water Sources

Other water source which can be used in the long term is recycling of treated wastewater. However, this option is relatively expensive and water quality / level of treatment required for this option to be developed is dependent on the various uses of recycled water. Treated / partially treated wastewater can be used in a number of ways:

- Industrial Use
- Agricultural / Irrigation
- Environmental and Recreational use
- Reinforcement of Potable Water Supply after adequate disinfection, etc.

Another option for indirect use of treated wastewater is to recharge aquifers or the replenishment of surface water reservoirs. Similarly, the option of transfer of treated wastewater back to Tana River catchment can provide the additional benefits of returning water for generation of hydropower. These options have to be studied in detail under the Proposed Sewage Master Plan.

Figure E2 – Existing Water Sources for Nairobi

WATER DEMAND PROJECTIONS (FOR NAIROBI CITY AND ENVELOP AREA)

Approximately 92% of Nairobi Population (approximately 2.9 million inhabitants) receive water from Nairobi City Water Sewerage Company (NCWSC) piped network either through direct connections, water kiosks or water vendors as described in Table E5 below.

Table E: Number of Households by Water Sources in Nairobi City

Water Sources:	**Pond / Dam**	**Lake**	**Stream**	**Spring/ Well/ Borehole**	**NCWSC Network**	**Jabia / Rain Harvesting**	**Other**	**Total**
Households	2,761	99	1,345	70,729	907,704	1,691	687	**985,016**
Percentage	0.28%	0.01%	0.14%	7.18%	92.15%	0.17%	0.07%	**100%**

Source: 2009 Population and Housing Census

However, the per capita water coverage in Nairobi's informal settlements is very low with the demand being far above the supply (Sogreah et al. 2005). Access to water in these areas is a major problem due to the high cost of water purchased from water vendors (about Kshs. 1,000 /m^3) as a result of inadequacy and unreliability of the existing water supply system.

Water kiosks are known to sell water at three times more than that charged by NCWSC.

According to NCC (1996), 12% of the plots in the informal settlements have direct access to water in the plot while the majority (86% of the plots) obtain water from kiosks and water vendors.

In the water demand calculation, it has been estimated that the high and medium income population have 100% water supply coverage by the public (NCWSC) network and are served by individual water connections.

Table E: Water Supply Coverage by Income Level

Year	**2010**	**2017**	**2020**	**2030**	**2035**
Population	3,257,615	4,107,466	4,517,800	6,086,401	7,063,903
High Income (IC)	6%	6%	6%	6%	6%
Medium Income (IC)	50%	50%	50%	50%	50%
Low Income (IC)	9%	12%	16%	22%	24%
Low Income (NIC)	35%	32%	28%	22%	20%
% of Pop. supplied by IC	**65%**	**68%**	**72%**	**78%**	**80%**

IC - Individual Connection

NIC - No Individual Connection

It is estimated that approximately 25,000 new connections will be required annually due to increased population and water supply coverage. It is therefore recommended that future financing to increase Nairobi City Water Supply situation should incorporate the need to incorporate the new water connections to ensure equitable water supply to the residents especially in the low income areas.

Table E: Water Demand Forecast – Nairobi City

Population Projections						
Year		**2010**	**2017**	**2020**	**2030**	**2035**
Low scenario	Population	3,250,338	4,035,762	4,398,910	5,687,515	6,438,453
	Growth Rate	3.6%	3.1%	2.9%	2.6%	2.5%
Medium scenario	Population	3,257,615	4,107,466	4,517,800	6,086,401	7,063,903
	Growth Rate	3.8%	3.4%	3.2%	3.0%	3.0%
High scenario	Population	3,260,647	4,193,984	4,666,816	6,555,578	7,783,445
	Growth Rate	3.9%	3.7%	3.6%	3.5%	3.5%
Income Distribution						
Low Income - 44%			Medium Income - 50%		High Income - 6%	
Population Served by Public Water Service Provider (Individual Connections)						
Year		**2010**	**2017**	**2020**	**2030**	**2035**
Percentage as I.Cs		65%	68%	72%	78%	80%
Water Demand Forecast, m^3/d						
Year		**2010**	**2017**	**2020**	**2030**	**2035**
Low scenario		581,912	728,293	802,206	1,053,452	1,198,674
Medium scenario		582,928	740,870	823,488	1,126,797	1,314,493
High scenario		583,351	756,322	850,479	1,213,417	1,448,104

