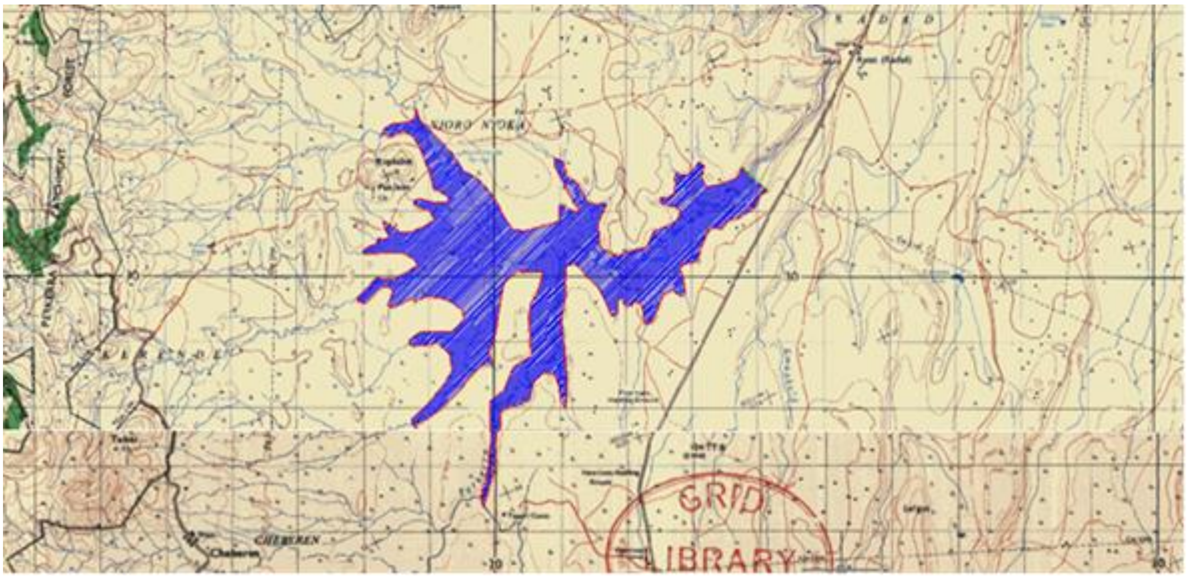
FEASIBILITY STUDY, DETAILED DESIGN AND PREPARATION OF TENDER DOCUMENTS FOR RADAT DAM, BARINGO COUNTY

Contract No. NIB/T/016/2013-14



Feasibility Study Report

In Association With

EAST AFRICAN ENGINEERING CONSULTANTS
P.O. BOX 30707, 00100
CHAKA ROAD, KILIMANI, NAIROBI
PHONE: (254 2) 2714514/15/2718861/2527995
FAX: (254 2) 2714516
Email: info@eaecgroup.com, eaeckenya@gmail.com, www.eaecgroup.com

BATCH ASSOCIATES LTD
No. 7A Diani Close, off Ole Odume Road
P.O Box 24103-00100, Nairobi, Kenya
Tel: +254 (0) 20 2018176,
Fax: +254 (0) 20 2621168,
Cell: +254 (0)721467213 /+254 (0)736451752
E-mail: info@batchassociates.co.ke
Webmail: www.batchassociates.co.ke

JULY 2014

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Abbreviations

CAAC	Catchment Area Advisory Committee
CFRD	Concrete Faced Rockfill Dam
DEM	Digital Elevation model
DTM	Digital terrain Model
EAEC	East African Engineering Consultants
EIA	Environmental Impact Assessment
EMCA	Environmental Management and Coordinating Act
FEAM	Federal Emergency Management Agency
IDD	Irrigation and Drainage Department
IPCC	International Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
NCWSC	Nairobi City Water and Sewerage Company
NIB	National Irrigation Board
NEMA	National Environmental Management Authority (of Kenya)
NGO	Non-Government Organisation
PAPs	Project Affected Persons
RBDA	River Basin Development Authorities
RGS	River Gauging Station
ToR	Terms of Reference
UNESCO	the United Nations Educational, Scientific and Cultural Organization
WRMA	Water Resources Management Authority
WRUA	Water Resource Users Association
WSP	Water Services Board

Summary

The contract	The service contract for "Consultancy Services for Feasibility Study, Detailed Design and Preparation of Tender Documents for Radat Dam, Baringo County" was signed between the National Irrigation Board (NIB) and an association of East African Engineering Consultants and Batch Associates Ltd., (The Consultant) on 13th January 2014.
Radat Dam project	The objective of the Radat dam project is to harness, conserve, and control and utilize the flood waters of Perkerra River. The project main target is to enhance development of the expanded Perkerra Irrigation Scheme through the construction of Radat dam, a multipurpose dam with a primary purpose of regulating Perkerra river flow to enhance irrigation development, flood control and hydropower generation. This development will contribute to increase in irrigation area and subsequently agricultural production, improvement of the livelihoods of farmers in the Baringo County and enhanced food self-sufficiency in Kenya as a whole. The proposed dam should meet the expanded irrigation demand of Perkerra irrigation project of 280,000m^3/day. Pre-Feasibility study identified 5 sites and recommended Radat Dam sites for further investigations. During this stage, focused studies were carried out at the proposed Radat dam site while limited generally studies were carried on the four other sites.
Scope of Services	The scope of Consultancy Services shall comprise; a) Feasibility studies at the potential dam sites to select the better alternative and to allow for the design of the dam to determine: b) carry out detailed investigations and designs of a dam at the selected site in line with established best practice worldwide, and c) Prepare pre-qualification and tender documents for all civil and supply works arising out of the detailed design including civil/structural works and power plants.
This report	The present report, the feasibility Study reports, presents findings of the preliminary field activities and investigations carried out at the proposed dam sites and the project area. The report details the outcome of the following; ***(a)*** Socio Economic Study ***(b)*** Hydrological and Water Resources study ***(c)*** Geological and soils surveys, ***(c)*** Topographical surveys and site evaluation studies ***(d)*** Environmental screening of sites, ***(e)*** Cost estimation and economic evaluation

	The report comprise the main report and three annexes; **Annex I: Socio Economic Study and ESIA Screening Report** **Annex II: Hydrological Study Report** **Annex III: Geological and Geophysical Investigation Report**
Perkera Irrigation Scheme	Perkerra Irrigation Scheme is situated 100Kms North of Nakuru near Marigat Township in Marigat District. The scheme derived its name from the River Perkerra, which is the source of Irrigation Water, and the only permanent river in the District. The Perkerra Irrigation Scheme Expansion Project Study, (Bhundia Associates 2012), proposed to expand the scheme irrigation area to 2020 hectares. The proposed expansion will increase the area currently under irrigation by eight times. To achieve this, water sources with a daily yield of 280,000m^3) is required. The current source of Perkerra irrigation water, the Perkerra River, can meet irrigation demand of upto 35,424m^3/day.
Perkerra River Basin	The river Perkera and its tributaries form the Perkera River basin which originates from Maji Mazuri ,Timboroa, Lembus, Chemorogok and Metkei forests. The Perkera irrigation scheme falls within the area drained by the Perkera River and its tributaries with a catchment area of about 1,411 km2. The river basin falls under the Rift valley drainage basin 2E, Kerio Valley sub-basin in the Rift Valley basin. Perkerra borders Molo river basin to the west and to east by Tapuchara river basin, which joins Perkera River at Marigati to form the Tigeri river basin.
Dam Sites	The pre-feasibility study identified five dam sites; Koipokaplelach, Kapng'etuny, Kaplelwo, Radat and Kipkabei dam sites. Radat site was recommended for full feasibility, detailed investigations and designs. The sites are taken to be indicative only; further investigation may vary or confirm the sites. Two of the sites Radat and Kaplelwo are located on the main Perkerra River; Koipokaplelach site is located on Tapuchara River while Kapng'etuny is located Ainopno River, all tributaries of the main Perkerra River. During this feasibility study, three possible locations were investigated at the Radat sites, Radat site 1, Radat site 2 and Radat site 3. Estimation of storage potentials of the proposed dam site was determined using contours generated from existing topographic information and topographic survey at the dam sites. Site storage/height/areas were generated for the four sites. The key features of the dam site are summarized here blow.

Dam Site	Estimated Storage potential (Mm^3)	Storage Height (m)	Reservoir Area (Ha)	Embankment Length (m)
Kaplelwo	30.7	45	138	1,150
Kopokaplelach	15.0	35	126	685
Kapng'etuny	5.6	45	40	500
Radat Site 1	267	95	907	415

Radat Site 2	228	85	833	435
Radat Site 3	157	70	686	300

Site Geology	The result of both reconnaissance geological survey and preliminary geophysical investigations shows that the geology of the proposed Radat dam project area is composed of volcanic rocks of Miocene to Pliocene age. Tuffs intercalated with sediments of the same age are also present in this area but with limited. The rocks are highly weathered and only slightly fractured. The deeper foundation rocks composed of basalts of Samburu type are more weathered than the upper horizons. The general project area has been affected by grid faulting but the nearest observed fault zone is around Radat Trading Center but it disappears as one approaches dam site 1 (the lower dam site). It significant to note that at the sites rocks on the right bank of Perkerra River are part of downthrown block of younger rocks that abut on older rocks on the left hand side of Perkerra River: This may mean that the older faulting may have been obscured the younger lava flows. The foundation rocks in the three dam sites have undergone almost similar pattern and intensity of weathering however, dam site 1 (the lower dam site) has apparently more stable foundation compared to the other two. The project area is characterized by abundance of rocks that can readily be used for rock-fill dam. The recent deposits in are composed of a thin layer greyish brown soil with cobbles and stones derived from the parent volcanic rocks. Finally it is concluded that proposed dam sites are suitable for a rock fill dam. However, further detailed geological investigations including core drilling and rock testing for strength will be necessary. The structural condition of the foundation rocks will also be necessary using seismic profiling. Around proposed dam site 3 (about 5km from dam site 1) a layer of red clay was observed with the tuffs and sediments that underlie Kwaibus olivine basalts in that area. The thickness and areal extent of this horizon may be of interest as source for impervious core material.

Recommended Reservoir Capacity

From the sites hydrological studies, evaluation of the potential dam sites and dam optimisation study, a reservoir with a net storage capacity of 124Mm³ will satisfy the objective of the proposed development project. This reservoir will regulate the river flow to guarantee irrigation abstraction of 3.25m³/s development to 2020Hectares of irrigation area. Full development of the irrigation area to 2020Ha, will be progressively attained between the second and the third year to allow impoundement. Dam parameters for the three Radat sites meeting the 120Mm³ are summarised below.

Dam Site	Storage Height (m)	Embankment Length (m)	Reservoir Area (Acres)	Crest Level (Masl)
Radat Site 1	75	415	1,218	1450
Radat Site 2	75	435	1,279	1445
Radat Site 3	70	300	1,374	1460

Dam Type

The proposed dam sites are underlain by rocks highly weathered volcanic rocks (basalts and phonolites that have affected by faulting in the general). Further seismic profiling proposed during detailed geological investigations will shed more light on the conditions the foundation. The prevailing site geological conditions favour a zoned rock-fill dam with an impervious core. In view of the above considerations, a zoned rock dam is suggested.

Construction materials in form red clay soil for an impervious core is apparently available within the dam site, but shell material will be readily available for both rock-fill and Rip Rap. Red clay soils will be further assessed at Radat Dam Site 3 area which also the preferred dam site for this project.

Proposed Dam structure

The size of the proposed dam has been determined from the storage is curves and the reservoir simulation results. A rock fill embankment dam with a clay core of a reservoir capacity of 124Mm³ and storage height of around 60m.

The embankment geometry at this preliminary stage has been taken as 1:.1.75 and 1:2.25 for upstream and downstream slopes respectively. A 10.0m crest width is suggested and a footbridge across the side spillway is proposed.

The overall downstream slope will be flatter than this because of the provision of 6.0 m wide berms at the coffer dam level running the entire length of embankment at the 25 m height from the embankment crest. These will also serve as the main artery for delivering fill materials from the excavation lots to the dam.

Land requirement

The 124Mm³ at the proposed site will flood sections of five sub locations of the project area as summarised below. It is worth noting, the larger part of the areas in within the river reserve.

Sub-Location	Site 1 (Acres)	Site 2 (Acres)	Site 3 (Acres)
Radat	432	377	117

Kimose	94	108	184
Tinomoi	401	345	359
Cheberen	0	0	8
Tebei	505	639	979
Total	**1,431**	**1,469**	**1,647**

Hydropower Generation

It is proposed that the regulated irrigation release of 3.25m³/s to the river be used for hydropower generation immediately downstream of the dam. The irrigation off-take to Perkerra scheme is located substantially downstream of the dam making it possible to release back the water for irrigation.

With the reservoir, the river flows can be regulated and they can be released through the power house (turbines) in such a manner as to maintain a uniform power generation. Using the available flow, 1.0MW of power can be uniformly generated throughout the year.

Estimated Costs

The estimated preliminary cost for the three Radat dam sites are summarised below. The cost includes cost of resettlement and related land acquisition costs.

Description of Works	Radat Site 1	Radat Site 2	Radat Site 3
A.1 PRELIMINARY WORKS	300,000,000	300,000,000	300,000,000
A.2 DIVERSION WORKS	83,250,000	83,250,000	83,250,000
A.3 DAM WORKS	8,933,286,990	8,879,472,490	7,042,419,267
A.4 SPILLWAY	370,562,500	356,125,000	356,125,000
A.5 RESERVOIR	251,250,000	260,015,000	280,015,000
A.6DAM ANCILLARY WORKS	1,532,500,000	1,561,500,000	1,440,000,000
A.7 HYDROPOWER GENERATION	500,000,000	500,000,000	500,000,000
A.8 Detailed Design and Construction Supervision (2.5%)	299,271,237	298,509,062	250,045,232
A.9 Contingencies and Price Adjustments (5%)	598,542,474	597,018,124	500,090,463
A.10 TOTAL COST	12,868,663,201	12,835,889,676	10,751,944,962
Add 16% VAT	2,058,986,112	2,053,742,348	1,720,311,194
A.11 NET COST	**14,927,649,314**	**14,889,632,025**	**12,472,256,155**

Project and its justification

The proposed Radat dam is expected to regulate flow in Perkerra to guarantee irrigation requirement of 3.25m3/s requirements to expand the Perkera irrigation scheme. The project will augment food security, reduce poverty level among the population in the project area as well as enhance commercial agricultural production. These will directly answer to the Vision 2030 for this country and the Worlds MDGs. The project will make contribution to increased employment opportunities in the project area, during construction and when operational. The latter particularly will be realized through the labour intensive vegetable and rice production. Employment will also be available throughout the construction period of main and in-field irrigation systems. A number of secondary benefits will also

	be realized which include: Improvement of farm households' nutrition; Income and employment opportunities generated through the marketing of farm produce; suppliers of crop inputs (seed, fertilizers and pesticides), contract services (land preparation and transport) and the agro-processing industry; and opportunities for employment local contractors during project implementation. Due to the high flow fluctuations and the water deficit in the Perkerra basin, a dam with a large reservoir is required to regulate the river flow. The consequence is a dam with a relatively high construction cost. From the economic and financial analysis, the dam project is not viable at capital discounting rates above 8%.
Recommended Dam	A 70m high with net reservoir capacity of 124Mm^3 is proposed at the proposed dam site 3. Thee regulated release of 3.25m^3/s will be used to generated hydro power of 1.0MW then released for irrigation downstream of the dam.
Recommended Dam site	The preferred dam site for the proposed Radat dam site is site 1. The site has the most stable geological foundation. The site also has the high storage potential of upto 257Mm^3 making a good site for even further expansion. The reservoir at this site will be confined to the river basin for around three kilometres before spreading out to flood around 500Acres in Tebei sub location. The dam and reservoir at this site will require 1,431 Acres of land which is 200acres less compared to site 3. The only disadvantages are submergence of the existing bridge crossing which is the only river crossing on Perkerra river at this point. Even though the bridge will be replaced, it may cause too much disruption. The site also has a wider valley that will make the dam embankment construction more expensive. In view of the above, Dam site 3 is recommended, The site has a potential for a 157Mm3 and will not submerge the existing bridge. The estimated construction cost at this site is Kshs.12.5Billion

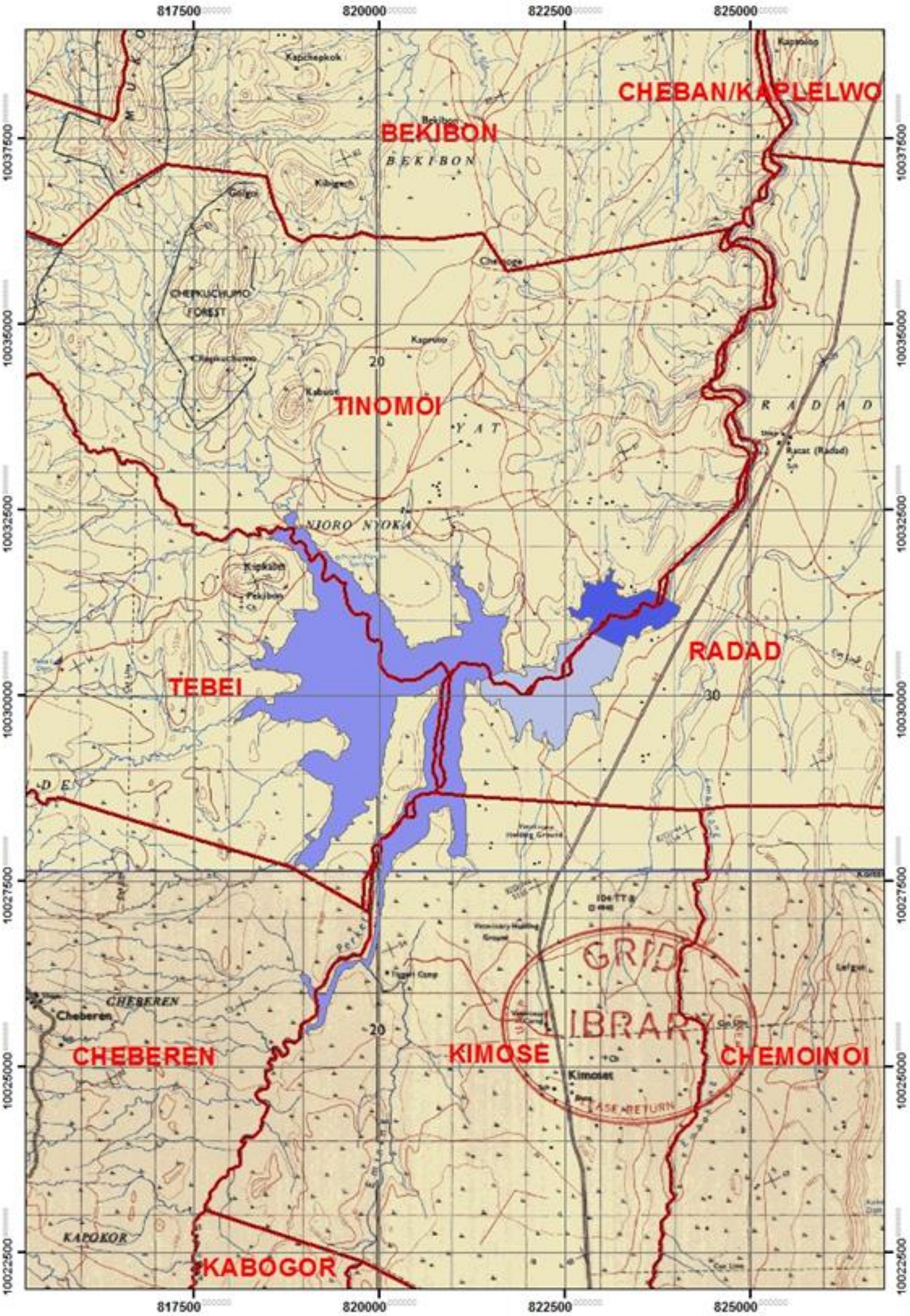
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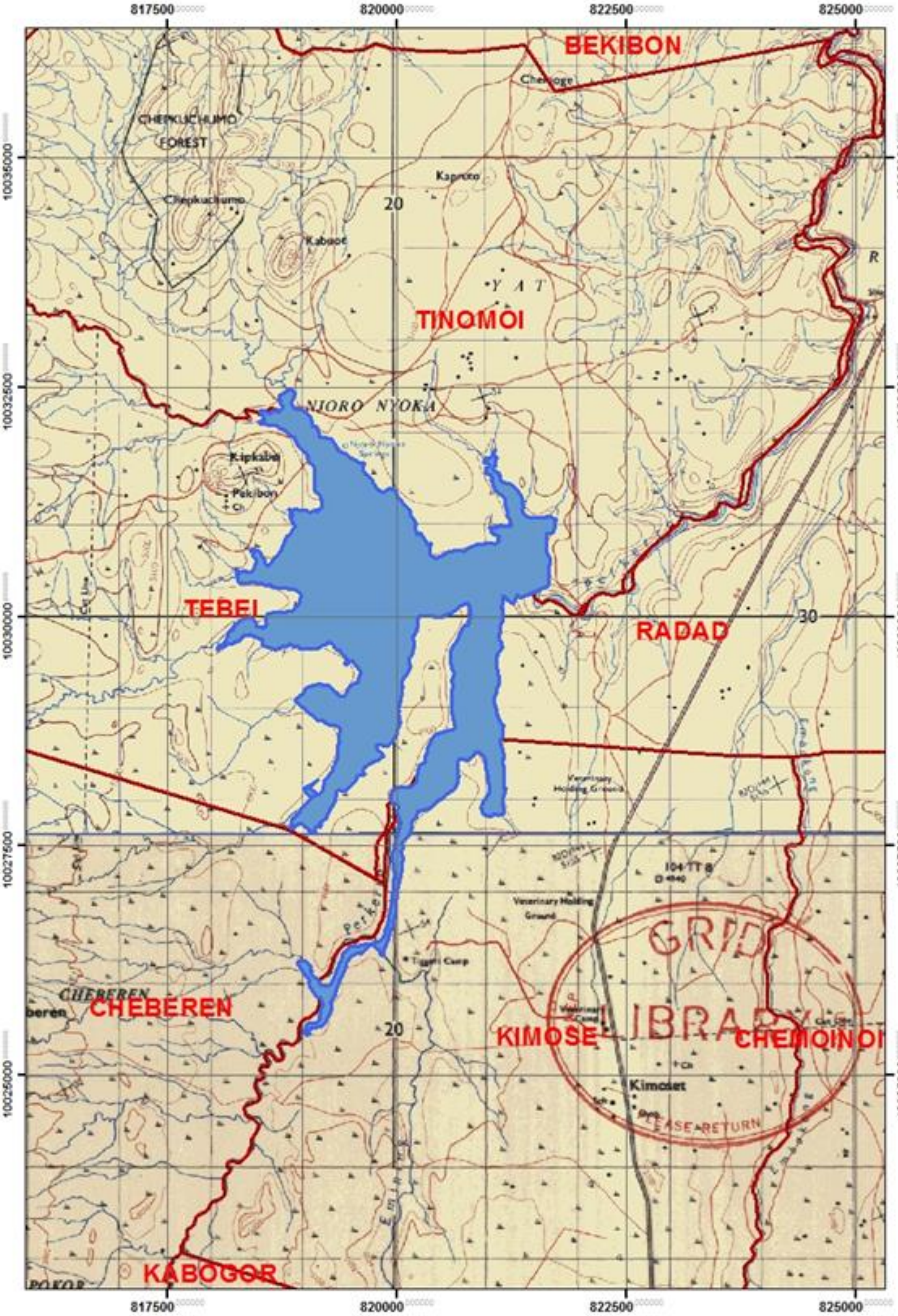
Figure 1:1 Dam Location Map



1 INTRODUCTION

1.1 Background

The objective of the Radat dam project is to harness, conserve, and control and utilize the flood waters of Perkerra River. The project main target is to enhance development of the expanded Perkerra Irrigation Scheme through the construction of Radat dam, a multipurpose dam with a primary purpose of regulating Perkerra river flow to enhance irrigation development, flood control and hydropower generation. This development will contribute to increase in irrigation area and subsequently agricultural production, improvement of the livelihoods of farmers in the Baringo County and enhanced food self-sufficiency in Kenya as a whole. The proposed dam should meet the expanded irrigation demand of Perkerra irrigation project of 280,000m^3/day.

Pre-Feasibility study identified 5 sites and recommended Radat Dam sites for further investigations. During this stage, focused studies were carried out at the proposed Radat dam site while limited generally studies were carried on the four other sites.

1.2 Perkerra Irrigation Scheme Expansion Project

Perkerra Irrigation Scheme is situated 100Kms North of Nakuru near Marigat Township in Marigat Sub County. It derived its name from the Perkerra River, which is the source of Irrigation Water, and the only permanent river in the District.

The construction of the irrigation Scheme started in 1954 after several feasibility studies, which showed that the Ilchamus flats (Plains) was suitable for Irrigation. The conceptual study was carried out in 1936 but due to financial constraints, construction was shelved until the "state of Emergency" period, when detainees provided labour for construction purposes. Marigat was one of the many detention Camps in the country at that time.

It is estimated that approximately 13,000 people will directly and indirectly benefit from the expanded project in Baringo and neighbouring Nakuru counties. . The Perkerra Irrigation Scheme Expansion Project Study, (Bhundia Associates 2012), proposed to expand the scheme irrigation area to 2020 hectares. The proposed expansion will increase the irrigation area eight times the area currently under irrigation from 254Ha. To achieve this, water sources with an annual yield of 280,000m3/day is required. The current source of Perkerra irrigation water, the Perkerra River, cam meet irrigation demands of up to 35,424m3/day.

1.3 Objectives and Scope of the study

The objective of this study is undertaken feasibility studies and detailed design of the proposed Radat dam. The dam to be located in across Perkera river will regulate the in the river while conserving flood flow for reliability utilisation for Perkerra irrigation scheme.

1.4 Scope of the study

The scope of Consultancy Services shall comprise;

a) Feasibility studies at the potential dam sites to select the better alternative and to allow for the design of the dam to determine:

b) carry out detailed investigations and designs of a dam at the selected site in line with established best practice worldwide, and

c) Prepare pre-qualification and tender documents for all civil and supply works arising out of the detailed design including civil/structural works and power plants.

1.5 The feasibility study

Preliminary studies at this stage were undertaken to identify the potential dam sites and select the better alternative. The selected dam will go through detailed investigations and design. The studies herein presented include the following;

1.5.1 Socio- Economic baseline Studies

- To conduct a social baseline in the project area.
- To conduct consultations with relevant stakeholders, including potentially affected persons, to obtain their views and suggestions regarding the environmental and social impacts of the proposed project.
- To identify potential negative and positive social impacts of the Project and propose mitigation measures.
- To prepare an SIA report incorporating results of social analysis

1.5.2 Topographic study

Topographic layout maps of the potential dam sited were prepared from data collected from topographic surveys. The maps are used delineate and to study the dam potential using the digital terrain models.

1.5.3 Hydrology and water management study

Hydrological study involved evaluation basin hydro-meteorological information to derive the following;

- Evaluation of the potential basin runoff yield and potential reservoir size at proposed site
- Carry out water balance study taking into account the proposed irrigation demand and other potential multi-purpose water usage
- Estimate maximum flood occurrences to be used in the reservoir water evacuation structures such as spillway and diversion
- Estimate the reservoir yield and reliability to meet the various water uses
- Estimate sediment load, evaluate reservoir loss and the requirement from dead storage

1.5.4 Geological and geotechnical study

- Undertake geological investigations and geophysical surveys to identify the geological condition, estimate the vertical profile of the underlying strata, identify ground weakness.
- Undertake preliminary material study to identify embankment materiel and recommend a preferred dam type.
- Undertake preliminary geological analysis to recommend and prepare terms of reference for detailed investigations and studies including core drilling, seismic surveys and borrow pit investigations.

1.5.5 Preliminary dam layout and design

Provide preliminary layout and design of the proposed dam at the recommended site.

1.5.6 Environmental and Social Impact Assessment (ESIA) study

- Conduct baseline socio-environmental study of the dam site, reservoir area and hydropower plant.
- Identify potential socio-environmental impacts of the project.
- Propose impact mitigation measures.
- Prepare a comprehensive environmental and social impact assessment ESIA study.
- Identify project affect persons and the need for resettlement (especially as the result of reservoir impounding).

1.6 Outline of the Feasibility Study Report

The Feasibility Report has been prepared to reflect the requirements of the Terms of Reference. The report is divided into ten sections as follows:-

Section 1 Introduction

This section covers the project outline, defines the scope of the study and extent of study area, and outlines the current water supply situation

Section 2 General Background Information

This section describes the location, climate, topography, geology and soils, water resources, administration, settlement and socio-economic aspects, natural resources and infrastructure of the project area.

Section 3 Socio-economic Studies

This section presents the findings of the socio-economic studies carried out for the project.

Section 4 Hydrology and Water Resources

This section reports on the hydrological and water resources study. Available runoff, reservoir yields and storage requirement and the dam regulation study is also covered.

Section 5 Geological and Geophysical Investigations

This section covers geophysical and geological investigation at the proposed dam site and reservoir area.

Section 6 Evaluation of the Dam option

This section covers the recommended design for the proposed dam and water supply project. It describes the proposed dam characteristic, preliminary design of dam features

Section 7 Environmental Impact Assessment

This section outlines the findings of the initial environmental impact assessment carried out for the various alternative dam sites in the project area.

Section 8 Project Cost Estimates and Economic Evaluation

The section covers the estimated project cost of the proposed dam and water supply system and implementation plan.

2 BACKGROUND INFORMATION

2.1 Project Location

The project area is under the administrative jurisdiction of Baringo County which according to the Constitution of Kenya has authority for Agriculture, Water and Irrigation which form some of the core objectives of the Project. In the project area, the Perkerra River forms the boundary between Baringo District/Sub County on the Northern bank and Mogotio District / Mogotio Sub County on the Southerly bank. In total five sub-locations spread across two administrative districts /sub counties of Baringo Central and Mogotio. The sub-locations affected are as follows: Kimose Sub-Location, Cheberen Sub-Location and Radat Sub-Location in Mogotio District/Sub County while in Baringo Sub County Tinomoi Sub-Location and Tebei Sub-Location are affected. It is here noted that Tebei Sub-Location and Tinomoi Sub-Location, which are administratively in Baringo Central Sub County and politically in Marigat Sub County.

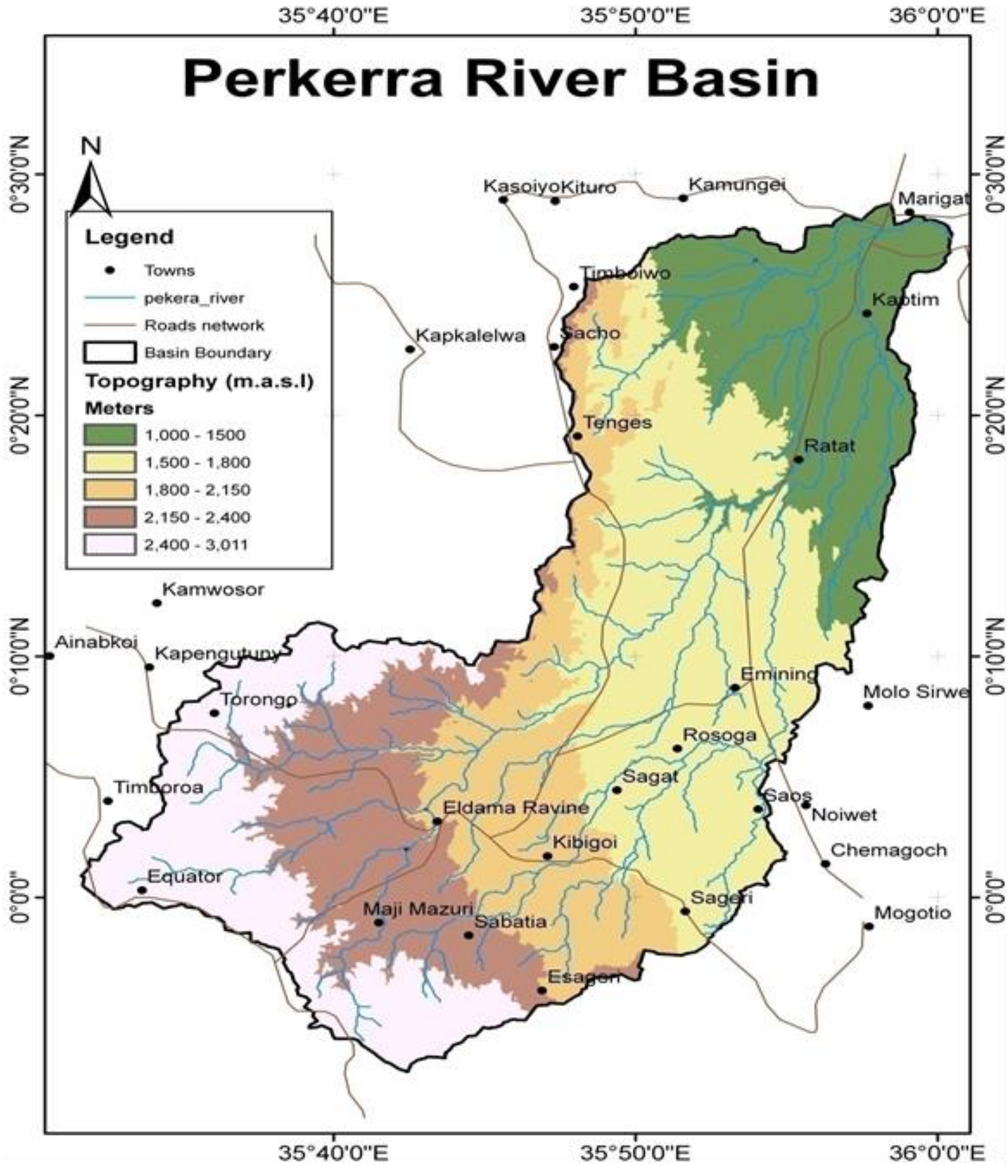
2.2 Topography

Baringo varies in altitude between 3000m above mean sea level at its highest points and nearly 700m above mean sea level at its low points. The County has the Kerio Valley on the western part, Lake Baringo and Bogoria in the eastern part forming the Loboi Plains which is covered mainly by the latchstring salt-impregnated silts and deposits and the Tugen Hills where the proposed dam project is located. The trend of the hills is north-south and mainly consists of volcanic rocks. The hills have steep slopes with prominent gullies. On the eastern and western parts of the hills are escarpments. River Perkerra flows in the hills in very deep gorges thus its suitability for the proposed project.

2.3 Rainfall

In general rainfall in the Koibatek and Baringo districts is seasonal and fairly reliable, with long rains coming between March and July with maxims occurring in May and the short rains occurring between September and November with the maxims in October. Minimum rain occurs in January. The average total rainfall per annum ranges between 800mm in the lowlands to 1200mm in the highlands. The mean average temperature is 30oC in the lowlands and 24oC in the highlands.

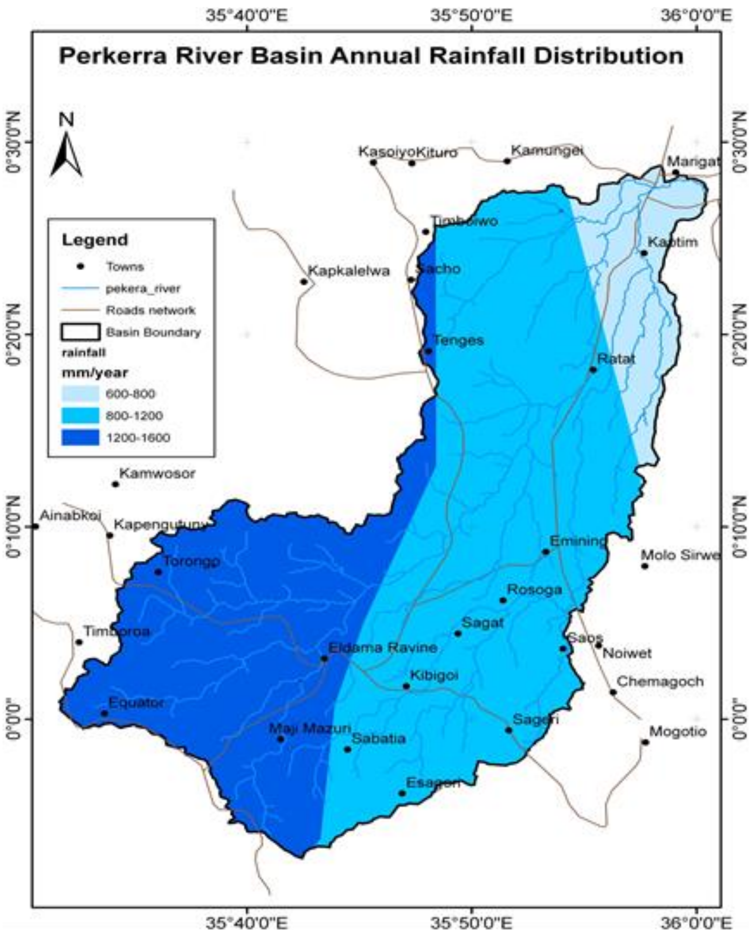
Most of the river water comes from the hill slopes, where annual rainfall is from 1,100 millimetres to 2,700 millimetres. The region around the Lake Baringo is semi-arid, with annual rainfall of 450 millimetres and annual evaporation rates of 1,650 millimetres to 2,300 millimetres.



2.4 Geology and Soils

The dam sites area lies within the East African Rift Valley which is bounded physiographically by the Elgeyo Escarpment to the west and Laikipia Escarpment to the east. The Tugen Hills stand out as a horst in the middle part of the main rift graben. The oldest rocks found in the area belong to the basement system. Fluvial sediments are deposited in the depressions of the basement. The general geological succession in the section of the Perkerra River is complex as it consists of a series of lava groups and one major tuff and sediment group all in unconformable relationship and frequently faulted.

The landscape of the project area is characterized by steep slopes of the Tugen Hills. The soils in the project area and Baringo in general are volcanic fluvisols of sandy/silty clay loam texture, slightly acid to slightly alkaline, highly fertile with adequate, P,K,Ca, Mg but low N and C.



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2.6 Hydrology and Drainage

The Perkerra River rises in the Mau Forest on the western wall of the Rift valley at 2,400 masl, dropping down to 980 masl at Lake Baringo. The river is formed from a union of several streams from the Lembus forest highland, Maji Mazuri, Timboroa, Chemeorok and Metkei forest. The river has several tributaries namely Tigeri (Chepkungur), Lelgal, Eldama Ravine, Narosura and Esageri. The Perkekrra river catchment is characterised by very steep slopes on the hillsides and gentle slopes in the middle and lower reaches where the surface is bear with very little undergrowth with a total catchment of 1,411km2. The the river flows into Lake Baringo whose drainage area is 6820 km2. The Lake is a Semi-Arid Lake which and according to reports it has reduced its depth from 8m in 1973 to 2.5m in 2003 due to siltation resulting from high soil erosion rates in the catchment which has affected the lakes turbidity.

Water quality in the area is mainly affected with silt due to poor land use practices such as deforestation, poor land management practices and overstocking of livestock. The area experience a water deficit for both domestic and livestock at 40m3/day and 50m3/day in the lower catchment due to high human and livestock population , irrigation and rainfall variability. The river flow has been reducing over the years and conflicts always arise between downstream and upstream users over resource development upstream for downstream usage.

2.7 Vegetation and Land use

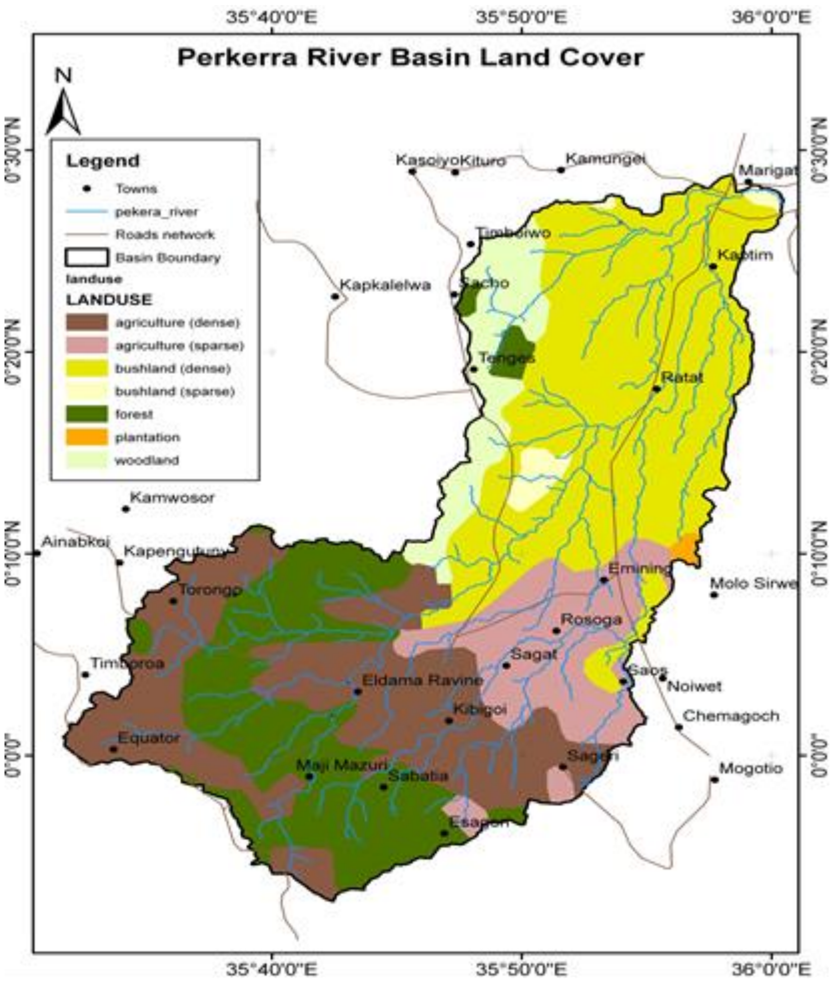
2.7.1 Vegetation

The major vegetation types in the catchment are forest 26%, evergreen and semi-deciduous bush land 37%, and deciduous and semi-deciduous bush land 37% (Onyando et al., 2005). In general the vegetation of the upstream of the project area consist mostly of woodlands in the hills and mountainous areas and dry woodland and bush lands in the lower areas such as Kimose. The project area has over 130 plant species spread in 50 families consisting of shrubs, herbs, climbers, grass, legumes, and orchids etc. which are used as source of food, shelter, animal fodder and human medicine. The main vegetation in the project area is acacia woodlands predominated with the Acacia commiphorra sp which is being lost due to deforestation induced by charcoal burning. Prosopis juliflora one of the world's worst invasive alien species according to the IUCN's list is found on the downstream of the project area mainly in Marigat. The invasive Cactus (***Opuntia stricta***), the medicinal ***Aloe turkanesis*** and the sisal plant were predominantly seen around Kimose and Radat sub-location.

The project area is predominately privately owned with pieces of government owned land but the County has conserved exotic and indigenous forests found in Kabarnet, Kabartonjo, Tenges, Lembus, Saimo, Sacho and Ol' Arabel and Eldama Ravine. The main exotic species grown are Grevellea Rabusta, Cuppressus lusitanic and Eucalyptus saligna. The forest closest to the project area is Tenges located upstream of the area and is still in its natural state

2.7.2 Land Use

River Pekerra is located in a heterogenous catchment with a fragile ecosystem with highlands with moderate climate and low lands with harsh climate. The project area is arid and semi-arid and the inhabitants of the Perkerra Catchment are pastoralist thus the land is mainly used as grazing land and for subsistence farming in the highlands as the climate there is conducive for crop growing. The farmers in the highlands practice conservation agriculture in order to reduce erosion but overstocking of livestock, deforestation which is evidently seen through charcoal burning is causing degradation of the catchment. Quarrying and sand harvesting is also starting to pick up in the area due to the increase in construction activities. The natural forest in the region are being exploited for timber, wood fuel and settlement



2.7.3 Wildlife

The project area especially Radat and Kimose forms part of the spatial corridor for Lake Baringo and Lake Bogoria National Game Reserve where the habitats of wild animals like the tortoise, hares, impala, rare kudu, antelope, hyenas, snakes are found. Other animals found in the lakes reserve are zebras, leopards, cheetahs, mongoose, monkeys, baboons, birds, hippopotamus (Hippopotamus amphibius), crocodile (Crocodylus niloticus), jackals and many other mammals, amphibians, reptiles and the invertebrate communities. Lake Baringo is home to about 500 species of birds and fauna, some of the migratory waterbird species being significant regionally and globally. The lake also provides an invaluable habitat for seven fresh water fish species one such species is Oreochromis niloticus baringoensis (Nile Tilapia) which is endemic to the lake. Additionally the area is a habitat for many species of animals including the.

During the study the tortoise and snakes were the most encountered animals though consultations with the community members and game wardens indicated that most animals come out in the evening when the temperature is cooler. Wild animals could be seen deep in the thickets under shades.

2.8 Water and Sanitation

The common source of domestic water in the area is the river (95.5%); Perkerra River was identified as the only all-weather river with other rivers being seasonal. The area is known to be a water deficit area with both for livestock and domestic use. The water quality is also low mainly due to high turbidity caused by high siltation. The project are has water surplus during the rainy season and acute deficit during the dry seasons due to the degraded environment and it is hoped that the development of the dam shall help restore the water problem and environmental damages.

2.9 Energy

Primary data from field survey shows that wood fuel is the main source of cooking energy in the entire project area standing at 94.7%. Further analysis shows that Kerosene (94.8%) was the main source of fuel for lighting for majority of respondents in the project area. Electrical power lines were seen to traverse the area but it is mainly supplied in the urban areas. The area has high solar energy potential which can be exploited during the project operation phase.

3 SOCIO ECONOMIC STUDY

3.1 Background Information

This section presents the socio-economic assessment, and current project socio-economic baseline situation formed through a combination of primary survey data, secondary data and stakeholder consultation. Knowledge of existing population, infrastructure (such as roads), available healthcare services and prevalent diseases, economic activity and literacy levels of the project area is essential to understanding project affected communities, potential benefits to recipient communities and likely challenges during project implementation.

3.1.1 Administrative Structures

The project areas are under administrative jurisdiction of respective decentralized local governments which function with autonomy to formulate development objectives and budgets in line with polices of the Central Government. This section briefly outlines the administrative structure of Kenya, particularly those administrative levels relevant to this Social Impact Assessment.

3.1.2 Location

The project area is under the administrative jurisdiction of Baringo County which according to the Constitution of Kenya has authority for Agriculture, Water and Irrigation which form some of the core objectives of the Project. In the project area, the Perkerra River forms the boundary between Baringo District/Sub County on the Northern bank and Mogotio District / Mogotio Sub County on the Southerly bank. In total five sub-locations spread across two administrative districts /sub counties of Baringo Central and Mogotio. The sub-locations affected are as follows: Kimose Sub-Location, cheberen Sub-Location and Radat Sub-Location in Mogotio District/Sub County while in Baringo Sub County Tinomoi Sub-Location and Tebei Sub-Location are affected. It is here noted that Tebei Sub-Location and Tinomoi Sub-Location, which are administratively in Baringo Central Sub County and politically in Marigat Sub County. Administrative areas are presented in table below.

Table 3:1: Project Area by Sub-county, District, Division, Ward, Location and Sub-Location

Serial	Sub County	District	Division	Ward	Location	Sub-Location
1	Mogotio	Mogotio	Kipngorom	Emining	Cheberen	Cheberen
2	Mogotio	Mogotio	Emining	Emining	Kimose	Kimose
3	Mogotio	Mogotio	Emining	Emining	Koibosoi	Radat
4	Baringo South	Baringo Central	Tenges	Marigat	Bekibon	Tinomoi
5	Baringo South	Baringo Central	Tenges	Marigat	Tuluongoi	Tebei

3.2 Demographics of the Proposed Project Area

Table 3:2: Project Area Population

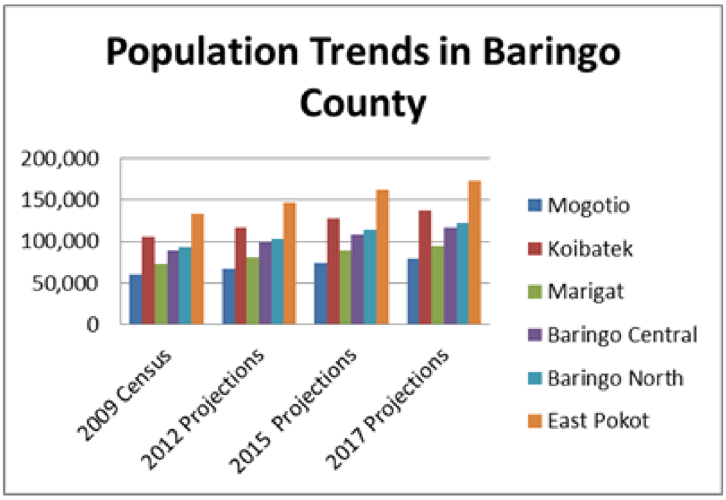
Serial	Sub-Location	Area in sq. km	Population in 2009 Census			Popn Density per sq. km	Estimated Population in 2014			Popn Density per sq. km
			Male	Female	Total		Male	Female	Total	
1.	Radat	78.39	948	1029	1,977	25.22	1133	1,230	2,363	33.97
2.	Kimose	35.7	664	683	1,347	37.73	794	816	1,610	45.09
3.	Cheberen	49.93	1,273	1,296	2,569	51.45	1521	1,549	3,070	61.49
4.	Tinomoi	49.95	621	627	1,248	24.99	742	749	1,491	29.85
5.	Tebei	30.93	468	439	907	29.32	559	525	1,084	35.05
	Total	244.9	3,974	4,074	8,048	32.86	4,749	4,869	9,618	39.27

Source: KNBS, *Population Census*, 2009

Table 3:3: Current and Projected Number of Households in the Project Area

Serial	Sub-Location	No of Household in 2009	Est. No. of Households in 2014
1	Radat	452	540
2.	Kimose	258	308
3.	Cheberen	480	574
4.	Tinomoi	240	287
5	Tebei	193	230
	Total	1,623	1,939

Overall, the total population of all 5 sub-locations to be affected by the proposed Radat Dam is estimated to be 9,618 people (up from 8,048 in the 2009 Census) Based on the expected potential social impacts, their extent and significance, proposed Radat Dam will affect property owners by way of land take, loss of structures, loss of crops, economic displacement in some cases and impact on community resources such as boreholes, schools, bridges and hospitals.



3.2.1 Sample Population

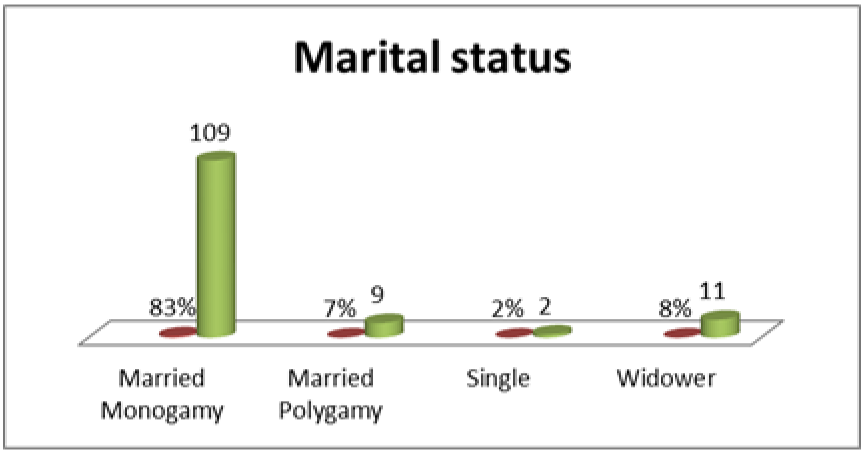
Out of the total 1,939 total households in the project area of 5 sub-locations, 150 households were purposively sampled, constituting 8% of the population. Each sub-location was allocation 30 households. Out of these, 14 households were non responsive, and 136 households responded, constituting 91% of the respondents. The average age of the respondent was 44 while the oldest respondent was 76 from Tebei Sub-Location while the youngest was a 22 year old from Tinomoi Sub-Location.

3.2.2 Sex of Respondents

From the field survey, it is evident that a large percentage of the household heads interviewed were male (88%) compared to female (12%) headed households. Further analysis shows that in the entire project affected locations male respondents were the majority compared to the female. This is because they own the land compared to the women. The ratio of males to females is 1:1, consistent with both the 2009 KNBS Census and the Baringo county CIDP.

3.2.3 Marital Status of the Respondents

With regard to marital status, most respondents were married at 90%, followed by widower or widowed at 8% and single at 2%, while none were divorced. Of the total population which declared itself married, 7% were in a polygamous marriage and 83% monogamous. In the entire project affected districts the widowed respondents were mainly female headed households compared to the male. Majority of the females who were widowed had lost their spouses as a result of natural causes.



3.2.4 Community Structure and Ethnicity

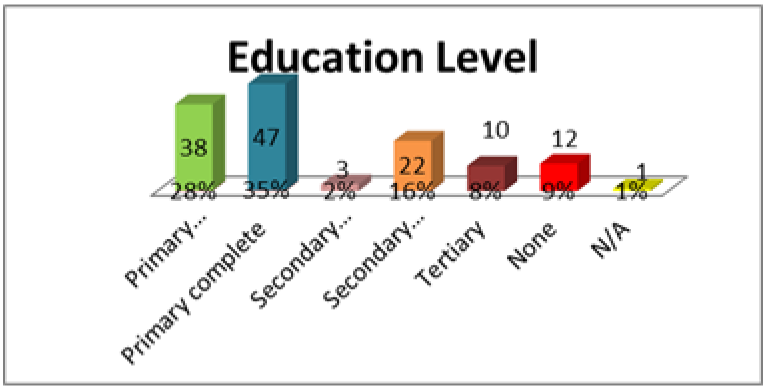
Ethnicity is one of the key considerations to be taken into account while designing social mitigation strategies. The general project area is peopled mainly by the Tugen Community, but with district sub-dialect variations across the five sub-locations. Radat Sub-location comprises mainly of the Eldorois sub tribe of the Kalenjin Community. The language predominantly spoken in the general project area is thus Tugen, with corresponding inflection to represent the sub dialects of Eldorois and Samor. Most residents speak Swahili and some communities such as Turkana, Kikuyu, Borana, Samburu, Luhya, Pokot have also been assimilated by marriage.

3.2.5 Migration

According to the respondents, 99% consider the project area as their ancestral home and have never moved to settle elsewhere. One percent (1%) of the population moved in to buy land especially near market centres of Kimose, Radat, Tinomoi, Tebei, and Cheberen. It was also revealed that a substantial number (at 70%) own pieces of land elsewhere in Baringo County.

3.2.6 Education

There are only primary and nursery schools located within the project areas. The secondary schools identified were very far away from the project area except for Cheberen Sub-Location. The nearest secondary schools were more than 5 km at the Northern Bank (Tebei and Tinomoi sub-locations) and around 2 km at Southern bank of Perkerra River (Radat and Kimose Sub-Location). During the field survey, only five primary schools were identified as being close to the project area in Tinomoi Sub-location while 10 schools were in Cheberen Sub-location. In the general area, day secondary schools were on average at least 5km from nearest homesteads. Thirty five percent (35%) of the house heads reported to have completed primary school, while 26% had incomplete primary education. Thus 61% of the population has only basic education at primary level and below.



3.2.7 Settlement Patterns

Generally the project area is semi-arid. The population is thus sparsely settled. Table 3:2 above shows that Cheberen has the highest population density at 62 people per square kilometer while Tinomoi is the least settled at 30 people per square kilometer. Indeed, three of the five sub-locations have population densities in the thirties. Kimose and Cheberen are the exception. The average population density is 40 people per square kilometer.

The Population density in Baringo County is 55 people per square km (source: Baringo County CIDP and the KNBS Census, 2009). The project area is thus considered sparse in Baringo County, which is itself considered sparsely settled by national standards. The distance from one household to the next is estimated at around 2 km.

3.2.8 Public Health

The entire project affected area has a sparse infusion of medical facilities. There is a dispensary in each of the sub Locations which are ill equipped. The most common ailments are malaria and hygiene related medical conditions such as cholera and typhoid. There is a notably high incidence of dental problems. This can be explained by the extremely low presence of pit latrines. Almost 90% of households have no pit latrines.

3.3 Leading Health Problems in the Project area

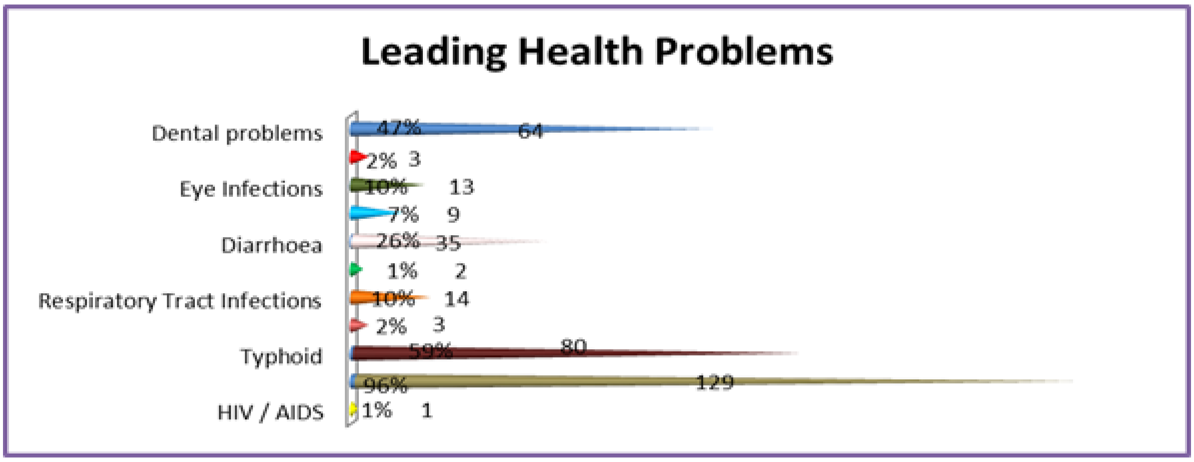


Table 3:4: Distance to the Nearest Health Facility in the Project Area

Distance (Km)	Total	Sub-Location				
		Cheberen	Tebei	Radat/Radat	Tinomoi	Kimose
Total	85	4	23	13	18	27
Mean	5	7	2	3	5	9
Range	18	6	4	4	13	17
Maximum	17	9	4	6	14	18
Minimum	1	3	1	2	1	1

Source: Field Survey Data.

