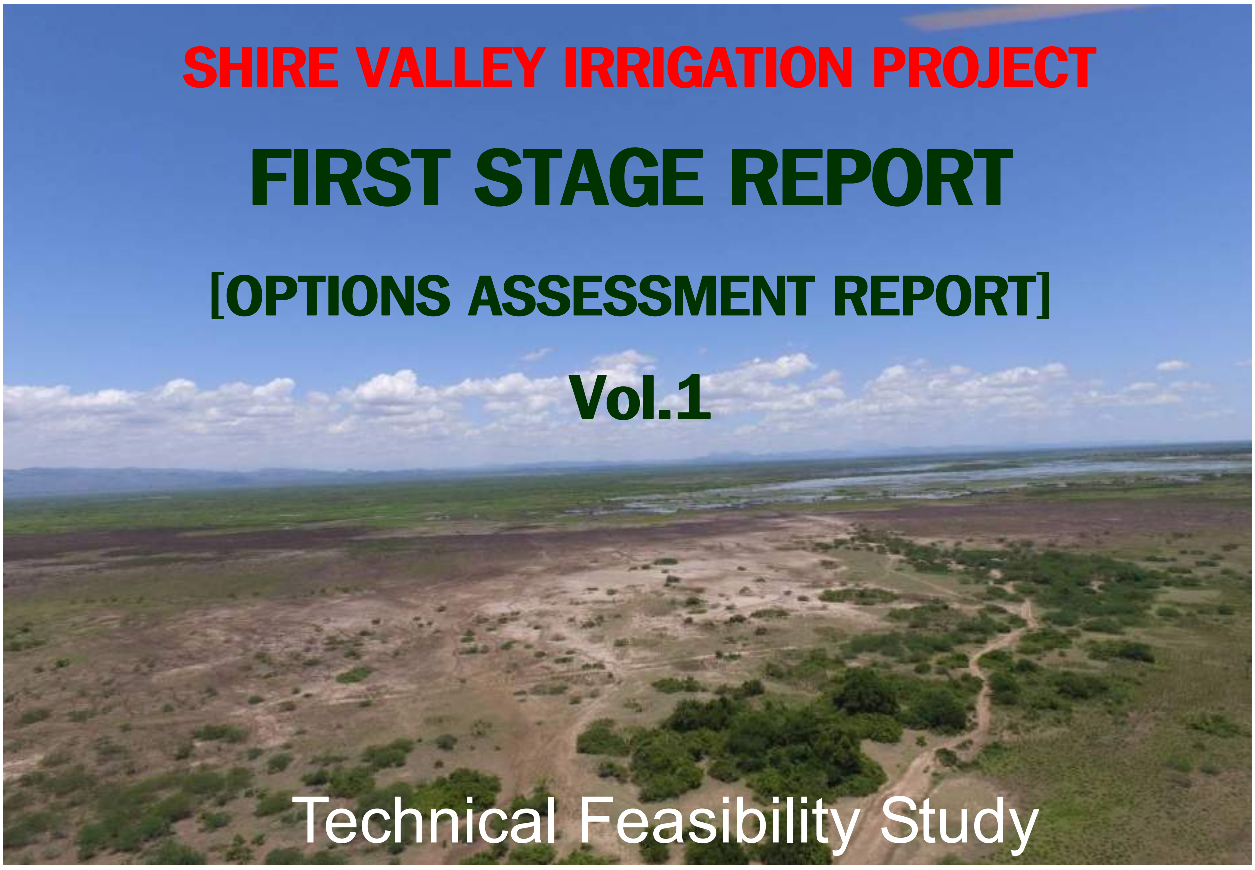
GOVERNMENT OF MALAWI

MINISTRY OF AGRICULTURE, IRRIGATION AND WATER DEVELOPMENT



SHIRE VALLEY IRRIGATION PROJECT

FIRST STAGE REPORT

[OPTIONS ASSESSMENT REPORT]

Vol.1

Technical Feasibility Study

August 2016

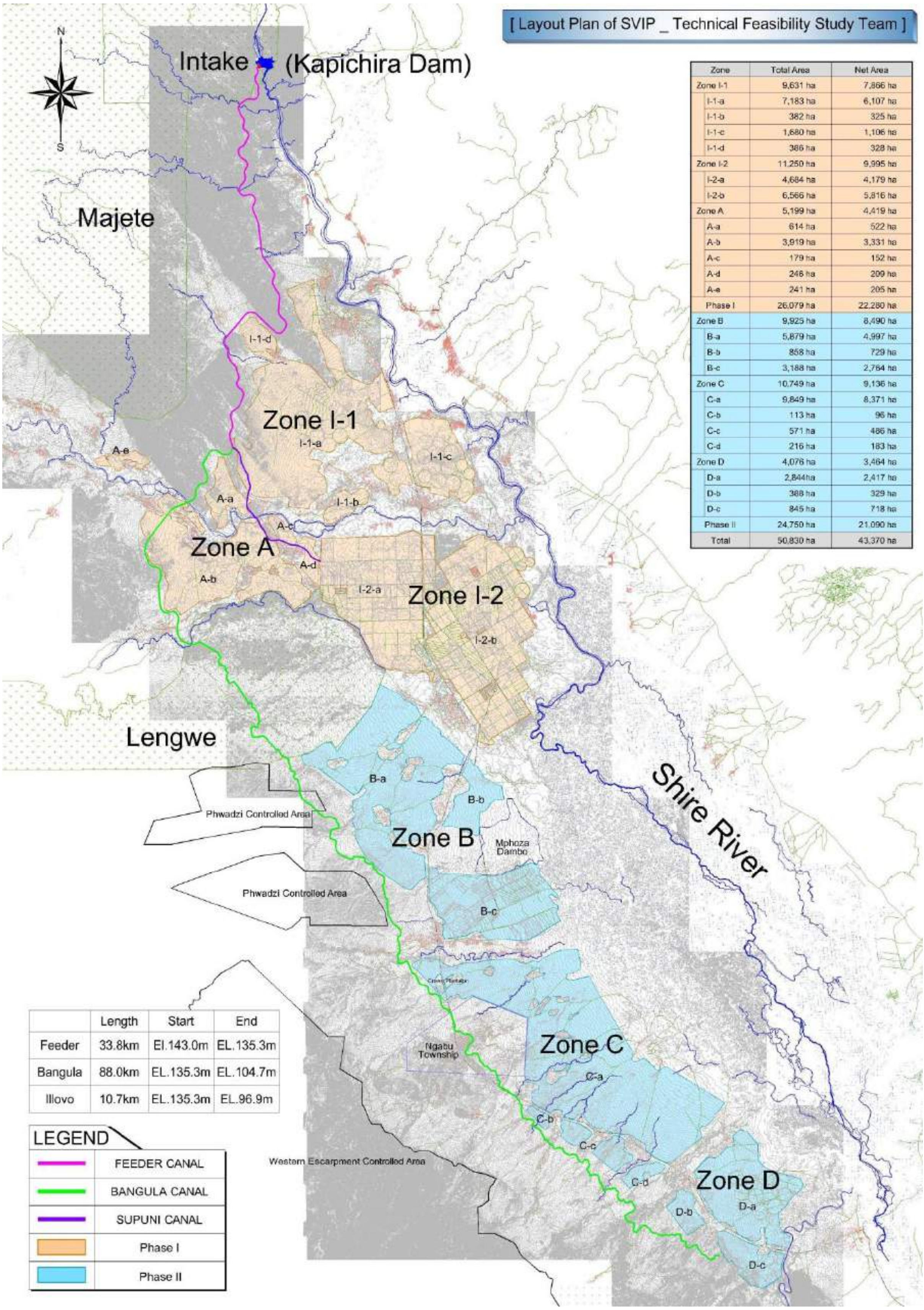
KOREA RURAL CORPORATION

in Joint Venture with

DASAN CONSULTANTS CO., LTD.,

GK WORKS CIVIL AND STRUCTURAL ENGINEER

Layout Plan of SVIP



Zone	Total Area	Net Area
Zone I-1	9,631 ha	7,866 ha
I-1-a	7,183 ha	6,107 ha
I-1-b	382 ha	325 ha
I-1-c	1,680 ha	1,106 ha
I-1-d	386 ha	328 ha
Zone I-2	11,250 ha	9,995 ha
I-2-a	4,684 ha	4,179 ha
I-2-b	6,566 ha	5,816 ha
Zone A	5,199 ha	4,419 ha
A-a	614 ha	522 ha
A-b	3,919 ha	3,331 ha
A-c	179 ha	152 ha
A-d	246 ha	209 ha
A-e	241 ha	205 ha
Phase I	26,079 ha	22,280 ha
Zone B	9,925 ha	8,490 ha
B-a	5,879 ha	4,997 ha
B-b	858 ha	729 ha
B-c	3,188 ha	2,764 ha
Zone C	10,749 ha	9,136 ha
C-a	9,849 ha	8,371 ha
C-b	113 ha	96 ha
C-c	571 ha	486 ha
C-d	216 ha	183 ha
Zone D	4,076 ha	3,464 ha
D-a	2,844ha	2,417 ha
D-b	388 ha	329 ha
D-c	845 ha	718 ha
Phase II	24,750 ha	21,090 ha
Total	50,830 ha	43,370 ha

	Length	Start	End
Feeder	33.8km	El.143.0m	EL.135.3m
Bangula	88.0km	EL.135.3m	EL.104.7m
Illovo	10.7km	EL.135.3m	EL.96.9m

EXECUTIVE SUMMARY

A. Preliminary Investigations

A.1. Topography

The TFS team obtained topographic information about SVIP area by studying various types of maps. This information was then used in determining the possible site for the intake structure for the project and in designing the route of the Feeder Canal and the path that the Main and Branch Canals would follow. And based on this information, it was decided that the intake for SVIP should be located on the western side of Shire River at Kapichira Dam as opposed to the site previously recommended by the CODA Consultancy Study. According to this arrangement, the Feeder Canal would convey the abstracted water from the Shire over a distance of 33.8 km to its outlet point at the starting point of both Bangula and Supuni Canals.

Since the route of the Feeder Canal would pass through Majete Game Reserve, the TFS has recommended putting in place appropriate mitigation measures to minimize adverse environmental impacts on the game reserve, and these have been highlighted in the Environmental and Social Impact Assessment (ESIA) of SVIP. For example, the design of the Feeder Canal may require fencing in order to safeguard animals from drowning in the water if the conveyance system were to be open to the atmosphere. Also, there would be need to minimize rock cutting work in the game reserve and install appropriate river crossing structures.

A.2. Soil Survey

The aim of the soil survey was to determine the irrigability and drainability of soils within SVIP areas. This was done by conducting a thorough review of previous soil surveys, carrying out field measurements, and conducting laboratory tests with a view to determining soil characteristics and associated soil profiles. All soil samples collected from pits were sent to Bvumbwe Agricultural Research Station and some to Lilongwe University of Agriculture and Natural Resources for detailed laboratory analysis. The results on soil classification and the suitability of the soils for crop irrigation awaits laboratory testing results from Bvumbwe Agricultural Research Station. But information obtained from previous studies show that soils in SVIP area are generally fertile and suitable for crop production and irrigated agriculture.

A.3. Geotechnical and Hydro geological Investigation

Data obtained from pits dug along the Feeder and Main Canals show that soils in SVIP are generally alluvial in nature, comprising sandy, clay and humus. As such, conveyance losses due to seepage expected to take place, therefore in this point of view lining of canal is recommended. Especially inside Majete area, the lined feeder canal is highly recommended to minimize the seepage loss. In this regard a buried concrete syphon could be considered as another option. During the preliminary design the pros and cons of the two alternatives shall be carefully assessed, and selected the more advantageous one.

On hydrogeological investigations, it was noted that generally SVIP area has adequate amounts of groundwater resources of acceptable quality for drinking water supply, although it some areas, especially on the western side of the Shire, groundwater is highly mineralized. This mineralization of groundwater is a direct result of the prevalent low hydraulic gradients arising from the flat topography of the area, coupled with low rates of groundwater recharge.

Values of adjusted sodium adsorption ratios for the water samples collected in the project area show that water resources in SVIP are generally suitable for irrigated agriculture. However, in areas where salinities of water resources are high, there will be need to implement water management practices like pre-plant irrigation to leach the accumulated surface salts in order avert salinity problems.

According to data obtained from the DHI report of 2015, the Lower Shire Valley receives an average of 956 mm of rainfall, with the lowest value of 583 mm; and experiences annual evapotranspiration rates of 1,966 mm. Furthermore, groundwater recharge rates are estimated to lie in the range of 80-100 mm/annum. However, it was difficult to precisely quantify surface runoff because most of the water that flows in the Shire is mainly derived from Lake Malawi. The same difficulty was encountered in determining the amount of water in storage within the study area. As such, the evaluation of the water balance proved rather difficult.

A.4. Floods

The regional flood frequency model is developed by establishing how the T-year floods “grow” from say 5 years to 100 years for all the stations to obtain the growth factor. Using the regional flood frequency model presented above, the T-years flood flows could be computed for the Candidate Rivers under this assignment for dam construction (alternative water source).

Site surveys for flooding were conducted at 17 villages. The surveys considered the areal extent of flooding, food heights, the duration of flooding, and the frequencies of flooding in the past. Floods of January 2015 were the most serious floods in the Lower Shire Valley. Most of the flooding takes place in areas along Mwanza and Nkombezi rivers.

The main observations are summarized below:

1) Inquiry investigation survey shows that inundation depth is around 1.0m in most of areas regardless of elevation except for areas in Zone-A located between Mwanza river and Nkombedzi river.
2) According to interviews conducted with the local community, it was noted that there are big differences in their knowledge about flood magnitudes, and hence their information may not be very useful.
3) A concentration of settlements in very low areas around the river banks makes it very difficult to calculate discharge using the slope-area method.
4) Areas along Mwanza river experience severe flooding because of the dramatically reduced cross sectional area of flow of the channel as a result of serious sedimentation that has taken place in the river because of its degraded catchment area.
5) Shire river area is also vulnerable to flooding but not many people live around Shire river area so flood damage is relatively low.
6) It may be necessary to dredge the bed of Mwanza river and build dykes along it in order to mitigate flood damage.

The current flood zoning map was compiled by overlaying satellite video topographic map developed by the World Bank in January 2015 on request by the Malawi Government. Important information was also taken from the Flood Risk Management Report (2015, BRL).

A.5. Socio-Economics

Most of SVIP area, apart from large estates such as Illovo and Kasinthula, is owned by small holder farmers who grow corn, sorghum, cassava, cotton plant and soybean under rain-fed agriculture. And because of the occurrence of inadequate rainfall and frequent droughts in the area, yields are generally very low. In addition to its vulnerability to droughts, SVIP area is also prone to flood disasters, with serious repercussions on crop production and loss of life and damage to property.

The Lower Shire Valley is one of areas in the country with a high number of livestock. The common types of livestock owned by households are cattle, goats, chickens, pigs, guinea fowl, ducks, rabbits, sheep, and pigeons. The main constraints to livestock production are diseases, scarcity of drinking water, fodder during the dry season, and stock theft.

Although most of the sugar grown at Illovo is exported abroad, a small proportion is sold locally to meet the domestic demand.

A.6. Development of GIS

The development of the GIS for the project area involved the use of satellite images with 0.5m vertical resolution and other types of topographic maps, and the 50cm Digital Elevation Model (DEM). It is envisaged that the GIS that has been developed will incorporate several layers of features on interest.

Recently acquired 0.5m high resolution satellite images were been used for this project. Ground Control Points (GCP) were acquired on site orthophotos for geo-processing work of this project. The DEM for the SVIP area was produced using existing elevation data and high resolution satellite images. The Index Contour Line (5m) and Intermediate Contour Line (1m) from DEM was then generated. And a Supplementary Contour Line (0.5m) was generated for very flat area. Finally, the contour lines generated were edited manually for cartographic output.

An orthophoto or orthoimage is an aerial photograph geometrically corrected ("orthorectified") such that the scale is uniform: the photo has the same characteristics as a map. Unlike an uncorrected aerial photograph, an orthophoto can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief lens distortion, and camera tilt.

Screen digitizing is a critical process to identify features and information on images and determine extractable geographical features and to analyze correlations by using satellite images.

The final GIS product will contain topographic map showing all physical features, such as, roads, rivers, soil types, land use, hills, etc and layers that contain all relevant information that would be obtained from the Technical Feasibility Study and the other consultancies ; ESIA, CCPLT, HM and ADPS.

B. Assessment of Technical Options

B.1. With / Without Illovo Estate

The evaluation results show that the With Illovo case gives a higher Benefit/Cost ratio than Without Illovo, and a relatively higher Internal Rate of Return (IRR). Therefore, TFS recommended that GoM should negotiate with Illovo so the latter can be involved in the implementation of SVIP.

The above analysis shows that if Illovo Estate is to be included in SVIP, the benefit, among others, would include:

- Release of up to 22.2MW of energy to the national grid
- Collection of water charges including the cost recovery of capital costs.

The first benefit (Release of up to 22.2MW to national grid) could be estimated comparing it with the construction cost of a new hydro-power station producing equivalent amount of electricity. Accordingly, the benefit of releasing electricity to national grid is estimated to be 44,400,000 USD. This benefit shall be considered as the main benefit to the GoM for including Illovo in the SVIP.

The second benefit will be accounted in the Financial Analysis of the project (Water charge including the cost recovery of capital cost). The GoM may include the water charge and increase the economic feasibility of the project.

On the other hand, ILLOVO Estate would benefit from foregone costs of electricity and O & M costs of the pumping stations. The estimated combined benefit would be 4,666,088 USD per year. With Illovo included in SVIP, the intake structure and Feeder Canal would have to be designed in such a way that they meet the water requirement of 50.0m^3/s. However, if Illovo is excluded from the project area, irrigation facilities would have to be designed to abstract and convey 35.3m^3/s; and the project cost would proportionally be reduced. In light of the above, the TFS Team recommends the inclusion of Illovo in SVIP.

B.2. Irrigable Areas to be Developed

B.2.1. Irrigable areas were delineated by considering several factors, namely: topography, soil fertility, existing farming systems, grazing areas, flood prone areas, residential areas, graveyards, and places of cultural heritage. The irrigable areas were then verified by field surveys.

In terms of topography, the following conditions were considered: slope, drainage condition, elevation and accessibility. Soil survey on project area was also carried out with a view of determining suitable areas for irrigation. Accordingly, a total of 43, 370 ha (net) have been identified for development under SVIP. Of this amount 22, 278 ha (net) is under Phase 1, while the remaining 21, 090 ha (net) is under Phase II.. The irrigation water requirement for the 43, 370 ha of SVIP has been estimated to be 50.0m^3/s (See details in Chapter 5). This value is the peak requirement, which shall be required for about two weeks during the month of September. The value is estimated based on the proposed cropping Pattern by Agricultural Development Planning Strategy (ADPS) Consultant and assuming an overall irrigation efficiency of 52%. The intake structures and the feeder canal are designed for th e maximum water requirement of the 50m^3/s in September.

B.2.2 In addition to irrigation, the required water for running all four generators of ESCOM at Kapichira is 270m^3/s. There is also a need to provide for an environmental flow of 17m^3/s. Thus the total water required for electricity generation, environmental flow and irrigation is 337m^3/s.

According to the previous studies of WRIS (2011) and Norplan (2013) and the present analysis of TFS, the available flow of Shire River at Kapichira Dam is sufficient to fulfill the water demands of ESCOM, SVIP and Environment at 80% exceedance probability. Even though the design water requirement is set for the peak requirement, there are several ways to economize irrigation water as follows:

- Adjust farming program to set harvesting period and preparation period for next cultivation in

September, which enable to use a small amount of water,

- Adjust cropping pattern to plant the crops which use less water in September,
- Reduce cultivating area during the dry period,
- Change the irrigation system from furrow irrigation to sprinkler/pivot irrigation system,
- Moreover, the completion of Kamuza barrage is expected to improve the water availability in the Shire river basin including SVIP.

In general through proper design of the cropping pattern and improvement of the irrigation efficiency (through farmers training, changing of irrigation methods, etc) the 50 m3/sec flow would be sufficient to irrigate the whole potential irrigable areas (50, 000 ha) in Shire Valley, including areas at Nsanje.

B.3. With / Without Lining the Feeder Canal

The size of the Feeder Canal will have to be large enough to convey the design water requirement of 50.0m^3/s which will supply the whole project area covering 43,370ha during both Phase I and Phase II. The geotechnical investigation carried along the feeder canal route revealed that the canal is passing through rocky and sandy soil areas which are highly permeable. Moreover the cross section of lined canal is smaller than that of the earth canal by 25m^2(45%), which reduces excavation works and environmental impact particularly in Majete area. Thus the Feeder Canal will be lined with 10cm thick concrete reinforced by 10mm diameter steel bars. However, at several locations along the canal, special structures such as siphon or bridges shall be constructed for crossing tributary rivers and roads. Further investigation will be conducted regarding the possibility of using earth canal for Bangula.

B.4. Main Canal Optimization

During the previous feasibility studies, Zone A was placed under Phase II. Since this zone is divided into the northern and the southern part by Mwanza river, the southern part cannot be irrigated by the Feeder Canal. Hence in order to supply water to this region, it is necessary to connect the Feeder Canal to the starting section of Bangula Canal by crossing the Mwanza River. The TFS has recommended crossing the Mwanza River using the shortest distance via a siphon. An area of 532ha that would be affected by the proposed syphon crossing of Mwanza River would partly be served by introduction of a small canal running from the northern side of Mwanza River to supply about 240.1ha of area around Moses village.

B.5. Phasing of the Project

The project's total irrigable area is 43,370 ha; but from the TFS's assessment, it has been noted that it is possible to add an area of 6, 000 ha (net) to SVIP. It has been assumed that the whole new irrigable area will be under furrow irrigation, an irrigation practice that has a low water application efficiency. Illovo proposes to use center pivot irrigation systems while Phata and Kasinthula associations already use center pivot irrigation systems.

In terms of the phasing of the project, four alternatives were proposed. Two of them include Illovo while the other two exclude Illovo. Therefore the choice of phasing of the project will be directly relate to availability of funding and whether Illovo is included in SVIP or not. However the TFS has recommended the With Illovo option.

B.6. Type of Cropping Patterns

This study was conducted to: determine suitable crops and cropping patterns; identify preferred crops by farmers; recommend crop-specific husbandry practices; determine costs of production and corresponding yields. There is a wide range of crops that are grown in SVADD including cereals, grain legumes, oil seeds, cash crops, vegetables and fruits. The top four preferred crops by farmers are sorghum, maize, cotton and millet. Other preferred crops are cowpea, sweet potatoes, pigeonpea, beans, sesame and cassava. These crops are grown primarily for food except cotton, a cash crop. Other preferred crops are cowpea, sweet potatoes, sesame, beans and different types of vegetables.

Potential crops recommended for SVIP based on ecological requirements and farmer preferences are sugarcane, maize, cotton, sorghum, pigeonpea, sweet potatoes, cowpea, beans, vegetables, bananas and mangoes. These crops are adapted to high temperatures except for beans that are recommended for winter production only. In terms of hectarage, it is proposed that 44% of the area should be allocated to sugarcane, 6% to fruits (bananas and mangoes) and the remaining 50% to annual crops.

For the annual crops, production can be intensified through a proper planned crop rotation systems under rainfed and irrigation. Crop rotations should consider the complementarity of different crops to minimize the negative interaction. Some of the crop characteristics to be considered are rooting habits and nutrient demand, susceptibility to pests to diseases, allelopathic effects and crop duration. Legumes such as pigeonpea should be followed by cereal crops (maize and sorghum) in order to benefit from nitrogen fixed by legumes. High crop productivity can be achieved with use of improved varieties, adequate water supply and good agronomic practices. Therefore, in the design process, there is need to consider the irrigation water requirement for the potential crops.

- Cotton is a cash crop and was listed among the top three preferred crops by farmers. Productivity of cotton can be enhanced by growing varieties that are pest resistant to reduce costs associated with pest management; and identification of markets with suitable varieties.
- Maize is recommended for both grain and seed maize production under rainfed and irrigation. Gross margins are higher with seed maize than grain production. At least two crops can be harvested in a year and there is high potential for high yield with good management and adequate water supply.
- Pigeonpea is a grain legume that is drought tolerant and adapted to wide environment conditions. As a legume, it can fix atmospheric nitrogen into inorganic forms thereby improving soil fertility. There are different varieties (short, medium and long duration) that can be grown to suit different needs. The crop has high market potential.
- Other crops that can be grown at small scale during specific times of the year are cowpea, beans and vegetables (fruit and leafy vegetables).

It is recommended that an orchard should also be established for bananas and mangoes of 6% of the land. Fruit production should be supported with investment in processing plants for value addition, diversification of products and reduce postharvest losses.

B.7. Options to Mitigate Environmental Impact

In order to minimize the environmental impact inside the Majete Game Reserve, the shortest route along the tourists road will be followed. It is recommended to use steel or concrete pipes instead of an open canal, which has more advantages from environmental point of view. This option will be further investigated during stage 2.

The canal is supposed to cross the Lengwe National Park for about 14km, with the width of 14~26m. If an overpass structure for animals to cross the canal is installed appropriately, it can mitigate negative impacts on the park. The number and length of the overpass structure will be discussed with ESIA team and the park management. To prevent animals from drowning, fences will be installed along the canal.

B.8. Use of Other Resources

Small catchments with rivers flowing into the SVIP area were investigated for potential dam sites both on the desk and field investigation. Ten (10) promising catchments were selected and analyzed. They are small catchments located in the sections through which the main canal of SVIP will pass. The result of the investigation shows that Nthumba, Phwadz, and Thangadzi have more comparative advantage in terms of location. However, all sites are prone to heavy siltation and not cost effective. As a result, it is not recommended to secure additional surface water resources through construction of supplementary dams.

C. Cost Estimation of SVIP

Project expenses consist of direct construction cost, consulting service fee (design & construction inspection), resettlement costs, public charges and tax (surtax), and reserve (quantity and price.). Direct construction cost encompass intake, canal, road, and land consolidation costs according to the plan. The total direct cost of SVIP project, is estimated at **527,448,600** USD. And the cost for the Phase I is estimated at 229, 093, 200 USD. A contingency of 20% was proposed based on the locally collected data and advice from the Department of Irrigation. The total cost is expected to increase when the cost required for settlement, tax and other public charges are included. In general the current estimates are preliminary and are subject to revision during stage 2.

D. Recommendations

The TFS reviewed all the deliverables stipulated in the ToR and made the following recommendations:

- The Government of Malawi should negotiate with Illovo in order for the latter to be involved in the implementation of SVIP since Illovo has already shown interest in the project through a water purchase agreement as its contribution. This is a win-win situation for both parties and Illovo can enhance its competitiveness on the World Sugar Market under this arrangement; and
- There is adequate water in the Shire for both hydropower generation and irrigation at Kapichira Dam. However, in four months of the years with low flows in a ten year or twenty year cycle, there may be need for prioritising between power generation and SVIP. But with good planning, the need for prioritisation could be avoided.

The upgrading of Kamuzu Barrage will increase dependable flows in the Shire thereby improving availability of water for all services including hydropower generation and irrigation in the Lower

Shire Valley. In light of the above, the proposed financing of SVIP should consider adopting efficient irrigation systems so that water is adequately available throughout the project life.

Abbreviations and Acronyms

ADD	Agriculture Development Division
AEDC	Agriculture Extension Development Coordinator
AEDO	Agriculture Extension Development Officer
Ads. SAR	Adjusted Sodium Adsorption Rations
AfDB	African Development Bank
AgDPS	Agricultural Development Planning Strategy
AWF	African Water Facility
CCPLTRPF	Communication, Community Participation, Land Tenure and Resettlement Policy Framework
CEC	Cation Exchange Capacity
DAO	District Agriculture Office
DEM	Digital Elevation Model
DOI	Department of Irrigation
ESCOM	Electricity Supply Corporation Of Malawi
EPA	Extension Planning Area
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental Social Management Plan
FAO	Food and Agricultural Organization
FIRR	Financial Internal Rate of Return
FGDs	Focus Group Discussions
GIS	Geographic Information System
GLCN	Clobal Land Cover Network

GoM	Government of Malawi
HEP	Hydro Electric Power-plant
HWSD	Harmonized World Soil Database
IMP	Irrigation Master Plan
IRLADP	Irrigation Rural Livelihood and Agriculture Development Project
ITCZ	Inter Tropical Convergence Zone
LCCS	Land Cover Classification System
MoAIWD	Ministry of Agriculture, Irrigation and Water Development
O&M	Operation & Maintenance
PC	Project Coordinator
PPP	Public Private Partnership
PTTC	Project Technical Team Coordinator
RAW	Readily Available Water
SMEP	Soil Moisture Extract Pattern
STDEV	Standard Deviation
SVADD	Shire Valley Agriculture Development Division
SVIP	Shire Valley Irrigation Project
TFS	Technical Feasibility Study
ToR	Terms of Reference
UNDP	United Nations Development Programme
WB	World Bank
WRAS	National Water Resource Assessment
WRIS	Water Resources Investment Strategy
ZAB	Zaire Air Boundary

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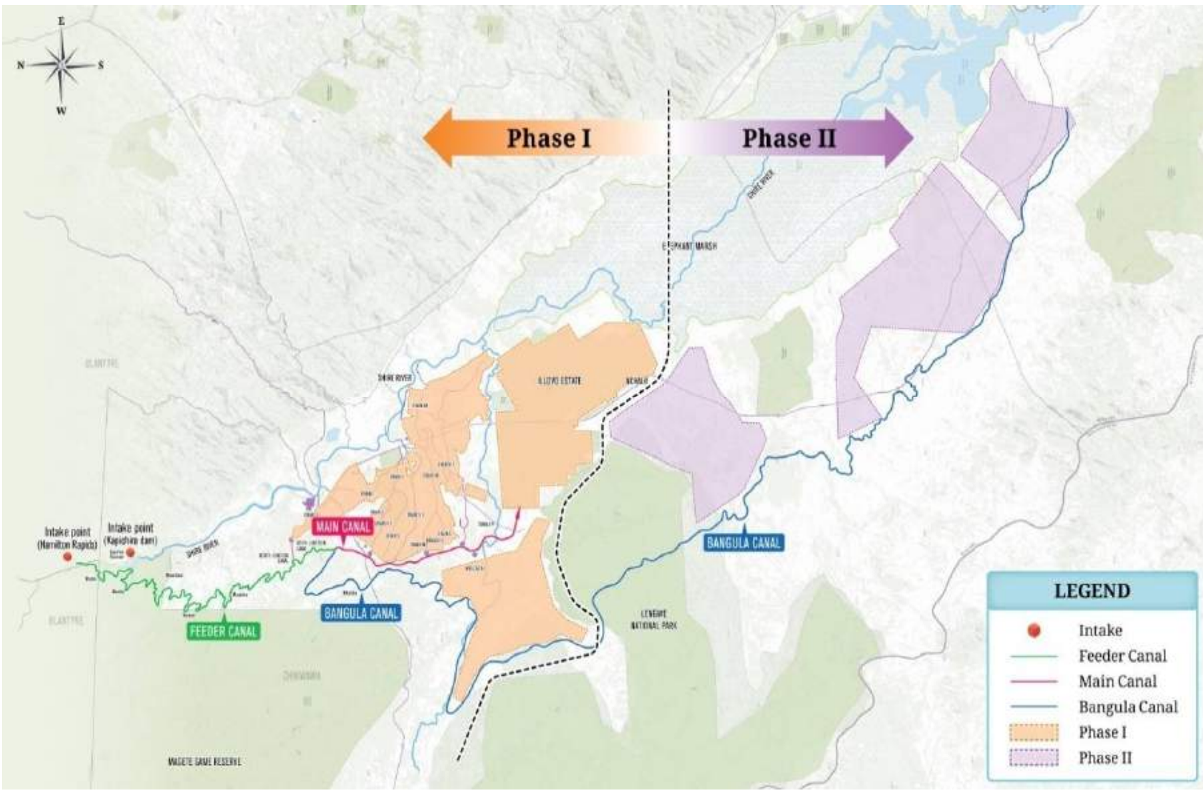
CHAPTER 1. INTRODUCTION

1.1. Project Overview

Since the 1940s, the Previous Government administration has been interested in the implementation of SVIP to develop irrigation in the Lower Shire Valley. Since then, the proposed project has been the subject of a large number of surveys and studies. However, so far these studies have not resulted in the preparation of a detailed project proposal acceptable for funding by donor agencies. The latest in the series was an AfDB-funded study by CODA and Partners in 2008 that was intended to synthesize the outputs from the previous studies and formulate a 42,000 ha irrigation project.

The AWF conducted a preparation/appraisal mission in March 2012 and produced a detailed appraisal report. The pre-feasibility report has found that phased development of 42,500 ha of lands under irrigated agriculture is feasible subject to other conditions being met to ensure its economic viability and sustainability. Similarly, the PPP study proposes viable options for private sector participation in different aspects of the project. These reports and their recommendations have been endorsed and accepted by the GoM and are available with the DoI for reference.

As per the pre-feasibility report, approximately 42,500 ha can be developed for irrigation in two phases (Phase I and Phase II), based on abstracting irrigation water from the River and conveying it by gravity to the irrigable area mainly through open canals. The intake would be located at the right bank of the pondage reservoir for Kapichira Hydroelectric Power Station (and therefore lower in elevation) from the originally proposed site at Hamilton’s Rapids by past studies. The proposed project area and layout are shown in Figure 1.1-12.



[Figure 1.1-1] Proposed Project Area and Layout

The two phases proposed by the pre-feasibility study are as follows:

Phase I of the project would extend to 21,408 ha, of which 9,995 ha have already been developed for sugarcane plantations by Illovo and 750 ha have been developed by out-growers. Phase I would include(a) the existing Illovo Estate at Nchalo, (b) the existing cane out-grower scheme at Kasinthula, (c) new land in the vicinity of Kasinthula, and (d) new land in the Mthumba Valley and new land between the Mwanza River and Lengwe National Park.

Phase II (21,092 ha, which is 42,500 – 21,408 = 21,092 ha) would be commanded by the Bangula Canal. Of this area, approximately 3,248 ha have already been developed by Illovo private company. This proposition suggests that the existing pumped water supply would have to be converted to a gravity supply, and the remaining 17,844 ha would be allocated to smallholders or their organizations.

1.2. Objectives of the Technical Feasibility Study (TFS)

The objective of this assignment is to undertake a detailed feasibility study, which would advance the pre-feasibility study already completed, with the aim of :

- Assisting the government in selecting the best technical and institutional options before developing a full feasibility (water allocation optimization, inclusion or not of Illovo Estate, with-without lining, etc.; stage 1);
- Based on the selected options, preparing the preliminary design and assessing the technical and economic feasibility of the project (stage 2), taking into consideration its phasing;

The Consultant - Korea Rural Community Corporation (KRC), in association with DASAN CONSULTANTS and GK Works - shall be expected to undertake these activities by building on the outputs and filling in the gaps of the previous studies, as well as taking into consideration the work and recommendations of the recent studies. It should be noted that while the feasibility study should focus on Phase I of the project, it would be necessary to cover the Phase II area in sufficient detail to confirm that a second phase would be (a) technically feasible and (b) economically viable. This is paramount because whether this phase will eventually proceed or not, will affect the design capacity of the intake and Feeder Canal.

1.3. Report Formation

This is the first stage report, which contains the whole results of the Consultants' study implemented during the first stage of study. The title of this report is the "options assessment report", which is actually a part of tasks, but the most important part.

The report consists of 4 volumes:

- Volume 1: Main Report
- Volume 2: Annexes
- Volume 3: Soil Survey Report (Draft)
- Volume 4: Hydro-Geology Report (Draft)

Soil survey report(Volume 3) and Hydro-Geology Report(Volume 4) are draft reports, because the laboratory analysis are still on-going. Later two final reports shall be submitted including the laboratory analysis.

CHAPTER 2. PRELIMINARY INVESTIGATION

2.1. Topography

2.1.1. Data Collection of Topographic Map

A topographic map is a basis for validating a review of any irrigation project. As such, it is absolutely necessary to collect as diverse and precise data as possible in order to carry out a thorough review of any given project. The followings are the topographic data that the TFS team collected in order to conduct a feasibility study of SVIP:

1) 1:1,000,000 topographic map: overall area of Malawi

2) 1:50,000 topographic map: SVIP project area (Table 2.1-1)

[Table 2.1-1] Project Topographic Map List

Drawing Sheet No.	Index to Adjoining Sheets		
1534D3 MAJETE			
1534D4 BLANTYRE WEST	1534D3	1534D4	
1634B1 NDAKWERA	MAJETE	BLANTYRE WEST	
1634B2 CHIKWAWA	1634B1	1634B2	
1634B4 NGABU	NDAKWERA	CHIKWAWA	
1634D2 and Part of 1634D1 MURUKANYAYA	1634B3/A4	1634B4	
1634B3 and Part of 1634A4 THERERE	THERERE	NGABU	
1635A3 and Part of 1635A4 MUONA MISSION		1634D2/D1	1635C1/C2
1635C1 and Part of 1635C2 CHIROMO		MURUKANYAYA	CHIROMO

3) 1:50,000 and 1:25,000 digital map

4) High resolution digital terrain model

5) Orthophoto map of scale 1:10,000 for the project area

6) Purchase of precise satellite digital map

2.1.2. Preparation of Topographic Map of SVIP Project Area

1) The TFS team conducted site survey based on draft drawings of SVIP project's waterway and zoning plan overlaid on 1:50,000 map before drawing the conceptual project plan using a 1:10,000 precise video digital map;

2) With the prepared 1:10,000 project plan, a site survey conducted, stakeholder consultations with residents were conducted, and discussions with related bodies to set up waterway course and project plan were held;

3) The waterway course and project zoning plan prepared under (2) above were used in conducting a surface/subsurface water survey, soil survey, and geotechnical investigations;

4) GIS survey work: apart from drawing the topographic map of the project area, a 1:5,000 scale topographic map using precise satellite video was developed. This map was used to develop a 1:5,000 scale of SVIP project plan including waterway and project zoning plan. During Phase II of the project, the GIS database will be developed by creating layers of all kinds of features based on a 1:5,000 scale of SVIP project plan.