Year 2009 Nairobi City Census Population - 3,138,369

Figure E3: Water Demand for High, Medium and Low Population Projections Scenarios – Nairobi City

Table E: Water Demand Forecast - Nairobi City Plus Envelop Areas

Population Projections						
Year		**2010**	**2017**	**2020**	**2030**	**2035**
Low scenario	Population	4,401,675	5,603,356	6,182,053	8,235,299	9,366,921
	Growth Rate	3.9%	3.5%	3.3%	2.9%	2.6%
Medium scenario	Population	4,416,424	5,774,282	6,443,464	9,000,052	10,538,134
	Growth Rate	4.3%	4.0%	3.7%	3.4%	3.2%
High scenario	Population	4,435,598	6,057,637	6,923,163	10,404,949	12,591,534
	Growth Rate	4.7%	4.7%	4.6%	4.3%	3.9%

Income Distribution		
Low Income - 42%	Medium Income - 52%	High Income - 6%

Population Served by Public Water Service Provider (Individual Connections)					
Year	**2010**	**2017**	**2020**	**2030**	**2035**
Percentage as I.Cs	53%	56%	62%	72%	76%

Water Demand Forecast, m^3/d					
Year	**2010**	**2017**	**2020**	**2030**	**2035**
Low scenario	685,522	886,230	1,001,015	1,391,262	1,621,312
Medium scenario	687,217	908,415	1,037,721	1,510,188	1,811,127
High scenario	689,037	942,125	1,098,823	1,707,882	2,117,194

Year 2009 Nairobi City plus Envelop Areas Census Population - 4,236145

Figure E4: Water Demand for High, Medium and Low Population Projections Scenarios – Nairobi & Envelop Areas

WATER RESOURCES DEVELOPMENT STRATEGY (FOR NAIROBI CITY)

The strategy for Nairobi and Satellite Towns' water supply should ensure that:

- all water supply demands are fully met up to the Year 2035 horizon,
- new sources of development are considered,
- all supplies are to a common approved standard for potable water supply,
- new water sources and facilities increase the reliability and security of water supply for Nairobi and Satellite Towns through:
    - optimal use of the existing facilities,
    - an increase of surface water storage sources,
    - diversification of water sources (surface water, groundwater, rainfall roof harvesting) when appropriate,
    - Development of local or mixed water supply systems for Satellite Towns.
- Efforts to reduce to minimum level physical water losses along the system (intakes, transmission pipes, treatment works, distribution schemes, etc.)
- Diversification of sources:
    - promote the steady development of boreholes to tap groundwater;
    - promote alternative water sources such as rainwater roof harvesting;
- Limit or avoid when possible competition between water uses on the water source (hydropower production, agriculture & livestock, downstream uses and environmental flow); and,
- Priority to be given to scenarios with minimal social and environmental impacts.

DEVELOPMENT OF SCENARIOS

The planning for Development of Future Water Resources for Nairobi and the Satellite Towns involves a comparison between known sources availability and projected water demands.

Proposed Scenarios

Six (6) main Scenarios have been established based on potential sourced under context of meeting the water demand for Nairobi up to Year 2035. These Scenarios have been prepared in view to meet the water demand of Nairobi City without considering the surrounding areas for which other local water resources are considered.

The scenarios involve the combination in different manners and with various scheduling of the following water schemes:

- Northern Collector Phase I with different sub-alternatives (whole collector from Maragua R. to Thika Reservoir, from Irati R. to Thika Reservoir only);
- Diversion from S. Mathioya to Maragua River to supplement Maragua Reservoir;
- Northern Collector Phase II either connected to Northern Collector I to supplement the supply to Thika reservoir or to Maragua 4 Reservoir;
- Ndarugu 1 Dam on Ndarugu River;
- Diversion from Chania River to Komu River to supplement Ndarugu 1 Reservoir.

The Scenarios reviewed and sequences of development are Tabulated in Table E10 on page 15.

Figures E5 and E6 on pages 16 and 17 respectively show Schematics of Scenarios 2 and 3a indicating Sources and Transmission Systems being considered. Figures E7 and E8 on pages 18 and 19 respectively show the Water Demand Forecast and the Design Horizons met by the Proposed Interventions for Scenarios 2 and 3a respectively.