As demonstrated in Table 3:4, Tebei and Cheberen have fairly near health facilities, while Tinomoi and Kimose have distant medical facilities. Respondents revealed that the average distance travelled to the nearest medical facility is 5km. The five Health Centres identified include, Radat Dispensary, Tebei Dispensary, Bekibon Health Centre, Emining Health Centre and Cheberen Dispensary. The health centres were adjudged to be not well stocked with medicines and staff. 80 % of the respondents felt that the medicines were often unavailable at the health facilities they frequented and they had to procure externally

Table 3:5: Cost of Medicine

	Total	Sub-Location				
		Cheberen	Tebei	Radat	Tinomoi	Kimose
Total	115	9	26	27	25	28
	100%	8%	23%	23%	22%	24%
Free	34	0	0	17	11	6
	30%	0%	0%	15%	10%	5%
Affordable	62	7	13	9	13	20
	54%	6%	11%	8%	11%	17%
Expensive	17	2	11	1	1	2
	15%	2%	10%	1%	1%	2%
Very Expensive	2	0	2	0	0	0
	2%	0%	2%	0%	0%	0%

Source: Primary data from field survey

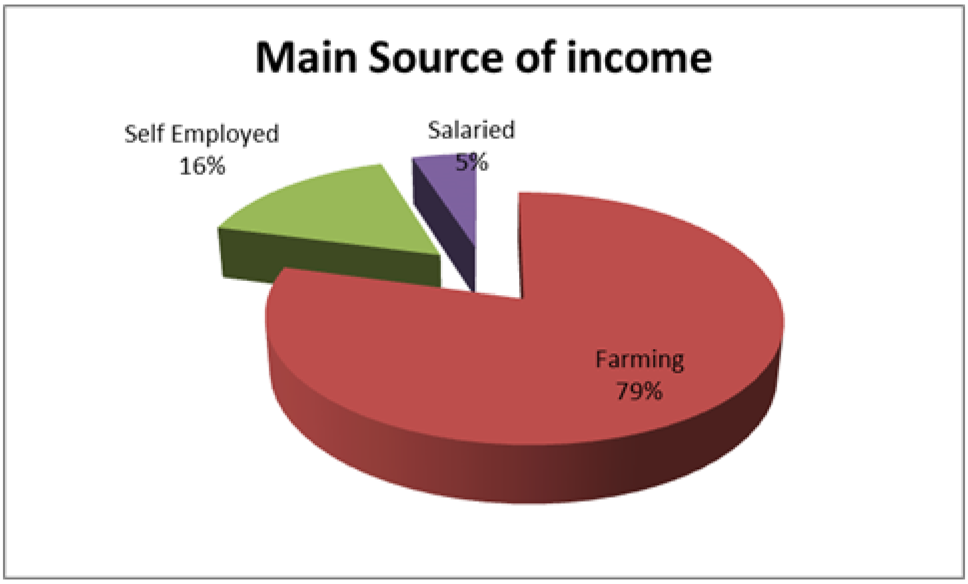
As shown in the figure above, 54% of respondents felt that the cost of medication was affordable. 69% of respondents felt that medication could be found at the private clinics and hospitals while 21% resorted to traditional medicine. With respect to HIV, only 22 % of respondents felt it was a serious problem while 43% did not know whether it was even a problem at all.

3.3.1 Gender Issues

The survey revealed that 12% of households in the project area were headed by women mainly widowed. During the FGDs, the participants demonstrated that women are not fully involved in decision making in the society. Land ownership and inheritance by women except through marriage is limited by culture and traditional practice. Men expressed willingness to bequeath land to their daughters but seemed hesitant to allow their sisters to inherit family land. Women who purchase land and property on their own were however not disallowed. It also emerged in the FGD's that women are disadvantaged in access to education. Given the hardship weather conditions, women face great hurdles accessing water, providing food for their children and access to health services.

3.3.2 Livelihoods and Occupation

The project area is a semi-arid and the main source livelihood is agro-pastoralist for the large part. The respondents indicated that 79% of their source of income is from agriculture.16% of the population are self-employed while only 5% are on salaried employment.



3.3.3 Employment Levels

As indicated, 5% of all incomes is earned from salaried employment. The total income from employment averages at Ksh. 333,652 amounting to Ksh 7,673,996; this constitutes 10% of the total household incomes. The most common salaried job is primary school teaching.

3.3.4 Income levels

As indicated above, agriculture constitutes 80% of household incomes. From the respondents, 22.06% of incomes derive from rain fed agriculture, while irrigated agriculture constitutes 5.04% while Fishing contributes 0.01% of incomes. Livestock contributes the greatest source of family income at 23.53%.Other sources of income are woodlots at 5.73% and fruit trees at 2.22%.Instructively, irrigated agriculture and fishing is anticipated to go up when Radat Dam is fully constructed.

Subsistence farming is the principal source of livelihood and majorly within the areas surveyed. Respondents reported growing a variety of crops ranging from food crops like maize, rice, sweet potatoes, beans, cassava and ground nuts both for food and for sale. Given the mixed nature of agriculture in the project area, majority of the households were found to be growing different kinds of crops and also rearing animals in some cases. Maize was the most highly grown crop among household (26%), sweet potatoes (21%), groundnuts (25%), cassava (20%), and beans. The above mentioned crops doubled as both cash and food crops.

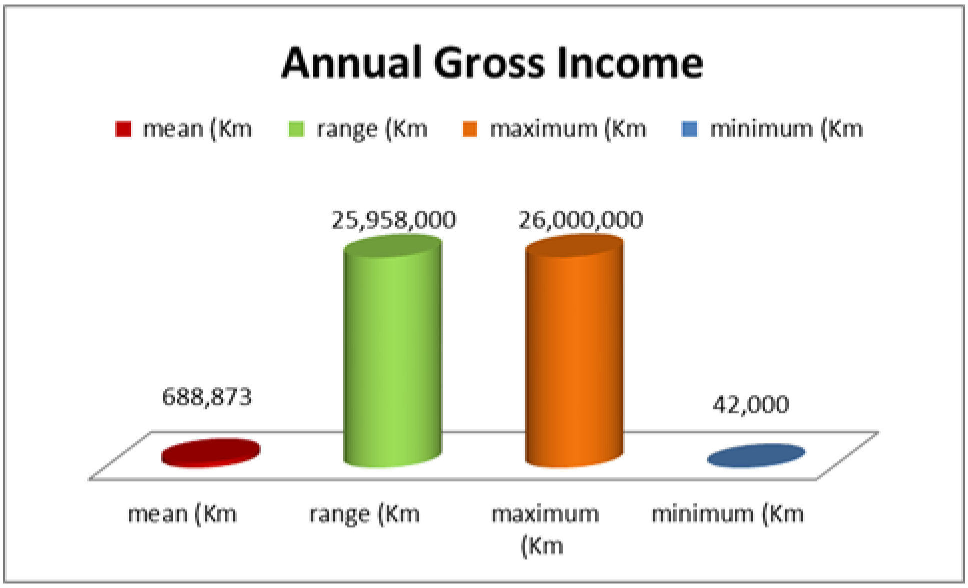
More to this respondents reported planting a variety of trees on their land. Trees are planted for a wide range of reasons including: to demarcate plots; provide shade and windbreaks; to provide a source of fuel and building materials; to produce fruit for sale and household consumption; to provide fodder; for herbal or traditional medicine, and, to improve soil moisture and fertility. The main fruit trees are jackfruit, avocado, mango, oranges and pawpaw.

Livestock farming is also a major farming practiced within the project area but done on a large scale with most households keeping not less than 5 cows, goats and poultry .Entrepreneurs contribute 8.27% to the household income, while other miscellaneous sources of income contribute 5%.

Respondents revealed that income from agricultural produce is used for procurement of domestic requirements such as sugar, salt, and soap. More to this the income earned helps to finance education for their children as well as access to healthcare services.

Table 3:6: Annual Gross Income

	Total	Sub-Location				
		Cheberen	Tebei	Radat	Tinomoi	Kimose
Total	136	27	26	27	26	30
mean (Ksh)	688,873	1,651,259	673,154	667,030	257,323	230,017
range (Ksh)	25,958,000	25,870,000	2,300,000	4,454,000	899,000	1,611,000
maximum (Ksh)	26,000,000	26,000,000	2,370,000	4,505,000	941,000	1,661,000
minimum (Ksh)	42,000	130,000	70,000	51,000	42,000	50,000



3.3.5 Business and Economic Activity in the Market Centers in the Project Area

This study involved taking a census of business infrastructure in the market centres around the proposed Radat Dam. The centres considered are: Radat, Tinomoi, Tebei, Cheberen and Kimose. Each centre bears the name of the sub-location.

Table 3:7: Business Activities Now Present at the Market Centres

Serial	Business Enterprise	Radat	Kimose	Tinomoi	Tebei	Cheberen	Total
1	Retail shops	10	12	08	20	12	62
2.	Wholesale shops	-	-	-	-	-	-
3.	Grain shops	1	-	3	6	1	11
4.	Agric Input Stores	-	-	1	-	1	2
5.	Butcheries/ meat shops	2	1	2	3	2	10
6.	Eateries/ restaurants	1	1	3	3	5	13
7.	Bars/ Pubs	-	3	-	1	2	6
8.	Hotels/ Guest Houses	-	2	-	-	1	3
9.	Chemists	-	-	-	-	1	1
12	Rental/ Residential Premises	6	8	4	10	10	38
13	Tailoring/ Dressmaking	2	5	2	2	5	16
14	Posho Mills	3	3	3	7	5	21
15	Clothes Shop	1	2	3	2	3	11
16	ICT/MPESA	-	1	-	-	2	3
17	Barbershop	1	1	1	1	2	6
18	Salon	1	1	1	1	2	6
19	Informal Business	2	2	3	3	3	13
20	Dobi / Laundry	-	-	1	-	-	1
21	Bookshops/ Stationers	-	-	2	-	2	4
22	Private School	-	-	-	-	1	1
23	Process Industry	-	-	-	-	1	1

3.3.6 Prices of Basic Commodities

The most common produce around the project area are, milk, beans, ground nuts, honey, millet, sorghum, soyabeans, livestock. (goats and zebu cattle) and some maize. From Radat the main market of produce is Marigat. For Kimose, the main market is either Marigat or Emining. Tebei and Cheberen take their produce to Tenges and Emining, while Tinomoi considers mainly Marigat as the main market.

Table 3:8: The Average Price of Basic Commodities

Serial	Commodity	Unit of measure	Av Price at Local Market in Ksh	Av. Price at External Market in Ksh
1	Milk	litre	40	65
2	Groundnuts	kg	100	200
3	Millet	kg	70	150
4	Honey	Litre	250	500
5	Sorghum	kg	100	250
6	Maize	2kg tin	100	200
8	Goat	units	3,000	5,500
9	Zebu Cow	unit	15,000	30,000
10	Goat Meat	kg	360	450

3.4 Sand mining and Stone quarrying

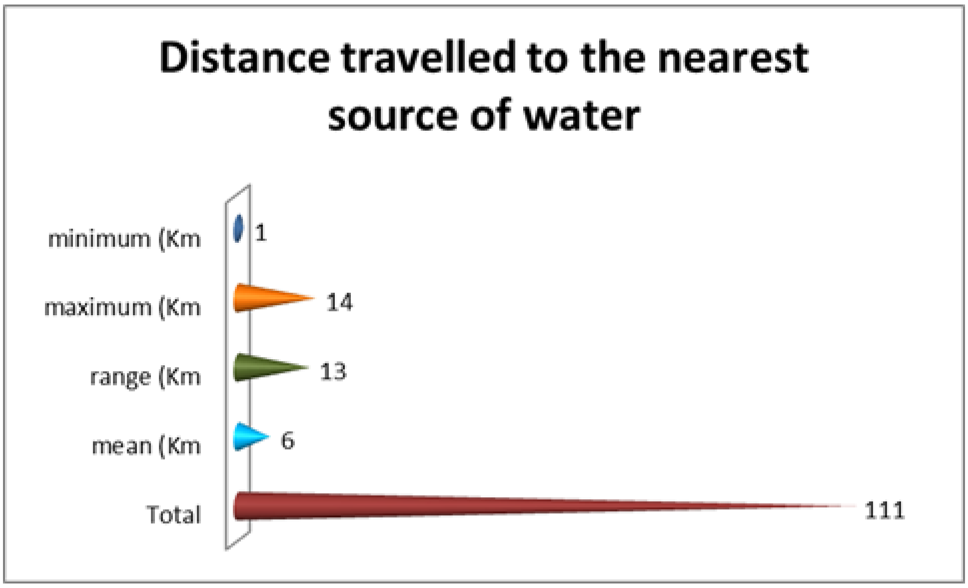
Sand mining and stone quarrying is also identified a source of livelihood in the project area. Salt licks are also leased out to livestock farmers within the quarry. The potential for sand harvesting and quarrying has yet to be attained. During field survey, some respondents especially those who are into mining business reported that it is a profitable business which has attracted both men and youth who have opted dropping out of school. On the banks of river Perkerra both in Radat and Tinomoi Sub-location, in Mogotio and Baringo Central districts respectively, children usually descend in the middle of the waters, scoop the sand which they transport and sell for Ksh 1000 per tonne. Most of the sand mined is sold to contractors and individuals who use it for construction works.

3.5 Communication and Infrastructure

Access to social services and infrastructure are some of the indicators of wealth, poverty and vulnerability. Access to services measured include, water and sanitation, roads and energy sources. These are explained below.

3.5.1 Water and sanitation

The common source of domestic water was the river (95.5%). Perkerra Dam was identified as the only all-weather river with other rivers being seasonal. The average distance travelled to get water during the rainy season is 2km and during the dry season is 6km. . According to women interviewed during focus group discussions, majority revealed using water from the river for bathing, drinking, cooking food and washing clothes. During the survey is was observed that some men bathed at the rivers whereas women carried water on their heads from the rivers to their homes for domestic use such for their husbands to bath, cooking, bathing small children and washing utensils. Many children also go to the rivers to collect water and to swim/bath. Most women wash cloths from the rivers to reduce water collecting trips they have to make. Some even wash utensils from there.



The respondents felt at 51% that the water sources were both inadequate and not sufficiently available. The quality was also found to be dubious, according to the FGDs, the water available was not safe and was often polluted

Energy

Primary data from field survey shows that wood fuel is the main source of cooking in the entire project affected area standing at 94.7%. Further analysis shows that Kerosene (94.8%) was the main source of fuel for lighting for majority of respondents in the project area.

3.5.2 Transportation and road access to the site

For most of the project area there are no paved roads. Only 4wheel drive vehicles can access the site. The Marigat – Nakuru road and the Emining – Tenges roads are tarmacked but they are all on the boundaries of the project area. Consequently the main mode of transport is motorcycle bodaboda. A few people use donkeys to transport goods. Nevertheless since there are hardly any local access roads to the site, implementation of the project will require construction of new roads and tracks to provide the access to the dam site, as well as to the temporary facilities such as cofferdams, quarries, batching and crushing plants, stockpiles, workshops and others.

3.5.3 Land ownership and Use

Land ownership in the project area is through title deeds held by the owners. All the land in the five sub Locations has been adjudicated and most owners have title. Even those who do not have physical title deeds, the leadership (Chiefs, Members of the County Assemblies and Registrar of lands) assured that all that the titles are available for collection. As indicated earlier land is used mainly for agro pastoralism. Zebu cattle, goats and donkeys are reared. Subsistence farming is also carried out. There is a lot of bee keeping across the entire project area. Honey and other wood lots constitute 6% of annual income and there is some commercial quarrying and sand harvesting at the shores of River Perkerra.

3.5.4 Vulnerable groups

The vulnerable groups in the project area were identified as the elderly widowed, and persons with physical disabilities. People living with HIV/AIDS also qualify to be categorized as a vulnerable group due to the stigma associated with the disease and discrimination, but due to lack of availability of data on them, they have not been included in this study.

3.6 Cultural Property

Cultural resources to be affected were noted to be circumcision shrines and caves mainly for historical reasons. Kolumkel in Tinomoi,Caves at Kaptolgugun,and others in Kipng'eke and Kabarbarma were some of the traditional sites. It is notable that due to the influence of the church most of these sites only has cultural and no spiritual value to the community. All these sites are found along the Perkerra River. They were observed to mainly tourist attraction

4 HYDROLOGICAL STUDIES

The hydrology of the river basin is essential in planning and design of proposed dam on the river. It is the river flows, its normal seasonal variations as well as its extreme flow events that determine the reservoir capacity, the size and type of the dam and the feasibility of the project. The hydrological study will estimate the river flows; minimum, normal and flood flows to allow optimization of the dam design.

The basis of the hydrologic study is the available hydro-meteorological data. Historical river flow data will form the primary data to be complimented by rainfall records when data is sparse. Rainfall data is modelled to convert to river flows.

4.1 Dam sites

The four identified dam sites are on Perkera River and its tributaries in the middle Perkera river catchment. This hydrological study of the dam sites, seeks to evaluate the water availability to fill the proposed dam development project and to provide adequate water for the proposed irrigation project. Table 4.1 below shows the site location and the catchment sizes at the sites.

Table 4:1 Dam sites – location and catchment areas

Dam site	**River**	**Dam catchment area (Km^2)**
Radat	Perkera	1,061.1
Kaplelwo	Perkera/Ainopno	1,148.7
Kopokaplelach	Kapuchara	40.8
Kapng'etuny	Ainopno	143.4

4.2 Perkerra River Basin

The river Perkera and its tributaries form the Perkera River basin which originates from Maji Mazuri ,Timboroa, Lembus, Chemorogok and Metkei forests. The Perkera irrigation scheme falls within the area drained by the Perkera River and its tributaries with a catchment area of about 1,411 km^2. The river basin falls under the Rift valley drainage basin 2E, Kerio Valley sub-basin in the Rift Valley basin. Perkerra borders Molo river basin to the west and to east by Tapuchara river basin, which joins Perkera River at Marigati to form the Tigeri river basin. The table below shows the characteristic of the three sub basins forming the Perkerra river basin.

Table 4:2 Basins details

Name of river	River sub-basins	Catchment area (Km^2)	Length (km)
Eldama/ Perkera	2ED	421	23
Emining	2EF	389	50
Perkera	2EE	601	80
Total		**1,411**	**103**

The proposed Radat dam is located in Radat area in Baringo County in the Northern parts of former Rift Valley province. In terms of drainage, the scheme is within Emining sub-basin in the Perkera river catchment, in drainage area 2, the rift valley drainage basin of Kenya.

The largest single drainage system in the project area is formed by the Perkera River and its tributaries from upstream to downstream. The river Perkera catchment can be divided into five sub catchments as follows.

River Perkera Sub – Catchment: this main catchment and it drains the eastern parts of the basin. The main rivers tributaries include, Kureswa, Magirip, Kirer, Kipsarita, Perkera, Eldama ravine and Kabiet. The main rivers originate from within the Kibimjor ranges from Sekenwo, Sana and Mtarakwa forests, Perkera river drains the central parts of the basin,

River Emining Sub – Catchment: this system drains the Western parts of the basin, the main river tributaries are Narosura, which originates from Mochongoi forest, Esageri , which originates from Kilombe forest and Kipkura , which originates from Kibimoi area and Isanda, which originates from Londian forest. The Emining River enters the Perkera River at Tiggoi area.

River Ainapno Sub – Catchment: this system drains the Western parts of the basin, the main river tributaries are Cheberena, which originates from Chemoge area, and chebsaita, Kibigechi all of which originates from Mukobe forest, there is no gauging station in this sub catchment.

River Lelgel Sub – Catchment: this system drains the Western parts of the basin, the main river tributaries are Chelelach bei, which originates from Maji Mazuri forest, Leigel, which originates from lembus forest and enters Perkera at siloi area.

River Chemususu Sub – Catchment: this system drains the Western parts of the basin, the main river tributaries are Chemusus, Kaplakawa and Tuigoin, Toronga and Markisis, all of which originates from the lembus forest, it enters the Perkera system at Kapchotoi area, there is no river gauging in this sub-catchment.

4.3 Characteristics of the Perkera river basin

The primary watershed characteristics governing stream flow can be divided into four categories: (i) **Precipitation** characteristics and basin area (ii) characteristics that affect hydrologic abstractions and runoff volumes such as land use and vegetation (land cover), soils, and antecedent moisture conditions (iii) topographic characteristics that affect runoff response time, such as watershed shape, drainage pattern, watershed slope, and stream channel slope and (iv) characteristics that affect the subsurface base flow, such as soils, soil moisture, vegetation, channel bed materials, stream channel length, geology and groundwater table. These characteristics affect different aspects of stream flow hydrograph and therefore need to mention briefly in the study. The characteristics of the Perkera river basin are as follows:

4.3.1 Topography and size

The Perkera basin is characterized by undulating terrain with highlands intersected by several valleys. The scheme area is part of the central Rift Valley area and escarpments occur in the East and West. In the upper areas of Emining catchment, some extinct volcanoes rise sharply over the surrounding plateaus such as the Kibimjor range, Tachasis escarpment, Kimata range, Mukobe range. The land slopes from about 3011 m a.s.l to 1000 m,a.s.l figure 4.1. The topography has a direct influence on surface runoff for the Radat, Kaplelwo, Kopokaplelach and Kapng'etuny dam sites.

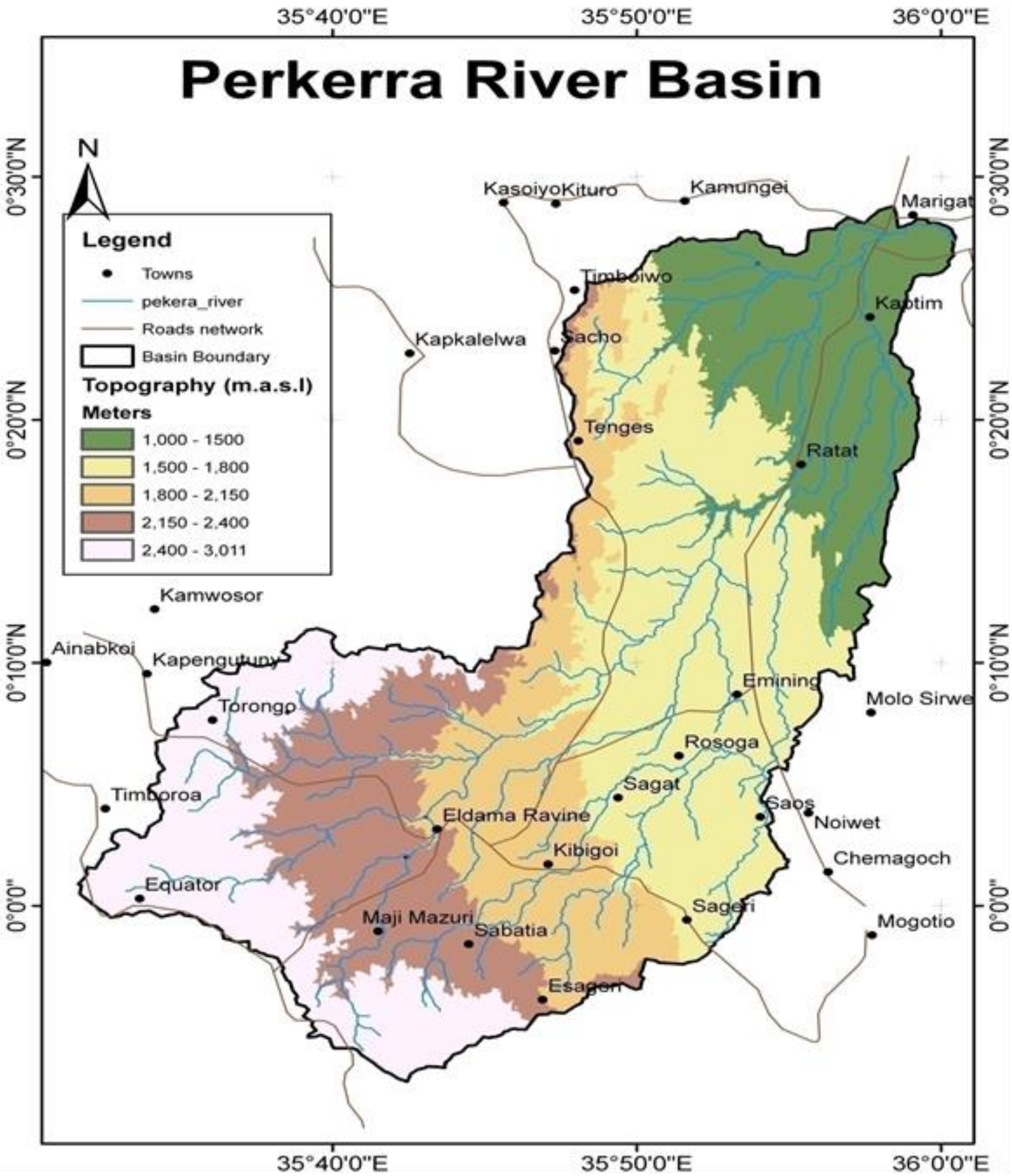


Figure 4:1 The Perkera River basin

4.3.2 Vegetation and Land Cover

Vegetation affects the hydrologic abstractions and runoff volumes through canopy interception, evaporation and evapotranspiration dynamics. The vegetation in the Perkera basin varies from the source areas to downstream as follows: highlands are covered by forest cover has been categorized into: plantation and indigenous, followed by grassland and bush land. Most of the forests are Gazzeted forests and only a few are not. The main exotic tree species found include Cypress, Eucalyptus and Pinus, while Podo, Cedar, Oleafricana and Waibugia are the main indigenous species. The vegetation of the basin was initially of savanna type, but now it is dominated by grassland with scattered forest stands of trees of herbs, shrubs acacia of woody vegetation complex. The plains are dominated by swamp vegetation and acacia of various species. The intense land use has reduced the original wood land to small patches, heavily covered by grassland and bushland, see plates 4.1- 4.3. The ground cover, together the soils influence the infiltration processes and subsequent runoff coefficient and surface runoff.


Plate 4.1: The Radat dam site and catchment area, note sediment deposits on the river bed and high water turbidity due to catchment degradation.	**Plate 4.2:** The Kopokaplelach dam site on Kapuchara river


Plate 4.3: Kapng'etuny dam catchment on Ainpno River	Plate 4.4:Kapang'etuny dam site and catchment area

4.3.3 Agro ecological and Land use

Land use and land cover affects the runoff characteristic of the basin, the land treatment practices, affect infiltration processes and therefore affects groundwater. The modification of land surface by the various land uses have varying effects on the runoff characteristics of a given drainage area, as it affects the hydrologic abstractions and runoff volumes. The land uses change from upstream to downstream as the ecological conditions change. The Perkera basin falls within three agro-ecological zones and the sequence is as follows: The project area basin falls within the Sunflower-Maize zone.

4.3.4 Climate of the Project Area

Climate is often considered the driving factor for stream flow, and it is spatially and seasonally variable in the Emining catchment in the Perkera River basin. The climate of the project area is heavily influenced by its geographical location and altitude. It varies with from upstream to downstream as follows:

Rainfall upstream areas: The mean annual rainfall is 1241 mm, with 60 % of 1112 mm reliability at Maji mazuri forest station at an altitude of 2331 m a.s.l. The lowest monthly rainfall here is 41 mm in January and the highest is 201 mm in April, see figure 4.2.

Rainfall Midstream: The mean annual rainfall is 652 mm, with 60% reliability of 598 mm at Perkera irrigation scheme at an altitude of 1066 m a.s.l. The lowest monthly is 41 mm in January and the highest is 86 mm in August. Rainfall downstream: The mean annual rainfall is 584 mm, with 60 % reliability of 467 mm at Nginyang health centre. The lowest monthly rainfall is mm in January and the highest is 64 mm in May.

The physical characteristics of the sites are more less the same, especially the topography, geology, soils and ground cover; these are the parameters which influence the runoff coefficient and therefore surface runoff.

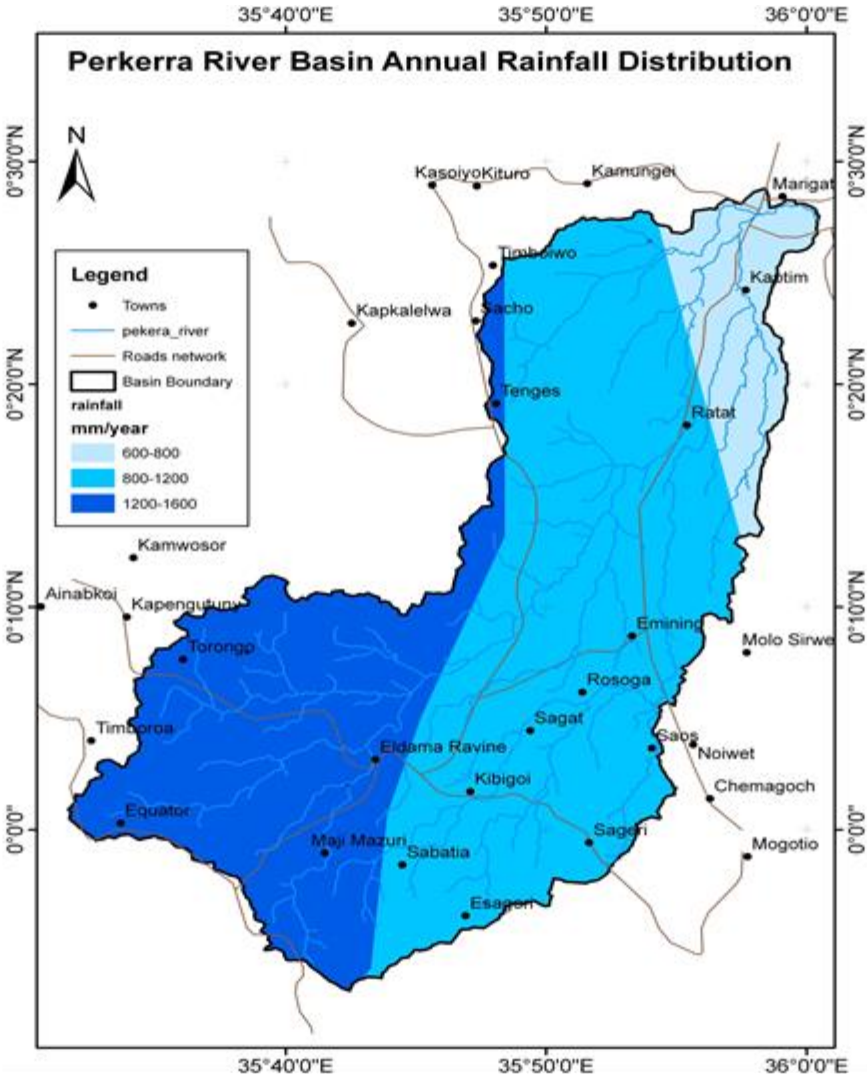


Figure 4:2 Rainfall distributions in the Perkera basin

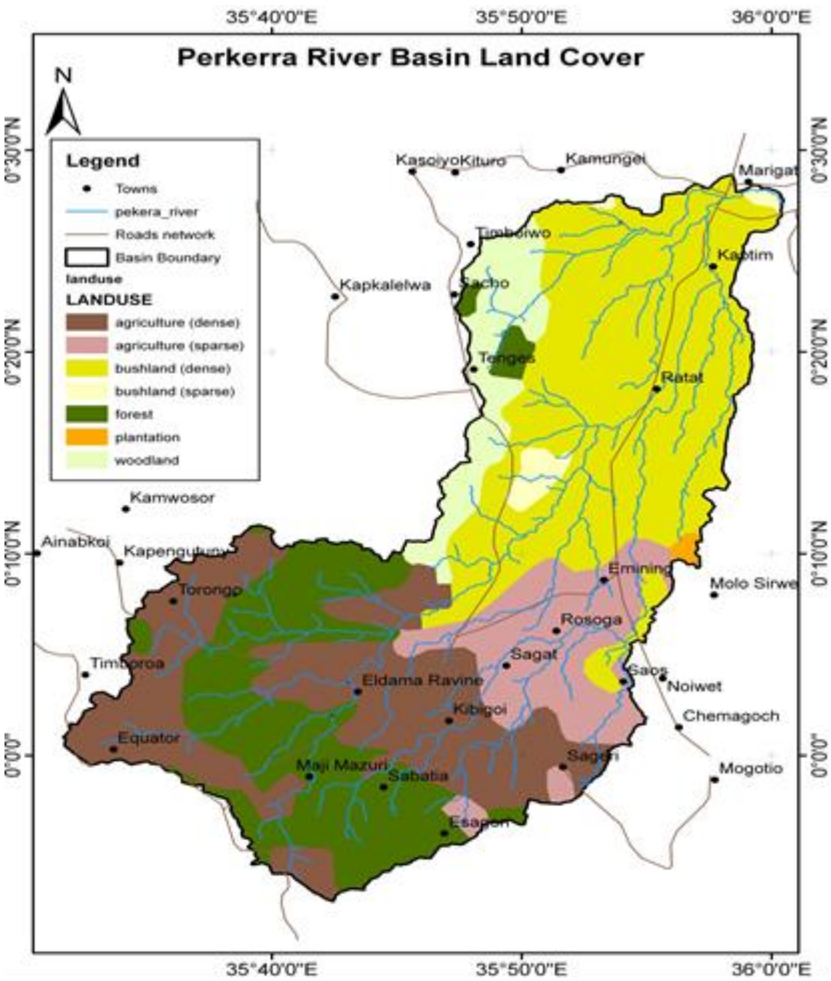


Figure 4:3 Perkera catchment land cover map

Rainfall and Temperature

Rainfall distribution in the project area exhibits a bimodal pattern, long rains in the months of March- April and short rains in June-August. April is the wettest month during the long rains and July during the short rains period, see tables 4.3 and figure 4.4 for Perkera scheme station.

Table 4:3 Mean monthly rainfall (mm) at Perkera station

Month	J	F	M	A	M	J	J	A	S	O	N	D
Mean	23.7	24.1	43.5	91.3	67.7	59.1	88.3	71.9	29.7	39.9	41.2	22.1
Minimum	0.0	0.0	0.0	16.0	6.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0

Temperatures: The temperatures at Perkera irrigation scheme are as follows: mean maximum temperature ranges between 30.3 °c in July and 33.7°c, February, the mean minimum temperature ranges between 16.2 °c in January and 18°c in April, the mean annual temperature ranges between 23.5°c in August and 25.7 °c – 22°c, table 4.4. Absolute temperature ranges between 10.2°c in June and December to 14.9 of in April, see table 4.4. Evaporation is very high ranging between 2100-2300 mm due low 35 % relative humidity.

Table 4:4 Temperature Perkera irrigation scheme

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Mean. Max	33.2	33.7	33.6	32.6	32.4	32.0	30.3	31.0	33.1	32.9	31.3	31.4	32.3
Mean. Temp	24.7	25.3	25.7	25.3	24.8	24.1	23.7	23.5	24.4	24.8	24.2	23.9	24.5
Mean. Min	16.2	17.0	17.8	18.0	17.2	16.3	17.1	16.1	15.7	16.8	17.2	16.5	16.8
Abs. Min	11.3	10.9	12.5	14.9	13.4	10.2	12.5	11.7	12.1	12.9	12.1	10.2	10.2

4.4 Rainfall Analysis

The purpose of rainfall data collection portion of the hydrological study of the project; was to collect all the available data for parameter that significantly affect stream flows in the basin. Historical rainfall conditions are the best guide to future stream flow conditions in the basin. Because historical data will form the primary basis for predicting future stream flows, in the basin, the rainfall data collection effort was one of the most important steps in completing the hydrological analysis for the project.

To achieve these, data on all seven climatic parameters (rainfall, evaporation, humidity, temperature, sun shine hours, wind, radiation,) were collected. The collected data was then organized, processed and analysed.

4.4.1 Rainfall data source

The climatological evaluation was based on three rainfall stations, namely Perkera scheme, Marigati, and Baringo farmers training centre (BFTC), see table 4.5.

Table 4:5 Meteorological stations within the project area

Station name	code	Type of station	Elevation (m)
Perkera irrigation	8935163	Full met	1148
Marigati station	8936053	Full met	1000
Baringo F.T.C	8935193	Rainfall	2099

4.4.2 Supplementing of Missing Rainfall Data

The purpose of this task was to use the collected data and reliable data years, to fill in the gap so as to as to develop continuous and consistent records of all parameters needed to estimate the present and future stream flows in the basin. Accurate rainfall analysis requires complete and consistent rainfall data at all critical points in the basins.

4.4.3 Analysis of Areal Rainfall

The rainfall obtained for particular stations relates to point rainfall. For runoff prediction purposes, the catchment averaged rainfall is required. This will be less than point rainfall; and it reduces as the catchment area increases. The catchment average rainfall can be determined from the point rainfall by applying an area reduction factor or multiplier factor. The Transport and Road Research laboratory (TRRL) gives a reduction factor formula which was used in this case as follows:

$$ARF = 1 - 0.044A^{0.275}$$

A is the catchment area in km2 = 1,181 Perkera EE07 km2

ARF = (the reduction factor or multiplier factor).

From table 4.6, the mean annual rainfall at, Perkera and Baringo F.T.C stations is 1,295.8 mm and 452.64 respectively .

Table 4:6 Mean monthly rainfall in the project area

Met Station/Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Baringo F.T.C	58.90	72.20	115.90	152.90	296.50	132.70
Perkera Agricultural research station	24.84	18.63	38.64	52.44	53.82	38.64
Met Station	Jul	Aug	Sep	Oct	Nov	Dec
Baringo F.T.C	94.80	64.35	68.05	77.40	81.80	80.30
Perkera Agricultural research station	62.10	58.65	25.53	25.53	31.74	23.46

4.4.4 Temporal Distribution of Rainfall

The rainfall analysis is based on actual storms although even design storms can be used, storms differ in a number of characteristics which have a significant effect on the hydrological design. The major characteristics are intensity, duration, volume and frequency which are all interdependent. Rainfall distribution in the project area exhibits a bimodal pattern, long rains in the months of March- April and short rains in June-August. April is the wettest month during the long rains and July during the short rains period, see figure 4.5 for Perkera Agricultural research station.

The rainfall distribution in the upstream parts of the catchment is represented by the Baringo F.T.C, figure 4.6, note the bimodal nature of the distribution, with a single peak in May.

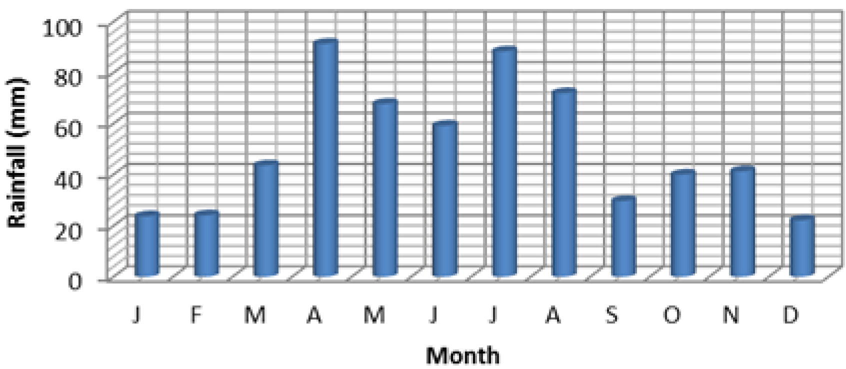


Figure 4:4 Mean monthly rainfall at Perkera Agricultural research station

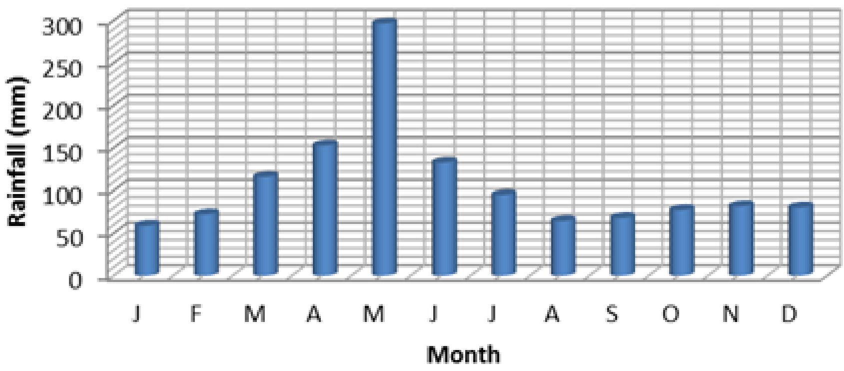


Figure 4:5 Mean monthly rainfall at Baringo F.T.C

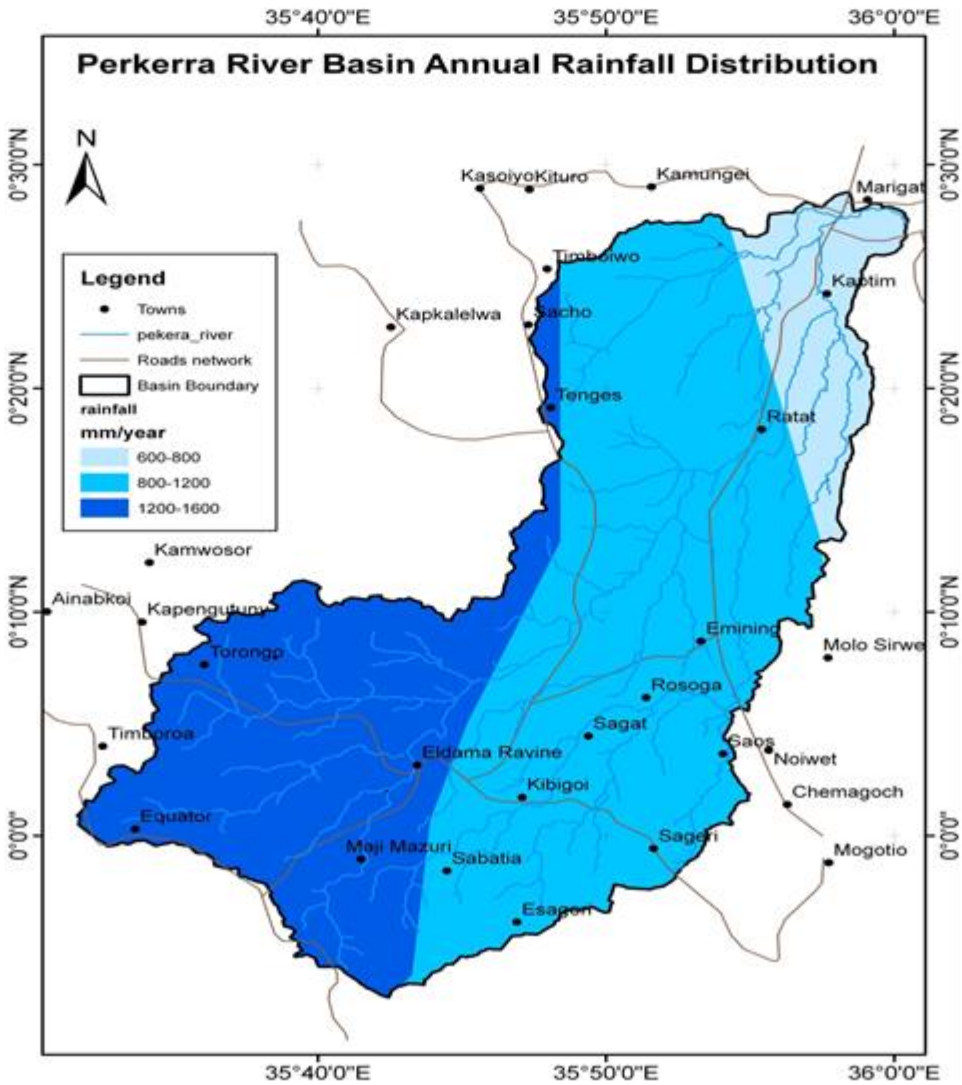


Figure 4:6 Mean annual rainfall spatial distribution in the Perkera basin

4.4.5 The Other Climatic Variables in the Basin

Apart from rainfall, the other climatic parameters are equally important, are as shown in table 4.7 and 4.8.

Table 4:7 Other climatic data for Perkera irrigation scheme (altitude 1148 m)

	Temperature (degree)				Relative humidity (%)						
Month	Daily max	Daily min	Extreme high	Extreme low	Daily max	Daily min	Daily Sunshine (hrs)	Daily wind Run(km)	Monthly Evaporation (mm)	Monthly Mean rainfall (mm)	No. of rainy days
J	33.2	16.3	36.7	10.5	54	31	9.8	73.2	238	36	4
F	34	17	38.1	10.6	53	30	10.0	75.5	233	27	4
M	34	17.6	37.7	10.5	56	32	9.6	76.8	259	56	6
A	33.1	17.8	37.2	13.1	65	39	8.4	67.1	202	76	10
M	32.5	17	36.7	13.0	63	40	9.0	61.9	199	78	9
J	32.2	16.4	35.8	10.2	61	37	9.5	60.0	193	56	7
J	30.4	16.7	34.6	11.0	68	43	8.6	57.9	180	90	9
A	31.1	15.9	35.1	11.0	68	41	8.9	59.9	188	85	10
S	33	15.6	37.3	10.2	58	34	9.4	67.1	216	37	5
O	33.2	16.4	36.7	11.9	55	34	9.0	69.8	227	37	9
N	31.7	17.1	39	11.8	61	39	7.9	67.4	196	46	7
D	32.1	16.4	36.1	10.2	55	37	8.4	70.8	228	34	4
Total	**390.5**	**200.2**	**441.**	**134.0**	**717**	**437**	**108.5**	**807.4**	**2559**	**656**	**84**
Max	**34**	**17.8**	**39**	**13.1**	**68**	**43**	**10.0**	**76.8**	**259**	**90**	**10**
Min	**30.4**	**15.6**	**34.6**	**10.2**	**53**	**30**	**7.9**	**57.9**	**180**	**27**	**4**
Ave	**32.5**	**16.7**	**36.8**	**11.2**	**59**	**36**	**9.0**	**67.3**	**213**	**54**	**7**

Source: Climatological Handbook, KMD

Table 4:8 Climatic data for Marigat Met Station

Station: Marigat				**Altitude:** 1000 m			**Position:** 36.03 S, 0.5 E	
Month	Min Temp [°C]	Max Temp [°C]	Humidity [%]	Wind [km/day]	Sun [hours]	Rad [MJ/m²/day]	ETo [mm/day]	Rain [mm]
January	16.5	33.1	48.45	120.86	10.36	24.64	5.12	48
February	17.0	33.6	46.75	120.6	10.24	25.31	5.45	20
March	18.0	33.8	50.35	120.6	9.57	24.56	5.41	57
April	18.5	32.2	57.11	112.32	8.66	22.47	4.82	64
May	17.0	32.6	59.21	103.68	9.86	23.05	4.67	83
June	16.0	32.0	55.7	112.32	9.93	22.34	4.51	39
July	17.0	30.0	60.48	103.68	8.56	20.64	4.17	77
August	16.0	30.8	59.28	103.68	9.21	22.64	4.48	87
September	15.60	32.5	52.91	112.22	9.81	24.48	4.97	38
October	16.80	33.0	53.15	112.32.	9.12	23.51	4.98	33
November	17.3	31.7	55.11	120.96	8.59	22.09	4.74	50
December	15.8	32.5	54.68	112.32	9.13	22.43	4.63	56
Average							**4.83**	**54.33**
Totals							**57.9**	**652**

Source: FAO CLIMWAT Database

4.4.6 Areal Probabilistic Rainfall

The rainfall frequency for the project area depends on the season. It is high during the long rains and low during the short rains season. The rainfall duration also follows the same trend as the frequency, and all of these influence the availability of water supply. Rainfall and runoff are correlated as the amount of rainfall affects runoff as indicated by hydrograph trends, but watershed and channel processes affect the transformation of rainfall to runoff.

Design rainfall is defined as the total amount of rain during the cropping season at which or above which the catchment area will provide sufficient runoff to satisfy the crop water requirements. If the actual rainfall in the cropping season is below the design rainfall, there will be moisture stress in the plants; if the actual rainfall exceeds the design rainfall, there will be surplus runoff which may result in damage to the structures. The design rainfall is usually assigned to a certain probability of occurrence or exceedance, see table 4.9.

Table 4:9 Design rainfall in the project areas based on Perkera station

Probability (%) of exceedance	Rainfall amounts (mm)	Dam site			
	Perkera station	Radat	Kaplelwo	Kopokaplelach	Kapng'etuny
95	3.7	3.33	3.59	0.11	0.44
90	8.6	7.74	8.34	0.26	1.03
80	14.6	13.14	14.16	0.44	1.75
75	**19.2**	**17.28**	**18.62**	**0.58**	**2.30**
60	34.9	31.41	33.85	1.05	4.19
50	44.0	39.6	42.68	1.32	5.28
40	58.0	52.2	56.26	1.74	6.96
30	73.4	66.06	71.20	2.20	8.81
20	99.8	89.82	96.81	2.99	11.98
10	131.8	118.62	127.85	3.95	15.82
5	165.7	149.13	160.73	4.97	19.88

From table 4.9, the monthly design rainfall (75%) exceedance rainfall is 19.2 mm for Perkera station ,17.28 mm for Radat,18.62 mm for Kaplelwo,0.58 mm for Kopokaplelach and 2.30 mm for Kapng;etuny dam site.

4.4.7 Estimation of PMP

The probable maximum precipitation is defined as the greatest or extreme rainfall for a given duration that is physically possible over a station or basin. From the operational point of view, PMP can be defined as that rainfall over a basin which would produce a flood flow with virtually no risk of being exceeded.

There are two approaches for estimating the PMP: The first approach uses the maximization and transposition of real or model storms which requires a large amount of data, a situation not obtainable in the Perkera River catchment. However the PMP for any part of Kenya can be obtained from PMP Isohyetal map of probable maximum precipitation, Obasi and Nimira, 1977), and for Perkera basin, it was estimated to be 200 mm.

The second approach utilizes the statistical analysis of the extreme rainfall. In the statistical approach, the annual series of the observed maximum rainfall depths for given duration are analysed to yield the mean and standard deviation. PMP is then expressed as the mean of the series plus K times the standard deviation. This is the approach to be taken to estimate the PMP for Radat dam catchment utilizing 24-hour duration.

The PMP equation is of the form:

$$\mathbf{PMP = \hat{Y} + K \times S_Y}$$

Where,

$\hat{Y}$ – The mean of the 24hour maximum annual rainfall

K – A constant equal to 15 for highland areas *(The study on the National Water Master Plan, 1992)*

S_Y- Standard deviation of the maximum annual depths for the 24 hour duration,

4.4.8 Runoff analysis

The amount of water harvested from the catchment area is a function of the amount of runoff created by the rainfall on the area. This runoff, for a defined time scale, is calculated by multiplying a "design" rainfall with a runoff coefficient. As not all runoff can be efficiently utilized (because of deep percolation losses, etc.) it must be additionally multiplied with an efficiency factor.

From the catchment topography and land cover evaluation, a runoff coefficient of C= 0.6, is appropriate for the perkera River catchment, and using this, the mean monthly runoff can be estimated using the design rainfall (75% reliability, K = 0.6. Based on Perkera station, the design rainfall is 19.2 mm and design runoff is 11.52 mm and at the dam sites, table 4.10.

Table 4:10 Design rainfall (mm) (75 %) and runoff at the dam sites

Perkera station		**Radat**		**Kaplelwo**		**Kopokaplelach**		**Kapng;etuny**	
Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff	Rainfall	Runoff
19.2	11.52	17.28	10.37	18.62	11.17	0.58	0.35	2.30	1.38

4.4.9 Effective Rainfall

Effective Precipitation (EP) is the amount of precipitation that is actually added and stored in the soil. During drier periods less than 5mm of daily rainfall would not be considered effective, as this amount of precipitation would likely evaporate from the surface before soaking into the ground. Effective precipitation enters the soil and becomes available to the plant. Effective rainfall (or precipitation) is equal to the difference between total rainfall and actual evapotranspiration. It considers losses due to runoff, evaporation and deep percolation. The equation used in the calculation is:

Effective Precipitation (mm) = (RAIN - 5) x 0.75, or (75 % probability rainfall).

Using this equation, the computation of the effective mean monthly and mean annual rainfall for Perkera station and its corresponding amount at the dam site based on the Perkera data and Marigat data are shown in table 4.11.

Table 4:11 Effective monthly and annual rainfall in the project area (mm)

item	Perkera station	Dam site	Marigat station	Dam site
Mean monthly rainfall	54.83	48.25	54.33	47.81
Effective monthly rainfall	37.37	44.50	37.00	32.78
Mean annual rainfall	658	579.04	652	573.75
Effective annual rainfall	489.75	575.29	485.25	426.57

Infiltration Rate

Infiltration is governed by two forces: gravity and capillary action. While smaller pores offer greater resistance to gravity, very small pores pull water through capillary action in addition to and even against the force of gravity.

The rate of infiltration is affected by soil characteristics including ease of entry, storage capacity, and transmission rate through the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity. For example, coarse-grained sandy soils have large spaces between each grain and allow water to infiltrate quickly. Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can close natural gaps between soil particles, and loosening soil through root action. This is why forested areas have the highest infiltration rates of any vegetative types.

The top layer of leaf litter that is not decomposed protects the soil from the pounding action of rain, without this the soil can become far less permeable. In chaparral vegetated areas, the hydrophobic oils in the succulent leaves can be spread over the soil surface with fire, creating large areas of hydrophobic soil. Other conditions that can lower infiltration rates or block them include dry plant litter that resists re-wetting, or frost. If soil is saturated at the time of an intense freezing period, the soil can become a concrete frost on which almost no infiltration would occur. Over an entire watershed, there are likely to be gaps in the concrete frost or hydrophobic soil where water can infiltrate.

Once water has infiltrated the soil it remains in the soil, percolates down to the ground water table, or becomes part of the subsurface runoff process. The basic Infiltration rates of various soils are shown in Tables 4.12 and 13.

Table 4:12 Basic Infiltration rates for various soils

Soil Type	Range of Basic Infiltration Rate (mm/hr)
Sand	>30
Sandy Loam	20 to 30

Soil Type	Range of Basic Infiltration Rate (mm/hr)
Loam	10 to 20
Clay Loam	5 to 10
Clay	1 to 5

Table 4:13 Generalized Values of run-off factor

Catchment soil types	Runoff factors (Kr)
Rocky and impermeable	0.8 to 1.0
Slightly permeable, bare	0.6 to 0.8
Slightly permeable, partly cultivated or covered with the vegetation	0.4 to 0.6
Cultivated, absorbent soil	0.3 to 0.4
Sandy bare soil	0.2 to 0.3
Heavy forest	0.1 to 0.2

Source: Guidelines for design, construction and rehabilitation of small dams and pans in Kenya)

4.4.10 Runoff coefficients

The design of water harvesting schemes requires the knowledge of the quantity of runoff to be produced by rainstorms in a given catchment area. It is commonly assumed that the quantity (volume) of runoff is a proportion (percentage) of the rainfall depth.

Runoff [mm] = K x Rainfall depth [mm]

An analysis of the rainfall-runoff relationship and subsequently an assessment of relevant runoff coefficients should best be based on actual, simultaneous measurements of both rainfall and runoff in the project area. As explained above, the runoff coefficient from an individual rainstorm is defined as runoff divided by the corresponding rainfall both expressed as depth over catchment area (mm):

$$K = \frac{\text{Runoff}\,[\text{mm}]}{\text{Rainfall}\,[\text{mm}]}$$

But for the project area, the runoff coefficient has been estimated from the catchment characteristics and using standard runoff tables, the catchment for the proposed dam sites can be described as being slightly permeable, partly cultivated or covered with the vegetation and k= 0.6, was adopted for the study.

4.4.11 Base Flow

Base flow (also called drought flow, groundwater recession flow, low flow, low-water flow, low-water discharge and sustained or fair-weather runoff) is the portion of stream flow that comes from "the sum of deep subsurface flow and delayed shallow subsurface flow". It should not be confused with groundwater flow. It is the discharge into a stream-flow from natural storages, particularly sustaining flow between rainfall events. The base flow can be estimated using the equation:

Direct flow (DF) = total flow (TF) - Base flow (BF)

The base flow can be estimated in two ways; by statistical method or modelling. Using the statistical method, it is estimated using the base flow index (BFI), which is a measure of the amount of low in a river during dry or low flows, used to characterize low flow and groundwater recharge in a catchment. It is calculated as flows:

BFI = Base flow / total flow or Lowest mean monthly flow / mean annual flow x 100. Using the this and the equation above, the base flow index for Perkera at 2EE07 was estimated to be = 0.22, which the used in the equation; Direct flow (DF) = total flow (TF) - Base flow (BF) , to estimate direct flows as 3.596 m3/sec and total flow 4.61 m3/sec. These values were then transposed to dam sites using catchment area proportioning method, see table 4.14.

Table 4:14 Flow characteristics at the three dam sites

Dam site	Catchment area (km^2)	Flows (m^3/sec)		
		Total flow	Direct flow	Base flow
Perkera 2EE07	1,181	4.61	3.596	1.05
Radat	1,061.1	4.14	3.23	0.91
Kaplelwo	1,148.7	4.48	3.50	0.98
Kopokaplelach	40.8	0.16	0.12	0.04
Kapng'etuny	143.4	0.56	0.44	0.12

4.4.12 Excess Rainfall

Excess rainfall is the portion of the rainfall that contributes to direct surface runoff (runoff that enters the stream during or soon after the storm). The excess rainfall is the difference between the total rainfall (measured amount) and the rainfall (precipitation losses) due to infiltration and interception (depression storage and canopy interception), this is the rainfall responsible for the peak of the runoff hydrograph.

Excess rainfall = total rainfall – rainfall losses.

4.4.13 Effective runoff

Effective runoff is as a result of the effective rainfall, if the ground is saturated or the catchment is impervious, then a high proportion of the rain becomes effective runoff, see table 4.15.

Table 4:15 Effective runoff in the project area (mm) based on Perkera scheme rainfall

item	**Perkera station**		**Dam site**							
			Radat		Kaplelwo		Kopokaplelach		Kapng'etuny	
	Effective rainfall	Runoff (mm)	Effective rainfall	Runoff (mm)	Effective rainfall	Runoff (mm)	Effective rainfall	Runoff (mm)	Effective rainfall	Runoff (mm)
Mean monthly rainfall	54.83	32.90	49.35	29.61	53.19	31.91	1.64	0.99	6.58	3.95
Effective monthly rainfall	37.37	22.42	33.63	20.18	36.25	21.75	1.12	0.67	4.48	2.69

Mean annual rainfall	658	394.8	592.2	355.32	638.26	382.	19.74	11.84	78.96	47.38
Effective annual rainfall	489.75	293.85	440.78	264.47	475.06	285.03	14.69	8.82	58.77	35.26

4.5 Hydrological analysis

Historical hydrological conditions are the best guide to predict future stream flow conditions in the basin. Relevant historical hydrological data was obtained, reviewed and processed for analysis. The specific hydrologic parameters or data elements collected included, daily and monthly stream flow from existing and discontinued RGs in the basin, daily or monthly diversion records from all significant diversions in the basin, annual summaries, water right data in the basin, sediment transport data and water quality data.

4.5.1 Hydrological Gauging stations

The gauging stations include Eldama 2ED01, 2ED02 and 2ED03, Perkera 2EE01, 2EE02, 2EE03, 2EE04, 2EE05, 2EE06, 2EE07, 2EE08 AND 2EE10 and Emining/Esageri 2EF01, 2EF02, 2EF03, Narosura 2EF04, and Esageri 2EF05 , see table 4.16 and figure 4.4. The analysis of their hisrory and working conditions are shown in table 4.16.