2.1.3. Basic Data of Project Area drawn from Topographic Map Analysis

2.1.3.1. Elevation Analysis

Elevation analysis was conducted using the existing digital map with a 1:10,000 scale. Analysis results of each zone are shown in Table 2.1-2. Both zone I-1 and zone A have the highest elevations in the project area with Majete Game Reserve and Lengwe National Park in the hinterland respectively. Zone I-1 has a wide range of elevation changes ranging from the lowest point to the highest point (i.e. EL.70-140m). Comparatively, zone A is located at high elevation area with a range in height of El.100-140m. Zone I-2 where Illovo Sugar Estate is located shows relatively even elevation distribution below El.100m. Zone B, C, and D fall under Phase II of SVIP, but exhibit elevation distribution ranging from 50 to 120m. Given that areas in this zone have the lowest elevations, a thorough review is required when setting up irritation plan for these areas to avoid ponding.

[Table 2.1-2] Elevation Distribution of the Project Area (unit: km^2)

Elevation (m)	Zone I-1	Zone I-2	Zone A	Zone B	Zone C	Zone D	Total
40~50	-	-	-	-	-	0.01	0.01
50~60	-	-	-	0.47	5.02	6.12	11.61
60~70	-	15.31	-	9.78	27.45	12.96	65.49
70~80	7.38	49.43	-	24.24	25.67	12.31	119.02
80~90	35.08	35.79	-	23.37	21.46	5.79	121.49
90~100	24.82	11.98	-	23.47	16.03	3.39	85.58
100~110	18.42	-	16.51	14.37	10.24	0.17	59.71
110~120	8.71	-	20.55	3.56	1.63	-	34.45
120~130	1.76	-	8.91	-	-	-	10.67
130~140	0.13	-	0.13	-	-	-	0.27
Total	**96.31**	**112.50**	**51.99**	**99.25**	**107.49**	**40.77**	**508.31**

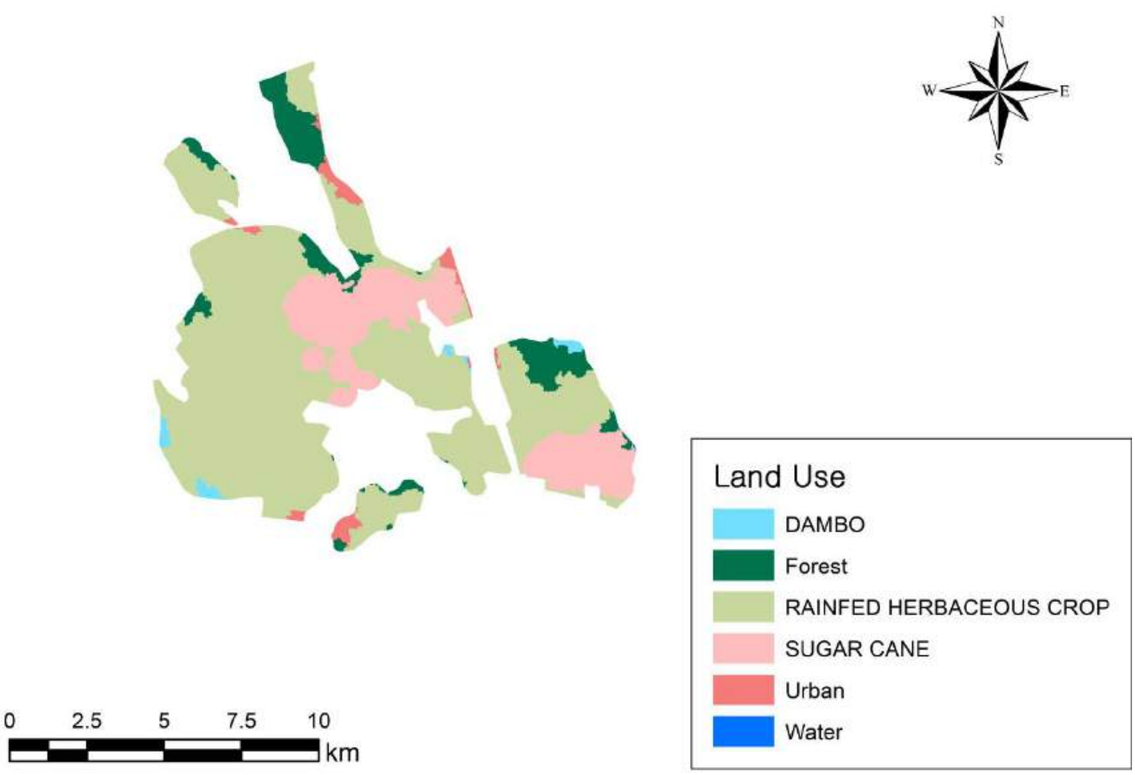
2.1.3.2. Land Use Status of the Project Area

The status of land use in the project area was analyzed using ‘Atlas of Malawi Land Cover and Land Cover Change 1990-2010 (FAO, GoM, Norwegian Embassy, June 2013)’ compiled by the Department of Surveys. And the results are shown in Table 2.1-3. The categorization was rearranged during the analysis in such a way that similar items were integrated into single categories. For example, woodland, forest, tree, etc were classified as forest. And from this integration, a total of eight land use classes were formed. It is apparent from land use analysis that Rainfed Crop takes up the largest part of the project area, i.e., 256.52km^2 (50.5%) of SVIP project area, followed by sugarcane 159.47km^2 (31.4%), forest (8.2%) and Dambo (5.3%).

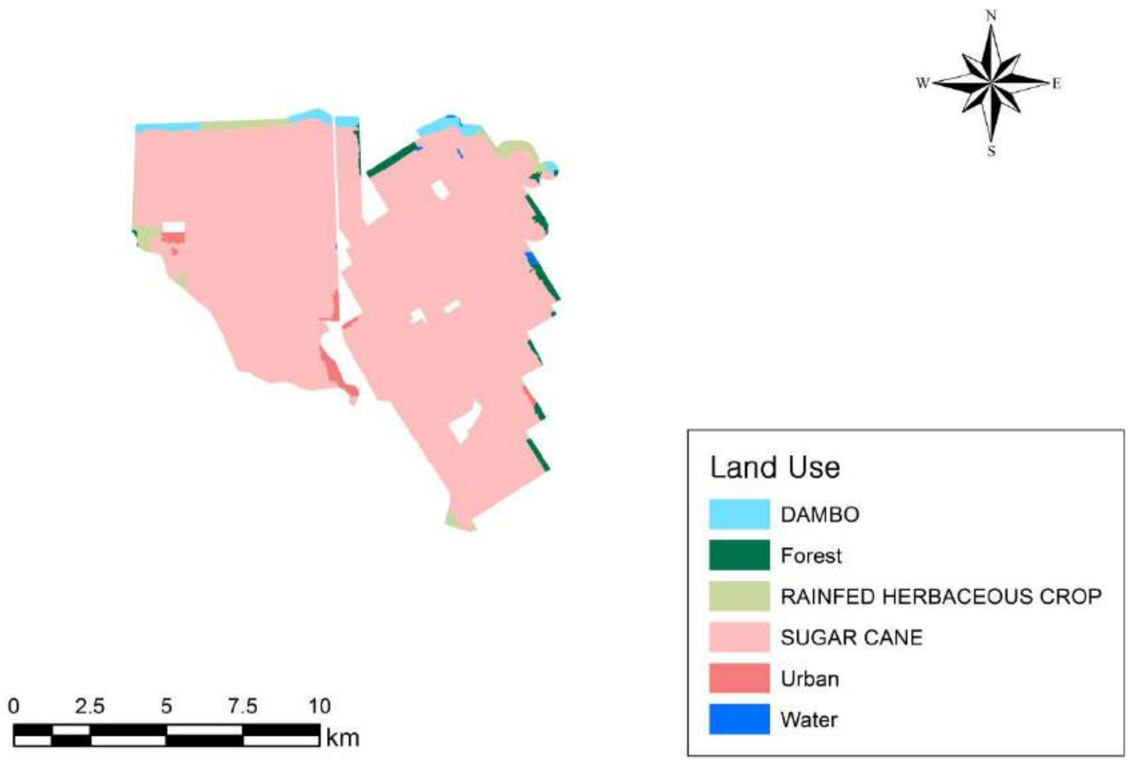
The urban area in the SVIP accounts for 4.4% of the total project area. Even though residential areas were avoided when selecting the project site from the 1:10,000 topographic map, some of the urban areas could not be avoided in during field surveys and hence have been included in the project area. Thus, the project area is expected to be modified slightly in accordance with precise site survey results. In addition, the drainage capacity of dambo areas will be improved in order to avoid ponding.

[Table 2.1-3] Land Use Status of the Project Area

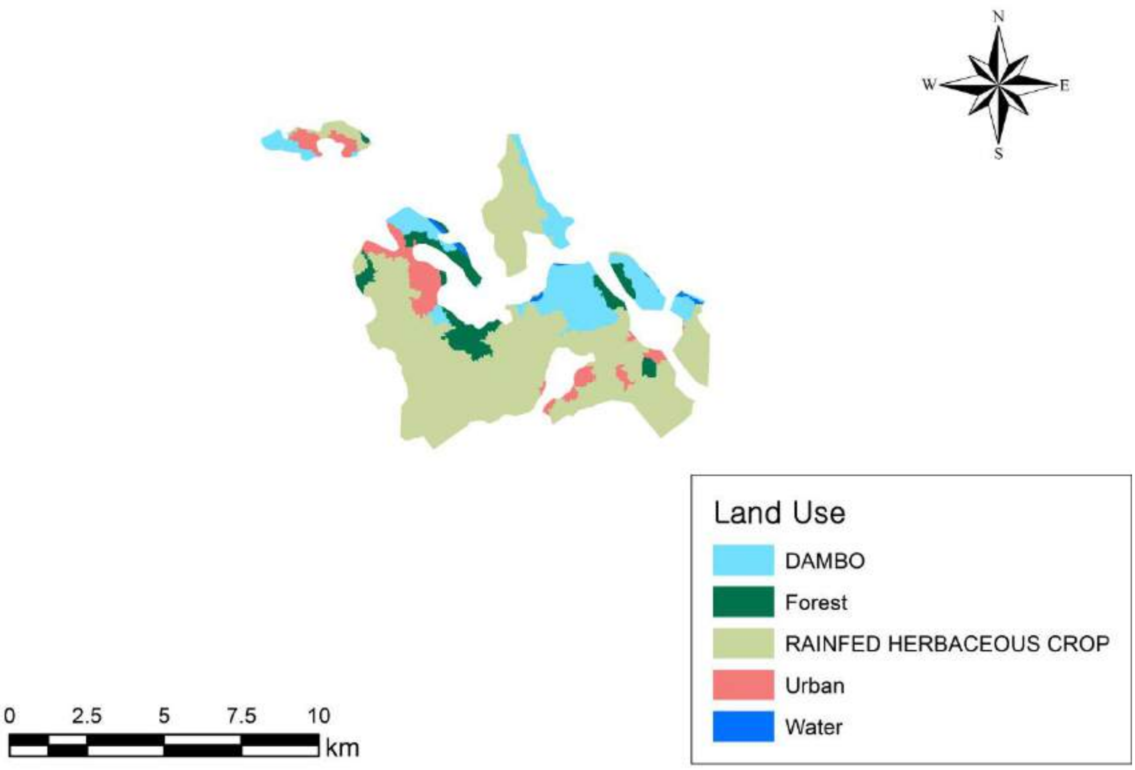
Land Use		Zone I-1	Zone I-2	Zone A	Zone B	Zone C	Zone D	Total
Dambo	Km^2	1.04	2.04	8.31	0.99	14.33		26.71
	%	0.2	0.4	1.6	0.2	2.8		5.3
Forest	Km^2	7.37	1.72	3.94	6.14	9.39	12.94	41.50
	%	1.4	0.3	0.8	1.2	1.8	2.5	8.2
Marsh	Km^2				1.07			1.07
	%				0.2			0.2
Orchard	Km^2						0.52	0.52
	%						0.1	0.1
Rianfed Crop	Km^2	69.58	2.46	36.07	53.21	79.82	15.38	256.52
	%	13.7	0.5	7.1	10.5	15.7	3.0	50.5
Sugarcane	Km^2	16.63	104.81		30.30		7.73	159.47
	%	3.3	20.6		6.0		1.5	31.4
Urban	Km^2	1.67	1.28	3.33	7.54	3.95	4.19	21.96
	%	0.3	0.3	0.7	1.5	0.8	0.8	4.3
Water	Km^2	0.01	0.19	0.35				0.55
	%	0.0	0.0	0.1				0.1
Total	Km^2	96.31	112.50	51.99	99.25	107.49	40.77	508.31
	%	18.9	22.1	10.2	19.5	21.1	8.0	100.0



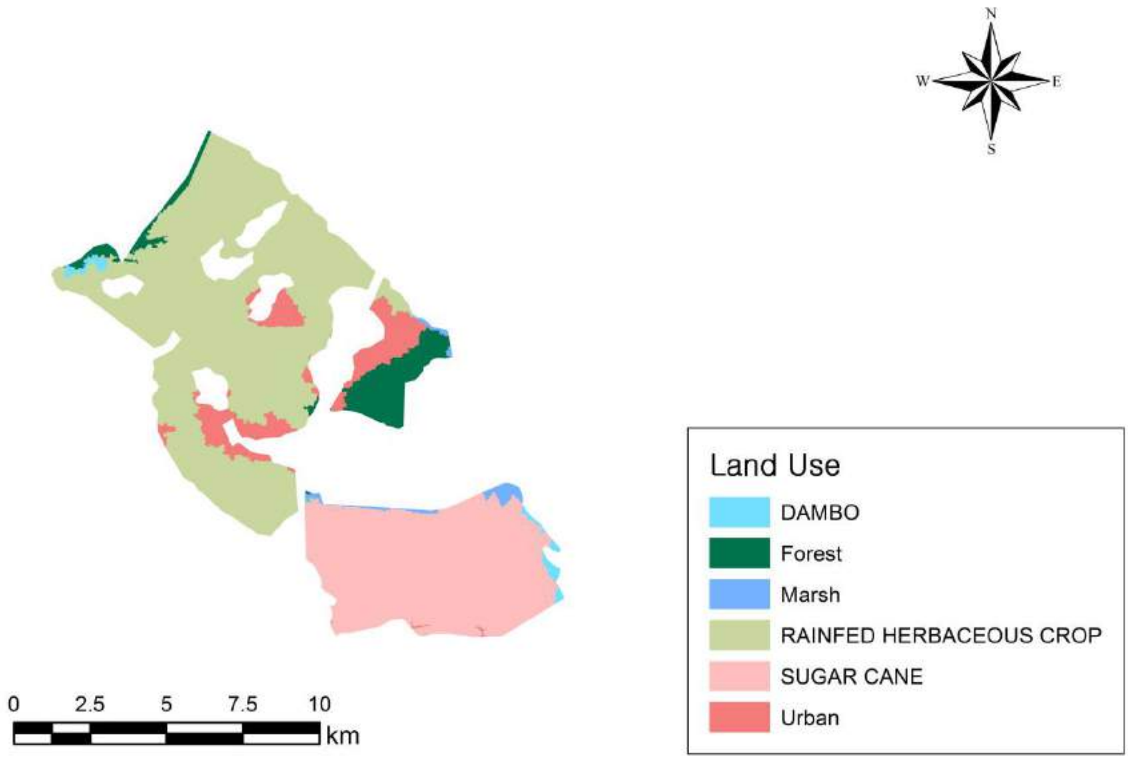
[Figure 2.1-1] Land Use of Zone I-1



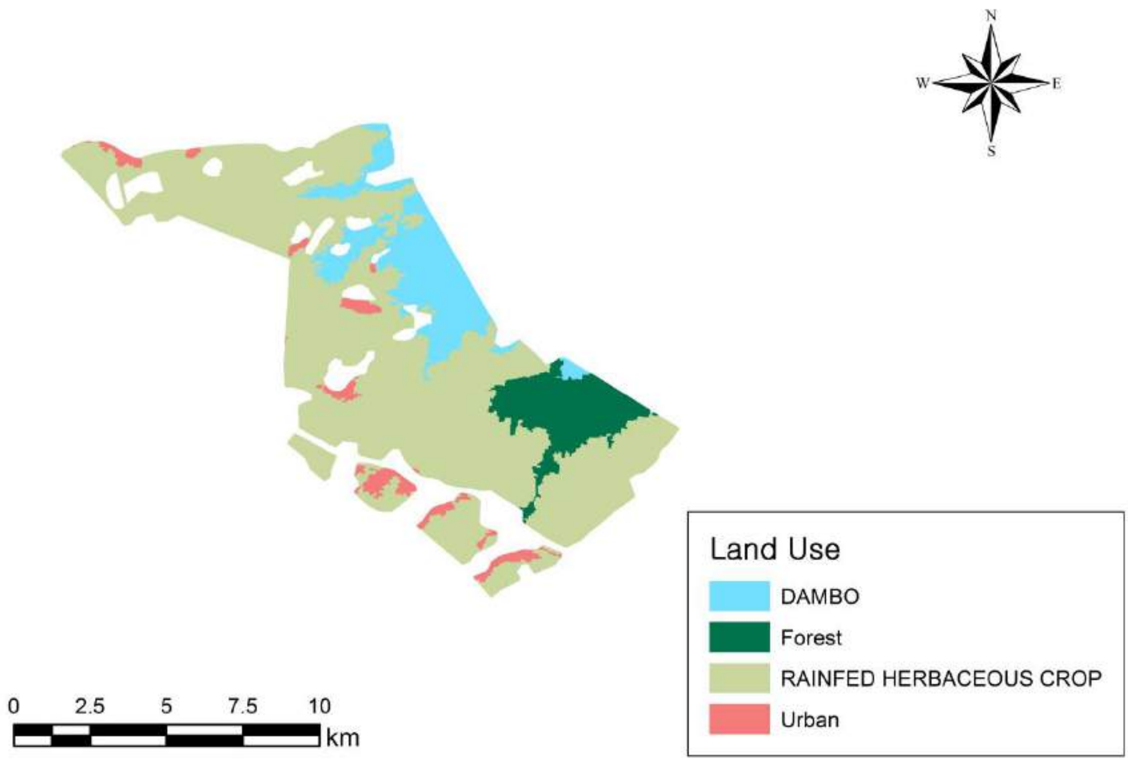
[Figure 2.1-2] Land Use of Zone I-2



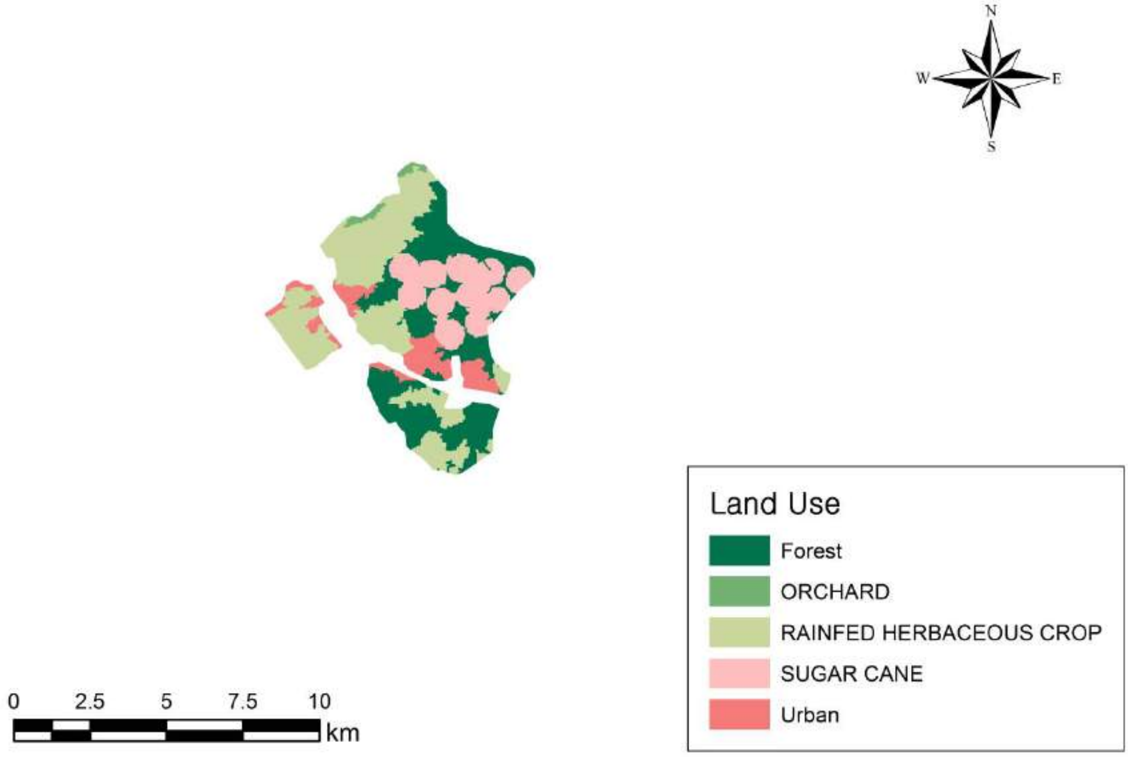
[Figure 2.1-3] Land Use of Zone A



[Figure 2.1-4] Land Use of Zone B



[Figure 2.1-5] Land Use of Zone C



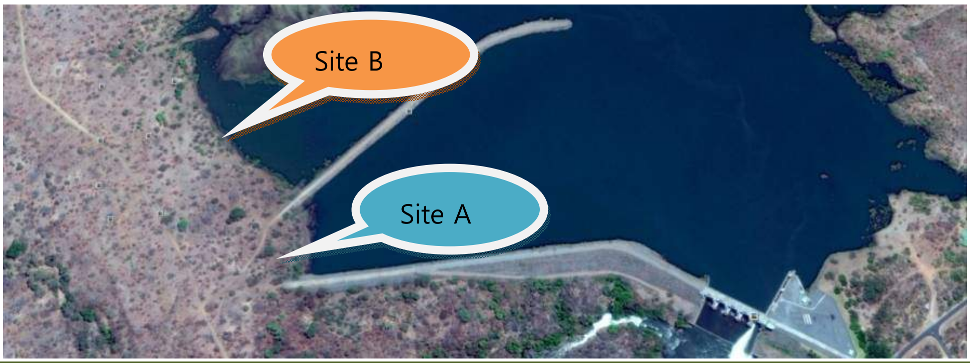
[Figure 2.1-6] Land Use of Zone D

2.1.4. Location of Intake Structure

In the CODA report of 2008, the location of the intake structure was proposed to be at the Hamilton rapids, upstream of Kapichira Dam. However, very recently the GoM decided to have the intake structure installed at the reservoir of Kapichira Dam. The selection of the site considered foundation stability, economic feasibility, effectiveness for O&M, construction conditions, water intake condition, and administrative aspects (Lengwe National Park, Majete Game Reserve, stakeholders, etc.).

Additionally, sedimentation was given serious consideration in the selection of the intake point for the project. During floods, the Shire River transports large volumes of sediments which could easily chock the intake if it is not properly located. Therefore, what is needed is to find a way in which the intake structure would not get clogged with sediments during severe floods. Figure 2.1-7 is a close photo of Site A and Site B, and Figure 2.1-8 shows two alternative sites for the intake structure on Kapichira Dam. Although the hydraulic modeling study recommended the latter, intuitively and from expert judgement, Site A has a comparative advantage over Site B.

[Figure 2.1-7] Location of Intake Structure at Kapichira Dam Site (Left: Site A, Right: Site B)

Items	Site A	Site B
Layout		
Advantages and Disadvantages	- Low sediment inflow - Stable water regime - Securing of water head - O&M condition is better - Shorter Feeder Canal	- A lot of sediment inflow - Unstable water regime - Securing of water head - O&M condition is worse - Longer Feeder Canal

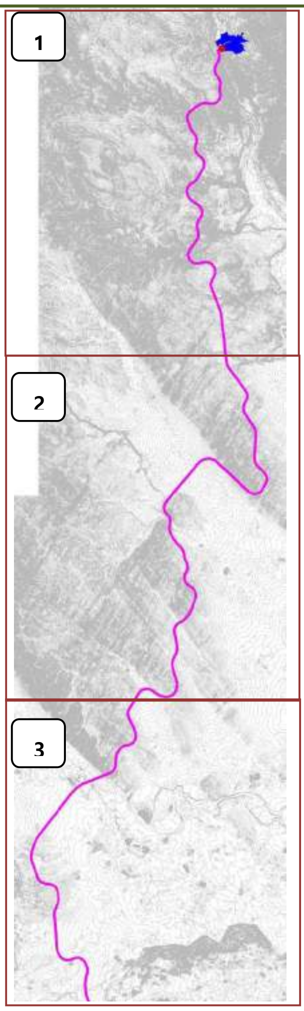
[Figure 2.1-8] Alternatives for the Sites of Intake Structures at Kapichira Dam

In terms of sedimentation, Site B is more prone to pile up sediment than the Site A. Figure 2.1-9 shows lots of sediment is piled up in the Site B. On the other hand, in terms of sedimentation the area of Site A has a better condition. On top of the advantage, ESCOM has a plan to implement dredging the whole reservoir area including the Site A. During the preliminary design sediment samples will be taken from the both sites A and B to decide on the best location of intake structure.

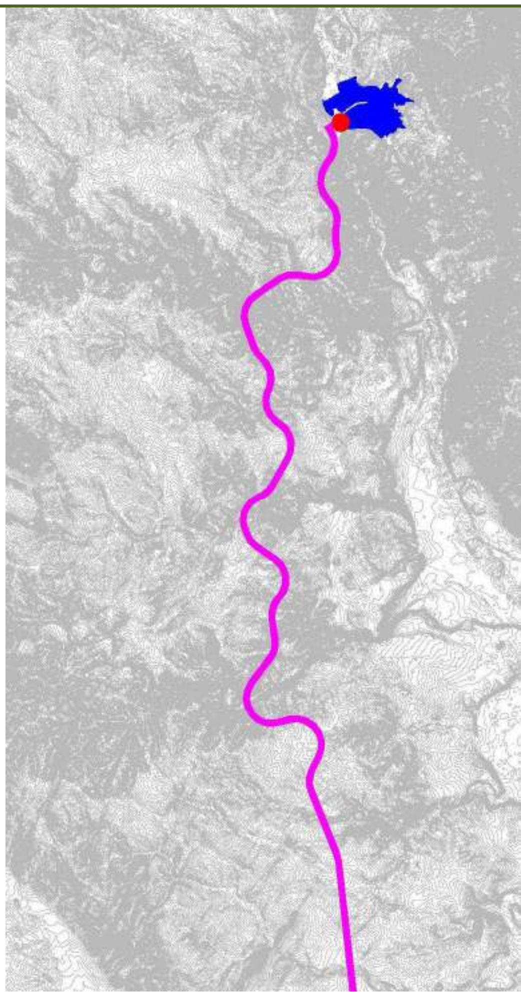
[Figure 2.1-9] Image of intake structure installed at the Site A

The Consultant (Artelia of France), who is responsible for Hydraulic Modelling of the Intake Structure and selection of the optimum site for the Intake location is currently undertaking the study. However the results of the study will not be available until the end of August, 2016. To avoid delays the Intake Structure will be designed at Site A in close consultation with the HM consultant, subject to change if the need arises.

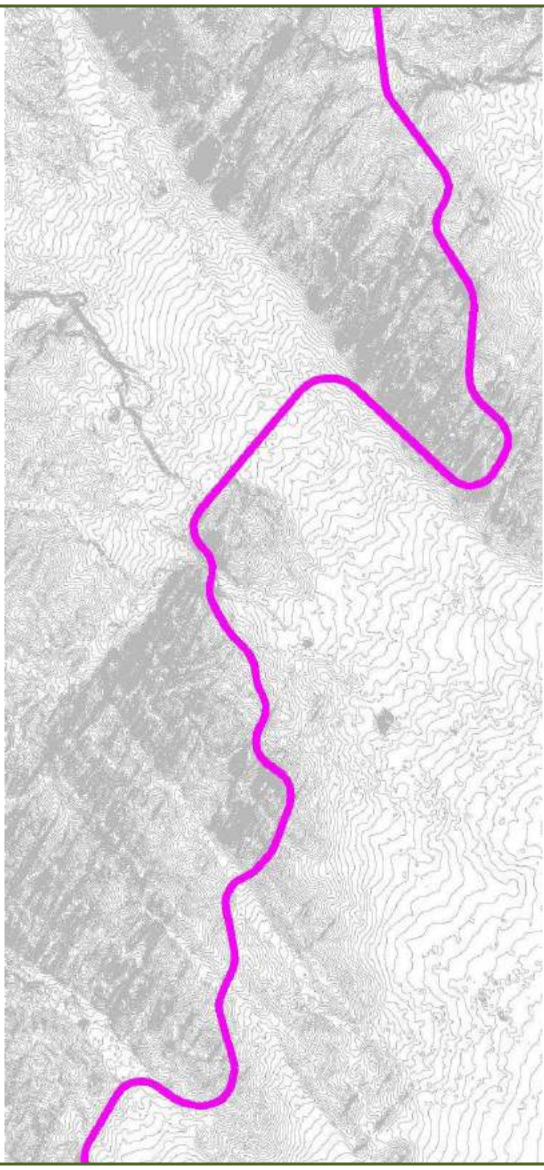
2.1.5. Topography of Feeder Canal Route



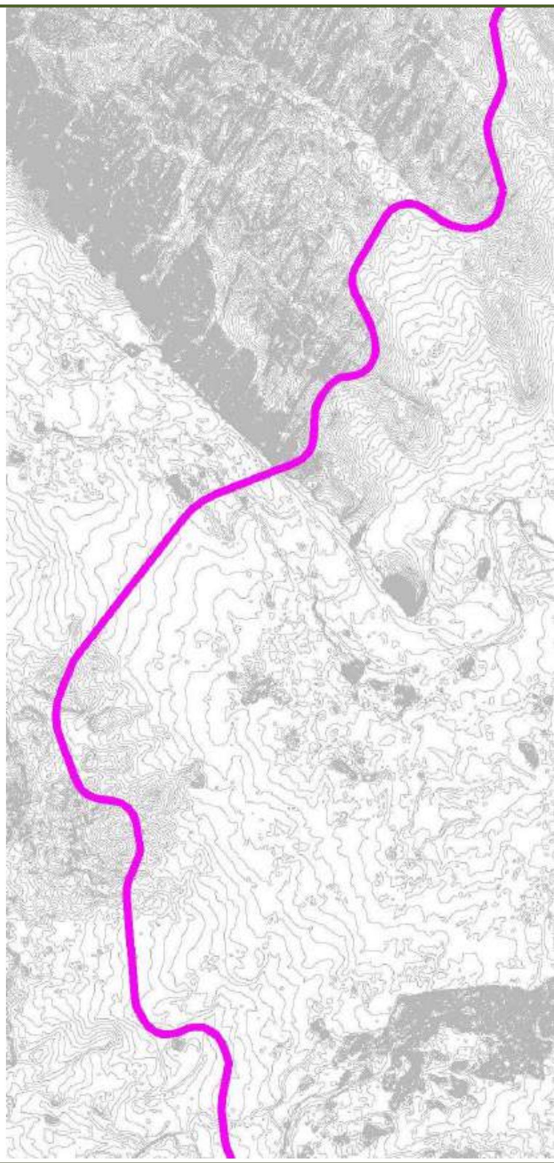
[Figure 2.1-10] Entire Feeder canal



[Figure 2.1-9] Section 1 of Feeder canal



[Figure 2.1-10] Section 2 of Feeder canal



[Figure 2.1-11] Section 3 of Feeder canal

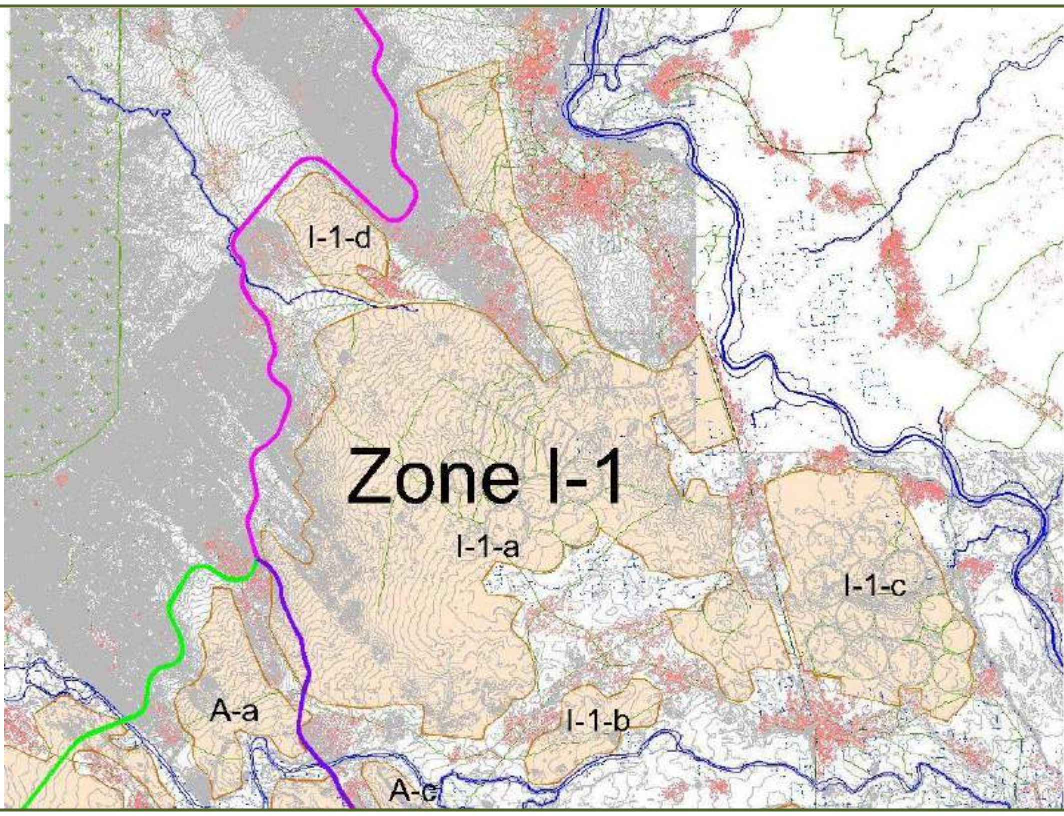
The length of the feeder canal is 33.8km-long, starting from the intake at El.143.00m at Kapichira dam to the end at El.135.26m, which is also the starting point of both Bangula and Supuni Canals. Figure 2.1-10 shows the area of the feeder canal while Figures 2.1-11 ~ 2.1-13 exhibit enlarged areas of feeder canal in three sections.

About 1 km of the feeder canal will pass through Majete Game Reserve, hence there will be need to minimize environmental impacts on the game reserve. In particular, the design will be required to minimize rock cutting work in the game reserve and safeguard animals from drowning in the open canal if this option is adopted.

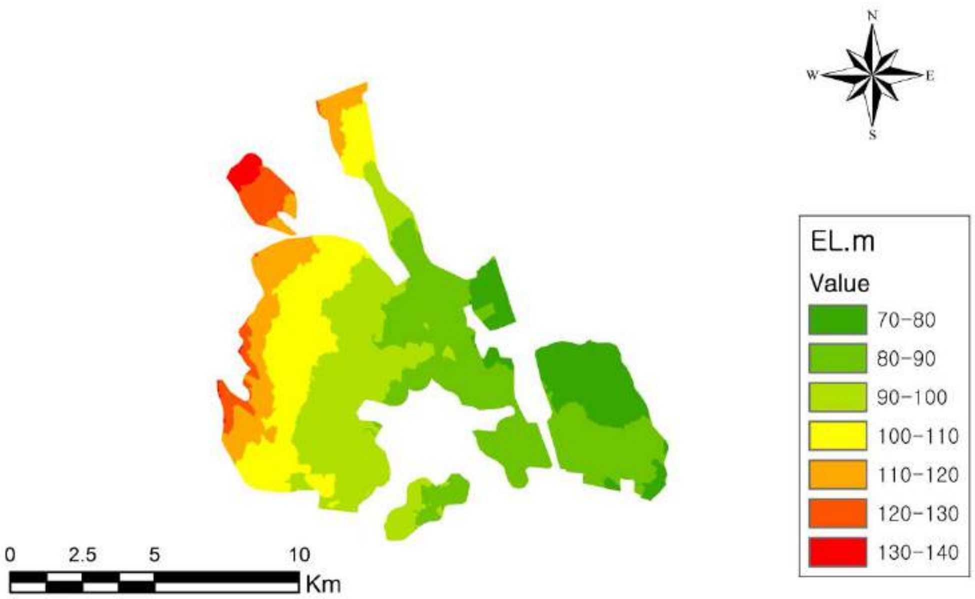
There are several small streams that traverse the feeder canal area, flowing from Majete Game Reserve to towards the Shire. In this respect, there will be need for construct structures for the canal to cross such streams. Use will be made of the 50-year flood in the design of crossing structures. Since the route of the feeder canal passes through big and small roads at several points, it will be necessary to thoroughly review what type of crossing structure to use.