SATELLITE TOWNS

Some of the Satellite Towns are located within the vicinity of Nairobi City (Nairobi Envelop) and will be considered as part of Greater Nairobi and thus within the "Effective Envelop of the Nairobi Water Demand:

Other Satellite Towns located at a distance from Nairobi City and not falling directly in the vicinity of the transmission mains such as Tala, Kangundo, Thika, Limuru, Ngong, Ongata Rongai, Mavoko, etc. will have separate systems respectively based on development of local sources to meet their present and future water demands. Potential Sources identified for Satellite Towns are given in Table E9 below.

Table E9: 90% Estimated Yields for Potential Sources

Site Name	Catchment Area km^2	MAI $M.m^3/yr$	Highest Dam Height m	Highest Gross Storage $M.m^3$	Ratio S/MAI	Ratio Y/MAI	Estimated Yield m^3/sec (m^3/day)
Kiama	13.06	17.710	20	2.696	0.152	0.500	0.281 (24,278)
Ruabura	28.51	17.083	45	18.858	1.104	0.700	0.379 (32,745)
Thiririka	61.14	21.209	30	7.338	0.346	0.460	0.309 (26,697)
Gatamayu 1	19.59	12.356	25	3.170	0.257	0.400	0.157 (13,565)
Gatamayu 2	100.41	53.831	40	7.083	0.132	0.320	0.546 (47,174)
Komothai 1	16.55	10.438	30	3.468	0.332	0.450	0.149 (12,873)
Komothai 2	28.74	9.970	30	3.945	0.396	0.480	0.152 (13,133)
Kamiti	10.07	2.795	30	6.734	2.410	0.400	0.035 (3,024)
Riara	20.72	5.227	20	7.163	1.370	0.600	0.099 (8,554)
Ruiruaka	21.71	5.477	25	5.889	1.075	0.500	0.087 (7,517)