Most of these stations were not visited as they were said to have been closed by WRMA, as the organization started monitoring the main stations in the main rivers, including Perkera 2EE07

Table 4:16 Hydrological network in the Perkera river basin

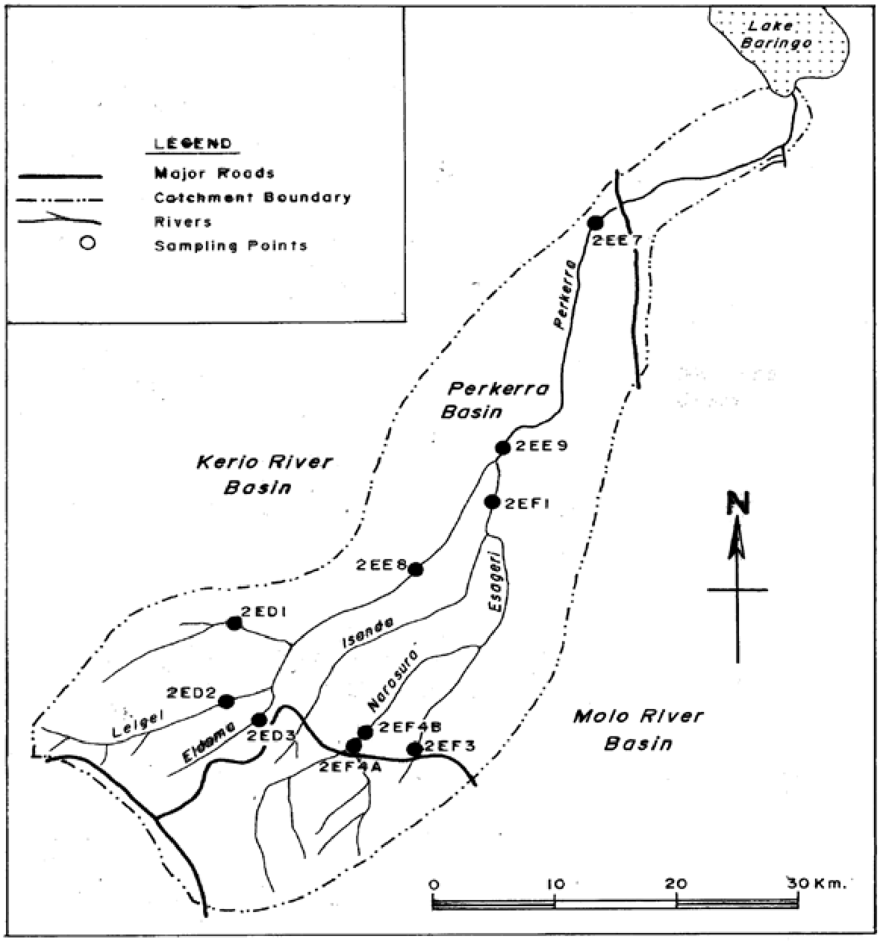
RGS code	River	type	condition	Rating	Catchment area (km²)
2EE02	Perkera	Staff gauge	Closed	Rated	unkown
2EE03	Perkera	Staff gauge	Closed	rated	1,075
2EE04	Perkera	Staff gauge	Closed	rated	1,339
2EE06	Perkera	Staff gauge	Closed	Not rated	unkown
2EE07A	Perkera	A/ Staff gauge	operational	rated	1,181
2EE08	Perkera			rated	500
2EE09	Perkera	Staff gauge	operational	rated	580
2EE10	Perkera	Staff gauge	closed	Not rated	1,329

Table 4:17 River gauging stations on Emining River catchment

RGS code	River	Type	Condition	Rating	Catchment area (km²)	Data period
2EF01	Esageri	Staff	Closed	Rated	365	1956-77
2EF02	Esageri	Staff	Closed	Not rated	257	1956-60
2EF03	Esageri	Staff	Closed	rated	60	1956-
2EF04	Narosura	Staff	Closed	rated	90	1956-

Table 4:18 River gauging stations on Eldama Ravine River catchment

2ED01	Tiger	Staff	Closed	Rated	135	1957-
2ED02	Tiger	Staff	Closed	Rated	108	1991-
2ED03	Tiger	staff	Closed	Rated	14	1979-



The Perkerra River Basin and river gauging stations.

Figure 4:7 Map of gauging stations on the Perkera River basin.

Hydrological evaluation for this project was based on daily and monthly river flow data from stations 2EE07 on Perkera, which captures all the flows from the upstream parts of the two basins. This station is downstream of the dam sites and it is representative for the hydrological conditions at the dam sites.

4.5.2 Evaluation of the existing data

The station RGS 2EE07 was selected because of the following reasons:

- It had good quality and consistent data for some reasonable (28 years) period, 1962-1989
- The data was fairly sufficient to give an indication of the water resources situation in the project area.

4.5.3 Miscellaneous gauging

From the records, there are several current meter gaugings done on the Perkera River at RGS 2EE07, at different times, ranges from 1962 to 2014. These data was used to develop the most recent rating curve for the station, the most recent gaugings are shown in table 4.19 and rating curve figure 4.8.

Table 4:19 The last five years current meter gauging at Perkera 2EE07

Serial No.	Date	Gauge height(m)	Discharge (m^3/sec).
1	12/2/2014	0.60	2.029
2	22/1/2014	0.65	3.146
3	31/1/2014	0.60	9.92
4	3/8/2013	1.09.	50.969
5	13/6/2013	0.65	9.245
6	13/5/2013	0.95	46.17
7	10/5/2013	1.22	60.366
8	8/5/2013	1.24	75.888
9	11/7/2012	0.78	24.570
10	14/6/2012	0.66	22.968
11	12/2/2012	0.48	1.15
12	12/1/2012	0.63	4.027
13	12/10/2011	0.68	3.055
14	3/12/20110	0.39	1.485
15	24/3/20110	0.76	18.24

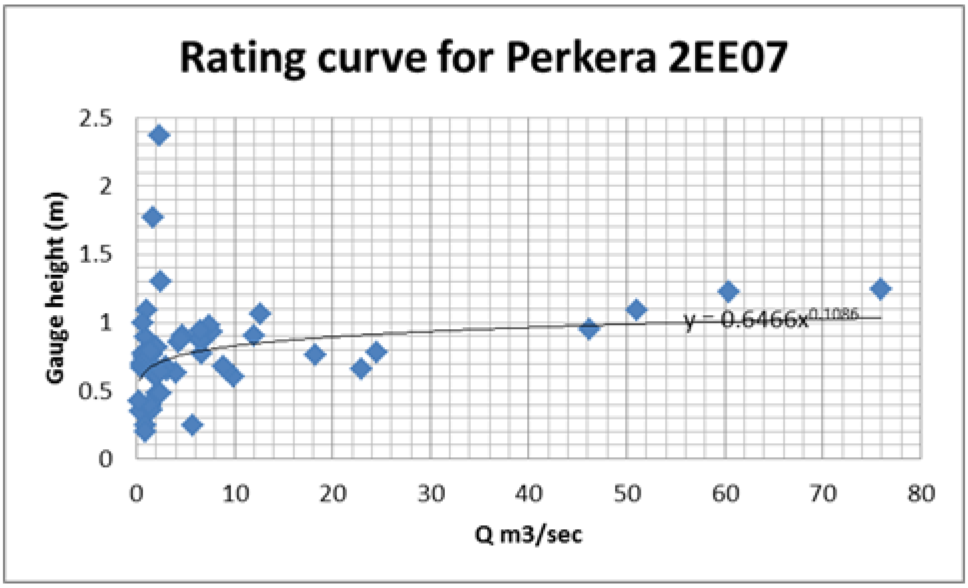


Figure 4:8 Rating curve for Perkera River at 2EE07

4.5.4 Low Flow Analysis

Flow duration curve were constructed to indicate the available water resources at various time periods. Flood frequency analysis was also carried out, so as to give the probability of occurrence of the various flood levels at the gauging and the dam sites. Low flow analysis was carried out to estimate the low flows in the two Rivers. This is important in the justification of the need for water storage in the two basins. The details of the analysis of the data from the two stations 3CB07 and 3BD03 are discussed below.

The analysis evaluates the available historical hydrologic data for Perkera River basin to deduce the hydrological trends in the project area.

4.5.5 Existing Water rights

There are a total of 25 water rights for Perkera, see table 4.20, a total of 10,692 m^3/day for normal and and 21,228 m^3/day flood water abstractions, for Perkera River.

Table 4:20 Water rights in the Perkera Rivers

Name of river	Normal flow water rights		Flood water rights	
Perkera	m^3/sec	**(m^3/day)**	m^3/sec	**(m^3/day)**
	0.124	10,692	0.247	21,228

4.5.6 Projects upstream of Radat dam site

There are some projects upstream of the proposed dam site and this includes

- Chemususu dam
- Institutional water supplies
- Public water supplies
- Individual abstractor

However more details about them were scanty from WRMA officials in Nakuru, although promised to supply such information latter.

4.5.7 Naturalized flow

The naturalized river flows for the Perkera and at the dam sites are shown in table 4.21.

Table 4:21 Naturalized flows mean monthly discharge at the dam sites

Month	flow m³/sec				
	Perkera 2EE07	Radat site	Kaplelwo site	Kopokaplelach site	Kapng'etuny site
January	1.507	1.356	1.462	0.045	0.181
February	1.877	1.689	1.821	0.056	0.225
March	3.027	2.724	2.642	0.091	0.363
April	4.717	4.245	4.575	0.142	0.566
May	6.527	5.874	6.331	0.196	0.783
June	4.217	3.795	4.090	0.127	0.506
July	4.817	4.34	4.672	0.133	0.578
August	7.327	6.594	7.107	0.220	0.879
September	5.397	4.857	5.235	0.162	0.648
October	3.447	3.102	3.343	0.103	0.413
November	4.237	3.813	4.109	0.127	0.508
December	3.137	2.823	3.043	0.094	0.376

<u>Hydrological Analysis for Perkera at 2EE07</u>

This is a station on the Perkera River is located at coordinates latitude N 00o 27'27'' E, longtitude 35o 57'57'' S, capturing water from upper and midstream of the basin and its tributaries and has an effective area of about 1,180 km2, see figure 4.9. The station was visited on 15/5/2014 at 11.45 am and the check reading was 0.58 m, giving a discharge 0.61 m3/sec. The station was found to be a good condition, having been rehabilitated in the year 2005 by WRMA.

According WRMA officials, the station was opened, a visit to the station indicated that the station is presently in a working condition, having rehabilitated in the year 2005

Plate 4.5: The first staff gauge at Perkera 2EE07, a check reading taken during the field visit to site was 0.56 m corresponding.	Plate 4.6:The second and third staff gauges at Perkera 2EE07

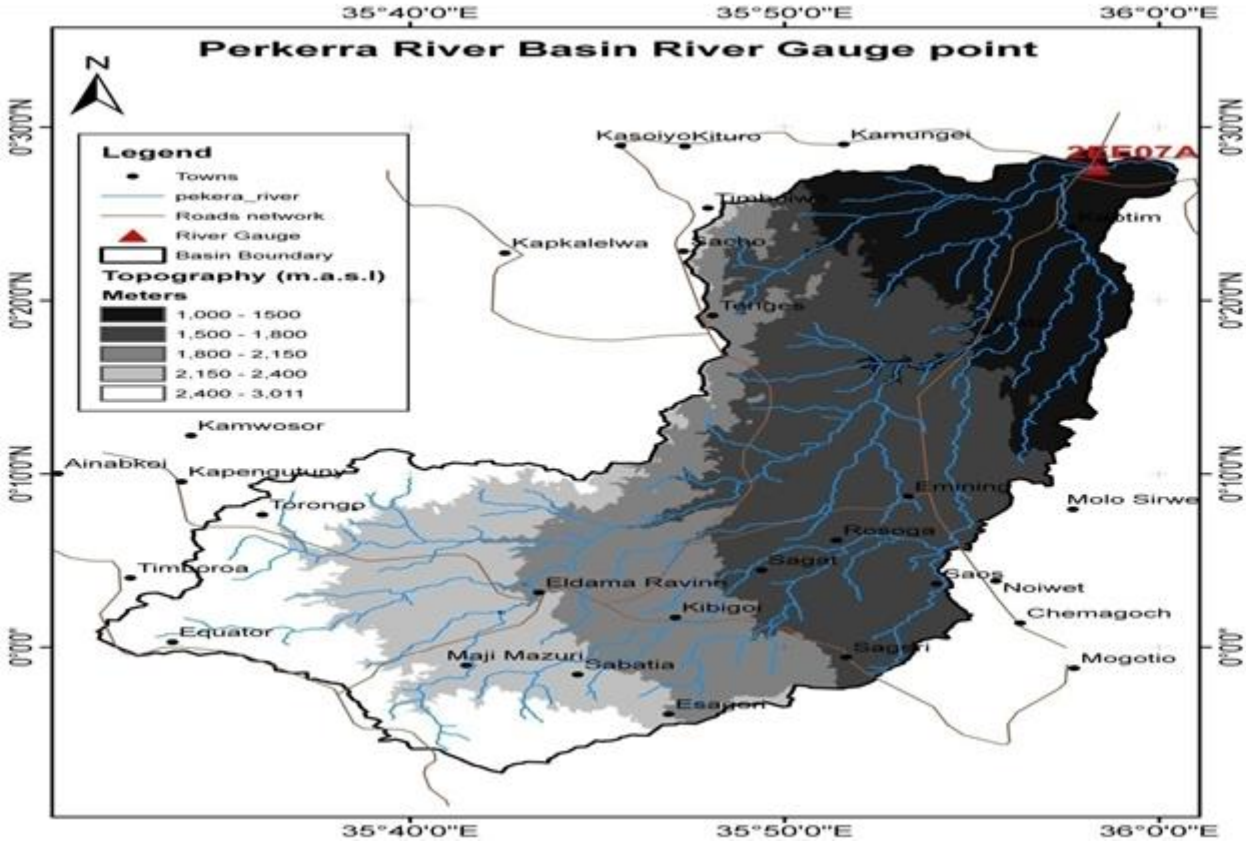
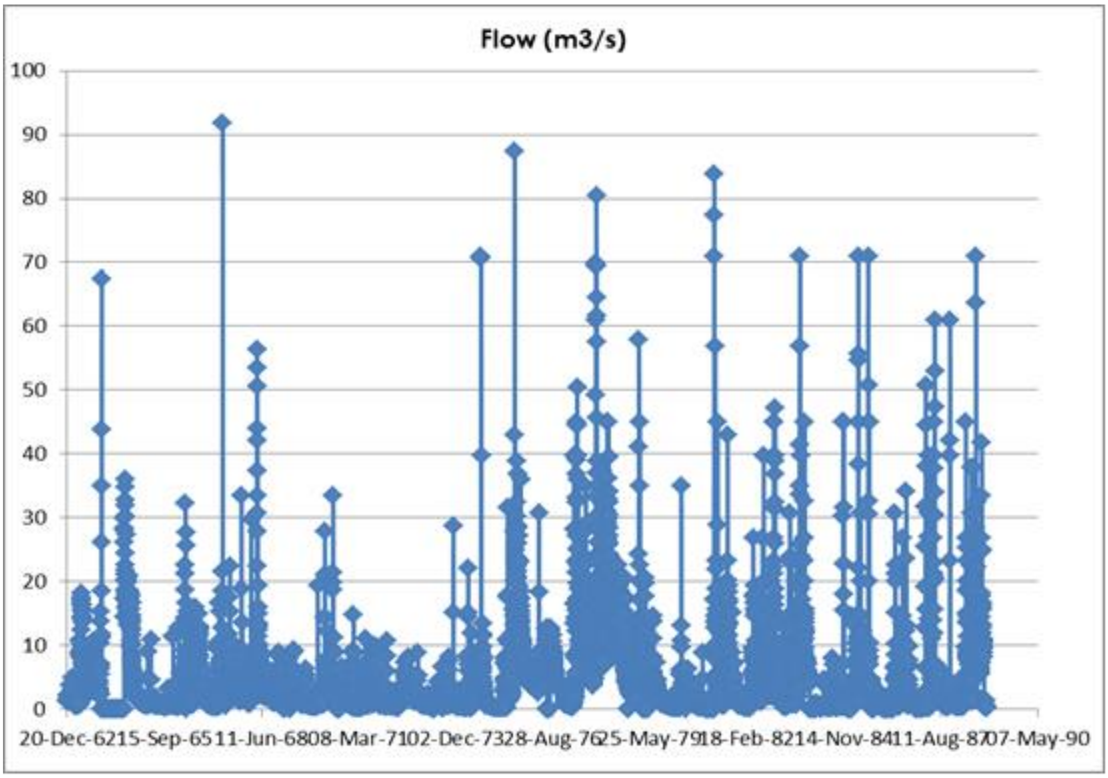


Figure 4:9 *Location* **of RGS 2EE07 in the Perkera river basin. The mean month average**

Table 4:21 Monthly summary statistic at Perkera 2EE07

Month	J	F	M	A	M	J	J	A	S	O	N	D
Mean	1.63	2.00	3.15	4.84	6.65	4.34	4.97	7.45	5.52	3.57	4.36	3.26
Max	37.43	57.87	83.87	55.65	91.72	60.91	70.96	87.35	36.90	45.03	80.50	67.37
Min	0.23	0.15	0.14	0.15	0.20	0.25	0.21	0.01	0.28	0.28	0.25	0.18

From table 4.21, the mean monthly flow for Perkera River at 2EE07 is lowest 1.63 m^3/sec in January and highest 7.45 m^3/sec in July. The flows from 2EE07 were transposed to the dam sites using the area proportioning method and the results are shown in table 4.22.



RGS2EE07time series (1962-1988)

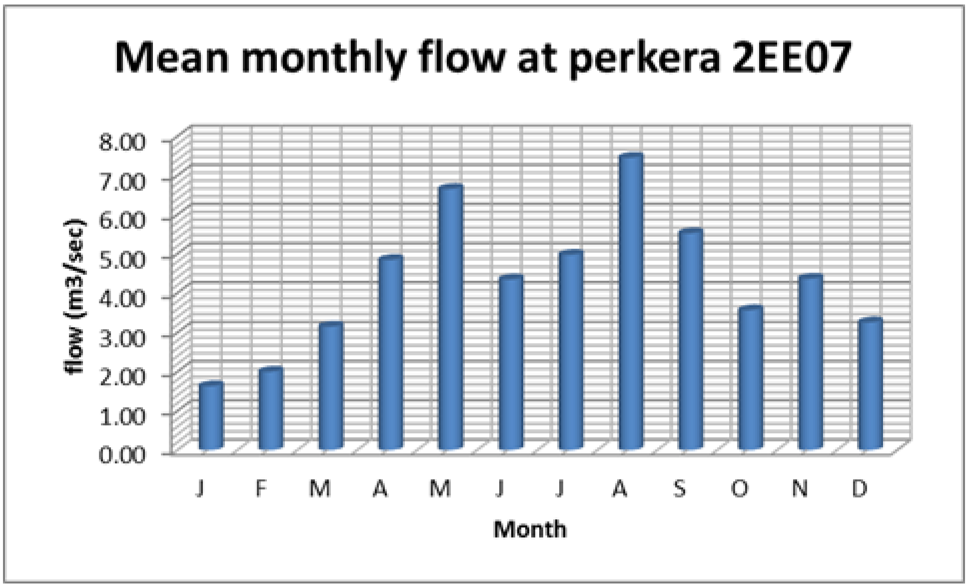


Figure 4:10 Mean monthly River flow at Perkera 2EE07

Table 4:22 The monthly mean flows at the dam sites

Month	**Mean flows at the sites (m^3/sec)**				
	2EE07	Radat	Kaplelwo	Kopokaplelach	Kapng'etuny
J	1.63	1.467	1.581	0.049	0.196
F	2.00	1.80	1.94	0.06	0.24

M	3.15	2.835	3.056	0.095	0.011
A	4.84	4.356	4.695	0.145	0.038
M	6.65	5.985	6.451	0.200	0.798
J	4.34	3.906	4.210	0.130	0.521
J	4.97	4.473	4.821	0.149	0.596
A	7.45	6.705	7.227	0.224	0.894
S	5.52	4.968	5.354	0.166	0.662
O	3.52	3.168	3.414	0.106	0.422
N	4.36	3.924	4.229	0.131	0.523
D	3.26	2.934	3.162	0.098	0.391

Table 4:23 The annual accumulated mean flows at the dam sites

Month	**Mean flows at the sites (m³/sec)**				
	2EE07	Radat	Kaplelwo	Kopokaplelach	Kapng'etuny
J	1.63	1.467	1.581	0.049	0.196
F	3.63	3.267	3.521	0.109	0.436
M	6.78	6.102	6.577	0.203	0.814
A	11.62	10.458	11.271	0.338	1.394
M	18.28	16.452	17.732	0.494	2.194
J	22.61	20.349	21.932	0.678	2.713
J	27.58	24.822	26.753	0.827	3.310
A	35.03	31.527	33.979	1.051	4.204
S	40.55	36.495	39.333	1.27	4.866
O	44.07	39.663	42.748	1.322	5.288
N	48.43	43.587	46.977	1.453	5.812
D	51.69	46.521	50.139	1.504	6.203

Based on the mean annual flow in table the table above, cumulatively a total of 46.521m^3/s at Radat, 50.139m^3/s at Kaplelwo, 1.504m^3/s at Kopokaplelach and 6.203m^3/s at kapng'etuny dam site.

<u>Data gap filling and reliability analysis</u>

The collected data from reliable years was used to fill gaps and develop continuous and consistent records. Accurate hydrological analysis requires complete and consistent stream flow data at all critical points in the basin.

The evaluation of the present water resource situation in the project area was carried out by analyzing mean daily flows over the years. A flow duration curve shows graphically the relationship between any given discharge and the percentage of time that this discharge is equalled or exceeded. A flow duration curve is helpful to provide answers to the following and related questions asked frequently.

- Does the river have uniform flow or does its flow fluctuate widely?
- What are the low-flow and high-flow river characteristics, i.e., is the river flashy?
- What percentage of the time does the river flow at certain discharge levels?
- If the river is to be used for, provide water supply, what percentage of time can the river support such services?

Flow duration analysis

The flow reliability analysis of the Perkera River at 2EE07 at various exceedance levels (flow duration) results are shown in tables 4.23 and in figure 4.11.

Table 4:24 Flow reliability at Perkera 2EE07

Reliability (%)	flow (m^3/sec)
2	29.903
5	17.631
10	11.827
50	**1.77**
75	0.676
80	**0.567**
90	0.384
95	**0.291**

From table 4.23 and figure 4.11, at the (Q95) the environmental flow dry weather flow or threshold discharge for river Perkera at 2EE07 0.291 m3/sec, Q80, normal flow is 0.567 m3/sec and the flood flow Q50 is 1.77 m3/sec, from the data analysed (1962- 1989), see table 4.24)

Table 4:25 FDC characteristics at Perkera River basin and at the dam sites (m3/sec)

Threshold (%)	Description	Basin	Radat site	Kaplelwo site	Kopokaplelach site	Kapng'etuny site
Q95	Reserve	0.291	0.262	0.282	0.009	0.035
Q80	Normal	0.567	0.510	0.545	0.017	0.068
Q75		O.676	0.608	0.656	0.020	0.081
Q50	Flood	1.77	1.593	1.717	0.0531	0.212

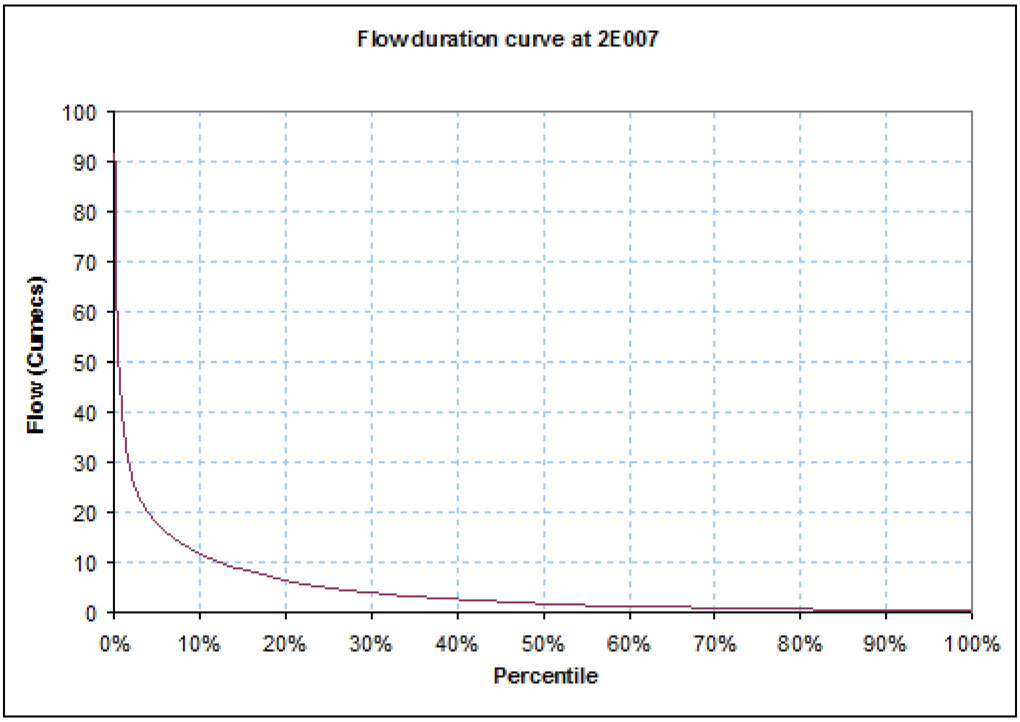


Figure 4:11 Flow duration curve for Perkera River at 2EE07

The Drainage Area Ratio Method

This method was used to interpolate the river flow data from the gauging station at 2EE07 to the proposed dam sites. This method assumes that the stream flow at an ungauged site for the same stream is the same per unit area or at least responds in the same fashion as that of the nearby, hydrologically similar stream gauging station used as an index, in this case 2EE07.

The dam catchment areas are estimated from the topographic maps, digital elevation models or GIS, stream flow statistics were computed for the index stations 2EE07, the statistics were then divided by the basin area to get the stream flow per unit area of the index station, and the value obtained is multiplied by the areas of the ungauged (dam catchments) to get the estimated statistics for the dam site. This method was most suitable for the two basins because the dams are on the respective Rivers as the index station, and has similarities in drainage area, basin characteristics and on climatic characteristics; therefore the river flow per unit area is assumed to be the same.

The general area ratio equation is:

Q ungauged = Q gauge (A ungauged /A gauge)

Where:

Q ungauged: is the flow at the ungauged site (proposed dam site)

Q gauge: is the flow at the gauged site

A ungauged: is the catchment area (km2) of the ungauged site (upstream of the proposed dam in km2)

A gauge: is the catchment area upstream of gauging station (2EE07).

This method allows the estimation of the availability of water at the dam site based on historic long-term information of the gauging station s 2EE07. The catchment area for the station 2EE07 is1,181 km2 and that of the dam sites were 1,061.1,km2, a ratio of = 0.9 for Radat, 1,148.7 km2, a ratio = 0.97 for Kaplelwo, 40.8 km2, a ratio = 0.03 for Kopokaplelach and 143.4 km2, a ratio = 0.12 for Kapng'etuny. These area ratios were then used to interpolate the flow data from the gauging station to the proposed dam sites, see table 4.24.

4.5.8 Flood Frequency analysis

Perkera 2EE07

The objective of flood frequency analysis is to estimate a high (peak) flow corresponding to a specific return period of occurrence, for dam design. This is to ensure that the flood water to be released through the spillway should not create flooding downstream. Thus a balance has to be worked out between the economy, efficiency in regard to flood moderation and safety.

Flood analysis can be based on, (i) Annual maximum peak discharges, (ii) Instantaneous peak flow), the runoff coefficient which is derived from the relationship between recorded flood hydrographs and concurrent rainfall, table 4.16, shows the flood frequency at Perkera 2EE07, based on river flows.

Different methods were used to ensure the results were reliable, as each method has its own strengths and weaknesses based on the assumptions they make. The probability distributions used in the analysis were, Gumbel and the Extreme value index (EVI), each of this probability makes certain assumptions about the catchment's characteristics and hence slightly different results. The goodness of fit test was done using, standard deviation, correlation coefficient and the Chi-square statistic, and the distribution with the lowest standard deviation and highest correlation coefficient, was picked as the best fit of flood data of the river, and was used to generated design floods for the sites, the Gumbel had the best fit to the observed data and therefore gives the most reliable results and was adopted for the study, see table 4.26.

Table 4:26 Design Floods of Perkera River at 2EE07

Return period (Year:T)	Gumbel (m3/sec)	EVI (m3/sec)
Q10,000	**251.15**	127.01
Q1,000	**197.44**	108.14
Q500	**181.26**	102.46
Q100	**143.64**	89.24
Q50	**127.35**	83.52
Q20	**105.62**	75.89
Q10	**88.84**	69.99
Q5	**71.34**	63.84
Q2	**44.90**	54.55

The estimated design floods at 2EE07 were then interpolated to the proposed dam sites and the design flood data at the dam site are shown in table 4.26.

Table 4:27 Design floods at the dam sites (m3/sec)

Return period (Years:T)	Basin 2EE07	Radat site	Kaplelwo site	Kopokaplelach site	Kapng'etuny site
Q10,000	251.15	226.035	243.616	7.545	30.138
Q1,000	197.44	177.696	191.517	5.923	23.693
Q500	181.26	163.134	175.822	5.438	21.751
Q100	**143.64**	**129.276**	**139.33**	**4.309**	**17.237**
Q50	**127.35**	**112.82**	**123.53**	**3.821**	**15.282**
Q20	105.62	95.058	102.451	3.169	12.674
Q10	88.84	79.956	86.175	2.665	10.661
Q5	71.34	64.206	69.20	2.140	8.561
Q2	44.90	40.41	43.553	1.347	5.388

From table 4.26 the (Gumbel) results, which had the best fit on the flood data, the Q100 year flood is 129.276 m3 /sec for Radat, 139.33 m3/sec for Kaplelwo, 4.309m3/sec for Kopokaplelach and 17.237 m3/sec for Kapng;etuny site . The Q50 year flood is 112.82 m3 /sec for Radat, 123.53 m3/sec for Kaplelwo, 3.821 m3/sec for Kopokaplelach and 15.282 m3/sec for Kapng'etuny dam site.

4.5.9 Flood Characteristics

Understanding the peak flood characteristics for the project area is a must for the success of the dam project; the various design flood computation methods are discussed as follows:

4.5.10 Inflow Design Flood

The criteria for selection of inflow design flood for safety of dam as per International Standards are:

International Commission on Large Dams (ICOLD)

This commission has laid down the norms for categorization as large dams.

- More than 15 m height measured from the lowest portion of the general foundation area to the crest
- A dam between 10 m and 15 m height provided it complies with at least one of the following conditions:
  - (a) Length of the crest of dam is not less than 500 m
  - (b) Capacity of reservoir formed by the dam is not less than 1 MCM
  - (c) Maximum flood discharge dealt by the dam is not less than 2000 m^3/s
  - (d) The dam had specially difficult foundation problem
  - (e) The dam is of unusual design
  - (f) The dam is located on highly seismic zone

Federal Emergency Management Agency (FEMA) Guidelines

***Flood Selection for Design* (or Evaluation):** The selection of the design flood should be based on an evaluation of the relative risks and consequences of flooding, under both present and future conditions. Higher risks may have to be accepted for some existing structures because of irreconcilable conditions. When flooding could cause significant hazards to life or major property damage, the flood selected for design should have virtually no chance of being exceeded. If lesser hazards are involved, a smaller flood may be selected for design. However, all dams should be designed to withstand relatively large flood without failure even when there is apparently no downstream hazard involved under present conditions of development.

Downstream Effects: Safety design includes studies to ascertain areas that would be flooded during occurrence of the design flood and in the event of dam failure. The areas downstream of the project should be evaluated to determine the need for land acquisition, flood plain management, or other methods to prevent major damages. Information should be developed and documented for disseminating to downstream interests regarding the continuing risks of flooding.

Kenyan standards

In Kenya, the Water Resources Management Authority (WRMA) recommends minimum design floods for hydraulic design of dam spillways on the basis of risk associated with drainage that may occur downstream on the event of embankment failure. Classification of dams is also based on the height, reservoir impoundment area and the dam catchment. The Tables below show the classification of dams and recommendations for spillway design flood, as per WRMA regulations.

Table 4:28 Classes of dams

Class of dam	Maximum depths of water at NWL (m)	Reservoir Impoundment (m^3)	Catchment area (m^2)
A (Low risk)	0-4.99	<100,000	<100
B (Medium risk)	5-14.99	100,000 – 1,000,000	100-1,000
C (high risk)	>15.0	>1,000,000	>1,000

Source, Water management rules, draft-June 2006

Table 4:29 Recommended design periods for the design of spillway

Class of dam	Minimum return period (Years)
A (Low risk)	I in 50
B (Medium risk)	1 in 100
C (high risk)	1 in 500

Source, Water management rules, draft-June 2006

The following criteria were adopted in previous studies in Kenya, (TNWS, Long Term Development Plan, Hydrology, Chapter 9, HH, 1986):

- River diversion works – 50 year return period
- Temporary works during dam construction – 50 year return period
- Dam spillway structures – Probable Maximum Flood (PMF)

Data Availability

Due to non-availability of Instantaneous peak discharge records for gauging station in the close proximity of dam site or even at Perkera gauging stations 2EE07, short interval meteorological data for the region, and hydro-meteorological method utilizing catchments characteristics with rainfall was adopted during the study. Considering the nature of data and current available information, the methodology for possible design flood estimation will be as discussed in following section. The runoff coefficient of C = 0.6 was adopted for all the dam sites.

4.6 Estimated Design Flood using empirical formula

The design flood was estimated using different empirical formulae and the highest of the results was adopted and used. Four different used are as follows:

(a) Dicken's Formula

$$Q_p = C\, A^{3/4}$$

Where,

A = Catchment area (km^2)
C = runoff coefficient
Qp= Peak Flood in m^3/s

(b) **Ryve's Formula**

$$Q_p = C.A^{2/3}$$

Where,

A = Catchment area (km^2)
C = runoff coefficient
Qp= Peak Flood in m^3/s

(c) **Metcalf and Eddy Formula**

$$Q_p = C\, A^{0.73}$$

Where,

A = Catchment area (km^2)
C = runoff coefficient
Qp= Peak Flood in m^3/s

(d) **Fanning Formula**

$$Q_p = C\, A^{4/5}$$

Where;

C = runoff coefficient
Where, A = Catchment area (km^2)
Qp= Peak Flood in m^3/s

These formulae are more useful because they do not experience application restrictions based on catchment size as the case with the rational formula.

(E) **The rational formula**

$$Q_{pF} = CIA$$

Where:

QpF is the flood peak in m^3/s

C is the runoff coefficient (proportion of precipitation that contributes to runoff

I is the rainfall /storm intensity in mm/hr

A is the catchment area in km^2

However this was not applicable to the study as the three of the four dam sites, had catchment high above the 50 km2 limit for its application. The summary of estimated peak flows using different methods are shown in table 4.30.

Table 4:30 Summary of peak flows estimates based on empirical formula

Empirical formula	**Peak discharge estimate (m^3/sec)**			
	Radat site	Kaplelwo site	Kopokaplelach site	Kapng'etuny site
Dicken's formula	111.55	118.39	9.69	24.86
Ryve's Formula	63.89	67.37	7.20	16.71
Metcalf and Eddy Formula	97.04	102.83	8.99	22.51
Fanning Formula	158.04	168.39	11.66	31.87

Based on empirical formulae results in table 4.30, the peak flow at the Radat dam site ranges between 63.89- 158.04 m^3/sec, and hence the higher value is adopted, 158.04m^3/s. For Kaplelwo, the peak flow ranges between 67.37- 168.39 m^3/sec and 168.39m^3/s is adopted, for Kopokaplelach, the peak flow ranges between 7.2- 11.66 m3/sec and 11.66m^3/s is adopted and for Kapng'etuny, the peak flow ranges from 16.71-31.87 m^3/s, and 31.87m^3/s is adopted.

4.7 Probable maximum flood (PMF)

Determination of PMF begins with the determination of the probable maximum precipitation, the PMF is the flood which is a direct result of PMP or is the highest flood a region will ever experience or Flood that may be expected from the most severe combination of the critical meteorological and hydrological conditions that are reasonably possible in a particular area.

PMF is the flood which is a direct result of PMP or is the highest flood a region will ever experience or Flood that may be expected from the most severe combination of the critical meteorological and hydrological conditions that are reasonably possible in a particular area. According to Obasi and Nimira (1977), the probable maximum flood PMF, is given by the following regression curve formulae:

PMF = (0.094 pmp –9.86) A 0.75

Where:

PMF: Probable Maximum Flood m^3/s

A: Catchment area (km2) of the project.

PMP: Probable Maximum Precipitation for upper Perkera = 200 mm (obtained from PMP Isohyets map Obasi and Nimira, 1977); m3/sec as the PMF for the project area, using the above equation, see the results in table 4.31.

Table 4:30 Probable maximum flood at the dam sites

Dam Site	Catchment area (km²)	PMF (m³/s)
Radat	1,061.1	1,662.09
Kaplelwo	1148.7	1,763.98
Kopokaplelach	40.8	144.32
Kapng'etuny	143.4	370.47

From table 4.25, Radat dam site has a peak flow of 158.04m3/s and a PMF of 1,662.09 m³/s, Kaplelwo dam site has a peak flow of 168.39 m3/sec and the PMF is 1,763.98 m³/s. For Kopokaplelach, the peak flow is 11.66m3/s and the PMF is 144.32 m³/s, for Kapng'etuny, the peak flow is 31.87 m3/sec and the PMF is 370.47 m3/sec, see the flood summary in table 4.32.

Table 4:31 Summary of flood estimates based on empirical formula

Dam Site	**Peak discharge estimate (m³/sec)**	**PMF (m³/sec)**
Radat	158.04	1,662.09
Kaplelwo	168.39	1,763.98
Kopokalelach	11.66	144.32
Kapng'etuny	31.87	370.47

Diversion Flood

Designing the discharge capacity of the diversion works may be thought of in terms of an optimization calculation taking safety into account. Optimization aims at minimizing:

- The construction cost of the diversion works
- The cost of the damage that would result from under design not only at the construction site itself but also for property downstream in the event of sudden failure.

As per BIS 14185: 2000, Criteria for Diversion Capacity for Embankment Dams is as follows:

For Small and Intermediate Dams

5 to 20 years flood frequency flood is taken to decide the capacity of diversion works. In case the diversion arrangements like tunnels are to be used subsequently as permanent structure like tunnel spillway, the capacity may be equal to the discharging capacity of the permanent structure, see table 4.33.

Table 4:32 Diversion floods (m3/sec)

Dam Site	**5 year flood estimate (m³/sec)**	**10 year flood (m³/sec)**	**20 year flood (m³/sec)**
Radat	64.21	79.96	95.06
Kaplelwo	69.20	86.18	102.45

Kopokalelach	2.14	2.67	3.17
Kapng'etuny	8.56	10.66	12.67

The return period adopted between 5 year and 20 years depends on the flow characteristic during the diversion time.

B: For Large Dams

For large dams it is desirable that 100 years flood should be adopted for diversion works, table 4.34.

Table 4.34: Diversion floods for large dams (m^3/sec)

Dam Site	100 year flood estimate (m^3/sec)
Radat	129.28
Kaplelwo	123.53
Kopokalelach	4.31
Kapng'etuny	12.67

From table 4.28, the 100 year flood for radat is 129.28 m3/sec, Kaplelwo 139.33 m3/sec, Kopokalelach 4.31 m3/sec and Kapng'etuny 12.67 m3/sec.

4.8 Basin Water Balance

The water balance of the Perkera river basin at the dam sites is shown in table 4.35.

Table 4:33 Flow reliability at the Perkera 2EE07 and dam sites

Reliability level	Flows (m3/sec)									
	2EE07(m3/sec)		Radat		Kaplelwo		Kopokaplelach		Kapng'etuny	
	Existing	available	Existing	available	Existing	available	Existing	available	Existing	available
Q50	1.77	1.523	1.593	1.346	1.717	1.47	0.053	-0.194	0.212	-0.035
Q75	0.676	0.552	0.608	0.484	0.656	0.532	0.02	-0.104	0.081	-0.043
Q80	0.567	0.443	0.51	0.386	0.545	0.421	0.017	-0.107	0.068	-0.056
Q95	0.291	0.291	0.262	0.262	0.282	0.282	0.009	0.009	0.035	0.035

Given the existing water rights in the basin, the dam sites at Kopokaplelach and Kapng'etuny will experience water deficits, while there is water surplus in the Radat and Kaplelwo dam sites.

4.8.1 Basin Water Yield

The water yield of a watershed may either be measured directly on a single outlet on the main stream or be calculated through empirical equations based on important physical properties of a particular watershed. Using the directly measured runoff values is, of course, the best way, but since it takes a long time and investments are delayed, the empirical method is preferred in applications.

The annual water yield expressed in the Turc method as reported by Shaw:

V = h.A.10

Where, V is the annual water yield of the basins (m3 year-1), A is the area of the basin (hectare) and h = -1,903 is the surface runoff height that occurred in the basin (mm year-

The surface runoff height is calculated as:

h = P – ET

ET is the areal evapotranspiration (mm year-1) and P is the mean precipitation (mm year-1). The estimated basin water yields at the dam sites aere shown in table 4.36.

Table 4:34 Basin/ dam site water yields

River/ dam site	Basin area (km^2)	Basin area (ha)	Water yield (m^3/year)
Perkera 2EE07	1181	118,100	-1,152,632,380
Radat	1,061.1	106,110	-1,035,612,378
Kaplelwo	1,148.7	114,870	-1,121,108,226
Kopokalelach	40.8	4,080	-39,819,984
Kapng'etuny	143.4	14,340	-14,054,175

From table 4.330, it is evident that the Perkera basin as a whole experiences large water deficits as water losses through evaporation at 1,631.98 mm annually, is far more compared to annual precipitation of 656 mm at the Kari met station.

4.8.2 Basin Groundwater Recharge

Groundwater recharge has been defined as the process of addition of water to the saturated zone. Because it is almost impossible to measure directly, recharge is usually estimated by indirect means. The Relationship of Krishna Rao was used as follows:

Krishna Rao gave the following empirical relationship to determine the ground water recharge in limited climatological homogenous areas, the equation is: R = K (P - X)

R is net recharge (mm) and P is mean annual precipitation (mm)The following relation is stated to hold good for different rainfall amounts; R = 0.20 (P - 400) for areas with P between 400 and 600 mm R = 0.25 (P - 400) for areas with P between 600 and 1000 mm R = 0.35 (P - 600) for areas with P above 2000 mm where, R & P are expressed in millimeters

P = 656 mm

R = 0.20(656-400)

R = 51.2 mm (the net ground water recharge(R) in the project area is 51.2 mm)

4.8.3 Evapotranspiration

Evapotranspiration (ETo) is the total amount of water lost through evaporation in the soil and transpiration ("breathing") of the plants. The annual evapo-transpiration is 1631.98 mm, see table 4.30.

This is quite high water losses, which has an implication on the water availability in the basin.

Table 4:35 Mean monthly Evapotranspiration (mm) at Kari research station Met.

Month	ET_0
	mm/month
January	158.72
February	152.6
March	167.71
April	162.3
May	144.77
June	135.30
July	129.27
August	134.30
September	149.10
October	154.38
November	142.38
December	143.53
Total	**1,631.98**

4.8.4 Net Evaporation from the Reservoir

Because of its nature, evaporation from water surfaces is rarely measured directly, except over relatively small spatial and temporal scales (Jones 1992). Evaporation from water is most commonly computed indirectly by one or more techniques. These include:

- pan coefficients × measured pan evaporation,
- water balance,
- energy balance,
- mass transfer,
- a combination of energy balance and aerodynamic techniques

The selection of the "best" technique to use for a particular computation is largely a function of the data availability, type or size of the water body, depth and the required accuracy of the estimated evaporation.

The most commonly used method in the Kenya for estimating evaporation from small, shallow water bodies, is to measure evaporation from a standard pan and then multiply by a coefficient.

<u>Evaporation Pan Method:</u>

E = Kp Epan

A pan Where Kp is the pan coefficient, = 0.7 and Epan is the evaporation from A Class. Based in the above equation, the net evaporation for the dams sites is 1631.98 x 0.7 = 1,142.4 mm, based on the Kari station and 2559 x 0.7 = 1,791.3 mm based on Perkera scheme station.

4.9 Sedimentation

The rate of sedimentation rate depends on the soil erodability of the soils of the basin, precipitation and the river capacity.

4.9.1 Reservoir Sedimentation

There is little existing records of sediment flow rates for Perkera River at RGS 2EE07 and none at the proposed dam sites and hence the sediment loading rate used in the study was estimated from another RGS on Perkera 2EE04. The National Water master plan (1992) Sectorial report B: on hydrology, provides sedimentation rates for major rivers in the country. The equation for the Perkera River basin is as follows:

Qs = aQb ,

Where:

Qs: is suspended load (ppm)

Q: is the discharge (cms)

a and b are constants, derived from data,

Table 4:36 Perkera River at RGS 2EE04 rating equation of suspended load and its volume

RGS	River	Catchment area (km2)	Annual mean discharge (m3/sec)	Rating equation		Mean (ppm)	Annual (ton/year
				a	b		
2EE04	Perkera	1,334	2.8	1197.201	1.010	3,387	390,033

From the table 4.35, the annual suspended load discharge at from the Perkera basin at 2EE04 is 390,033 tonnes/ year. Since the area of the Perkera basin is at 2EE04 is 1,334 km2, then the mean sediment yields for Perkera basin at 2EE07, with an area of 1,181 km2, is 345,299.08 tons/year or is 292.4tones/km^2/yr. When this is transposed to the dam sites, the results are as shown in table 4.36.

Table 4:37 Estimated sedimentation rates at the dam sites

Site	Catchment area (km2)	Sediment load (m3/year)	Yield (tones/km2/yr)
Perkera at 2EE07	1,181	345,299.08	292.4
Radat site	1,061.1	310,769.82	292.87
Kaplelwo site	1,148.7	334,940.11	291.58
Kopokaplelach site	40.8	10,358.97	253.90
Kapng'etuny site	143.4	41,435.89	288.95

From table 4.36, Radat dam site experiences sedimentation rates of 310,769.82 m^3/year or 292.4 tones/km^2/year, Kaplelwo 334,940.11 m^3/year or 292.87 tonnes/km^2/year, Kopokaplelach 10,358.97 m3/year or 253.9 tonnes/km^2/year and Kapng'etuny 41,435.89 m^3/year or 288.95/km^2/year.

4.9.2 Estimation of Sedimentation Level

The sedimentation levels in the Perkera basin and at the proposed dam sites are quite high and hence siltation problems for the dams is real and there is need for increased efforts in catchment conservation. During the field visits, there was evidence of serious watershed degradation evidenced by intensive charcoal burning as witnessed by several bags of charcoal along the roads in the area.

4.10 Hydrological Impacts of the proposed dams on the river basins

There are several hydrological impacts of dam construction in a river basin, this includes;

- Magnitude of the extremes: Dams are quite effective at accomplishing what they were designed to do as the most dramatic shifts occur in the decreased magnitude of 1-day maximum flows. A somewhat different pattern emerges for minimum flows, minimum flows tend to increase following impoundment, but this is most true for the longer duration events.
- Changes in hydrograph variability equally profound effects have occurred in parameters associated with the shape of the hydrograph. The characteristics of the hydrograph, as revealed by show significant changes in the number of reversals and in mean rise rates and fall rates. Besides greatly modifying the sequencing of hydrograph peaks, the day-to-day rate of change is also dramatically affected, especially for the rise rate of the hydrograph.
- The pulsing response of flows serves critical riparian functions, Changes in the frequency and duration of flows of a particular stage and discharge can significantly disrupt terrestrial and aquatic ecology.
- Changes in the timing of flows whether these dams are flood control, irrigation, or hydropower, they are all associated with storing water for subsequent releases. This storing component significantly affects the release timing and greatly disrupts the pre-impact natural flow regime's expected timing of flows. This effect occurs on the scale of total monthly stream flow and in the timing of extreme maximum and minimum flows in the river, especially during rain seasons, as they reduce to allow reservoir storage (filling).
- Modifies temperature and local climatic conditions, like temperature

5 GEOLOGICAL STUDIES

5.1 Background Information

The Perkerra Irrigation Scheme Expansion Project Study proposed to expand the scheme irrigation area to 2020 hectares, which will be eight times its present area. Such expansion will require 25Mm3 90 day storage dam project. The Terms of Reference require the Consultant to review a pre-feasibility report on the proposed dam project. The Consultant has carried out reconnaissance surveys in the project area to gather relevant information in order to produce a feasibility study report for the proposed dam project.

The proposed Radat Dam project is on Perkerra River. Four (4) dam sites (Radat, Kaplelwo. Koipokaplelach and Kapng'etuny) were initially proposed. However, Radat Dam site at a proposed dam height of 80m has been identified as the best option to meet the potential of the proposed dam project.

The current feasibility study carried out reconnaissance geology and preliminary geophysical investigations on Radat Dam site. Initial soil investigations by trial pits were also done at this site. The proposed Radat Dam project has three sites which have potential to meet the estimated storage of up to 260Mm^3. The three sites were studied to establish the geological conditions of the foundation rocks in order to select the most suitable site for detailed geological investigations.

5.2 Objective of Investigations

The general objective of the reconnaissance geological survey and preliminary geophysical investigations was to study the geological aspects of the general project area and evaluate the foundation conditions at the proposed dam site. The specific objectives were to:

1. Study of the geological conditions of the general project area.
2. Evaluate the structural geological conditions in relation to foundation stability.
3. Evaluate foundation conditions and the nature of overburden at the dam site.
4. Evaluate geological lateral variations within the dam site area.
5. Select possible sites for core drilling to evaluate geological variations with depth.
6. Evaluate the need for foundation treatment and the mode of foundation treatment.
7. Assess availability of construction materials within close proximity to the dam sites.

5.3 Scope of Works

The TOR for the feasibility study requires the Consultant to carry out reconnaissance geological survey and preliminary geophysical investigations within the Radat proposed dam project area. The scope of work entailed desk study of available geological, hydrogeological and soil survey reports of the general project area. This was followed by reconnaissance geological investigations for ground-truthing of the information in reviewed reports.

Preliminary field geophysical investigations were carried out at using geo-electrical resistivity method in order to:

i. Establish the depth to bedrock at the dam site(s);

ii. Study lateral geological variations along the proposed dam axis;

iii. Determine the presence of buried geological features such as fractures, local faults and lithological changes, e.g. buried paleao-river beds that would be highly permeable;

iv. Select the most suitable dam site for further detailed geological and geophysical investigations; and

v. Determine the thickness of overburden at the dam site and the nature of cut-off to be done.

The field work also included initial evaluation of availability of suitable construction materials by excavation of trial pits to collect soil samples from the dam general project area. This was to evaluate the suitability of the soils as embankment construction fill materials. The field investigations were carried out from 24th through 30th April 2014.

5.4 Location of Project Area

The proposed Radat dam project area is 30km south-west of Marigat Township, in Koibatek District of Baringo County. The proposed dam project is a zoned rock fill dam with an impervious core to be constructed across Perkerra River whose upper reaches is the Mau Escarpment Hills. The location of the proposed Radat project area is shown on Figure 5.1.

5.5 Geological Reconnaissance Investigations

5.5.1 Review of Previous Geological Works

The most comprehensive study of the geology of the general project area is covered by Report No. 83 of the Mines and Geological Department, “Geology of the Eldama Ravine-Kabarnet Area” by J. Walsh (1969). The project area is in Radat-Marigat plains with low lying volcanic hills. The Perkerra River has deeply incised into the almost relief forming steep gorges. Review of previous geological studies of the general project has been covered in depth in that Report No. 83.

The geology of the general Radat project area is composed of volcanic rocks of Miocene to Pliocene period. Rock exposures of the volcanic rocks and some tuffs with intercalating sediments are found at river valley flanks and the floodplain. Previous geological studies have been done by many geologists who had interest in the formation of Great Rift Valley system.

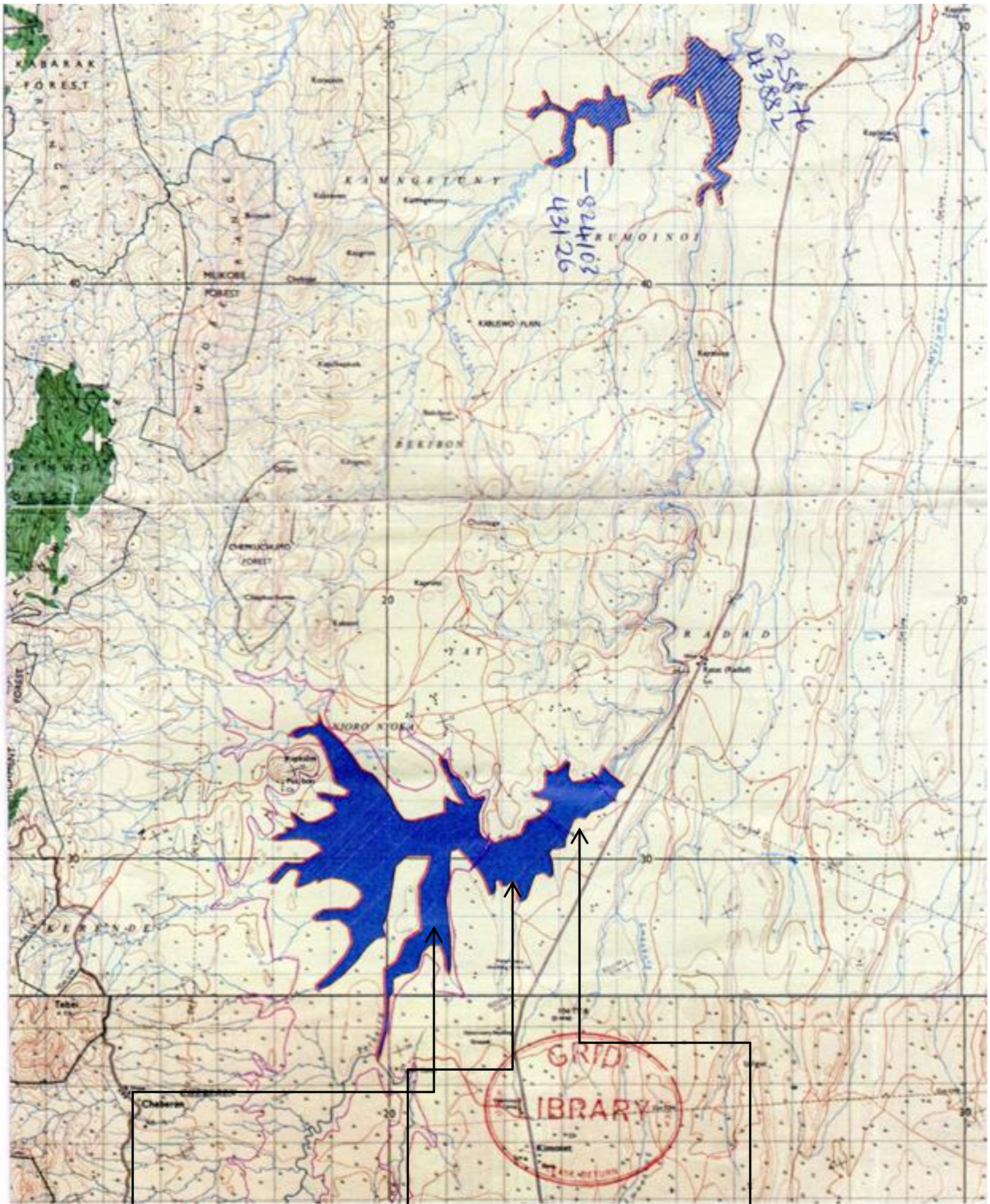


Figure 5:1 Location of Proposed Radat Dam Project Area

Upper Radat Dam site   Middle Radat dam site   Lower Radat dam site (main)

5.5.2 Review of Previous Geological Works

The most comprehensive study of the geology of the general project area is covered by Report No. 83 of the Mines and Geological Department, "Geology of the Eldama Ravine-Kabarnet Area" by J. Walsh (1969). The project area is in Radat-Marigat plains with low lying volcanic hills. The Perkerra River has deeply incised into the almost relief forming steep gorges. Review of previous geological studies of the general project has been covered in depth in that Report No. 83.

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5.5.3 Geology of the General Project Area

The geology of the general project area is composed of volcanic rocks of Miocene to Recent age. The oldest volcanic in the succession are basalts of the Samburu Basalt series (Tvb1). The Samburu basalts are largely hard, fine-grained and non-porphyritic. These basalts area deeply weathered and exist only as fragments solid rock in clayey formation.

The next oldest volcanic rocks in the succession are non-porphyritic phonolites of the Lower non-porphyritic phonolite series (Tvp1). Together with upper porphyritic phonolites they are described as the Uasin Gishu phonolites.

The next oldest rocks in the succession are the Eldama Ravine tuffs and sediments (Tvf2) that rest on the Uasin Gishu phonolites or the Samburu basalts (as was observed both at proposed dam site 2 and dam site 3).The sediment are riverine in origin and wedge out near Radat.

The next oldest rocks in the succession are basalts of the Kwaibus olivine basalts (Tvb3) that overlie the Eldama Ravine tuffs and sediments. These basalts are grey, fairly coarse-grained with macroscopic phenocrasts of feldspar, olivine and pyroxene.

The next oldest rocks in the succession (the youngest unit in the area) are phonolites of the Lower porphyritic Lake Hannington Phonolites unit (Tvp3). These rocks are exposed on the right hand side of Perkerra River valley at Radat area where they are faulted with a down to the east. They directly abut on the phonolites (Uasin Gishu phonolites). The succession of the rocks in the project area is as summarized here below:

1. Lower porphyritic Lake Hannington Phonolites unit (Tvp3).
2. Kwaibus olivine basalts (Tvb3).
3. Eldama Ravine tuffs and sediments (Tvf2).
4. Uasin Gishu phonolites.
5. Samburu Basalt series (Tvb1).

5.6 Detailed Geology of the Project Area

The geology of project area is composed of volcanic rocks of Miocene to Recent period. The volcanic rocks exposed in the proposed Radat project area have been variously weathered and only slightly fractured. The oldest rocks the Samburu basalt have been intensely weathered and can only be observed as solid fragments in weathered clayey formation. The younger volcanic rocks are also variously weathered and slightly fractured with the youngest Kwaibus basalts forming discontinuous scarps on the upper flanks of the steep river valleys (see Plate 2.1).