2.1.6. Topography of Project Area

2.1.6.1. Zone I-1



[Figure 2.1-14] Topography of Zone I-1



Division		70~80	80~90	90~100	100~110	110~120	120~130	130~140	Total
Area	Km^2	7.38	35.08	24.82	18.42	8.71	1.76	0.13	96.31
	%	7.7	36.4	25.8	19.1	9.0	1.8	0.1	100.0

[Figure 2.1-12] Elevation Distribution of Zone I-1

Zone I-1 straddles over areas of T/A Kisisi, Katunga, and Maseya. Figure 2.1-13 shows the topography of Zone I-1 area while elevation distribution is shown in Figure 2.1-14. Majete Game Reserve to the northwest of the area has good forest floor with some high mountains. Mwanza River marks the southern boundary of this zone.

Zone I-1 has been divided into three areas as indicated in Table 2.1-4.

[Table 2.1-4] Area of 3 Sectors of Zone I-1

Division	I-1-a	I-1-b	I-1-c	I-1-d
Total Area : 9,631 ha	7,183 ha	382 ha	1,680 ha	386 ha
Net Area : 7,866 ha	6,107 ha	325 ha	1,106 ha	328 ha

In general, the topography of the zone creates a gradual slope from Majete towads the Shire to the southeast. The highest elevation is about 130m while the lowest is about 70m, with an average slope of 0.3%. Given that the average slope for furrow irrigation is 0.1%, it is envisaged that land grading works will be done without much difficulty. This kind of slope is also good for center pivot irrigation.

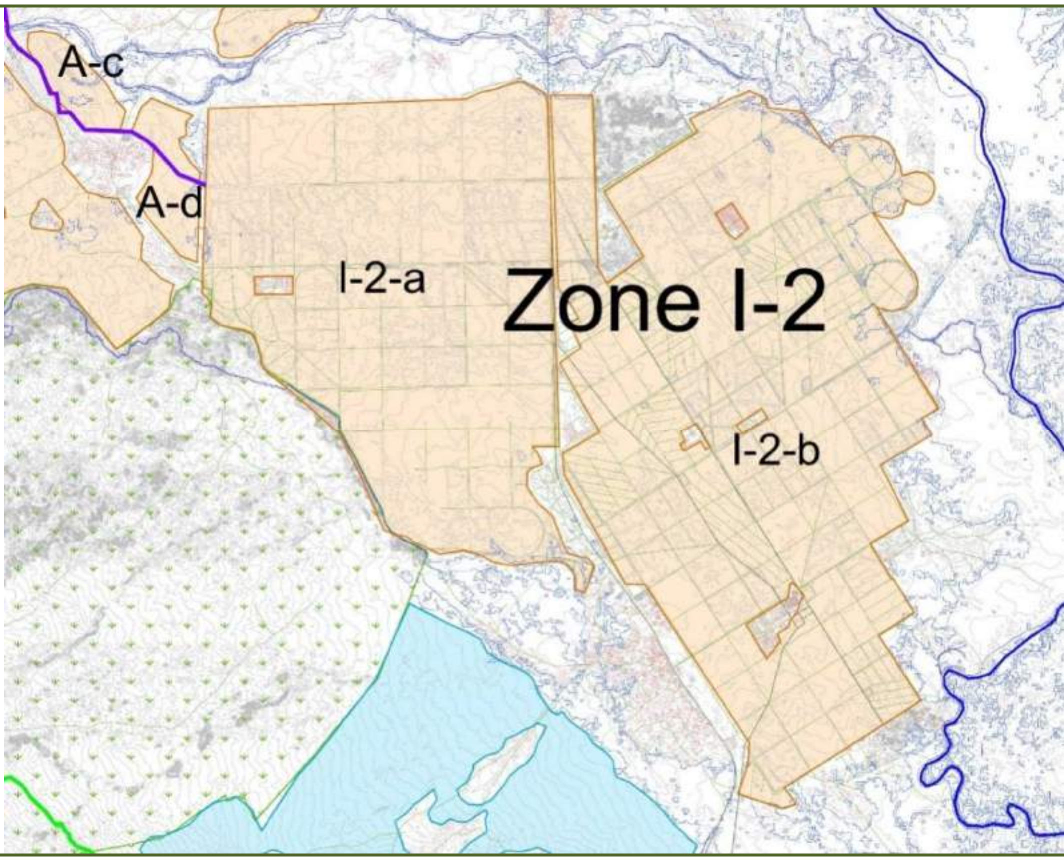
Sande Ranch, Phata Estate as well as Kasinthula Association are located in this zone. In future, Presscane, an ethanol manufacturer, will expand its sugarcane area after constructing an irrigation system that will cover 2,270ha. Currently, Kasinthula Association uses both furrow and center pivot irrigation systems while Phata Estate only uses center pivot irrigation. Table 2.1-5 shows the status of estates within the project area.

[Table 2.1-5] Existing Large Estates in Zone I-1

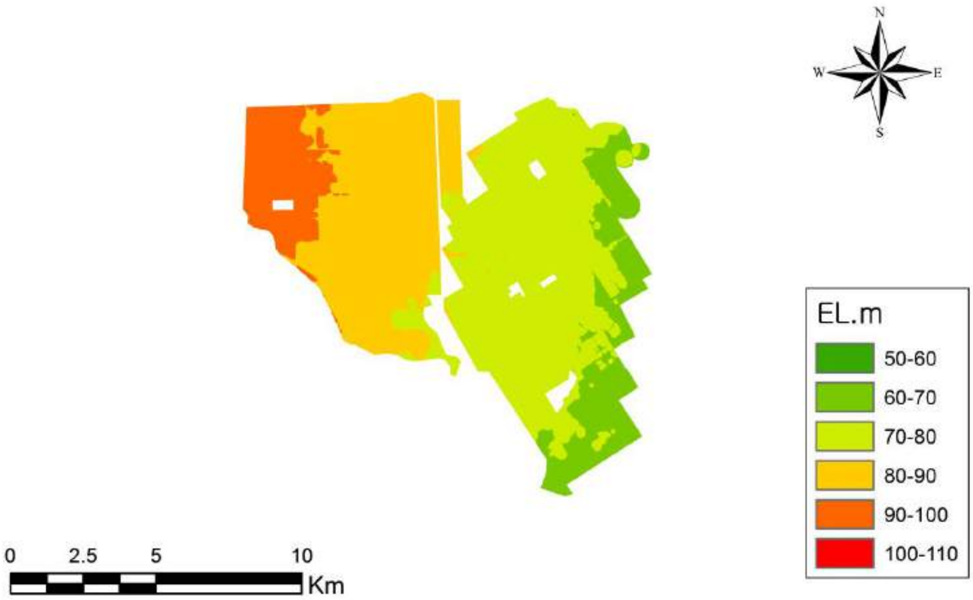
Total	Kasinthula	Sande Ranch	Phata	Presscane
2,179 ha	1,429 ha	454 ha	296 ha	(2,270 ha)

The Main Road (M8) connects the road network from the north to the south of Chikwawa Boma, the center of the district, and secondary road (S136) traverses the upper boundary of the district from east to west. Streams flowing through the zone disappear around the upper boundary as they approach the Shire because of the porous nature of the area and because of sedimentation problems that they experience, hence such streams only flow during the rainy season and mostly come down in spates after a rainfall event.

2.1.6.2. Zone I-2



[Figure 2.1-13] Topography of Zone I-2



Division		40~50	50~60	60~70	70~80	80~90	90~100	100~110	Total
Area	Km^2	0.00	0.00	15.31	49.43	35.79	11.98	0.00	112.50
	%	0.0	0.0	13.6	43.9	31.8	10.6	0.0	100.0

[Figure 2.1-14] Elevation Distribution of Zone I-2

Zone I-2 is located about 20km south of Chikwawa on Main Road (M8). Mwanza River marks the northern boundary of the region while Legnwe National Park marks the western boundary, and Shire River marks the eastern boundary. Zone I-2 is owned by Illovo Sugar Estate which produces raw sugarcane material for Illovo Sugar Company. The Estate occupies most of T/A Lundu area. Figure 2.1-15 shows the topography and Figure 2.1-16 exhibits elevation distribution of Zone I-2. Zone I-2 is divided into two regions by Main Road (M8) which passes through the center of this region. And each of the areas is described in Table 2.1-6

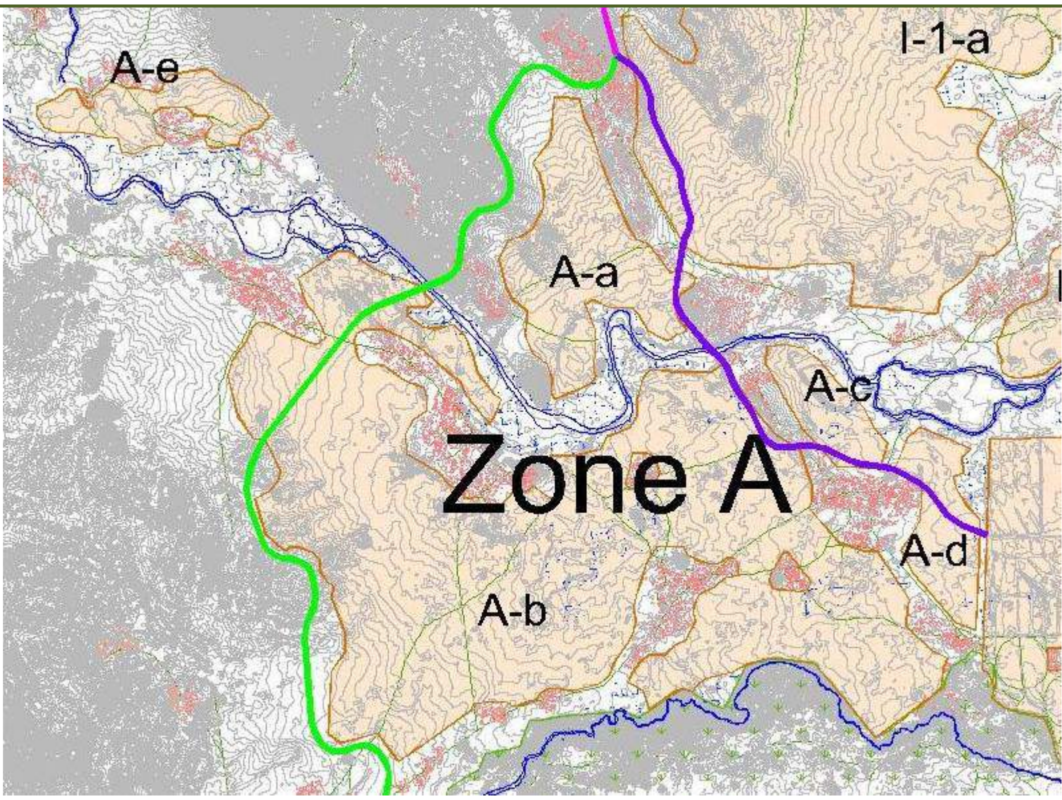
[Table 2.1-6] Areas of 2 Sectors of Zone I-2

Division	I-2-a	I-2-b	Remark
Total Area : 11,250 ha	4,684 ha	6,566 ha	
Net Area : 9,995 ha	4,179 ha	5,816 ha	

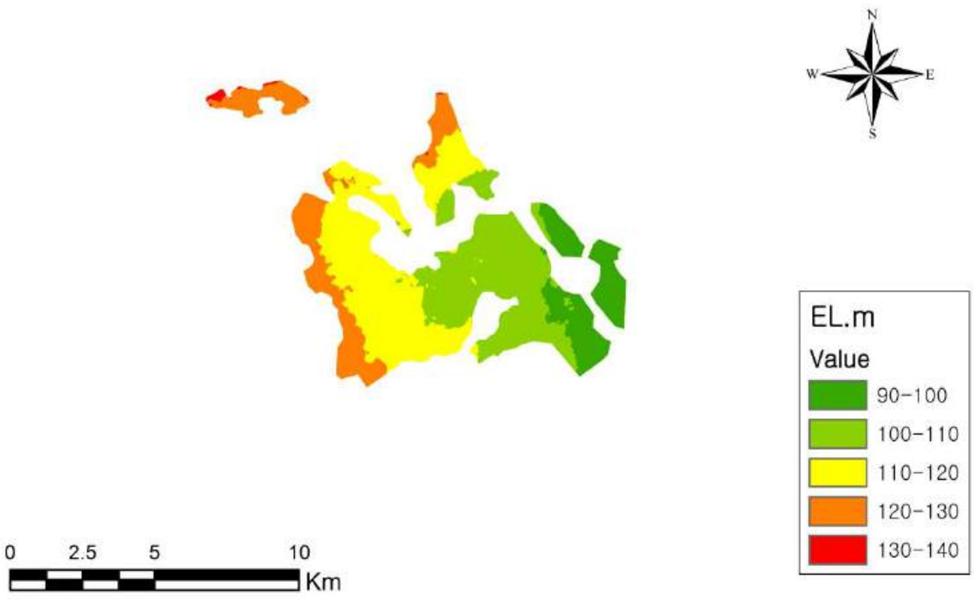
The farm land and irrigation systems in this Zone are well-maintained since its development as a large scale sugarcane plantation in 1956. Currently, irrigation water of 15m^3/s is pumped and supplied through 6-phased pump from Shire River via an aqueduct, and the water is applied to the field using center pivot, sprinkler, furrow and underground (subsurface) irrigation systems.

This area has a gradual slope from Lengwe National Park to Shire River to the east. The highest point is approximately 98m and the lowest is 66m. The average slope is around 0.23% and Sector I-2-b (0.17%) is flatter than Sector I-2-a (0.3%). Accordingly, Sector I-2-b is ideal for furrow irrigation. It is therefore not surprising that it applies both furrow and center pivot irrigation systems.

2.1.6.3. Zone A



[Figure 2.1-15] Topography of Zone A



Division		70~80	80~90	90~100	100~110	110~120	120~130	130~140	Total
Area	Km^2	0.00	0.00	5.89	16.51	20.55	8.91	0.13	51.99
	%	0.0	0.0	11.3	31.8	39.5	17.1	0.3	100.0

[Figure 2.1-16] Elevation Distribution of Zone A

Zone A is located within T/A Chapananga and Katunga. Figure 2.1-17 and Figure 2.1-18 show topography and elevation distribution of Zone A respectively. Mwanza river flows into the region from northwest towards the east. As a result, Mwanza river is divides the region into the north and south of the district. Zone A is divided in 4 areas and each of the areas is described in Table 2.1-7.

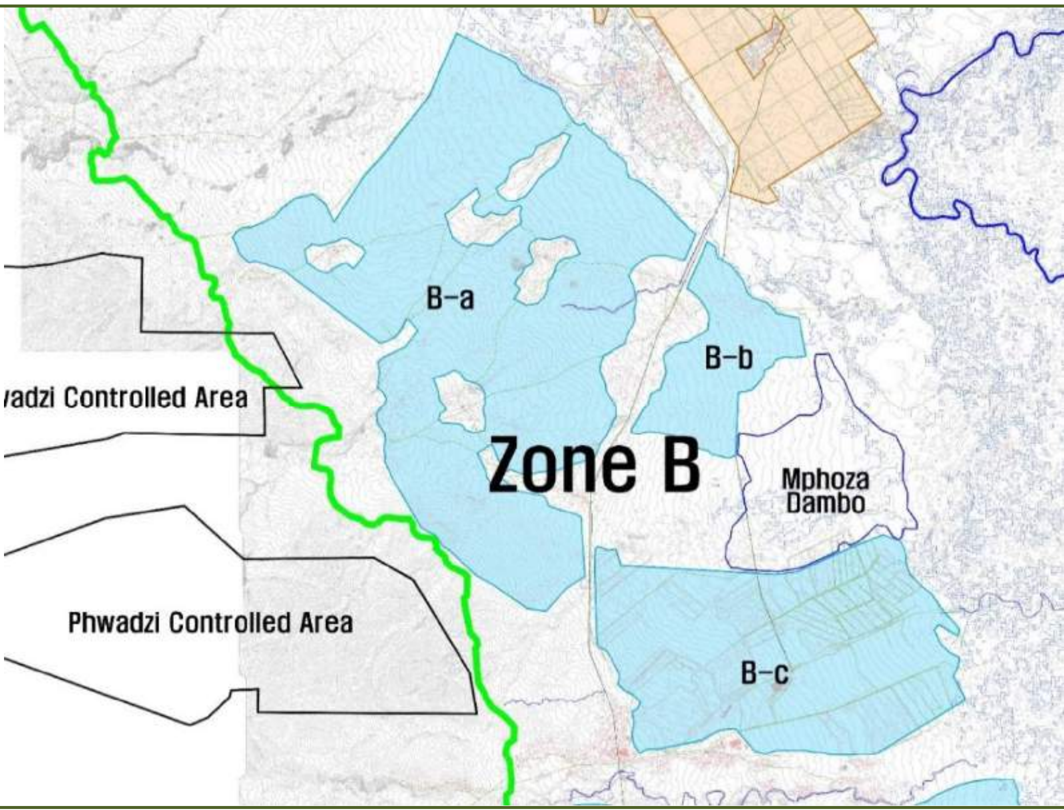
[Table 2.1-7] Areas of Each Sector of Zone A

Division	A-a	A-b	A-c	A-d	A-e
Total Area : 5,199 ha	614 ha	3,919 ha	179 ha	246 ha	241 ha
Net Area : 4,419 ha	522 ha	3,331 ha	152 ha	209 ha	205 ha

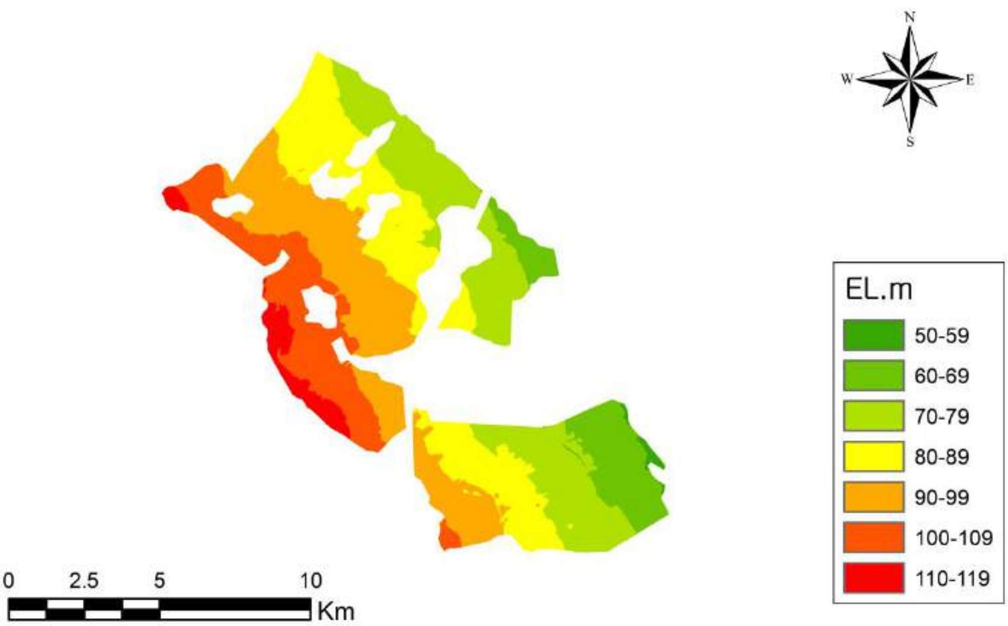
This has a gradual slope to Shire river (east) from Lengwe National Park. The elevation of the highest point is approximately 130m and the lowest is 100m. The 0.3% of average slope makes this region ideal for furrow irrigation.

The district road (Mbewe ~ Mandalande ~ Nchinika) links villages within the district while the tertiary road (T423) connects Mbewe ~ Ndakwera along Nkomhezi Wa Fodya river in the south. The center is Mbewe village, located on the Main Road (M8).

2.1.6.4. Zone B



[Figure 2.1-17] Topography of Zone B



Division		50~60	60~70	70~80	80~90	90~100	100~110	110~120	Total
Area	Km^2	0.47	9.78	24.24	23.37	23.47	14.37	3.56	99.25
	%	0.5	9.9	24.4	23.5	23.7	14.5	3.6	100.0

[Figure 2.1-18] Elevation Distribution of Zone B

Zone B is in T/A Ngabu. Figure 2.1-19 and Figure 2.1-20 show the topography and elevation distribution of Zone B respectively. This region is located between Shire river and the mountains that mark the border between Malawi and Mozambique to the west. The southern boundary is naturally marked by Namikalango river. The center of Zone B is Nchalo village in the north and Alumenda village to the south.

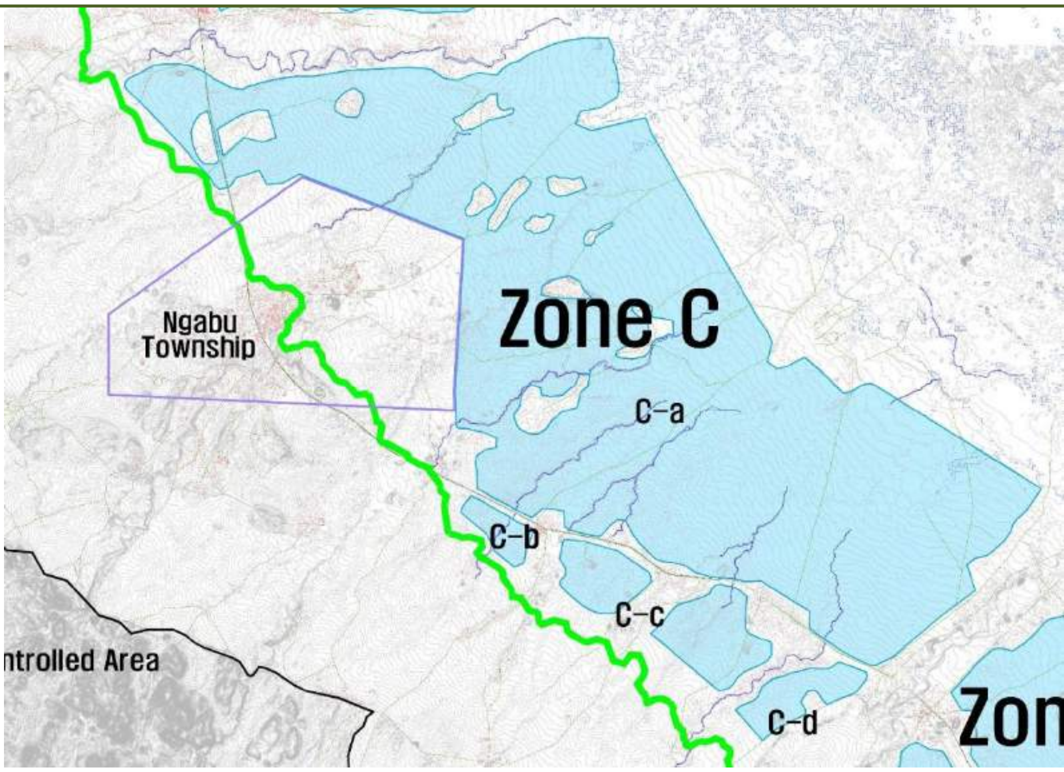
This area has a gradual slope from mountains to the west to Shire River towards the east. The highest elevation is El.105m while the lowest is at El.55m. The average slope of the region is steeper compared to other regions in the project area, and hence ideal for furrow irrigation. However, this region will require more land leveling than others, and therefore more costly to develop.

Zone B is divided into 3 areas and each of the areas is described in Table 2.1-8. Zone B-c is Alumeda Estate, a large sugarcane plantation of Illovo.

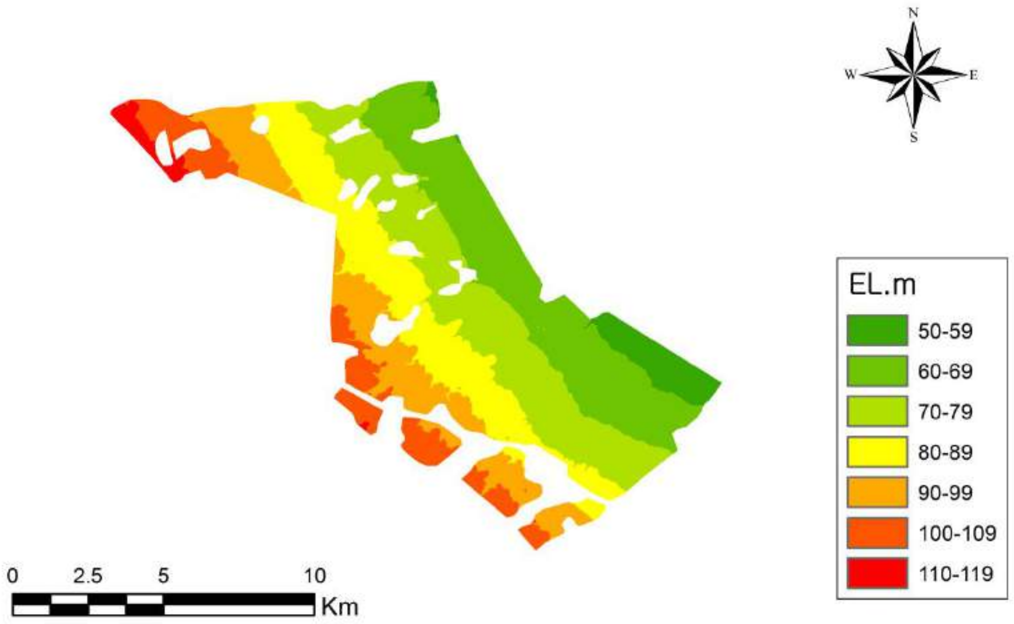
[Table 2.1-8] Area of 3 Sectors of Zone B

Division	B-a	B-b	B-c	Remark
Total Area : 9,925 ha	5,879 ha	858 ha	3,188 ha	
Net Area : 8,490 ha	4,997 ha	729 ha	2,764 ha	

2.1.6.5. Zone C



[Figure 2.1-19] Topography of Zone C



Division		50~60	60~70	70~80	80~90	90~100	100~110	110~120	Total
Area	Km^2	5.02	27.45	25.67	21.46	16.03	10.24	1.63	107.49
	%	4.7	25.5	23.9	20.0	14.9	9.5	1.5	100.0

[Figure 2.1-20] Elevation Distribution of Zone C

Zone C is in T/A Ngabu together with Zone B. Figure 2.1-21 shows the topography of Zone C while Figure 2.1-22 shows the elevation distribution. Like Zone B, this area lies between the mountains in to west along the Mozambique border and the Shire river to the east. Its elevation is lower than that of the Main Road (M8). Namikalango river marks the northern boundary while Mafume river marks the southen boundary of this zone. Mafune river marks the boundary between Chikwawa and Njanje district.

The center of Zone C is Ngabu village located in the middle of northern part of Chikwawa.. Masanduko village lies between Dolo village and Shire river. Tertiary road (T424) leads to the center of Ngabu in the north of the zone and District roads (D387, D388, D389, and D390) connect the zone to the rest of the district.

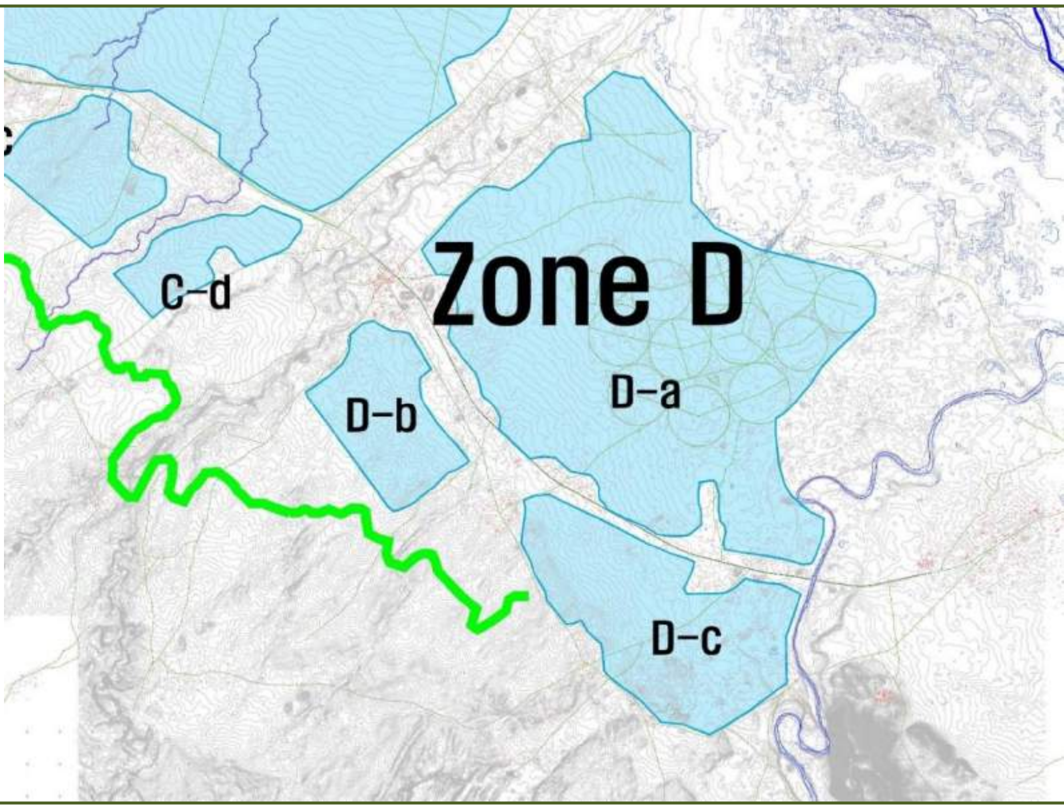
Zone C is located at the lowest altitude among all areas of the project. Elevation of more than 60% of area is lower than El.80m. Therefore, this area is expected to frequently experience severe flooding during the rainy season. In this regard, there is need to consider installing efficient drainage system during the implementation of the project in order to avert ponding.

The elevation of the highest point is about El.105m and the lowest is El.55m, similar to Zone B. The average slope is 0.5%, higher than that of Zone B. Thus, this region is also ideal for furrow irrigation with comparatively more land leveling cost expected to be incurred. Zone C is divided into 4 areas and each area is shown in Table 2.1-9.

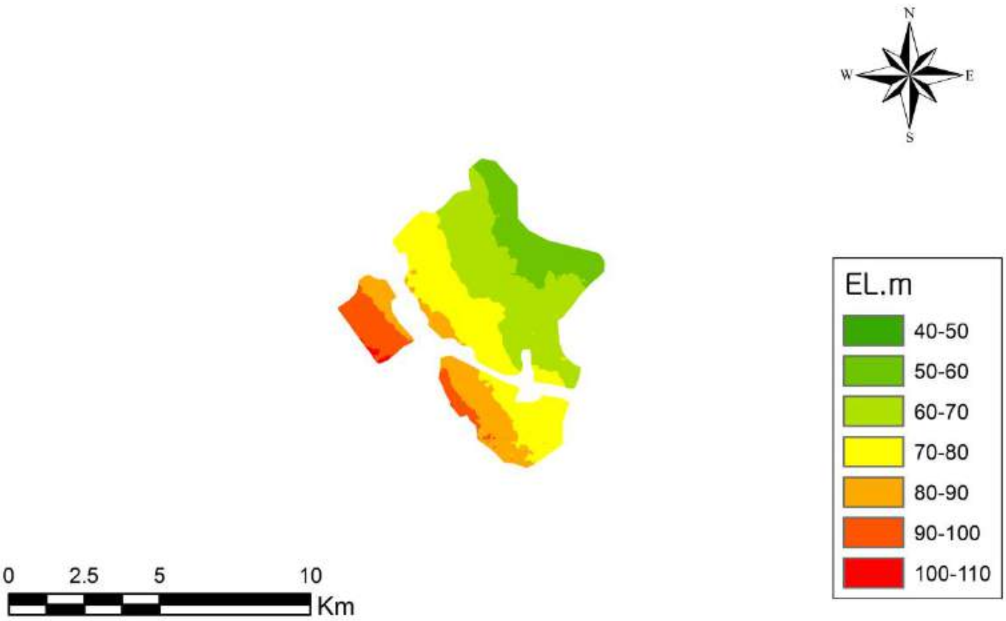
[Table 2.1-9] Area of 4 Sectors of Zone C

Division	C-a	C-b	C-c	C-d	Remark
Total Area : 10,749 ha	9,849 ha	113 ha	571 ha	216 ha	
Net Area : 9,136 ha	8,371 ha	96 ha	486 ha	183 ha	

2.1.6.6. Zone D



[Figure 2.1-24] Topography of Zone D



Division		40~50	50~60	60~70	70~80	80~90	90~100	100~110	Total
Area	Km^2	0.01	6.12	12.96	12.31	5.79	3.39	0.17	40.77
	%	0.0	15.0	31.8	30.2	14.2	8.3	0.4	100.0

[Figure 2.1-21] Elevation Distribution of Zone D

Zone D is in Nsanje district and is within T/A Tengani. The center of the zone is Bangula village to the south and Mbenje village to the east, towards Shire river. Chikwawa is separated from Nsanje by Mfume river, and Thangadzi river marks the southern boundary of the zone. Figure 2.1-23 and Figure 2.1-24 shows topography and elevation distribution of Zone D respectively.

During the rainy season, the water drains from high mountains to the west along the Mozambique border to Shire river in the east. In particular, three rivers of Shire, Ruo, and Thangadzi rivers meet at Bangula village, the end point of Zone D. Therefore, it must be fully considered when designing irrigation and drainage systems to avoid flooding.

The highest elevation is about El.95m and the lowest is about El.50m, and the width between the east and west boundaries is the narrowest of all the zones. It is the steepest area with an average slope of 0.6% of project site. Thus, this region is ideal for furrow irrigation with a high cost of land leveling expected.

Zone D is divided into 3 areas and each area is shown in Table 2.1-10. Zone D-a includes 819 ha of Kaombe Estate of Illovo. This has been developed as a large farming complex to grow sugarcane by pumping the water from Shire river.

[Table 2.1-10] Areas of 3 Sectors of Zone D

Division	D-a	D-b	D-c	Remark
Total Area : 4,077 ha	2,844 ha	388 ha	845 ha	
Net Area : 3,464 ha	2,417 ha	329 ha	718 ha	

2.1.7. Survey Results for the Preliminary Investigations

Accurate orthophoto maps in digital format (s=1:10,000) and high resolution digital terrain model were used in conducting preliminary investigations pertaining to SVIP. A detailed topographic map was then compiled for the project area. In Stage 1, a preliminary survey focused on the project area and the route of the canal. Tasks at this stage were as follows:

i) Drawing the water canal route on the map (s=1:10,000);

ii) Setting chain numbers at every 1,000 m on the canal route on the map;

iii) Extracting cross sections at important points within 30~50 m range on both sides of the canal;

iv) Recording main structures: Writing down information such as chain number, distance, coordinates for each structure, so that the detailed topographic survey (s=1:500) could be done during the preliminary design.