Table E10 - Summary of Scenarios / Implementation Periods

PROPOSED FUTURE WATER SOURCES	Expected Yield		Scenarios / Implementation Periods					
	m^3/s	m^3/d	Scenario 1	Scenario 1a	Scenario 2	Scenario 3	Scenario 3a	Scenario 4
1. WELLFIELD IN KIUNYU AND RUIRU	**0.75**	**64,800**	**2012 - 2015**	**2012 - 2015**	**2012 - 2015**	**2012 - 2015**	**2012 - 2015**	**2012 - 2015**
2. NORTHERN COLLECTOR PH I TO THIKA DAM	**1.6**	**138,240**	**2012 - 2016**	**2012 - 2016**	**2012 - 2016**	**2012 - 2016**	**2012 - 2016**	**-**
Transmission to Gigiri Reservoirs via Ndunyu Chege T. Works			2012 - 2016	-	-	2012 - 2016	-	-
Pumping from Gigiri Reservoirs to Kabete Reservoirs			2012 - 2016	-	-	2012 - 2016	-	-
Transmission to Kabete Reservoirs via Ngorongo T. Works			-	2012 - 2016	2012 - 2046	-	2012 - 2016	-
3. NORTHERN COLLECTOR PH I (IRATI)	**0.6**	**51,840**	**-**	**-**	**-**	**-**	**-**	**2012 - 2016**
Transmission to Gigiri Reservoirs via Ndunyu Chege T. Works			-	-	-	-	-	2012 - 2016
Pumping from Gigiri Reservoirs to Kabete Reservoirs			-	-	-	-	-	2012 - 2016
4. MARAGUA DAM + S. MATHIOYA TRANSFER TO THIKA DAM	**0.9**	**77,760**	**-**	**-**	**-**	**2012 - 2018**	**2012 - 2018**	**-**
Transmission to Gigiri Reservoirs via Ndunyu Chege T. Works			-	-	-	2012 - 2018	-	-
Pumping from Gigiri Reservoirs to Kabete Reservoirs			-	-	-	2012 - 2018	-	-
Transmission to Kabete Reservoirs via Ngorongo T. Works			-	-	-	-	2012 - 2018	-
5. MARAGUA DAM + S. MATHIOYA TRANSFER TO MARAGUA DAM	**0.66**	**57,024**	**2012 - 2018**	**2012 - 2018**	**-**	**-**	**-**	**-**
Transmission to Gigiri Reservoirs via Ndunyu Chege T. Works			2012 - 2018	2012 - 2018	-	-	-	-
Pumping from Gigiri Reservoirs to Kabete Reservoirs			-	-	-	-	-	-
6. MARAGUA DAM WITH NATURAL INFLOW + S. MATHIOYA TRANSFER	**1.85**	**159,840**	**-**	**-**	**-**	**-**	**-**	**2012 - 2018**
Transmission to Gigiri Reservoirs via Ndunyu Chege T. Works			-	-	-	-	-	2012 - 2018
Pumping from Gigiri Reservoirs to Kabete Reservoirs			-	-	-	-	-	2012 - 2018
7. NORTHERN COLLECTOR PHASE II (S. MATHIOYA TO N. MATHIOYA) TO THIKA DAM	**1.38**	**119,232**	**-**	**-**	**-**	**2016 - 2022**	**2016 - 2022**	**-**
Transmission to Gigiri Reservoirs via Ndunyu Chege T. Works			-	-	-	2016 - 2022	-	-
Pumping from Gigiri Reservoirs to Kabete Reservoirs			-	-	-	2016 - 2022	-	-
Transmission to Kabete Reservoirs via Ngorongo T. Works			-	-	-	-	2016 - 2022	-
8. NORTHERN COLLECTOR PHASE II (MARAGUA TO N. MATHIOYA) TO THIKA DAM	**1.75**	**151,200**	**-**	**-**	**2014 - 2018**	**2016 - 2022**	**2016 - 2022**	**-**
Transmission to Kabete Reservoirs via Ngorongo T. Works			-	-	2014 - 2018	-	-	-
9. NORTHERN COLLECTOR PHASE II (S. MATHIOYA TO N. MATHIOYA) TO MARAGUA DAM	**1.54**	**133,056**	**2017 - 2021**	**2017 - 2021**	**-**	**-**	**-**	**2016 - 2021**
Transmission to Gigiri Reservoirs via Ndunyu Chege T. Works			2017 - 2021	2017 - 2021	-	-	-	2016 - 2021
Pumping from Gigiri Reservoirs to Kabete Reservoirs			2017 - 2021	2017 - 2021	-	-	-	-
10. NDARUGU DAM	**2.5**	**216,000**	**2021 - 2026**	**2021 - 2026**	**2018 - 2024**	**2021 - 2026**	**2021 - 2026**	**2019 - 2024**
Transmission to Gigiri Reservoirs			2021 - 2026	2021 - 2026	2018 - 2024	2021 - 2026	2021 - 2026	2019 - 2024
11. CHANIA TO KOMU RIVER TRANSFER	**2.1**	**181,440**	**2029 - 2032**	**2029 - 2032**	**2028 - 2031**	**2029 - 2032**	**2029 - 2032**	**2030 - 2037**
Transmission to Gigiri Reservoirs			2029 - 2032	2029 - 2032	2028 - 2031	2029 - 2032	2029 - 2032	2030 - 2037

Legend:

-	Component not being Implementated under respective Scenario

Figure E5: Schematic Diagram of Scenario 2

Figure E6: Schematic Diagram of Scenario 3a

Figure E7 –Scenario 2 - Water Demand and Implementation Schedule of Planned Interventions

Figure E8 –Scenario 3a - Water Demand and Implementation Schedule of Planned Interventions

Least Cost Analysis

Table E10: Summary of Least Cost Analysis

Item	Scenario 1	Scenario 1A	Scenario 2	Scenario 3	Scenario 3A	Scenario 4
Initial Capital Cost Million US$	1,025.34	1,040.93	896.66	1,024.32	1,053.25	987.20
Present Value of Capital Costs	$522.10	$527.90	$469.29	$512.62	$538.28	$499.60
Present Value of Fixed Maintenance Costs	$98.63	$97.53	$95.55	$98.00	$99.00	$96.01
Present Value of O&M Costs	$276.62	$210.99	$214.99	$278.59	$177.05	$323.19
Present Value of Economic Costs	$897.35	$836.42	$779.84	$889.22	$814.33	$918.80
Discounted Value of Water	$1,309.63	$1,323.53	$1,292.95	$1,360.24	$1,380.96	$1,348.23
Average Incremental Economic Cost	0.69	0.63	0.60	0.65	0.59	0.68
KSH/m^3	62	57	54	59	53	61

Environmental Impacts

Environmental impacts resulting from the proposed diversion of water for the Nairobi water supply will include impacts from: a) construction of weirs, tunnels and associated structures, b) construction of dams, c) construction of transmission pipelines and treatment works, d) from operation of these systems, including upstream impacts, and e) changes to the downstream hydrology of the river basins as a result of reduced flow in the rivers. Of these, the major environmental impacts are considered to be related to the reduced downstream flows.