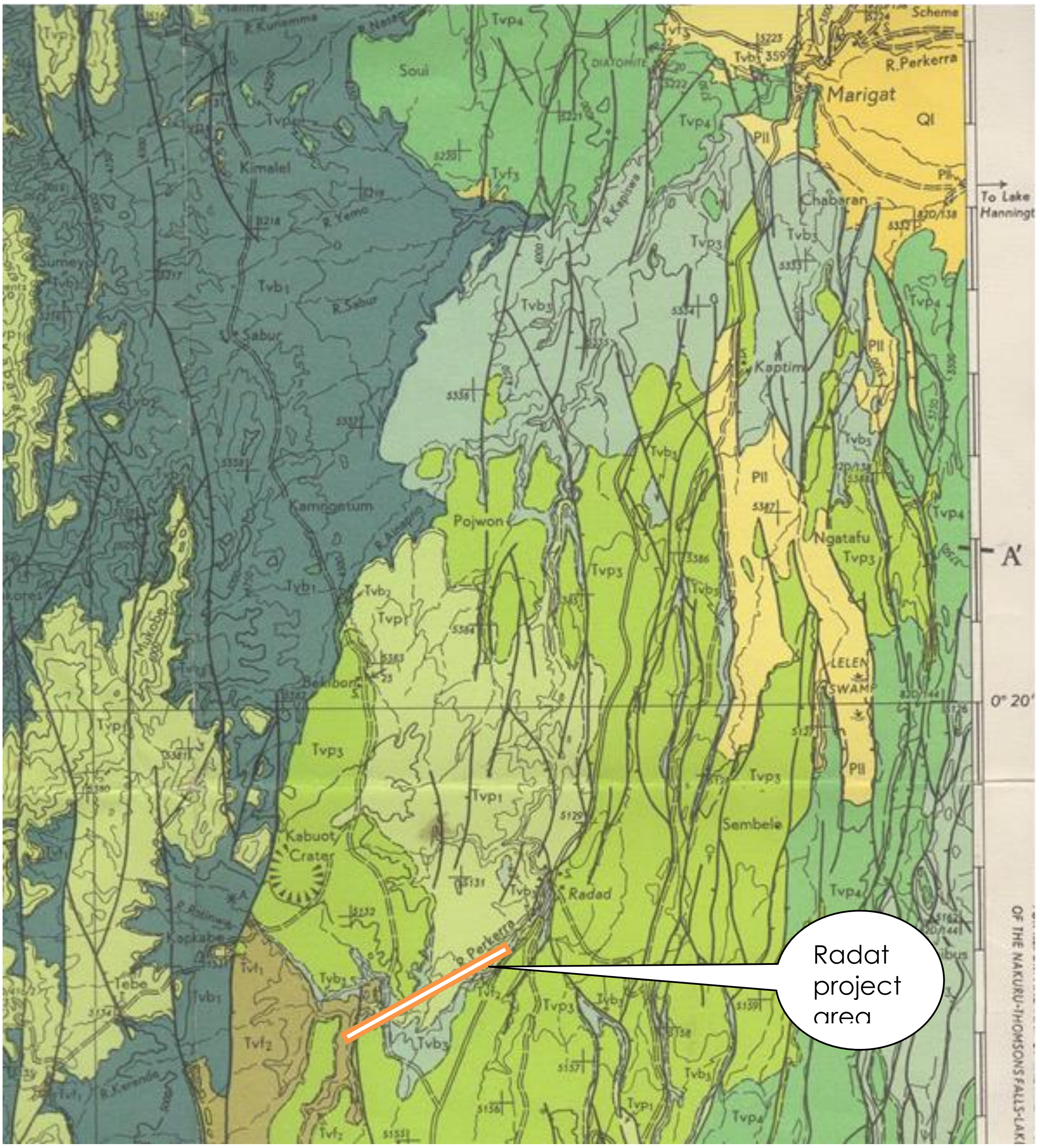


Figure 5:2 A geological map of the general proposed Radat project area is shown in Figure 2.1.

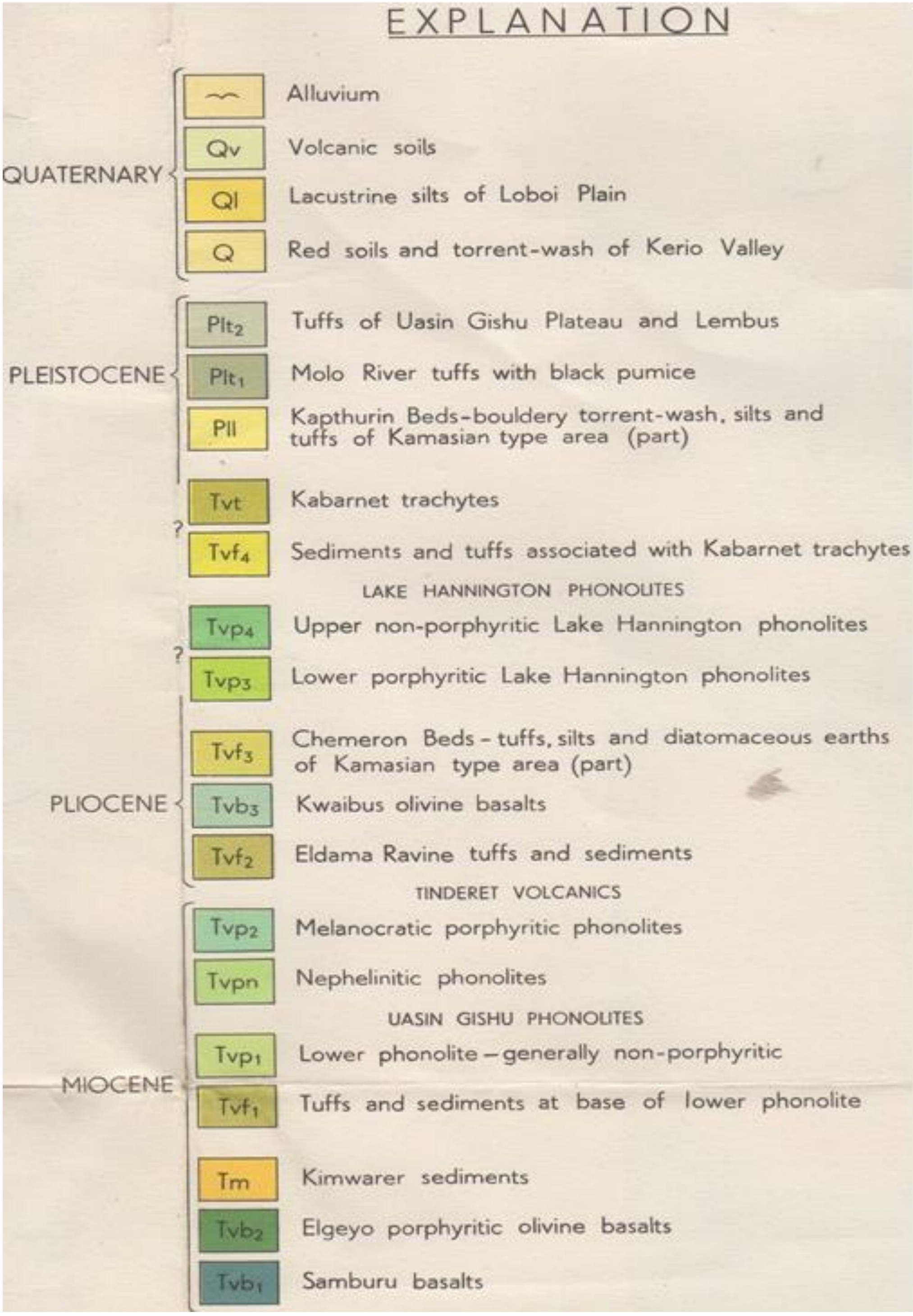


Figure 5:3 **Geological map of the general project area (extract from J. Walsh, 1969)**

The ground surface is strewn with cobbles and boulders with very thin layer of soils derived from the weathering of the parent rocks. Also significant is the presence of volcanic breccia which is the product of faulting activity in the area.

	
Plate 5.1(a): Highly weathered Samburu basalts upstream of the bridge site	**Plate 5.1(b)** Phonolites resting weathered basalts near the Bridge (dam site 3)

The rocks have disjointed lateral extent leading to absence of continuous bedrock as observed in geophysical investigations. Eldama Ravine tuffs and sediments are well exposed in proposed dam site 3 where sediments are intercalated with tuffs (Plate 2.4).

	
Plate 5.1(c): Intercalated tuffs and sediments Dam site 3 area	Plate 5.1(d): Intercalated tuffs and Sediments resting on basalts (Dam site 3 area)

	
Plate 5.1 (e) Steep-sided left bank at Radat dam site 1	Plate 5.1 (f): Young Basalts resting on completely weathered Old basalts (Samburu basalts)

A map of detailed reconnaissance geology of the proposed Radat dam project area is shown Figure 5.4.

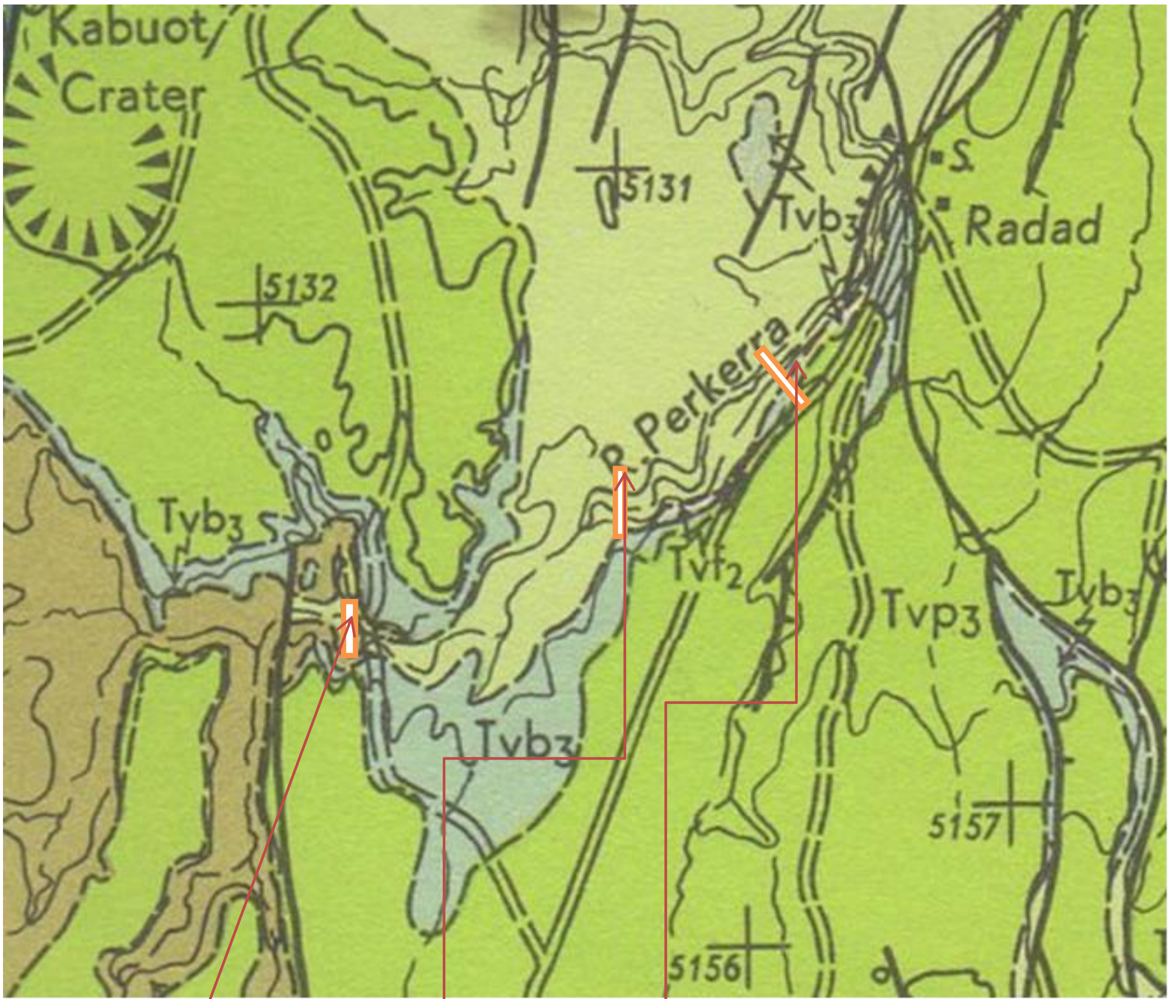


Figure 5:4 Geological map of Proposed Radat Dam Site Area

Proposed Dam Site 3 (Kipting' Bridge) | Proposed Dam Site 2 | Proposed Dam Site 1

Geological Key

PLIIOCENE AGE

Tvp3	Lower porphyritic Lake Hannington phonolites
Tvb3	Kwaibus olivine basalts
Tvf2	Eldama Ravine tuffs and sediments
Tvp1	Lower phonolite – generally non-porph

5.7 Structural Geology of the Project Area

The structural geology Radat dam project is characterized by intense faulting that especially affected the young volcanic rocks during the formation of the Great Rift Valley during Quaternay times. Of particular interest during the design process of the proposed Radat dam would nature of faulting and to what extent the foundation rocks have been affected faulting. The general project area has undergone grid-faulting, but around the proposed Radat has only experienced minor faulting that dies out south-westwards. A map of the structural pattern the general project area is shown Figure 2.3.

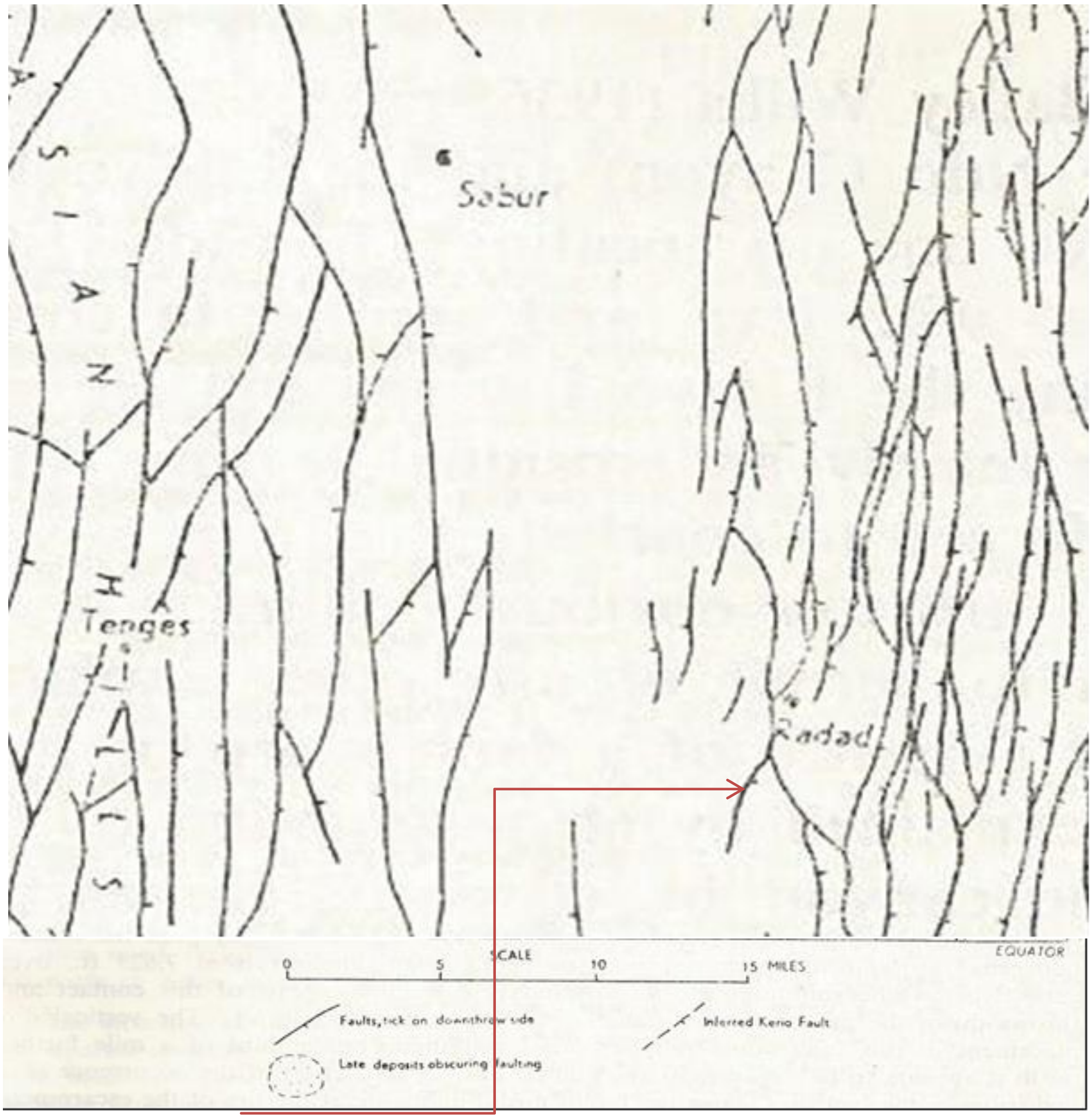


Figure 5:5 Map of Structural Pattern of Radat Project Area Proposed Radat Project Area

5.8 Seismic Activity in the General Project Area

The seismicity of the project area can be assessed from existing reports. Due to the highly faulted nature Radat project area it is deemed prudent for seismic survey to be carried out in this area. This will produce useful information which will be necessary for during the design of the proposed dam.

In the seismic zoning map of Kenya (Loupekine, 1971) the project area lies in Zone VIII - IX in the Modified Mercalli Scale of earthquake intensities. The seismic zoning map of Kenya is given in Figure 5.6, while the Modified Mercalli Scale of earthquake intensities is summarized in Figure 5.7.

In accordance to available data on earthquake parameters, other areas with similar geological setting have applied the following design parameters:

- Design Basis Earthquake (DBE): amax = 0.20g;
- Maximum Credible Earthquake (MCE): amax = 0.45g.

We believe a design basis earthquake (DBE) loading of amax = 0.25g and maximum credible earthquake (MCE) of amax = 0.45g can be applied in stability analysis during the designing of the Radat dam.

Consideration is also made on other earthquake factors that may have influence on dam stability, namely close proximity to earthquake epicentres and the historical background of earlier earthquakes. The distribution of earthquake epicentres in Kenya is shown Figure 2.6. A map of widely felt earthquakes in Kenya is presented in Figure 2.7: the project area is located about 50 km from the estimated epicentre of the major shocks of the 1928 Subukia earthquake (M=7) with estimated peak ground acceleration of 50cm/sec2 or 0.05g.

Other considerations are the effects of the filling of the dams: in a number of reported cases the filling of dam reservoirs has resulted in induced seismicity. The mechanism behind induced seismicity is generally thought to be:

- The triggering effect of additional stresses from the weight of the water, and
- The reduced friction along faults because of increased pore water pressure.

Historical data have shown that no induced earthquake of magnitudes greater than 5 have occurred for dams lower than 100m height. The filling of Radat dam of 80m is not expected to result in induced earthquake.

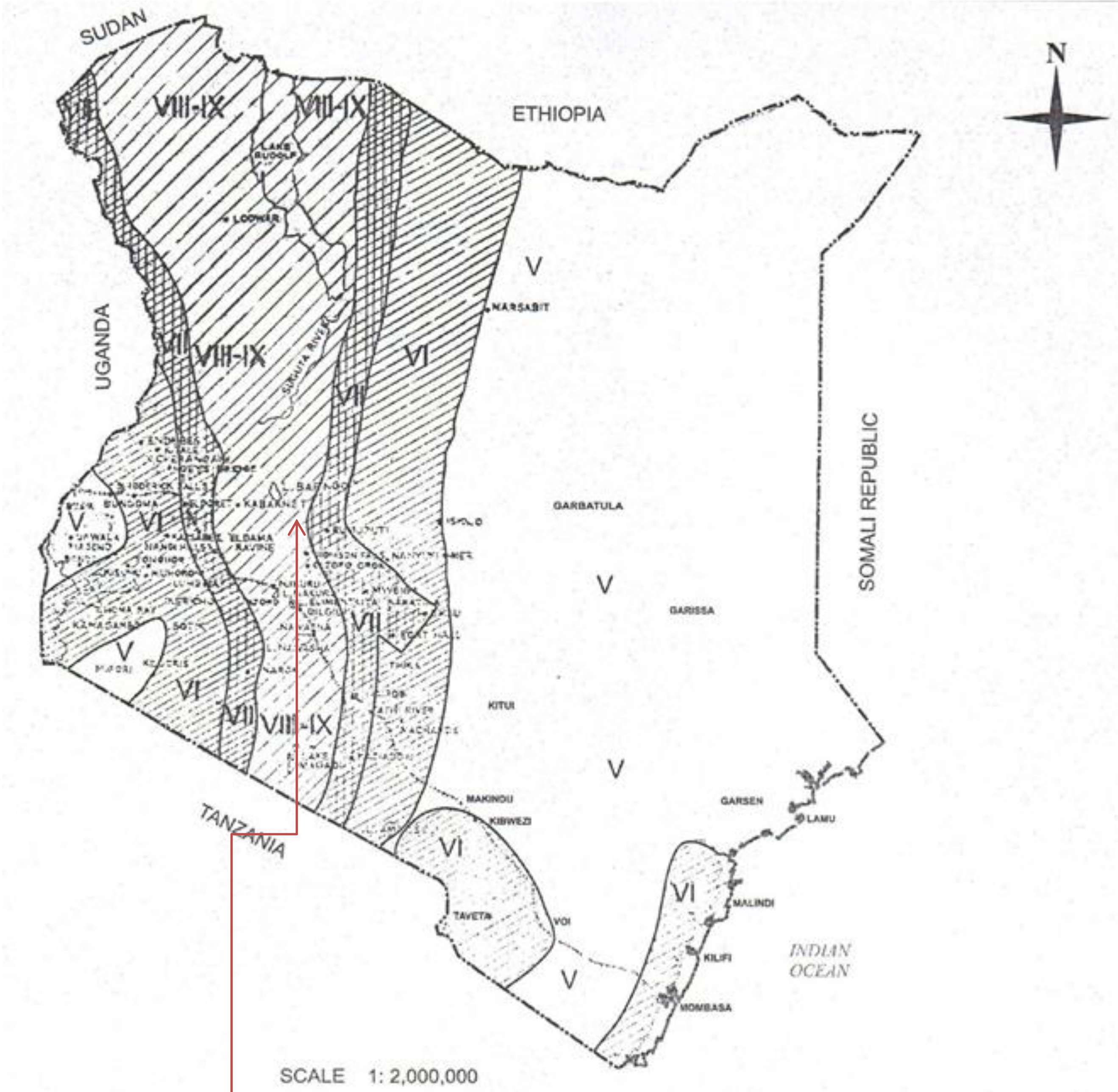


Figure 5:6 **Seismic Zoning Map of Kenya (I. S. Loupekine, 1971**

Proposed Radat Dam Project Area

Intensity Zone	Descriptive Term	Effects	Acceleration (cm/s^2)	Acceleration (g)
I	Imperceptible	Not felt. Registered only by seismographs.	< 1	< 0.001
II	Very slight	Felt in upper storeys solely By persons at rest.	1 – 2	0.001 – 0.002
III	Slight	Felt indoors. Vibrations like those caused by light trucks passing by.	2 – 5	0.002 – 0.005
IV	Moderate	Hanging objects swing. Vibrations like those caused by heavy trucks or a jolt such as that occasioned by a heavy object striking the wall. Parked cars are set in seesaw motion. Windows, doors and crockery rattle.	5 – 10	0.005 – 0.01
V	Fairly Strong	Felt outdoors. Sleeping persons wakened. Small objects not anchored are displaced or overturned. Doors open and close. Shatters and pictures are set in motion. Pendulum clocks stop and start or change their speed.	10 – 20	0.01 – 0.02
VI	Strong	Walking is made difficult. Windows, crockery and glass break. Knick-knacks, books, etc. fall off shelves; pictures fall from wall. Furniture moves or is overturned. Cracks in weak plaster and materials of construction Type D. Small bells ring (church, school).	20 – 50	0.02 – 0.05
VII	Very Strong	Noticed by car drivers and passengers. Furniture breaks. Materials of construction Type D sustain serious damage. In some cases, cracks in materials of construction Type C. Weak chimneys break at roof level. Plaster, loose bricks, stones, tiles, shelves collapse. Waves created on ponds.	50 – 100	0.05 – 0.10
VIII	Destructive	Steering of cars made difficult. Very heavy damage to materials of construction Type D and some damage to materials of Type C. Partial collapse. Some damage to materials of Type B. Stucco breaks away. Chimneys, monuments, towers and raised tanks collapse. Loose panel walls thrown out. Branches torn from trees. Changes in flow or temperature of springs. Changes in water levels of wells. Cracks in moist ground and on steep slopes.	100 – 200	0.10 – 0.20
IX	Highly Destructive	General panic. Materials of construction Type D completely destroyed. Serious damage to materials of Type C, and frequent collapse. Serious damage also sustained by materials of Type B. Frame structures lifted from their foundation, or they collapse. Loadbearing members of reinforced-concrete structures are cracked. Pipes llying below ground burst. Large cracks in the ground. In alluvial areas, water, sand and mud ejected.	200 – 500	0.20 – 0.50
X	Extremely Destructive	Most masonry and wooden structures destroyed. Reinforced steel buildings and bridges seriously damaged; some of them destroyed. Severe damage to dams, dykes and weirs. Large landslides. Water hurled onto the banks of canals, rivers and lakes. Rails bent.	500 – 1000	0.50 – 1.00
XI	Disaster	All structures collapse. Even large, well constructed bridges are destroyed or seriously damaged. Only a few buildings remain standing. Rails greatly bent and thrown out of position. Underground wires and pipes break apart.	1000 - 2000	1.00 – 2.00
XII	Major disaster	Large-scale changes in the structure of the ground. Overground and subterranean streams and rivers change in many ways. Waterfalls are created, lakes are dammed up or burst their banks. Rivers alter their courses.	> 2000	> 2.00

Construction method A: Good workmanship, mortar and design; reinforced especially laterally, and bound together using steel, concrete, etc.; designed to resist lateral forces.
Construction method B: Good workmanship and mortar; reinforced but not designed to resist strong lateral forces.
Construction method C: Ordinary workmanship and mortar; no extreme weaknesses such as failing to tie in at corners, but neither reinforced nor designed to resist horizontal forced.
Construction method D: Weak materials such as adobe; poor mortar, low standards of workmanship; horizontally weak.

Figure 5:7 Modified Mercalli Scale (1956) of Intensities

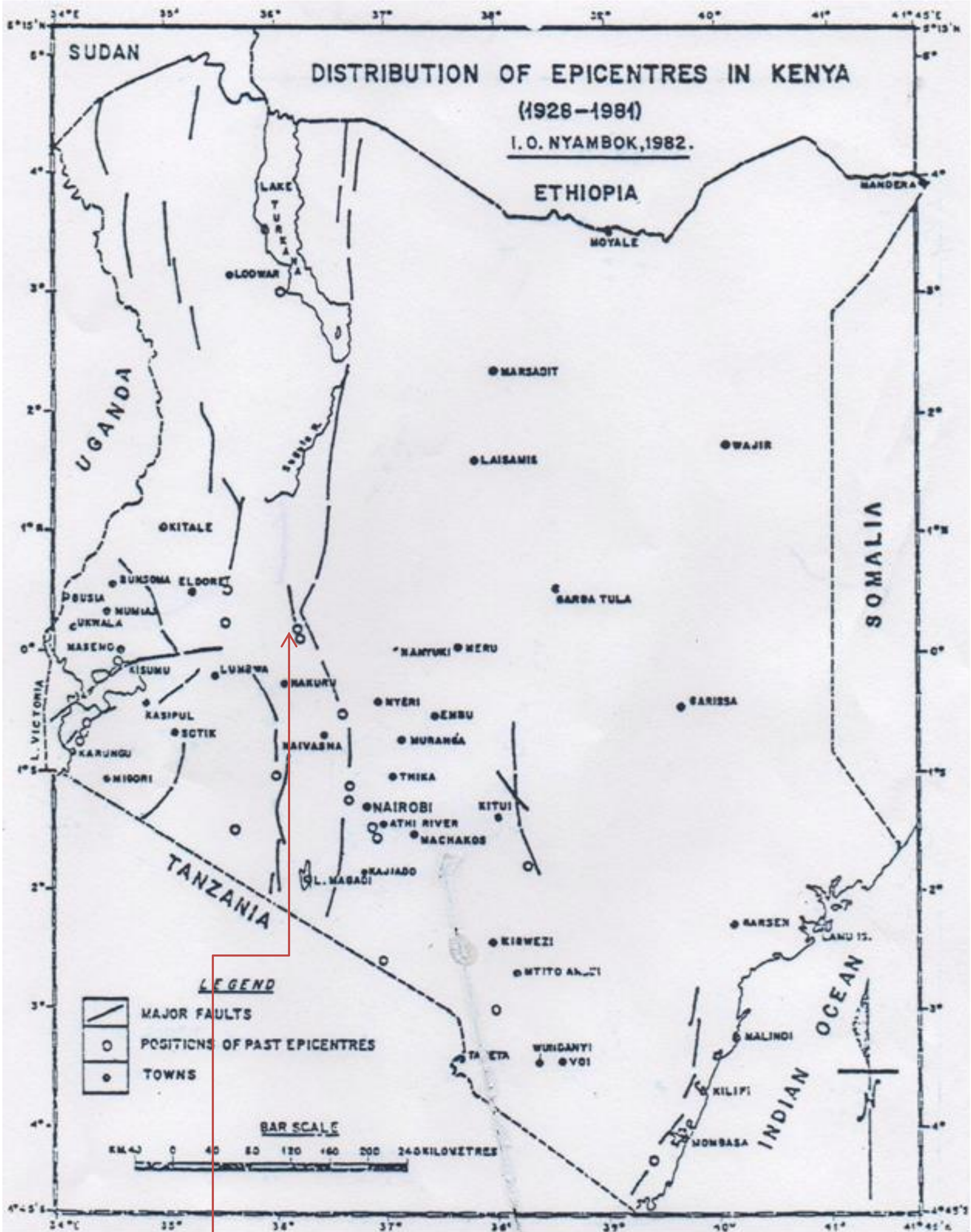


Figure 5:8 Distribution of Earthquake Epicentres in Kenya (I. S. Nyambok, 1982)

Project Area o - Epicntre

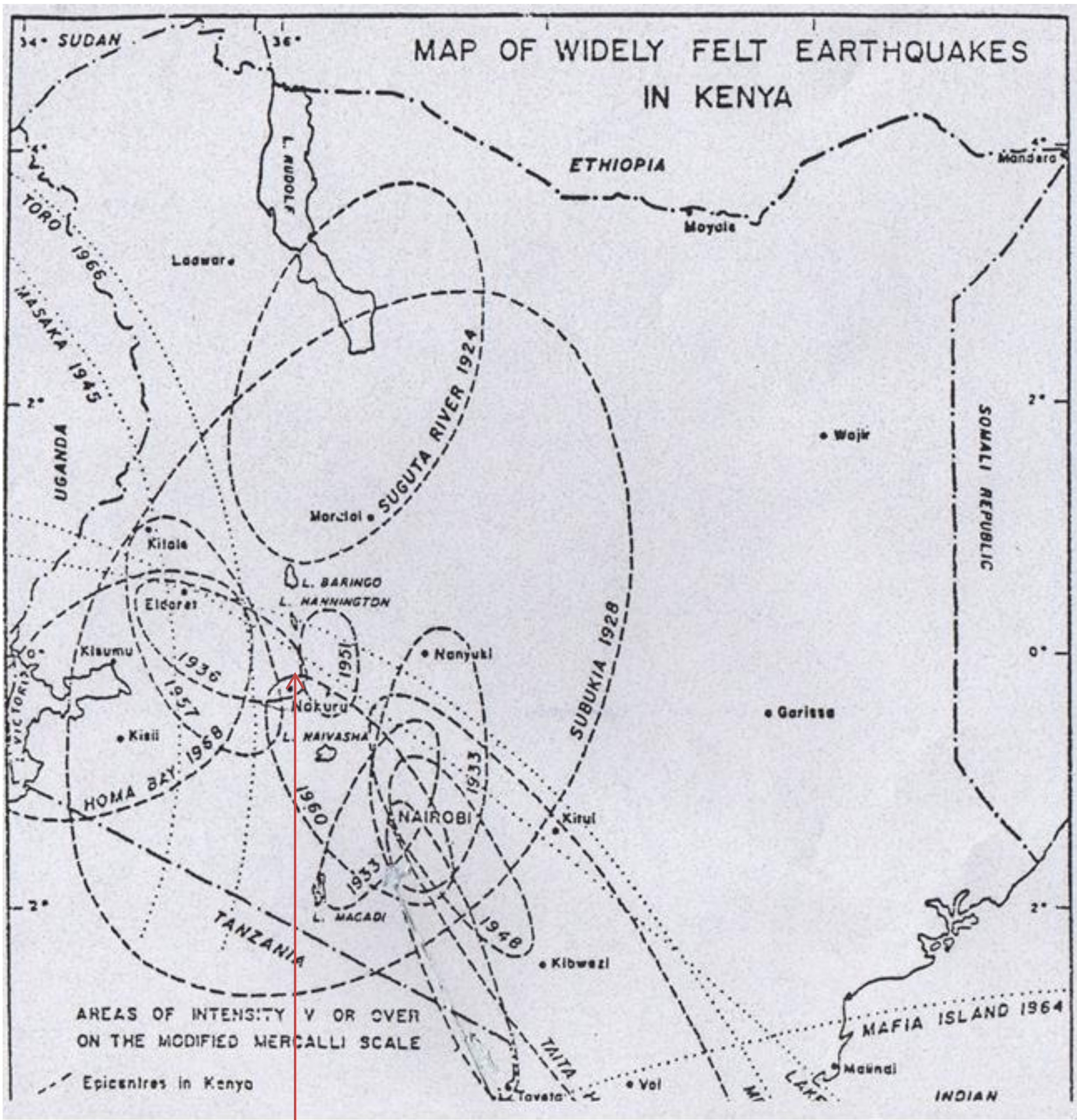


Figure 5:9 Map of Widely Felt Earthquakes in Kenya (I. S. Nyambok, 1982)

Proposed Radat Dam Project Area

5.9 Preliminary Geophysical Investigations

5.9.1 Overview of Geophysical Methods Applied

In the effort to study the subsurface geological conditions of the dam site, geo-electrical resistivity methods were employed by use of ABEM SAS 300B Terrameter and GEOTRON at Radat dam site. The machines used employ geo-electrical principles and have reliable efficacy. The equipment is of high resolution and therefore quite effective in subsurface exploration.

Two approaches were applied which include: Horizontal Electrical Resistivity Profiling (HERP) and Vertical Electrical Sounding (VES). The profiling and soundings were designed to capture certain areas of in the proposed dam site. The layout of the profile lines was influenced by the geomorphology of the dam site area and construed general strike of the underlying rocks. The profile lines were carried out perpendicular to the drainage pattern in order to investigate the lateral variations of the subsurface features (this being underlain by volcanic rocks, subsurface features vary very frequently and at small distances). The soundings (VES) were carried out at points noted to have deep weathering or weaknesses detected by profiling. The aim of vertical electrical soundings (VES) was to probe the variations of rocks with depth and also to establish the depth to bedrock.

In this method electric current is introduced into the ground using current electrodes (A and B), thus creating an electric field between them and the potential difference in that field is measured using potential electrodes (M and N). According to Ohm's Law, the resistance of rock formations (as the conductor) is obtained by dividing the potential difference (at any point in that field) by the electric current. The property that determines the conducting nature of any material is known as resistivity which obtained by multiplying the measured resistance with a geometric coefficient K. The geometric coefficient is dependent on the configuration of the electrodes. The Wenner configuration was used for profiling technique while the Schlumberger configuration was used for vertical electrical soundings (VES) with the array of electrodes as shown in Figure 3.1.

The resistivity ρa is obtained as follows:

$$\rho_a = K * \Delta V / I$$

where: $K = \pi \left(\frac{(AB/2)^2 - (MN/2)^2}{MN} \right)$

ρ_a – Apparent resistivity in Ohm.m
K – Geometric coefficient
π – Pie constant = 3.142
AB – Current electrodes separation
MN – Potential electrodes separation.

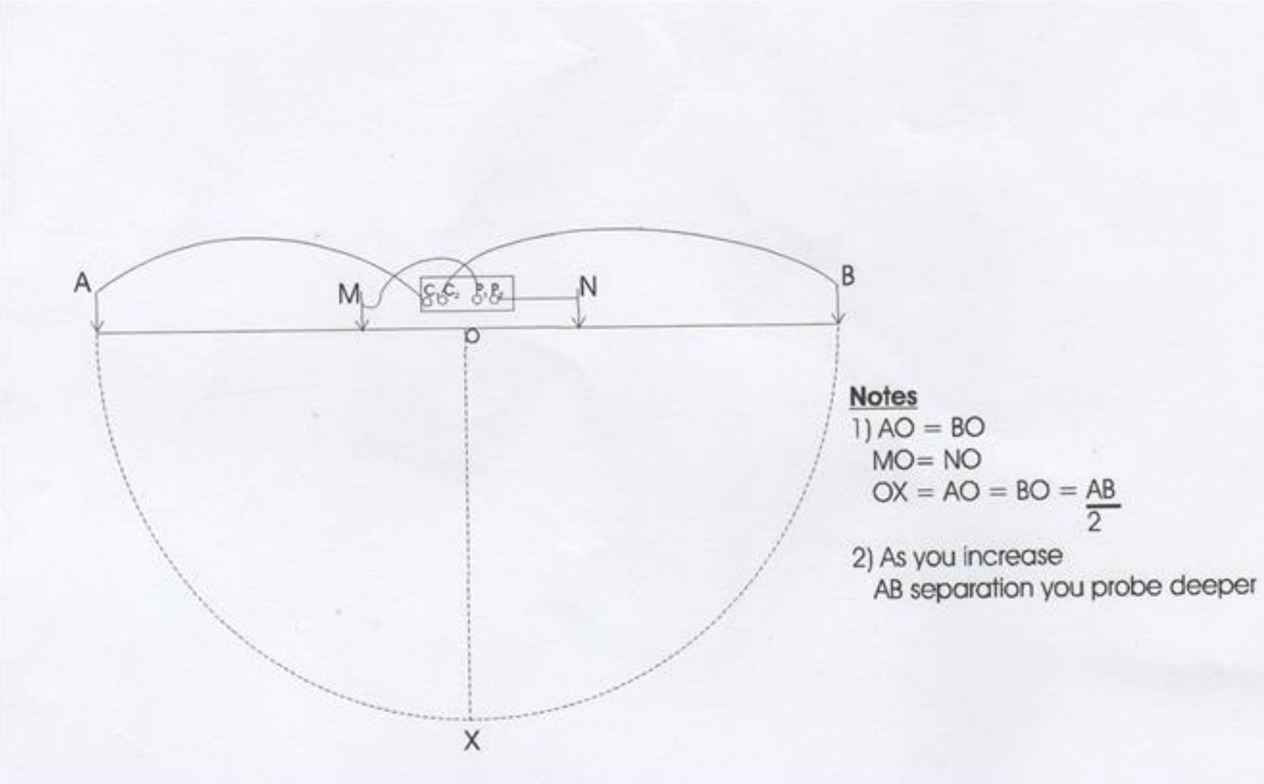


Figure 5:10 Schematic Schlumberger Configurations of Electrodes

5.10 Geophysical Field Investigations

Preliminary field geophysical investigations were carried out from 25th to 30th April 2014 in three proposed dam sites. Proposed Dam Site 1 is about 1km from Radat Trading Center; Proposed Dam Site 2 is about 2km Radat Trading Center; and Proposed Dam Site 3 is about 5km (near the bridge to Kenamoi).

5.10.1 Results of Geophysical Investigations at Dam Site 1

The layout plan of geophysical profiles (HERPS) and vertical electrical soundings (VES) at Radat Proposed Dam Site 1 shown on Figure 5.11. The coordinates of the vertical electrical sounding (VES) locations are in Table 5.1.

Table 5:1 Coordinates and Elevation VES Points (HERP 1 & 2 in Dam site 1)

HERP LINE No.	VES No.	X	Y	Elevation (m)
RADAT HERP I	RAD1-1VES 1	0823943	0031073	1368
	RAD1-1VES 2	0823918	0031087	1369
	RAD1-1VES 3	0823884	0031104	1375
	RAD1-1VES 4	0824085	0031055	1408
	RAD1-1VES 5	0824047	0031069	1396
	RAD1-1VES 6	0824008	0031079	1375
RADAT HERP 2	RAD1-2VES 7	0824019	0031174	1373
	RAD1-2VES 8	0824059	0031165	1384

	RAD1-2VES 9	0823938	0031192	1403
	RAD1-2VES 10	0824123	0031129	1415

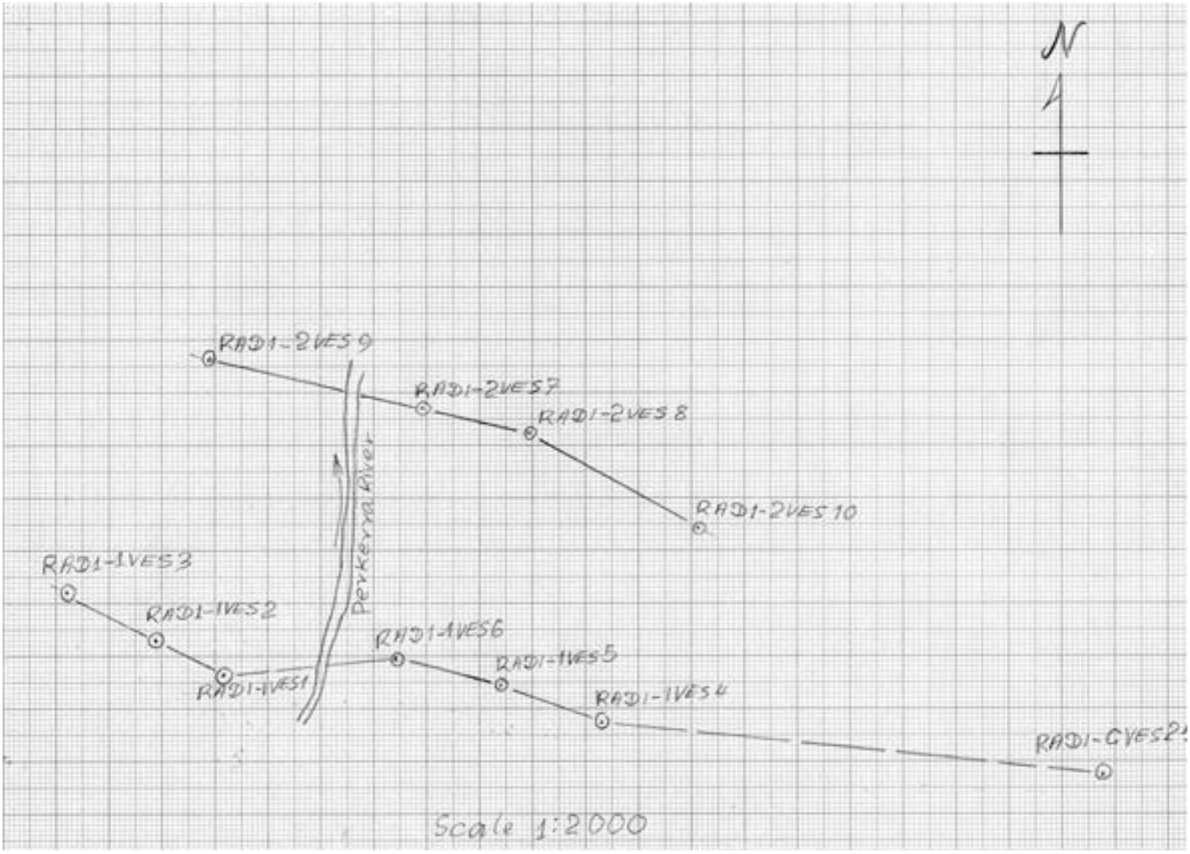


Figure 5:11 Layout Plan of HERP and VES in Radat Proposed Dam Site 1

The river valley at this is very rocky and with steep cliffs so that only two horizontal electrical resistivity profiles (HERP) were carried out. Six vertical electrical soundings (VES) were selected on the profiles and done. Detailed results of interpreted geophysical investigations are given in the Appendices.

Interpretation of Geophysical Investigations Results

Due to the rugged nature of the topography production of results in 2D and 3D tomography presented challenges because of many gaps resulting extrapolations. We have generated a 2D tomography of the foundation using the electrical profiling and vertical electrical data obtained in the field. The field HERD field data were plotted as in Figure 5.12.

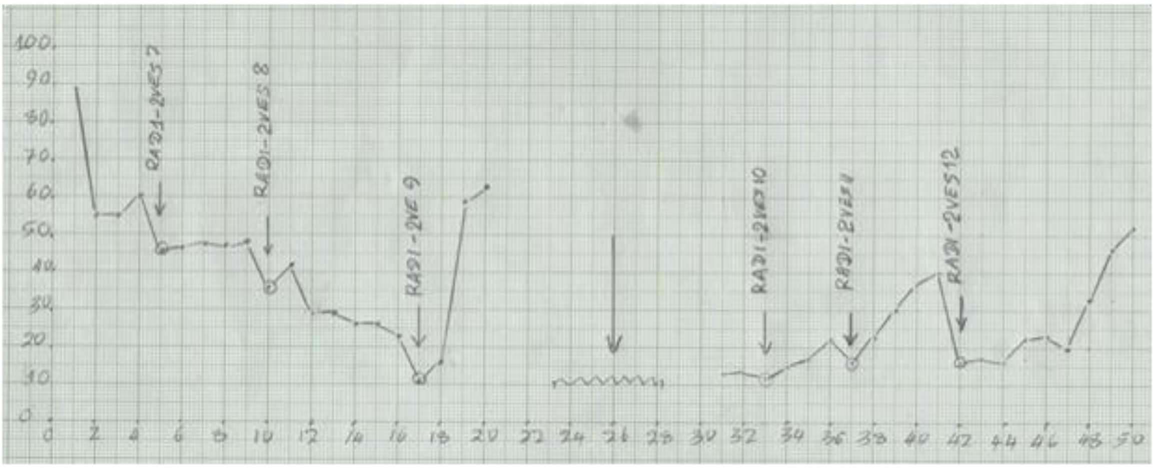


Figure 5:12 HERP Field Data

The interpreted geophysical investigations results for Proposed Dam Site 1 are presented in Tables 5.2 and 5.3.

Table 5:2 Interpreted Geophysical Results for VES on HERP Line 1 (Main Dam Axis)

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RAD-HERP 1	RAD1-1VES 1	0.0 – 1.4	1	24	Top soil composed of fine sands and silts
		1.4 – 6.5	5	30	Wet sandy clay with silts
		6.5 – 7.7	1	28	Wet sandy clay with silts
		7.7 – 24.0	16	9	Wet clay
		24 – 47.0	23	17	Wet clay with fine sands and silts
		> 47		10	Wet clay with silts
	RAD1-1VES 2	0.0 – 1.4	1	152	Top soil composed of weathered rock
		1.4 – 3.9	1.5	15	Wet clay with fine sands and silts
		3.9 – 7.3	3	43	Wet clayey sands with silts
		7.3 – 10.6	3	20	Wet sandy clay with silts
		10.6 – 26.3	16	16	Wet clay with fine sands and silts
		26.3 – 26.7	0.5	15	Wet clay with fine sands and silts
		> 26.7		20	Wet sandy clay with silts
	RAD1-1VES 3	0.0 – 1.3	1	110	Top soil of weathered rock-gravelly sands
		1.3 – 1.9	0.5	9	Thin layer of wet clay
		1.9 – 5.3	3	19	Wet sandy clay with silts

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
		5.3 – 15.7	10	13	Wet clay with silts
		15.7 – 16.6	1	30	Wet clayey sands with silts
		> 16.6		40	Wet clayey sands with silts
	RAD1-1VES 4	0.0 – 3.3	3	39	Top soil of wet clayey sands with silts
		3.3 – 7.4	4	2500	Fresh volcanic rock – basalts
		7.4 – 9.5	2	550	Slightly weathered volcanic rock-basalt
		9.5 – 12.0	2.5	750	Slightly fractured volcanic rock-phonolite
		12.0 – 24.0	12	640	Slightly weathered volcanic phonolite
		> 24.0		2000	Fresh volcanic rock - phonolite
	RAD1-1VES 5	0.0 – 1.4	1	33	Top soil of clayey sands with silts
		1.4 – 1.5	0.1	9	Thin layer of clay
		1.5 – 11.2	9	8	Wet clay
		11.2 – 12.9	1	82	Thin layer of wet sands
		12.9 – 28.0	15	13	Wet clay with silts
		28.0 – 30.0	2	10	Wet clay with silts
		> 30		500	Slightly weathered volcanic rock
	RAD1-1VES 6	0.0 – 1.0	1	18	Wet/moist top soil of sandy clay with silts
		1.0 – 2.3	1	8	Wet clay
		2.3 – 4.6	2	6	Wet clay
		4.6 – 9.4	5	8	Wet clay
		9.4 – 21.5	12	5	Wet clay
		> 21.5		10	Wet clay with silts

A deep vertical electrical sounding (VES) was done as control at the top of the right abutment at proposed dam site 1 (RADAT1-CVES 25) in order to evaluate the succession of rock formations from the top: The position of this VES is X: 0824275 (E), Y: 0031075 (N) at elevation 1475m. The data for this VES is included in Table 5.3 for correlation with VES on HERP Line 1.

Table 5:3 Interpreted Geophysical Results for CVES 25 on HERP Line 1 (Main Dam Axis)

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RAD-HERP 1	RAD1-CVES	0.0 – 1.2	1	389	Top soil composed of weathered rocks

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
	25	1.2 – 4.7	3.5	36	Clayey sands with silts and cobbles
		4.7 – 18.9	14	87	Wet sands with gravel and cobbles
		18.9 – 43.9	25	18	Wet sandy clay with silts
		43.9 – 78.1	34	60	Wet sands with gravel and cobbles
		78.1 – 122	44	12	Wet clay with silts
		> 122		100	Wet highly weathered volcanic rock

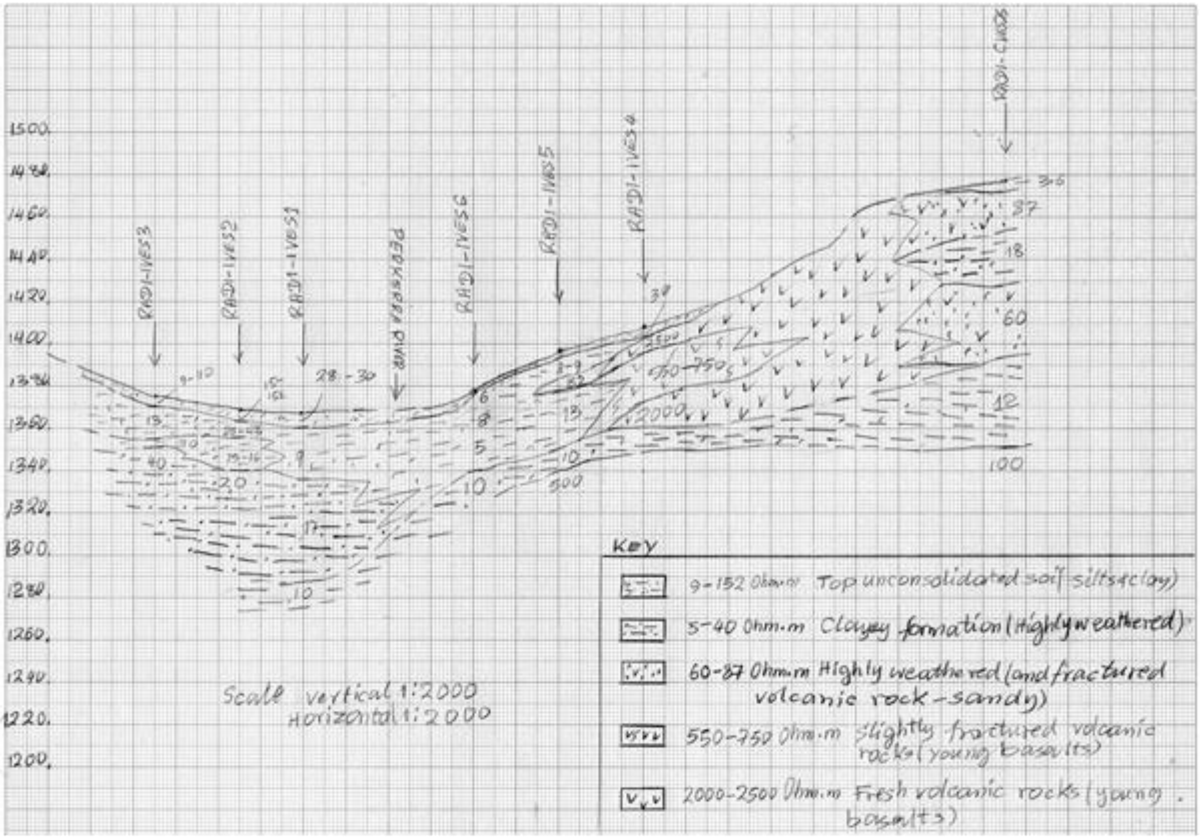


Figure 5:13 Geological correlation cross section along Profile Line 1

Geological correlation cross section was done for only VES on HERP Line 1, however the interpreted geophysical results for VES on HERP Line 2 (50m downstream of the main proposed dam axis) are given in Table 5.4

Table 5:4 Interpreted Geophysical Results for VES on HERP Line 2 (50m downstream main axis)

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RADAT1-HERP2	RAD1-2VES 7	0.0 – 1.6	1.5	218	Top soil composed of sands and gravel
		1.6 – 3.2	1.5	22	Wet clay with fine sands and silts
		3.2 – 6.6	3.5	11	Wet clay with silts
		6.6 – 7.0	0.5	9	Wet clay
		7.0 – 12.4	5.5	8	Wet clay
		12.4 – 23.4	11	7	Wet clay
		> 23.4		10	Wet clay with silts
	RAD1-2VES 8	0.0 – 0.9	1	581	Slightly weathered volcanic - basalts
		0.9 – 1.6	0.5	8	Thin layer of wet clay
		1.6 – 5.2	4	50	Wet sands
		5.2 – 6.1	1	9	Wet clay
		6.1 – 11.0	5	4	Wet clay
		11.0 – 14.0	3	9	Wet clay
		14.0 – 37.5	23.5	1935	Fresh volcanic rocks – phonolites
		> 37.5		200	Slightly weathered volcanic rock
	RAD1-2VES 9	0.0 – 1.7	2	119	Top soil composed of weathered rocks
		1.7 – 7.9	6	20	Wet clay with fine sands and silts
		7.9 – 12.8	5	13	Wet clay with fine sands and silts
		12.8 – 19.2	6	12	Wet clay with silts
		19.2 – 32.0	12	14	Wet clay with fine sands and silts
		32.0 – 63.9	32	11	Wet clay with silts
		> 63.9		20	Wet clay with fine sands and silts
	RAD1-2VES 10	0.0 – 1.1	1	169	Top soil composed of weathered rocks
		1.1 – 1.2	0.1	5	Wet clay
		1.2 – 8.9	8	6	Wet clay
		8.9 – 9.0	0.1	5	Wet clay
		9.0 – 9.1	0.1	4	Wet clay
		9.1 – 115.4	106	3	Wet clay
		115.4		5	Wet clay

5.10.2 Assessment of Proposed Dam Site 2

Geological correlation cross section (Figure 5.18) shows that the foundation rocks at Radat Proposed Dam Site 2 are highly weathered and fractured. However, different rock formations have been differently affected by weathering. The foundation rocks may also have been affected by a minor transverse fault that is notable at Radat area but not well observed at the site. The weathering and faulting actions have resulted in highly fragmented foundation rocks producing volcanic breccia, with clayey fine sands and silts leading in low resistivity values.

The deep control vertical electrical sounding (RADAT1-CVES 25) done at the top of the right abutment gives a more complete picture of the vertical geological variation at this site. A reconnaissance geological map of proposed Radat dam site area is shown on Figure 3.4.

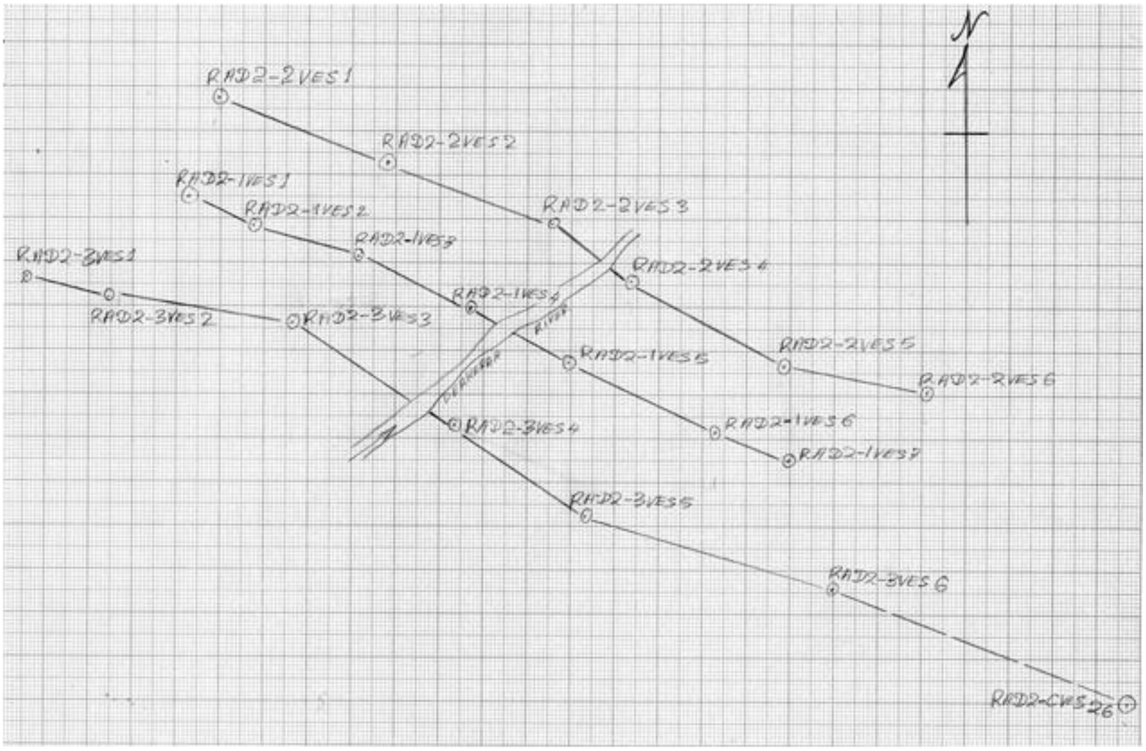


Figure 5:14 Layout plan of HERP and VES in Radat Proposed Dam Site 2

The interpreted geophysical investigations results for Proposed Dam Site 2 are presented in Tables 5.5 – 5.8. Geological correlation cross section along Profile Line 1 (HERP 1 – proposed Dam Axis) is presented in Figure 5.18.