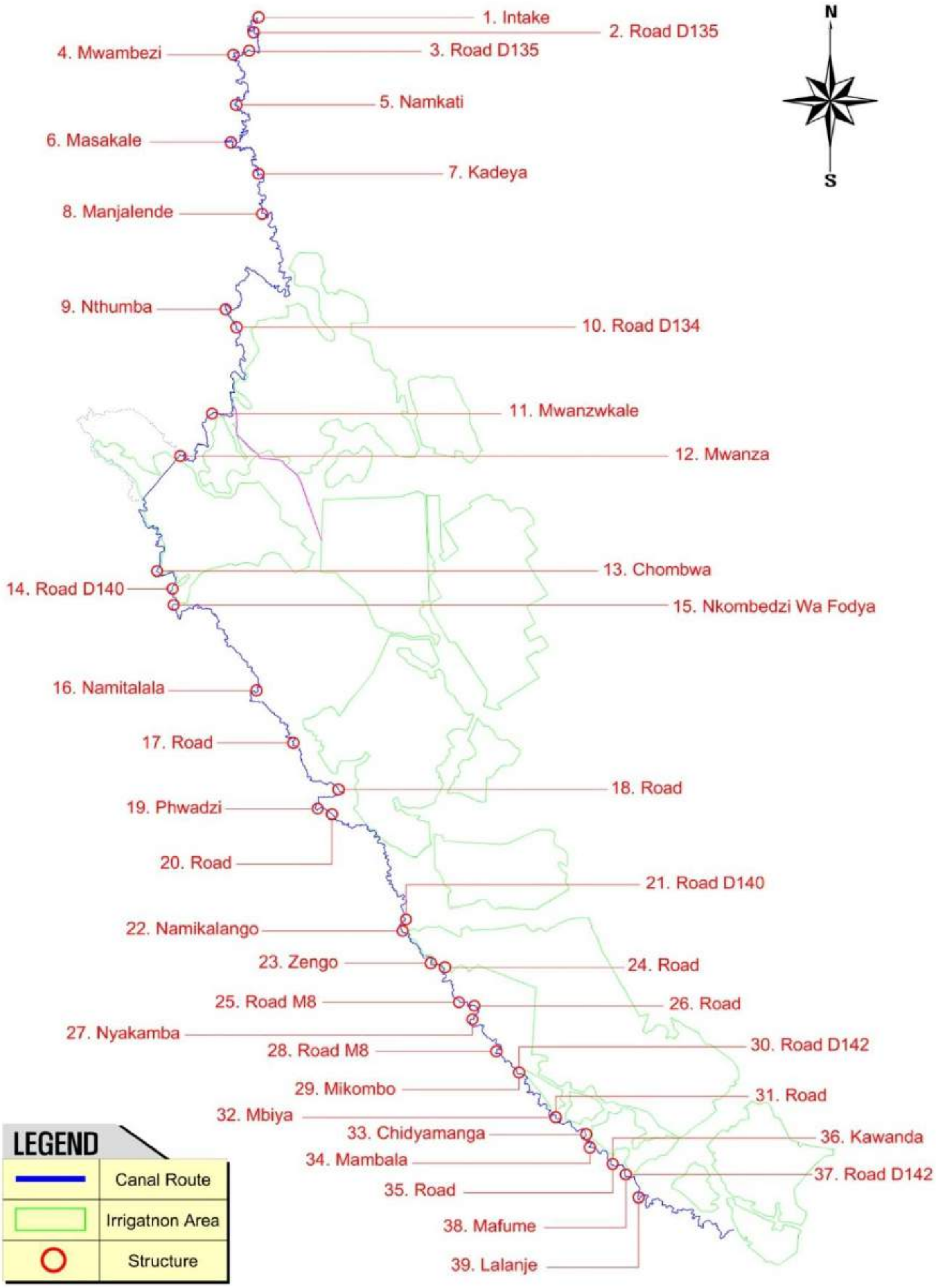
Table 2.1-11 and Figure 2.1-25 shows the list and location of the main structures.

[Table 2.1-11] List of the Main Structures

Division		Location	Type	Chain No.	Coordination (X,Y)
1	Feeder	Intake	Longitudinal Structure	0+000	867073.6 , 8242379.0
2	Feeder	Road D135	Longitudinal Structure	2+854	686850.7 , 8241561.7
3	Feeder	Road D135	Longitudinal Structure	5+706	686512.7 , 8240341.4
4	Feeder	Mwambezi	Cross sectional drain structure	7+451	685546.3 , 8240111.8
5	Feeder	Namkati	Cross sectional drain structure	15+207	685641.4 , 8236817.1

6	Feeder	Masakale	Cross sectional drain structure	23+092	684964.2 , 8234499.8
7	Feeder	Kadeya	Cross sectional drain structure	29+213	686951.3 , 8232689.9
8	Feeder	Manjalende	Cross sectional drain structure	34+350	687303.0 , 8229997.1
9	Feeder	Nthumba	Cross sectional drain structure	54+620	684998.1 , 8224103.1
10	Feeder	Road D134	Longitudinal Structure	56+447	685678.0 , 8222840.7
11	Bangula	Mwanzwakale	Cross sectional drain structure	65+053	684143.1 , 8217209.7
12	Bangula	Mwanza	Cross sectional drain structure	74+667	682103.8 , 8214518.7
13	Bangula	Chombwa	Cross sectional drain structure	86+446	680709.8 , 8207253.4
14	Bangula	Road D140	Longitudinal Structure	89+012	681690.1 , 8206077.3
15	Bangula	Nkombedzi Wa Fodya	Cross sectional drain structure	90+740	681726.3 , 8205085.1
16	Bangula	Namitalala	Cross sectional drain structure	103+707	687069.3 , 8199615.1
17	Bangula	Road	Longitudinal Structure	110+753	689313.0 , 8196286.2
18	Bangula	Road	Longitudinal Structure	116+505	692163.4 , 8193271.2
19	Bangula	Phwadzi	Cross sectional drain structure	119+898	690914.9 , 8192136.3
20	Bangula	Road	Longitudinal Structure	120+808	691654.4 , 8191843.8
21	Bangula	Road D140	Longitudinal Structure	133+459	696347.7 , 8185059.8
22	Bangula	Namikalango	Cross sectional drain structure	134+614	696143.0 , 8184260.3
23	Bangula	Zengo	Cross sectional drain structure	138+140	697967.6 , 8182255.2
24	Bangula	Road	Longitudinal Structure	139+149	698667.3 , 8182027.1
25	Bangula	Road M8	Longitudinal Structure	142+906	699750.9 , 8179830.8
26	Bangula	Road	Longitudinal Structure	144+407	700722.5 , 8179569.4
27	Bangula	Nyakamba	Cross sectional drain structure	145+730	700586.9 , 8178716.1
28	Bangula	Road M8	Longitudinal Structure	150+142	702102.3 , 8716710.0
29	Bangula	Mikombo	Cross sectional drain structure	152+613	703349.3 , 8175444.7
30	Bangula	Road D142	Longitudinal Structure	153+101	703685.5 , 8175224.0
31	Bangula	Road	Longitudinal Structure	158+997	705776.0 , 8172632.0
32	Bangula	Mbiya	Cross sectional drain structure	159+286	705896.4 , 8172384.3
33	Bangula	Chidyamanga	Cross sectional drain structure	162+716	707588.1 , 8171179.8
34	Bangula	Mambala	Cross sectional drain structure	163+740	707911.1 , 8170606.4
35	Bangula	Road	Longitudinal Structure	166+025	709263.1 , 8169731.2
36	Bangula	Kawanda	Cross sectional drain structure	166+613	709536.0 , 8169380.9
37	Bangula	Road D142	Longitudinal Structure	167+852	710138.7 , 8168897.4
38	Bangula	Mafume	Cross sectional drain structure	168+034	710172.9 , 8168720.7
39	Bangula	Lalanje	Cross sectional drain structure	170+365	710969.1 , 8167389.0

* Chainage and coordinates of structures could be changed during the preliminary design.



[Figure 2.1-22] Location of Main Structures

2.2. Soil Survey

TOR Requirements

- Carry out high intensity (semi-detailed) soil surveys for the above mentioned area to fill any gaps from existing soil surveys from previous work. These detailed soil surveys, including sampling, observations and final soil survey maps, should be in conformity with FAO/UNESCO guidelines for feasibility-level soil surveys.
- Setup a suitable standard land classification system for assessment of irrigability and drainability within the proposed irrigation development areas, and use topographic and soil survey results and other relevant information to delineate and evaluate land units in terms of suitability for irrigated agriculture development.
- Collect and analyze soil samples required for the determination of standard physical and chemical properties of the soils required for evaluation of soil suitability for the proposed crops. The Consultant should take appropriate measures to verify and ensure quality and reliability of laboratory testing and results.
- Critically evaluate and analyze findings of the soil surveys and land characteristics of the proposed project area and identify and delineate major land systems and categories.

(Note: Soil Survey Report is submitted with this main report. See the independent report for the details of soil survey.)

2.2.1. Introduction

In the Technical Feasibility Study for SVIP, the Soil Survey was intended to achieve four main objectives, namely:

a) To collect detailed soil data to supplement existing datasets;
b) To develop a standard land classification system for irrigability and drainability of soils in the project area;
c) To collect and analyze soil samples in order to determine soil properties; and

To prepare soil and land suitability maps for cropping options

In view of the four objectives highlighted above, the Soil Survey involved the implementation of the following activities: desk studies and preliminary works, field investigations, soil analysis, and land evaluation for crop production.

2.2.2. Soil Classification

2.2.2.1. Methodology

Harmonized World Soil Database (HWSD) and Soil Atlas of Africa were downloaded from the FAO homepage (http://www.fao.org). These provided information on soil types and properties. Additionally, SoilGrids 1km and digital soil database of ISRIC complemented other sources of soil data.

The Soil Survey team also acquired the FAO digital map and the CODA book of drawings on soil classification and land suitability of Phase 1 area from the Government of Malawi covering the entire project area. Illovo Group also provided soil data on soil survey points, classification and recent soil properties of Illovo Sugar Estate areas.

Before the commencement of field investigations, an awareness-raising workshop was held in the project area, attended by several stakeholders: farmers, chiefs, council members, and specialists with a view to explaining to them the details of the project, and helping them to understand the purpose of the soil survey.

By examining 1:10,000-scaled aerial photo map taken in 2013 on ArcGIS, 380 standard soil survey points, i.e. reference points were marked in the project zones, except for Illovo Sugar Estate. Soils were observed at 1-3 points in a cell. In total, soil survey points numbered 1,101 (380 pit description + 721 auger). It was noted that soil surveys were already done at 1,226 points by Illovo Sugar Estate. These have adequate details and hence were used in the current study.

The survey area comprised six zones which were then divided to 17 subzones stretching on both sides of M1 road from the uppermost zone of Ⅰ-1-a to the lowermost of D-c. The total area covered by the survey was about 58,895 ha including commercial farms of Kasinthula, Phata, and Illovo Sugar Estates.

Two main soil profile description types were used, namely: pit and augering as described by FAO Guidelines. As of 6th January 2016, routine profile description had been done at 346 pits and 614 augering sites in the project area. In part of Zone C, a semi-profile description was adopted instead of the routine approach which involves digging a 40 cm× 50 cm small pit. And this was done at 34 sites and 107 auger points.

A total of 907 soil samples was collected from topsoil or subsoil horizons. After conducting the carbonate reaction test in the laboratory of KARS, all samples from soil pits were sent to Bvumbwe Agricultural Research Station (BARS) located 13 km south east of Blantyre for further analysis for parameters such as soil texture, soil reaction (pH), organic carbon (OC), available phosphorus (P2O5), electrical conductivity (EC), cation exchange capacity (CEC), base saturation (BS), sodium absorption ratio (SAR), exchangeable sodium percentage (ESP), and bulk density (BD). The analyses were based on FAO analytical procedures for examination of physical-chemical characteristics and the final soil classification (FAO, 2014).

World reference base for soil resources (WRB) 2014 was used to identify soil types at the survey points. Field classification was carried out by professionals based on profile/landscape photos, soil description and information sheets. At selected pits, a comparative survey was done by the Korean soil survey team with a view to comparing and harmonizing the classification. Allocation of a WRB to a soil type at each point, based on diagnostic horizons, properties, and materials, was confirmed from field investigation and soil analysis as well.

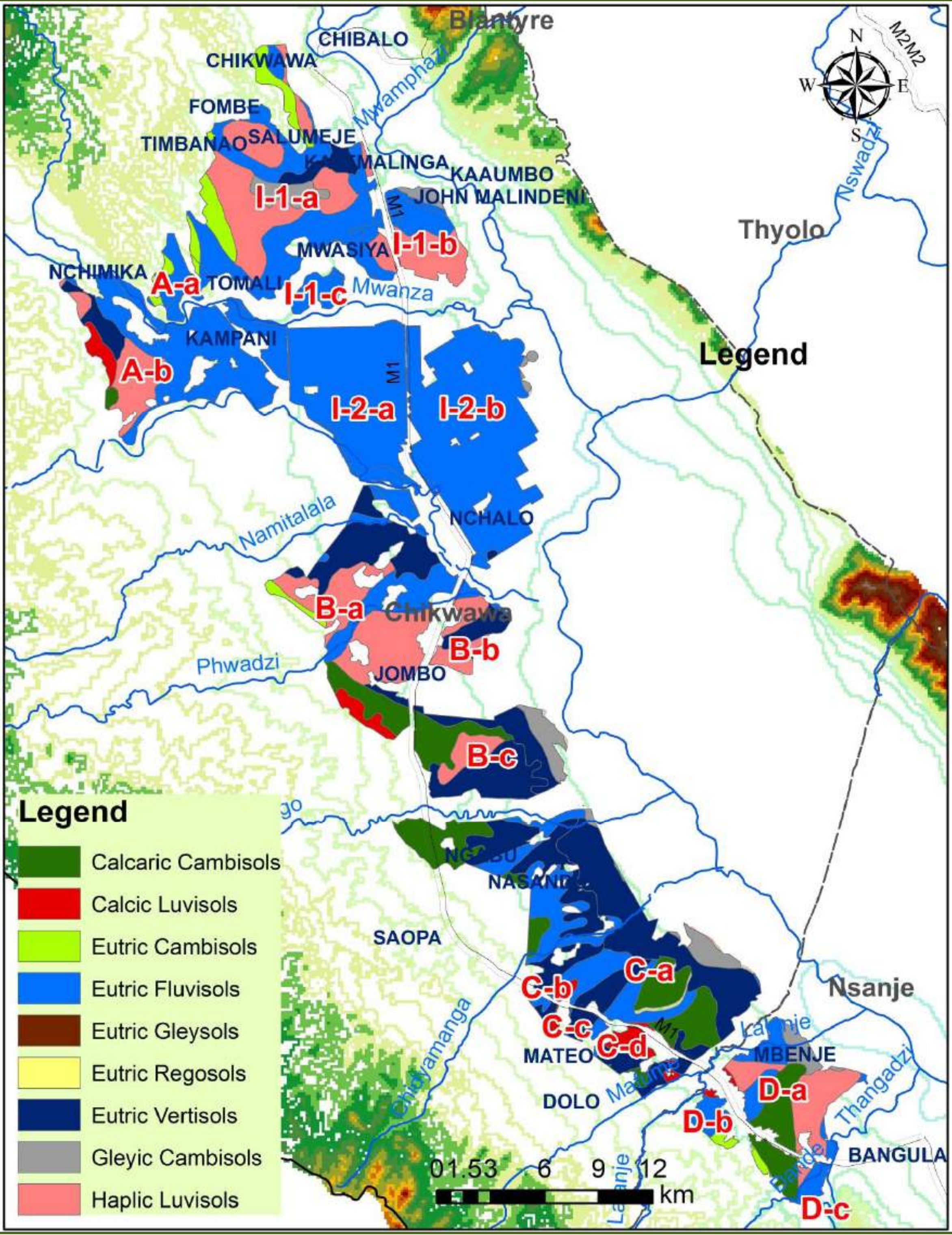
2.2.2.2. Previous Studies

From the FAO digital soil map of the Lower Shire Valley Area, nine soil types (RSGs + the second-level prefixes) were extracted from an area of approximately 55,000 ha by masking it with the current soil survey zones. Almost all soil types are found in areas with flat to gentle slopes (Table 2.2-1 and Figure 2.2-1).

[Table 2.2-1] Soil Types of Survey Zones in FAO Digital Soil Map

Soil Type	Area (ha)	Description	Soil Texture	pH	EC (dS/m)
Calcaric Cambisols	4,970.7 (9.1 %)	Very deep or deep, moderately well or well drained, brown, medium textured partly calcareous soils of medium or high chemical fertility	SL/SL SCL/SCL	7.0	0-2
Calcic Luvisols	955.4 (1.7 %)	Moderately deep, well drained, dark brown, medium textured gravelly calcareous soils of moderate chemical fertility	L/L	7.0	0-2
Eutric Cambisols	1,305.0 (2.4 %)	Moderately deep, well drained, yellowish brown or brown, coarse and/or medium texture, frequently skeletal subsoil of moderate chemical fertility	LS,SL /SCL	5.5-6.0	0-2
Eutric Fluvisols	25,544.8 (46.5 %)	Very deep, poorly to well drained, dark brown, variable textured soils of moderate or high chemical fertility	Variable	5.0-6.0	0-2
Eutric Gleysols	0.2	Very deep, poorly to imperfectly drained, dark grey, medium to fine textured soils of moderate chemical fertility	SCL/SCL	5.5	0-2
Eutric Regosols	18.4	Shallow, moderately well drained, dark brown, medium textured gravelly soil of moderate chemical fertility	L/L	6.0	0-2
Eutric Vertisol	10,797.0 (19.7 %)	Very deep, imperfectly to poorly drained, dark grey, fine textured soils of moderate chemical fertility	SC/SC	7.0	0-2
Gleyic Cambisols	1,803.5 (3.3 %)	Very deep, imperfectly to poorly drained, dark brown to grey, medium to fine textured soils	SCL/SCL	7.0	2-4
Haplic Luvisols	9,450.4 (17.2 %)	Very deep, well drained, brown, medium textured soils of medium chemical fertility	SL/SCL	5.5	0-2
n/a	42.5				
Sum	54,887.9				

Description is summarized about soil characteristics in the attribute table of FAO digital map.
LS: loamy sand, SL: sandy loam, SCL: sandy clay loam, SC: sandy clay, L: loam



[Figure 2.2-1] FAO Digital Soil Map

Nine soil map sheets pertaining to I-1-a, I-1-b, I-1-c zones (9,146 ha) were digitized from the CODA Books of Drawing done in 2008, where soils are classified into 12 soil units according to FAO guidelines and USDA Soil Taxonomy. Five of them occupy 78.5 % of three zones of the project area, and these soil units are: Ft, St, Et, Ef, and At. General characteristics of soil units are presented in Table 2.2-2.

[Table 2.2-2] Soil Units in the 2008 CODA Book of Drawing

Symbols	Order	Suborder	Great Group	Subgroup	Area (ha)
Ft	Entisols	Fluvents	Ustifluvents	Typic	961
St	Entisols	Psamments	Ustipsamments	Typic	1,328
Et	Inceptisols	Ochrepts	Ustochrepts	Typic	1,069
Ef	Inceptisols	Ochrepts	Ustochrepts	Fluventic	1,468
Ev	Inceptisols	Ochrepts	Ustochrepts	Vertic	445
At	Alfisols	Ustalfs	Haplustalfs	Typic	2,355
Av	Alfisols	Ustalfs	Haplustalfs	Vertic	430
Nt	Alfisols	Ustalfs	Natrustalfs	Typic	52
Ns	Alfisols	Ustalfs	Natrustalfs	Salorthidic	575
Ct	Vertisols	Usterts	Chromusterts	Typic	90
Pt	Vertisols	Usterts	Pellusterts	Typic	373
					9,146

Illovo Sugar Estate spreads over six zones, namely: I-1-a, I-1-b, I-2-a, I-2-b, B-c, and D-a and comprises Nchalo, Alumenda, Sande Ranch, Phata, Kasinthula, Kaombe-mcp, and Kaombe Trust. In 2015 sugarcane was cultivated in a total of 15,757 ha in these seven estates.

The following six soil types are commonly found in Illovo Sugar Estate: Calcaric Cambisols, Eutric Cambisols, Eutric Fluvisols, Eutric Vertisols, Gleyic Cambisols, and Haplic Luvisols. Eutric Fluvisols are the dominant type, and they are generally very deep soils with poorly to moderately or well drained, and variable texture. They occur on all I-2-a and I-2-b zones. At the lower eastern edge of Nchalo and Kaombe, Gleyic Cambisols have EC values ranging from 2-4 dS/m at which sugarcane is vulnerable to damage if adequate water is not applied to the crop. Additionally, some of Eutric Fluvisols soil occur near river basins and sometimes get flooded and are poorly drained.

However, the soil survey has shown that Illovo Sugar Estate has 42 soil types according to WRB Soil Classification. Some of the soil types are named by combining two RSGs. Vertisols occur in most of the fields (23.1%), followed by Luvisols, Calcisols, Nitisols, Arenosols, and several combined RSGs.

As noted from the FAO Digital Map, Vertisols are one of the most dominant soil types. However, most of the fields are classified as having Cambisols and Arenosols, Calcisols, Gleysols, Nitisoils and these soils are more common than Fluvisols. Generally, soils in Ilovo Sugar Estate contain significant sodium and salts accumulated naturally or by irrigation. These minerals may cause adverse effects on sugarcane growth in the future. Ten out of 42 soils (Calcisols/Vertisols, Cambisols /Albeluvisols, Cambisols/Ferralsols, Cambisols/Fluvisols, Gleysols/Plinthosols, Nitisols /Gleysols, Plinthosols, Vertisols, Vertisols/Cambisols, and Vertisols/Gleysols) have a higher level of exchangeable sodium percentage than the mean value (6.89%). It has been noted that Gleysols/Plinthosols are sodic (ESP > 10%) and Nitisols/Vertisols are saline (ECe >2 dS/m) while Vertisols/Cambisols are saline sodic (ESP > 10%, ECe >2 dS/m).

[Table 2.2-3] Soil Types in Illovo Estates from FAO Digital Soil Map

Soil Type	Area (ha)	Description	Soil Texture	pH	EC (dS/m)
CMca	1,765 (6.3 %)	Very deep or deep, moderately well or well drained, brown, medium textured partly calcareous soils of medium or high chemical fertility. Slightly and moderately eroded.	SL/SL SCL/SCL	6.5-7.0	0-2
FLeu	19,928 (70.9 %)	Very deep, poorly to well drained, dark brown, variable textured soils of moderate or high chemical fertility. Slightly eroded. Exceptionally or frequently flooded.	LS,SL/LS,SL Variable	5.0-6.0	0-2
VReu	3,168 (11.3 %)	Very deep, imperfectly to poorly drained, dark grey, fine textured soil of moderate chemical fertility. Moderately or severely ponded.	SC/SC	7.0	0-2
CMgl	477 (1.7 %)	Very deep, imperfectly to poorly drained, dark brown to grey, medium to fine textured. Exceptionally flooded and severely eroded.	SCL/SCL	7.0	2-4
LVha	2,774 (9.9 %)	Very deep, well drained, brown, medium textured soils of medium chemical fertility. Slightly eroded.	SL/SCL	5.5	0-2
Sum	28,112 (100 %)				

1) Description is summarized about soil characteristics in the attribute table of FAO digital map.
2) LS: loamy sand, SL: sandy loam, SCL: sandy clay loam, SC: sandy clay, L: loam
3) FLeu: Eutric Fluvisols, LVha: Haplic Luvisols, VReu: Eutric Vertisols, CMca: Calcaric Cambisols, CMgl: Gleyic Cambisols

2.2.2.3. Updated Classification

From previous studies and from field observations, the updated soil classification presented in Table 2.2-4 was developed for SVIP. This classification is based on soil texture, rock fragments, drainage, flooding and ponding, carbonate content, erosion, crack development, etc.

Above all, based on applicable qualifiers and RSGs, analysis and synthesis of soil field records is to be done to classify soil at each point followed by soil mapping. In general, procedures to make a two dimensional soil map are composed of terrain analysis out of topographic maps, scattering survey points into cells, making polygons by soil type in each cell overlapping terrains as well as the previous soil maps, and the last grouping polygons across cells.

[Table 2.2-4] Applicable RSGs and Qualifiers

RSG	Considerations	Principal Qualifiers	Supplemented Qualifiers
Cambisols	Drainage Erosion Ponding Rock fragments Soil texture $CaCO_3$	Leptic Gleyic Stagnic Fluvic Vertic Skeletic Salic Sodic Calcaric Dysric/Eutric	Arenic/Clayic/Loamic Colluvic Takyric
Fluvisols	Drainage Soil texture Rock fragments Flooding, ponding	Gleyic Stagnic Skeletic Calcaric Dystric/Eutric	Arenic/Clayic/Loamic Humic Ochric
Gleysols	Drainage Flooding, ponding Salinity	Oxygleyic/Reductigleyic Calcic Fluvic Calcaric Dystric/Euric	Arenic/Clayic/Loamic Salic Sodic Takyric Vertic
Regosols	Rock fragments	Skeletic	Loamic
Vertisols	Drainage Crack development $CaCO_3$ Erosion Ponding Salinity	Salic Sodic Petrocalcic/Calcic Skeletic Haplic	Calcaric Gleyic Stagnic Gilgaic
Arenosols	Drainage Flooding, ponding Salinity	Gleyic Sodic Fluvic Dystric/Eutric	Ochric Stagnic
Luvisols	Rock fragments Drainage $CaCO_3$ Erosion Crack development	Leptic Stagnic Vertic Ferric Calcic Skeletic Endocalcic Haplic	Clayic/Loamic Colluvic Fluvic

2.2.3. Land Suitability

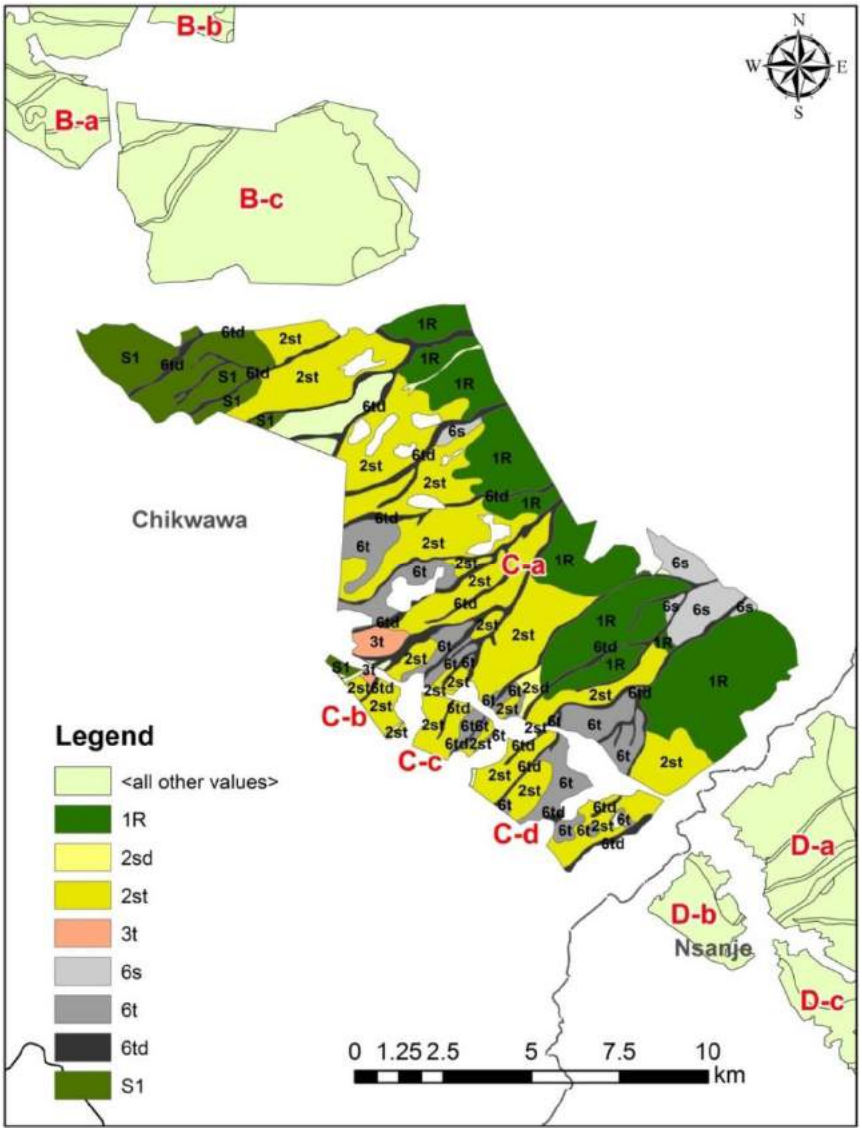
2.2.3.1. Case Studies

Land suitability in the 1969 FAO Irrigation project maps was classified into nine classes, namely: 1, 2, 3, 1R, 2R for arable land and S1, S2, S3 for limited arable land, and 6 for non-arable land (Table 2.2-5). Mapping symbols for parcels on the land suitability map were coined in combination of land class, soil deficiency, drainage deficiency, and land development.

In Zone C digitized from the old 169 FAO project maps, for instance, arable or limited arable land reached 9,295 ha that is approximately 75% of the total area.

[Table 2.2-5] Land Suitability Classes of Zone C in 1969 FAO Project Map

Land Class	2sd	2st	3t	S1	1R	6s	6t	6td	Sum
Ha (%)	53 (0.4%)	4,872 (39.5%)	113 (0.9%)	966 (7.8%)	3,344 (27.1%)	411 (3.3%)	1,349 (10.9%)	1,240 (10.0%)	12,348 (100%)



[Figure 2.2-2] Land Suitability Map of Zone C from 1969 FAO Project Maps

Land suitability for maize, bulrush millet, groundnuts and cotton under improved traditional management is shown on four maps digitized from PDF-format map sheets at scale 1:250,000 published in 1991 as part of land resources evaluation report by J. H. Venema. Four suitability classes are used: Highly suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), and Not Suitable (N). The descriptions of land suitability classes are summarized in Table 2.2-6. The spatial distribution of land suitability classes depends on crop type so much so that N class is only 20.6% for cotton but about 90% for maize.

[Table 2.2-6] Land Suitability Class by Crop

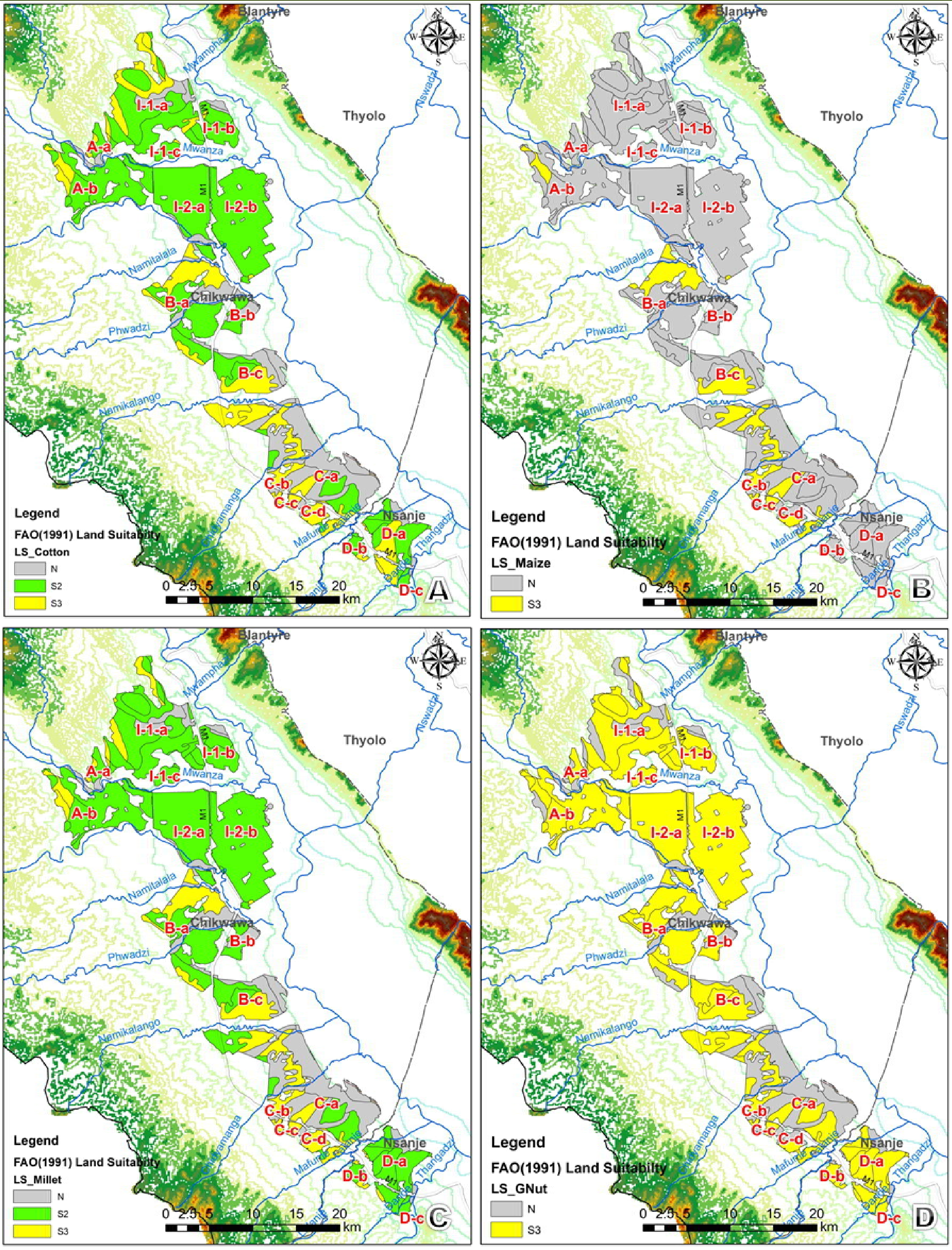
Crop	Land Suitability Class (Area (ha, %))				
	S1	S2	S3	N	Sum
Cotton	-	31,671 (57.7%)	11,902 (21.7%)	11,310 (20.6%)	54,883 (100%)
Maize	-	-	6,366 (11.6%)	48,517 (88.4%)	54,883 (100%)
Bulrush millet	-	34,930 (63.6%)	8,643 (15.7%)	11,310 (20.6%)	54,883 (100%)
Groundnuts	-	-	41,593 (75.8%)	13,290 (24.2%)	54,883 (100%)

Ilovo Estates introduce soil potential to evaluate land suitability for commercial sugarcane farming. It has 8 classes of 1, 2A, 3A, 3B, 4A, 4B and 5 in the downgrading order based on soil physical-chemical properties by soil type. Especially, ESP (Exchangeable Sodium Percentage) is the main reason for many soil types to be assessed Class 5.

[Table 2.2-7] Soil Potential Classes of Illovo Estates

Soil Potential Class	1	2A	2B	3A	3B	4A	4B	5
Downgrading reasons	none	pH Topsoil clay %	pH EC	pH Topsoil clay% ESP Structure ERD[1] TAM	pH Topsoil clay% ESP Structure ERD TAM Permeability	pH Structure ESP	pH Topsoil clay% ESP Structure ERD TAM Permeability	pH EC ESP Structure ERD TAM

[1] Effective rooting depth



[Figure 2.2-3] Land Suitability Maps (FAO 1991). A: Cotton, B: Maize, C: Millet, D: Groundnut

2.2.3.2. Land Suitability Criteria

Land evaluation entails the analysis of data about the land, namely its soils, climate, vegetation, etc., with a view to improving the use of that parcel of land. Generally, land evaluation involves the assessment of land performance when the land is used for specific purposes, e.g., irrigated agriculture in the current feasibility study.

AEZ developed by FAO is a quantitative assessment of plant adaptability to a certain region. The growing period forms the basis for a quantitative climatic classification for each chosen crop, assuming rain-fed agriculture. An agro-climatic adaptability classification matches each crop with climate and soil resources. The soil and landscape requirements comprise both internal soil properties and external site qualities, not contemplating land modifications. A crop production cost is provided by soil and climatic zone, and is aimed at judging whether yields exceed costs. The ultimate output of an AEZ is a map of suitability classes S1, S2, S3, N1 and N2, based on predicted relative biomass production, for high and low inputs.

In the present study, land suitability could be evaluated for major crops in terms of irrigated improved farming primarily based on soil characteristics such as soil texture and rock fragments, fertility (OC, pH, salinity, etc.), effective rooting depth, drainage class, erosion, flooding and ponding potential obtained from the above-mentioned soil survey. In addition, a more specific Canadian land classification manual for irrigation was also compared with other methods to draw a best land suitability criterion for the present project.

2.2.3.3. Land Suitability by Crop

In order to develop a composite map of land suitability by crop type, maps such as the FAO project map, CODA map, and Ilovo Farm Suitability maps will be digitized and used in the development of a land suitability map for SVIP. In the meantime, assessment of agricultural conditions such as climate change, agricultural practices and technology, and demands may shed some light on land suitability by crop type.

2.3. Geotechnical Investigation

TOR Requirements

1) Stage 1

- Carry out geotechnical investigations along the feeder canal in order to quantify the seepage (stage 1) and provide the required information for the preliminary design (stage 2)

2) Stage 2

- Carry out geotechnical investigations required to undertake the preliminary design.
- Identify, investigate and record the construction material types in quantities, and quality, as well

2.3.1. Objectives of Geotechnical investigations

(Note: the section "2.3.1. Geotechnical Investigation" is currently on-going, and the results shall be included in the Stage II report.)