11.1 No Project Option

A “No Project Option” Alternative was considered not to be viable in any eventuality. The “No Project Option” Alternative would imply that the status quo is maintained and no additional water supplies are developed. From an environmental and socio-economic perspective, the “No Project Option” Alternative is not a suitable solution for affected communities and for Kenya as a whole.

11.2 Environmental Flows

There is now an increasing recognition, worldwide, that modifications made to river flows need to be balanced with maintenance of ecological services depending on the availability of water. The river flows that are required to maintain these services are termed "Environmental Flows". The Kenya Water Act (2002) supports the principle of maintaining environmental flows in river systems and calls for a reserve to be set for all rivers and to be considered in all water allocation plans.

11.3 Upstream Impacts

Water Quality - The requirements for provision of good quality water supplies will be to minimize negative impacts of upstream land use on water quality, including runoff and erosion, prevention of excess nutrients entering the river, prevention of agricultural pesticides and herbicides entering the river, as well as minimizing change in woody cover and land use within the catchments.

Catchment Protection - Deforestation in the Aberdare Range and reduced vegetation cover in the other parts of the river catchments will inevitably result in increased runoff during higher rainfall periods and in increased turbidity and suspended solids in the river flows. This will result in siltation at the weirs and intakes, as well as in downstream reservoirs, and requirements for more expensive treatment.

An important and major part of the catchments of the proposed Northern Collector weirs and abstraction sites are included within the protected areas of the Aberdares, including the Aberdare National Park and neighbouring Aberdare Forest Reserve. Significant parts of all of the catchments associated with the proposed Northern Collector schemes are therefore considered to be under a “high” protection status.

It is recommended that the Forest Reserve land is managed to provide maximum catchment protection, and that any potential deforestation in these areas is minimized.

Tea Cultivation -Tea is an important crop in those areas of the catchments. In terms of its environmental impact tea has advantages over other crops grown in these zones. The deep roots and ground cover provided by tea plants result in relatively good soil and water conservation.

11.3 Impacts on Ecosystem

Potential environmental impacts will result from the creation of the diversion sites and structures themselves, and from operational management of diversion sites and the impacts on downstream riverine ecosystems, including maintenance of instream and riparian habitats. Downstream impacts on riverine ecosystems are considered to be the primary environmental impacts associated with the development of these water supply abstraction sites. The most important mitigation measures are the release of good quality Reserve Flows capable of maintaining important environmental services, and satisfying downstream water requirements. Additional impacts are related to a) construction and b) operation of the diversion sites and associated transmission pipelines, as well as to reservoirs that have additional site level or local level impacts.

Protected Areas and Endangered Species - Downstream of the proposed intake sites, and upstream of Masinga Reservoir, there are currently no protected areas associated with the rivers from which abstraction is planned.

Impacts from Construction - Impacts that can be expected from construction include: potential soil erosion resulting from site preparation and construction activities, including weirs, tunnels and pipelines; pollution from machinery and construction activities; land acquisition; access roads; settlement, and workmen's camps. Potential positive impacts include improved access enabling farm produce to gain better access to markets, as well as some limited local employment opportunities. The overall impacts from construction are considered to be manageable with appropriate mitigation measures. Scenarios with less overall construction can be expected to have reduced impacts.

Impacts from Operation - Primary environmental impacts resulting from operation of the diversion sites and reservoirs are related to the change in downstream hydrology, through changes to water flow patterns, quantity and quality. The provision of adequate downstream environmental flows is considered to be essential for all rivers as a component of Reserve Flows.