Table 5:5 Interpreted Geophysical Results for Dam SITE 2 (VES on HERP Line 1 Main Dam Axis)

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RADAT2-	RAD2-	0.0 – 1.9	2	1598	Dry top soil with volcanic

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
HERP1	1VES 1				boulders
		1.9 – 5.6	4	266	Dry soil with volcanic cobbles
		5.6 – 13.0	7	32	Wet/moist sandy clay with silts
		13.0 – 29.3	16	100	Weathered volcanic rock
		> 29.3		50	Wet sands
	RAD2-1VES 2	0.0 – 1.4	1	435	Top soil of sands and cobbles
		1.4 – 5.4	4	30	Wet/moist sandy clay with silts
		5.4 – 6.5	1	7	Wet clay
		6.5 – 18.7	12	13	Wet clay with silts
		18.7 – 20.7	2	7	Wet clay
		> 20.7		5	Wet clay

Table 5:6 Geophysical Results for Dam SITE 2 (VES on HERP Line 1 Main Dam Axis)-contd.

HERP No.	**VES No.**	**Depth (m)**	**Thickness (m)**	**Resistivity (Ohm-m)**	**Formation Description**
RADAT2-HERP1	RAD2-1VES 3	0.0 – 1.1	1	20	Top soil of moist clay and silts
		1.1 – 4.0	3	5	Wet clay
		4.0 – 4.1	0.1	9	Wet clay
		4.1 – 10.0	6	19	Wet clay with silt
		> 10.0		3	Wet clay
	RAD2-1VES 4	0.0 – 1.0	1	67	Top soil composed of sands and sits
		1.0 – 1.1	0.1	8	Wet clay soil
		1.1 – 11.1	10	7	Wet clay
		11.1 – 56.0	46	4	Wet clay
		56.0 – 66.8	11	6	Wet clay
		> 66.8		5	Wet clay
	RAD2-1VES 5	0.0 – 2.0	2	181	Top soil composed of sands and gravel
		2.0 – 3.3	1	74	Wet sandy soil
		3.3 – 4.7	1	86	Wet sandy soil
		4.7 – 10.7	6	41	Moist/wet sandy clay with silts
		10.7 – 59.2	48.5	7	Wet clay
		59.2 – 74.6	15	8	Wet clay
		> 74.6		20	Wet clay with silt
	RAD2-1VES 6	0.0 – 1.6	1.5	35	Top soil composed of fine sands
		1.6 – 5.9	4	96	Wet sandy formation

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
		5.9 – 7.8	2	83	Wet sandy formation
		7.8 – 12.1	4	7	Wet clay
		12.1 – 26.9	15	11	Wet clay with silts
		> 26.9		30	Wet sandy clay with silts
	RAD2-1VES 7	0.0 – 1.2	1	27	Top soil composed of sandy clay
		1.2 – 8.0	7	31	Wet/moist sandy clay with silts
		8.0 – 25.9	18	15	Wet clay with silts
		> 25.9		40	Wet clayey fine sands silts
	RAD2-CVES26	0.0 – 3.1	3	206	Top soil composed of sands and gravel
		3.1 – 5.3	2	175	Weathered formation- sands and gravel
		5.3 – 13.7	8	157	Weathered formation- sands and gravel
		13.7 – 25.1	12	47	Moist/wet clayey sands with silts
		25.1 – 35.2	10	23	Wet clay with silt
		35.2 – 74.8	40	18	Wet clay with silts
		> 74.8		10	Wet clay

Table 5:7 Interpreted Geophysical Results for Dam SITE 2 HERP Line 2 (50m Downstream Axis)

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RADAT2-HERP 2	RAD2-2VES 1	0.0 – 2.1	2	1063	Dry top soil with volcanic boulders
		2.1 – 2.2	0.1	216	Dry soil with volcanic cobbles
		2.2 – 23.4	21	126	Weathered volcanic rock
		23.4 – 56.8	33	52	Wet sands
		> 56.8		5000	Compact fresh volcanic rocks
	RAD2-2VES 2	0.0 – 1.2	1	59	Top soil composed of sands and sits
		1.2 – 2.6	1	11	Wet/moist clay with silt
		2.6 – 6.0	3	33	Moist sandy clay with silts
		6.0 – 40.9	35	8	Wet clay
		> 40.9		100	Weathered volcanic rock - basalts
	RAD2-2VES 3	0.0 – 1.2	1	36	Top soil composed of fine sands and sits

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
		1.2 – 4.3	3	9	Moist clay with silt
		4.3 – 8.4	4	19	Wet clay with silt
		8.4 – 16.1	8	9	Wet clay
		16.1 – 56.7	41	3	Wet clay
		56.7 – 56.8	0.1	4	Moist clay
		> 56.8		10	Wet clay with silt
	RAD2-2VES 4	0.0 – 2.5	2.5	42	Top soil composed of fine sands
		2.5 – 5.2	3	50	Wet/moist sands
		5.2 – 6.3	1	9	Wet clay with silt
		6.3 – 43.3	37	7	Wet clay
		> 43.3		10	Wet clay with silt
	RAD2-2VES 5	0.0 – 1.2	1	344	Top soil of sands and cobbles
		1.2 – 2.3	1	36	Moist/wet sandy clay with silts
		2.3 – 3.0	1	24	Wet clay with silts
		3.0 – 5.5	2.5	184	Slightly weathered volcanic rock
		5.5 – 7.7	2	79	Wet/moist sands
		7.7 – 19.3	12	42	Wet clayey fine sands silts
		19.3 – 21.8	2.5	43	Wet clayey fine sands silts
		21.8 – 31.4	10	128	Weathered volcanic rock - basalts
		> 31.4		200	Slightly weathered volcanic rock
	RAD2-2VES 6	0.0 – 0.7	0.7	185	Dry soil with volcanic cobbles
		0.7 – 3.1	2	153	Weathered volcanic rock
		3.1 – 15.5	12	9	Wet clay
		15.5 – 19.4	4	157	Slightly weathered volcanic rock
		> 19.4		500	Slightly weathered volcanic rock

Table 5:8 Geophysical Results for Dam SITE 2 HERP Line 3 (50m Upstream of Main Axis)

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RADAT2-HERP 3	RAD2-3VES 1	0.0 – 1.7	2	1168	Dry top soil with volcanic boulders
		1.7 – 2.2	0.5	212	Dry soil with volcanic cobbles
		2.2 – 4.2	2	540	Slightly weathered volcanic rock

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
		4.2 – 13.1	9	68	Weathered formation composed of sand
		13.1 – 17.9	5	30	Moist/wet sandy clay with silts
		17.9 – 28.5	10.5	62	Wet sands
		28.5 – 56.4	28	50	Wet sands
		> 56.4		200	Slightly weathered volcanic rock
	RAD2-3VES 2	0.0 – 1.5	1.5	1841	Dry top soil with volcanic boulders
		1.5 – 2.8	1	966	Dry top soil with volcanic boulders
		2.8 – 11.4	9	165	Slightly weathered volcanic rock
		11.4 – 14.1	3	52	Wet sands
		14.1 – 26.9	3	25	Wet clay with silts
		> 26.9		10	Wet clay with silts
	RAD2-3VES 3	0.0 – 1.2	1	162	Top soil composed of sands and silts
		1.2 – 7.7	6.5	14	Wet clay with silt
		7.7 – 14.6	7	37	Moist/wet sandy clay with silts
		14.6 – 26.6	12	26	Wet clay with silts
		26.6 – 34.0	7	165	Slightly weathered volcanic rock
		> 34.0		1000	Fresh volcanic rock – phonolite
	RAD2-3VES 4	0.0 – 2.8	3	45	Top soil composed of fine sands and sits
		2.8 – 3.5	1	133	Weathered volcanic rock
		3.5 – 4.1	0.5	9	Moist clay with silt
		4.1 – 17.4	13	3	Wet clay
		17.4 – 30.8	13	7	Wet clay
		30.8 – 379	348	3	Thick layer of wet clay
		> 379		6	Wet clay
	RAD2-3VES 5	0.0 – 2.1	2	42	Top soil composed of fine sands and sits
		2.1 – 2.7	0.5	16	Wet clay with silt
		2.7 – 8.5	6	37	Moist/wet sandy clay with silts
		8.5 – 9.4	1	18	Wet clay with silt
		9.4 – 22.7	12	8	Wet clay
		> 22.7		20	Wet clay with silts
	RAD2-3VES 6	0.0 – 1.4	1	280	Top soil of sands and cobbles
		1.4 – 2.4	1	5	Wet clay

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
		2.4 – 8.3	6	6	Wet clay
		8.3 – 16.0	8	4	Wet clay
		16.0 – 22.5	6.5	8	Wet clay
		> 22.5		30	Wet sandy clay with silts

The deep control vertical electrical sounding (RADAT2-CVES 26) done at the top of the right abutment gives a more complete picture of the vertical geological variation at this site. A geological correlation cross section of proposed dam site 2 area is shown on Figure 3.6.

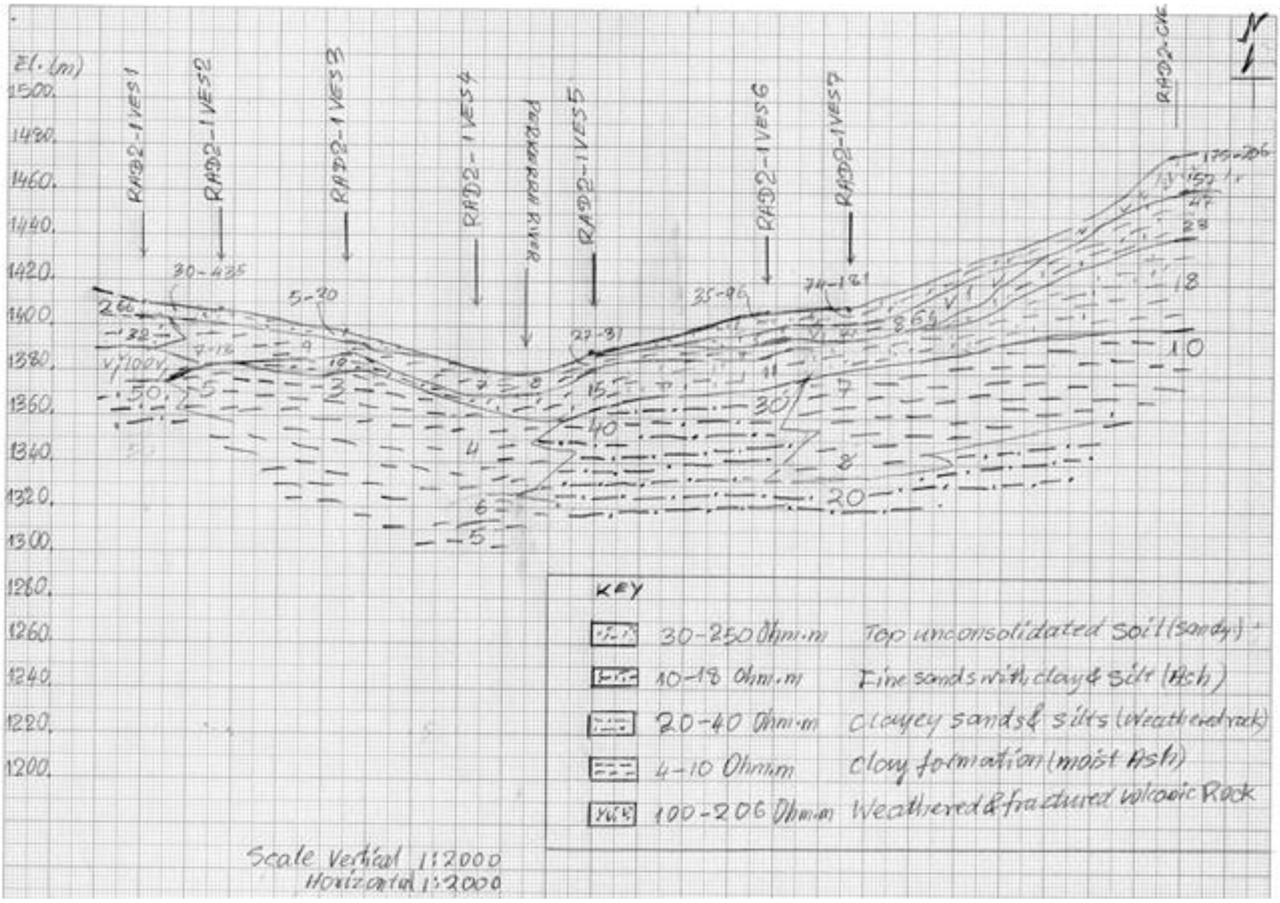


Figure 5:15 Geological Correlation map of Proposed Dam Site 2 Area

5.10.3 Assessment of Proposed Dam Site 3

Geological correlation cross section (Figure 5.20) shows that the foundation rocks at Radat Proposed Dam Site 3 are highly weathered and fractured. However, different rock formations have been differently affected by weathering. The foundation rocks may also have been affected by a minor fault that is notable at Radat area but not well observed at the site. The weathering and faulting actions have resulted in highly fragmented foundation rocks producing volcanic breccia, with clayey fine sands and silts leading in low resistivity values.

The deep control vertical electrical sounding (RADAT1-CVES 26) done at the top of the right abutment gives a more complete picture of the vertical geological variation at this site.

Reconnaissance geological and preliminary geophysical investigations were also carried out at Proposed Radat Dam Site 3 upstream of the Bridge (Kipting') on the road to Kenomoi, about 5km from Radat Trading Center. The layout plan of HERP and VES in Radat Proposed Dam Site 3 is shown in Figure 5.19 (field HERP Data is Shown Figure 5.20), while the same layout in 3D is given in Figure 5.21. The geological Correlation cross-section of Proposed Dam Site 3 Area is given on Figure 3.22. The coordinates and elevation of the VES in Radat Proposed Dam Site 3 are given in Table 5.9.

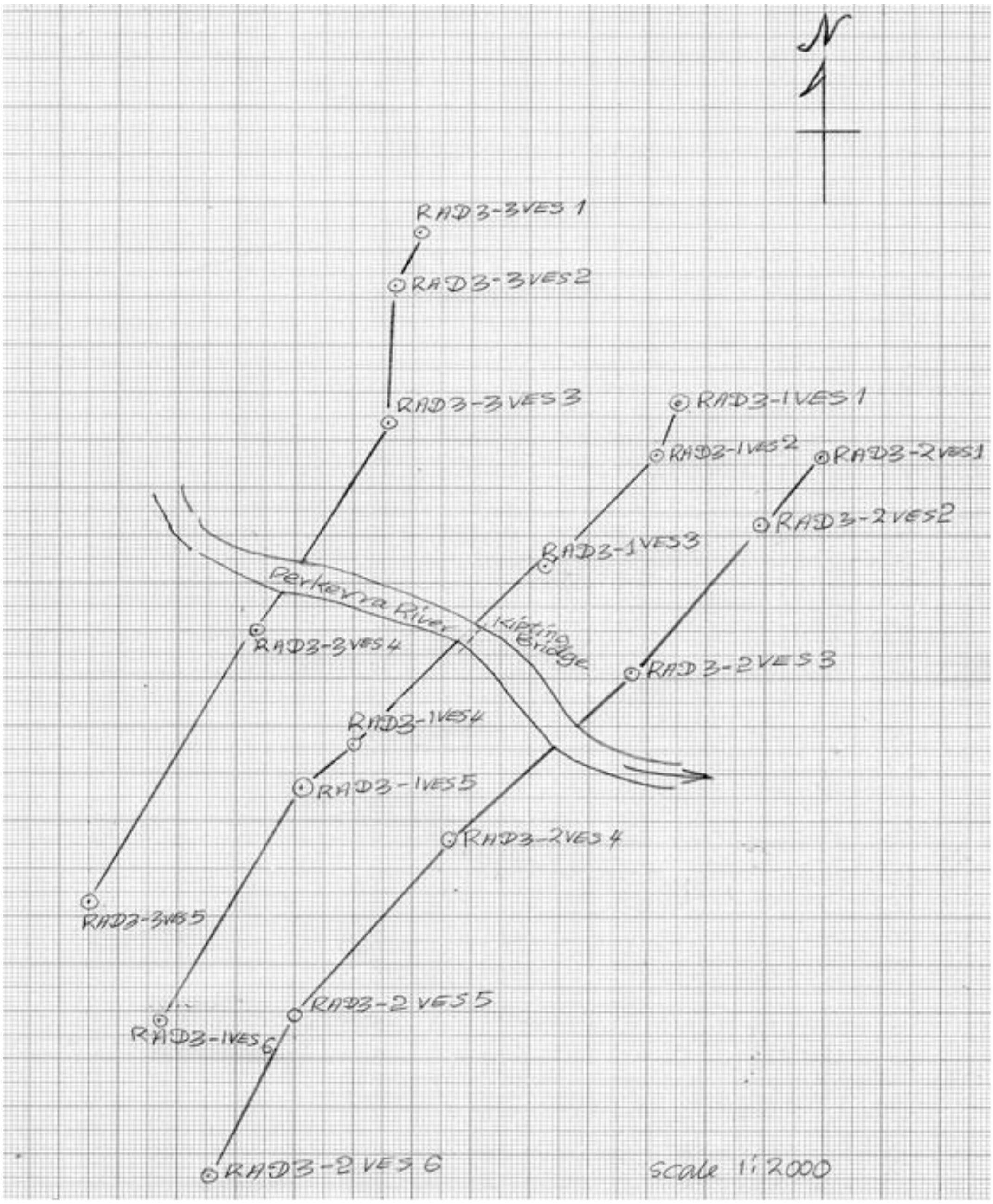


Figure 5:16 Layout plan of HERP and VES in Radat Proposed Dam Site 2

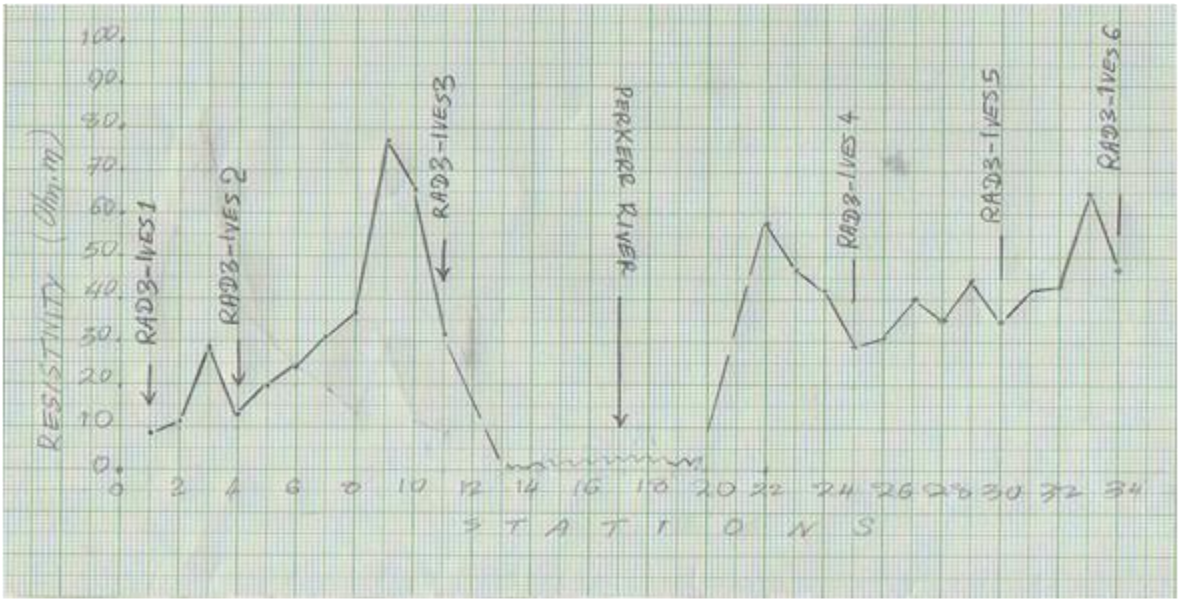


Figure 5:17 HERP Field Data

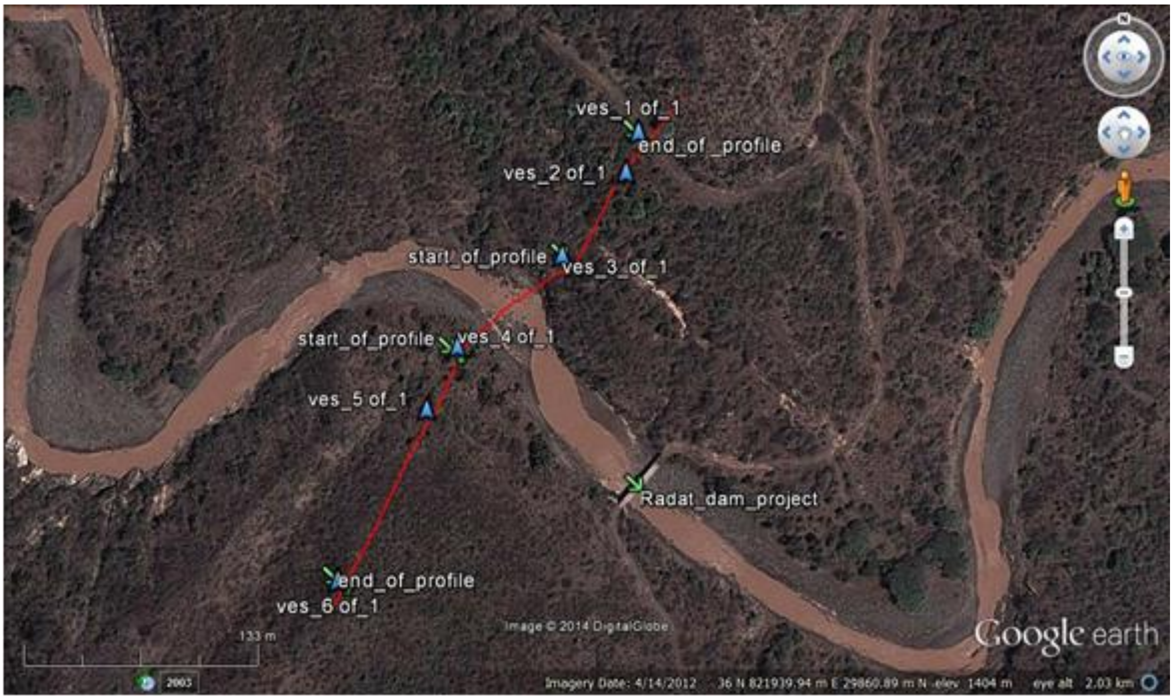


Figure 5:18 : Layout of HERP and VES in Dam Site 3 Kipting Bridge Area (in 3D)

Due to the rugged nature of the topography production of results in 2D tomography presented challenges because of many gaps resulting in extrapolations. We have generated a 2D tomography of the foundation using the electrical profiling and vertical electrical data obtained in the field. The generated 2D tomography is presented in Figure 3.9..

Table 5:9 Coordinates and Elevation of VES Points (HERP 1 - 3 in Dam site 3)

HERP LINE No.	VES No.	X	Y	Elevation (m)
RADAD3 HERP I	RAD3-1VES 1	0821970	0029976	1450
	RAD3-1VES 2	0821963	0029954	1436
	RAD3-1VES 3	0821925	0029907	1400
	RAD3-1VES 4	0821860	0029852	1386
	RAD3-1VES 5	0821842	0029814	1401
	RAD3-1VES 6	0821794	0029716	1446
RADAD3 HERP 2	RAD3-2VES 1	0822019	0029953	1443
	RAD3-2VES 2	0821998	0029924	1437
	RAD3-2VES 3	0821954	0029862	1412
	RAD3-2VES 4	0821893	0029811	1391
	RAD3-2VES 5	0821840	0029709	1440
	RAD3-2VES 6	0821811	0029651	1453
RADAD3 HERP 3	RAD3-3VES 1	0821882	0030047	1464
	RAD3-3VES 2	0821874	0030025	1456
	RAD3-3VES 3	0821872	0029968	1434
	RAD3-3VES 4	0821827	0029880	1386
	RAD3-3VES 5	0821770	0029767	1426

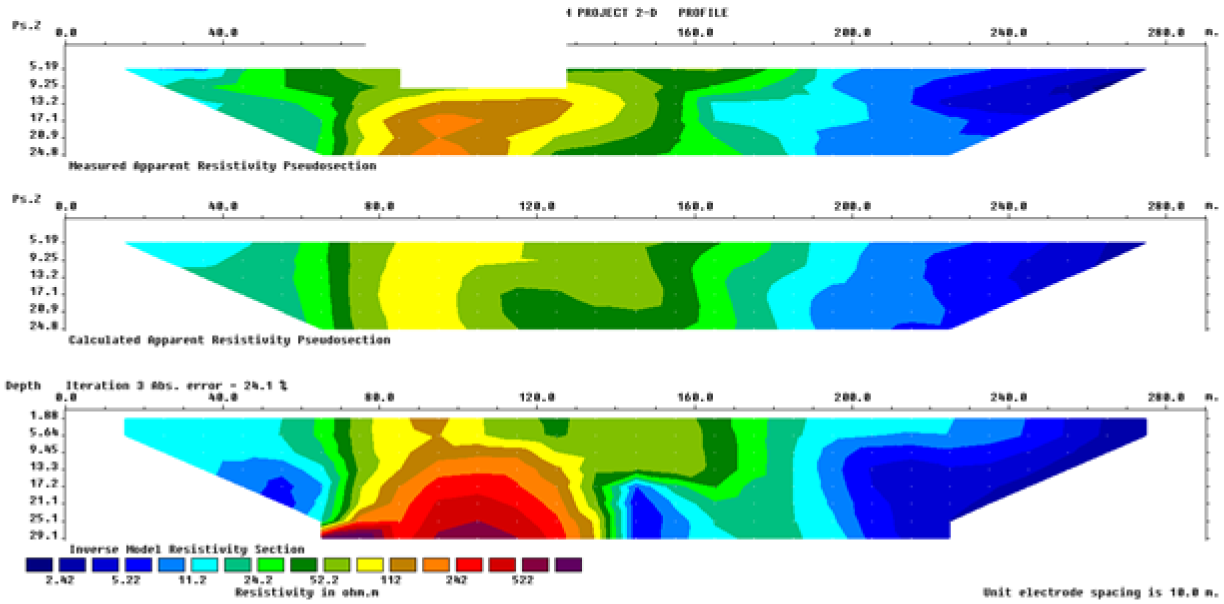


Figure 5:19 Generated 2D Geophysical Model of Selected Radad Dam Site (Kipting Bridge Area)

Notes:

1. 1) The foundation at the middle (center) this profile is underlain by clayey fine sandy formation (resistivity values 11.2 – 52.2 ohm.m). This is

the riverbed area. At depth the formation turns highly clay due to highly weathered older basalts of Saburu Type.

2. On the Left Hand Side a block relatively high resistivity values (52.2 – 522 ohm.m) was detected: this is of localized extent and it is due the young basalt exposed in this area overlying phonolites.
3. Further up on the left bank (resistivity values 5.2 – 112 ohm.m) is weathered phonolites resting/abutting on tuffs and sediments of Eldama Ravine Series (these were observed in the field (see Plate 2.4a above).
4. On the right hand side (Right Bank from riverbed area) the foundation is composed of weathered phonolites overlain by a thin layer of young basalts (Kwaibus type). The phonolites are underlain/abutting on tuffs and sediments (Eldama Ravine Type). The resistivity values progressively from 52.2 ohm.m to 2.42 ohm.m (from clayey sands to highly clay formation)

The evaluations compare very well with the geological correlation cross-section obtained from resistivity sounding (VES) data in Figure 3.13 below. The interpreted geophysical investigations results for Proposed Dam Site 3 are presented in Tables 5.10 – 5.12.

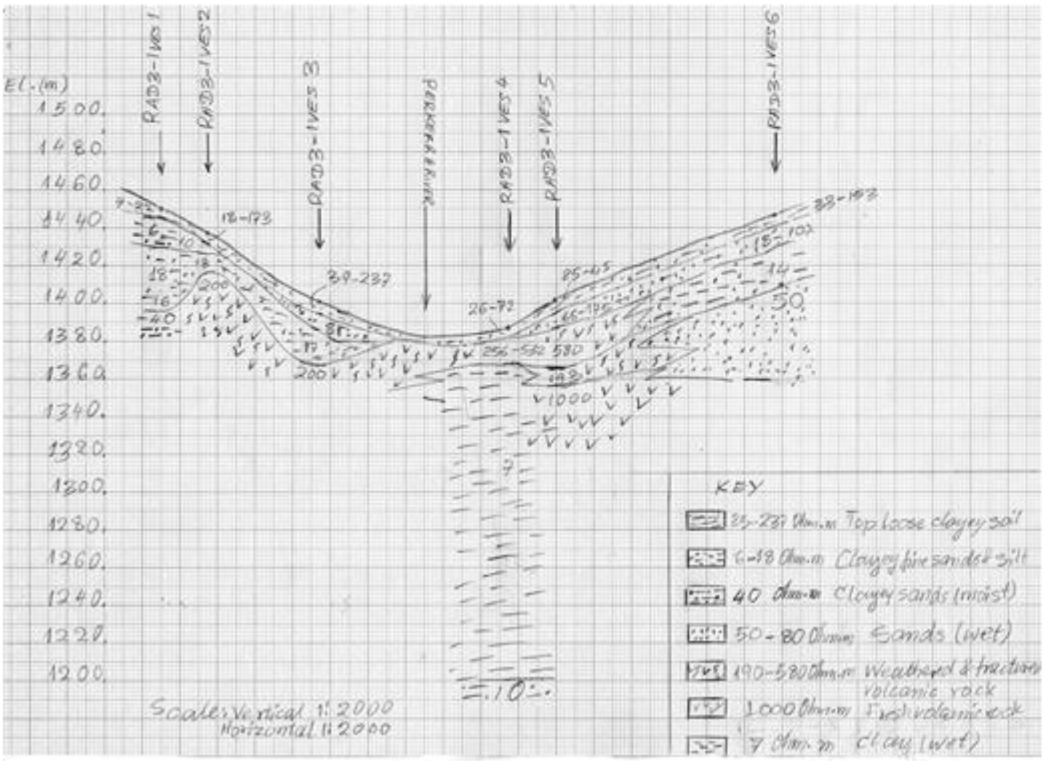


Figure 5:20 Geological correlation cross section along Profile Line 1 (Radad Site 3)

Table 5:10 Interpreted Geophysical Results for Dam SITE 3 HERP Line 1 (Proposed

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RADAT3-HERP 1	RAD3-1VES 1	1.0 – 1.5	1.5	1841	Top very slightly fractured volcanic rock

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
		1.5 – 2.8	1	966	Slightly Afractured rocks
		2.8 – 11.4	9	165	Weathered volcanic rock – moist
		11.4 – 14.1	3	52	Weathered wet volcanic sandy formation
		14.1 – 26.9	3	25	Wet clay with fine sands and silts
		> 26.9		10	Wet clay with silt
	RAD3-1VES 2	0.0 – 1.2	1	162	Weathered volcanic rock – moist
		1.2 – 7.7	6.5	14	Wet clay with silt
		7.7 – 14.6	7	37	Wet clay with fine sands
		14.6 – 26.6	12	26	Wet clay with fine sands and silts
		26.6 – 34.0	7	165	Slightly weathered wet volcanic rock
		> 34.0		1000	Fresh volcanic rocks - phonolites
	RAD3-1VES 3	0.0 – 2.8	3	45	Top soil composed of clayey fine sands
		2.8 – 3.5	1	133	Slightly weathered volcanic rock
		3.5 – 4.1	0.5	9	Thin layer of wet clay
		4.1 – 17.4	13	3	Wet clay
		17.4 – 30.8	13	7	Wet clay
		30.8 – 379	348	3	Thick layer of wet clay
		> 379		6	Wet clay
	RAD3-1VES 4	0.0 – 2.1	2	42	Top soil composed of clayey fine sands
		2.1 – 2.7	0.5	16	Wet clay with silt
		2.7 – 8.5	6	37	Wet clayey fine sands and silts
		8.5 – 9.4	1	18	Wet clay with fine silts
		9.4 – 22.7	12	8	Wet clay
		> 22.7		20	Wet clay with fine sands and silts
	RAD3-1VES 5	0.0 – 1.4	1	280	Slightly weathered volcanic rock
		1.4 – 2.4	1	5	Wet/moist clay
		2.4 – 8.3	6	6	Wet/moist clay
		8.3 – 16.0	8	4	Wet clay
		16.0 – 22.5	6.5	8	Wet clay

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
		> 22.5		30	Wet clayey fine sands and silts
	RAD3-1VES 6	0.0 – 1.2	1	45	Top soil composed of clayey fine sands
		1.2 – 2.2	1	25	Wet clay with silt
		2.2 – 2.7	0.5	43	Wet clayey fine sands and silts
		2.7 – 6.8	4	172	Slightly weathered volcanic rock
		6.8 – 14.8	8	66	Wet sandy formation
		14.8 – 35.5	21	580	Very lightly fractured volcanic rock
		35.5 – 44.1	9	193	Slightly weathered volcanic rock
		> 44.1		1000	

Table 5:11 Geophysical Results for Dam SITE 3 HERP Line 2 (50m Downstream of Dam Axis)

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RADAT3-HERP 2	RAD3-2VES 1	0.0 – 2.0	2	45	Top soil composed clayey fine sands
		2.0 – 2.1	0.1	3	Wet clay
		2.1 – 6.3	4	5	Wet clay
		6.3 – 87.5	81	3	Wet clay
		> 87.5		10	Moist clay with silts
	RAD3-2VES 2	0.0 – 1.0	1	20	Top soil composed clay
		1.0 – 7.2	6	7	Moist/wet clay
		7.2 – 11.9	4	9	Wet clay
		11.9 – 12.0	0.1	7	Wet clay
		12.0 – 19.9	8	6	Wet clay
		19.9 – 50.0	30	7	Wet clay
		> 50.0		3	Wet clay
	RAD3-2VES 3	0.0 – 1.1	1	271	Loose top soil composed of boulders
		1.1 – 3.6	2.5	27	Moist clay soil
		3.6 – 14.1	10.5	95	Moist sand formation
		14.1 – 251	137	8	Wet clay
		> 251		15	Wet clay with silts and fine sands
	RAD32-	0.0 – 2.0	2	98	Loose top soil – sandy

	2VES 4	2.0 – 2.5	0.5	47	Moist clayey fine sands and silts
		2.5 – 6.3	4	83	Wet/moist sands
		6.3 – 17.4	11	43	Moist clayey fine sands and silts
		17.4 – 51.0	34	66	Wet sands
		51.0 – 55.0	4	45	Wet clayey fine sands and silts
		> 55.0		1000	Fresh volcanic rocks (phonolites)
	RAD3-2VES 5	0.0 – 1.4	1	119	Top loose and dry soil
		1.4 – 3.2	2	9	Moist clayey soil
		3.2 – 7.2	4	41	Wet/moist clayey fine sands and silts
		7.2 – 25.2	18	28	Wet sandy clay with silts
		25.2 – 26.0	1	20	Wet sandy clay with silts
		26.0 – 78.3	52	8	Thick layer of wet clay
		> 78.3		40	Wet clayey fine sands and silts
	RAD3-2VES 6	0.0 – 1.4	1	38	Top moist clayey soil
		1.4 – 2.4	1	13	Moist clayey soil
		2.4 – 20.6	18	28	Wet sandy clay with silts
		20.6 – 22.2	2	20	Wet sandy clay with silts
		22.2 – 43.8	22	15	Wet clay with silts
		> 43.8		40	Wet clayey fine sands and silts

Table 5:12 Geophysical Results for Dam SITE 3 HERP Line 3 (50m Upstream of Dam Axis)

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
RADAT3-HERP 3	RAD3-3VES 1	0.0 – 1.8	2	76	Moist loose top soil (clayey fine sands)
		1.8 – 6.2	4	53	Wet sands and silts
		6.2 – 22.5	16	9	Wet Clay formation (deep weathering)
		22.5 – 51.1	29	9	Wet Clay formation (deep weathering)
		> 51.1		30	Wet sandy clays and silts
	RAD3-3VES 2	0.0 – 1.5	1.5	45	Moist loose top soil (sands clay)
		1.5 – 2.3	1	13	Wet sandy clays with silts
		2.3 – 14.6	12	3	Wet Clay from (deep

HERP No.	VES No.	Depth (m)	Thickness (m)	Resistivity (Ohm-m)	Formation Description
					weathering)
		14.6 – 20.3	6	8	Wet Clay formation (deep weathering)
		> 20.3		50	Wet sands and silts
	RAD3-3VES 3	0.0 – 1.5	1.5	174	Top unconsolidated soil will boulders
		1.5 – 5.7	4	18	Wet sandy clays with silts
		5.7 – 14.6	9	59	Wet sands
		14.6 – 31.1	17	19	Wet sandy clays with silts
		> 31.1		40	Wet clayey sands and silts
	RAD3-3VES 4	0.0 – 1.1	1	61	Top loose clayey soils
		1.1 – 2.8	2	9	Wet Clay formation (deep weathering)
		2.8 – 8.7	6	18	Wet sandy clays with silts
		8.7 – 10.7	2	14	Wet sandy clays with silts
		10.7 – 25.0	14	68	Wet sands- aquiferous
		> 25.0		800	Slightly fractured volcanic rocks
	RAD3-3VES 5	0.0 – 1.3	1	118	Loose top soil with weathered boulders
		1.3 – 8.9	7.5	45	Wet clayey sands and silts
		8.9 – 10.0	2	61	Wet sands- aquiferous
		10.0 – 19.2	9	25	Wet Clayey fine sands and silts
		19.2 – 44.7	25.5	15	Wet sandy clays with silts
		> 44.7		40	Wet clayey sands and silts

Figure 5:21 Geophysical investigations in progress at Dam site 3

5.10.4 Assessment of Proposed Dam Site 3

Geological correlation cross section (Figure 5.20) shows that the foundation rocks at Radat Proposed Dam Site 3 are highly weathered and fractured. However, different rock formations have been differently affected by weathering. The foundation rocks may also have been affected by a minor transverse fault that is notable at Radat area but not well observed at the site. The weathering and faulting actions have resulted in highly fragmented foundation rocks producing volcanic breccia, with clayey fine sands and silts leading in low resistivity values. Of particular interest is thick layer of clay observable at the riverbed area at this site.

5.11 Discussion

Both field geological reconnaissance survey and preliminary geophysical investigations have indicated that the foundation rocks at the three proposed Radat dam sites are highly weathered and slightly fractured. The geological correlation cross sections at the three proposed dam sites are generally similar:

- The foundation at the riverbed is composed of clayey fine sands and silts with a thickness of over 80m (in all the three dam sites);
- The foundation on the abutments is composed highly weathered volcanic rocks (basalts of Samburu Basalt Series) which are mainly clayey sands gravel;
- At dam site 1 the right hand side abutment (the upper section) the foundation is composed of fresh volcanic rocks (basalts of Kwaibus series) – these basalts are observable on the detailed reconnaissance map (Figure 3.4);
- At dam site 2 the upper section composed of fresh volcanic rocks is absent; the foundation is composed of highly weathered rocks with fragments underlying parent rocks;
- The foundation on left hand side abutment is similar in all the three dam sites and is composed of highly weathered basalts of Samburu basalt series; and
- The foundation at dam site 3 the river bed area is underlain by a very clay layer of 100m.

A general observation is that the at depth the foundation is composed of clays with silts and clayey fine sands which are deemed to be products of weathering of the oldest rock in this area – the Samburu basalts (these well exposed at dam site 3).

5.12 Preliminary Construction Materials Investigations

5.12.1 Overview of Constructions Materials Survey

During reconnaissance visits it was observed that soils suitable for in an earth fill dam were apparently absent. It was therefore proposed that since the project area is replete with rocks can be used for a rock fill dam, preliminary survey to identify areas with potential rock fill construction materials.

During the current preliminary survey observations were made at areas with potential as source areas for impervious core identified.

5.12.2 Soil Sampling by Trial Pits

Preliminary soil sampling by trial pits was done at areas with potential as source areas for impervious core materials. It was noted that in most localities the soils were shallow grey and brownish clayey silts and fine sands with gravel and cobbles derived from the weathering the underlying volcanic rocks.

Seven trial pits (TP) were dug and samples collected: One (1) at Radat Dam Site 1, Four (3) at Radat Dam Site 2 and Three (3) at Radat Dam Site 3. The coordinates of points the where the samples were collected are given in Table 5.13. Test was also made on a rock sample collected from the riverbed area.

5.12.3 Results of Laboratory Soil Testing

The soils have been taken for laboratory but the full results have not been received.

Table 5:13 Coordinates of Trial Points

Dam Site	TP No.	Coordinates		Remarks
		X	Y	
RADAT SITE 1	TP2- Rad 1 (LB)	0823922 (E)	0031111 (N)	On Figure 3.
RADAT SITE 2	TP1-Rad 2 (LB)	0822994 (E)	0030664 (N)	On Figure
	TP2- Rad 2	0823440 (E)	0030083 (N)	On Figure
	TP3- Rad 2	0823782 (E)	0031178 (N)	On Figure
RADAT SITE 3	TP1- Rad 3	0821969 (E)	0029972 (N)	On Figure 3.7
	TP2- Rad 3	0822020 (E)	0029700 (N)	Plate 4.1
	TP3- Rad 3	0822120 (E)	0029512 (N)	On Figure 3.7

One particular soil sample seems to have promising characteristics was collected from TP near the Bridge (Kipting). This area is recommended detailed soil investigation by auger method. A spot of this area is shown in the figures below

Figure 5:22 A Layer of Red Clay Soil in Tuffs and Sediments (Soil sample collected here)

Figure 5:23 A Layer of Red Clay Soil – same above sowing overlying Basalts

Kwaibus Basalts (Tvb_3) Red Clay Soil at the top of Tuffs and Sediments (Tvf_2)

5.12.4 Results of Laboratory Soil Testing

The samples were submitted for laboratory analyses to the "Soil Mechanics Laboratory, of Civil & Construction Engineering of University of Nairobi". The results of laboratory testing are summarized in Table 4.2.

Table 5:14 Summary of Laboratory Soil Testing Results

Sample	Atterberg Limits				Compaction 2.5kg		Triaxial		Permeability	Sieve Analysis
	LL %	PL %	PI %	SL %	MDD g/cm³	OMC %	C Kg/cm²	ø deg.	K cm/sec	
TP2- Rad 1 (LB)	34	I8	16	5.7	1576	19.6	0.04	26^0	7.939×10^{-5}	See graph
TP1-Rad 2 (LB)					1414	25.1	0.08	26^0	1.020×10^{-4}	See graph
TP1-Rad 2 (RB)							0.08	25^0	5.021×10^{-4}	See graph
TP2- Rad 2 (0.9m)	53	28	25	10	1559	18.5	0.13	23^0	1.250×10^{-3}	See graph
TP3- Rad 2					1685	16.1	0.12	23^0	4.486×10^{-5}	See graph
TP1- Rad 3					1498	23.3	0.07	27^0	3.836×10^{-4}	See graph
TP2- Rad 3					1712	13.6	0.10	24^0	7.931×10^{-4}	See graph
TP3- Rad 3					1256	34.4	0.08	27^0	2.707×10^{-4}	See graph

Notes: Results of the following tests are attached in the soil Laboratory test results Appendix.

a. *Results for Sieve Analysis – the grading curve graphs are given separately.*
b. *Pin Hole Test indicated that all the samples are NON DISPERSIVE.*
c. *Consolidation and UCS presented separately*

5.12.5 Interpretation of Soil Testing Results

Particle Size Grading (sieve analysis)

The sieve analyses for eight (8) samples and one rock sample indicate percentage passing Sieve No. 200 (grain size for fine sand) is more than 60% for nearly all the soil samples and that the percentage retained is less than 50%. This means that all the samples are fine grained and further classification can be done using Atterberg Limits (results on Atterberg Limits were received for two samples only). These will be analysed using Plasticity Chart in order to get a further representative classification of the soils in the project area. Otherwise the soils in the project area are clayey fine sands with some gravel. The fact that the soils are non-dispersive is an indication that the silt content is low. The grading curves are presented in Figure 4.1a to 4.1h

Comments:

1) Curve for sample TP1-Rad2 (LB) is CLAYEY fine SAND with some gravel.
2) Curve for sample TP1- Rad 2 (LB) is fine SAND with gravel.
3) Curve for sample TP1- Rad 2 (LB)-taken from100m from riverbed is silty sand with gravel.
4) Curve for sample TP2- Rad 2 is fine SAND with gravel.
5) Curve for sample TP2- Rad 2 (0.9m) from upper zone (0.9m depth) is fine silty SAND with very little gravel.
6) Curve for sample TP1- Rad 3 – in Kipting area is fine SAND with gravel and some silt.

7) Curve for sample TP2- Rad 3 is SAND with some silt and some little gravel.
8) Curve for sample TP3- Rad 3 (Kipting near the Bridge) is fine SAND with some silt little gravel.
9) Curve for rock sample taken from the riverbed is sand with gravel.

All samples indicate they are fine SANDS with gravel and a few with silt. The FINES will be classified using Plasticity Charts.

Atterberg Limits

In using Atterberg Limits to classify the fine grained soils a Plasticity Chart was drawn and Plasticity Indices are plotted against the Liquid Limits for all the samples analyzed. Clays plot above the A-line while Silts plot below it.

The soils samples analyzed for Radat Dam Site plot above A-line, indicating that the soils are Clays with some fine sand and some silt. This is a good finding because silts are incompressible and also tend to cause piping. The Plasticity Chart for samples analyzed is presented on Figure 4.2.

The suitability of the soils as fill material is also confirmed by the relatively high Plasticity Index for the individual (seven greyish browm) soil samples. By definition Plasticity Index of a soil is 'the range of moisture content over which soil is plastic or malleable'. In the given soil samples the Plasticity Index lies between 18 % and 35 % with an average of 25%. This consideration excludes results for sample of rock collected from the riverbed area.

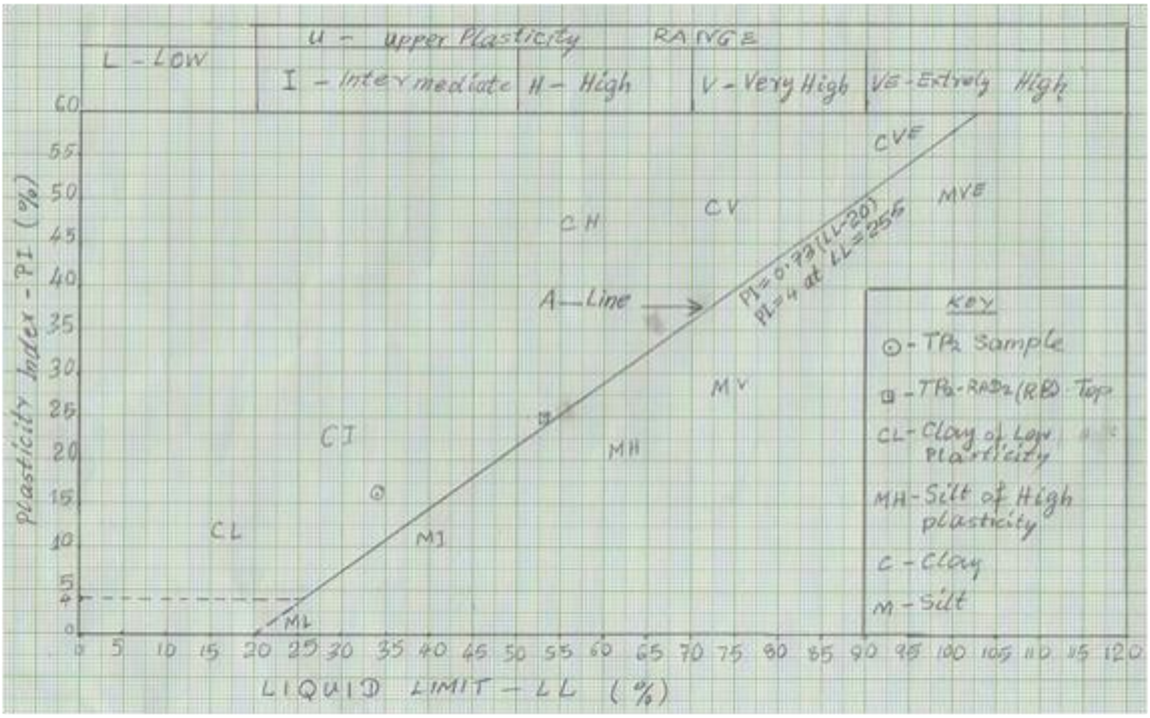


Figure 5:24 Plasticity Chart for Samples analyzed

Note: All samples plot above "A" – Line, the FINES are Clay

The soils are clearly fine SAND with some FINES. A further refined classification may be used, combining the use of ***A-line*** and ***U-line***. This is used when LL = 45% and PI = 25%. The samples collected have average LL = 43.5% and PI = 20.5%. The equation for ***A-line*** is PI = 0.73(LL-20), while for ***the U-line*** it is PI = 0.9(LL-8). The final further classification is shown on Figure 4.3.

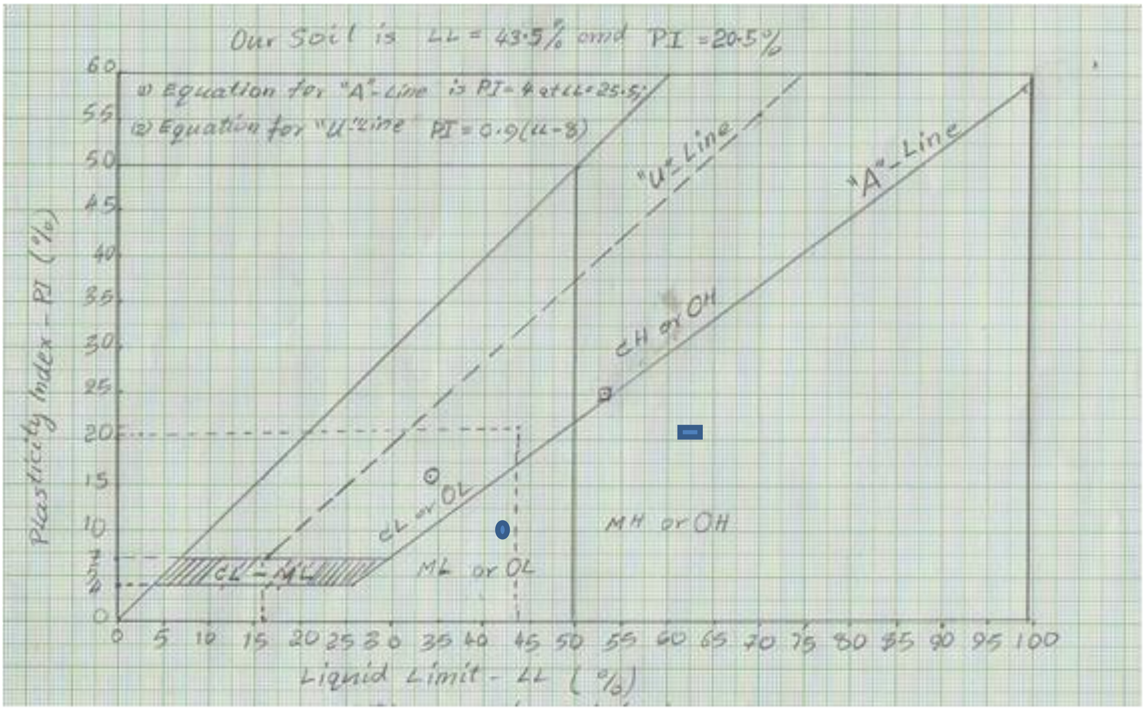


Figure 5:25 Plasticity Chart for the Samples Analyzed

TP2 2-Rad 2 Sample (RB) at the top

From these evaluations the soils are clayey fine SANDS (SCI to SCH) of intermediate to high plasticity with some gravel.

5.12.6 Other Soil Characteristics

Compaction Tests (Proctor Test)

Compaction tests indicate that Maximum Dry Density (MDD) ranges between 1256g/cm3 and 1712g/cm3 (with an average of 1529 g/cm3) and Optimum Moisture Content (OMC) ranges between 13.6% and 34.4% (with an average of 21.5%). This means that the soils are compactible but the rather low OMC means low requirement of water due to the sandy nature of the soil.

Shear Box Tests

Shear Box test results indicate that the Cohesion Coefficient C varies between 0.04 and 0.13kg/cm2 with an average of 0.09kg/cm2. This is due to the presence of fine sand but the Cohesion Coefficient C is acceptable. The angle shearing, ø has range of 23° to 27° with an average of 25° which acceptable although ideally it should be in the range 18° – 24°.

Permeability K

The soils have a high permeability Coefficient K ranging between 6.213 x 10-5 and 1.250 x 10-3 cm/sec. In equivalent terms this is in the range of 51.8 – 833.3 lugeon values. This is rather very high permeability that will require foundation treatment by grouting.

5.12.7 Filter Materials (Sand)

No investigations were conducted for evaluation of filter materials. However, there is sand along the riverbed which needs to be tested and evaluated for suitability for use as filter material. The dam site is replete with rocks and boulders of volcanic origin that will require to be tested for suitability as rock-fill dam construction and also for construction aggregate. Any filter sand must satisfy the following criteria:

- **D15filter/D15base ≥ 5, and**
- **D15filter/D85base ≤ 5;**
- where: D15filter = sieve opening size that allows 15% of the filter material to pass;
    - D15base = sieve opening size that allows 15% of the base material to pass; and
    - D85base = sieve opening size that allows 85% of the base material to pass.

These are the criteria to be checked for sand samples, especially sand in relation to the embankment fill material which will be used as the base material (these requirement criteria may be varied for a rock-fill dam).

5.12.8 Proposed Type of Dam

On evaluation of the geological setting of the project area (the structural geology and the tectonics), we note that the area is underlain by rocks highly weathered volcanic rocks (basalts and phonolites that have affected by faulting in the general). The seismicity is taken into account in deciding a design basis earthquake (DBE) loading of amax = 0.30g and maximum credible earthquake (MCE) of amax = 0.45g in stability analysis during the designing of Radat dam. Further seismic profiling proposed during detailed geological investigations will shed more light on the conditions the foundation.

Construction materials in form red clay soil for an impervious core is apparently available within the dam site, but shell material will be readily available for both rock-fill and Rip Rap. Red clay soils will be further assessed at Radat Dam Site 3 area which also the preferred dam site for this project.

We therefore proposed ***a zoned rock-fill dam with an impervious core***. The only materials to be evaluated in detail to estimate the quantity is the red clay soils. The aggregate and sand for construction of the diversion channel (and other concrete works) can be sourced within the dam site area.

5.13 Conclusion and Recommendations

5.13.1 Conclusion

The results of both reconnaissance geological survey and preliminary geophysical investigations have confirmed findings of desk study that the geology of the proposed Radat dam project area is composed of volcanic rocks of Miocene to Pliocene age. Tuffs intercalated with sediments of the same age are also present in this area but with limited.

The rocks the project area are highly weathered and only slightly fractured. The deeper foundation rocks composed of basalts of Samburu type are more weathered than the upper horizons. The general project area has been affected by grid faulting but the nearest observed fault zone is around Radat Trading Center but it disappears as one approaches dam site 1 (the lower dam site). It significant to note within the proposed Radat dam project area rocks on the right hand side of Perkerra River are part of downthrown block of younger rocks that abut on older rocks on the left hand side of Perkerra River: This may mean that the older faulting may have been obscured the younger lava flows.

The foundation rocks in the three dam sites have undergone almost similar pattern and intensity of weathering however, dam site 1 (the lower dam site) has apparently more stable foundation compared to the other two. The project area is characterized abundance rocks that can readily be used for rock-fill dam. The recent deposits in are composed of a thin layer greyish brown soil with cobbles and stones derived from the parent volcanic rocks.

Finally it is concluded that proposed dam site 1 (the lower dam site) is suitable for a rock fill dam. However, further detailed geological investigations including core drilling and rock testing for strength will be necessary. The structural condition of the foundation rocks will also be necessary using seismic profiling.

Around proposed dam site 3 (about 5km from dam site 1) a layer of red clay was observed with the tuffs and sediments that underlie Kwaibus olivine basalts in that area. The thickness and areal extent of this horizon may be of interest as source for impervious core material.

5.14 Recommendations

The observations and inferences made from the preliminary investigations have led us to recommend the following:

1. Detailed geological including core and testing of the rock strength at the proposed Radat dam site 1. Three sites for core drilling are proposed as follows:
   - Borehole No. 1 at river bed (RADAT1-1VES 6) – right bank (Coordinates X: 0824008 (E); Y: 0031079 (N); El. 1375m above mean sea level);
   - Borehole No. 2 at RADAT1-1VES 4 – right bank (Coordinates X: 08224085 (E), Y: 0031055 (N); El. 1408m above mean sea level); and Borehole No. 3 at RADAT1-1VES 3 – left bank (Coordinates X: 0823884 (E); Y: 0031104 (N); El.1375m above mean sea level).
2. Geophysical investigations by seismic profiling to establish the structural conditions of the foundation to check presence of older faults, and

3. Fully fledged materials survey that should include identification of suitable quarries for the rock fill and laboratory testing of the rocks. The extent of the clay soils observed during this survey will need to be tested using auger method.

6 EVALUATION OF DAM OPTIONS

6.1 Proposed Dam Site

The pre-feasibility study identified five dam sites; Koipokaplelach, Kapng'etuny, Kaplelwo, Radat and Kipkabei dam sites. Radat site was recommended for full feasibility, detailed investigations and designs. Two of the sites Radat and Kaplelwo are located on the main Perkerra River; Koipokaplelach site is located on Tapuchara River while Kapng'etuny is located Ainopno River, all tributaries of the main Perkerra River.

During this feasibility study, three possible locations were investigated at the Radat sites, Radat site 1, Radat site 2 and Radat site 3.

Estimation of storage potentials of the proposed dam site was determined using contours generated from existing topographic information and topographic survey at the dam sites. Site storage/height/areas were generated for the four sites. The key features of the dam site are summarized here blow. The dam sites locations is shown on the site layout map, Drawing Appendix.