Objectives

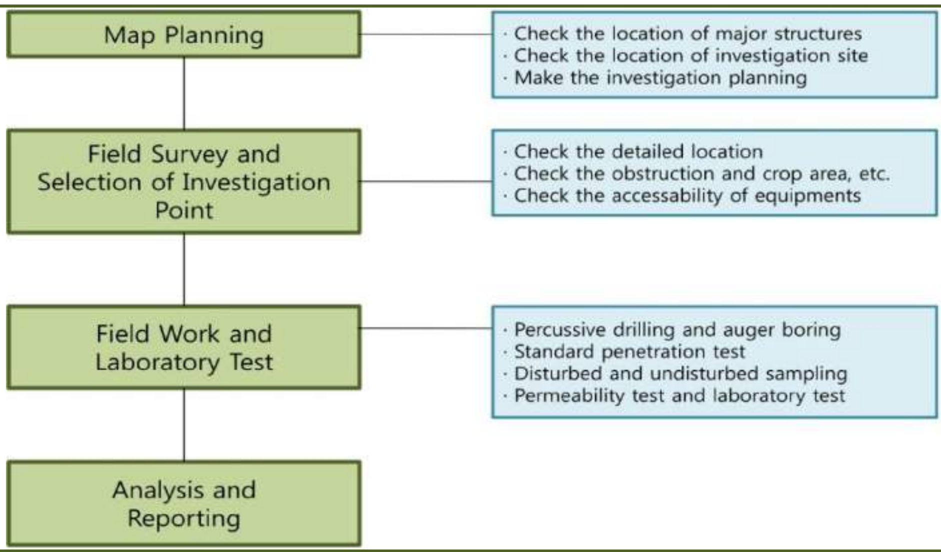
The purpose of geotechnical investigation was to obtain the information, i.e., the structure foundation, earthwork and seepage analysis of canal for the preliminary design through the verification of the geotechnical status in SVIP canal route.

According to the ToR, the geotechnical investigation was supposed to be undertaken during Stage 2. Therefore, the results of geotechnical investigation would be included in the Stage 2 report.

Work Scope

The geotechnical investigation focused on the Feeder canal, Bangula canal and Supuni canal, with a total length of 132.5km.

Procedure of Geotechnical Investigation



[Figure 2.3-1] Flow Chart of Geotechnical Investigation

Geotechnical Investigation and Analysis

The geotechnical investigation comprised field surveys, laboratory tests and material surveys. As stipulated in the ToR, the Consultant selected 28 points along the canal for geotechnical investigations, covering the feeder canal as well as the entire route of the canal where percussive drilling and auger boring was done.

Additionally, 20 points were selected along the canal for permeability tests. Table 2.3-1 ~ Table 2.3-4 show the location of investigation sites.

[Table 2.3-1] Coordination of Percussive Drilling and Auger Boring (Feeder Canal)

Division	Coordination(X)	Coordination(Y)	Division	Coordination(X)	Coordination(Y)
BH-A	686,895	8,243,053	BH-7a	686,827	8,233,919
BH-1	687,065	8,242,376	BH-8	687,227	8,230,525
BH-2	687,002	8,242,353	BH-9	688,103	8,228,704
BH-3	687,016	8,242,312	BH-10	688,807	8,225,246
BH-4	687,007	8,241,230	BH-11	686,596	8,226,466
BH-5	686,463	8,240,248	BH-12	685,911	8,224,369
BH-5a	684,839	8,240,356	BH-13	685,652	8,222,834
BH-6	686,438	8,237,896	BH-14	686,163	8,221,108
BH-7	686,303	8,236,287	BH-15	685,320	8,218,020

[Table 2.3-2] Coordination of Percussive Drilling and Auger Boring (Bangula Canal)

Division	Coordination(X)	Coordination(Y)	Division	Coordination(X)	Coordination(Y)
BH-16	684,049	8,217,595	BH-19	679,938	8,211,724
BH-16a	683,246	8,215,276	BH-20	679,924	8,210,266
BH-17	682,089	8,214,494	BH-21	680,629	8,208,430
BH-18	681,169	8,213,292	BH-22	681,605	8,207,101

[Table 2.3-3] Coordination of Percussive Drilling and Auger Boring (Supuni Canal)

Division	Coordination(X)	Coordination(Y)	Division	Coordination(X)	Coordination(Y)
BH-23	687,273	8,214,217	BH-24	689,558	8,211,321

[Table 2.3-4] Coordination of Permeability Test

Division	Coordination(X)	Coordination(Y)	Division	Coordination(X)	Coordination(Y)
P/T-1	685,319	8,218,020	P/T-11	698,810	8,182,103
P/T-2	682,089	8,214,494	P/T-12	703,761	8,175,634
P/T-3	679,924	8,210,266	P/T-13	705,858	8,172,694
P/T-4	681,605	8,207,101	P/T-14	707,631	8,171,814
P/T-5	681,278	8,205,535	P/T-15	710,412	8,169,054
P/T-6	683,444	8,204,933	P/T-16	714,797	8,166,150
P/T-7	686,030	8,201,739	P/T-17	717,172	8,165,297
P/T-8	689,191	8,196,727	P/T-18	687,273	8,214,217
P/T-9	693,933	8,191,090	P/T-19	687,345	8,213,157
P/T-10	696,240	8,185,028	P/T-20	689,558	8,211,321

Each site for geotechnical investigation was checked through the reconnaissance survey for ease of accessibility with regard to the geotechnical investigation equipment. And as stated in the preceding discussion, the investigations were conducted using percussive drilling or auger boring.

[Figure 2.3-2] Check of Drilling Point (left) and Percussive Drilling & Standard Penetration Tes t(right)

The geotechnical investigations and laboratory test were done in accordance with the Malawi's recommended standards. Standard penetration test (SPT) was carried out in boreholes at intervals of 1.5m. In addition to SPT, samples were collected from boreholes at intervals of 1.5m for laboratory testing.

Geotechnical investigation works included the following;

a) Percussive drilling and Auger boring,
b) Standard penetration test,
c) Disturbed and undisturbed soil sampling,
d) Permeability test and laboratory tests for disturbed and undisturbed soil samples.

Laboratory tests included the following;

a) Atterberg limits,
b) Sieve analysis,
c) Triaxial test,
d) Unit weight and specific gravity.

The Consultant supervised the field and laboratory tests and evaluated the results.

Material Investigations

The examination of construction material was aimed at providing data on quantities and quality of the materials, as well as their availability and proximity within the project area. During materials' investigations, 8 sands or gravel borrow pits and 4 quarry pits were examined.

2.3.2. Determining Seepage Losses in the Feeder Canal

The geotechnical tests on the feeder canal focused on seepage losses and hydraulic conductivities. Since an infiltrometer was not readily available for use in the determination of seepage losses at the 10 selected points on the feeder canal (Table 2.3-5 and Figure 2.1-25), starting with Point 1 at the Intake of the Feeder Canal and ending with Point 10 close to Road D134, an alternative method involving digging pits was adopted.

[Table 2.3-5] List of the Main Structures

Division		Location	Type	Chain No.	Coordination (X,Y)
1	Feeder	Intake	Longitudinal Structure	0+000	687073.6 , 8242379.0
2	Feeder	Road D135	Longitudinal Structure	2+854	686850.7 , 8241561.7
3	Feeder	Road D135	Longitudinal Structure	5+706	686512.7 , 8240341.4
4	Feeder	Mwambezi	Cross sectional drain structure	7+451	685546.3 , 8240111.8
5	Feeder	Namkati	Cross sectional drain structure	15+207	685641.4 , 8236817.1
6	Feeder	Masakale	Cross sectional drain structure	23+092	684964.2 , 8234499.8
7	Feeder	Kadeya	Cross sectional drain structure	29+213	686951.3 , 8232689.9
8	Feeder	Manjalende	Cross sectional drain structure	34+350	687303.0 , 8229997.1
9	Feeder	Nthumba	Cross sectional drain structure	54+620	684998.1 , 8224103.1
10	Feeder	Road D134	Longitudinal Structure	56+447	685678.0 , 8222840.7

The 10 points along the feeder canal were located in the field using a GPS unit. The following steps were thereafter followed in the determination of percolation rates:

(a) Excavation of the soil layer which was to be assessed for percolation rate by digging a pit measuring 1m by 1m and by 0.5m depth. All the loose material was then removed from the sides and bottom of the pit (Figure 2.3-3 and 2.3-4);

(b) A smaller pit measuring 300 mm by 300 mm and 300 mm deep was dug in the larger pit (Figure 2.3-5);

(c) Water was then poured into the small pit to wet the soil, i.e. presoaking, prior to taking measurements of percolation time (Figure 2.3-6);

(d) After thoroughly wetting the soil, the small pit was then filled with water, noting the time that was taken for the water to drop by 225 mm, with a minimum of 10 minutes considered adequate for recording the percolation time (Figure 2.3-7); and thereafter

(e) Seepage losses were calculated by dividing the depth of water drop by the time taken.

[Figure 2.3-3] Measuring the Surface Dimension of the Pit

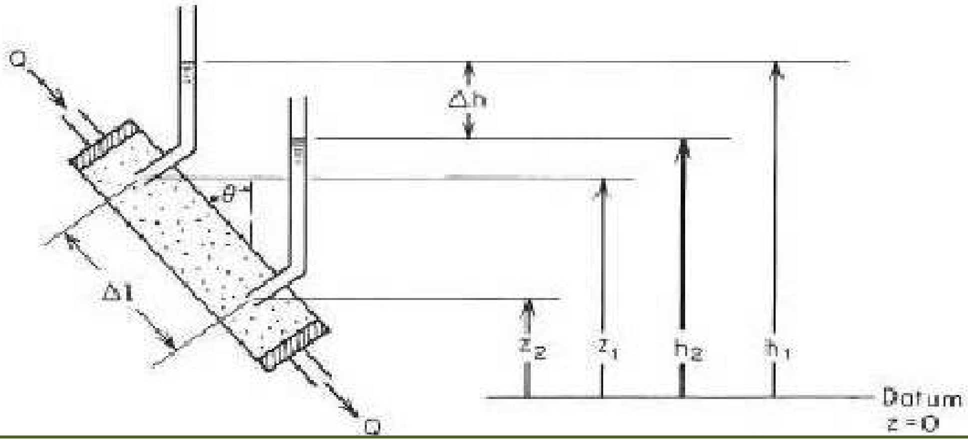
[Figure 2.3-4] Digging the Pit

[Figure 2.3-5] The 300mm by 300mm by 300mm Hole

[Figure 2.3-6] Presoaking the Hole

[Figure 2.3-7] Recording Time Taken for the Water Level to Drop to 225 mm

After conducting the percolation test in the field, soil samples were collected from each pit for laboratory testing at the Civil Engineering Laboratory at the Malawi Polytechnic to determine the respective hydraulic conductivities of the soils excavated from the pits using the Darcy's experimental setup as shown in Figure 2.3-8.



[Figure 2.3-8] Laboratory Setup for Permeability Test

Note,

$$Q = -KA\frac{dh}{dl}$$

Where, K is the permeability, Q is the discharge, A is the cross-sectional area of flow, and dh/dl is the hydraulic gradient.

[Figure 2.3-9] Permeability Test

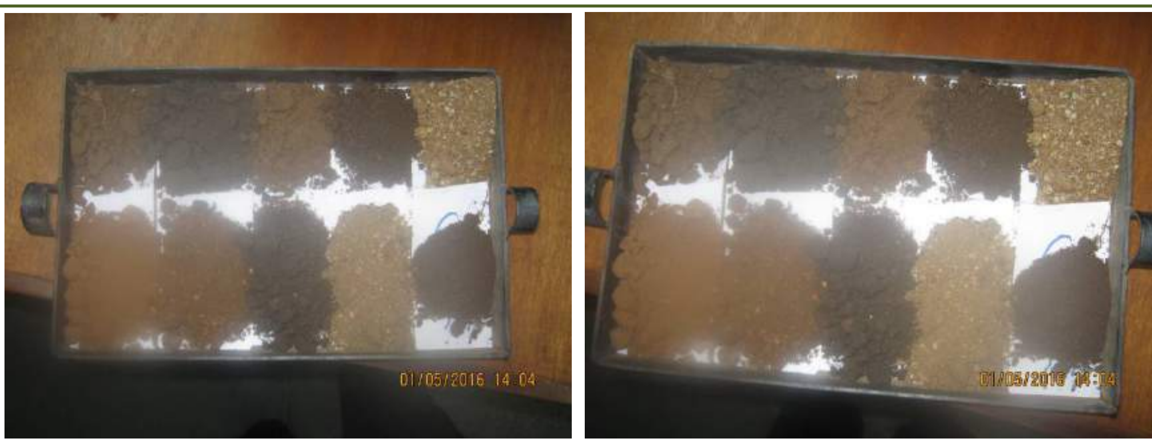
Geotechnical Assessment

Presented in Table 2.3-6 are brief descriptions of soil profiles exhibited by the pits excavated at the 10 selected points along the feeder canal.

[Table 2.3-6] Description of Soil Profiles

Site Number	Description of Soil Profile
1	0-400 mm, dark brownish soil, comprising clays, fine sands, and humus; >400 mm, reddish brown soil, containing clays and fine sands.
2	0-300 mm, black soil, consisting of clays, fine sands, and humus; >300 mm, loamy sandy soil
3	0-250 mm, reddish brown soil, comprising fine sands and clays; >250 mm, reddish brown sandy soil.
4	0-400 mm, dark brownish soil, containing fine sands and clays; >400 mm, brownish sandy soil.
5	0-300 mm, dark greyish soil, with fine sands and clay; >300 mm, decomposed metamorphic rock of gneiss origin, with feldspars
6	0-400 mm, dark brownish soils, containing fine sands and clays; >400 mm, brownish sandy soil
7	0-400 mm, decomposed rock of gneiss origin, with feldspars; >400 mm, decomposed rock
8	0-400 mm, dark brownish soil, comprising clays and fine sands; >400 mm brownish sandy soils
9	0-400 mm, decomposed lateritic rock; >400 mm, decomposed lateritic rock.
10	0-330 mm, dark brownish soil, comprising clays and fine sands; >330 mm, reddish sandy loam soils

It is clear from the description of the soil profiles that the soils along the feeder canal are generally sandy in nature comprising clays and humus. As such, conveyance losses due to seepage expected to take place, therefore in this point of view lining of canal is recommended. Especially inside Majete area, the lined feeder canal is highly recommended to minimize the seepage loss. In this regard a buried concrete syphon could be considered as another option. During the preliminary design the pros and cons of the two alternatives shall be carefully assessed, and selected the more advantageous one.



[Figure 2.3-10] Soil Samples Collected from the 10 Points on the Feeder Canal

Presented in Table 2.3-7 and Table 2.3-8, respectively, are the results of the percolation and soil permeability tests conducted at Points 1 to 10 on the feeder canal.

[Table 2.3-7] Results of the Percolation Test

Site Number	Time Elapsed (min)	Total Water Drop (mm)	Percolation Rate (mm/sec)
1	18	221	0.20
2	21	150	0.12
3	10	225	0.38
4	32	180	0.09
5	24	220	0.15
6	20	200	0.17
7	23	220	0.16
8	21	120	0.10
9	10	140	0.23
10	10	95	0.16

Note: Percolation Rate = Total Water Drop/Time Elapsed

[Table 2.3-8] Results of Soil Permeability

Sample No.	Hydraulic Gradient	Length of Sample (mm)	Volume (cm^3)	Time (min)	Coefficient of Permeability (mm/sec)
1	6.52	225	562	45	0.063
2	6.52	226	540	45	0.061
3	6.52	226	594	45	0.067
4	6.52	226	952	45	0.108
5	6.52	225	2580	45	0.291
6	6.52	225	1660	45	0.187
7	6.52	225	2160	45	0.244
8	6.52	226	584	45	0.066
9	6.52	226	844	45	0.095
10	6.52	226	440	45	0.050

Note from the preceding discussion that,

$$Q = -KA\frac{dh}{dl}$$

Where, K is the permeability, Q is the discharge, A is the cross-sectional area of flow, and dh/dl is the hydraulic gradient.

According to the soil classification developed by Myslivec and Kysela (1978), the soils excavated at the 10 pits fall within the group of Loess Loam (Table 2.3-9), with coefficient of permeability in the range of 10^{-2} to 10^{-4}.

[Table 2.3-9] Permeability for Various Soils (Source: Myslivec and Kysela, 1978)

Type of Soil	Coefficient of Permeability k [m/day]	Motion of Water Particle by1 cm for Hydraulic Gradient i = 1 per time
Soft sand	10^2 - 10	6 s - 10 min
Clayey sand	10^{-1} - 10^{-2}	100 min - 18 hrs
Loess loam	10^{-2} - 10^{-4}	18 hrs - 70 days
Loam	10^{-4} - 10^{-5}	70 days - 2 years
Clayey soil	10^{-5} - 10^{-6}	2 years - 20 years
Clay	10^{-6} - 10^{-7}	20 years - 200 years

<u>Conclusion</u>

Study findings show that the area that will be traversed by the feeder canal comprises sandy soils which will likely result in high seepage losses if the canal is not going to be paved or lined with concrete. Additionally, it has been recommended to use concrete pipes buried in the ground to be used as a water conveyance system so as to reduce evaporation losses and to protect wild animals from drowning.

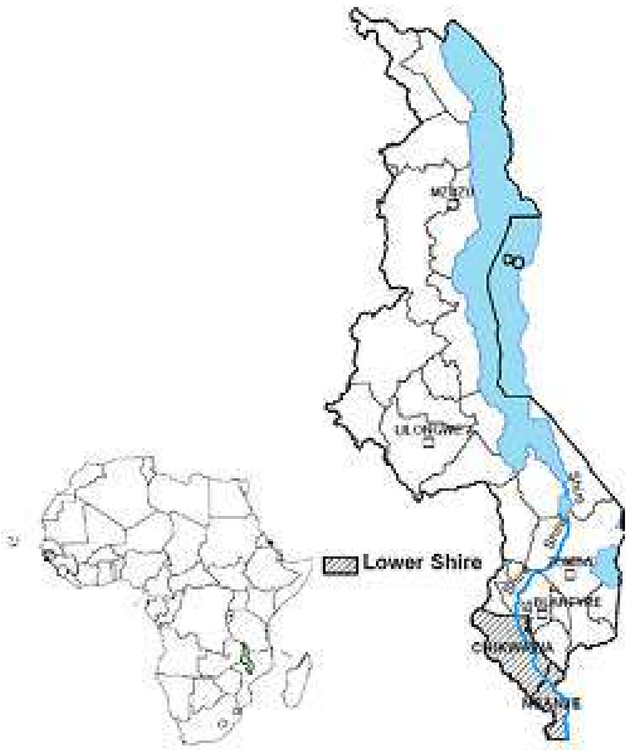
2.4. Hydrogeology

TOR Requirements
Collect all available and relevant hydrogeological data of the proposed development areas required for evaluation of: (a) present and historical ground water table levels and fluctuations/behavior; (b) ground water potential in the area in terms of groundwater availability, safe yield and groundwater quality; and (c) future ground water regime and behavior after the development of irrigation in the project area; (d) impacts of seepage and percolation and drainage from the irrigation canals; and (e) identification of drainage control and ground water table control, ground water quality control measures that need to be incorporated into the detailed

(Note: This "Hydrogeology" part of the report is included in an independent report with 'Geotechnical Investigation' part. Refer to that report for more details

2.4.1. Location and Climate

The Lower Shire Valley is located at the extreme southern part of Malawi (Chavula, 1989), see Figure 2.4-1. More than 70% of the area lies in Chikwawa District and the rest falls within Nsanje District. The Lower Shire Valley is bounded on the east by the Thyolo Escarpment which marks the edge of the lift faulting at the extreme southern end of the Great East African Rift System, and on the west by Mozambique. The Lower Shire Valley extends south from latitudes 16.25 degrees to 16.3 degrees, with an estimated area of 2,835 km^2. The road network provides the main link between the Lower Shire Valley and the rest of the country (Chavula, 1989).



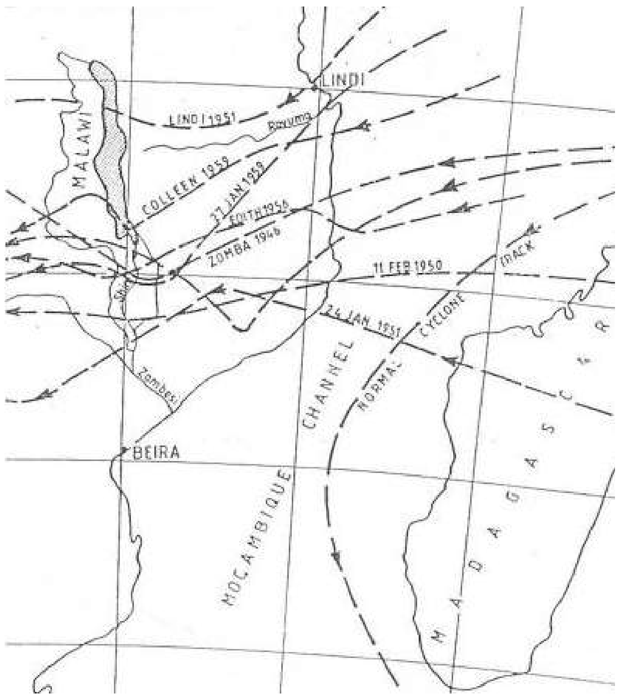
[Figure 2.4-1] Location of the Lower Shire Valley (Source: Monjerezi, 2012)

The climate of the Lower Shire Valley is characterized by two well defined seasons, namely: the dry season from May to October, and the rainy season from November to April. The Inter Tropical Convergence Zone (ITCZ), the Zaire Air Boundary (ZAB), and Tropical Cyclones (Figure 2.4-2) are three large-scale (synoptic) systems that bring rainfall to the Lower Shire Valley (Kululanga and Chavula, 1993).

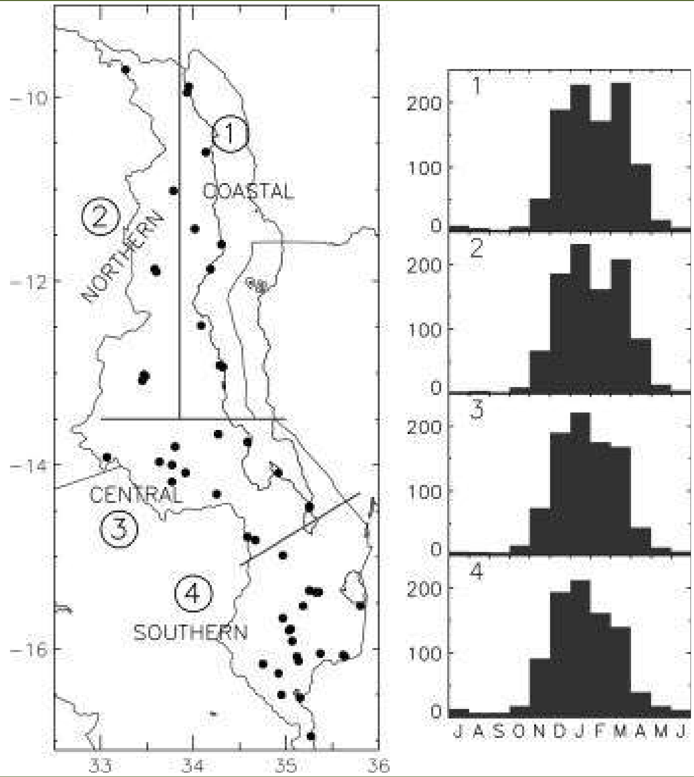
Figure 2.4-3 shows four homogeneous rainfall regions in Malawi, with the stations within them and the typical seasonal cycle of rainfall (mm per month) in each region; whereas Table 2.4-1 shows rainfall onset, end, and duration (Nicholson et al, 2013). Chikwawa and Ngabu Meteorological Stations, main weather stations in the Lower Shire Valley, are indicated in Table 1 as Stations 20 and 21 respectively. Figure 2.4-4 shows mean annual and seasonal rainfall in mm (based on the period 1962 - 2009).

[Table 2.4-1] Rainfall Onset, End, and Duration in Malawi (Source: Nicholson et al, 2013)

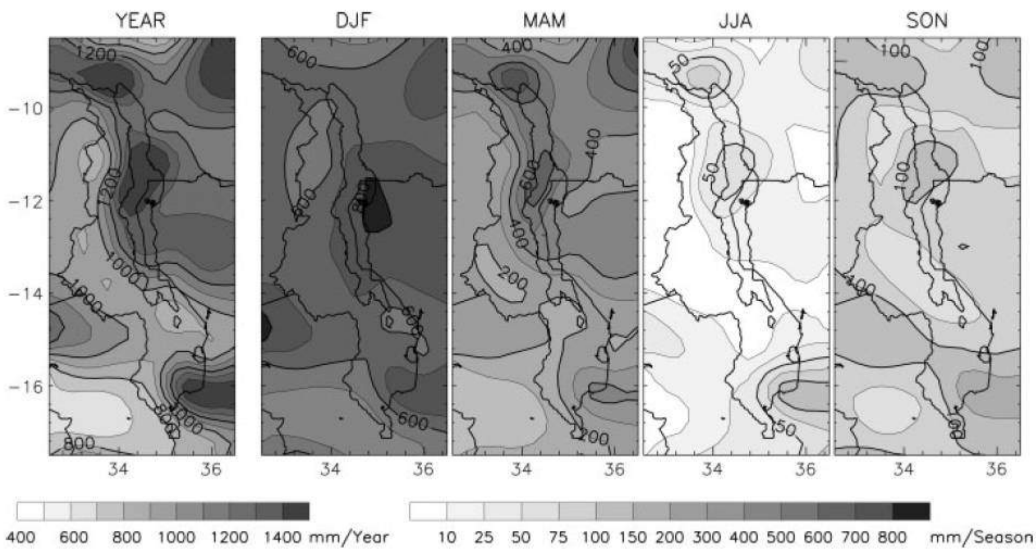
Region	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**3**	**3**	**3**
Station	1	2	3	4	5	6	7	8	9	10	11
Onset	12/4	11/19	11/23	12/1	11/27	12/6	11/27	12/1	12/4	12/3	11/28
End	4/20	4/28	5/8	4/14	4/4	3/19	3/30	3/20	3/24	4/1	3/21
Duration	138	161	167	134	129	104	124	108	111	120	114
Region	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**4**	**4**	**-**
Station	12	13	14	15	16	17	18	19	20	21	-
Onset	11/27	11/27	12/4	11/23	11/27	11/15	11/14	11/13	11/29	11/25	-
End	3/23	3/27	3/19	3/27	3/17	3/17	4/4	4/5	3/13	3/19	-
Duration	117	122	106	126	111	123	142	144	105	114	-



[Figure 2.4-2] Cyclone Track (Source: Water Department/UNDP, 1986)



[Figure 2.4-3] Left: Four Homogeneous Rainfall Regions of Malawi and Stations within them. Right: The Typical Seasonal Cycle of Rainfall (mm/month) in Each Region (Source: Nicholson et al, 2013).



[Figure 2.4-4] Mean Annual and Seasonal Rainfall in mm based on the Period 1962 ~ 2009

The highest wind speeds in the Lower Shire Valley are recorded between May and June (Chavula, 1989), but generally they range from 104-295 km/day. During the dry season the prevailing winds are the strong southeast trade winds (locally known as Mwera) which are relatively dry and produce clear weather conditions. The wet season is associated with weak northeast trade winds (locally known as Mpoto).

Temperatures in the Lower Shire Valley are the highest in Malawi. They range from 13.4-37.5℃, over even higher. The high temperatures also mean very high evaporation rates, rising from 107 mm in June to 274 mm in October (Chavula, 1989).

2.4.2. Topography, Vegetation and Soils

The topography of the Lower Shire Valley can be divided into six physiographic units or zones, namely: the Thyolo-Chikwawa piedmont, the Elephant Marsh, Plain Drift, Mwanza Valley, Makande Plain, and the Ruo Outwash Plain (Chavula, 1989). The Thyolo-Chikwawa Piedmont lies at an elevation ranging from altitudes 46-108 m above sea level. It comprises gently sloping southwest facing piedmont on the face of the Thyolo Escarpment.

The dominant vegetation types in this zone are lowland woodland species, mainly as remnants in cultivation savanna stercula – adonsonio and acacia albida – cordyla associations. Grey brown soils of medium texture, generally fertile and well supplied with alluvial fans, are the commonest in this zone.

The Elephant Marsh is located at an altitude of 31-92 m above sea level. It comprises a flat perennial marsh and riverine landforms. It consists of marsh grassland and reeds, and hydromorphic alluvials of variable texture and fertility.

The Drift Plain lies at an altitude of 46-154 m above sea level. It comprises flat dambos. Brown soils with medium texture are commonly found.

The Mwanza Valley lies at an altitude ranging from 77-292 m above sea level. It comprises gently sloping piedmont on either side of the narrow alluvial plain of the Mwanza River. The commonest type of vegetation found in the area is lowland savanna and thicket often reduced to cultivation savanna. Brown soils of medium texture prevail in this zone.

The valley floor itself is slightly tilted down from west to east. The average height of the valley floor is about 107 m around Chikwawa and 91 m around Ngabu. On the lower land the original vegetation has been cleared to make room for gardens but baobab and boras palms are a notable feature of the landscape. The plains have generally very gently sloping topography but the erosion hazard is variable depending on the soil type.

2.4.3. Geology

Most of the area is underlain by gneisses and granulites of the basement complex or by sedimentary and volcanic rocks of Karroo age (Figures 2.4-5 ~ Figure 2.4-8). Over large areas on the floor of the Lower Shire Valley these rocks are observed by colluvium and river alluvium (Chavula, 1989; Monjerezi, 2012).

The basement complex rocks are of high grade and can be assigned to either the amphibolite or granulite facies. Quartzofeldspathic hornblende and pyroxene gneisses occur around and north/west of Chikwawa Boma. The lowest beds of the Karroo successions are the coal shales which outcrop over a fairly large area around the headwaters of Mkombezi wa Fodya River. They comprise grey and black mudstones, carbonaceous shales with thin coal beds, and interbedded grits and sand stones. Overlying these beds is a sequence of thick sandstones, shales, mudstones and limestones, surrounded by grits and sandstones (Chavula, 1989).

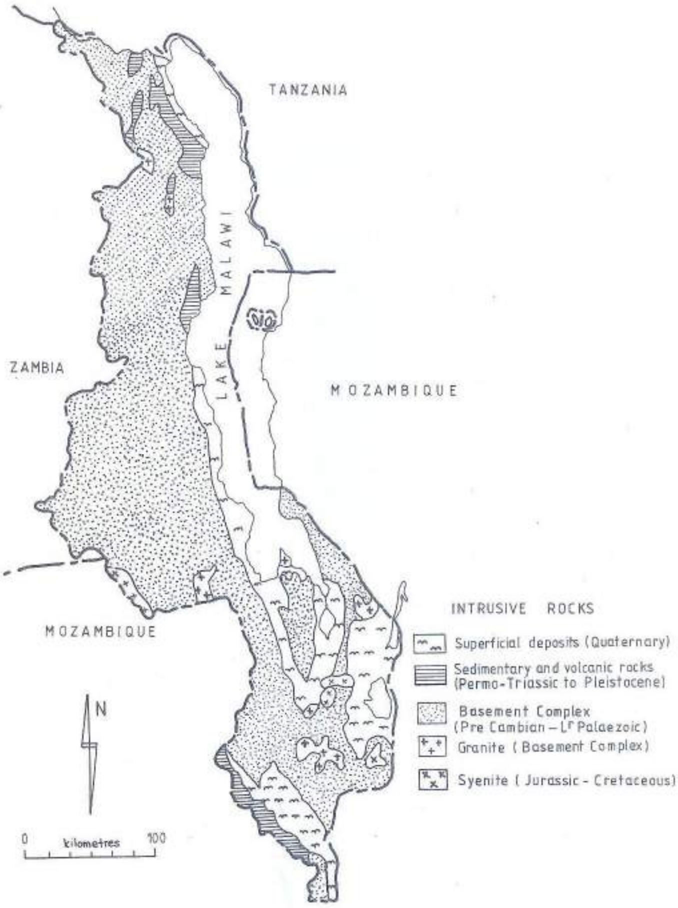
The deposition of these sediments was followed by a period of vulcanicity of late Karroo age. Basalt lava flows outcrop south and west of Ngabu and minor intrusions of dolerite are found throughout the Karroo sediments and the basement complex.

Unconsolidated superficial deposits are wide spread in the Lower Shire Valley. River alluvium mainly sand and silt is found on the banks of the Shire and other rivers within the area. Most of the valley infilling is of the nature of pedisediment deposits resulting from downhill movement of masses of debris carried by gravity, rain-wash and stream action in the course of pediplanation.

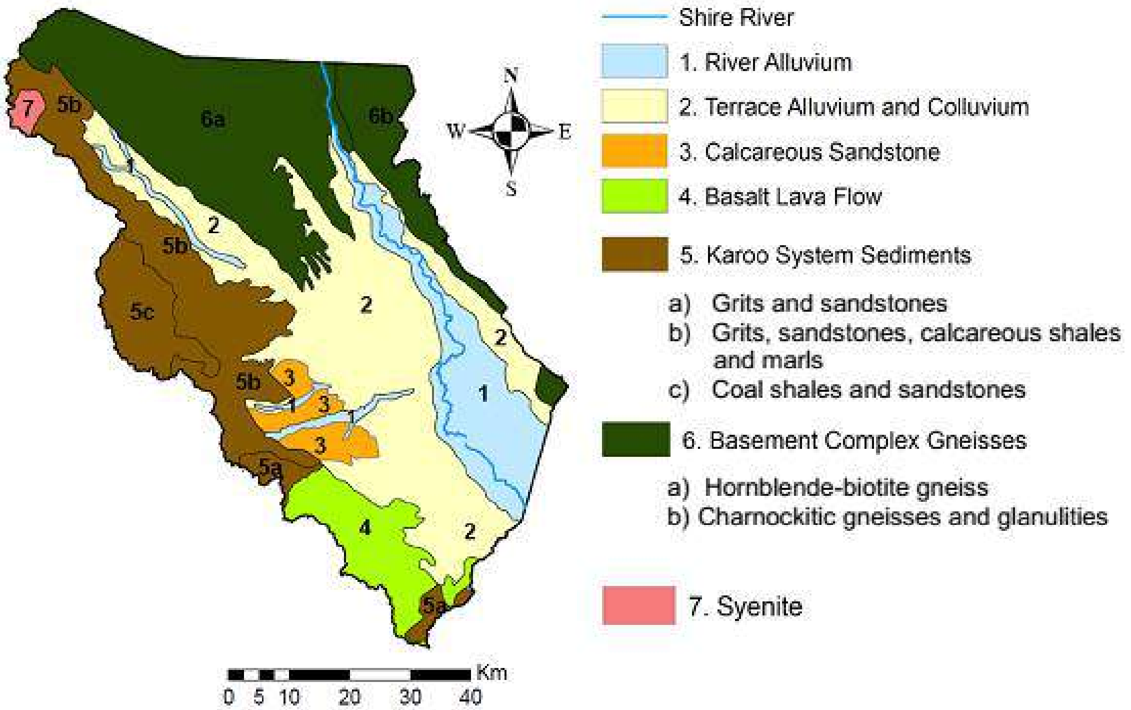
Faulting has been very severe in the Lower Shire Valley mostly associated with the development of the Great East African Rift Valley System. The eastern margin of the rift is represented principally by the Thyolo Fault (Figure 2.4-8). West of the Shire River the Karroo rocks down faulted against the basement complex along the Mwanza Fault.

2.4.4. Drainage

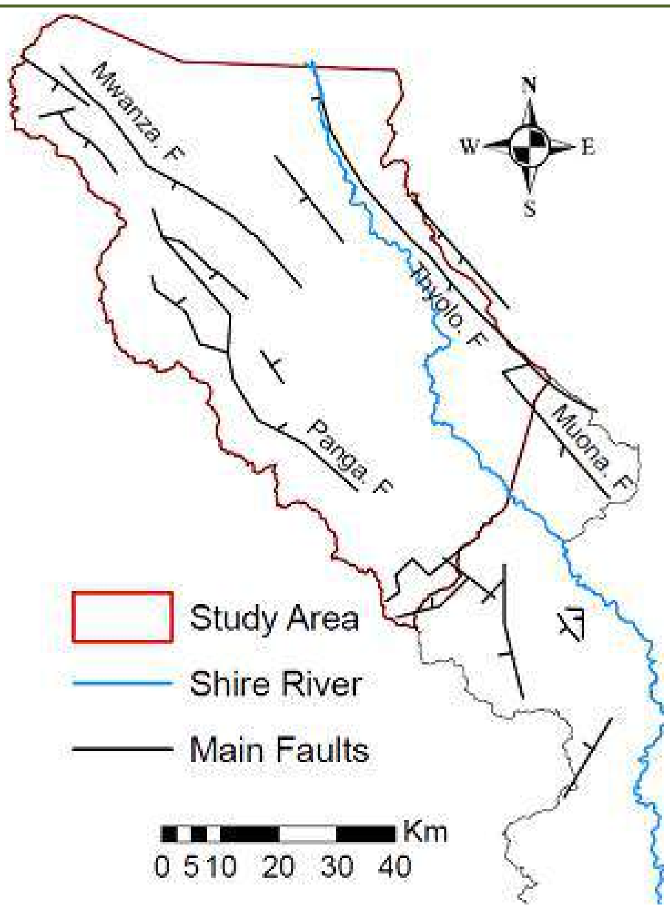
The Lower Shire Valley is drained by the Shire River and its tributaries. The Mwanza River which is the main tributary of the Shire rises some 48 kilometers to the north and is perennial until it reaches the Mwanza Marsh below which the river flows over the alluvial plain of the Shire and is seasonal.