Additional impacts from operation, related to changes in flow rates, include significant increases in flow over short stretches of river, for example where flow is diverted from South Mathioya to Maragua River and the proposed diversion of flow from Chania to Komu Rivers. In particular, the increased flow will result in potentially increased erosion of river banks requiring specific mitigation measures.

Aquatic and Riparian Environments - Weirs, dams and other structures along a river or stream will have inevitable impacts on fish species living in the rivers. In particular, obstacles to upstream movement or migration need to be avoided and, where present, fish ladders or other means of passage need to be provided.

Interbasin Transfers - Impacts on the Athi basin are not expected to be significant as the rivers on which the proposed intakes are situated (Irati, Gikigie, Maragua, South Mathioya, Hembe, Githugi, and North Mathioya) are connected to tributaries of the Tana. All negative impacts on downstream flows will therefore occur in the Tana basin. However, transfers of water will take place from these rivers to locations within the Athi basin. It is therefore expected that increased consumption will result in increased waste water ultimately flowing into the Athi River.

11.4 Environmental Monitoring Plan

In order to fully achieve mitigation, it is necessary to monitor actual impacts and the mitigation measures that are incorporated, and to adapt management strategies based on the results of monitoring. The Environmental Monitoring Plan (EMP) that will be further developed during subsequent stages based on the chosen development scenario will include recommendations that the following be monitored:

- Regular monitoring of flows upstream and downstream of all diversion structures and storage reservoirs. This will include the monitoring and reporting of Reserve Flows, including both Environmental Flow and Compensation Flow components;

- Regular monitoring of increased flows downstream of relevant diversion outlets, such as South Mathioya to Maragua Rivers from Northern Collector 2, together with surveys and monitoring of possible erosion problems in land adjacent to stretches of river with increased flow;
- Regular surveys of aquatic fauna upstream and downstream of the intake weirs;
- Changes to communities of aquatic fauna downstream of the intake weirs;
- Changes to communities of aquatic fauna in reservoirs;
- Changes to riparian vegetation downstream of the intake weirs;
- Changes in demand for water downstream of the intakes, including changes in demand related to increased demand for agricultural production;
- Water quality, including regular testing for chemical pollution from agricultural inputs upstream of intake points;
- Monitoring of sediment loads at intake weirs and downstream of intakes;
- Forest cover in the Aberdares catchment area;
- Land use and land cover, including agricultural activities in the catchment areas of the rivers associated with the Northern Collector phases 1 and 2;
- Impacts of changes in the quality and availability of water supplies from rivers and associated streams on public health, including those communities dependant on downstream flows.

In addition, Construction Environmental Management Plans will be required to deliver a practical and achievable plan of management and to ensure that any environmental impacts during the construction phases are minimised. Plans will need to be developed prior to construction once full design and construction details are available.

The following issues will need to be included:

- Physical setting, flora and fauna, ensuring minimal environmental impact and proposing mitigation measures;
- Prevention of interruption to existing infrastructure installations and services, including the building of alternative access routes as required;
- Resettlement and land compensation, including compensation for potential loss of livelihoods;
- Ensure that noise and vibrations are kept to acceptable standards;
- Water quality management, dust and air quality, soil and groundwater contamination control;
- Waste management, land contamination, erosion and sediment control, and
- Environmental Performance Monitoring.

Operational Environmental Management Plans will also be required. These should focus on sound environmental management practices undertaken to minimise adverse impacts on the environment during normal operation of the intake sites, reservoirs and water transmission tunnels and pipelines. The following issues will need to be included:

- Overall management strategy, including environmental performance monitoring and regular reporting;
- Maintenance of environmental integrity, including the provision of adequate downstream environmental flows, and the maintenance of compensation flows for downstream communities;
- Energy management, including measures to ensure minimizing greenhouse gas emissions.