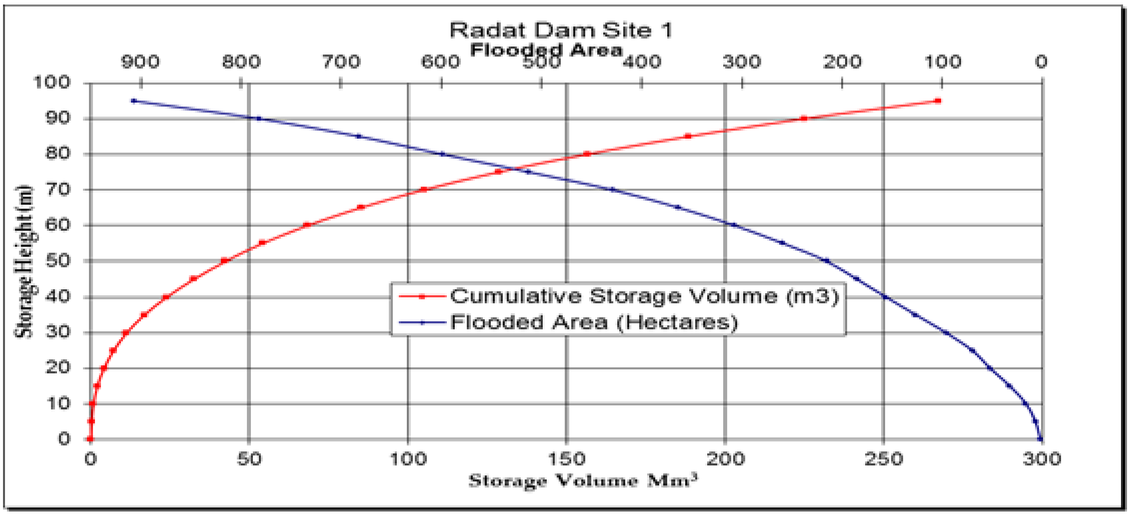
Table 6:1 Dam sites physical characteristics

Dam Site	Estimated Storage potential (Mm^3)	Storage Height (m)	Reservoir Area (Ha)	Embankment Length (m)
Kaplelwo	30.7	45	138	1,150
Kopokaplelach	15.0	35	126	685
Kapng'etuny	5.6	45	40	500
Radat Site 1	267	95	907	415
Radat Site 2	228	85	833	435
Radat Site 3	157	70	686	300

The sites have storage potential ranging from $5.6Mm^3$ up to $267Mm^3$ for dam heights of between 35-90mm height.

6.1.1 Radat Dam Sites

<u>Radat Site 1</u>
Three potential sites were investigated within the area. The first sites 1, is located 2.5 km upstream of Radat shopping centre. The river valley at the site is approximately 95 deep with a reservoir potential of up to 267Mm3. The reservoir will be confined to the river valley for around 3.5km before spreading to a wider area. The site Storage/Area/Depth Curve is shown in the figure below.

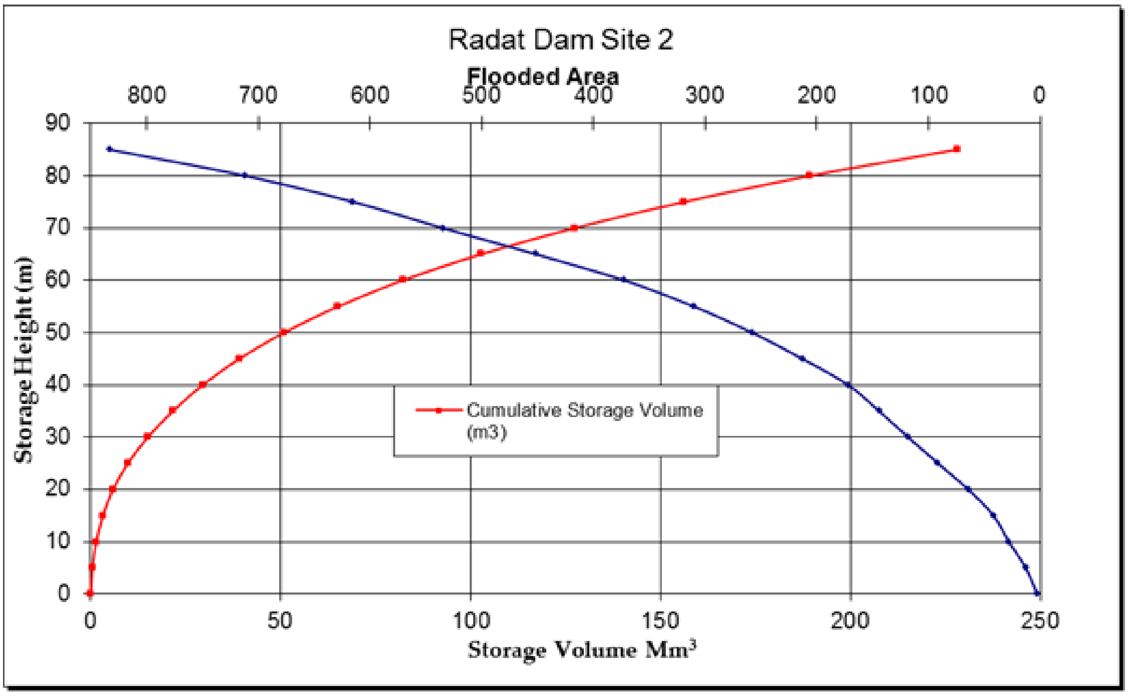


A dam of maximum reservoir potential at this site will cover an area of 2240 acres and will submerge the existing bridge that connects the river banks, an important river crossing. The dam and reservoir characteristics are summarized below.

Description	Parameter
Optimal Dam Height (m)	95
Optimum Storage (Mm^3)	267.2
Fetch at maximum height (km)	8.0
Total Reservoir surface Area (Acres)	2240
Basin Catchment at Site (km^2)	1,061.1
Mean Annual flow (m$^{3?s}$)	3.88
Public Facility/Institution to be submerged	Bridge.

Radat Site 2

The dam site 2 is located approximately 1.0km upstream of site 1 on a narrow section of the river. The site has a potential for 85 high with a reservoir potential of up to 228Mm3. The site Storage/Area/Depth Curve is shown in figure below.

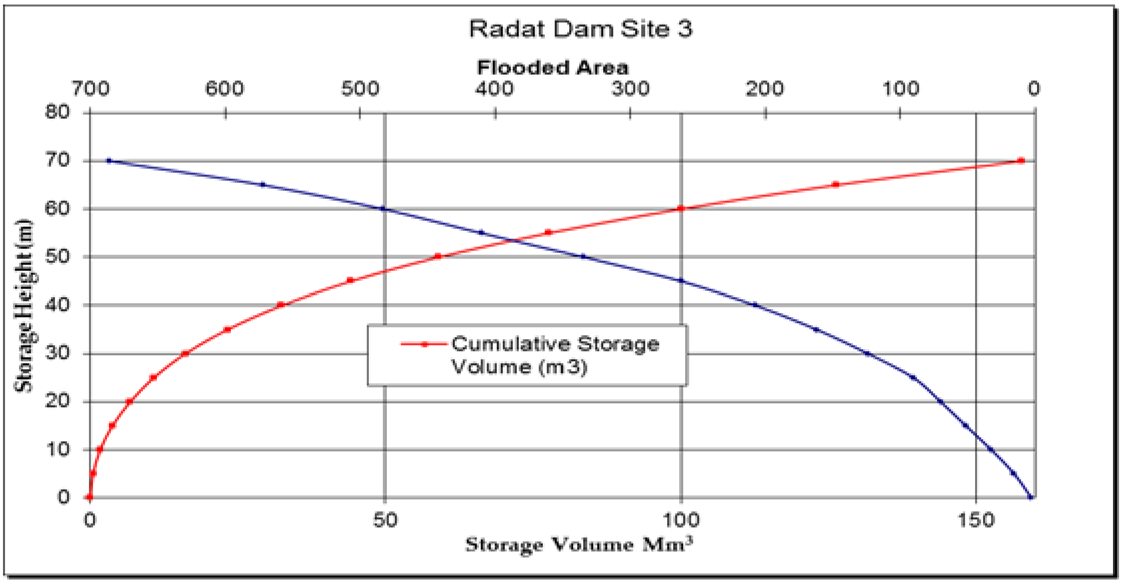


A dam of maximum reservoir potential at this site will cover an area of 2060cres and will also submerge the existing bridge that connects the river banks, an important river crossing. The dam and reservoir characteristics are summarized below.

Description	Parameter
Optimal Dam Height (m)	85
Optimum Storage (Mm³)	228.0
Total Reservoir surface Area (Acres)	2060
Basin Catchment at Site (km²)	1,061.1
Mean Annual flow (m³)	3.88
Public Facility/Institution to be submerged	Bridge.

Radat Site 3

The proposed dam site 3 is located slightly downstream of the confluence of Perkera river and several streams that join the main river form Tenges side. The side will be upstream of the main bridge linking the two sides of Perkera River. The site has a potential for a 70m high with a reservoir potential of up to 158Mm³. The site Storage/Area/Depth Curve is shown in figure below.

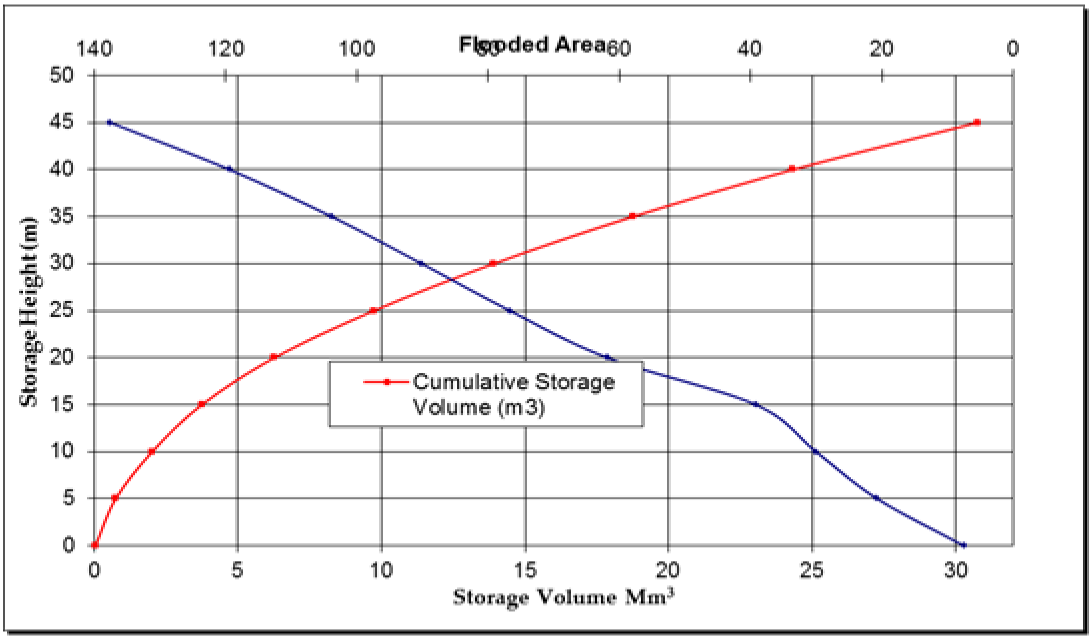


A dam of maximum reservoir potential at this site will cover an area of 1694acres and will also submerge the existing bridge that connects the river banks, an important river crossing. The dam and reservoir characteristics are summarized below.

Description	Parameter
Optimal Dam Height (m)	70
Optimum Storage (Mm^3)	157
Total Reservoir surface Area (Acres)	1,694
Basin Catchment at Site (km^2)	1,061.1
Mean Annual flow (m^3)	3.88
Public Facility/Institution to be submerged	Bridge.

Kaplelwo Site

The kaplelwo site is located on a narrow river valley immediately downstream of the confluence of Perkerra and Ainopno rivers. The river valley at the site is approximately 45 deep with a reservoir potential of up to 30.7Mm^3. The site Storage/Area/Depth Curve is shown in the figure.

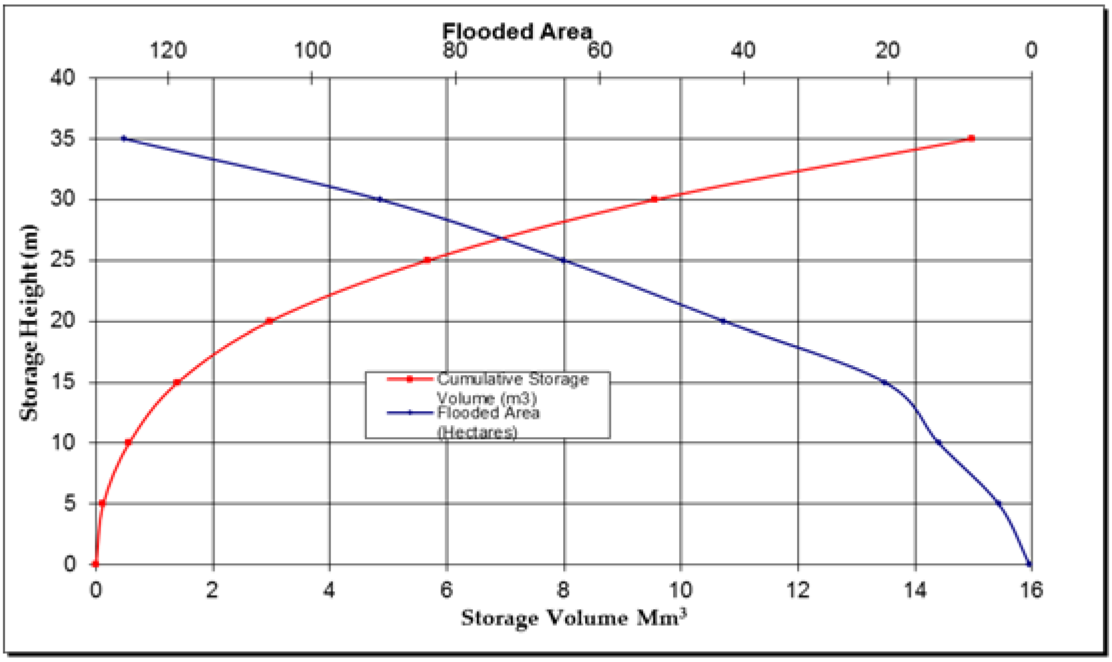


A dam of maximum reservoir potential at this site will cover an area of 340acres. The dam will not interfere with any existing public institution. The dam and reservoir characteristics are summarized below.

Description	Parameter
Optimal Dam Height (m)	85
Optimum Storage (Mm³)	228.0
Total Reservoir surface Area (Acres)	2060
Basin Catchment at Site (km²)	1,148.7
Mean Annual flow (m³)	4.18
Public Facility/Institution to be submerged	None

Kopokaplelach

Kopokaplelach site is located on Kapuchara River slightly upstream of the Marigat/Perkera river crossing. The site has a potential for a 35m dam with a potential storage of approximately 15mM3. The site Storage/Area/Depth Curve is shown in figure below.

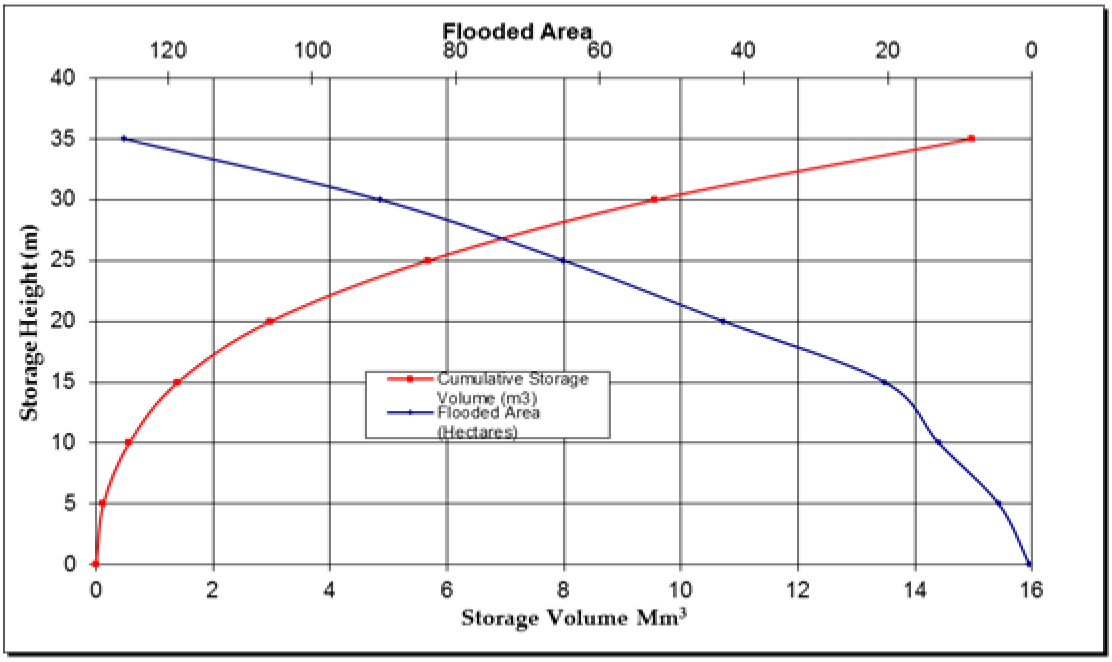


A dam of maximum reservoir potential at this site will cover an area of 310acres. The dam will not interfere with any existing public institution. The dam and reservoir characteristics are summarized below.

Description	Parameter
Optimal Dam Height (m)	35
Optimum Storage (Mm³)	15
Total Reservoir surface Area (Acres)	310
Basin Catchment at Site (km²)	40.8
Mean Annual flow (m³)	0.13
Public Facility/Institution to be submerged	None

Kapng'etuny

Kopokaplelach site is located on Ainopno River slightly upstream of the Marigat/Perkera river crossing. The site has a potential for a 35m dam with a potential storage of approximately 15mM3. The site Storage/Area/Depth Curve is shown in the figure below.



A dam of maximum reservoir potential at this site will cover an area of 310acres. The dam will not interfere with any existing public institution. The dam and reservoir characteristics are summarized below.

Description	Parameter
Optimal Dam Height (m)	35
Embankment Length (m)	650
Optimum Storage (Mm^3)	15
Dam Catchment at Site	
Total Reservoir surface Area (Acres)	310
Basin Catchment at Site (km^2)	143.4
Mean Annual flow (m^3)	0.44
Public Facility/Institution to be submerged	None

6.2 Water Demand and Reservoir capacity requirements

6.2.1 Irrigation demand

The Perkerra Irrigation Scheme Expansion Project Study, (Bhundia Associates 2012), proposed to expand the scheme irrigation area to 2020 hectares. The proposed expansion will increase the area currently under irrigation by eight times. The irrigation water availability for irrigation use for the two project scenarios (with or without storage) are summarised below.

Irrigation Method	Available water, m^3/day		Water demand, m^3/ha/day	Net irrigable area, ha	
	Without Storage	With Storage		Without Storage	With Storage

Surface	35,424	280,800	139.03	254.	2020

To achieve this expansion, water sources with a daily yield of 280,000m^3 is required. The current source of Perkerra irrigation water, the Perkerra River, can meet irrigation demand of up to 35,424m^3/day. To improve reliability Irrigation guidelines normally recommend one day on-farm storage or either 90day or 180 day storage at the water source. The 90 and 180 day irrigation storage for the proposed development is 25.3m^3 and 50.6m^3 respectively.

6.2.2 Domestic Water demand

The existing water rights on the Perkerra River are 0.124m^s/s and 0.247m^3/s for normal and flood flow respectively. These demand are projected to rise with time, however due to lack of sufficient information to project on current demand (location of schemes, estimated and projected population, kind of water schemes) , allowance has been made for future demand based on the rivers Q95 equivalent to 0.291m^3/s.

6.2.3 Environmental/Riparian release

General guidelines propose to allocate 15% of the mean stream flow to the environmental water rights. With mean flow of 3.88 m^3/s at the proposed dam site, 0.56m^3/s is allocated to the environment flow requirement.

6.2.4 Total dam release

The estimated total (optimal) dam release for the proposed irrigation development, domestic water demand and environmental rights is 4.12m^3/s.

6.2.5 Hydro-power Generation

The theoretically power available from falling water can be expressed as

$$P_{th} = \rho\ q\ g\ h$$

Where;

P_{th}= power theoretically available (W)

ρ = density (kg/m^3) (~ 1000 kg/m^{3}for water)

q = water flow (m^3/s)

g = acceleration of gravity (9.81 m/s^2)

h = falling height, head (m)

Efficiency

Due to energy loss the practically available power will be less than the theoretically power. Practically available power can be expressed as

$$P = 1000\ \mu\ q\ g\ h$$

Where;

P = power available (W)

μ = efficiency (in general ranging 0.75 to 0.95)

Equation (2) can be simplified to express practically available hydropower in kW

$$P \sim 10\ \mu\ q\ h\ (kW)$$

The proposed dam will be between 60-70m high, considering the other water release scenario, evaluation of the hydro-power generation potential has several limitations when considered concurrent to the downstream release. However considering that the dam will regulate river flow for use substantially downstream of the dam, it is proposed that power generation using the design release from the reservoir (simulation below).be considered immediately downstream of the dam.

6.3 Optimisation of Reservoir capacity

A rigorous reservoir modelling and yield analysis was undertaken to determine the required capacity of the dam to meet the estimated water demands. The analysis was based on the daily base inflow derived from the naturalised stream flow. A water balance approach was used to balance the inflow, storage and release to meet the project ultimate release of 4.12m3/s. Losses due to evaporation and seepages and downstream release and demand abstractions are the key parameter for the analysis.

6.3.1 Hydrological modelling

The objective of this hydrological modelling is to try and simulate the anticipated hydrological occurrences through the dam during its operation. The other objective of the modelling was to obtain consistent and reliable flow series at dam in order to evaluate properly the water resources available at the dam site.

The reservoir simulation is undertaken using daily records measured at the Marigat KARI meteorological Station and calibrated using river flow data form RGS 2EE07. None of the streams discharging into the dam is currently gaged making modelling to entirely depend on rainfall data form the Marigat station and RGS 2EE07. The simulation was undertaken between the period of January 1970 and November 1988. This is the period with consistent flow data at RGS 2EE07 and rainfall data to allow calibration.

The dam catchment assumed as a single basin comprising of three sub basins discharging at the proposed dam, the catchment physical parameters are presented in the table below following physical characteristics.

Parameter	Perkera	Emining	Kapuchoi
Length (km)	80	50	12.5
Highest Elevation (Masl)	2135		
Elevation at Dam site (Masl)	935		
Slope (m/m)	0.04	0.02	0.01
Area (km2)	601	289	69

6.3.2 Reservoir simulation

To simulate flow through the dam, the hydrological software HEC-HMS was used. Different models enable rainfall-runoff simulation. The following choices have been made:

- The Soil Moisture Accounting model has been chosen to calculate runoff volume. It is the recommended model for long term modelling.
- To model the direct runoff, the Clark hydrograph is also the best fitting method in this case.

- To model the groundwater flow, the linear reservoir method is to be associated to the Soil, Moisture Accounting

The Soil Moisture Accounting enables to calculate the volume of water ending in the river from precipitation through four transit layers;

- Vegetation (canopy)
- Surface (depressions)
- Soil
- Aquifers

The Clark hydrograph is used to calculate the direct runoff, by staggering the precipitation volume. The groundwater flow is assumed to be linear.

6.3.3 Transform Parameter

The transform parameters

- The time of concentration, Tc
- The storage coefficient, R

There are different ways to calculate the time of concentration, Kirpich equation, presented below, is used for the modelling.

$$T_c = 0.0189 * \frac{L^{0.77}}{S^{0.385}{}_c}$$

Where:

- L is the length of the longest flow path
- I is the average slope in m/m
- A is the area of the basin in km2. Values for the sub-basins are:

Catchment	Perkera	Emining	Kapuchoi
L (km)	80.00	50.00	12.50
I (m/m)	0.04	0.02	0.01
A(KM2)	601.00	289.00	69.00
Tc (hr)-Kirpich	6.69	6.08	2.73
R-Kirpich	2.87	2.61	1.17

First estimation for the storage coefficient can be calculated. For the Clark unit hydrograph method, the ratio R/(TC+R) has been found to be constant on a regional basis. For a value of this ratio of 0.1, the hydrograph rises steeply and might be representative of the response of an urban basin. For a value of 0.7, the unit hydrograph is much more attenuated and might be representative of a flat swampy basin. Here, an average value of 0.3 will be used.

$$\frac{R}{T_c + R} = 0.3$$

6.3.4 Optimization of the model

First manual calibration was done to eliminate excessively high floods, or too weak base flow. The most sensible parameters were determined:

- Soil capacity (mm)
- Soil infiltration and soil percolation (mm/hr)
- Groundwater (1 and 2) capacities (mm)
- Groundwater percolation (mm/hr)
- Groundwater coefficient (hr)

The soil parameters influence more the time of reaction of the basin, and the volume of peak flows (due essentially to direct runoff). The groundwater parameters have more influence on base flow.

6.3.5 Simulation Scenarios

The reservoir simulations calculate the operation of the dam take into consideration:

- The inflow (water resources from precipitation and base flow upstream of the dam)
- The release of water for irrigation, environmental requirement and existing water rights
- Available outflow that could be used for to meet the various water uses

Irrigation Water demand

The irrigation demand from the dam is assumed to be realised progressively to allow development of irrigation areas to the envisaged 2020Hectares in between two to four years depending on the simulated scenario. This allows the dam to impounded water to as safe storage thereby avoiding draining the dam complete. It is envisaged that irrigation development will progressive to achieve the full 2020Hecatares. The dam is considered to be on not good reliability when it drains out during the simulations.

The simulation runs were undertaken for a period between 1970 and 1988, a period with consistent flow and rainfall data to ensure calibration. The water demand scenarios considered are summarised below.

Scenario	Irrigation Release	Storage (X1000m^3)			Dam Height (m)		
		Min	Mean	Max	Min	Mean	Max
Scenarion-1	1500(1)-2020(2)	632	65,742	124,014	6	49.9	64.6
Scenarion-2	1000(1)-1500(2)-2020(2)	632	75,516	124,014	6	52.8	64.6
Scenarion-3	500(1)-1000(2)-2020(3)	632	77,138	124,602	6	53.1	64.7
Scenarion-4	2020	Dam Empties in the second year					
Scenarion-5	1000	3,634	44,837	56,423	15	46.6	49.2

Scenarion-6	1500	884	64,011	86,955	7.1	50.4	57.1

Note; 1500(1)-2020(2)-1500Ha of irrigation land put to irrigation in Year1 of dam operation, 2020Ha of the land put in irrigation in year 2 of dam operation.

6.3.6 Outcome of the simulation

The outcome of the basin modelling and the reservoir simulation are presented in the figures below. A scenario that ensure release of the anticipated 4.12m³/s for the entire duration with acceptable fluctuation in storage is the recommended.

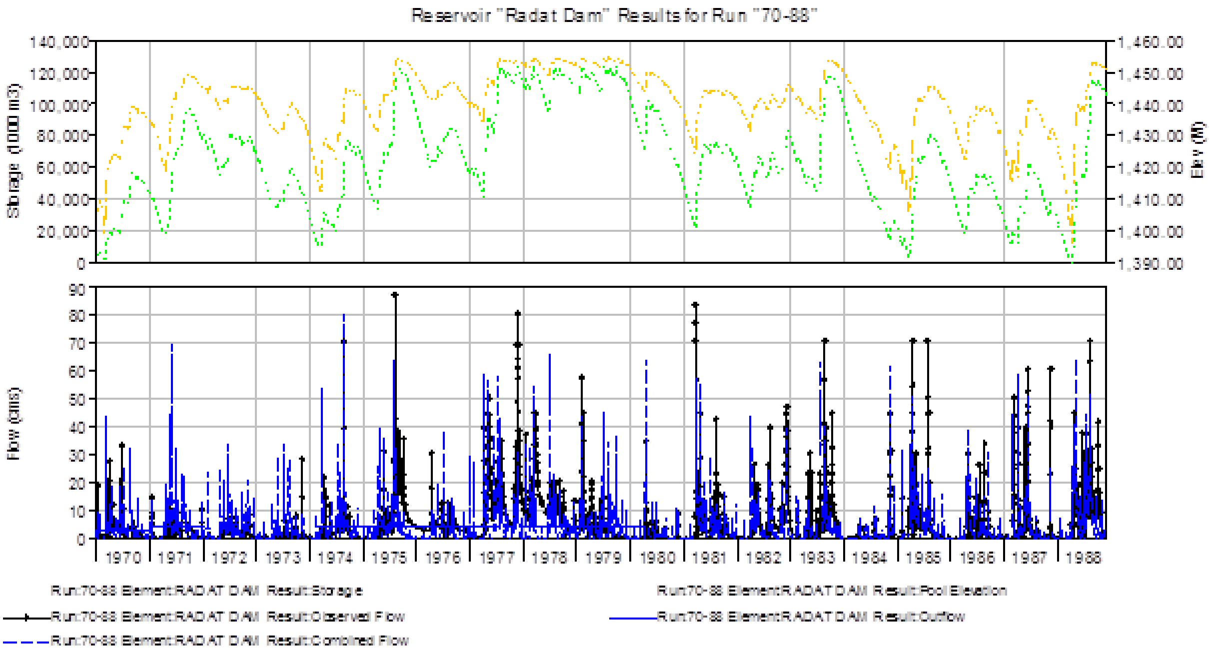


Figure 6:1 Reservoir Storage and dam height- Scenario 1 (64m)

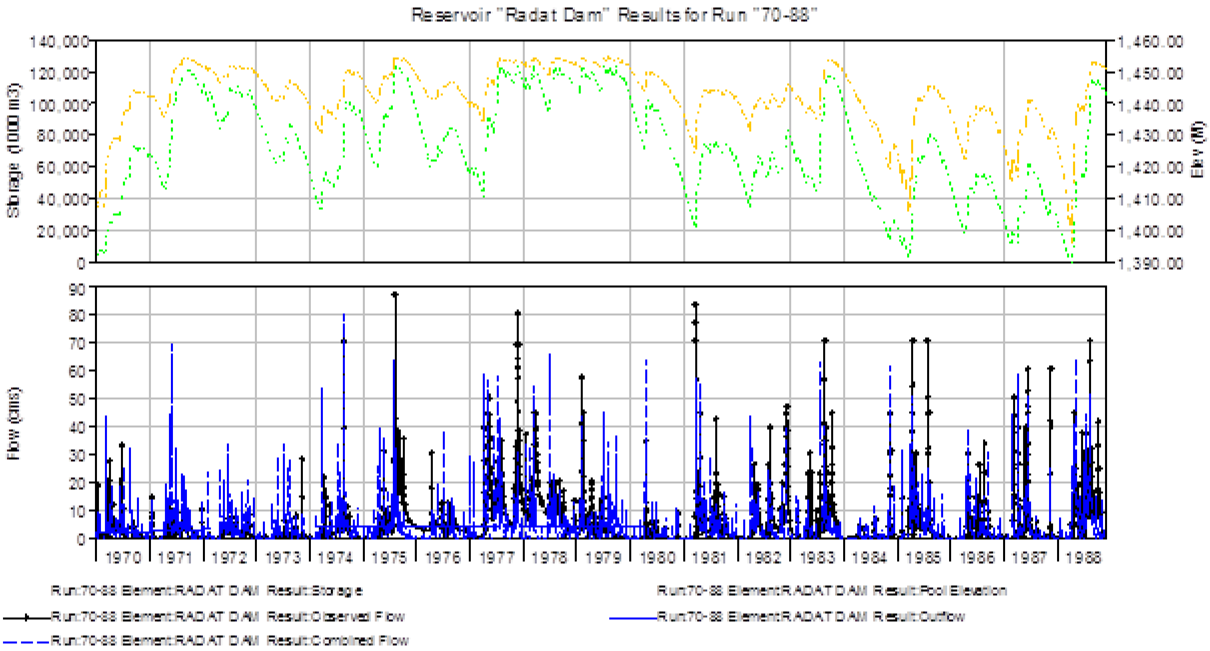


Figure 6:2 Reservoir Storage and dam height- Scenario 2 (64m)

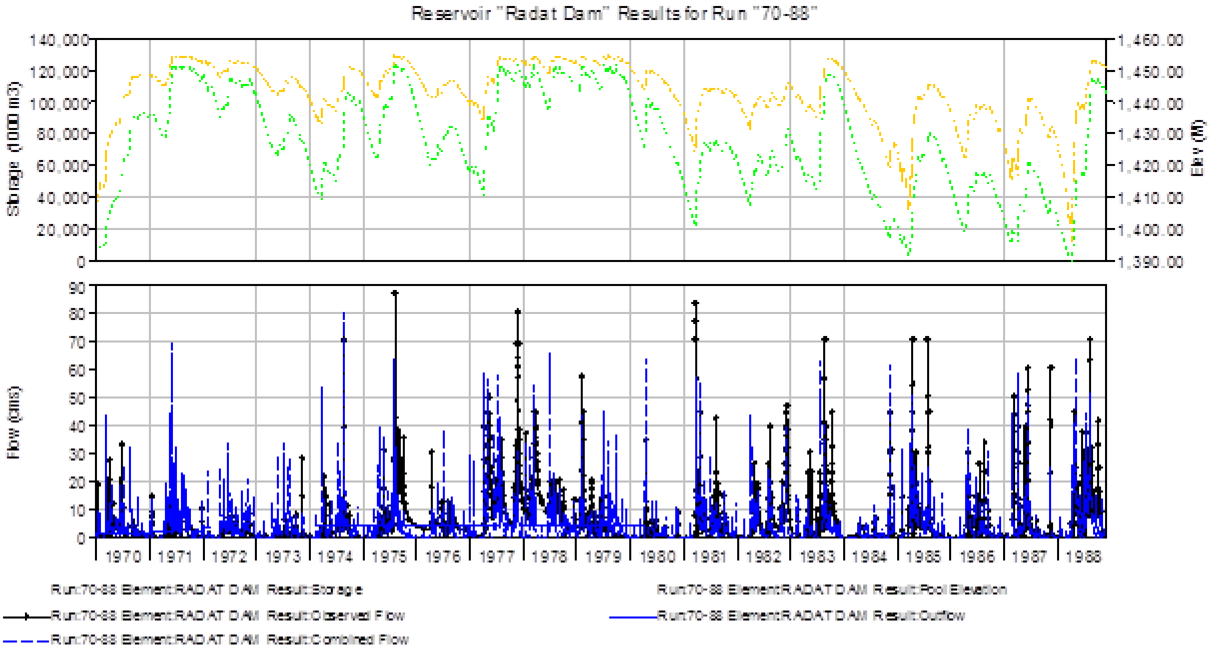


Figure 6:3 Reservoir Storage and dam height- Scenario 3 (64m)

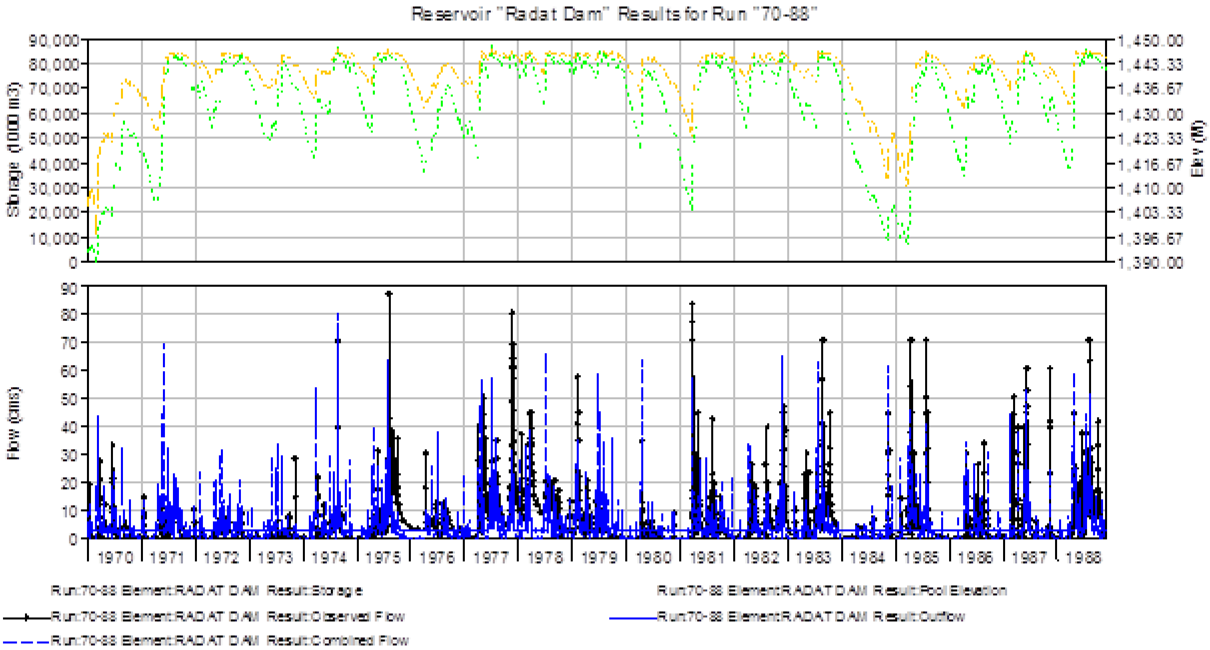


Figure 6:4 Reservoir Storage and dam height- Scenario 5 (56m)

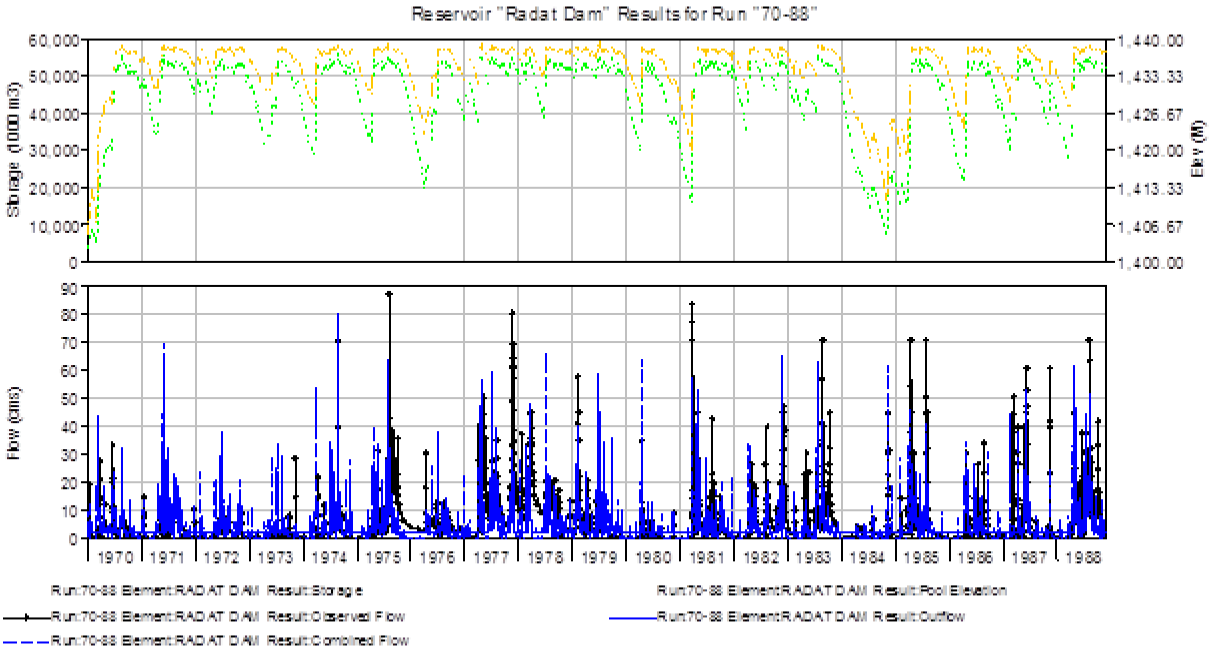


Figure 6:5 Reservoir Storage and dam height- Scenario 6 (48m)

6.4 Hydropower generation

It is proposed that the irrigation release of $3.25m^3/s$ to the river be used for hydropower generation immediately downstream of the dam. The irrigation off-take to Perkerra scheme is located substantially downstream of the dam making it possible to release back the water for irrigation.

With the reservoir, the river flows can be regulated and they can be released through the power house (turbines) in such a manner as to maintain a uniform power generation. Using the available flow, 1.0MW of power can be uniformly generated throughout the year.Proposed Dam

6.4.1 Reservoir Capacity

From the sites hydrological studies, evaluation of the potential dam sites and dam optimisation study carried above, a reservoir with a net storage capacity of $120Mm^3$ will satisfy the objective of the proposed development project. This reservoir will regulate the river flow to guarantee irrigation abstraction of $3.25m^3/s$ for the proposed irrigation development to 2020Hectares of irrigation area. Full development of the irrigation area to 2020Ha, will be progressively attained between the second and the third year.

6.4.2 Proposed Dam site

The characteristic of the various dam sites in regard to the feasibility components of the study are summarised below.

Parameter	Radat Site A	Radat Site A	Radat Site A	Kaplelwo	Kopokaplelach	Kapng'etuny
$120mm^3$ potential	Yes	Yes	Yes	No	No	No
Mean Annual Flow	3.88	3.88	3.88	4.18	0.13	0.44
Geological Condition	The proposed dam sites are underlain by rocks highly weathered volcanic rocks (basalts and phonolites that have affected by faulting in the general).					
Reservoir Area at $(120Mm^3)$-Ha				N/A	N/A	N/A
Environmental Impacts	Similar	Similar	Similar	Similar	Similar	Similar
Relocation of existing infrastructures	Bridge	Bridge	None	None	None	None

6.4.3 Recommended Dam site

The preferred dam site for the proposed Radat dam site is site 1. The site has the most stable geological foundation. The site also has the high storage potential of upto 257Mm3 making a good site for even further expansion. The reservoir at this site will be confined to the river basin for around three kilometres before spreading out to flood around 500Acres in Tebei sub location. The dam and reservoir at this site will require 1,431 Acres of land which is 200acres less compared to site1. The only disadvantages are submergence of the existing bridge crossing which is the only river crossing on Perkerra river at this point. Even though the bridge will be replaced, it may cause too much disruption. The site also has a wider valley that will make the dam embankment construction more expensive. In view of the above, Dam site 3 is recommended, The site has a potential for a 157Mm3 and will not submerge the existing bridge.

6.4.4 Dam type

The proposed dam site is underlain by rocks highly weathered volcanic rocks (basalts and phonolites that have affected by faulting in the general). Further seismic profiling proposed during detailed geological investigations will shed more light on the conditions the foundation. The prevailing sire geological conditions favour a zoned rock-fill dam with an impervious core. The only materials to be evaluated in detail to estimate the quantity is the red clay soils. The aggregate and sand for construction of the diversion channel (and other concrete works) can be sourced within the dam site area. In view of the above considerations, a zoned rock dam is suggested. The layout plan and typical cross-section are shown in the book of drawings. The embankment geometry at this preliminary stage has been taken as 1:.1.75 and 1:2.25 for upstream and downstream slopes respectively. A 10.0m crest width is suggested and a footbridge across the side spillway is proposed.
Dam Construction Materials

Construction materials in form red clay soil for an impervious core is apparently available within the dam site, but shell material will be readily available for both rock-fill and Rip Rap. Red clay soils will be further assessed at Radat Dam Site 3 area which also the preferred dam site for this project.

6.4.5 Proposed Dam

The size of the proposed dam has been determined for the storage is curves and the reservoir simulation results. A rock fill embankment dam with a clay core of a reservoir capacity of 124Mm³ and storage height of around 60m; measured from the dam crest down to the lowest point in the natural riverbed at the downstream toe of the embankment. The slopes of the embankment will be 1V:2.25H on the upstream side, and 1V:1.75H downstream. The overall downstream slope will be flatter than this because of the provision of 6.0 m wide berms at the coffer dam level running the entire length of embankment at the 25 m height from the embankment crest. These will also serve as the main artery for delivering fill materials from the excavation lots to the dam.

Net Freeboard

Wind action in long reservoir fetch produce wave development and setup causing water to rise above the Normal water level. The net freeboard is given by the following formula;

$$= h_w + \frac{v_{w^2}}{2g}$$

Where, h_w = Wave height

V_w = Wave Velocity (m/s)

$$h_w = 0.5 + 0.33\sqrt{L}$$

$$V_w = 1.5 + 0.66 * h_w$$

L=reservoir fetch in the wind direction in km, 4.0km for the proposed dam.. The net freeboard is estimated as 1.42m, say 1.5

6.4.6 Spillway Type, Location and Size

Design Standards

International Commission on Large Dams (ICOLD)

This commission has laid down the norms for categorization as large dams.

- More than 15m height measured from the lowest portion of the general foundation area to the crest
- A dam between 10m and 15m height provided it complies with at least one of the following conditions:
  a) Length of the crest of dam is not less than 500m
  b) Capacity of reservoir formed by the dam is not less than 1 MCM
  c) Maximum flood discharge dealt by the dam is not less than 2000 m^3/s
  d) The dam had specially difficult foundation problem
  e) The dam is of unusual design
  f) The dam is located on highly seismic zone

ICOD recommends use of PMF (probable maximum flood) and 1:10,000 year flood occurrence for hydraulic designs of spillway of large dams.

FEMA Guidelines

Flood Selection for Design (or Evaluation): The selection of the design flood should be based on an evaluation of the relative risks and consequences of flooding, under both present and future conditions. Higher risks may have to be accepted for some existing structures because of irreconcilable conditions. When flooding could cause significant hazards to life or major property damage, the flood selected for design should have virtually no chance of being exceeded. If lesser hazards are involved, a smaller flood may be selected for design. However, all dams should be designed to withstand relatively large flood without failure even when there is apparently no downstream hazard involved under present conditions of development.

Downstream Effects: Safety design includes studies to ascertain areas that would be flooded during occurrence of the design flood and in the event of dam failure. The areas downstream of the project should be evaluated to determine the need for land acquisition, flood plain management, or other methods to prevent major damages. Information should be developed and documented for disseminating to downstream interests regarding the continuing risks of flooding.

Kenyan standards

In Kenya, the Water Resources Management Authority (WRMA) recommends minimum design floods for hydraulic design of dam spillways on the basis of risk associated with drainage that may occur downstream on the event of embankment failure. Classification of dams is also based on the height, reservoir impoundment area and the dam catchment. The Tables 4.6 and 4.7 show the classification of dams and recommendations for spillway design flood, as per WRMA regulations.

Table 4.6: Classes of dams

Class of dam	Maximum depths of water at NWL (m)	Reservoir Impoundment (m^3)	Catchment area (m^2)
A (Low risk)	0-4.99	<100,000	<100
B (Medium risk)	5-14.99	100,000 – 1,000,000	100-1,000

C (high risk)	>15.0	>1,000,000	>1,000

Source, Water management rules, draft-June 2006

Table 4.7: Recommended design periods for the design of spillway

Class of dam	Minimum return period (Years)
A (Low risk)	I in 50
B (Medium risk)	1 in 100
C (high risk)	1 in 500

Source, Water management rules, draft-June 2006

6.4.7 Design inflow floods

The derived design inflow flood for the two dam sites are summarised below.

Table 6:2 Spillway design floods

Design Flood	**Flow (m3/s)**
1 in 100	129.28
1 in 1,000	177.70
1 in 10,000	226,04
PMF	1,662.09

6.4.8 Location

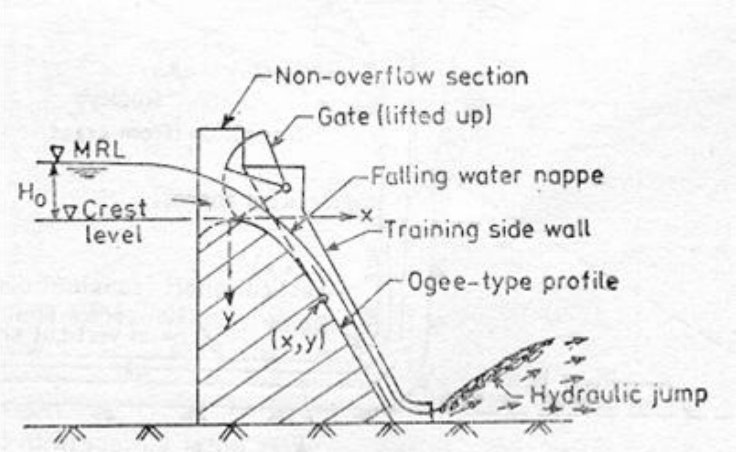
The final location of the spillway will be established after further the survey, geological information and constructability requirements. At this stage it is recommended the spillway be located on the right abutment.

6.4.9 Spillway type

Spillways may be broadly categorized as service spillway and emergency type spillway. The service spillways are those which are in constant use in every flood when the reservoir level exceeds the crest level of the spillway. An emergency spillway, also known as auxiliary spillway, is one which is rarely used and come into operation during extraordinary flood when the actual flood discharge exceeds the design capacity of the service spillway. Considering the topography of the dam site and the proposed spillway location, three spillway types are considered; an ogee shaped Drop inlet and Side Channel drop spillway. The various types of service spillways in common use are briefly described below:

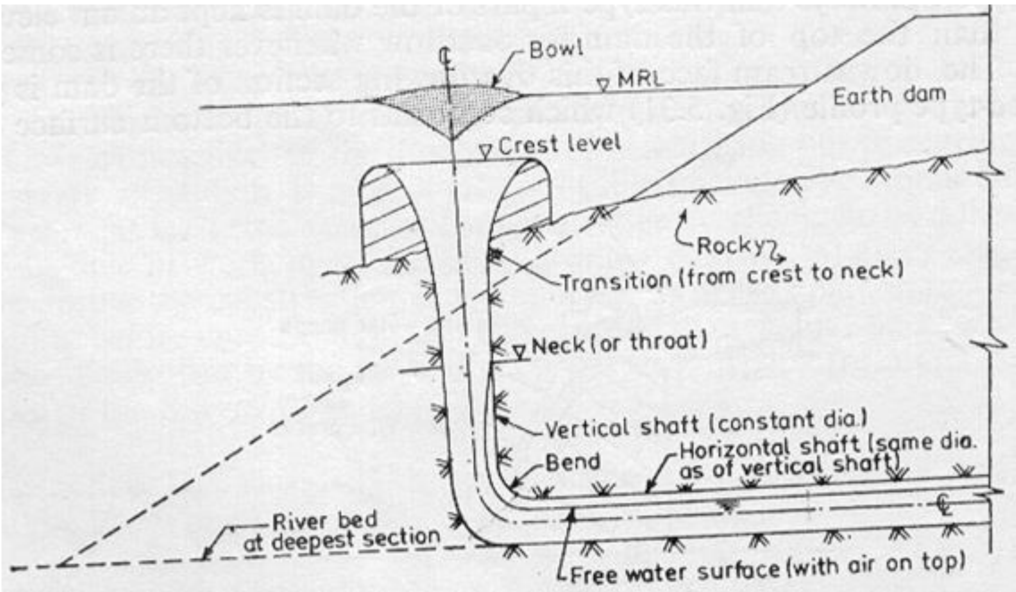
Ogee spillway

The ogee spillway as shown has a control weir, which is ogee or S-shaped in profile. Ordinarily, the upper curve of the ogee spillway is made to conform closely to the profile of the lower nappe of a ventilated sheet falling from a sharp-crested weir. Flow over the crest is made to adhere to the face of the profile by preventing access of air to the underside of the sheet. For discharges at designed head, the flow glides over the crest with no interference from the boundary surface and attains near-maximum discharge efficiency. The profile below the upper curve of the ogee is continued tangent along a slope to support the sheet on the face of the overflow and flow onto the apron of a stilling basin or into the spillway discharge channel. This type of spillway is commonly used in high dams and it is suitable to handle large flood flows. Fig. 4 gives the values of K and n as function of approach velocity head (ha) for finding ogee spillway profile.



Drop Inlet (Shaft or Morning Glory) Spillways

A drop inlet or shaft spillway, as the name implies, is one in which the water enters over a horizontally positioned lip, drops through a vertical or sloping shaft, and then flows to the downstream river channel through a horizontal or near horizontal conduit or tunnel. The structure may be considered as being made up of three elements; namely, an overflow control weir, a vertical transition, and a closed discharge channel. Where the inlet is funnel-shaped, this type of structure is often called a "morning glory" or "glory hole" spillway. The figure below illustrates a typical drop inlet spillway.

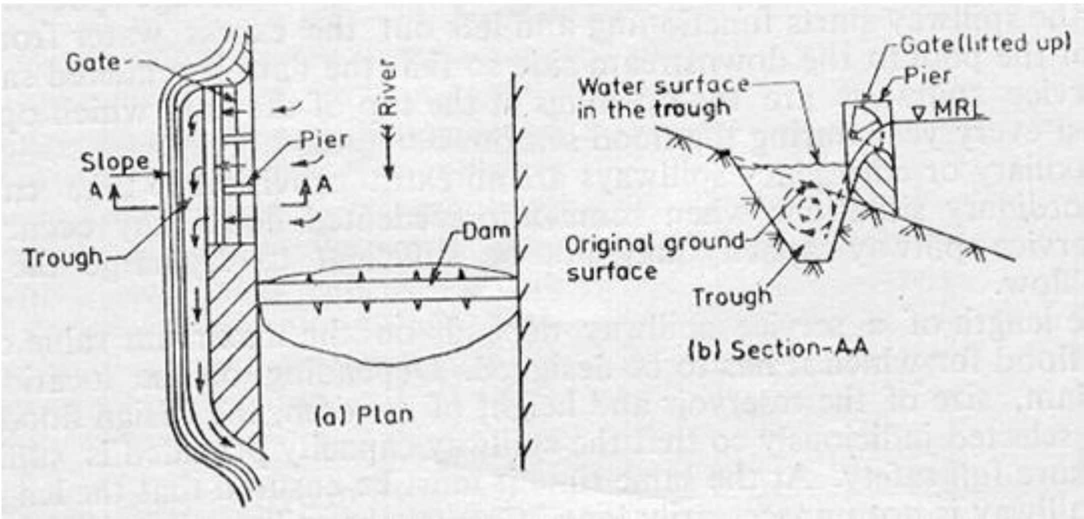


Discharge characteristics of the drop inlet spillway may vary with the range of head. The control will shift according to the relative discharge capacities of the weir, the transition, and the conduit or tunnel. For example, as the heads increase on a glory hole spillway, the control will shift from weir flow over the crest to orifice flow in the transition and then to full pipe flow in the downstream portion.

A drop inlet spillway can be used advantageously at dam sites in narrow valleys where the abutments rise steeply or where a diversion tunnel or conduit is available for use as the downstream leg. Another advantage of this type of spillway is that near maximum capacity is attained at relatively low heads; This characteristic makes the spillway ideal for use where the maximum spillway outflow is to be limited. This characteristic also may be considered disadvantageous, in that there is little increase in capacity beyond the designed heads, and should a flood occur. This would not be a disadvantage if this type of spillway were used as a service spillway in conjunction with an auxiliary or emergency spillway.

Side Channel Spillway

In a side channel spillway, the waterfalls from the reservoir over a service spillway like ogee type spillway into a narrow channel excavated from the side towards the abutment of the dam. The flow in the side channel is at right angle to the direction of the incoming flow from the reservoir. The side channel is provided with a control section at its end to ensure that the flow in the side channel is at sub-critical stage and there is thorough mixing of the incoming super critical jet in the side channel trough portion. The water from the side channel usually enters a chute type spillway after the control section. The figure below illustrates a typical side channel type of spillway commonly used for earthen and rock fill type dams



6.4.10 Proposed Spillway Type

A side channel drop spillway is proposed with a concrete sill, concrete lined inflow and outflow channels. The spillway is located on the side of the river bank to be determined during detailed designs. The spillway will be excavated in hard rock.

6.4.11 Design Floods

The spillway design flood for the preliminary sizing of the proposed spillway is estimated in chapter four (hydrological investigations). Three methods were used for estimation of the spillway design floods; Empirical Formula, Flow frequency Analysis and MPF. The derived floods using the most conservative of the methods are summarised below.

The criteria used for the hydraulic design is based on the findings of the hydrological studies review of the previous studies which has yielded less flows in comparison to the previous studies. These details are used in sizing of hydrological structures. The following design flows are adopted for the design.

Table 6:3 Design Flows

Hydraulic Structure	Daily Peak Flow (m^3/s)	Criteria
Diversion Works	64.206	In in 5year Flood
Main Spillway	177,70	1000
	226.035	10,000
	1,662.09	PMF
Compensation flow	0.45	30% of Q95,15% of mean flow

6.4.12 Hydraulic Design of Spillway

The spillway is design on the basis of the guidelines recommended by the practice manual for water services in Kenya, 2005. The formula below is used for calculation of spillway depth;

$$Q = C L_e H_e^{1.5}$$

Where:

Q - discharge capacity, m^3/s

C - discharge coefficient, from U.S. Army Corps of Engineers

He - total specific energy above the crest, m

Le - effective length of the crest, m Le= L - 2(nKp + Ka)He

Where:

L - length of the crest, m

n - number of piers

Kp - pier contraction coefficient, 0.01

Ka - abutment contraction coefficient, 0.2

The relationship between the reservoir head, Hd and the maximum reservoir levels, The calculated Ogee spillway parameters for the PMF are summarised below

$H_d = 0.74 H_e$, with piers

Parameter	Crest length	Approach Head (He)	Design Head (Hd)
Value	65m	5.0m	3.7

6.4.13 Gross Freeboard

The gross dam freeboard is 5.0 + 1.5 = 6.5m

6.5 Intake Works

The intake works will consist of an intake tower with a steel pipe. The steel pipe will be conveyed through a box culvert. A twin off take pipeline will be provided, one for domestic water and another one for irrigation water. The capacities for the two offtake works are as follows.

Category	Off take (m^3/s)
Irrigation Release	3.25
Environmental and General Water Use	0.87

6.6 River Diversion

River Diversion is provided to convey the normal river flow across the dam channel during the construction period. Downstream water release will also be conveyed through the conduit during the operation of the dam.

The diversion works are usually sized to pass a flood flow of return periods between 2 to 25 years, with 1 in 5 years being the common practice. Peak Flood flow of 54.75m3/s is used to size the diversion conduit/culvert. 2 number 3.5m wide by 2.5m deep culvert are estimated using the manning's equation. The combined capacity of the culverts is 240m3/s. The capacity of the culvert is checked below;

$$Q = 0.82 * A\sqrt{2gh}$$

$$A = \frac{Q}{0.82\sqrt{2gh}}$$

Where:

Q=m^3/s

$$A = Crosssectionalarea\,(m^2)$$

$$g = 9,81$$

$h = Totalhead = 7m$, 1/2H

$$A = \frac{148}{9.61} m^2$$

$$A = 15.4 m^2$$

2No 3.5 by 2.5 m box culverts (A=17.5m2) is provided. The culvers will be used to divert normal and expected flood flows during the construction of the dam. Some of The culverts will be block on completion of construction. Two of the culvers will be used afterwards, one as a conduit for off-take works, and the other as a downstream release/compensation flow conduit.

6.7 Coffer Dam

In order to facilitate diversion of water through the culvert, a 5m high coffer dam will be constructed upstream of the main embankment wall. The coffer dam will ultimately be incorporated into the main embankment wall and hence the need to optimize its parameters against those of the diversion culvert. However, with such a high coffer dam, the dimensions of the tunnel will be small and this will result in reduced cost of concrete that will be used in the construction of the culvert.

6.8 Dam Instrumentation

Monitoring of the post construction operation of the dam is an important safety requirement. The dam embankment requires monitoring for settlement, horizontal movement, pore pressure and seepage. Monitoring of ensuing weather parameters is also required in informing the dam operation and regulation.

Appropriate instrumentation enables the dam properties to be monitored during operation. These will help to give advance indication of the potential effects of any initial deficiencies or any deterioration during operations. Instruments will be required to monitor the following design and operation parameters.