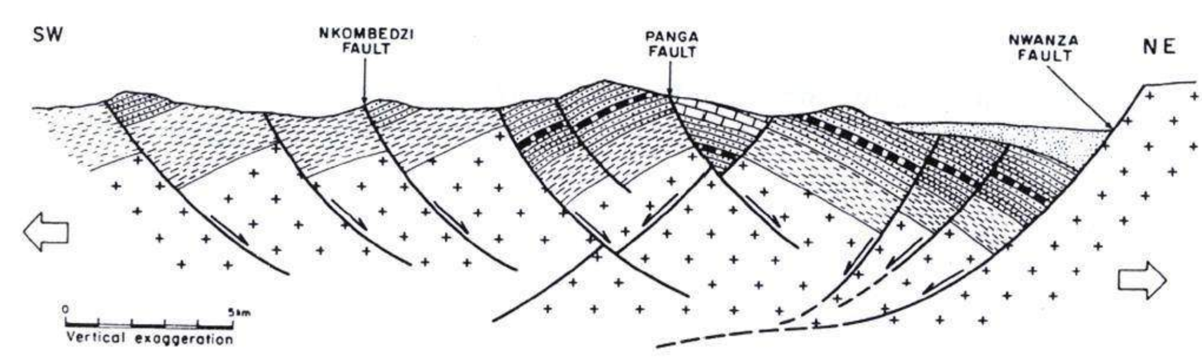
[Figure 2.4-5] General Geology of Malawi (Source: Water Dept/UNDP, 1986)



[Figure 2.4-6] Detailed Geology of the Lower Shire Valley (Source: Monjerezi, 2012)



[Figure 2.4-7] Main Faults in the Lower Shire Valley



[Figure 2.4-8] Schematic Cross-section of the Lower Shire Valley showing the Effects of the Faults within the Basin (Source: Castaing, 1991)

Apart from the Mwanza River, the following are some of the rivers that arise from the west of the Lower Shire Valley: Mkombedzi wa Fodya, Phwadzi, Namikalango, Mafume, Dandi, and Thangadzi. Their channels are well defined in the middle reaches but generally disappear as the Shire is approached. These rivers come down seasonally. This is not only due to the very intermittent rainfall coupled with high evaporation rates but principally to the porous nature of the area. The same applies to some of the tributaries of the Shire that arise from the eastern side of the Lower Shire Valley.

2.4.5. Scope of Tasks

The study involved the implementation of two main activities, namely:

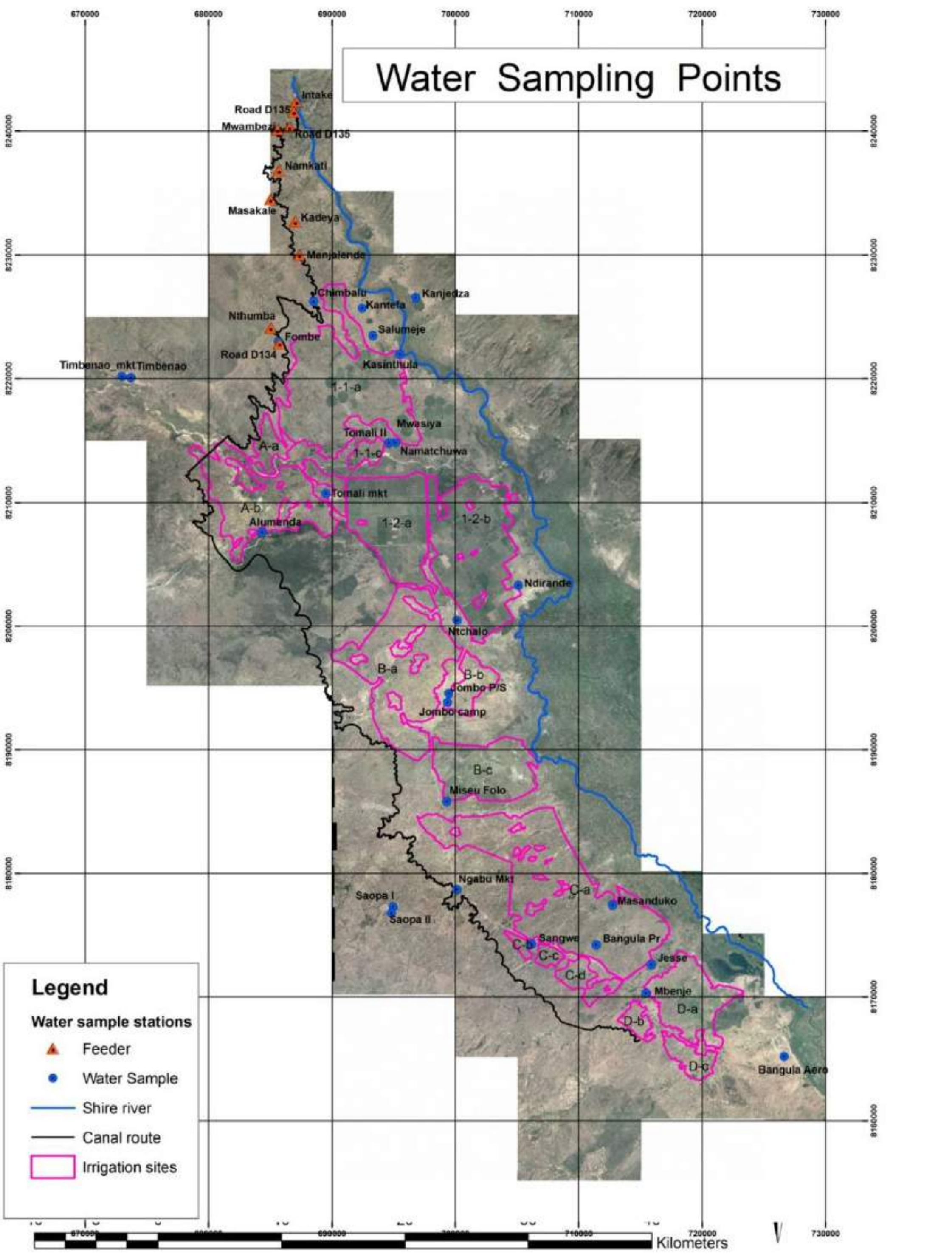
1) Conducting water quality testing of groundwater and surface water resources within the Shire River Irrigation Project, focusing on physical, chemical and biological aspects of the water;
2) Determining the ground water balance of the Lower Shire Valley.

2.4.6. Determining the Suitability of Groundwater for Drinking and Irrigated Agriculture

In order to determine the suitability of the water for drinking water supply and irrigated agriculture, a team of water quality specialists from the Water Quality Laboratory of the Ministry of Agriculture, Irrigation and Water Development based in Blantyre was tasked to collect 28 water samples from boreholes in predetermined blocks (Figure 2.4-9, Tables 2.4-1) and the Shire River to test the water for its suitability for domestic use, focusing on its chemical composition, physical parameters, and biological quality. These results were compared with the existing Malawi and WHO standards. Values of Adjusted Adsorption Ration (Adj. SAR) were calculated using the procedure described by Ayers and Westcot (1976) in an FAO Irrigation and Drainage Paper 29 titled “Water Quality for Agriculture” in order to assess the suitability of the water for irrigated agriculture.

[Table 2.4-2] Location of Water Quality Sampling Points

Sample No.	Name	Type	Easting	Northing
550	Intake	Shire River	687073.60	8242379.00
551	Kanjedza	Borehole	696810.53	8226556.36
552	Chibalu	Borehole	688530.43	8226240.33
553	Kantefa	Borehole	692462.43	8225696.86
554	Kasinthula	Canal	695500.55	8221978.39
556	Salumeje	Borehole	693298.67	8223485.01
557	Namatchuwa	Borehole	695149.18	8214840.72
558	Mwasiya	Borehole	694623.35	8214820.69
559	Tomali mkt	Borehole	689528.04	8210733.82
560	Tomali II	Borehole	694623.11	8214829.99
561	Fombe	Borehole	685688.54	8223000.47
562	Timbenao_mkt	Borehole	672992.37	8220179.57
563	Timbenao II	Borehole	673731.72	8220094.55
564	Alumenda	Borehole	684332.11	8207611.94
565	Ndirande	Borehole	705094.21	8203308.31
566	Ntchalo Tr.	Borehole	700144.16	8200498.24
567	Jombo P/S	Borehole	699472.08	8194552.98
568	Jombo camp	Borehole	699370.43	8193828.42
569	Miseu Folo	Borehole	699296.78	8185805.66
570	Ngabu Mkt	Borehole	700130.06	8178684.34
571	Saopa I	Borehole	694961.59	8177296.09
573	Saopa II	Borehole	694802.62	8176781.00
574	Sangwe	Borehole	706166.75	8174280.43
575	Jesse	Borehole	715873.31	8172617.33
576	Mbenje	Borehole	715423.07	8170300.59
577	Masanduko	Borehole	712744.36	8177441.49
578	Bangula Pr.	Borehole	711398.70	8174232.77
579	Bangula Aero	Borehole	726630.67	8165213.48



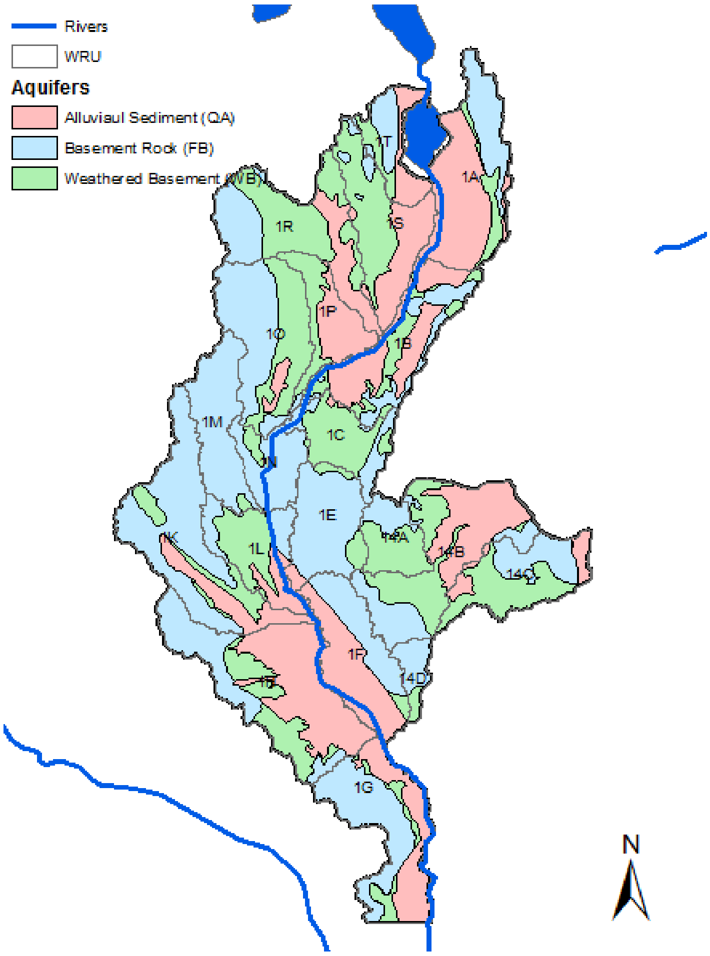
[Figure 2.4-9] Water Sampling Blocks

2.4.7. Evaluation of Water Balance

Evaluation of the water balance of the Lower Shire Valley was mostly done through literaturerev iew, involving studies done the Water Department/UNDP in 1986, Chavula in 1989, Monjerezi in 2012, and DHI in 2015.

2.4.8. Assessment of Groundwater Quantity

The Lower Shire Valley is dominated by the alluvial aquifer system, with some sections consisting of Pre-Cambrian Basement Complex Aquifers (Figure 2.4-10). The alluvial aquifers are fluvial in nature, but highly variable in character in both vertical sequence and lateral extent. Most lithological records obtained from boreholes provide very little information about the successions.



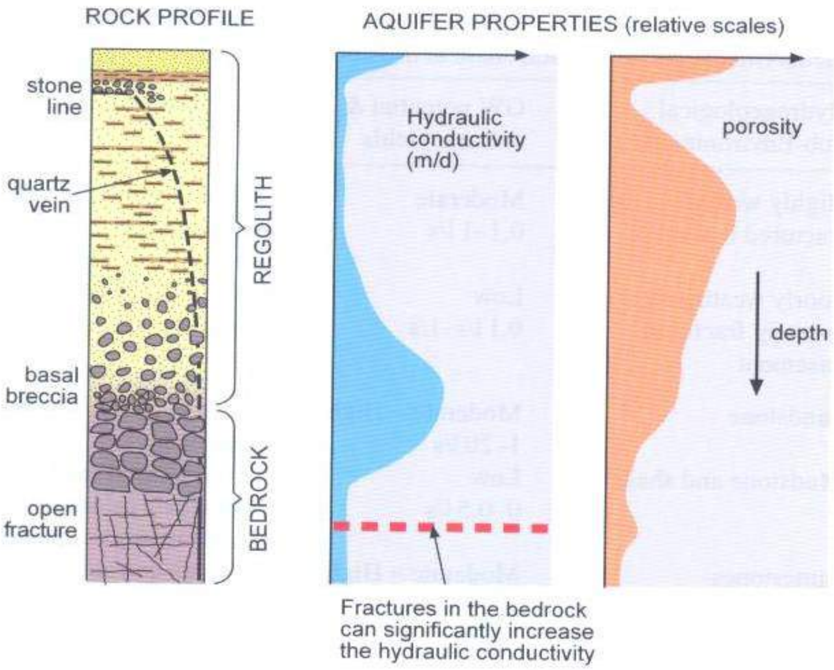
[Figure 2.4-10] Various Aquifer Types in the Shire River Basin (Source: Monjerezi, 2012)

Generally, talluvial aquifers produce high yields, in excess of 15 L/s (Chavula, 1989). Typical transmissivity values for alluvial aquifers lie in the range of 50-300 m^2/day, with hydraulic conductivity values in the order of 1-10 metres per day. Storage coefficient values normally lie in the range of $1*10^{-2}$ to $5*10^{-2}$ (Water Department/UNDP, 1986).

The PreCambrian Basement Complex aquifers are not as dominant and extensive in the Lower Shire Valley (Figure 2.4-10) as they are countrywide. These are generally low yielding (1-2 L/s). The prolonged in situ weathering of the crystalline basement rocks has produced a layer of unconsolidated saprolite material (Figure 2.4-11) that forms an important source of water supply for domestic requirements. The weathered zone is best developed over plateau areas where it is commonly 15-30 m thick and locally even thicker (Water Department/UNDP, 1986).

Typical transmissivity values for the weathered Basement Complex aquifer lie within the range of 5-35 m^2/day, with hydraulic conductivity values of 0.5-1.5 m per day. Storage coefficient values for the aquifers normally lie in the range of $5*10^{-3}$ to $1*10^{-2}$.

Annual groundwater recharge ranges from 15-80 mm (Water Department/UNDP, 1986). However, studies done by Chavula (1989) established that the annual recharge for the eastern side of the Lower Shire Valley alluvial aquifer may greater than 200 mm/year. But the rate of groundwater abstraction still remains very low, and estimates put the figure at less than 1 mm per year (Water Department/UNDP, 1986; Chavula, 1989).



[Figure 2.4-11] Profile of Precambrian Basement Complex Aquifer (Chilton and Foster, 1995)

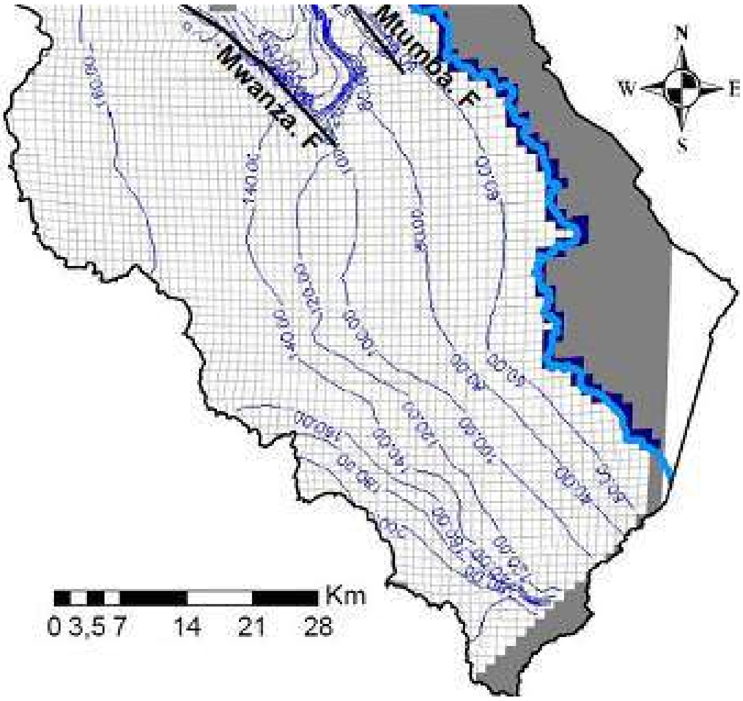
It is clear from the preceding discussion that the alluvial aquifers of the Lower Shire Valley are very rich in groundwater resources, adequate for drinking as well as irrigated agriculture.

Recommendation: SVIP area has adequate ground water resources for drinking water supply and irrigated agriculture.

2.4.9. Assessment of Groundwater Quality

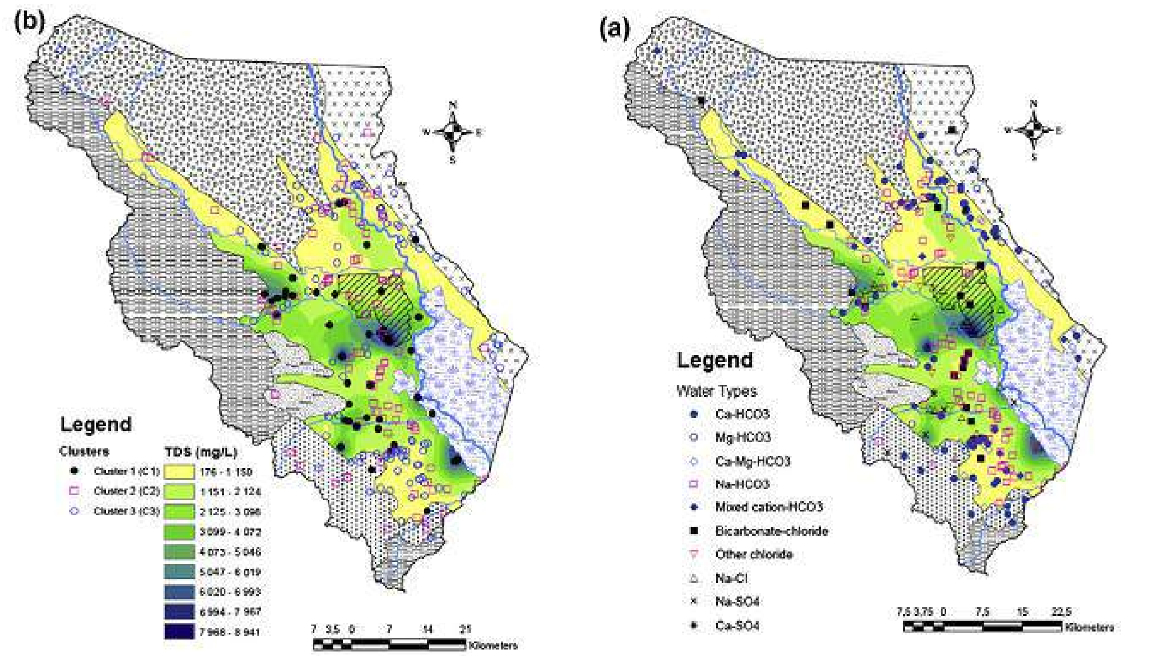
Results of water quality analysis are presented in Annex. The salinity of the 28 water samples as measured by electrical conductivity ranges from 307 µS/cm (0.0307 mmhos/cm) at Kasinthula Canal to 11,669 µS/cm (11,669 mmhos/cm) at Nchalo Sugar Estate at Ndirande Residential Area. Generally, fluoride values are low, ranging from 0.04-0.56 mg/L. The pH of the water ranges from 6.97-8.68, implying that the water is ranges from neutral to slightly alkaline.

The piezometric surface presented by Figure 2.4-12 shows that groundwater flow is generally towards the Shire River (Chavula, 1989; Monjerezi, 2012), making the Shire an influent river.



[Figure 2.4-12] Piezometric Surface of the Lower Shire Valley

The current results are in agreement with findings from previous studies done by Bath (1981), Chavula (1989) and Monjerezi (2012). Groundwater in the western side of the Shire River has much higher salinity vales than groundwater on the eastern side. This is explained by low hydraulic gradients in the former which facilitates the dilution of rock minerals by the groundwater whereas the steep gradients on the eastern side enables faster groundwater flow rates which facilitate fast replenishment thereby rendering groundwater to be fresh (Figures 2.4-13).



[Figure 2.4-13] Spatial Distribution of TDS Values(left) and Groundwater Types(right)

According to the groundwater quality interpretation done by Chavula (1989), groundwater mineralization in the Lower Shire Valley is mostly a direct result of either gypsum dissolution or carbonate weathering, cation exchange process, and the dissolution of evaporate minerals (e.g., borehole at Ndirande Residential area within Illovo Sugar Estate at Nchalo with very electrical conductivity value, and equally high values of Na^+ and Cl^-).

The quality of groundwater resources in the Lower Shire Valley is ideal for drinking although some areas exhibit the occurrence of groundwater with high salinities. This problem may be avoided by screening out layers of the aquifer that have saline groundwater and tapping groundwater from those aquifer layers that have fresh water only.

Recommendation: Ground water resources in the SVIP is good for drinking water supply although some areas have salty water.

2.4.10. Water Quality for Irrigated Agriculture

Hydrogeological investigations were intended to assess the suitability of groundwater resources for drinking water supply as well as irrigated agriculture, and determining the water balance. Generally the quality of groundwater resources in SVIP is suitable for drinking water supply, although it has been noted from several previous studies and the analysis conducted during the TFS that groundwater on the western side of the Shire is more mineralized than on the eastern side. This is a direct result of the prevalent low hydraulic gradients in this area coupled with low rates of groundwater recharge. Salinity values of 28 water samples collected in the project area range from 307 µS/cm (0.0307 mmhos/cm) at Kasinthula Canal to 11,669 µS/cm (11,669 mmhos/cm) at Nchalo Sugar Estate at Ndirande Residential Area. Generally, fluoride values are low, ranging from 0.04-0.56 mg/L. The pH of the water ranges from 6.97-8.68, implying that the water ranges from neutral to slightly alkaline.

According to the FAO Irrigation and Drainage Paper 29, there are three key problems associated with using poor quality water for irrigated agriculture, namely: salinity, permeability, and toxicity. Generally, water resources in SVIP are suitable for irrigated agriculture although in some cases there might be need for the implementation of water management practices, such as seed placement and pre-plant irrigation to leach the accumulated surface salts highlighted in FAO Irrigation and Drainage Paper 29. Water samples collected from boreholes located at Chibalu, Kantefa, Timbenao II, Ndirande at Illovo Sugar Estate, Jombo Primary School, Miseu Folo Clinic, Masanduko, and Bangula Airdrome show EC values >3,000 µS/cm and therefore may likely cause increasing salinity problems. But this could be resolved by adopting management practices highlighted in FAO Irrigation and Drainage Paper 29. However, water samples collected from the intake and from Kasinthula canal do now show any problems associated with the salinity of the water.

According to the FAO Irrigation and Drainage Paper 29, water with EC values >500 µS/cm is likely not to cause permeability problems while water with EC values ranging from 500-200 µS/cm has a high likelihood of causing increasing permeability problems, and water with EC values <200 µS/cm may cause severe permeability problems. All water samples analysed show EC values >200 µS/cm and hence considered unlikely to cause severe permeability problems. But using the same criteria, water samples collected in the Shire at the intake and at Kasinthula Canal fall within the increasing permeability zone. But it is worth noting that water from the Shire finds wide application for irrigated agriculture and that the project area comprises sandy soils with humus and clays and hence unlikely to cause ponding and excessive seepage. Hence the water from the Shire is ideal for crop irrigation with regard to permeability

Toxicity is a problem that occurs when certain constituents in the water (e.g., boron, chloride, and sodium) are taken up by the crop and accumulate in amounts that result in reduced yields. In order assess the toxicity of the water in regard to sodium, values of Adjusted Sodium Adsorption Rations (Adj.SAR) were computed for the water samples using procedures highlighted in the FAO Irrigation and Drainage Paper 29. Values of Adj.SAR range from 1.0 to 82.6. Ten (10) water points show severe toxicity problems to sodium because their Adjusted Sodium Adsorption Ratio values are greater than 9. Values of chloride concentration range from 0.4 to 81.1 meq/L and seven boreholes show values greater than 10 meq/L, implying severe toxicity to chloride. Irrigation management system would be applied in order to lessen the problem of toxicity in such a situation. But water samples collected from the Shire at the intake and Kasinthula canal do no show toxicity problems associated with sodium and chloride. In light of the above, the quality of water from the Shire is ideal for irrigated agriculture.

Generally, the quality of both surface and ground water resources in the Lower Shire Valley is ideal for irrigation as evidenced by the acceptable range of Adj. SAR obtained from water samples collected from boreholes and the Shire River, although some areas exhibit the occurrence of groundwater with high salinities. But as stated in the preceding discussion, this problem may be avoided by screening out aquifer layers that have saline groundwater and tapping groundwater from those aquifer layers that have fresh water only. Excessive seepage and ponding problems are not expected to occur when using water from the Shire for irrigation because the soil characteristics in the project area are not conducive for the two scenarios, i.e., alluvial soils with clays and humus.

Recommendation: Water resources in the SVIP are good for irrigated agriculture.

2.4.11. Evaluation of the Water Balance

In its simplified form the water balance equation for the Lower Shire Valley may be written as:

$$\Delta S/dt = P + Rs - Rg - Et$$

Where, P is precipitation, Rs is surface runoff, Rg is groundwater discharge, Et is evapotranspiration, and $\Delta S/dt$ is water in storage.

According to data obtained from the DHI report of 2015, the Lower Shire Valley receives an average of 956 mm of rainfall, with the lowest value of 583 mm; and experiences annual evapotranspiration rates of 1966 mm. Furthermore, groundwater recharge rates are estimated to lie in the range of 80-100 mm/annum. However, it was difficult in the TFS to precisely quantify surface runoff because most of the water that flows in the Shire is mainly derived from Lake Malawi. The same difficulty was encountered in determining the amount of water in storage within the study area. As such, the evaluation of the water balance proved rather difficult.

Notwithstanding problems associated with the evaluation of the water balance for the Lower Shire Valley, it is clear that are of SVIP is rich in surface water resources, mainly flowing in the Shire River itself. Also, the alluvial aquifer in the project area contains large volumes of groundwater resources, with adequate yields to support irrigated agriculture.

Recommendation: SVIP area has abundant water resources, comprising surface water from the Shire River and ground water from the alluvial aquifer. These resources would meet the demand for irrigated agriculture and domestic water supply.

2.5. Analysis of Floods

. TOR Requirements

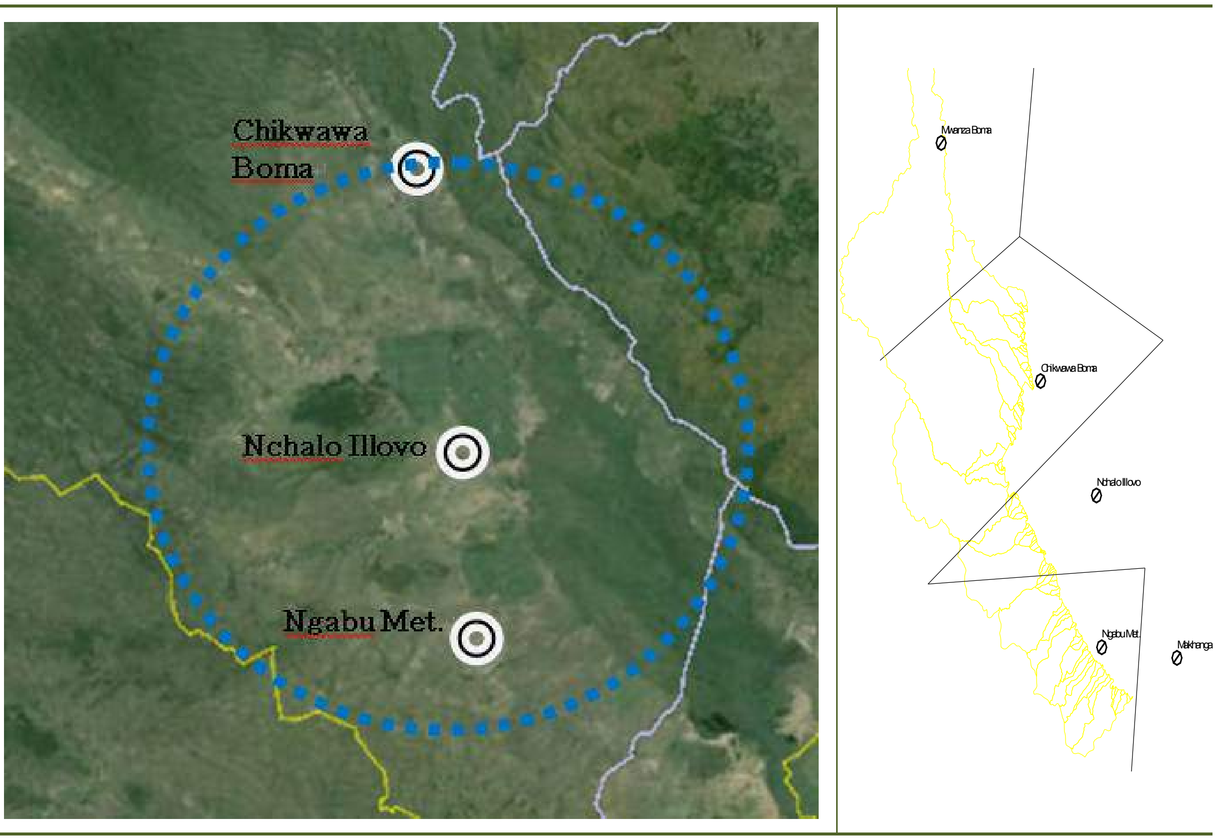
- Collection of flood damage level, strength, damage type of the project area through investigation of residents
- Preparation of map of possible flooding area, Review of frequency of flooding area

. Suggestion

- Preparation of map of possible flooding area and establishment of flooding prevention plan
- Preparation of map of possible flooding area
- Collection of related data (status of Shire river, soil characteristics, basic, slope, and altitude)
- Site survey and inquiry investigation

2.5.1. Meteorological and Water Level Station

There are 4 meteorological stations within the project area located at Mwanza, Chikwawa, Nchalo, and Ngabu. Data from each station were studies in order to understand a review of the meteorological characteristics of SVIP area. And the location and status of the four meteorological stations are shown in Figure 2.5-1 and Table 2.5-1.



[Figure 2.5-1] Location and Status of Meteorological Station

[Table 2.5-1] Location and Status of Meteorological Station

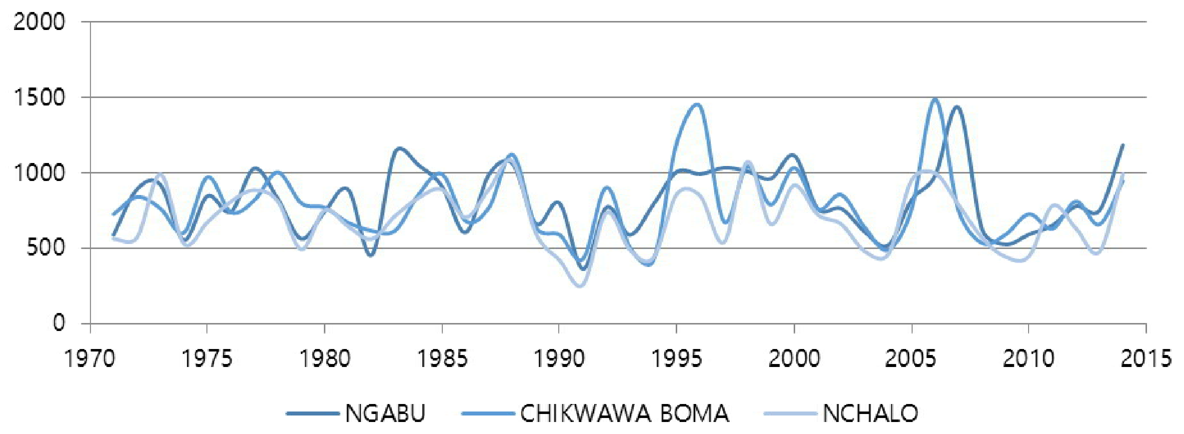
Rainfall Station	Location		Start Year	Remark
	Long.	Lat.		
Mwanza	34.5167	-15.6167	1965	
Chikwawa	34.7833	-16.0333	1960	
Nchalo	34.93333	-16.2333	1971	
Ngabu	34.95	-16.5	1960	

2.5.2. Rainfall

Table 2.5-2 shows monthly average and monthly maximum rainfall data from 1971 to April of 2015 at Nchalo meteorological station. It is clear from the table that the highest rainfall at Nchalo was recorded in Jan. 2015, with an average rainfall value of 706.8mm.

[Table 2.5-2] Monthly Average Rainfall (1971~2015)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Oct	Sep	Nov	Dec
Ave	190.2	137.8	95.3	36.2	13.5	13.3	17.8	6.9	7.1	13.9	50.7	124.3
Max	576	347.7	258	210.7	63.8	45.3	50.5	53	55.1	107.4	164	269.5
Min	31.2	8.6	10.2	0	0	0	0	0	0	0	1.3	8.6



[Figure 2.5-2] Yearly Rainfall Distribution of Chikwawa, Nchalo and Ngabu Station

The rainfall pattern is very similar at all the stations; and among the 4 stations, Chikwawa rainfall station had the longest record while the data for Nchalo covered the shortest period. Table 2.5-3 shows maximum rainfall (1971~2015) in SVIP.

[Table 2.5-3] Maximum Rainfall of SVIP Station (1971~2015)

Rainfall Station	1day		2day		3day		Consecutive days	
	Day	Rainfall	Day	Rainfall	Day	Rainfall	Day	Rainfall
Mwanza	11-Dec-94	159.0	20-Dec-01	200.2	5-Mar-88	250.7	24-Jan-93	295.9
Chikwawa	11-Dec-94	172.5	20-Dec-01	235.7	5-Mar-88	336.5	24-Jan-93	362.4
Nchalo	11-Dec-94	137.7	20-Dec-01	178.3	5-Mar-88	208.8	24-Jan-93	226.3
Ngabu	11-Dec-94	165.0	20-Dec-01	186.0	5-Mar-88	226.8	24-Jan-93	274.0

2.5.3. Probability Rainfall Analysis

In order to extract maximum rainfall values from corresponding duration curves, data collected from Mwanza, Chikwawa, Nchalo and Ngabu rainfall satations were used. Maximum rainfall was analyzed based on a 24-hour duration. The probability distribution, parameter estimation and goodness of fir test were then carried out, and the results are shown in Table 2.5-4, 2.5-5 and Figure 2.5-3.