Multi-Criteria Analysis

Table 12.1 – Multi-Criteria Analysis - Weighting Criteria / Allocation of Weightings on Page 24

Table 12.2 – Multi-Criteria Analysis - Weighting of Criteria and Ranking of Scenarios on Page 25

Table E12.1 - Multi Criteria Analysis - Weighting Criteria / Allocation of Weightings

1. MANDATORY CRITERIA											
Sustainability issue		**Headline Criteria**	**Sub-Criteria**	**Description**			**Scenario 1**	**Scenario 1A**	**Scenario 2**	**Scenario 3**	**Scenario 3A**	**Scenario 4**
1.1	Technical& Natural Resources	Water Quality	Water Demand	Quantity of w ater supply to meet 2035 demand for i) Nairobi & satellite tow ns, ii) local demand and catchment w ide.			Yes	Yes	Yes	Yes	Yes	Yes
1.2	Technical& Natural Resources	Water Quality	Security of the Resource	Risk of supply option to long term or extended change: dry years, climate change etc			limited risk	limited risk	high risk	limited risk	limited risk	limited risk
1.3	Technical& Natural Resources	Water Quality	Reliability of the Resource	Number of additional and independent w ater Sources & Routes			4 new Sources & 3 additional major WS routes	4 new Sources & 4 additional major WS routes	3 new Sources & 3 additional major WS routes	4 new Sources & 3 additional major WS routes	4 new Sources & 4 additional major WS routes	4 new Sources & 3 additional major WS routes
Screening of scenario against mandatory criteria							consider	consider	consider	consider	consider	consider
2. ECONOMIC CRITERIA - LEAST COST ANALYSIS												
2.1	Economic	Cost	Average Incremental Economic Cost (AIEC)	Normalised discounted Average Economic cost/m3 (Capex and O&M) of the proposed scenario over the projected life of the infrastructure		in USD/m3	0.69	0.63	0.60	0.65	0.59	0.68
				(>0.70, 0.00), (0.67-0.69, 0.25), (0.64-0.66, 0.50), (0.61-0.63, 0.75,) (<0.61,1.00)		Score	**0.25**	**0.75**	**1.00**	**0.50**	**1.00**	**0.25**
2.2	Economic	PVEC	NPV of Capex and O&M	Present Value of Economic Costs (PVEC)		in MUSD	897.35	836.42	779.84	889.22	814.33	918.80
				(>900, 0.00), (875-900, 0.25), (850-875, 0.50), (800-850, 0.75), (<800, 1.00)		Score	**0.25**	**0.75**	**1.00**	**0.25**	**0.75**	**0.00**
2.1	Economic	O&M Cost	NPV of O&M Costs	Present Value of Operation and Maintenance costs over the projected life of the infrastructure		in MUSD	276.62	210.99	214.99	278.59	177.05	323.19
				(<200, 1.00), (200-225, 0.75), (225-250, 0.50), (250-275, 0.25), (>275, 0.00)		Score	**0.00**	**0.75**	**0.75**	**0.00**	**1.00**	**0.00**
3. OTHER CRITERIA - LEAST COST ANALYSIS												
Sustainability issue		**Headline Criteria**	**Sub-criteria**	**Description**	**Poor**	**Medium**	**Good**	**Scenario 1**	**Scenario 1A**	**Scenario 2**	**Scenario 3**	**Scenario 3A**	**Scenario 4**
A. Technical & Natural Resources 0 0,5 1													
3.1.	Technical & Natural Resources	Water Quantity	Diversification of the resource	Share of alternative sources to surface w ater (groundw ater roof catchment, . recyling etc.)	below 5% of total w ater demand 2035	betw een 5 to 10% of total w ater demand 2035	maintained to 10% of w ater demand in 2035	1.0	1.0	1.0	1.0	1.0	1.0
3.3.	Technical & Natural Resources	Water quantity	Water flow s/ Competition w ith hydropow er	Water left dow nstream meets dow nstream demand for local hydropow er run-off-river	Licensed HEP yearly flow s affected by more than 10%	Licensed HEP yearly flow s affected by less than 10%	Licensed HEP yearly flow s maintained	0.5	0.5	0.5	0.5	0.5	0.5
3.4.	Technical & Natural Resources	. Water Quantity	Water ter flow s /Competition w ith other dow nstream uses	Water left dow nstream meets licensed flow s dow nstream	unsuited: less than 50% of flow s met	Satisfactory (70% of licensed flow s met)	Good (100% of licensed flow s met)	1.0	1.0	1.0	1.0	1.0	1.0
B. Economic													
3.5.	Economic	Infrastructure	New infrastructure	Use and build upon existing infrastructure & resources	All new infrastructure	Some use existing	Most existing	0.5	0.5	0.75	0.5	0.5	0.25
3.6.	Economic	Cost	Opportunity cost	Opportunity cost for hydropow er &/or alternative w ater uses lost (discounted over project economic life)	Opportunity cost > 0,10 USD/m3	0,05 USD/M3< Opportunity cost < 0,10 USD/m3	Opportunity cost < 0,05 USD/m3	0.5	0.5	0.5	0.5	0.5	0.5
C. Environment													
3.7.	Environment	Water quantity	Dow nstream environmemtal impact	Impacts on environments dow nstream; w ater flow patterns, dow nstream w ater and land use from reduced environmental flow s	significant impact	some impact	No change	0.25	0.25	0.5	0.25	0.25	0.25
3.8.	Environment	Water quality	Upstream impact including catchment protection	Impacts of upstream land use on w ater quality : runoff & erosion, nutrients/pesticides runoff, change in w oody cover and land use.	significant issues	manageable issues	no issues	0.5	0.5	1.0	0.5	0.5	0.5
3.9.	Environment	Ecology	Construction	Environmental impacts from construction, including w eirs, dams and transmission systems	significant impact	some impact	Minimal impact	0.5	0.5	0.75	0.5	0.5	0.5
3.10	Environment		Operation	Environmemtal impacts from operation, including managememt of intake sites, aquatic fauna abd riverine ecosystems, incl impacts on protected areas and vulnerable species.	significant impact	some impact	Minimal impact	0.5	1.0	1.0	0.5	1.0	0.5
D. Social													
3.11.	Social	Access	Water access	Equity of access to w ater, impact on upstream and dow nstream domestic, commercial, and stakeholders	Specific w ater supply use only	Several sectors have access	All sectors can use	0.5	0.5	0.25	0.5	0.5	0.5
3.12.	Social	Amenity	Resettlement / Compensation / Land loss	Population to be resettled and total land losses from dam storage reservoirs, WTW, etc.	Significant resettlement and land losses	Manageable resettlement /Land losses	No resettlement/land losses	0.5	0.5	0.75	0.5	0.5	0.5
						Sub-total - other criteria		**6.75**	**9.00**	**10.75**	**7.00**	**9.50**	**6.25**