- Pour water pressure in the fill
- Total pressure in embankment core
- Settlement and distortion
- Seepage flow
- Reservoir water level

6.9 Ancillary Works

7 SOCIAL AND ENVIRONMENTAL IMPACT STUDIES

7.1 Project Description

The overall objective of the Radat Dam project is to bring more land under irrigated agriculture for purposes of enhancing food security and income generation in Perkerra Irrigation Scheme in Baringo County. The aim of the proposed project is to develop a multi-purpose regulatory dam along the Perkerra River with the main purpose of providing irrigation water to the expanded Perkerra Scheme, generating hydro-electric power, flood mitigation and water supply. To obtain its objectives, the project proponent (NIB) proposes to undertake the following:

- Develop a dam with sufficient capacity to support ultimately irrigation development of 2020Ha
- Expand the existing Perkerra irrigation scheme

The proposed project will enable the farmers conduct sustainable irrigation throughout the year. The scope of the current study is to detailed investigation and design of the dam proposed dam to meet the above objectives. The design of the irrigation infrastructure; irrigation canals, access roads, on farm systems and related support infrastructure were undertaken by NIB during the Irrigation development Studies in 2012.

7.1.1 Project Justifications

The Perkerra Irrigation Scheme Expansion Project Study, (Bhundia Associates 2012), proposed to expand the irrigation area to 2020 hectares. The proposed expansion will increase the area currently under irrigation by eight times. To achieve this, water sources with a daily yield of 280,000m^3 is required. The current source of the Perkerra irrigation scheme, the Perkerra River, can meet irrigation demand of 294Ha equivalent to 35,424m^3/day thus the need of developing flood flow regulating dams along the Perkerra river to enable supply the water year round.

7.1.2 Project Location

The proposed project covers five sub-locations namely Radat, Kimose, Tebei, Cheberen and Tinomoi whose administrative details are provided in table 1.3.2(b) below and layout map under appendix 1.

Table 7:1 Project Area by Sub-county, District, Division, Ward, Location and Sub Location

No./S	Sub County	District	Division	Ward	Location	Sub Location
1	Mogotio	Mogotio	Kipngorom	Emining	Cheberen	Cheberen
2	Mogotio	Mogotio	Emining	Emining	Kimose	Kimose
3	Mogotio	Mogotio	Emining	Emining	Koibosoi	Radat
4	Baringo South	Baringo Central	Tenges	Marigat	Bekibon	Tinomoi
5	Baringo South	Baringo Central	Tenges	Marigat	Tuluongoi	Tebei

7.1.3 Perkerra River

Perkerra River is the only perennial river in the project area, The river has it source in the Mau Forest on the western embankment of the Rift valley at 2,400 masl, dropping down to 980 masl at Lake Baringo. The catchment area has steep slopes on the hillsides, gentle slopes in the middle and lower reaches towards Lake Baringo where the surface is bear with very little undergrowth flattening out. The Perkerra basin has an estimated catchment area of 1411km^2 and it drains into Lake Baringo whose drainage area is 6820 km^2. Most of the water of the Perkerra River System comes from the hill slopes, where annual rainfall is between 1,100mm and 2,700mm. The region around the lake is semi-arid, with annual rainfall of 450 millimetres and annual evaporation rates of 1,650 mm to 2,300mm. The proposed project aims to store the run-off generated from the basin by constructing a barrier along the river.

7.1.4 Proposed Dam

65m High (effective storage) zoned rock fill embankment with a central impervious core is proposed. The dam will have a storage capacity of 124Mm^3. The dam will ensure reliable release of 3.25m^3/s for the proposed irrigation and 0.87m^3/s for environmental and domestic water demands. At full capacity the reservoir will cover approximately ***1647Acres***of land spread in the five sub locations as summarised below.

Sub-Location	Site 1 (Acres)	Site 2 (Acres)	Site 3 (Acres)
Radat	432	377	117
Kimose	94	108	184
Tinomoi	401	345	359
Cheberen	0	0	8
Tebei	505	639	979
Total	**1,431**	**1,469**	**1,647**

7.2 Study Methodology

7.2.1 Overview

The main objectives of the (E&SIA) Study are to:

- Examine the impacts of the proposed project on the physical, biological, socio-economic and socio-cultural environment;
- Conduct studies to establish the current status of the environmental baseline parameters;
- Propose mitigation measures for the identified potential and likely impacts; and
- Develop an Environmental Management and Monitoring Plan (EMP) to guide the project team during the implementation of the mitigation measures.

The study approach involved undertaking data collection through field and, socio-economic surveys and literature review. The findings of the data collection were evaluated using the three main EIA methodologies namely scoping, screening and detail analysis.

Project screening was the first step undertaken during the study; it involved collecting basic data on the project and evaluating the need of conducting an E&SIA and the category of study to be undertaken. After the screening exercise, the consulting team concluded that the project is to undergo a full EIA, as per the requirement of the second schedule of EMCA, 1999.

The project scoping stage which followed the screening stage was been applied to narrow down the project issues to those requiring a detailed analysis. The process involved

- Consulting and informing the affected public about the proposed project;
- Consulting and gathering the views and concerns of key stakeholders about the proposed project;
- Reviewing relevant documents such as policies, plans and programs;
- Documenting issues raised by the stakeholders.

The scoping exercise was conducted through field visits at the proposed project site and desktop studies to establish the following:

- The projects zone of impact including the Project Affected Persons (PAP) and their perception on the proposed project;
- Baseline data on the environmental status, socio-economic and socio-cultural status;
- Legal Policies, Legislative and Institutional Framework governing the proposed project;
- Views of key stakeholders including the County Government, Administrative and departmental heads at the Sub-County and district headquarters;
- Views of the local communities and the people of the Baringo County;
- Licenses and permits availability and appended conditions;
- Types of waste to be generated, proposed management and disposal methods;
- Parameters requiring detailed studies; and
- Potential positive and negative project impacts.

The assessment evaluated all relevant processes associated with the proposed project and came up with terms of reference of undertaking further studies and mitigation measures for identified impacts to ensure sound environmental management during and after the project. This step enabled collection of primary and secondary data on the proposed project. The primary data was collected through the qualitative and quantitative methods of data collection. Qualitative data was collected through filed visits/site walks, public and stakeholders consultation while quantitative data was collected through the use of sampled questionnaires for household survey and Focus Group Discussions (FGD). The secondary data was collected through literature review, which included a study of the following:

- Policies, Acts and Regulations
- Baringo County Integrated Development Plan
- Project area topographical and cadastral map
- Previous project study documents

- Literature materials on the project including those on Wetland Management, Plant Species, Culture, Irrigation Project Development and Management among other project parameters.

Detailed analysis of the finding was undertaken to evaluate the actual project impacts, including impacts of project benefits and those of the project components among other project parameters. At the detailed analysis stage, a comprehensive analysis of the study findings was conducted, through the use of data analysis software; literature material on dam projects, including materials on policies and regulations governing their development and management. The findings of the analysis were used to identify the study gaps, uncertainty, identify areas requiring detailed studies and guide the scoping report writing.

A socio-economic baseline survey was undertaken for the proposed project, through administration of pre-defined questionnaires. To enable capture the different strata of Project Affected Persons, namely the households, institutions, commercial entities and the public in general, two categories of questionnaires were developed. In total, one hundred and fifty (150) households were interviewed in the six administrative locations likely to be traversed by the project and at least 15 stakeholders meeting held in the project area

The findings at the scoping stage shall guide further E&SIA studies which shall involve the assessment and quantification of the possible impacts from the proposed project on the residents of five sub-locations and the Country at large. The study shall also involve the development of a separate RAP document, whose objective is to provide guidelines that ensure that the livelihoods of the Project Affected Persons are restored to their pre-impact level as much as practically possible.

Literature review pertaining to the land usage and the surrounding area's history shall be undertaken. This will include the review of the land inheritance process and status of land adjudication/registration.

7.2.2 Desk Study

In order to prepare this Report, the Environmental team has reviewed various specialised study reports prepared under this project. The Reports include the following:

- The Inception Report;
- Relevant legal and regulatory documents;
- Relevant practice manuals
- Stakeholders comments during preparation and presentation of the inception Report;
- Incorporated comments from the stakeholders upon submission of the Project Report.

7.2.3 Site Visits

The project team visited the site in March, and undertook the following:

- Site analysis: Reconnaissance of the approximate site boundaries, identify site constraints, develop impression of topography, soils, existing developments, practicality of developing water supply infrastructure in the proposed area;
- Meet the County Government, Central Government and key stakeholders in the Project Area to allow for smooth information dissemination to the general public.
- Undertake stakeholders consultation through a workshop in Marigat on ----February 2014

The initial site visits led to the preparation of the Inception Report, which was submitted in February 2014. A further site visit was undertaken in the month of May 2014, to undertake additional site assessment exercise, and conduct public meetings. The possibility of resettlement of persons was established, hence the need for an initial socio-economic survey to provide baseline information.

7.2.4 Baseline Socio Economic Survey

As part of the scoping exercise a detailed reconnaissance survey, field investigations and public participation was conducted throughout the project area and the neighbouring communities in order to collect perceived information on impacts associated with biophysical and socio-economic dimensions of the project implementation.

The site walk assessment survey was conducted at the proposed project sites and surrounding areas including households in the vicinity of the site. This involved a systematic field traversing to quantify perceived impacts of project on:-

- Land acquisition for project development;
- Land/water conflicts, ownership and usage;
- Institutions and organizations in the area;
- Vegetation cover of the area;
- Existing underground and surface waters and methods of protection from contamination and extinction;
- Waste management including disposal methods and sites;
- Water and Soil Pollution levels;
- Environmental Health and Safety (EHS);
- Road infrastructure and other facilities which will be used during project implementation;
- Water sources to be used during the project implementation and maintenance phases; and
- Effluent management.

7.2.5 Public Consultations

Several consultative meetings have been undertaken for the study and this was initiated by the project site handover when client, NIB introduced the project team to the County Government and physically showed the consultant the project sites. This handover meeting was followed by key stakeholders' inception meeting which was held on the 13th of March 2014 at Marigat Town and the aim of the meeting was to disseminate information on the proposed project to the area leadership who were to in term trickle the information to the local community. These stakeholders meeting was attended by key stakeholders which included;

- leaders within probable zone of impact and all key influencers of policy;
- leaders from communities likely to be directly or indirectly affected by the dam project;

- The national and county government including Baringo County Government led by the Governor and the County Executive responsible for Water and Irrigation were engaged;
- Heads of departments in Agriculture, Lands, Irrigation, Environment, Water, Wildlife, Forestry, Livestock development and the Regional (former Provincial Administration) were all engaged;
- The County Ward Representatives, Sub-County Administration, Ward Administrators, Chiefs and Assistant Chiefs from Mogotio, Marigat and Baringo Central Sub Counties were also fully involved since they are the key contacts with the residents who are likely to be affected by the proposed Dam directly.

In addition to the key stakeholders meeting, several public meetings were held with the community members in the various sub-locations. The meetings were held in two steps one was the project introductory meetings held between 17th to 24th March 2014 and detailed scoping meeting which was held between 8th and 24th May 2014. At both stages the meetings were called by the area chiefs and their assistant chiefs with the assistance of the village elders and it also involved the County and National Government who were represented by the Members of County Assembly, Sub-County Administrators, and the Members of parliament Constituency Office. Meetings were held at areas identified by the Chiefs and the local community and all the discussions held during the public forums were minuted and the copies of the minutes attached to this report with the list of attendants and their appended signatures (Appendix 3). A brief of the content of discussions held during the public surveys are discussed in the sections on study findings. The consultations were held in three languages; English, Kiswahili and the local 'Tugen' language, which pre-dominated the consultations. The consultants used English or Kiswahili language in the communities depending on the attendant's preferred communication language; a local was always on standby to translate the discussions in 'Tugen'. The community members appreciated the use of their local dialect and stated that it made them understand the proposed project components more.

Consultations with the heads of departments were conducted on a one on one basis at the County and National government at the County level, Sub-County, region and district levels which included consulting officers at County Offices in Baringo, the District Headquarters (Mogotio and Baringo Central), Sub-County Headquarters at Mogotio and Baringo Central) and Constituency Office at Mogotio and Marigat (Baringo South). The aim of the consultative meetings was to obtain data related to the past and present status of the project area, that is significant to the management of the project both during and after implementation in order to ensure sustainable environmental management.

7.2.6 Engineering Studies

The consultant's study encompassed undertaking several engineering studies which included hydrological studies, geological studies (geophysical investigations geological and geotechnical investigations, laboratory testing of construction materials and topographical and land surveys. Most of the studies are still ongoing and their findings shall be presented in the final ESIA report.

7.2.7 Constraint and Limitation

The consultants noted that, the potential impact of the project will be on land use especially on settlement and land use. Most of the community members had no objection to the project as long as they were properly compensated and adequately informed on the management of the project. The main issues of concern during the study were:

- The community have had bad experiences in the past with Governmental Agencies undertaking development in the area. This arouse scepticism, mistrust sometimes bordering on hostility from the residents
- Poor road network in the project area;
- Poor attendance of consultative meetings or generally late attendance forcing the team to reschedule the meetings;
- The development plans of the areas are yet to be officially launched making assess to currently baseline information a challenge.

Despite the short comings, the study was successfully conducted and the community members finally welcomed the project.

7.3 Overview of Environmental Baseline Conditions

Catchment Management: Efforts are being made by several institutions in the area including the Water Resources Management Authority and Department of Agriculture to conserve the catchment area by training locals on environmental conservation through such practices as natural rejuvenation (cutting trees to stem to allow for re-growth); alternative sustainable income generation activities as the area has been facing a lot of environmental degradation due to the current practices being undertaken by the community members. Apart from pastoralism which involves overstocking of animals the community engage in charcoal burning as an alternative source of livelihood and it seems to becoming their main stay as the animals are lost during the dry season due to lack of water and forage. The income generation activities being promoted are bee keeping, good agricultural practices (mulching and terracing of farms) in Tenges and Kinorum. Though tree planting is being advocated in the area to support the bee keeping industry the smoke from charcoal burning kills the bees or reduce their productivity. Bee keeping is also being affected due to lack of reliable markets and efforts are being made to attract investors in the area to develop a honey processing factory in the area as mitigation measure to environmental degradation.

Soil erosion and Siltation: Siltation in the area is considered to be high as studies have shown that the depth of Lake Baringo which is fed by the Perkerra has reduced from 8m in 1973 to 2.5m in 2003. The studies showed that the IKae has grown turbid and this could be attested by the visual observation of the river which was turbid throughout its length an indication that soil erosion is high in the area. Siltation is also seen to be high due to degradation of the vegetation cover which loosens the alluvial soils in the area further making it easy to be carried by agents of erosion such as storm water run-off, wind, livestock among others. Some silts could be coming from area further upstream of the project area as the area immediately upstream of the project area such as Tenges and Kinorum is considered not to produce high silt as they have indigenous forests cover and farmers undertake good farm management as the farms are terraced in addition to that the farms have furrows and ridges and the fallow land have tree vegetation cover. Tebei area has indigenous forest and, trees and shrubs in the private lands as area not cultivated thus erosion is low. The upstream areas have conducive climate for farming thus the communities have food sources and also act as income sources thus they do not engage much in charcoal burning.

Water Demand and Access: The project area is known to be water deficit and experience long periods of drought. Perkerra River is the main if not the only source of water to majority of the community members. The water table in Tinamoi was found to be high and with litte rainfall the areas would get soggy and even some households become inhabitable. Consultation with the community members indicated that they don't have to dig deep to access the water table and as opposed to other area where flood forces they to migrate they are forced to migrate due to the swampiness of the and proposed that the dam be located in the area.

Waste management: The project area is predominately rural area with no industries and vehicles traffic thus has natural ambient environment apart from areas where charcoal is brunt where smoke emission was visualized. The area has no visible solid waste deposits or air quality problems.

7.3.1 Physical Environment

7.3.2 Climate and Topography

The project area is located in an arid and semi-arid region with high day time temperatures of upto 30^{0}C during the dry months. The annual rainfall in the hilly areas is estimated to be between 1,100 millimetres to 2,700 millimetres and in the low lands around Lake baringo it is 400mm. The area gets very windy before the rains starts and the rains are normally short and associated with heavy downpour which is accompanied with thunder.

In general rainfall in the Koibatek and Baringo districts is seasonal and fairly reliable, with long rains coming between March and July with maxims occurring in May and the short rains occurring between September and November with the maxims in October. Minimum rain occurs in January. The average total rainfall per annum ranges between 800mm in the lowlands to 1200mm in the highlands. The mean average temperature is 30oC in the lowlands and 24oC in the highlands.

Most of the river water comes from the hill slopes, where annual rainfall is from 1,100 millimetres to 2,700 millimetres. The region around the Lake Baringo is semi-arid, with annual rainfall of 450 millimetres and annual evaporation rates of 1,650 millimetres to 2,300 millimetres.

Baringo varies in altitude between 3000m above mean sea level at its highest points and nearly 700m above mean sea level at its low points. The County has the Kerio Valley on the western part, Lake Baringo and Bogoria in the eastern part forming the Loboi Plains which is covered mainly by the latchstring salt-impregnated silts and deposits and the Tugen Hills where the proposed project is located. The trend of the hills is north-south and mainly consists of volcanic rocks. The hills have steep slopes with prominent gullies. On the eastern and western parts of the hills are escarpments. River Perkerra flows in the hills in very deep gorges thus its suitability for the proposed project.

The Perkerra river catchment is characterised by very steep slopes on the hillsides and gentle slopes in the middle and lower reaches where the surface is bear with very little undergrowth. The altitude of the area is estimated to be between 3000m above mean sea level at its highest points and nearly 700m above mean sea level at its low points. The project area is arid and semi-arid and the inhabitants of the Perkerra Catchment are mainly pastoralist but farming is undertaken in the highlands around Tenges upstream of the project area.


Plate 7.1(a): Deforestated area showing loose baresoils


Plate 7.1 (b): Loose sandy soild by the River bank in Radat


Plate 7.1 (c): View of the Perkerra River in Tinamoi sub-location showing the Turgen hills in the background


Picture 7.1 (d): Picture showing the degraded Loboi plains near Lake Baringo

7.3.3 Land use:

River Perkerra is located in a heterogeneous catchment with a fragile ecosystem with highlands with moderate climate and low lands with harsh climate. The project area is arid and semi-arid and the inhabitants of the Perkerra Catchment are pastoralist thus the land is mainly used as grazing land and for subsistence farming in the highlands as the climate there is conducive for crop growing. The farmers in the highlands practice conservation agriculture in order to reduce erosion but overstocking of livestock, deforestation which is evidently seen through charcoal burning is causing degradation of the catchment. Quarrying and sand harvesting is also starting to pick up in the area due to the increase in construction activities. The natural forest in the region are being exploited for timber, wood fuel and settlement.


Plate 7.2: Hills left void of vegetation due to deforestation

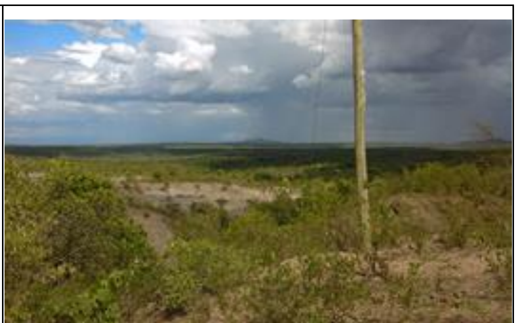


Plate 7.2(b): Vast degraded land in Tinamoi/Tebei area

 Plate 7.2 (c): Erosion and deposits on a seasonal arm of the Perkerra	 Plate 7.2 (d): Erosion on degraded hill slopes in the project area

<u>Livestock keeping</u>

Apart from pastoralism which involves overstocking of animals the community engage in charcoal burning as an alternative source of livelihood and it seems to becoming their main stay as the animals are lost during the dry season due to lack of water and forage. The income generation activities being promoted are bee keeping, good agricultural practices (mulching and terracing of farms) in Tenges and Kinorum. Though tree planting is being advocated in the area to support the bee keeping industry the smoke from charcoal burning kills the bees or reduce their productivity. Bee keeping is also being affected due to lack of reliable markets and efforts are being made to attract investors in the area to develop a honey processing factory in the area as mitigation measure to environmental degradation.

<u>Wildlife</u>

The project area especially Radat and Kimose forms part of the spatial corridor for Lake Baringo and Lake Bogoria National Game Reserve where the habitats of wild animals like the tortoise, hares, impala, rare kudu, antelope, hyenas, snakes are found. Other animals found in the lakes reserve are zebras, leopards, cheetahs, mongoose, monkeys, baboons, birds, hippopotamus (Hippopotamus amphibius), crocodile (Crocodylus niloticus), jackals and many other mammals, amphibians, reptiles and the invertebrate communities. Lake Baringo is home to about 500 species of birds and fauna, some of the migratory waterbird species being significant regionally and globally. The lake also provides an invaluable habitat for seven fresh water fish species one such species is Oreochromis niloticus baringoensis (Nile Tilapia) which is endemic to the lake. Additionally the area is a habitat for many species of animals including the. The wildlife roam freely on the local communities land but the County Government in collaboration with community members are planning to develop a conservancy in the area so as to attract tourism and promote imitated tourism programmes such as the Trans Rift Trail a treking tourism attraction. The development of the dam will enable the wildlife department create more touristic programmes in the area

Several salt licks are located in the privately owned farms and are used by wild animals to supplement their nutrients requirements

7.3.4 Geology and Soils

<u>Geology</u>

The project forms part of the Tugen hills which runs in the north-south and mainly consists of volcanic rocks. The hills have steep slopes with prominent gullies. The

Perkerra River flows in deep gorges of the Baringo in the Loboi plains. The geology of the area shows that the area has good landscape for storage of large volumes of water. The oldest rocks found in the area belong to the basement system. Fluvial sediments are deposited in the depressions of the basement. The general geological succession in the section of the Perkerra River is complex as it consists of a series of lava groups and one major tuff and sediment group all in unconformable relationship and frequently faulted.

Soils:

The soils in the project area and Baringo in general are volcanic fluvisols of sandy/silty clay loam texture. The river sediments are slightly acid to slightly alkaline and highly fertile. This soils are unconsolidated and loose thus are easily eroded which will require management in form of reforestation and programmes to reduce deforestation so as to reduce transportation of silt to the river and subsequently the dam.

7.3.5 Hydrology and Drainage

The Perkerra River rises in the Mau Forest on the western wall of the Rift valley at 2,400 masl, dropping down to 980 masl at Lake Baringo. The river is formed from a union of several streams from the Lembus forest highland, Maji Mazuri, Timboroa, Chemeorok and Metkei forest. The river has several tributaries namely Tigeri (Chepkungur), Lelgal, Eldama Ravine, Narosura and Esageri. The Perkekrra river catchment is characterised by very steep slopes on the hillsides and gentle slopes in the middle and lower reaches where the surface is bear with very little undergrowth with a total catchment of 1,411km2. The the river flows into Lake Baringo whose drainage area is 6820 km2. The Lake is a Semi-Arid Lake which and according to reports it has reduced its depth from 8m in 1973 to 2.5m in 2003 due to siltation resulting from high soil erosion rates in the catchment which has affected the lakes turbidity.

Water quality in the area is mainly affected with silt due to poor land use practices such as deforestation, poor land management practices and overstocking of livestock. The area experience a water deficit for both domestic and livestock at 40m3/day and 50m3/day in the lower catchment due to high human and livestock population , irrigation and rainfall variability. The river flow has been reducing over the year's and conflicts always arise between downstream and upstream users over resource development upstream for downstream usage.

The main Perkerra river has several tributaries including Kureswa, afirip, Kirer, Kipsarita, Perkerra, Eldama Ravine and Kabiet.

7.3.6 Vegetation

The vegetation of the area is mainly acacia woodland and shrubs thickets growing in the dry and rocky hills. The vegetation predominated with the Acacia commiphorra sp which is being lost due to deforestation brought about by charcoal burning. Prosopis juliflora one of the world's worst invasive alien species according to the IUCN's list is found in Marigat. The Cactus (Opuntia stricta) also an exotic invasive plant was seen mainly in Kimose and Radat sub-location. The medicinal Aloe turkanesis which is currently considered almost extinct in the wild was seen in various parts of the project area especially in Kimose. The sisal plant Agave sisalana were predominantly seen around the locatios as they were mainly used for demarcating land boundaries.

The major vegetation types in the catchment are forest 26%, evergreen and semi-deciduous bush land 37%, and deciduous and semi-deciduous bush land 37% (Onyando et al., 2005). In general the vegetation of the upstream of the project area consist mostly of woodlands in the hills and mountainous areas and dry woodland and bush lands in the lower areas such as Kimose. The project area has over 130 plant species spread in 50 families consisting of shrubs, herbs, climbers, grass, legumes, orchids etc which are used as source of food, shelter, animal fodder and human medicine. The main vegetation in the project area is acacia woodlands predominated with the Acacia commiphorra sp which is being lost due to deforestation induced by charcoal burning. Prosopis juliflora one of the world's worst invasive alien species according to the IUCN's list is found on the downstream of the project area mainly in Marigat. The invasive Cactus (Opuntia stricta), the medicinal Aloe turkanesis and the sisal plant were predominantly seen around Kimose and Radat sub-location.

The project area is predominately privately owned with pieces of government owned land but the County has conserved exotic and indigenous forests found in Kabarnet, Kabartonjo, Tenges, Lembus, Saimo, Sacho and Ol' Arabel and Eldama Ravine. The main exotic species grown are Grevellea Rabusta, Cuppressus lusitanic and Eucalyptus saligna. The forest closest to the project area is Tenges located upstream of the area and is still in its natural state.

Plate 2.1.5: Acacia woodland in Bekibon

Plate 2.1.5(b)Cactus (Opuntia stricta) an exotic invasive plant found in the project area

Plate 2.1.5(c): Birds nest and beehive perched on the acacia tree

Plate 2.1.5(d): A field officer observing a tortoise cross the road

7.3.7 Water Resources

The common source of domestic water in the area is Perkerra River. The river was identified as the only all-weather river with other rivers being seasonal. The area is known to be a water deficit area with both for livestock and domestic use. The water quality is also low mainly due to high turbidity caused by high siltation. The project are has water surplus during the rainy season and acute deficit during the dry seasons due to the degraded environment and it is hoped that the development of the dam shall help restore the water problem and environmental damages.

7.3.8 Energy

Primary data from field survey shows that wood fuel is the main source of cooking energy in the entire project area standing at 94.7%. Further analysis shows that Kerosene (94.8%) was the main source of fuel for lighting for majority of respondents in the project area. Electrical powerlines were seen to traverse the area but it is mainly supplied in the urban areas. The area has high solar energy potential which can be exploited during the project operation phase.

7.4 Alternatives including the Proposed Action

7.4.1 Project Alternative

The alternative to the proposed dam project is to limit the irrigation project to 254Hectares supported by the normal river flow.

7.4.2 The No Action Alternative

The No Action Alternative with respect to the proposed project implies that the status quo is maintained and the irrigation scheme is no expanded. This option is the most suitable alternative from an extreme environmental perspective, as it ensures non-interference with the existing conditions. The anticipated environmental impacts resulting from construction and occupation activities would not occur.

This option will however involve several losses both to the project proponent, farmers and, other stakeholders in the society and for Kenya at large. The No Project Option is the least preferred one as the anticipated socio-economic and environmental benefits that would accrue to from the project will be foregone.

7.4.3 Alternative design and technology

The proponent and the various professionals involved in the project this is the engineers, and surveyors and environmental consultants shall evaluate the various alternative sites, designs and technologies. The options shall also be communicated to the stakeholders including the community members through a series of consultative public forums so as to get their views on the available alternatives. As part of preliminary studies, a rock filled dam has been proposed and it shall be further evaluated against other dam types.

In regard to socio-economic evaluation, construction of the dam will mean resettlement of people within the earmarked dam and reservoir area, which will lead to several impacts such as high costs of relocation, movement of a section of the community to other areas which might lead to several other socio-cultural impacts among other issues. Therefore alterative site evaluation needs to be considered so as to reduce the project impacts and associated costs.

7.5 Public Participation

7.5.1 Legal Requirement

The Kenyan Constitution, Section 17 of the Legal Notice 101 of June 2003 and several other pieces of regulations on natural resources management such as the Water Act 2002, requires that all development projects and Environmental Impact Assessment process in Kenya incorporate Public Consultation. The aim is to ensure that all stakeholders with interest to the project are identified and catered for in the project planning, construction and operation phases. Of necessity, stakeholder consultations should take place alongside project planning to ensure that project design puts in place measures to cater for stakeholder concerns in the entire project cycle. The need of public consultation is also supported by other statutory requirements like the Forest Act and several policies.

7.5.2 Approach to the Consultations

Review of Selected Documents Relevant to the Project

The consultants reviewed several documents on guidelines of environmental assessment and other technical reports containing data and baseline information on the project area's environment. The available data was subsequently analyzed during evaluation of the project potential impacts and development of data capturing tools. Some of the documents reviewed include:

- Documents assembled and generated from previous studies
- Design report for the dam;
- National census reports;
- County Integrated Development Plans;
- Policies and Acts relevant to the proposed project and
- Secondary literature on dam development and environmental conservation.

Pre-Field Briefing

Briefing was used to harmonize the views of both the client and the consultant and it consisted of discussions between the consultant and the client before embarking on the assignment. This afforded both parties an opportunity to discuss the Terms of Reference, the work schedule, and the proposed approach and methodology put forward by the consultant. The consultant's itinerary and requisite assistance from the client in terms of provision of introductory letters, clients representative and briefing, also helped the consultant to understand more clearly the client's views, future vision and expectations of the project and thus stay focused on the project objectives and activities. A framework for coordination and communication between the client and the consultant was discussed and agreed upon.

Identification of Core Stakeholders

A stakeholder analysis was undertaken for the study and this involved identifying all the people with interest or people likely to be affected by the project and categorizing them into groups based on their involvement on contribution to the project. The categories used included primary or secondary stakeholders. The key informants were consulted on sectoral policy and to advise on the required EIA study safeguards in order to minimize negative impacts in respective sectors. The list of identified stakeholders is provided under annex 6 of this report.

7.5.3 Modalities for Stakeholder Consultation

Public Consultations

Public consultation was conducted throughout the project area in form of public forums in the months of March and May 2014. In total twelve (12) official public forums in addition to impromptu consultative meeting with interests groups were held at the sub-location level with the assistance of the local administration. The meetings were called by the area chiefs and assistant chiefs through the village elders. The initial meetings held in March was mainly for introductory purposes to disseminate the proposed project plans to the community members, to get their views and to introduce the land surveyor to them so that he could initiate the project area boundary identification process. The meetings held in May were follow up meetings whose aim was to collect baseline information, issues of interest/concern from the community members based on their understanding of the proposed project and also gauge the level of project acceptability. All the discussions held during the public forums were minuted and the copies of the minutes are attached to annex 3 of this report with the list of attendants and their appended signatures. The consultations were held in three languages namely English, Kiswahili and the local 'Turgen' language. The consultants used the English and/or Kiswahili language in the different communities depending on the community members preferred communication language and a local was always on standby to translate the discussions in 'Turgen'. The community appreciated the translation of the content under discussion and stated it made them understand the project proposal and associated components better. The output of the discussion indicated that the community members are receptive of the project apart from those in Radat who are still to come to terms with the project. At least 95% of the public forum attendants have understood the project objectives and have accepted it be implemented in their area provided mitigation measures of anticipated negative impacts are implemented as required. Since the Radat site was seen to have the highest project potential there is need to engage the community further and develop mechanisms to quench the fears and the uncertainty they associate the project with. If consultation outcomes indicate otherwise alternative sites will have to be considered as community members residing near the alternative sites have welcomed the project and are ready to have it developed in the area.

7.5.4 Highlights of the stakeholder meetings

<u>The Inception Consultative Stakeholders Meeting held on 13th March 2014 at the Sun City Hotel Marigat</u>

- 39 participants out of the invited 42 attended which was outstanding since even those who failed to attend sent apologies.
- A major positive was the attendance and engaged participation of the Deputy Commissioner of Baringo Central District Mr. N. Tanui, who officially opened the proceedings. Of special note was the attendance and presentation by the Manager of National Irrigation Board who represented the NIB.
- The Chief Officer responsible for Water and Irrigation attended as did 2 Members of the County Assembly, and all the Chief and Assistant Chiefs of the affected areas attended.
- Of special note is the representation of marginalized Eldorois group as well as the participation by the leadership of the Marigat Group Ranch.
- The Manager of the NIB Marigat gave an overview of the Irrigation program current existent and the rationale for Radat dam in increasing irrigable area. He also addressed all concerns raised by the participants concerning ongoing projects by NIB.
- The consultant team gave a detailed presentation of the proposed dam with a draft design. Proposed the timelines that will guide the feasibility study and design was presented and stakeholders and leaders requested to fully support it.

- The area leaders present during the consultations were and the others they represented were very positive about the project and were supporting its immediate implementation.
- The next steps in the project schedule was the topographical survey fo the proposed sites to delineate the dam areas. The participants especially the Chiefs and assistant chiefs were requested to support and facilitate the surveyor's work by informing the community about the project and the planned exercise.
- The plenary session of the meeting was active as the leader engaged the consultants in a question and answer session which contributed a lot to the project planning and some of the key issues discussed included: impacts of previously developed dams in the County such as the Chemususu and Kirandich Dam; issues of compensation of those who will be displaced ; factoring of mitigation measures for the identified potential negative environmental effects in the design and holding of project follow up meeting at the sub-location level.

Meeting with Chiefs and Assistant Chiefs to plan sub locational visits: 13th March 2014

After the Inception meeting at Marigat, a brief meeting was held by the Social Development Expert, the Environmental Expert and Project Engineer to follow up on the request for community meetings at the sub-location level before the Surveyor is deployed. It was deemed that the same message that had been transmitted to the leaders be also transmitted to the communities likely to be affected by the project as Constitutionally required this meeting was aimed to win the good will of the people and, to develop a cooperation relationship and, for them to support the study and design and also to enable gather their initial concerns/input for consideration in the dam design.

The resolution was passed in the meeting for the team to begin mobilization of the community members immediately and the meetings were scheduled to begin on Monday 17th March 2014.

Community Forums held between 17th – 21st March 2014

A set of five (5) community forums were held across the earmarked project area found within the Perkerra Basin. The meeting were held at sub-location level and it targeted all community members in the locations and more so those who are likely to be significantly impacted by the dam. Community forums were coordinated through the office of the local Chief and his Assistant chiefs in the following administrative areas: Radat, Kimose, Cheberen, Tebei and Tinomoi. The Meetings were attended by a representative sample of the local population led by the Chief and the Assistant Chief. A standard presentation format was used in all the meetings where presentations were made by the Social Development Expert, The Surveyor, The Environmental Expert and the Engineer. A standard protocol was used for gathering information where the Environmentalist captured the minutes and the concerns or issues raised and the Social Development Expert moderated the proceedings. Since the main object of the first meeting was information, they took about two hours on average. A details matrix indicating the date of meeting, venue and the number of participants is found under annex 7 of this report.

Community Forums held between 8th – 23rd May 2014

In these meetings, questions or queries from PAP's were discussed and uncertainties clarified. Each sub location had at least two meetings, with the second on leading to

FGD. First meeting was held at Kimose on 19th May 2014 with Radat, Tinomoi, Tebei and finally Cheberen following in the week ending 23th May 2014.

Additional follow up meetings wherever requested by communities, were held either to provide information to potential PAP's who missed earlier sessions or clarify aspects (especially on land take, compensation and resettlement) of the project that were not properly understood. Because of community anxieties over the project, at least six Meetings were held at Kipting Bridge on the boundary between Radat, Kimose and Tinomoi Sub location. These meetings were requested by members of the community who felt they would be affected and were opposed to the project. These meetings were held on 9th, 12th 14th and 16th of May 2014 alongside other informal meetings. The meetings of 12th and 16th May were attended by all Government agencies, with representation from the governor's office, the members of the county assembly and the provincial administration. The leadership of the Communities was also present and raised their concerns and fears. On 17th, they resolved to allow the socioeconomic and environmental study to proceed. Different groups of stakeholders were consulted and these include fish mongers, women groups and individual persons. The main aim of consulting them was find out social economic impacts related to health, economy and environment of the people living within the flood area.

Using contact address information on the project brochure, affected people occasionally visited the consultant's office or called by telephone or email correspondence to seek additional information. Community meetings were attended by a broad spectrum of residents including women, elderly people and youths. A record of the meetings is attached.

7.5.5 Environmental and Socio-Economic Survey

Upon the completion of a comprehensive literature review, a household survey was undertaken with the aim of conducting interviews with the communities and stakeholders identified at household level and to undertake a ground truthing of the information collected from secondary literature. The household survey methods including a two-stage sampling design was adopted. The first stage was the random selection of households within the project area while the second and ultimate stage was the selection of competent enumerators within the locality. The boundaries of each village were identified by the enumerators together with the community leaders. For each selected village a list of corresponding households was compiled with help of community leaders a day before the surveys. The interviewed households were randomly selected from the compiled list basing on an array of random numbers.

Since the Project could also have wider community impacts, such as creation of construction jobs and potential impacts resulting from land acquisition, vegetational clearance and structure relocation, it was also important to understand what community perspectives were in regards to the project. To gather this information, a census questionnaire which was to be answered by sampled population in the project area was designed to cover issues of demographic of the area, socio-economic engagements and environmental information. A copy of the questionnaire is attached under annex 2 of this report.

<u>Conceptual Design</u>

This ESIA survey gathered community baseline information and initiated a process of dialogue with stakeholders to enable understand the likely social and environmental impacts of a large project of this scale, it was important to collect views at household level from stakeholders in the communities to be affected. In particular, it was important to collect information relating to the following issues:

- What households and stakeholders within the proposed dam area knew and did not know about the Project and sources of their information
- How important they thought the project was
- What benefits they hoped it might bring
- What negative effects concerned them
- What suggestions they had about increasing positive benefits and
- What suggestions they had for reducing negative effects

The questionnaire helped gather the broader baseline information of the entire project area and for resettlement purposes, 100% of the identified PAPS will be engaged when the dam contour has been demarcated and those affected clearly established.

Data processing and analysis

Household data questionnaire was collected from enumerators and cleaned up and then forwarded to a professional data analyst to develop an SPPS database framework. During database cleaning, trial runs for variables 'descriptive, frequencies and cross-tabulations were used to identify inconsistent information that would be double checked and rectified. Routine examination of these trial runs outputs were undertaken to uncover dirty data. The data entry team sought clarifications with the field team whenever they thought necessary.

Questionnaire Design

The ESIA questionnaire was designed to have a household section and community characteristics section which captured environmental information in addition to the socio-economic information. The household section had three modules covering:

- information about the project;
- household characteristics; and
- living standards

The community characteristics section had five modules covering:

- basic demography
- village/community economy
- education, culture and local politics
- health and healthcare services and
- natural environment

7.5.6 Consultations with Stakeholders in Government

This category of stakeholders was consulted by visiting them in their respective offices. Consultations were made with individual officers and to enhance the discussions, summarized checklists were used to guide the interviews the discussions started with the consultant team explaining the project objectives to the target officer, following which they were asked to identify their most fundamental concerns or benefits on the project.

The aim of the consultative meetings with the governmental representatives, was to obtain data related to the past and present operations of the project, that are significant to the management of the project both during and after implementation and to ensure sustainable environmental management. A total of twenty four (24) government and non-governmental offices were visited and their heads interviewed in connection with the proposed project.

7.5.7 Brief on the arising issues discussed in the meetings

- All the meetings resolved to allow the surveyor to commence work and to facilitate operations by availing youth to guide them through the terrain. They were happy to learn that some little income would accrue to the participating youth.
- All the meetings raised concerns of how they would benefit from the project: It was proposed that the design be such that benefits would befall both the catchment area and the reservoir area. It was proposed that other project be developed to support those who won't directly benefit from the dam either due to their current or future location and the proposals made included development of smaller dams, smaller irrigation schemes, small water supply schemes and community amenities such as schools, roads and hospitals as part of the dam.
- The Community of Kimose and Radat felt that they would be most affected by the dam and thus requested some shares in the proposed irrigation scheme.
- There was concern for cultural artefacts that would probably be submerged by the dam that needs conservation
- In view of challenges be-devilling Chemususu dam in the same Baringo County, some participants felt they needed guarantees and reliable commitments from the Project proponent and not the Consultant on the benefits they shall accrue from the project. They thus requested that in future meetings, someone from the National Irrigation Board attend the meeting: It was suggested to them to form project committee that shall engage stakeholders on their behalf. All the meetings resolved to form committees to follow up on the project and to further discuss and identify their interests in the project
- Participants were concerned about the mode of compensation both for the individuals who will be directly affected and may need to relocate and those who will be affected by the micro climate created by the man made "lake" that is the dam. They requested that mitigation measures be factored in the design so that all the issues are addressed.
- There were concerns about the benefits they will get from the projects such as job to be created by the dam project and the need to ensure that locals in their diversity benefit from the project.
- They also needed to know who will be custodians of the by-products of the dam such as the fish, generated electricity among others
- They proposed as part of compensation they be allocated shares in the proposed expansion of the irrigation scheme or as an alternative irrigation projects de developed upstream so that they can also undertake agriculture

so as to reduce their dependence on relief food and also find a source of income

- They proposed that all wildlife in the project area be relocated before the dam is full so as not to lose them through drowning or other project associated hazards
- They suggested that the local community be allowed to access medical facilities built by the contractor or the proponent should stock their hospitals with medicine and provide mitigation measures to hazards they will be exposed to due to the project

7.6 Key findings from stakeholder consultation

7.6.1 Project Implementation

Common stakeholder queries and concerns were:

- How long will the project development take because this is useful for entrepreneurs who may wish to develop services that support project development?
- All dam projects seem to be concentrating on River Perkerra; what effects will the development have on other planned projects along the Nile?
- What considerations were taken to choose the best location of the dam and what were the alternatives?
- Back flooding may affect others areas that were not in the plan. How will the project ensure that the same volume of water flows down to downstream communities?
- Will the County get electricity from the project and how long will Proposed Radat Dam be on the grid?
- The proposed project if implemented may damage the already existing roads; therefore effort should be made to maintain all existing access roads or better still improve on them.
- Which are the actual homesteads to be affected by the project? How soon will valuation data of affected PAPs be given to district officials in charge?
- We now get water for free , why should we allow a project that will force us to buy water from the same source we have always got free water
- Why should the dam be called Radat Dam and not an all-inclusive name like Perkerra Dam?

7.6.2 Land

- Who gives consent on surveying affected land? Is it the land owners, the present occupant, or is it a compulsory requirement of law?
- Where will the PAPs whose land is going to be affected be resettled? Is there enough land? Could the PAPS be shown the land before they accept the project?
- What happens to land that ownership has changed hands but title has not been transferred?

7.6.3 Timely, equitable compensation

- Will it be government rates or commercial rates or will the PAP determine his own price for the land he vacates?

- Most government projects get problems during the compensation stage especially if given in instalments. Will compensation be done in instalments?
- Are squatters on the affected land compensated?
- Will the government/NIB compensate PAPs with no land title deeds or those who have not collected the title deeds?
- Is "good will" of an economic facility compensated? Will the potential of land be compensated

7.6.4 Employment

- Will the proposed project consider employment for the locals?
- When employing workers for the project, won't the contractors consider academic qualifications and bribes?
- Is it possible to sign an MOU beforehand assuring that locals will be given priority?

7.6.5 Grievances

- In case of any grievances, where will the offices be located?
- There are repercussions of a dam after it has been built. People employed by the project end up contributing to crime after the project ends. What measures have been put in place for such cases?

7.6.6 Benefits

- The dam as presently proposed seems to be benefit Marigat and the downstream people more that people upstream who will be conserving the dam? Is it to possible to factor in benefits for upstream people also?
- Could the project should set up facilities such as schools, health centers or roads as a corporate social responsibility.
- Is there a plan for revenue/project benefit sharing with stakeholders?
- Now that Kipting Dam will likely be sunken by the dam, can another one constructed?

7.6.7 Stakeholder involvement

A common complaint by the residents was the feeling of being rushed and not being sufficiently consulted. They have suspicions of big government projects and their experience in Chemususu dam, Kirandich Dam, Chemeron Dam, all in Baringo County has made them mistrust big dam projects. In their view, PAPs and communities around the dams previously constructed were not well treated.
It is recommended that a continuous engagement with the communities be set up. The challenges of resistance happened before the PAPs were even identified. It can only get worse get into the compensation phase. Sufficient time and resources should be set a part for consultations

7.6.8 Conclusion of the Public Consultation Findings

Generally the public response to the proposed project is positive and majority of the community members would like the project implemented. The major shortcoming is some of the community members do not believe on the proposed project's outcome. These shortcomings shall be mitigated by the proponent by:

- Ensuring an appropriate RAP is develop and implemented before project commencement;
- Acquiring land only required for the development; and

- By implementing the EMP to ensure that all the anticipated potential negative impacts are mitigated against or maintained to acceptable minimum levels which suggests also alternative project sitation in case agreements are not reached at earmarked site.

7.7 Anticipated Environmental Impacts

The project is anticipated to have in overall a cumulative positive impact as the negative impacts are seen to be less that the positive impacts. Some of the potential positive impacts identified through the studies are listed below.

Construction and project operation activities involve a series of defined physical operations and these include site preparation which covers vegetation clearance, excavation works, building works for the project camps etc. All these activities are potentially significant sources of impacts both significant and insignificant. On completion of project construction phase, the operation phase activities are also associated with impacts which the study team evaluated.

To ensure project sustainability, both environmentally and socio-economically, there is need to enhance the identified positive impacts and minimize or mitigate the negative impacts.

7.7.1 List of potential Impacts

Below is an outline of the anticipated project impacts which are categorized into either positive or negative. The impacts have further been grouped according to the phase in which they are likely to occur in the project's life cycle, namely the construction or operation phase. A detailed Environmental Management and Monitoring Plan in presented under annex 10 of this report.

<u>Anticipated Positive Impacts during Construction</u>

- Creation of employment;
- Creation of markets for project development materials;
- Increased business opportunities for local traders;
- Increased revenue to the Government through tax and duty payment; and
- Increased visitations to the project area which will thus lead to increased economic activities and in turn lead to development of secondary projects and businesses.
- The development of the dam will improve the areas micro-climate and make it cooler, increase soil moisture thus increase vegetational growth which will help combat climate change as vegetation are known to hold about 70-95% of the water (green water) thus the they can be sued as moisture reservoirs to help regulate the temperature at the same time control run-off and siltation.

7.7.2 Anticipated Negative Impacts during Construction

- Increased river sediments and eutrophication thus reduced water quality;
- Increased soil degradation at working areas due to compaction
- Interference with local infrastructure including access routes, power lines;

- Interference with access to the river for existing water users due to increased abstraction for construction purposes;
- Destruction of vegetation on river riparian and private lands;
- Increased consumption of fossil fuel;
- Increased soil erosion;
- Increased exhaust emissions thus change in air quality;
- Increased solid waste and need of disposal sites;
- Increased exposure to risks and accidents thus affecting the health and safety of workers and the community members;
- Interference with socio-economic activities;
- Increased land demand thus affecting its value and resettlement costs and process;
- Loss of properties and livelihoods;
- Degradation of cultural practices due to loss of cultural and historical sites ;
- Relocation and separation of communities;
- Interference with socio-cultural set up;
- Increase in social vices including alcoholism and drug abuse, HIV/AIDS; and
- Reduced capacity building, especially if local skills are not sought during engagement of the project workers.
- Loss of wildlife habitats, salt licks, breeding sites and displacement of wildlife in general from their spatial area

7.7.3 Anticipated Positive Impacts during Operation

- Annual and regulated supply of water
- Reduced siltation
- Improve areas micro-climate this will be positive as the area is very hot and the dam will increase the humidity creating a cooling effect;
- Increased economic generating activities such as fisheries, bee keeping, tourism, irrigation agriculture and creation of secondary businesses or income generating activities
- Increase natural vegetation cover in the periphery of the dam
- Reduced downstream and upstream water conflicts due to reliability of water flow
- Revival of dried river beds which have been affected with change in areas environment such as degradation which has reduced water retain in the area
- Increase natural vegetation cover in the periphery of the dam and entire catchment if rehabilitation programmes are developed and implemented;
- Increase in organised agricultural production through irrigation;

- Increase in agricultural productivity;
- Diversification of agricultural activity to include zero-grazing, aquaculture;
- Increased food insecurity;
- Creation of employment;
- Optimization of time use through continuous engagement in agricultural activities;
- Reduction in poverty;
- Increased development of the project area due to attraction of secondary businesses;
- Positive attitude towards the National Irrigation Board(NIB) by the local community;
- Improvement in the service industry as project will attract financial institutions, medical facilities, learning institutions, light industries including revival of food processing industries e.g. rice mills
- Increased water quality and quantity of the Perkerra River
- Reduced incidences of floods and damage associated with them
- Provision of water supply to areas that were initially facing shortage
- Reduced in river sediment and improvement of the water quality at the Lake
- Continuous flow in the river due to the regulated release of the stored water thus helps improve the Lake's water levels.
- Revival of dried river beds which have been affected with change in areas environment such as degradation of the catchment which has reduced water retention in the area

7.7.4 Anticipated Negative Impacts during Operation

- Increased eutrophication of underground and above ground water due to inorganic farming ;
- Inter-basin exchange of water;
- Increased damming, subsequent storage, inappropriate water allocation and irrigation activities along the river will continue to deprive the Lake Baringo water thus its water levels will continue to dwindle thus affecting the aquatic and terrestrial life that depends on it.
- Possible salinization of the water during operation due to water logging leading to deterioration of river water quality and soil nutrient profile.
- Increase agriculture in the upstream area which will be associated with the use of organic fertilisers will lead to degradation of water quality due to eutrophication of the water thus affect human, animal and wildlife health and the soil quality;
- Reduced access to the riverine resources by community members;
- Chances of introduction of invasive aquatic weeds;

- Increase in disease vectors such as mosquitoes, snails and leeches.
- Increase in solid waste generation mainly of organic nature which if not well managed shall contribute to global warming and wetlands eutrophication
- Increased exposure to risks and subsequent accidents e.g. drowning of children, small animals etc.
- Increased damming and subsequent storage and irrigation activities along the river will continue to deprive the Lake Baringo water of water thus its water levels will continue to dwindle thus affecting the aquatic and terrestrial life that depends on it.
- Soil degradation due to vegetation clearance and in working areas, earth works and storage of material at project site
- Increase agriculture in the upstream area which will be associated with the use of organic fertilisers will lead to degradation of water quality due to eutrophication of the water thus affect human, animal and wildlife health and the soil quality;
- Health and safety risks associated with construction accidents, equipment's, chemicals, drowning and health induced diseases associated with water storage such as malaria, bilhazia among others
- Possible salinization of the water during operation due to water logging leading to deterioration of river water quality and soil nutrient profile.
- Loss of salt licks which are used by the wildlife to supplement their nutrient requirements.
- Spread of invasive plant species both to the upstream and downstream of the dam which will affect the Laek and the community dependent on it.

7.8 Anticipated Socio Economic Potential Impact

This section details the predicted social, economic and health impacts and their mitigation measures. There will be permanent and temporary impacts owing to displacement of settlements, loss of land, social infrastructure, increased health risk and agricultural land etc. These are explained below.

7.8.1 Positive Impact

i. Employment Opportunities: Many people will be employed during construction expected to last a number of years, with priority being given to qualified local residents when possible, and recruitment done together with local chiefs and MCAs. Local employees will mostly be unskilled and semi-skilled workforce hired from the local communities.

ii. Economic benefit of workers camp through purchase of foodstuffs from local people. Sale of food and consumer sundries to construction workers on a daily basis for the years of construction could considerably benefit traders in local communities. The camps will require diesel fuel, food, drinking water and other consumer goods. It would be a significant social benefit if the camp procured some of the required food supplies (fish, tomatoes, onions, cassava, sweet potatoes, Irish potatoes and bananas) from local farmers or farmer organizations. Income earned over the construction period would make a noticeable positive socio-economic change among local farmers. Other supplies procured from national suppliers would have the same economic benefit.

iii. With the high demand in Baringo County and low supply capacity that currently exists, the operation of Radat Dam would be welcome as it would contribute 11million cubic metres of water for irrigation and domestic use. This will lead to industrialization and national economic development as it increases food security and improves public health indicators.

iv. Access to the project area will require construction of new roads or improving existing ones. Construction of new or improvement of existing local roads will improve transport in communities with secondary benefits such as enhanced access to health services and efficient local administration functions. This is a long-term socio-economic c benefit for local communities.

v. Flooding which has been a menace in Baringo County leading to massive destruction will be contained.

vi. Hydro Electric generation will provide extra income for the both the NIB and the Baringo County government which will sell power to the national grid. More electricity means increased industrialization.

7.8.2 Negative Impacts and their Mitigation

i) Displacement of People: Construction of the dam, inundation of reservoir will result in the displacement of people. The total number of people to be affected is yet to be determined but some people from the five sub Locations of Radat, Kimose, Cheberen , Tebei and Tinomoi will be affected. Although these will be compensated and resettled, there is inevitable loss of structural social ties with people they lived by all their lives.

Mitigation

- All affected people should be compensated with options categorized according to the impacts as per PAP report.
- Those to be relocated should be assisted to move to their preferred locations. Those who are viewed as vulnerable will be provided with additional assistance.
- Affected business will be entitled to income restoration compensation.
- Compensation payments, should be monitored to ensure households remain in a similar socio-economic situation or better than pre-project levels. This will also monitor potential squandering of financial compensations.
- In kind settlement seems to the preferred by extremely vulnerable and unable to replace dwelling even if cash was given.
- Asset-for-asset compensation should be provided to affected persons who choose this option for fear of inability to purchase equivalent assets they previously owned.

ii) Loss of livelihood: Within the project area, PAPs will lose their only sources of livelihoods including small farming land, and all activities they solely depend on. Loss of livelihoods will result from loss of land following its acquisition for construction of Radat Dam . As already mentioned 80% of the population depends on agriculture while others practice sand mining and stone quarrying as their major source of income, therefore constructing the dam will disrupt their livelihood hence increasing on the poverty levels.

Mitigation

- During compensation, the project proponent working with local leaders shall sensitize compensation recipients about careful financial discipline to avoid misuse and eventual impoverishment.
- Project schedules shall be discussed prior to construction and during construction, in order for farmers to time their land-use activities to coincide with construction and not to unnecessarily suspend their activities.

iii) Effect on Social Infrastructure: Overstretching of community infrastructure such as roads connecting to villages, schools, health centers and water points. For example construction of the dam will flood community roads in villages such Kipting Dam on the border between Tinomoi, Radat and Kimose. This is a vital dam which connects the people in three sub-locations.

Mitigation

- NIB shall, as a contractual obligation require the contractor to use local labour (wherever feasible) to avoid impacts that would arise from increase in local population due to non-indigenous workers. This would also improve income opportunities and economic development of the local populations.
- The contractor shall be required to minimize pressure on local resources. The contractor should endeavour to find own water for construction activities when community sources are insufficient.
- To reduce pressure on health care facilities, NIB's contractor shall have their own medical clinic and should negotiate a sub-contract with hospital facilities, in order to deal with more serious health issues of the contractor employees.
- The Bridges and other infrastructure destroyed should be rebuilt elsewhere appropriate to the Community.

iv) Misuse of cash compensation: As indicated elsewhere in this report, the prevailing Culture around the five locations affected by the dam and in Baringo County generally, women have no ownership over land or most other family property implying that men will be the recipients of cash compensation before project implementation. Cash compensation could create vulnerability to women and children if misused by male household heads instead of restoring pre-project livelihoods and replacing assets (land or dwellings) lost to the project. These negative effects can be long-term and irreversible.

Mitigation

- PAPs shall be advised about wise use of money to avoid misuse bringing destitution to their families.
- Monitoring of how compensation payment is spent will need to be a part of the RAP internal and external monitoring.

v) Population Influx into village were construction camp are located: Owing to the high unemployment levels within the project area, any significant development that could result in employment will tend to attract large numbers of job seekers. This influx is expected to start during construction phase. It is difficult to estimate the number of people who will be attracted by the project but once the people hear about the project very many will come to seek employment.

Mitigation

- To minimize population influx in the area, the contractor should give preference to employing local labour.
- HIV/AIDS awareness programs shall be conducted in the project areas by the contractor.

vi) Occupational safety and public risk: The project will have health and safety risks to construction workers and the general public. This risk will originate from moving equipment, material transportation through population centers and construction along alignments adjacent to residential areas, potentially posing accident risk to the general public. Health risks may originate from inadequate or improper sanitation on site.

Mitigation

- The contractor should have a fully functional clinic at the project site and this can be used by local people who suffer from injuries associated with project workers.
- Contractors shall provide all workers with requisite Personal Protective Equipment (PPE) appropriate to the job at hand. Foremen will be responsible for not permitting a worker on site unless they are wearing the appropriate PPE. The Contractor shall provide appropriate signage reminding use of PPE at appropriate locations in the project area including ancillary work sites.
- Contractor shall ensure adequate fire safety at workers camp by ensuring presence of fire-fighting equipment.
- Contractor shall provide on-site toilet and washing water for workers.
- Contractor shall provide ―No smoking‖ signs in office, communal places construction camps as well as high risk areas prone to fire hazards e.g. near fuel tanks.
- Working with local leaders, the contractor will sensitize local people about safety near construction sites, possible accident risk and how they can be avoided.
- The contractor will have a fully functional clinic at the project site and this can be used by local people who suffer from injuries associated with project workers.

vii) Road traffic risks: Vehicles hauling concrete weir and line construction materials and workers might cause traffic hazards in trading centres, near schools, health centres and churches. Children, women and elderly people are often at higher risk of traffic related accidents. Presently, the traffic load in the area is very light but this will change with the project arrival.

Mitigation

- The contractor will control haulage speed especially in trading centers or near schools by placing requisite warning signs.
- Drivers will be inducted at the start of the Project about road safety and due diligence to ensure safety of other road users.

viii) In-migration into project area: The indirect effects of inward migration will include greater pressure on natural resources such as fuel wood, building materials, grazing and cultivated land. The occurrence of employment opportunities may attract an external workforce to the project areas from the rest of Baringo or indeed from other counties. This may lead to complications of HIV AIDs spread and other social vices.

Mitigation

- The Contractor should implement health, STD and HIV/AIDS awareness/training for the workforce.
- Contractor should ensure that the workplace has adequate access to medical facilities.
- Sensitization of the local communications should be carried out to manage community expectations of the project.
- The contractor should ensure preferential treatment is given to the local communities at the time of employment in order to combat conflicts/tensions in the project area.

ix) Impact on religious and cultural resources: The project will impact on the cultural heritage of the area at the household and at community level. At the household level, the cultural properties to be impacted are the graves of households in the area to be inundated. The Tugen do not traditionally mark grave sites but they want these respected nonetheless. Where the grave must be moved (unlikely), the RAP should provide for moving.

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x) Construction noise and vibration: Noise and vibration from various construction activities on Proposed Radat Dam will originate from, blasting of rocks, excavation, drilling and grading works, and even though the project area is sparsely inhabited, noise may affect the neighbouring villages.