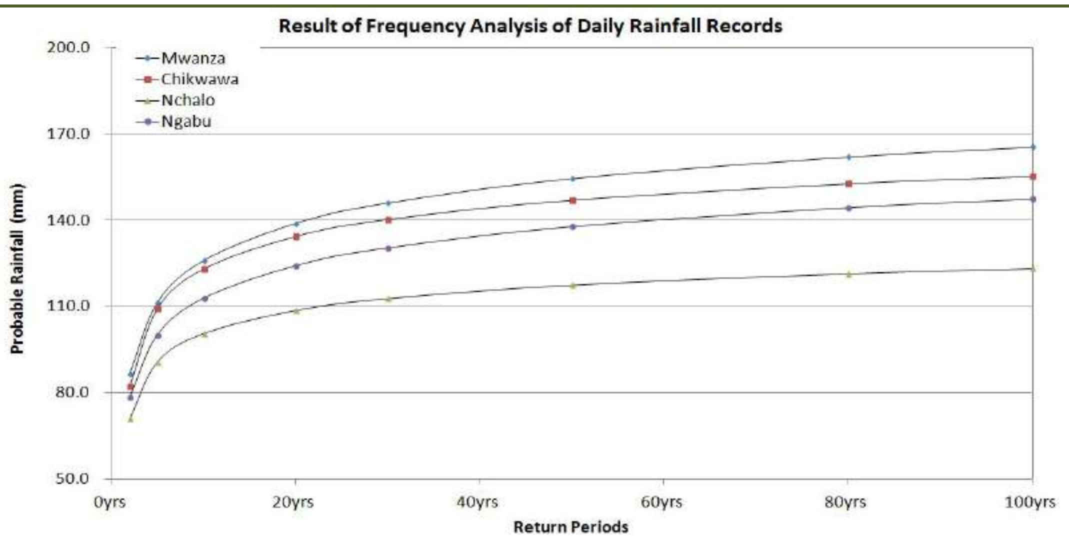
[Table 2.5-4] Distribution Type of SVIP Basin

Rainfall Station	1day		2day		3day		Consecutive Days	
	Para. Est. Method	Opt. Distribution	Para. Est. Method	Opt. Distribution	Para. Est. Method	Opt. Distribution	Para. Est. Method	Opt. Distribution
Mwanza	MLM	GAM2	PWM	GAM3	MLM	GAM2	MLM	GAM2
Chikwawa	PWM	WBU2	PWM	GAM3	PWM	GAM2	MLM	GAM2
Nchalo	PWM	WBU2	MLM	GAM2	MLM	GAM2	MLM	GAM3
Ngabu	MLM	GAM2	MLM	GAM2	MLM	GAM2	MLM	GAM2

※ MLM : Method of Maximum Likeloodhood, PMW : Mtehod of Probability Weighted Moments, GAM2 : Gamma 2 parameter, GAM3 : Gamma 3 parameter, WBU2 : Weibull 2 parameter

[Table 2.5-5] Probability Rainfall by Return Period of SVIP Station

Rainfall Station	Rainfall by Return Period(mm)							
	2yrs	5yrs	10yrs	20yrs	30yrs	50yrs	80yrs	100yrs
Mwanza	86.6	111.3	126.0	138.9	146.0	154.5	162.0	165.5
Chikwawa	82.3	109.2	123.1	134.4	140.3	147.0	152.7	155.3
Nchalo	71.0	90.7	100.6	108.6	112.7	117.4	121.3	123.1
Ngabu	78.4	100.1	112.9	124.2	130.4	137.8	144.4	147.4



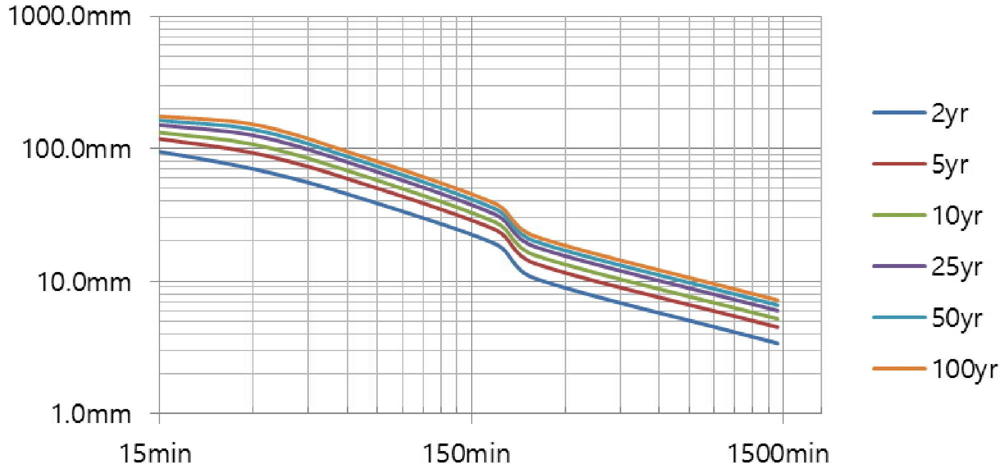
[Figure 2.5-3] Probability Daily Rainfall - Frequency of SVIP Basin

Table 2.5-6 is the rainfall intensity-duration data at lower Shire valley.

[Table 2.5-6] Rainfall Intensity (mm/hr) - Duration Values for Different Return Periods

Return Period	Rainfall intensity (mm/hr) for duration					
	15min	30min	1 hours	3 hours	6 hours	24 hours
2	94.8	70.2	45.4	19.0	10.5	3.4
5	118.4	92.8	59.3	24.3	13.6	4.5
10	132.4	107.6	68.2	27.7	15.7	5.2
25	150.4	125.8	79.2	31.7	18.2	6.0
50	163.2	139.2	87.1	34.9	20.0	6.6
100	175.2	152.4	95.0	38.2	21.8	7.2

(Shela, O. N. R. (1990) Frequency analysis of short duration rainfall intensities in Malawi, Wat. Resour. Branch Report no. TP15, Lilongwe, Malawi)

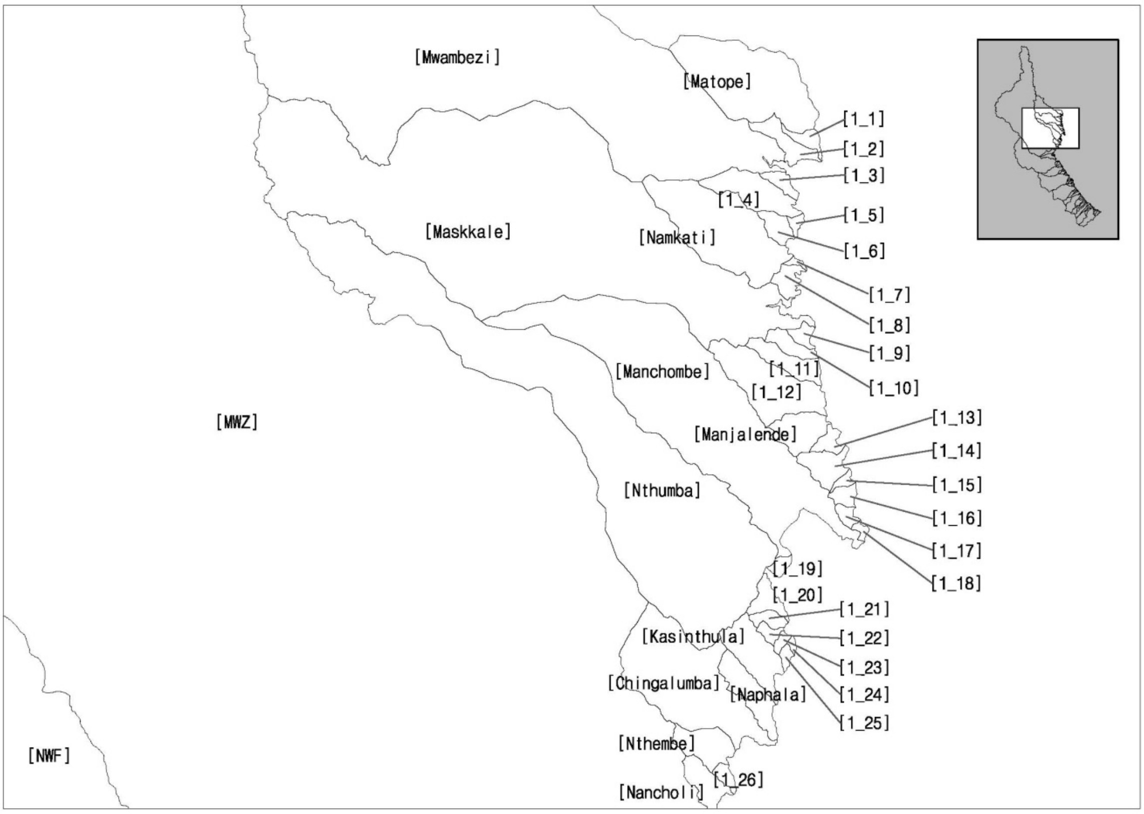


[Figure 2.5-4] Rainfall Intensity - Duration - Frequency Curves

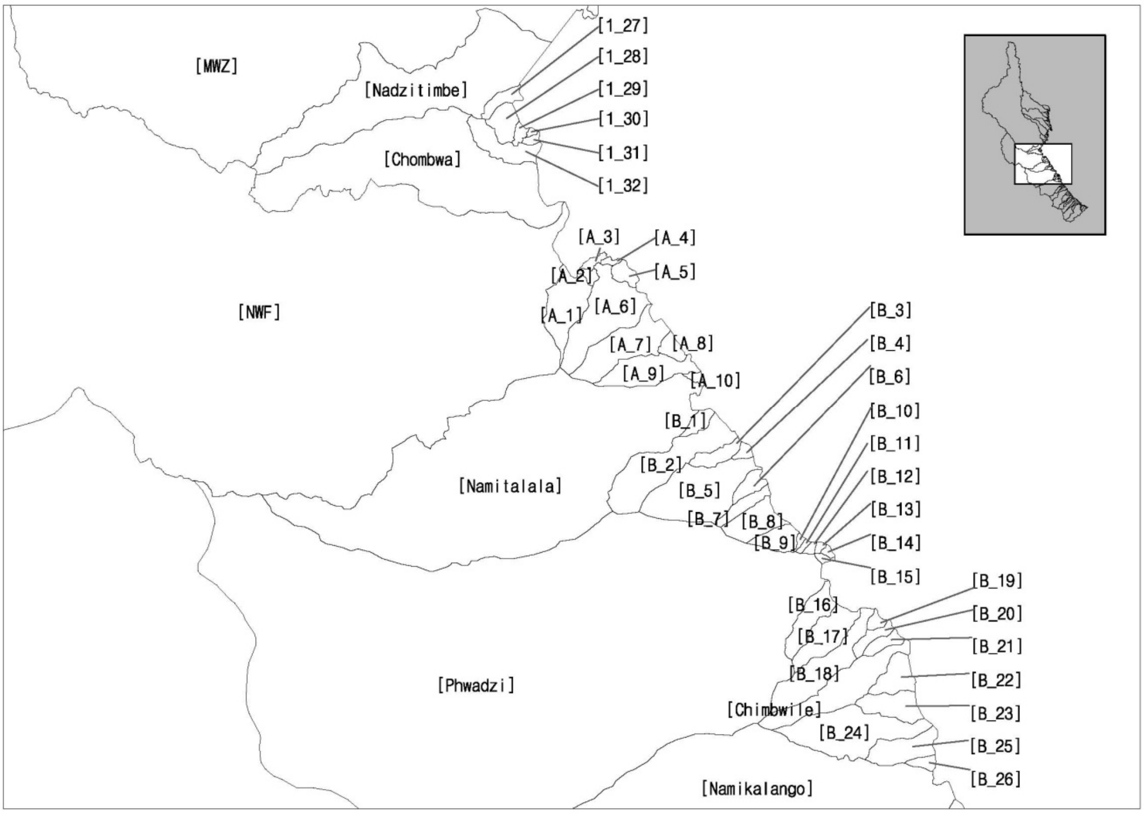
According to Table 2.5-6, rainfall intensity of 2-year frequency and of 1-hour duration is 45.4mm/hr, and rainfall intensity of 10-year frequency is 68.2mm/hr. Rainfall intensity of this size is similar to that exceeding 1,000mm of yearly rainfall. Given that the actual yearly rainfall in the project area is 700mm, this is a relatively high rainfall intensity.

2.5.4. Basin Characteristics

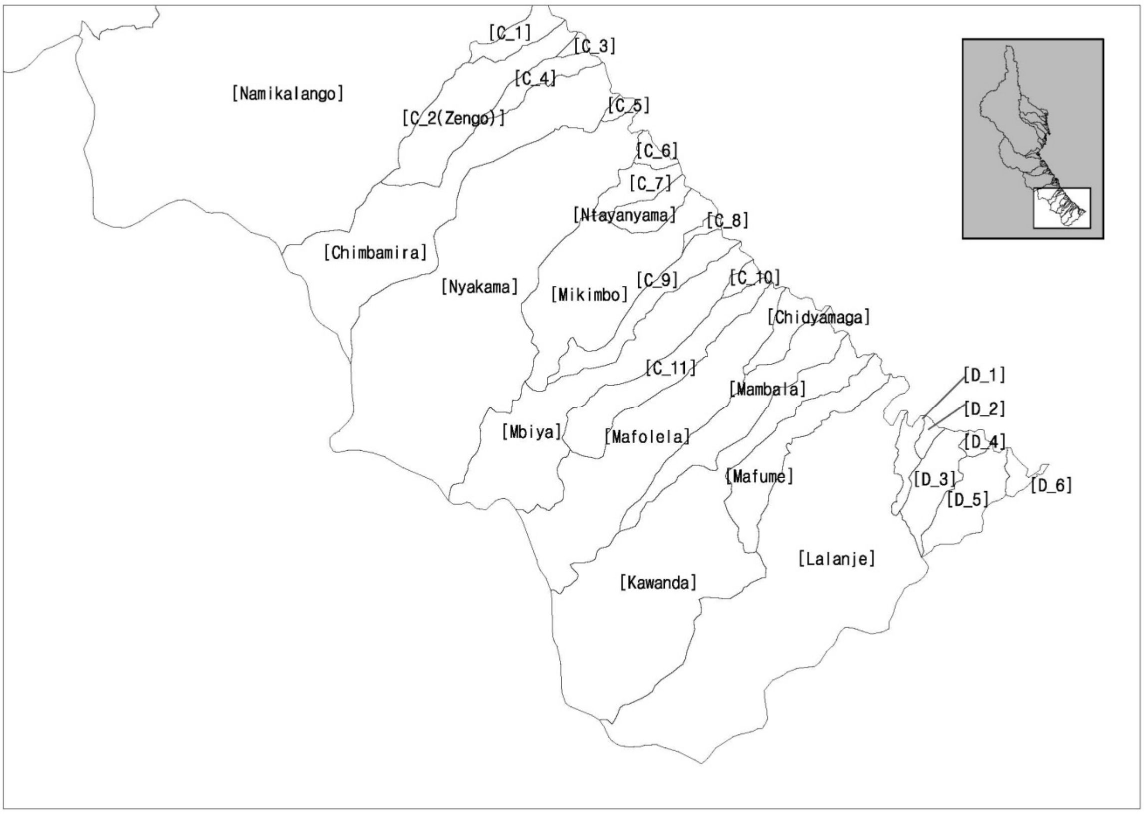
Basin area and extension of a river course are critical in understanding a stream and in analyzing its hydrology. Generally, these two parameters are estimated from topographic maps. During the study, it was noted that 83 catchments within SVIP out of 116 have 0.5 value of basin factors or smaller. It can therefore be inferred from the findings that more than 70% of the basins have a long and narrow shape. Figure 2.5-5 shows the basin of SVIP. Basin factors are presented in Annex 2.



[Figure 2.5-5] Catchment Basin Map of SVIP (1)



[Figure 2.5-6] Catchment Basin Map of SVIP (2)



[Figure 2.5-7] Catchment Basin Map of SVIP (3)

2.5.5. Flood Runoff Analysis

The aim of the flood prevention plan is to develop flood control and prevention measures in order to reduce or prevent flood damage by relating the magnitude of the discharge to the expected return period and the associated flood damage. In the current study, three methods for estimating flood discharge were used, namely; 1) Clark Watershed-Routing Method, 2) SCS Synthetic Unit Hydrograph Method, and 3) Rational Method. And the results obtained are presented in Annex 3.

2.5.6. Regional Flood Frequency Model

Regional flood frequency models find wide application in situations where catchments are not gauged. And since dams have been proposed to be constructed in the project area across rivers which are not gauged, the application of a regional model was an absolute necessity. Under the SVIP project, Mwambezi, Nthumba, Kakoma, Mwanza, Nkombedzi, Phwadzi, Namikalango, Mafume, Dande and Thangadzi rivers are being considered for the construction of dams, and in principle they would require good and long records of annual instantaneous flows from which to calculate discharge values of given return periods. But since such data are not available, a regional flood frequency model was used. The development of a flood frequency model assumes that river basins are homogenous.

2.5.6.1. Rivers Considered

Details regarding selected dams sites from where supplementary water resources for the project could be abstracted are presented in Table 2.5-7.

[Table 2.5-7] Candidate Areas for the Development of Supplementary Water Resources

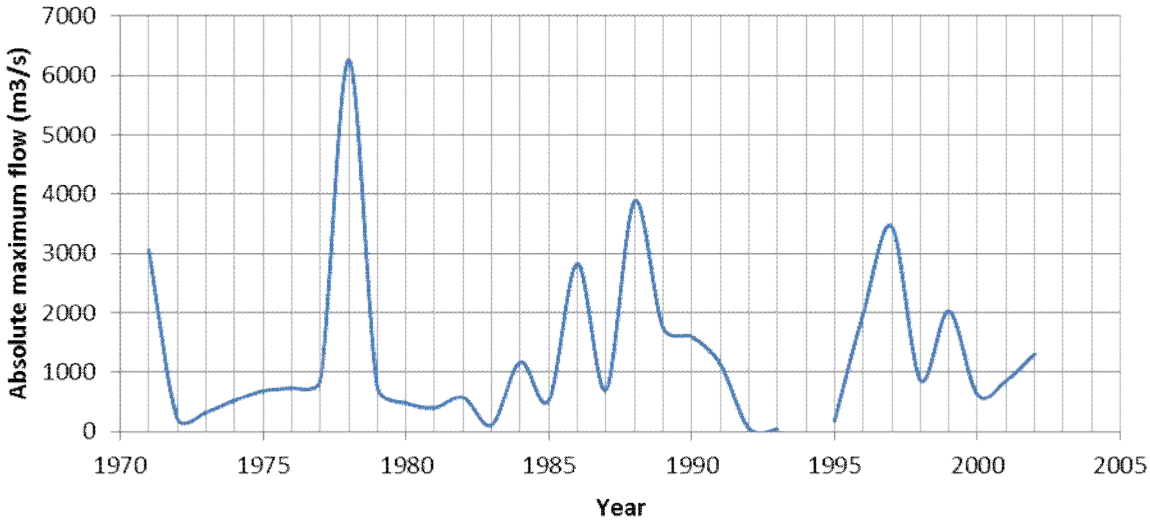
River	Location	Area (km^2)	Type of Dam
Mwambezi	Outside Majete Game Reserve	162	Dam H = 20m; L = 150m
Nthumba	Outside Majete Game Reserve	70	Dam H = 13m; L = 200m
Kakoma	Boundary of Lengwe National Park	49	Dam H = 15m; L = 100m
Mwanza	Between Majete Game Reserve and Lengwe National Park	1,100	Intake barrage
Nkombedzi	Within National Park	195	Dam H = 18m; L = 90m
Phwadzi	Outside of National Park	179	Dam H = 07m; L = 250m
Namikalango	Outside of National Park	135	Dam H = 08m; L = 310m
Mafume	Boundary of Forest Reserve	42	Dam H = 08m; L = 70m
Dande	Outside of Mwabvi Game Reserve	53	Dam H = 07m; L = 300m
Thangadzi	Outside of Mwabvi Game Reserve	223	Dam H = 17m; L = 200m

In order to develop a flood frequency model that could be used for the estimation of design discharge for any point within the Shire River Basin, annual instantaneous maximum flow data for 12 stations within the Shire River Basin were collected from the Department of Water Resources. These are hydrometric stations are listed below:

Mwamphanzi 1E1	-	Left bank of the Shire
Likabula 1E2	-	Left bank of the Shire
Mapelera 1F1	-	Left bank of the Shire
Mwanza 1K1	-	Right bank of the Shire
Wamkulumadzi 1M1	-	Right bank of the Shire
Rivi Rivi 1R3	-	Right bank of the Shire
Nkasi 1S7	-	Right bank of the Shire
Chisombezi 14A3	-	Left bank of the Shire
Thuchila 14B2	-	Left bank of the Shire
Nswadzi 14B3	-	Left bank of the Shire
Ruo 14C2	-	Left bank of the Shire
Ruo 14D1	-	Left bank of the Shire

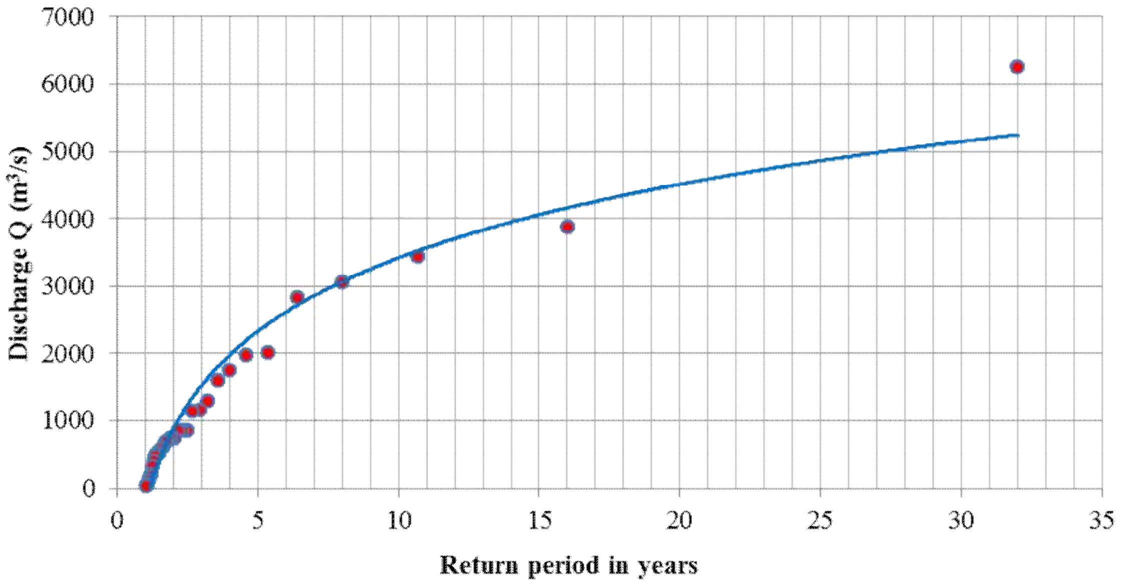
2.5.6.2. Annual Instantaneous Maximum Flows

Annual maximum instantaneous flows (flood flows) were isolated from daily flow data and these were plotted against the years they occurred (Figure 2.5-8). As can be seen in Figure 2.5-8 the highest flood for Rivi Rivi River occurred in 1978 when 6,259m^3/s passed through gauging station 1R3.



[Figure 2.5-8] Annual Instantaneous Maximum Flows for Rivi Rivi 1.R.3

The same procedure was repeated for other stations. A probability plot was then developed for each station as shown by Figure 2.5-9 where the return period was plotted against the discharge.



[Figure 2.5-9] Plot of Q (m^3/s) and Return Period Tr in Years

The relationship for the Rivi Rivi for instance was Q (Tr) = 1571.9 ln(Tr) – 200.33. This relationship had a correlation coefficient of 0.96. Calculations were carried out for 5, 10, 20, 25, 50 and 100 year return periods and the results are presented in Table 2.5-8.

[Table 2.5-8] Calculated Discharges in m³/s at Given Return Periods (years)

River	Area (km^2)	Q(5)	Q(10)	Q(20)	Q(25)	Q(50)	Q(100)
Mwamphanzi 1.E.1	311	97.2	132	168	179	214	249
Likabula 1.E.2	566	58.6	79.0	99.5	106	126	147
Mapelera 1.F.1	61.5	125	189	253	274	338	402
Mwanza 1.K.1	1,650	814	1,237	1,660	1,797	2,220	2,643
Wamkulumadzi 1.M.1	586	146	221	295	319	293	467
Rivi Rivi 1.R.3	775	2,330	3,420	4,509	4,860	5,950	7,039
Nkasi 1.S.7	236	285	448	611	664	826	989
Chisombezi 14.A.3	76.4	312	443	574	616	748	879
Thuchila 14.B.2	1,440	1,550	2,332	3,114	3,366	4,148	4,930
Nswadzi 14.B.3	380	825	1,231	1,637	1,768	2,174	2,581
Ruo 14.C.2	193	211	299	386	415	502	590
Ruo 14.D.1	4,640	2,549	3,606	4,663	5,003	6,060	7,117

2.5.6.3. Homogeneity Test

The method used for testing homogeneity of the river gauging stations of the Shire River Basin used in this analysis is the discordancy measure, also known as the STU-index method which considers the means of the en situ data, including and excluding the largest instantaneous maximum flow values obtained from those stations. The mean annual absolute maximum flow $\bar{Q}1g$ at a particular gauging station g including the largest value in the series is given by:

$$\bar{Q}_{1g} = \frac{1}{n} \times \sum_{i=1}^{n}$$

Where $\bar{Q}1$ is the mean absolute maximum flow including the highest value;
n is the total number of the series;
g is the river gauging station; and
i is the series.

Similary, the mean annual absolute maximum flow $\bar{Q}2g$ at a particular gauging station g excluding the largest value in the series is given by:

$$\bar{Q}_{2g} = \frac{1}{.} \times \sum_{i=1}^{n-1} \qquad \text{………..…………………….(1)}$$

Upon computing the two values $\bar{Q}1g$ and $\bar{Q}2g$ it was possible to calculate the discordancy measure which in this case is represented by the symbol ḍ. The discordancy measure was then computed using the formula:

$$ḍ = \frac{\bar{Q}_{1g} - \bar{Q}_{2g}}{y} \qquad \text{……………………………………………….(2)}$$

Where ḍ is the discordancy measure or the STU index;

$\bar{Q}1g$ and $\bar{Q}2g$ are as explained above; and

y' is as given in the equation below.

$$y' = \left[\frac{\bar{Q}_{1g}^{\;2}}{n} + \frac{\bar{Q}_{2g}^{\;2}}{n-1}\right]^{1/2} \qquad \text{.....(3)}$$

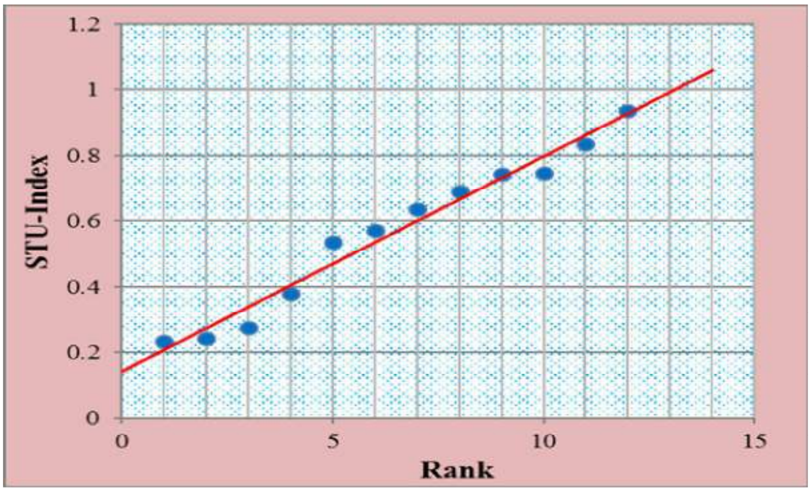
The computed values of d́ from equation (2) were then ranked from smallest to largest valued and arranged against their rank. When plotted, if the resultant plot shows a straight line, then the "region" in which the river gauging stations are located is considered homogeneous. This process was performed for all the stations used in this study as illustrated by Table 2.5-9.

[Table 2.5-9] Computed Values for Calculating STU

River	MWA	LIK	RUO	MKU	NKA	RIV	MAP	CHI	THU	NSW	MWAN	RUO UP
$\bar{Q}_1$	62.55	38.16	1456.91	74.27	127.85	1287.72	61.33	186.20	802.13	436.95	406.73	127.83
$\bar{Q}_2$	59.44	34.98	1133.90	59.33	103.64	1122.01	44.46	173.34	681.43	365.82	322.49	116.22
$\bar{Q}_1 - \bar{Q}_2$	3.91	3.18	323.01	14.94	24.21	165.71	16.86	12.86	120.70	71.13	84.24	11.62
$\bar{Q}_1^2/n$	148.64	91.01	192962	239.83	628.68	53491.1	208.96	1155.68	20755.2	6158.88	6127.01	510.64
$\bar{Q}_2^2/n\text{-}1$	135.89	81.57	128573	160	429.65	41963.6	116.27	1036.1	15478.2	4460.81	4000	435.71
SUM	284.53	172.58	321535	399.83	1058.33	95454.6	325.23	2191.78	36233.5	10619.7	10127	946.35
y'	16.87	13.14	567	20	32.53	309	18.03	46.83	190	103	101	30.76
d'	0.232	0.242	0.57	0.747	0.744	0.536	0.935	0.275	0.635	0.69	0.834	0.378

[Table 2.5-10] Rank and STU Index

Rank	1	2	3	4	5	6
STU-Index	0.232	0.242	0.275	0.378	0.536	0.570
Rank	**7**	**8**	**9**	**10**	**11**	**12**
STU-Index	0.635	0.690	0.744	0.747	0.834	0.935

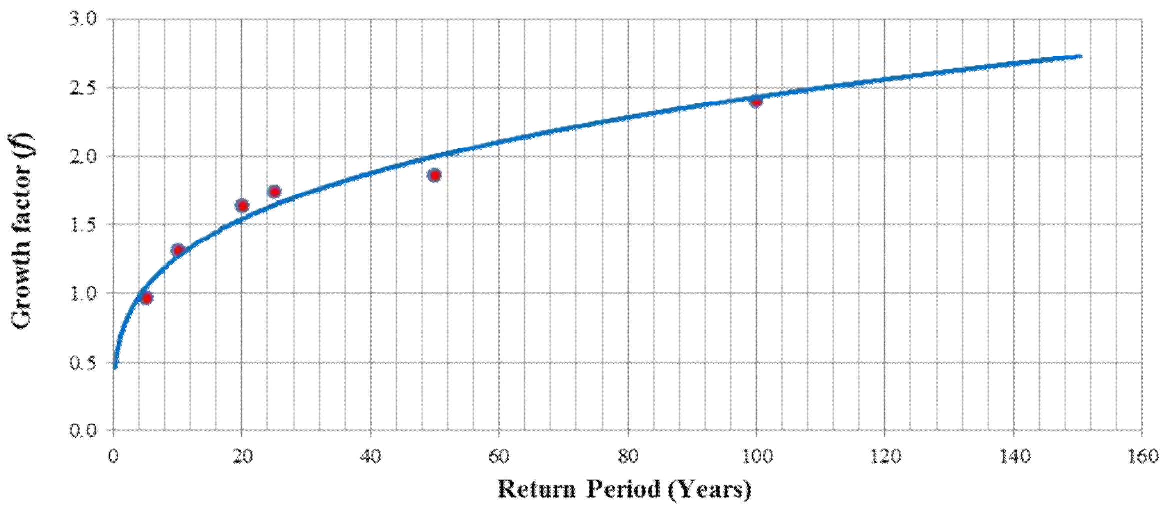


[Figure 2.5-10] Plot of STU Values against Their Rank

As noted from Figure 2.5-10, all the rivers from the West and East Bank show that they are homogeneous since a reasonably good fit (that of a straight line) was obtained. Given that the rivers of both banks of the Shire flow in a homogeneous "region", a regional flood frequency model was then developed with confidence and will be used for calculating the T-Year flood from any gauged and ungauged catchment.

2.5.6.4. The Regional Flood Frequency Model

The regional flood frequency model is developed by establishing how the T-year floods "grow" from say 5 years to 100 years for all the stations to obtain the growth factor. The growth factors are shown in Figure 2.5-11 below.



[Figure 2.5-11] Growth Factors of the Floods of the Tributaries of Shire

The basin area was also plotted against the T-year floods and the relationship between the two was determined. A regional flood frequency model developed for the tributaries of the Shire is is presented below:

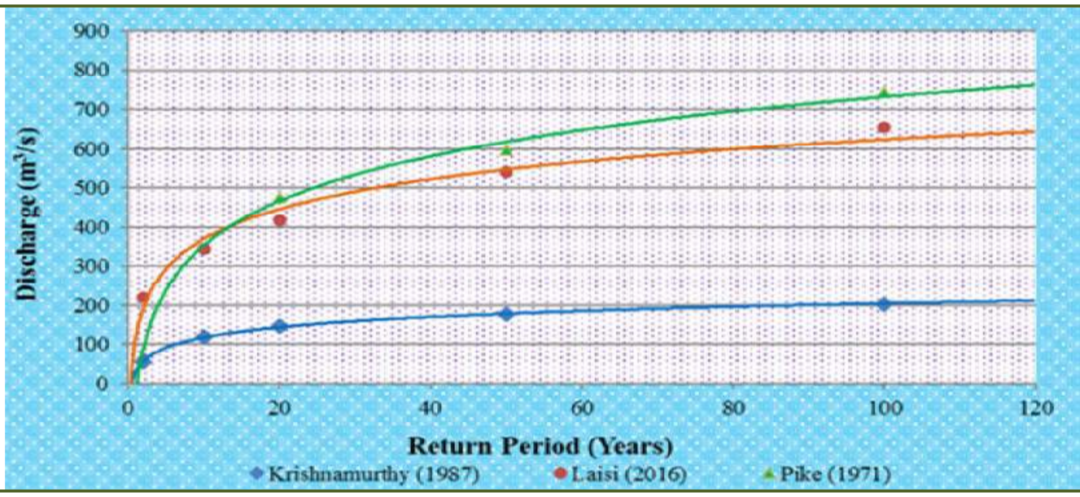
Q (Tr) = 0.66 (Tr) 0.28 . A 0.98

Where Q (Tr) is the discharge in m^3/s for a return period of T-years;

Tr is the return period; and

A is the basin area above the selected point of intervention.

This model was tested (validated) with previous models by Pike and Krishnamurthy and Figure 2.5-12 as shown below. The benefit of the developed model is that it can be used for any size of basin without resorting to any other formula.



[Figure 2.5-12] Results Obtained Using Different Models Developed for Malawi

Using the regional flood frequency model presented above, the T-years flood flows could be computed for the Candidate Rivers under this assignment for dam construction. Table 2.5-11 shows the T-year flood magnitudes for the rivers under consideration.

[Table 2.5-11] Computed Flood Magnitudes for the Candidate Rivers

River	Area (km^2)	Q_2 (m^3/s)	Q_5 (m^3/s)	Q_{10} (m^3/s)	Q_{20} (m^3/s)	Q_{25} (m^3/s)	Q_{50} (m^3/s)	Q_{100} (m^3/s)
Mwambezi	162	117	151	184	223	238	289	351
Nthumba	70	51.5	66.6	80.9	98.2	104	127	154
Kakoma	49	36.3	47.0	57.0	69.2	73.7	89.5	109
Mwanza	1,100	766	990	1,202	1,460	1,554	1,887	2,291
Nkombedzi	195	141	182	221	268	285	346	421
Phwadzi	179	129	167	203	246	262	318	387
Namikalango	135	98.1	127	154	187	199	242	293
Mafume	42	31.2	40.4	49.0	59.5	63.3	76.9	93.4
Dande	53	39.2	50.7	61.6	74.8	79.6	96.6	117
Thangadzi	223	160	207	252	306	325	395	480

2.5.7. Field Survey of the Flooding Area

Site surveys for flooding were conducted at 17 villages in November 2015. The surveys considered the areal extent of flooding, food heights, the duration of flooding, and the frequencies of flooding in the past.

Floods of January 2015 were the most serious floods in the Lower Shire Valley. Most of the flooding takes place in areas along Mwanza and Nkombezi rivers.

Thus, villages near the Mwanza and Nkombezi rivers are vulnerable to flood damage. Since these rivers have shallow depths because they have been filled with sediments washed down from their respective catchments, they experience sever flooding. Results of investigations are presented in Annex 4. The main observations are summarized below:

1) Inquiry investigation survey shows that inundation depth is around 1.0m in most of areas regardless of elevation except for areas in Zone-A located between Mwanza river and Nkombedzi river.

2) According to interviews conducted with the local community, it was noted that there are big differences in their knowledge about flood magnitudes, and hence their information may not be very useful.

3) A concentration of settlements in very low areas around the river banks makes it very difficult to calculate discharge using the slope-area method.

4) Areas along Mwanza river experience severe flooding because of the dramatically reduced cross sectional area of flow of the channel as a result of serious sedimentation that has taken place in the river because of its degraded catchment area.

5) Shire river area is also vulnerable to flooding butnot many people live around Shire river area so flood damage is relatively low.

6) It may be necessary to dredge the bed of Mwanza river and build dykes along it in order to mitigate flood damage. research of residents of flood damaged area shows.

2.5.8. Flood Mapping

Utilization of the Inquiry Investigation Result

The flood zoning map for the project area is expected to be completed during Phase 2 after which adequate data will have been collected by the Consultant. In light of the above, the current flood zoning map was compiled by overlaying satellite video topographic map developed by the World Bank in January 2015 on request by the Malawi Government. Important information was also taken from the Flood Risk Management Report (2015, BRL).

Preparation of Flooding Map

Table 2.5-12 shows the extent of flooding in each zone by return period. These data were obtained from the flood zoning map of SVIP.

[Table 2.5-12] Inundation Area of Each Zone by Return Period

Zone	Total Area	Return Period				
		5 years	10 years	20 years	50 years	100 years
I-1	9,631 ha	59 ha (0.7%)	196 ha (2.2%)	272 ha (3.1%)	272 ha (3.1%)	395 ha (4.5%)
I-2	11,250 ha	1,987 ha (17.7%)	2,458 ha (21.9%)	2,611 ha (23.2%)	3,190 ha (28.4%)	3,601 ha (32.0%)
A	5,199 ha	1,267 ha (25.5%)	1,369 ha (27.6%)	1,415 ha (28.5%)	1,532 ha (30.9%)	1,614 ha (32.5%)
B	9,925 ha	-	4 ha (0.0%)	29 ha (0.3%)	495 ha (5.0%)	837 ha (8.4%)
C	10,749 ha	162 ha (1.5%)	748 ha (7.0%)	906 ha (8.4%)	1,249 ha (11.6%)	1,326 ha (12.3%)
D	4,076 ha	46 ha (1.1%)	101 ha (2.5%)	109 ha (2.7%)	134 ha (3.3%)	141 ha (3.5%)

Analysis of Flooding Status

1) 5- year frequency flood

Low lands of Shire and Mwanza rivers are most vulnerable to 5-year floods. Among them, Zone A in Phase I region is highly prone to flood damage. As Mwanza and Nkombedzi rivers converge at low lying areas of Zone A, and because of the reduced cross sectional area of flow of the channel of Mwanza river, serious flooding takes place in this part of Zone A. The northern part of Illovo Sugar Estate lies within Zone A.