Table E12.2: Multicriteria Analysis - Weighting of Criterias and Ranking of Scenarios

Sustainability Issue		Headline Criteria	Sub-criteria	Weighting %		Scenario 1	Scenario 1A	Scenario 2	Scenario 3	Scenario 3A	Scenario 4
1.	Natural Resources	Water Quantity	Diversity of the Resource	10.0%		0.10	0.10	0.10	0.10	0.10	0.10
2.	"	"	Water Flows/Competition with Hydropower	10.0%		0.05	0.05	0.05	0.05	0.05	0.05
3.	"	"	Water Flows/Competition with other Downstream Users	10.0%	30%	0.10	0.10	0.10	0.10	0.10	0.10
B. Economic											
5.	Economic	Cost	Present Value of Economic Costs (PVEC)	15.0%		0.04	0.11	0.15	0.04	0.11	0.00
6.	"	Cost	Average Incremental Economic Cost (AIEC)	7.5%		0.02	0.06	0.08	0.04	0.08	0.02
7.	"	Cost	O&M	7.5%		0.00	0.06	0.06	0.00	0.08	0.00
8.	"	Infrastructure	New infrastructure	7.5%		0.04	0.04	0.06	0.04	0.04	0.02
9.	"	Cost	Opportunity Cost	7.5%	45%	0.04	0.04	0.04	0.04	0.04	0.04
C. Environment											
10.	Environment	Water quantity	Downtream Environmental Flow	5.0%		0.01	0.01	0.03	0.01	0.01	0.01
11.	"	Water quality	Upstream Impact	5.0%		0.03	0.03	0.05	0.03	0.03	0.03
12.	"	Ecology	Construction	2.0%		0.01	0.01	0.02	0.01	0.01	0.01
13.	"	"	Operation	3.0%	15%	0.02	0.03	0.03	0.02	0.03	0.02
D. Social											
14.	Social	Access	Water access	5.0%		0.03	0.03	0.01	0.03	0.03	0.03
15.	"	Amenity	Resettlement / Compensation / Land loss	5.0%	10%	0.03	0.03	0.04	0.03	0.03	0.03
			TOTAL	**100.0%**		**49%**	**68%**	**80%**	**51%**	**72%**	**44%**