Mitigation

- A grievance procedure should be put in place to enable communities in the project area report noise or vibration effects resulting from construction works.
- Monitoring of noise in the project area should be undertaken to ensure it does not exceed regulatory limits.
- Any damages caused by vibrations shall be compensated by the contractor.

xi) Land take and associated socio-economic effects: A number of settlements which will not be displaced will permanently or temporarily lose agricultural land.

Mitigation

- All affected people will be compensated as per the RAP report. Those to be relocated will be assisted to move to their preferred locations.
- Those who are viewed as vulnerable will be provided with additional assistance necessary at the time of their displacement.
- Affected business may be entitled to income restoration compensation.
- The project may also lead to loss of livelihood for people in the project area. The majority of people in the project area are primarily farmers while other practice small-scale trading (selling produce in road-side markets). Therefore loss of farmland will lead to temporary loss of livelihoods, recovery of which may be delayed by inept use of compensation payments.

xii) Although PAPs will be compensated, cash compensation could create **vulnerability of women and children** if misused by male household heads.

Mitigation

- During compensation, the project working with local leaders shall sensitize compensation recipients about careful financial discipline to avoid misuse and eventual impoverishment. PAPs should be advised about wise use of money to avoid misuse bringing destitution to their families.
- Monitoring of how compensation payment is spent will need to be a part of the RAP internal and external monitoring.

xiii) **Impacts of camp and equipment yard operation**: While set up and use of the camp and equipment yard will have positive impacts such as employment and economic or trade opportunities for local people, there are also potential negative impacts such as:

- Excessive lighting at camp and yard,
- Localized waste oil and fuel spills,
- Noise and air emissions from electricity generator,
- Fire risk at camp site and yard,
- Soil compaction at camp and yard,
- Over-speeding, night travel and wildlife poaching,
- Improper camp and yard decommissioning,
- Improper waste management at both camp and equipment yard.

Consultations were conducted with stakeholders to introduce the project, its potential benefits and impacts as well as addressing any concerns raised. Issues raised are summarized below but were mostly related to social-economic conditions and environmental conservation.

7.9 Mitigation and Monitoring Programs

This section highlights the mitigation measures for the expected negative impacts of the proposed Project. The potential impacts and the possible mitigation measures have herein been analysed under four categories: Planning and design, Construction and Operation. The following measures should be considered as mitigation measures of the negative impacts associated with the proposed Project during construction phase.

7.9.1 Interference with the physical setting

The structures to be developed should be aesthetically acceptable to blend in with the surrounding. No residential facilities shall be erected on site and the proponent shall as much as possible complete the works in such a way that natural aesthetics shall be retained at the locations. Restoration shall be undertaken to ensure that the original setting is as much as possible retained.

7.9.2 Interruption of key installations

The following should be done for all crossings of installations:

- Formal request for permission from affected property owners;
- Formal engagement of key land and other property owners neighbouring the project;
- Passing of relevant information to each of the affected parties;

- A work plan with clear responsibilities for each party should be developed to ensure smooth execution of the construction.

7.9.3 Land take

The implementation of this project shall be preceded by the acquisition of land. A detailed Resettlement Action Plan (RAP) will be required.

7.9.4 Noise, dust and vibration

Significance of noise impacts depends on whether the Project would increase noise levels above the existing ambient levels by introducing new sources of noise. Noise impacts would be considered significant if the Project would result in the following:

- Exposure of persons to, or generation of, noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies;
- Exposure of persons to, or generation of, excessive ground-borne vibration or ground-borne noise levels;
- A substantial permanent increase in ambient noise levels (more than 3 dBA) in the project vicinity above levels existing before the project; and
- A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing before the project.

The Proponent through the Contractor shall put in place several measures that will mitigate noise pollution arising during the construction phase. The following noise-suppression techniques will be employed to minimise the impact of temporary construction noise at the Project site:

- Install portable barriers to shield compressors and other small stationary equipment where necessary;
- Use of quiet equipment (i.e. equipment designed with noise control elements);
- Limit pick-up trucks and other small equipment to a minimum idling time, observe a common-sense approach to vehicle use, and encourage workers to shut off vehicle engines whenever possible;
- Provision of appropriate personnel protective equipment;
- Construct mainly during the day; and
- Consider labour-based construction methodologies.

The following measures can help mitigate the dust generation, soil erosion and damage likely to arise during the construction phase:

- Minimizing the number of motorised vehicles on use;
- Rehabilitate disturbed areas;
- Provide scour checks on over-15% slopes or when working in loose soils;
- Manage erosion agents including water by channelling it into predetermined areas;
- Use predetermined tracks;
- Avoiding machinery working in seasonally marshy areas, pans and floodplains;

- Wet all active construction areas as and when necessary to lay dust;
- Pave, apply water when necessary, or apply (non-toxic) soil stabilizers on all unpaved access roads, parking areas and staging areas at construction sites; and
- Undertake staff training and allocate roles to trained/responsible staff members.

7.9.5 Disposal of excavated soil

The excavated soil will be disposed of through re-spreading in areas that require landscaping, so as to enhance aesthetics around the project area. Remaining excavated soil will be disposed of in areas identified in collaboration with the local community and administration, either for landscaping or other uses.

7.9.6 Water demand

The Proponent through the Contractor shall ensure that water is used efficiently at the site by sensitising construction staff to avoid irresponsible water use.
Furthermore any water handling equipment, facility and systems shall be appropriate for the intended usage. Water used during construction shall reflect the level of conservation achieved by the Contractors. Documentation of amounts of water used will therefore be mandatory.

7.9.7 Accidents and hazards

To reduce the workers' accidents and hazards, the Proponent will develop and commit the Contractors to Site Occupational Health and Safety rules and regulations as stipulated in the Occupational Safety and Health Act, 2007. In this regard, the Proponent is committed to provision of appropriate personal protective equipment, as well as ensuring a safe and healthy environment for construction workers as outlined in the EMP.
Workers' accidents shall be mitigated by enforcing adherence to safety procedures and preparing a contingency plan for accident response. In addition, safety education and training shall be emphasized.

7.9.8 Raw materials extraction and their efficient use

The Contractors will source construction materials such as sand and hard core from registered and approved quarry and sand mining firms whose projects have undergone satisfactory environmental impact assessment/audit and received NEMA approval. Since such firms are expected to apply acceptable environmental performance standards, the negative impacts of their activities at the extraction sites are considerably well mitigated. To reduce wastage, the Contractor will only order for what will be required through accurate budgeting and estimation of actual construction requirements.

7.9.9 Solid waste management

It is recommended that construction waste be recycled or reused as much as possible to ensure that materials that would otherwise be disposed of as waste are diverted for productive uses. In this regard, the Contractor will ensure that construction materials left over at the end of construction will be used in other projects rather than being disposed of. The Proponent shall put in place measures to ensure that construction materials requirements are carefully budgeted and to ensure that the amount of construction materials left on site after construction is kept minimal.
Additional recommendation for minimization of solid waste during construction of the proposed Project include the use of durable, long-lasting materials that will not need to be replaced often, thereby reducing the amount of construction waste generated over time.

7.9.10 Flora and fauna disturbance

Clearance of vegetation (mainly grass and trees) in the Project area will be inevitable. However, the Proponent will ensure proper demarcation of the Project area to be affected by the construction works. This will be aimed at ensuring that any disturbance to flora is restricted to the actual Project, and avoid spill over effects on the neighbouring areas. In the same vein, there will be strict control of construction vehicles to ensure that they operate only within the area to be disturbed by access routes and other works.

Furthermore permission shall be sought from the various owners and institutions concerned where vegetation has to be disturbed in order to allow for any development work.

7.9.11 Operation and Maintenance Philosophy

To minimize maintenance cost that will be encountered during the operation of the proposed Project, the Proponent will consider the following measures:

- Approve the use of durable materials;
- Maintain all installations in sound working conditions;
- Ensure maintenance is carried out to the design specifications;
- Implement a strict monitoring and evaluation programme; and
- Ensure that future modifications are in line with the design criteria as detailed by the Project Engineers.

7.9.12 Reduced downstream flows on Perkerra River

The Proponent shall monitor the hydrology to determine the level of reduced downstream flow and to determine the right levels of abstraction and apply for amendment of the abstraction license from WRMA. The hydrological monitoring report shall highlight the levels of abstraction that are sustainable in tandem with the population water demand levels.

7.9.13 Energy management

To ensure efficient energy consumption, energy saving policies, technologies and management strategies in the overall Project management scheme should be included. To complement these measures, it will be important to monitor energy use during the operation of the proposed Project and set targets for efficient energy use. Appropriate power transformers and accessories shall be installed in conjunction with the power distribution company.

Secondly, liaise with the power suppliers (Kenya Power Ltd) to ensure that the plant receives quality energy supplies as required.

7.10 Mitigation of Decommissioning Phase Impacts

All mitigation measures referred to under the construction phase will be applicable during decommissioning. Furthermore the following shall be undertaken under the decommissioning phase.

The Proponent shall undertake a thorough consultation with stakeholders to establish the following:

- Determine the anticipated impacts and provide mitigation;
- Develop a decommissioning schedule; and
- Create awareness among stakeholders.

The Proponent shall carry out all works based on the findings of the stakeholders' consultations. At the end of these works, the Proponent shall obtain the relevant Certificates.

7.11 Socio-Economic Management Plan (SMP)

The period of construction will bear both positive and negative social impacts that can be avoided or mitigated with recommendations herein proposed. Overall, the project will have immense long-term social-economic benefit for the country in terms of increased food security through irrigation, greater access to reliable water supply, control of flooding and possible hydro power added to the grid hence spurring local and national development. Consequently a plan is proposed to guide the management of the socio economic issues that may arise in implementing the project.

Table 7:2 Socio-Economic Problems Experienced Around the Proposed Dam Area

Serial	Problem	Causes	Effects	Suggested intervention strategies
1	**Population** Relatively sparsely populated village settlement	Recently inhabited by immigrant families	Underdeveloped basic community infrastructure	Support provision of basic community infrastructure to enable for peaceful coexistence
2	**Settlement** Undeveloped community basic infrastructure	A relatively marginalized community	Poor access to educational, health and other basic community services	Support provision of basic community infrastructure to enable for peaceful coexistence
3	**Communication** Site inaccessible when wet	Poorly maintained earth access road	Inaccessibility to the all-weather road and service centres	Construct an all-season access road to link site with main tarmac road
4	**Land Use** a) Inefficient land use practices in small peasant holdings	Continued use of low technology application for agric. Production	Low agric. Productivity	Introduce agro forestry among the community
	b) Encroachment of riparian areas	Inadequate enforcement of laws regarding use of riparian areas.	Reduced volume of river flow for downstream users	Enforce laws in place for the protection of water resources
5	**Community Organisation** Weak community organization	Relatively underdeveloped community	High prevalence of poverty levels	Support provision of a strategic basic community infrastructure
6	**Employment** High rate of youth unemployment	Low productivity of small farm holdings	Rural-urban migration	Give preference to the locals when recruiting labor for the dam construction
7	**Incomes** Low incomes earned from livelihood activities	Low productivity of the agricultural sector	Increasing poverty levels among the populations	Link the dam to the growth of the local economy during construction and

Serial	Problem	Causes	Effects	Suggested intervention strategies
				operation activities
8	**Public Health** High incidence of waterborne diseases	Use of drinking water from unsafe sources	Increased morbidity rates among the population	Connect water supply operations to the village settlement
9	**Gender Issues** Fewer women than men hired in public work projects	Traditional attitudes and discrimination mindset against women.	Gender imbalanced labour force	Institute affirmative action in the recruitment of casual workers in the Dam construction activities

7.12 Socio-Economic Impact Mitigation Measures

Table 7:3 Socio-Economic Impact Mitigation Measures of the Dam Sub-Project

Socio-economic impacts	Proposed mitigation measures
Impact avoidance measures Public health: Increased rate of HIV/AIDS infection and prevalence in labour camps and the neighboring communities	a) Contractors be obliged to conduct intensive HIV/AIDS prevention awareness campaigns amongst their staff in the workplace and in their labour camps. b) Contractors equally be obliged to extend the workplace HIV/AIDS prevention campaigns to the neighboring communities.
Impacts minimization Community structure Disruption of community traditional life cycles by the introduction of alien social practices at the labour camps and built up settlement	**Intensive community engagement for peaceful co-existence** a) Conduct community and other stakeholders consultation meetings immediately upon the commencement of the project implementation and thereafter, periodically b) Accord priority in the employment of local people in the available skilled and unskilled job opportunities c) Provide appropriate basis social infrastructure to the neighboring communities –to be the centre of diffusion of positive social change processes
Impacts compensation Settlement: displacement of the population – to give way to the construction of infrastructural developments associated with the dam sub-project Conversion of agric land into a built- up settlement	a) Undertake a comprehensive resettlement action plan (RAP) for all the displaced families b) Ensure that all the project affected persons (PAPS) are fully compensated before civil works commence

Table 7:4 Socio-Economic Impact Mitigation Measures of the Hydropower Production Sub-Project

Socio-economic impacts	Proposed mitigation measures
Impacts avoidance measures Public health: high risk of HIV/AIDS infection in the HPP construction labour camps and the neighboring communities	a) Mandatory for civil works contractors to carry our intensive HIV/AIDS prevention campaigns among the staff in the workplace and in the labour camps b) Include in the civil works contract that the contractor should extend the workplace HIV/AIDS prevention campaigns to the neighboring communities
Impact minimization measures Community structure: disruption of traditional community life cycles – by the introduction of alien norms and values, practiced at the labor camps and the emerging built-up settlement	**Community engagement – for peaceful coexistence** a) Conduct community consultation meetings immediately upon the commencement of the project implementation and thereafter periodically b) Accord priority in the employment of the local people in regard to the available skilled and unskilled job opportunities c) Provide appropriate basic social infrastructure to the communities in the neighboring settlements – to serve as centres of diffusion of positive social change processes
Socio-economic impacts	**Proposed mitigation measures**
Impact compensation Settlement: displacement of the population- to give way to the construction and operation of infrastructural developments associated with the HPP Conversion of agricultural land into a built – up settlement	a) Undertake a comprehensive resettlement action plan for the displaced families b) Ensure that all the project affected persons are fully compensated before civil works commence

Table 7:5 Socio-Economic Impact Mitigation Measures of the Irrigation Sub-project

Socio-economic impacts	Proposed mitigation measures
Impact avoidance Community structure: likely inter-ethnic feuds in the management of the irrigation resource	a) Support establishment of strong irrigation water users association (IWUAs) b) Carry out a comprehensive capacity building program for the IWUAs – to function as effective and democratic community economic organizations
Impact minimization Public health : Open irrigation canals may provide breeding ground for mosquitoes and other vectors	a) Institute effective mosquitoes and other vectors control programs b) Consider adopting the more efficient drip irrigation method for the sub – project
Impact compensation Settlement : irrigation canals	a) Arrange for appropriate compensation mechanisms for portions of land taken by irrigation

Socio-economic impacts	Proposed mitigation measures
may have to pass through peoples shambas – due to topographical dictates	canals way leaves.

Table 7:6 Socio-Economic Impacts Management Plan

	Socio-economic impact	Proposed mitigation measures	Responsibility for implementation	Indicators for successful implementation	Means of monitoring of implementation	Response for monitoring	Frequency for monitoring
1	High risk of HIV/ AIDS infection in the Dam labor camps	Oblige contractors to conduct intensive HIV/AIDS prevention awareness campaigns among the workers, as well as among the neighboring communities	Civil works contractors- in collaboration with the ministry of public health and other agencies	Percentage decline in the rate of HIV/AIDS prevalence recorded at the baseline – by gender	1. Baseline survey report 2. Statistics on the rates of infection by gender 3. Progress reports	1. Project sociologist 2. Project steering committee	Quarterly – reports annual reviews Mid-term review
2	Displacement of the population to give way to the construction of infrastructural development associated with the dam and HPP sub-projects	a)Undertake comprehensive resettlement action plan for the displaced families b) Ensure all the project affected persons are fully compensated before civil works commence	Project – sociologist in collaboration with the provincial admin	1. Percentage of displaced person resettled 2. Percentage of affected persons affected persons fully compensated 3. Minimal conflicts recorded as arising from the RAP implementation	1. Census of displaced persons 2. Inventory of affected assets 3. List of compensation of the PAPS – and amounts paid	1. Project manager 2. Project steering committee	First 6 months immediately after commencement of project implementation Quarterly reviews Semi annual review

	Socio-economic impact	Proposed mitigation measures	Responsibility for implementation	Indicators for successful implementation	Means of monitoring of implementation	Response for monitoring	Frequency for monitoring
3	Open water mass may provide breeding ground for mosquitoes and other vectors	1. Institute effective mosquitoes and other vectors control program in the canal areas 2. Consider adoption of more efficient drip irrigation method	The project agronomist – in conjunction with the ministry of public health	Percentage declines in the rate of malaria and other vectors infected recorded at the baseline	Baseline survey report statistics on the rates of infection of the participating community members	Project manager Project steering committee	Quarterly reports Annual reviews Mid-term review
4	Likely feuds in the among ethnic communities over water resources and other project benefits	1. Support establishment of strong irrigation water users association (IWUAs) 2. Carry out comprehensive capacity building program for the IWUAs to function as effective and democratic	Project agronomist in conjunction with the ministry of agriculture and irrigation	1. Promulgated democratic IWUA constitutions for each zone 2. Regular IWUA committee and general meetings 3. Implemented capacity building programs	1. Zonal IWUA constitutions 2. Minutes of committee and general meetings 3. Reports on capacity building initiatives	Project manager Project steering committee	Quarterly reports Annual reviews Mid-term review

	Socio-economic impact	Proposed mitigation measures	Responsibility for implementation	Indicators for successful implementation	Means of monitoring of implementation	Response for monitoring	Frequency for monitoring
		community economic organization					
5	Disruption of traditional community life cycles – by the introduction of alien norms and values and practices at the labour camps and built-up settlements (construction and operational phase)	Community engagement for peaceful coexistence 1. Conduct regular community consultation meetings 2. Accord priority in the employment of local people for available skilled and unskilled job opportunities 3. Provide appropriate basic social infrastructure to the neighboring communities	Project sociologist Agronomist Contractor NIB/County Government/Contractor	NO. of irregular meetings held No. and types of job opportunities accorded to locals Nature and types of basic social infrastructural facilities installed	Minutes of meetings Manpower complement document Inventory of installed facilities	Project manager Project steering committee	Quarterly reports Annual reviews Mid-term review

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Design				
Social issues: Water supply for people living around the dam	Not Applicable:- Social Responsibility by NIB.	• Include community water project in the project design; • Provision of livestock watering points at strategic points.	Review of design documentation	Project Engineer; NIB.
Construction				
Public consultations, participation and Disclosure:	EMCA:	• Identification of a Community Liaison Officer within NIB; • Establish and maintain communication channels with the community members and any other stakeholders of relevance to the project; • Constitute a Community Consultation Committee (CCC) to monitor the project; • Keep the public informed of project development and its relevance to the community members; • NIB to arrange for training of the committee members on relevant aspects of the project; • Establish a community involvement programme; • Evaluate implemented activities; • Maintain contact information of the members of the CCC. • Prior to project commencement, public awareness information packages should include clear information on the compensation (if any) that will be given; • Give notices for displacement / eviction in good time; • Give warning on water supply interruptions in good time; • Set a reasonable quota target for local skilled and unskilled labour.	At project inception and periodically during construction.	Building/civil contractor; Project Environmental-list and Resident Engineer.
Site preparation	EMCA:	• Choice of suitable area specific style architecture and colourings by the contractor and Resident Engineer during site preparation;	Daily auditing and	Building/civil contractor;

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
and specific construction works.		• Provide informative signs about the construction at a conspicuous location along the service roads; • Stipulation in construction contract on sourcing of materials from an approved site; • For preliminary design purposes, the allowable bearing value for foundations should be calculated in relation to the weight and area of bed rock and compacted fill to avoid any structural failures; • Super-plasticized and water-retardant concrete may be used to make pouring easier and reduce shrinkage and cracking hence stabilizing structures and minimising any potential impacts; • Interior concrete slabs should be structurally supported by foundations embedded in the bedrock. Slabs not structurally supported in bedrock may be subject to some distress and cracking; • Existing loose fill soils should be removed and re-compacted; • Periodic monitoring by the Resident Engineer is recommended for sloughing and slumping on any slope that may occur especially during rainy seasons; • Adequate site drainage should be provided. All roof and surface drainage should be conducted away from foundation and slope areas via engineered non-erosive devices to existing storm drain facilities on the street. In no case should water be allowed to pond within the site, drain towards structures or flow in a concentrated and uncontrolled manner down the slope; • The contractor should ensure that water is not allowed to pond on the pad, flow towards any foundations or wall, or sheet-flow over any descending slope; • Temporary un-surcharged excavations should be considered to the depths and slope ratios stipulated by the Resident Engineer;	spot checks; Report monthly: Records of Minutes of site start-up meetings; Resident Engineer inspection records.	Project Environmenta-list and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Site preparation and specific construction works.	EMCA:	• Soils exposed in the cuts should be kept moist but not saturated, to reduce the tendency for ravelling and sloughing during construction; • The Resident Engineer should ensure that the top of the cut slopes are barricaded to keep vehicles and heavy storage loads at least five feet away from the top of the slopes; • During the rainy season, the contractor should ensure that berms are constructed and maintained along the top of slopes and plastic sheets placed over the slopes to prevent runoff water from eroding the slope faces; • When excavations exist on a site, the contractor should ensure that the area is fenced and warning signs posted; • The contractor should ensure that all deep excavations are properly covered and secured; • Earth materials generated by the contractor from foundation and sub-grade excavations should either be removed from the site or properly compacted by the contractor; • The Resident Engineer and Contractor should ensure that fill temporarily stockpiled on the site are placed in a stable area, away from slopes, excavations and improvements.	Daily auditing and spot checks; Report monthly: Records of Minutes of site start-up meetings; Resident Engineer inspection records.	Building/civil contractor; Project Environmenta-list and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
HIV/AIDS and Increased disease risk.	The Public Health Act:	• The Resident Engineer has to ensure that management of Sexually Transmitted Infections (STI's) occurrences due to social interaction between immigrant workers and local populations is conducted through: • Selecting appropriate locations for construction camps; • Education and sensitisation of workers and the local communities on STI's including provision of condoms to the project team and the public; • Where possible conduct regular sensitisation campaigns and monitoring and evaluation of the modes used during the two year course of the project. • The contractor has to Institute HIV/AIDS awareness and prevention campaign amongst workers for the duration of the contract e.g. erect and maintain HIV/AIDS information posters at prominent locations as specified by the Resident Engineer; • The contractor has to ensure that staff are made aware of the risks of contracting or spreading sexually transmitted diseases; • The contractor has to ensure that the project workers are educated on the local culture; • The Resident Engineer has to ensure the strengthening of cultural organizations and encouragement of competitions; • The contractor has to ensure the mobilization and sensitization of the population on reproductive health and STIs; • The Resident Engineer has to ensure that the project contributes to the creation of an atmosphere that is conducive to the functioning of all social centers which are in the project zone of influence;	Daily auditing and spot checks; Report monthly.	Building/civil contractor; Project Environmentalist and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Leakage / Flooding from the Dam.	EMCA.	• The implementers (NIB) of the project will have to work closely with various HIV/AIDS organisations working in the project zone of influence in order to achieve the best results. • Leaking equipment should be repaired immediately or removed from the site by the contractor maintenance crew; • The Resident Engineer should ensure strict monitoring of the dam and related infrastructure through the use of leak detection mechanisms; • The Resident Engineer and the contractor should assemble and clearly list the relevant emergency telephone contact numbers for staff, and brief staff on the required procedures.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.
Site related oil spills.	EMCA.	• The contractor should ensure that the employees on site are aware of the company procedures for dealing with spills and leaks from oil storage tanks for the construction machinery though induction and safety training; • In case of spillage the contractor should isolate the source of oil spill and contain the spillage using sandbags, sawdust, absorbent material and/or other materials approved by the Resident Engineer; • The Resident Engineer and the contractor should ensure that there is always a supply of absorbent material such as saw dust on site during construction, readily available to absorb/breakdown spill from machinery or oil storage; • All vehicles and equipment should be kept in good working order, serviced regularly and stored in an area approved by the Resident Engineer; • The contractor should assemble and clearly list the relevant emergency telephone contact numbers for staff, and brief staff on the required procedures.	Daily auditing and spot checks; Report monthly. Material Safety Data Sheets.	Building/civil contractor; and Resident Engineer.
Impacts on Vegetation.	EMCA.	• The contractor has to ensure that the clearance of the site for construction purposes is kept to a minimum; • The Resident Engineer has to ensure that removal of vegetation is avoided until such time as clearance is required and exposed surfaces re-vegetated or stabilised as soon as practically possible;	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
		• Areas affected by construction related activities and/or susceptible to erosion must be monitored regularly by the Resident Engineer for evidence of erosion, these include: • Areas stripped of topsoil; • Soil stockpiles; • Spoil sites. • Where erosion does occur on any completed work/working areas, the Contractor shall reinstate such areas and areas damaged by the erosion at his own cost and to the satisfaction of the Project Engineer and Environment Safety Officer; • The Resident Engineer has to ensure that provision of trickle flows is incorporated in the project to improve conditions downstream for riparian flora and fauna; • The Resident Engineer has to ensure that the current dam project and any proposed future expansion should maintain its maximum dimensions to limit its effects on native vegetation.		
Alteration of Natural Drainage systems.	EMCA; Water Act; Lakes and Rivers Act.	• The Resident Engineer has to ensure that a study on the hydrologic regime of the river is undertaken and the findings of the study are implemented; • Feasibility of reviving additional source systems should be investigated by a consultant appointed by NIB with a view to adding them to the system; • The Resident Engineer has to ensure strict supervision of workers during works on river courses to protect the flora and fauna in the river ecosystem; • The Resident Engineer should monitor changes in the drainage system and develop mitigation measures for possible outcomes on the system structures and the environment; • The Resident Engineer should ensure that construction at major river crossings is done during the dry season; • The Resident Engineer (RE) should ensure that the banks of waterways are reinforced with concrete, and the major rivers are crossed using the horizontal drilling technique.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Waste Production	EMCA:	• The Contractor should adhere to the site waste management plan; • The Resident Engineer and contractor should ensure that spoil from excavations is arranged according to the various soil layers. This soil can then be returned during landscaping and rehabilitation, in the correct order which they were removed that is top soil last; • The contractor should separate hazardous from non-hazardous wastes. Hazardous wastes include waste contaminated with petroleum product and chlorine. Waste should then be handled, collected, transported and disposed according to the Environmental Management and Co-ordination (Waste Management) Regulations; • The Resident Engineer has to ensure that waste is recycled and re-used where possible. Recycling bins for glass, metal, newspaper, plastic bottles and other recyclable site solid wastes should be provided at public facilities and/or for site curb-side collection. Waste that cannot be re-used on site should be transported to the correct NIB yard; • The Contractor should consider cost of on-site vs. off-site recycling efforts; including reduced cost of transporting smaller volumes of materials. For preparation of materials for dumping or recycling the following should be considered: • Crushing of concrete and asphalt for reuse as road base/sub-base, erosion protection or ground cover; • Chipping of wood waste/brush for reuse as fuel, ground cover and soil amendment; • Shredding of bale or compact metals to reduce volume of materials transported;	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Waste Production	EMCA:	• Compacting of materials going to landfills to minimize volume, both from site as well as at landfill; • Re-use of cleared vegetation and trench excavation within the project area; • Recycling of packaging waste (e.g. bottles, cans, boxes, drums); • Recycling of office paper; • Recycling of waste oils and batteries; and • Re-use of excess chemicals (e.g. solvents, herbicides) on other projects. • For waste handling the contractor should provide litter collection facilities such as bins; • The contractor should comply with the requirements of the OSHA Act 2007 and Building Rules on storage of construction materials; • Final disposal of the site waste should be done at a location that shall be approved by the Resident Engineer in accordance with the waste management plan after consultation with the local authority; • The Resident Engineer should ensure that several high quality waste management facilities are put in place, including waste storage structures, engineered hazardous and non-hazardous solid waste landfills, and a hazardous waste-capable incinerator as per specifications of Third Schedule of the Waste Management Regulations of 2006; • The tender documents should specify proper solid waste handling as provided in the waste management plan during site preparation phase of construction prior to project works commencing in identifying optimal waste re-use options and licensed disposal areas. This should strictly be adhered to by the Contractor; • The contractor should not burn wastes on site or dump in an open pit; • The Resident Engineer should ensure that the contractor provides proper handling and storage procedures for hazardous wastes e.g. fuel oil should be stored in areas with concrete floor and forecourt as well as containment to handle spills; • The Resident Engineer should ensure that excavation activities that normally contribute to severed vegetation roots, compaction of surrounding soils, as well as siltation of area waters and subsequent dumping of spoil are properly managed such that land which is not required for buildings is left undisturbed.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Impacts on Soils	EMCA:	• The contractor should ensure that excavated soil is properly piled to heights of 2 metres maximum to prevent possible wash-out into watercourses; • The contractor should ensure that excavations are limited as far as possible during the dry season to avoid washing away of soil by rain; • Compaction activities that take into account atterberg limits may force the contractor to source for suitable soil with less water content that may not exist on site. This new spoil source areas should be properly rehabilitated by the contractor in order to avoid soil erosion activities; • The material store should be determined by the Contractor in collaboration with the Resident Engineer. The material stores should consider specific storage conditions for specific materials e g segregation of chemicals, bunding and hard standing (concrete) for storage of fuel oil, storage of machinery and equipment etc; • The Resident Engineer should ensure that areas for the storage of fuel and other flammable materials comply with the Factories and Other Places of Work (Fire Risk Reduction) Rules 2007; • The Resident Engineer must ensure that all chemicals and fuels are stored in accordance with manufacturer's instructions; • The Resident Engineer should ensure that oil and grease used during construction are stored in suitable containers and not thrown or disposed of on land or water. Suitable containers include: • Drum spill containers with zinc plates hoisted on removable galvanized grates for ease of cleaning; • Drum storage with spill containment (Approximately 205litres) able to catch and hold any potential spills; • Bunded oil storage and transfer kit of 100 litres capacity, comprising of twin skinned tank for storage and transfer of engine, gear, diff and hydraulic oils. • The contractor has to ensure that oil Storage areas or secondary containment are constructed of waterproof reinforced concrete or approved equivalent, which is not adversely affected by contact with chemicals captured within them; • Stockpile areas should be approved by the Resident Engineer based on: • Level of sites and platforms(Should be level); • Easy or convenient access; • Hazard identification concerning the stacking site in relation to health and safety. • The Contractor should ensure that delivery drivers are informed of all procedures and restrictions (including 'No Go' areas) required;	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Impacts on Soils	EMCA:	• The contractor should ensure that construction related impacts like erosion and cut slope destabilization should be addressed through landscaping and grassing, carting away and proper disposal of construction wastes in the various site works; • The contractor has to ensure that recommended compaction of spoil areas is undertaken and effective drainage of spoil sites in order to avoid land instability in form of soil subsidence, slip and mass movement.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.
Air, Dust and Noise Emissions	EMCA: The Public Health Act.	• The contractor should provide dust masks to all personnel on work site; • The Resident Engineer has to ensure that all works are conducted during the day; • The Contractor has to ensure that periodic water spraying is carried out to suppress dust during excavations and backfilling; • The Resident Engineer has to ensure that dust generating activities (excavation, handling and transport of soils) are not undertaken during times of strong winds; • The Resident Engineer has to ensure that earthwork operations are suspended wherever visible dust is affecting adjoining activities; • The Resident Engineer has to ensure enforcement by the contractor in the provision of vehicles delivering soil materials with covers to reduce spills and windblown dust; • Any complaints received by the Contractor regarding dust should be recorded and communicated to the Resident Engineer; • The Resident Engineer has to ensure that dust emissions are kept at a minimum especially in areas with human settlements; • The Resident Engineer has to ensure that all construction machinery are maintained and serviced in accordance with the contractor's specifications, manufacturer's standards and the Fossil Fuel Regulations 2003; • The Environmental Management and Co-ordination (Noise and Excessive Vibration Pollution) (Control) Regulations 2009, The Factories and Other	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
		Places of Work (Noise Prevention and Control) Rules 2005 and World Bank limits.		
Air, Dust and Noise Emissions	EMCA: The Public Health Act.	• Contractor staff should conduct regular monitoring on the efficacy of the methods used to minimise noise and dust emissions and give recommendations thereof.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.
Impacts on Water Resources	EMCA; Water Act; Lakes and Rivers Act.	• All Contractor's water handling facilities must be checked by the Resident Engineer before start of construction; • The contractor has to ensure that all washing of equipment is undertaken in designated maintenance areas which should be equipped with suitable impermeable floor (preferably concrete) and sump/oil trap; • The Resident Engineer has to ensure that the use of detergents for washing are restricted to low phosphate/nitrate-type detergents; • The Resident Engineer has to ensure that water containing such pollutants as cements, concrete, lime, chemicals and fuels are discharged into a designated waste water treatment facility; • The contractor should ensure that runoff loaded with sediment and other suspended materials from the site/working areas are prevented from discharging to the adjacent rivers by use of loose rock boundaries along the construction site; • The Contractor should notify the Project Engineer of any pollution incidents	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
		on site; • The Resident Engineer has to ensure that adequate security is provided for monitoring of the dam against vandalism.		
Impacts on Water Resources	EMCA; Water Act; Lakes and Rivers Act.	• The Resident Engineer has to ensure that a comprehensive water monitoring program is established • The Resident Engineer has to ensure that dam-related infrastructure is not installed during the rainy season so as to lessen the problems caused by soil erosion; • The Resident Engineer has to ensure that the contractor erects retaining walls or like structures for springs protection against siltation from sandbanks; • The contractor has to ensure that a well-designed fence is provided around the dam area to provide protection against common wildlife in the area, as well as human interference; • Runoff control measures should be instituted by the contractor to reduce sediment loads from all construction sites. These measures should be made mandatory by the Resident Engineer for contractors. This is required to protect not only water quality but also aquatic life, both in tributary streams and in the Rivers.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Occupational health and safety.	Occupational Safety and Health Act:	• The Resident Engineer should ensure that the contractor complies with all standard and legally required health and safety regulations as promulgated by Occupational Safety and Health Act (Part XI: section 96) as pertains to construction activities; • The Contractor should provide a standard First Aid kit on site. As per the Factories (First Aid) Rules 1977.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.
Occupational health and safety.	Occupational Safety and Health Act:	• All works which may pose a hazard to humans and domestic animals are to be protected, fenced, demarcated or cordoned off as instructed by the Resident Engineer. If appropriate, symbolic warning signs must be erected; • For fire and safety the Contractor, should ensure compliance to the Factories and Other Places of Work (Fire Risk Reduction) Rules 2007. • The Resident Engineer should ensure that the Contractor is instructed in the use of all materials that may have negative environmental (including health) effects;	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Occupational health and safety.	Occupational Safety and Health Act:	• The Resident Engineer has to ensure that If any material or substance is used that is at any point in the future deemed to be deleterious to health, then it must be replaced with an acceptable alternative; • The Contractor has to adhere to safety regulations outlined in the Local Government Adoptive by-laws, Building Order 1968 (Building Code) and the Building Operations and Works of Engineering Construction (The Occupational Safety and Health Act 2007); • The Resident Engineer should ensure strict safety management through close attention to design, work procedures, materials and equipment.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.
Impact on Utilities	EMCA; Water Act.	• For the Power supply, the contractor should obtain necessary approvals / permits from KPLC under the direction of the Resident Engineer; • The contractor should obtain necessary approval forms from the Resident Engineer for the sourcing of water for construction works; • Construction workers should be sensitised by the contractor on the importance of energy management; • The Resident Engineer has to monitor water consumption and utilisation; • The contractor should sensitise construction workers on the importance of proper water management; • The Resident Engineer has to ensure that all wastewater are drained into approved drainage facilities.	Daily auditing and spot checks; Report monthly.	Building/civil contractor; and Resident Engineer.
Contractor Code of Conduct	EMCA; Building Rules Occupation	• The contractor should undertake an initial environmental awareness training session prior to any work commencing on site, where the target audience is all project personnel. The training should include but not be limited to the following: • Basic awareness and understanding of the key environmental features of	Daily auditing and spot checks; Report	Building/civil contractor; and Resident Engineer.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
	al Health and Safety (OSHA) Act.	the work site and environs; • Understanding the importance of and reasons why the environment must be protected; • Ways to minimise identified environmental impacts; • Relevant requirements of the Environmental Management Plan (EMP) provided in this report; • Health risks pertinent to the site, including prevention of communicable diseases; • Prevention and handling of fire. • The Environmental consultant should conduct environmental awareness training in liaison with the Contractor and the Resident Engineer; • The Resident Engineer and the contractor has to ensure that site staff found to be involved in incidences of theft or pose other security risks to the local community are to be dismissed and reported to the authorities.	monthly.	
Environmental Monitoring.	EMCA.	• Provision of progressive demolition of support structures not required for project operation; • Progressive rehabilitation of construction sites including camp sites, spoil disposal sites, Quarry and borrow pit areas using bioengineering measures; including re-vegetation, and other soil stabilization measures, • Progressive reinstatement of services affected by the dam; • Monitoring programs will be necessary for noise, air quality, and dust during the construction phase; • Environmental monitoring during construction should be conducted twice (2) a year for the entire project by the Project Environmental scientist in order to ascertain the level of compliance of the works to the developed environmental management plan (EMP).	Daily auditing and spot checks; Report monthly.	Building/civil contractor; Resident Engineer. and Project Environmental scientist.
Operation				
Leakage / Flooding from	EMCA, Water Act.	• The NIB Management should undertake regular surveillance to ensure in the highly unlikely event that a loss occurs, it is quickly detected and the	Daily auditing and	NIB Management.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
the Dam		amount of water lost minimised by shutting down and isolating damaged sections; • The NIB Management should ensure that aquifer depletion is prevented through aquifer monitoring to determine the safe yield and limit abstraction levels to the safe yields; • The NIB Management should ensure the immediate shutdown of the dam (central control) and subsidiary controls from the reservoirs once a leak has been detected; • NIB Management should ensure that secondary leak containment facilities are installed or provided to limit the ponding and flooding; • NIB management should form and designate an emergency response team with access to specially designed and strategically located water leak response equipment; • NIB management should install and enforce the utilization of special marker tape with an electric alarm to detect breakage; • NIB management should ensure Installation of a pressure variation leak detection system capable of responding to small sub-surface leaks; • NIB management should ensure monitoring of the distribution network by special patrols.	spot checks; Report monthly.	
Site related oil spills.	EMCA	• Rehabilitation of oil contaminated areas should be conducted through treatment and remediation of areas affected by oil spills from machinery and storage.	Daily auditing and spot checks; Report monthly.	NIB Management.

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Possibility of dam failure:	EMCA, Water Act.	• Immediate shutdown of the dam works(central control) once a leak has been detected; • Installation of secondary leak containment facilities to limit the ponding and flooding; • Designation of an emergency response team with access to specially designed and strategically located water leak response equipment.	Daily auditing and spot checks; Report monthly.	NIB Management.
Loss containment:	EMCA, Water Act.	• Use of special marker tape with an electric alarm to detect breakage; • A pressure variation leak detection system capable of responding to small sub-surface leaks.	Daily auditing and spot checks; Report monthly.	NIB Management.
Loss detection:	EMCA, Water Act.	• Monitoring of the dam by special patrols.	Daily auditing and spot checks; Report monthly.	NIB Management.
Waste Production	EMCA.	• The NIB management should abide by the waste management plan within this report that includes handling, collection, storage and disposal of operation waste.	Daily auditing and spot checks; Report monthly.	NIB Management.
Impacts on Soils	EMCA.	• During operation, NIB management has to ensure that proper engineering designs and equipment are accompanied by sound management practises. Poor maintenance of the dam will result in failure of the system resulting to subsequent leakages and ponding.	Daily auditing and spot checks; Report monthly.	NIB Management.
Impacts on Water	EMCA,	• NIB management should ensure operations of the dam do not adversely impact the environment by adhering to the Environmental management	Daily auditing and	NIB

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
Resources.	Water Act, Lakes and Rivers Act.	plan.	spot checks; Report monthly.	Management.
Impact on Utilities.	EMCA; Energy Act, Water Act.	• NIB should maximise the contribution of daylight to reduce use of artificial lighting in the buildings; • NIB should select the most efficient lighting system design and minimum lighting level appropriate for the required application; • NIB should ensure Installation of energy saving appliances; • NIB should ensure selection of the most effective lighting controls for optimal operating efficiency and minimum energy wastage.	Daily auditing and spot checks; Report monthly.	NIB Management.
Corporate Social Responsibility	N/A	• Water companies should sensitise affected communities on the dam and its related infrastructure. This can also be used as a platform by water companies to target new consumers; • Water companies should inform the affected communities on good case practices and water conservation measures to control wastage; • NIB and Water companies should look into the reduction in tariffs so that people can afford the water; • WRMA in conjunction with NIB and any other interested water sector stakeholders (such as NGOs and CBOs) should inform affected communities and develop alternative options for supplementary water supply.	Periodic	NIB Water Supply Companies
Corporate Social Responsibility	N/A	• There is need for awareness and education programmes to foster changes in stakeholders' attitudes on equitable distribution of the water supply. • The availability of a grievance mechanism will give the residents a channel to state their issues and probably get them solved and prevent vandalism.	Periodic	NIB Water Supply Companies
Vandalism and illegal connections /tapping.	Water Act; The Penal Code.	• NIB should provide adequate non-chlorinated water points for the residents' livestock; • NIB should ensure that monthly patrolling is done by air, and quarterly patrolling by foot. Most of the patrols should be conducted in sensitive areas depending on the need;	Daily auditing and spot checks; Report monthly.	NIB

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
		• NIB should train and hire local villagers for foot patrolling.		
Dam access Road.	EMCA. The Public Health Act (Chapter 242, Part IX):	• Wear and tear of drainage structures leading to erosion and gulleying; • Road safety risks to both humans and wildlife; • Dilapidation of sections of road surface by wildlife hooves and livestock on their way to watering points; • The herders also wear the road when transporting livestock to market centers; • As the road passes through bush and thicket, lack of constant maintenance means the road is easily encroached by bush and thicket.	Daily auditing and spot checks; Report monthly.	NIB Management.
• Indirect Impacts				
Protection of Riparian Lands	EMCA; Water Management Rules 2007.	• Management of riparian land where the dam and its related infrastructure pass through.	Periodic monitoring	Water Resources Management Authority; NIB
Decommissioning				
Change of use situation	EMCA; Water Act.	• In a situation where there is a change of use, decommissioning process may entail dam alterations; • Upon demolition of some associated infrastructure, the affected land will need to be reclaimed or restored into a natural condition through landscaping and planting of vegetation.	Daily auditing and spot checks; Report monthly.	NIB

Environmental Issue	Standards and Guidelines	Management and Mitigation	Monitoring Requirements	Responsibility
End of life Situation	EMCA; Water Act.	• In a situation where the dam and associated infrastructure have completed their useful life, decommissioning process will entail demolition of the erected infrastructure and dismantling of the entire associated system; • Site clearing of the site and reclaiming or restoring the affected land into a natural condition will then follow; • Restoration of the affected land may involve the filling in of dam-related infrastructure and any other open pits and grading the land to its natural contours, then planting appropriate tree species and under cover vegetation to hold the soil in place and to prevent flooding; • Planting of trees however, may not be necessary if the site is immediately taken over for another development; • The recovery of the dam will depend largely on the economic conditions prevailing at the time of decommissioning.	Daily auditing and spot checks; Report monthly.	Civil contractor; NIB
Re-vegetation during all levels of decommissioning	EMCA.	• The reclamation and restoration process should include stakeholder consultations to avoid introduction of unsuitable vegetation (such as introduction of eucalyptus along river valleys) or invasive weed species.	Monitoring of any proposed decommissioning programme	Civil contractor; NIB

8 PROJECT COST ESTIMATES AND ECONOMIC EVALUATION

8.1 Cost Estimates

Preliminary dam construction costs were estimated based on preliminary design proposals discussed in the preceding chapters of this report. The costs are derived using prevailing construction rates in Kenya. The scope of works is expected to involve embankment construction, spillway excavation, draw off works and tower, relocation of infrastructure site roads instrumentation and ancillary works such as fencing and site roads.

Unit costs were developed from the prevailing construction costs of clearing of borrow sites, striping of top soil, excavation, hauling, stockpiling, placing and compacting to approved maximum dry density. The unit costs take into account of other construction elements such as spillway, draw-off and construction of other ancillary works. The overall dam construction cost is developed from the following components of the bills of quantities as presented in the table 8.1 below.

The estimated cost for the construction of the three dam options of Radat Dam are summarised below. A more accurate cost estimate will however be produced during the detailed design stage.

Table 8:1 Estimated Project Cost

Description of Works	Radat Site 1	Radat Site 2	Radat Site 3
A.1 PRELIMINARY WORKS	300,000,000	300,000,000	300,000,000
A.2 DIVERSION WORKS	83,250,000	83,250,000	83,250,000
A.3 DAM WORKS	8,933,286,990	8,933,286,990	7,042,419,267
A.4 SPILLWAY	370,562,500	356,125,000	356,125,000
A.5 RESERVOIR	251,250,000	356,125,000	280,015,000
A.6DAM ANCILLARY WORKS	1,532,500,000	356,125,000	1,440,000,000
A.7 HYDROPOWER GENERATION	500,000,000	500,000,000	500,000,000
	11,970,849,490	10,884,911,990	10,001,809,267
A.8 Detailed Design and Construction Supervision (2.5%)	299,271,237	299,271,237	250,045,232
A.9 Contingencies and Price Adjustments (5%)	598,542,474	601,823,624	500,090,463
A.10 TOTAL COST	12,868,663,201	12,939,207,926	10,751,944,962
Add 16% VAT	2,058,986,112	2,070,273,268	1,720,311,194
A.11 NET COST	**14,927,649,314**	**15,009,481,195**	**12,472,256,155**

The estimated cost for the construction of the Radat Dam and the related auxiliary works for the three sites range between 12.5 and 15 Billion Kenya Shillings. A more accurate cost estimate will however be produced during the detailed design stage.

8.2 Project Financial And Economic Evaluation

In this section, conventional economic and financial analyses to determine the viability of the recommended project is considered and appropriate recommendations made. The economic value of the project to the beneficiary and the country is ascertained in terms of social enhancement, poverty reduction, food security, import substitutions, export earnings, recurrent expenditure (including O&M costs), etc. All capital, operation, maintenance and replacement costs are also estimated. The cost benefit ratio, internal rate of return and sensitivity analysis is also analysed.

Project Replacement costs will be based on a replacement period of 10 years for electrical and infield equipment, 8 years for the operation and maintenance equipment; 15 years for irrigation facilities made with concrete and a project life of 30 years. Discounting rates are to be used to examine the net present value for costs and benefits. The objective of the economic analysis is:

- Evaluation of the project contribution to the development of society
- Evaluation of the direct and indirect economic impacts, and qualitative estimation of the indirect economic benefits and costs
- Computation of the economic return of the proposed project, in comparisons with their costs along the time horizon of these projects.

8.2.1 Basic Assumptions

For cost-benefit analysis, various factors have to be considered. All these factors play essential role in the decision process though to varying degree. Most important factors are the project investment costs and the accruing benefits. The following assumptions have been made for the financial and economic analysis:

- There will be ready and consistent market for the proposed farm produce;
- The economic life of the dam is assumed to be 30 years;
- The project will be fully implemented and start operations in second year; with 50% being in the first and 25% in the second and third years respectively
- A capital discounting rate of between 8% and 12% is assumed
- Crop intensities of 100%, 140% and 180% have been assumed for the first, second and the third cropping years respectively. A higher cropping intensity can however be achieved depending on water availability and how well organized farmers are in terms of carrying out critical farm operations such as land preparation;

8.2.2 Project Costs

The economic analysis is based on the preliminary construction cost which excludes initial administrative costs. The economic cost will be disbursed according to the construction schedule to be developed. The project construction and operation and maintenance costs for the various proposed options are summarized below.

Capital Costs

The estimated project cost are summarised in section above summarised in chapter 8 of the report.

Recurrent costs

Recurrent costs refer to the annual expenses required to continuously operate and maintain the proposed dam project and the related components. These includes maintenance and operation expenditures such energy, chemical, personnel costs and cost of repairs. They do not include regular replacement and debt services charges and depreciation. The following four main groups are considered as recurrent cost in undertaking financial analysis.

- Personnel costs
- Operation and maintenance costs
- Administration Costs,
- Statutory Costs (WRMA, NEMA etc)

Maintenance Costs

The maintenance cost for the project will increase with age. The annual cost is estimated as a percentage of the construction costs. The rates used are adopted form the practice manual for water supply services.

Item description	Economic life (years)	Capital cost (Ksh)	% maintenance Cost	Annual Maintenance Costs (Kshs)
Radat Site 1	30	12,270,120,727	0.50	61,350,604
Radat Site 2	30	11,184,183,227	0.50	55,920,916
Radat Site 3	30	10,251,854,498	0.50	51,259,272

It is assumed that WRMA will levy water abstraction fee to the dam project at a fee of 10% of the net revenue.

8.2.3 Project Benefits

Benefits accruing from the proposed project are classified as either direct or indirect. Direct benefits are those, which arise as direct results of the investment programs. Indirect benefits on the other hand are those which require a further management or investment decisions by the farmer in order to achieve any additional gains in output or productivity. With indirect benefits the propose project is regarded as the initial infrastructural investment required as a precursor to improved irrigation and farm management practices. The benefit analysis has constructed in such a way to analyses the impact of these benefits.

Benefit I -The project benefit is estimated as the difference between the annual net production values under in the future with and without project implementation. The crop production will gradually increase after commencement of the partial operation of the project. The build-up period for a fully developed production will assumed annual project benefit amounts indicative of the gross margins for the crops grown by the farmer within the project area as assembled.

Benefit II- benefits due to increase in crops yield with proper irrigation practice and good farm management. In the absence of any project and of adequate water management at the arterial level it would be unrealistic to project the performance of the project at a constant value. The situation "with project" will anticipate a gradual improvement in performance at farm level as cultivators react to the greater reliability and efficiency of water management in output and crop margins.

Irrigation Benefits

Currently the main agricultural activities in the areas are confined to rain-fed agriculture grown during the long and short rainy season mainly for subsistence. The area has huge potential for agriculture but this has not been explored due to inadequate rainfall. Farmers keep Zebu and Dairy cattle, sheep goats and local poultry. Oxen are kept to assist farm operation during land preparation and planting. Dairy cattle keeping is only with a few farmers same as exotic poultry. The dam project is proposed to put approximately 17,500 hectares of land to irrigated agriculture.

Increase in Crop Yield and Production

Present yield of crops in the project area remains at low level due to low input, poor farm management and climatic stresses. After the completion of year-round irrigation system, yield of crops is expected to sharply increase and stabilize through farmers being accustomed to irrigation farming practices and intensive agriculture. The target yield and production of crops in future with-project condition as set forth were presented earlier, making reference to various data in Kenya and in the country with a similar climatic condition and Farm Management Handbook. Moreover, present district level statistics are used to project current yields.

Table 8:2 Gross Margins for Food and horticultural crops in the region.

Enterprise/Crop	Rainfed Condition			Irrigated Conditions		
	Total revenue (Kshs.)	Total Variable cost (Kshs.)	Gross Margin (Kshs.)	Total revenue (Kshs.)	Total Variable cost (Kshs.)	Gross Margin (Kshs.)
Mangoes	0	0	0	412,500	81,810	330,690
Bananas	0	0	0	335,775	53,528	282,248
Tomatoes	120,000	59,425	60,575	264,000	90,700	173,300
Water melon	90,000	47,000	43,000	180,000	65,700	114,300
Onions	90,000	63,140	26,860	160,000	96,120	63,880
Green grams	25,200	11,470	13,730	50,400	23,300	27,100
Grain Maize	24,000	14,020	9,980	54,000	29,630	24,370
Sorghum	18,000	10,975	7,025	39,960	22,270	17,690

Yield of crops grown under non-irrigation conditions is so assumed to stay at the same level of the present yield. Under with-project condition, cropping intensity becomes doubled; non-harvested area is sharply decreased; to the contrary, yield of each crop is sharply increased. The Economic analysis was undertaken for Horticultural (Average gross Margins of Kshs 193,000) and Food Crops (Average Gross Margins of Kshs 23,000)

Computing the Benefit-Cost Ratio

To compute the benefit- cost ratio, we must decide on the discount rate to be used. Two discount rates are commonly used, Opportunity cost of capital and the borrowing rate, a third less common one, the social rate of return is also used. Probably the best discount rate to use is the opportunity cost of capital. However it is difficult to estimate the actual opportunity cost of capital. In most developing countries it is assumed to be somewhere between 8 and 15%. The social rate of return, a rate which, as it is suggest reflects the time preference of the society as a whole than does the opportunity cost of capital.

Choosing the Discount Rate

For benefit cost ratios or net present worth calculations the most appropriate rate is the opportunity cost of capital that rate which will just result in all the capital in the economy being invested if all possible projects were undertaken which yielded similar or more return. 8, 10, 12% is used iteratively in this study; the figure generally lies between 8 %and 15%. A different (generally lower) rate of interest should be used for public projects than for private projects. It should be emphasized that financial rates of interest such as the government borrowing rate or the prime-lending rate are always too low to justify their use in economic analysis.

8.3 Cash Flow Analysis in Financial Terms

Cash flow analyses were prepared for each project. The flows are set out on the base assumptions for costs and benefits as discussed earlier, with all prices included in financial terms. The economic assessment has been done through different parameters such as:

- ✓ Net Present Value / Worth (NPV/W)

NPV is the difference of total discounted benefits to the total discounted costs.

- ✓ Benefit cost Ratio (B/C)

B/C is the ratio of total discounted benefits to the total discounted costs.

- ✓ Internal Rate of Return (IRR)

IRR is that discount rate which makes NPV zero. Equation for IRR is given below:

$$IRR = a\% + \left[\frac{A}{A-B} X(b\% - a\%) \right]$$

Where a is the lower discount rate

b is the higher discount rate

A is the NPV at rate a%

B is the NPV at rate b%

Two discounting rates have been used to determine IRR. If the final value of IRR is found to be greater than the upper discounting rate; then, project is economically viable. The discounting factors adopted for the benefit cost ratio and the net present worth is at 8%. The results of the analysis are presented in Appendix D (sensitivity analysis).

8.4 Sensitivity Analysis

8.4.1 Approach

The general guidelines for sensitivity analyses set out in the terms of reference include the effects of higher or lower capital and production costs, yield and prices. The potential effect of a delay in the execution of the project is also referred to specifically for review. The technique of sensitivity analysis is particularly important in a project of this kind where both difficulties with planning data and complex inter-relationships between potential investments decisions can obscure decision-making.

8.4.2 Sensitivity Tests

In addition to NPV and IRR analysis, the project was subjected to sensitivity analysis as follows:

- 20% increase in investment cost;
- 20 % decrease in revenues;
- 10% increase in operation and maintenance costs.

Summary of results is provided in the table below. The results show that the project return positive NPVs and IRRs greater than 8-10 % even when project costs are increased by 20%, revenue is decreased by 20% or maintenance cost increased by 10 %. The project is thus financially and economically viable.

The analyses with the above variations are presented in appendix. Summary of sensitivity analysis is presented in the table below.

Table 8:3 Results of Sensitivity Analysis for Radat Dam Site 1

Description	Net Present value	Present Value of benefits	Present Value of costs	Cost benefit (b/c) ration	Internal rate of return (IRR)
Base Case:	3,033,680,195	18,464,871,427	15,431,191,232	1.20	9.46%
<u>Sensitivity Analysis:</u>	-				
Investment Costs Increase by 20%	109,818,403	18,464,871,427	18,355,053,024	1.01	6.94%
Benefits Decrease by 20%	-659,294,090	14,771,897,142	15,431,191,232	0.96	6.49%
Operation and maintenance costs Increase by 10%	2,871,303,741	18,464,871,427	15,593,567,686	1.18	8.50%

Table 8:4 Results of Sensitivity Analysis for Radat Dam Site 2

Description	Net Present value	Present Value of benefits	Present Value of costs	Cost benefit (b/c) ration	Internal rate of return (IRR)

Description	Net Present value	Present Value of benefits	Present Value of costs	Cost benefit (b/c) ration	Internal rate of return (IRR)
Base Case:	4,399,380,631	18,464,871,427	14,065,490,796	1.31	10.27%
Sensitivity Analysis:	-				
Investment Costs Increase by 20%	1,734,288,189	18,464,871,427	16,730,583,238	1.10	7.80%
Benefits Decrease by 20%	706,406,346	14,771,897,142	14,065,490,796	1.05	7.34%
Operation and maintenance costs Increase by 10%	4,251,374,914	18,464,871,427	14,213,496,513	1.30	9.44%

Description	Net Present value	Present Value of benefits	Present Value of costs	Cost benefit (b/c) ration	Internal rate of return (IRR)
Base Case:	5,571,899,079	18,464,871,427	12,892,972,348	1.43	11.08%
Sensitivity Analysis:	-				
Investment Costs Increase by 20%	3,128,972,368	18,464,871,427	15,335,899,059	1.20	8.64%
Benefits Decrease by 20%	1,878,924,793	14,771,897,142	12,892,972,348	1.15	8.17%
Operation and maintenance costs Increase by 10%	5,436,231,320	18,464,871,427	13,028,640,107	1.42	10.35%

8.5 Conclusions and Recommendations

8.5.1 Conclusions

Due to the high flow fluctuations and the water deficit in the Perkerra basin, a dam with a large reservoir is required to regulate the river flow. The consequence is a dam with a relatively high construction cost. From the economic and financial analysis, the dam project is not viable at capital discounting rates above 8%. The irrigation will help the farmers achieve higher yields, cropping intensities, gross margins, and reduce the current production risks. This needs a strategy that supports farmers to start with the crops they know even for the marketing aspects. The system seeks to irrigate the areas presently under rain-fed crops. This project concept is based on the fact that water is a resource, which can be delivered to anybody anywhere and hence has the least impact on the social setup of the community as they are today.

8.5.2 Recommendations

It is recommended that the project be implemented after undertaking of the detailed investigations and design of the proposed components. More emphasis however should be on production of high value horticultural crops.

8.5.3 The Project and its justification

The proposed Radat dam is expected to regulate flow in Perkerra to guarantee irrigation requirement of 3.25m3/s requirements to expand the Perkera irrigation scheme. The project will augment food security, reduce poverty level among the population in the project area as well as enhance commercial agricultural production. These will directly answer to the Vision 2030 for this country and the Worlds MDGs. The project will make contribution to increased employment opportunities in the project area, during construction and when operational. The latter particularly will be realized through the labour intensive vegetable and rice production. Employment will also be available throughout the construction period of main and in-field irrigation systems. A number of secondary benefits will also be realized which include: Improvement of farm households' nutrition; Income and employment opportunities generated through the marketing of farm produce; suppliers of crop inputs (seed, fertilizers and pesticides), contract services (land preparation and transport) and the agro-processing industry; and opportunities for employment local contractors during project implementation.

Appendices

Appendix I: Drawings

Appendix II: Cost Estimates