From the hydrological analysis, a 5-year flood has potential to inundate Namikalngo River and low lying areas in Ngabu which fall under Phase II of the SVIP. Such a flood however, may not cause flooding in Lalanje and Thangadzi rivers because of they have adequate channel capacity to convey such a flood and confine it within their respective channels.

2) 10-year and 20-year frequency flood

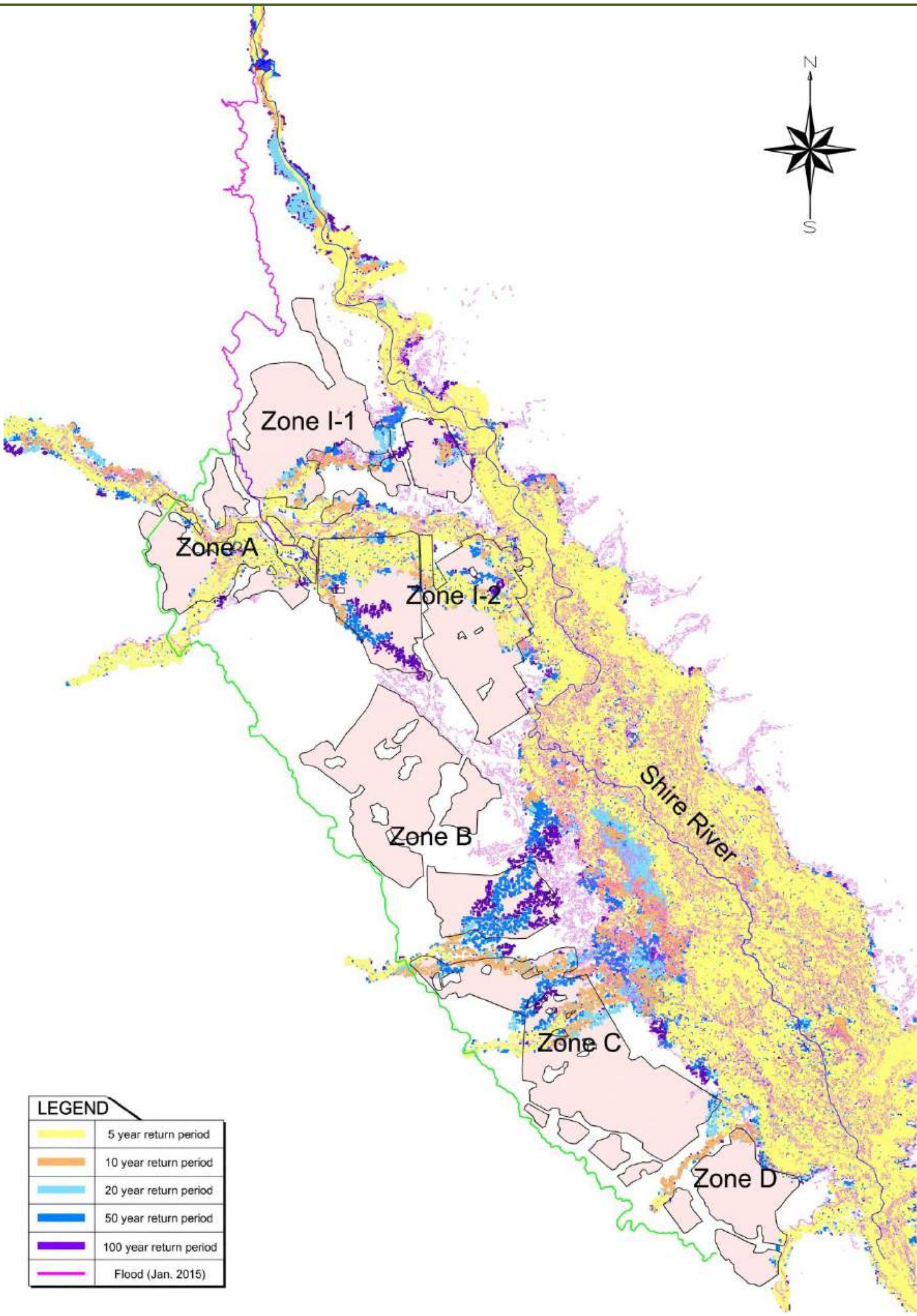
Areas likely to be effected by 10-year and 20-year frequency flood are similar to those that are effected by the 5-year flood, with some areas within Zone C.

3) 50-year frequency flood

Part of Illovo Sugar Estate area is likely to be affected by a 50-year flood. Flooding of Namikalngo River has been noted to cause severe flooding at the Estate, particularly at Alumenda. Severe flooding also takes place at Ngabu.

Evaluation of SVIP Project Area based on Flooding Status Analysis

A 10-year flood is the standard for flood evaluation of farming land. Based on that, results show that Phase I region generally experiences inundation, in particular, areas around Nchalo Sugar Estate area. Also, low lands of Zone A are vulnerable to inundation. Among Phase II regions, limited area of Zone C is prone to flood damage. Most of the project areas except those mentioned above are comparatively safe from a 10-year flood. Thus, SVIP project area is generally safe from the 10-year flood, and hence ideal for irrigation farming. But for those areas prone to flood damage, there will be need to put in place appropriate flood mitigation measures.



[Figure 2.5-13] Flood Map for the Project Area

2.6. Socio-Economics

TOR Requirements

- Develop a socio-economic survey in Phase I and II areas and use the findings to establish the "without project situation" (in particular crop budgets). The survey should include, but not be limited to, collection and critical review and analysis of all available data and information relating to the existing cropping patterns, farming systems, land tenure and holdings, prices, costs and returns in the proposed irrigation development areas; Given that the Socio-Economic service provider will also carry out a socio-economic survey, both Consultant shall closely liaise in order to avoid duplication and share data and results.
- Carry out an analysis of existing and potential value chains for smallholder farmers / smallholder organizations and prepare detailed cropping patterns, crop budgets and farm models for the most promising options, with a clear exposition of the origin and validity of prices used and feed this information in a participatory verification exercise and value chain development support facilitated by the Socio-Economic provider;

2.6.1. Socio-Economic Situation of the Project Area

2.6.1.1. Shire Valley Agricultural Development Division *(Cited from the SVADD term reports)*

General Information

Shire Valley Agricultural Development Division (ADD) is one of the eight ADDs in the country. The ADD consists of two administrative districts of Chikwawa and Nsanje. These districts are divided into 11 Extension Planning Areas (EPAs) which are further subdivided into 184 agricultural extension sections. The estimated total area for the ADD is 684,000 hectares with Chikwawa occupying 490,000 hectares and Nsanje 194,000 hectares. The total cultivatable land for the ADD is 313,215 hectares (257,902ha for Chikwawa and 55,308ha for Nsanje). The ADD has a total of 163,706 farm families with 104,681 in Chikwawa and 59,025 in Nsanje. The climate of Shire Valley is characterized by very high temperatures (25 ^{0}C to 40^{0}C) combined with low and erratic rainfall (400 mm to 800 mm) where weeks of dry spells are common during the rainy season (Meteorological Data, 2005). But, ironically, Shire Valley ADD is prone to flooding which is largely generated by gross mismanagement of the environment in the upper catchments of the Shire River and its numerous tributaries. Naturally, this phenomenon often affects agricultural and other infrastructural development.

2.6.1.2. Natural Disasters

Floods

The ADD was affected by heavy floods between January and February, 2015. A total of 19,060 hectares of cropping area was affected. The extent of damage to the crops ranged from 75% to 100% production loss for the affected areas. The total number of households affected by the floods was 70,416. This number is for households whose crops and livestock were affected by floods. The crops that were affected include: maize, millet, rice, sorghum, ground nuts and cotton. The floods lowered yield and production prospects as some fields were washed away. Initially, it was estimated that area for the irrigated season, yields and production would increase due to increase in area under residual moisture and adequate available moisture. However, now this assumption is not true because some areas were heavily silted and others had the top layer developing a hard surface that is difficult to work with. There has also been an accelerated depletion of residual moisture which has affected crop productivity. Refer to Table 2.6-1 and 2.6-2 for the effects of floods in the ADD on crops.

[Table 2.6-1] Summary of the Effects of Floods by Crop as at 30th June, 2015

Affected Crop	Affected Area (ha)	Affected Farm Families
Maize	10,792	31,368
Sorghum	1,524	4,499
Millet	907	3,674
Rice	4,269	26,770
Cotton	1,531	4,105
Sweet potato	20	96
Ground nuts	17	161
ADD-Total	19,060	70,416

(Source: 2014/15 SVADD Third Round APES Report)

[Table 2.6-2] EPA Summary of the Effects of Floods as at 30th, 2015

DISTRIC/EPA	Planted Area (ha)	Affected Area (ha)	% Affected Area	Affected Farm Families	Extent of Damage
Kalambo	14,138	877	6	2,710	Severe
Mbewe	20,486	2,127	10	8,701	Severe
Mitole	17,557	1,726	10	7,520	Severe
Livunzu	11,888	3,018	25	17,689	Severe
Mikalango	30,113	1,435	5	5,046	Severe
Dolo	15,667	720	5	2,356	Severe
Sub-Total	**109,849**	**9,903**	**9**	**44,022**	**Severe**
Makhanga	9820	6,620	67	16,400	Severe
Magoti	6769	141	2	363	Severe
Mpatsa	7416	510	9	2,613	Severe
Zunde	8046	1,380	17	4,520	Severe
Nyachilenda	8790	506	6	2,498	Severe
Sub- Total	**40,841**	**9,157**	**22**	**26,394**	**Severe**
ADD TOTAL	**150,690**	**19,060**	**13**	**70,416**	**Severe**

(Source: 2014/15 SVADD Third Round APES)

The floods also affected livestock production where a total of 450 cattle, 9,216 goats, 44 sheep, 1,639 pigs and 69,760 chickens died among other livestock species. For details refer to Table 2.6-3 below.

[Table 2.6-3] Loss of Livestock due to Floods in the ADD

Livestock Species	Chikwawa District			Nsanje District			Add Total		
	Pop.	No Affected	No Died	Pop.	No Affected	No Died	Pop.	No Affected	No Died
Cattle	145,053	21,082	64	37,256	9,764	386	182,309	30,846	450
Goats	268,756	80,635	1,451	143,466	100,000	7,765	412,222	180,635	9,216
Sheep	5,191	925	11	1,529	1,102	33	6,720	2,027	44
Pigs	91,253	26,593	328	44,288	31,000	1,311	135,541	57,593	1,639
Chicken	554,114	148,535	24,463	535,074	382,000	45,297	1,089,188	530,535	69,760
G/fowl	64,874	13,565	1,182	57,390	21,870	13,321	122,264	35,435	14,503
Ducks	58,368	3,598	1,121	75,668	23,100	9,021	134,036	26,698	10,142

(Source: 2014/15 SVADD Third Round APES Report)

Furthermore, the floods affected fishing and fish farming activities in the ADD by flooding fish ponds to the extent that some fish were washed away from the ponds.. A total of 17 fish ponds covering an area of 7,550m^2 were affected and currently need major maintenance.

The floods also damaged road infrastructure and a number of institutional structures. In Makhanga EPA, the floods damaged the EPA offices, all institutional houses for members of staff and motorcycles as they had remained if flooding water for a period of over 2 weeks. The floods had also washed away household items, kitchen utensils and other personal belongings in staff houses in Makhanga EPA.

Dry Spells

The ADD experienced dry spells from mid-February 2015 to the time farmers were harvesting their summer crops. The dry spells affected crop production because they occurred when most of cereal crops were at reproductive stage. They caused wilting in most crops especially cereals which were at reproductive stage. The dry spells led to premature drying of cereals and boll drop in cotton.

During the first half of 2015/16 season, the ADD started receiving planting rains in mid December 2015 that prompted farmers to plant crops in their field. However this was followed by dry conditions to the extent that most areas in the ADD did not receive rains for a period more than two weeks. The current dry spells are already negatively affecting crop development that will in turn affect crop yield. Some crops that were planted had difficulties to germinate due to lack of moisture since rains tailed off within the same period that crops were planted. Those that germinated experienced moisture stress conditions which led to wilting of crops especially cereals in the fields. However, for crops grown in the dimbas are better off than those grown in the upper dry land.

2.6.2. Agricultural Situation

2.6.2.1. Existing Cropping Pattern

Most of the agricultural production is under rainfed and crops are planted in November/December and harvested after 3~5 months (April/May) depending on the type of crop. During the dry season (April/May to October), irrigation farming is practiced at a small scale by smallholder farmers along the Shire river except for Kasinthula research station and commercial farms under Illovo. There are a number of crops grown by in the area primarily for household consumption with an exception of cotton and sugarcane as cash crops (See Table 2.6-4). The main crops grown by smallholder farmers are maize, sorghum, millet, cotton, sweet potatoes, cassava, rice, groundnut, vegetable crops, pigeonpea, cowpea, sesame, common beans, cassava and tropical fruits (pawpas, mangoes, bananas, and citrus fruits).

Farmers practice both sole and intercropping. Sorghum, maize and millet are usually intercropped with cowpea or pigeonpea or beans. Cotton is primarily sole cropped, however, some farmers intercrop cotton with cowpea to optimize use of pesticides applied to cotton. Crops planted in sole stands are rice, groundnut, sweet potatoes and cassava.

2.6.2.2. Estimated Crop Yields

Table 2.6-4 show results on estimated grain yields for some crops on smallholder farmers Chikwawa district compared to the national average and potential yields.

[Table 2.6-4] Estimated Yields for Some Crops Grown on Smallholder Farms in Chikwawa District

Crop	Yield (kg/ha)	National average yield ** (kg/ha)	Potential Yield ** (Kg/ha)
Maize (Rainfed)	100 ~ 1,500	2,000 – 3,000 (Hybrid);	6000 – 10000 (Hybrid)
Maize (Irrigated)	1,000 ~ 2,000	1,400 – 2,400 (OPV)	5,000 (OPV)
Sorghum	350 ~ 1,400	600	3000-3,400
Millet	250 ~ 500	500-800	2,000
Rice (unmilled)	1,500 ~ 2,250	Rainfed : 1,000 – 1,500 Irrigated : 4,000	Rainfed: 2,500 – 4,000 Irrigated: 6,000
Cotton	400 ~ 800	700-800	2,500 – 3,000
Pigeonpea		400-800	2500
Cowpea	700	300-600	2000
Beans	100 ~ 1,200	300-800	2,000 – 2,500

*Compilation from focus group discussions conducted in February 2016
**National average yield in Malawi reported by the Ministry of Agriculture and Food Security (2012)

2.6.2.3. Cost of Production

Information on cost of production for the main crops grown in the area was collected through FGDs and results are presented below for the various crops in the EPAs.

[Table 2.6-5] Cost of Production

Crops	Cost (MWK/acre)	Cost (MWK/ha)	Remarks
Maize	209,921	518,322	
Cotton		497,984	
Sorghum	132,600	327,407.41	
Tomato		476,049	
Bean	518,957	29,830	
Rice	50,500	841,666	

2.6.2.4. Prevailing Prices of Major Commodities in the ADD

Marketing of both crops and livestock had continued in the ADD. The prices of maize and most other products were higher this period than they were same time last year due to scarcity of the commodities in the ADD as detailed in Table 2.62.6-6 below. These prices are farmgate prices that is taking into consideration cost of production. They are average prices vendors were buying from farmers in the district on average.

[Table 2.6-6] Prevailing Prices of Some Commodities as at 30th June, 2015

Commodity	Unit	Average Prices per Kilogram	
		This Season 2014/15	Last Season 2013/14
Maize	Kg	K130.00	K110.00
Rice Polished	Kg	K477.00	K412.00
Phaseolus beans	Kg	K753.00	K681.00
Groundnuts (shelled)		K611.00	K591.00
Cow Peas	Kg	K333.00	K337.00
Pigeon peas	Kg	K429.00	K343.00
Cassava	Kg	K180.00	K168.00
Sweet potatoes	Kg	K204.00	K132.00
Tomato	Kg	K193.00	K278.00
Bananas	Kg	K222.0	K200.00
Cabbage	Kg	K159.00	K185.00
Chinese cabbage	Kg	K197.00	K160.00
Goat meat	Kg	K1,200.00	K1,200.00
Beef	Kg	K1,200.00	K1,200.00
Hen	Each	K2,000.00	K1,250.00
Cock	Each	K2,400.00	K1,750.00
Broiler	Each	K2,500	K2,000.00
Guinea fowl	Each	K1,700.00	K1,200.00
Beef Cattle	Each	K150,000.00	K135,000.00
Live oat	Each	K150,000.00	K12,000.00

Source: 2014/15 SVADD Third Round APES Report

2.6.2.5. Gross Margins

Gross margins for potential crops are shown in Table 2.6-7. The variable costs of the different crops were estimated during the focus group discussions with farmers in the study area. All crops have potential for high productivity. Overall, seed maize gives the highest gross margins followed by pigeonpea, beans, cotton.

[Table 2.62.6-7] Gross Margins (MK/ha) of Potential Crops

Variable	Maize grain	Maize seed **	Sorghum	Cotton	Rice	Pigeonpea	Common bean**	Tomatoes**
Total variable costs * (MK/ha)	518,322	518,322	255,391	497,985	841,667	240,000	518,957	1,484,697
Estimated yield (kg/ha)	5,000	4,000	2,500	2,000	1,500-4,000	1,800	2000	30,000
Price (MK/kg)	160	400	120	350	500	400	600	180
Income (MK/ha)	800,000	1,600,000	300,000	640,000	1,000,000	720,000	1,200,000	6,300,000
Gross Margin (MK/ha)	281,678	1,081,678	44,609	142,015	158,333	480,000	681,083	4,815,303

*Source: Compilation for FGDs conducted in February 2016 as indicated in Tables 15-20 except for pigeonpea. The cost excludes the cost of irrigation water for winter production
**Recommended for winter production only.

2.6.3. Irrigation Farming

The department is mandated to facilitate the increase and stabilization of agricultural production through promotion of small and large scale irrigation projects with human and financial resources provision from the beneficiaries, the private sector, NGO's and the public sector. Shire Valley ISD is therefore facilitating use of irrigation technologies with due attention to efficient utilization of water resources. Some of the technologies that are being promoted for the smallholder irrigation include:

- Small scale gravity fed irrigation schemes
- Small scale motorized pump based irrigation schemes
- Treadle pump based irrigation schemes
- Watering cans

Since 2010/11, area under sustainable irrigation in the ADD has been fluctuating due to a number of reasons as is indicated in Table 2.6-7 below;

[Table 2.6-7] Area under Sustainable Irrigation

Year	Area (ha)	Remarks
2010/11	2,852	This was the baseline figure
2011/12	3,246	Increase in area under sustainable irrigation due to continued inflow of treadle and motorized pum s into the ADD
2012/13	2,917	Area under sustainable irrigation decreased as two big irrigation schemes in the ADD (Muona and Nkhate) were undergoing rehabilitation with support from IRI-ADP
2013/14	2,984	There was no significant change in area as there were frequent breakdowns of motorized pumps coupled with scarcity of spare parts for motorized pumps
2014/15	3,500	The ADD is projecting a total area of 3,500ha under sustainable irrigation as the two rehabilitated schemes are now operational. Additionally 6 more schemes have being developed by different Government projects and NGOs such as AISP and SIVAP.

(Source: SVADD's ISD Annual Report, 2014/15)

Using resources from AISP, the ADD has managed to complete construction of all the 5 schemes which were under construction covering an area of 293.6ha and these include; Mkulowamitete, Ntolongo, Nyamphembere and Makhapha in Nsanje district and Mittawa in Chikwawa district. Thima and Chidzimbi are new sites in Chikhwawa district which, are yet to be reviewed and tendered out.

[Table 2.6-8] Status on Construction Works of AISP Solar Powered Schemes in SVADD

ID	Name of Scheme	Area (ha)	Remarks
I	Mittawa	33.6	Intake and the pumping sump not yet constructed. Most of the earth canals were however damaged by the floods and some fields also got silted up.
2	Makhapa	150	All works completed except installation of pumps and solar panels. The flood protection bund was partly scoured by the floods and minor damage was noted on drains.
3	Nyamphembere	30	Intake, pipe line from the intake to the sump and pumping sump were designed and are awaiting construction. Some parts of the flood protection bund were washed away by the floods.
4	Ntolongo	41	Pumping sump was constructed but was washed away by the floods. The contractor is on site re-constructing the sum
5	Nkulowamitete	36	The pipeline is supposed to be redone as the flow of water from the intake to the sum is not ood enou h.

(Source: SVADD's ISD Annual Report, 2014/15)

Using IRLADP funds, under the irrigation rehabilitation and development component, the project was rehabilitating government irrigation schemes, constructing new small scale schemes and developing mini irrigation schemes. In Shire Valley ADD, Nkhate and Muona Irrigation Schemes were selected for rehabilitation and the schemes are currently operational. The project was also involved in rehabilitating Mchere irrigation scheme in Mpatsa EPA.

Under SIVAP, the ADD will develop four (4) irrigation schemes covering a total area of 1,012ha. Under phase 1, the project has managed to rehabilitate a total of 125ha of land at Masenjere irrigation scheme in Nsanje district and to date; the identified and engaged contractor in the name of Foundation for Irrigation and Sustainable Development (FISD) managed to;

- Construct a river diversion weir.
- Install 465.72m of main pipe line from the intake structure.
- Construct an energy dissipater at chainage 466m from the intake weir.
- Construct a lined main canal of 1470.61m long.
- Construct lined secondary canals with a total length of 948.41m.
- Construct lined tertiary canals with a total length of 4000m.
- Construct irrigation system structures including division boxes and drop structures.
- Construct culverts.
- Construct access roads and
- The flood protection bund.

Under phase 2, the project will develop 3 schemes in Chikwawa district. So far the project has managed to conduct the following activities in three schemes of Chilengo, Likhubula and Mwamphanzi which would be developed under the phase two of scheme development;

- Irrigation Engineers from DOI have completed designing Chilengo irrigation scheme(conducted profile surveys and review of the designs was done)
- SMEC consultants who are being paid by Irrigation Rural Livelihoods and Agriculture Development Project (IRLADP) have completed designing Likhubula scheme
- GOPA consultants who were being paid by Rural Income Diversification Project (RIDP) have completed designing Mwamphanzi irrigation scheme in Chikhwawa.

[Table 2.6-9] Summary of Works Done in SIVAP Project Sites

ID	Name of Scheme	Total Area	District	Progress Made
1	Masenjere (phase 1)	125 ha	Nsanje	Construction works completed (100%)
2	Chilengo (phase 2)	250 ha	Chikhwawa	Designs already done by Department of Irrigation, waiting for construction works by SIVAP
3	Likhubula (phase 2)	300 ha	Chikhwawa	Designs for the scheme being done by SMEC in progress
4	Mwamphanzi (phase 2)	377 ha	Chikhwawa	Designs for the scheme already done by GOPA, waiting for construction works by the project

(Source: SVADD's ISD Annual Report, 2014/15)

2.6.4. Land Use in the SVIP Areas (This section used the report of CCPLT&RPF team)

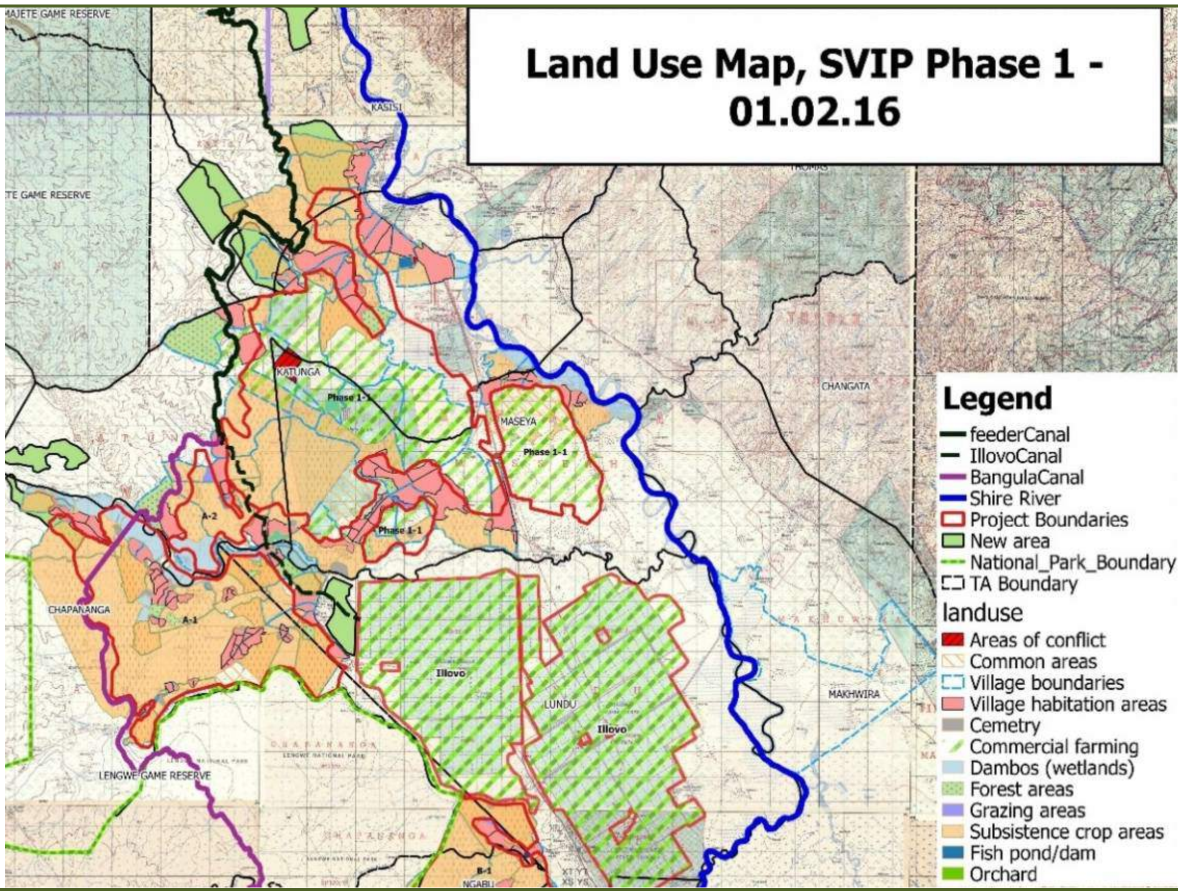
General land use in both SVIP phase areas is summarized in Table 2.6-10 below.

[Table 2.6-10] SVIP General Land Uses

#	Land Cover	Land Use	Phase 1 Area		Phase 2 Area		Total SVIP Area	
			Ha	%	Ha	%	Ha	%
1	Agriculture	Commercial/ sugar cane	16,122*	51,8	5,919	20	22,041	36,3
		Pastoral/ grazing	57	0,2	2196	7,4	2,253	3,7
		Crops/ subsistence farming	8,858	28,5	15,552	52,5	24,410	40,2
		Orchard/ tree crop	3	0,0	0	0	3	0,0
2	Settlement	Habitation	3,555	11,5	3,846	13,0	7,402	12,2
3	Other	Wetlands (*dambos*)	1,248	4,0	43	0,1	1,290	2,1
		Cemeteries	173	0,6	240	0,8	413	0,7
		Forests	886	2,9	1,726	5,8	2,611	4,3
		Fish ponds	30	0,1	4	0,0	24	0,1
		Other	118	0,4	110	0,4	228	0,4
	TOTAL		**31,050**	**100,0**	**29,635**	**100,0**	**60,686**	**100,0**

The total areas covered are 31,050 has in phase 1 and 29,635 has in phase 2. This is 30% more than the 21,015 has for phase 1 and 21,485 has for phase 2 indicated as project areas in the TOR. The reason is that at the time of the field registration the canal route and potential irrigation areas were not yet defined by the TFS and the field study had to be completed before the onset of the rainy season. Therefore, it was decided to cover all Villages or Group Villages located partly or completely within the project area defined by the TOR to ensure that all areas of the SVIP will be covered. Thus around 30% additional area in phase 1 and 27% in phase 2 were registered during the field investigations, as can be seen in the Land Use Map for phase 1 below in Figure 2.6-1, where the project area boundaries are marked with thick red lines.

Commercial agriculture in the Shire Valley is dominated by sugarcane production in over 50% of the phase 1 area. This is primarily the Illovo estate, who occupies around 12,000 has. There are also two smallholder sugarcane farms – Kasinthula with 1,340 has and Phata, which is in the process of implementing a second phase, bringing the total area of commercial crops up to 800 has. In addition, another cooperative is being established, named KAMA, which is going to produce sugarcane on a 2,000 has area adjacent to the Kasinthula scheme initially and intends to expand to 6,000 has in the future. KAMA has entered into a business agreement with the ethanol company Presscane. The outgrowers' organizations will be described in more in details in the following chapter 4.



[Figure 2.6-1] Land Use Map. Phase 1

For the remaining crop areas, the dominant farming system is maize-mixed. According to the household questionnaires, maize accounts for approximately 24% of agricultural land use and is planted mainly for subsistence purposes together with pearl millet (31%) or sorghum (18%). An important cash crop is cotton (17%), while beans and rice only accounts for 3 and 4% of the area. Livestock are mainly kept by farmers on post-harvest crop residue fields and small open-access grazing areas; only a few communal grazing area were identified in the inventory.

2.6.5. Livestock Production

The main types of livestock found in the area include cattle, goats, chickens, pigs, ducks, guinea fowl, mbira, rabbits, sheep and pigeons. These are kept for food, source of livelihood and manure for improving soil fertility. Problems with livestock production include diseases, shortage of forage and drinking water and fodder during the dry season, and theft. In some areas, there are conflicts between crops and livestock such as in conservation agriculture where crop residues are retained in the field and a farmer with livestock would like to feed crop residues to cattle. Another conflict is on the long duration crops or crops grown in dry season may be grazed by livestock as livestock are left on free range system

2.6.6. Land Tenure

No public land, including government land, were found within SVIP except the Lengwe National Park, where the Bangula Canal will pass for a 14 km long stretch.

Private Leaseholds

An investigation of the private leaseholds at the Regional Lands Office in Blantyre and at the Deeds Registry in Lilongwe reveals that a relatively large part of the SVIP project area is private owned land held by leasehold titles, mainly due to the existence of the large Illovo sugar estate. Also Kasinthula outgrowers' scheme has obtained a lease on a part of their area and other large private properties are owned by Presscane, S.V. Cattle Ranch and Crown Plantation, as shown below in Table 2.6-11.

There also exists a number of smaller private leases, but the majority of these are outside the SVIP area or located within village habitation areas, and will therefore not be in conflict with any land allocation related to the irrigation scheme.

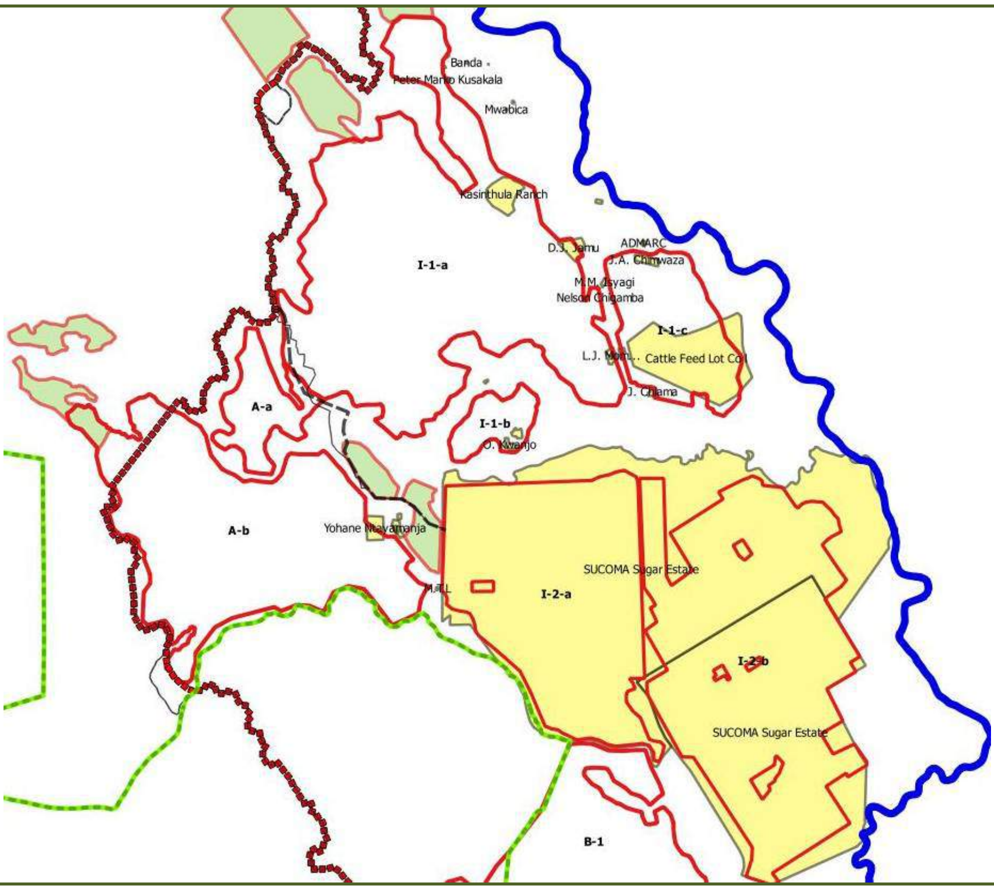
In total 36,1% of the SVIP area is private owned as opposed to only 11% as an average for the district. In phase 1 48,2% of the SVIP area is private owned.

[Table 2.6-11] Private Leaseholds within SVIP Area

	Total Area	Net Area	Private leaseholds	Part of leases within SVIP	%
Phase 1	25,057	21,410	15,430	12,067	48.2%
Phase 2	24,750	21,090	8,353	5,905	23.9%
Total	49,807	42,500	23,783	17,972	36.1%

Name of leaseholders	Illovo	Kasinthula	Presscane	Crown Plantation	Sande Ranch	Others
Phase 1	11,939	99	0	0	0	34
Phase 2	3,188	0	1,155	249	1,257	71
Total	15,127	99	1,155	249	1,257	105

Figure 2.6-2 below shows the private leases in phase 1. Illovo (earlier named Sucoma Sugar Estate) has a private leasehold for more than 15,000 hectares, including the lease for Cattle Feed Lot Co. However, only around 12,000 hectares are within the SVIP area. Apart from Illovo, only Kasinthula Ranch has a lease of 99 hectares and other small leaseholders cover 34 hectares.



[Figure 2.6-2] Private Leaseholds in Phase 1

The private leaseholds in phase 2 can be seen in the Figure 2.6-3 below.

The two large irrigation schemes Alumenda owned by Illovo (Sucomo Sugar Estate) and Kaombe (Presscane Ranch) have private leaseholds. Another large private leasehold held by S.V. Cattle Ranch covers the whole of the potential new area north of Alumenda.

Further, Crown Plantation has two leaseholds in area B-b with a total area of 249 hectares and another 7 private leaseholds with a total area of 71 hectares are wholly or partly affected by the SVIP. Several of these private leaseholds are located within the irrigation zone B-b.

When comparing the extension and location of the smaller leaseholds with the situation in the field as can be seen in the orthophotos, there are a number of these leaseholds which don't seem to be active, since there cannot be registered any boundaries in the orthophotos. A verification in the field on whether leaseholds are active or not will be carried out for the leaseholds located close to or within the proposed future irrigation blocks.

[Figure 2.6-3] Private Leaseholds in Phase 2

Customary Tenure

Customary tenure is the predominant landholding system in the SVIP in 64% of the project land area. In customary areas, land is held by families usually by a male member (81%), sometimes by a female member (15%), and less frequently both men and women (usually as spouses) are joint rights-holders to their land (4%). Of the male land owners, 35% is under the age of 35 and of the female owners 29%[2].

Almost all landholders have acquired their land by inheritance directly from either their father or mother[3]. Almost all land has been allocated. Land scarcity means that access to land through allocation by a family head or traditional authority (chief, group village head or village head) is now uncommon.

Tenure is generally perceived as secure, probably due to the centrality of inheritance law in the customary landholding system. Traditional authorities have no direct role or influence on how land is assigned to family heirs. Land transfers or sales to non-family members or to persons from outside the community or village are prohibited, although land rentals are less restricted. Only when land is abandoned does a traditional authority or family head once again have a direct role in (re)allocating rights to that land.

The inventory, questionnaire survey and informant interviews did not reveal any cases of informal landholding, either over private, public or customary land. In all cases people were found occupying

2 Results from the household interviews.
3 National Census of Agriculture and Livestock 2006/2007. NSO, April 2010

and using land within the law – statutory or customary – or with the consent of a recognized authority – official, traditional or family.

2.6.6.3. Producer Organizations

Trusts and Farmers' Groups

For the proposed SVIP, an organisational set up with a Trust, secondary association and several primary associations on the ground would work to facilitate contract farming. The Trust would acquire ownership of land through a long-term lease, develop and administer the aggregated land for irrigation on behalf of the farmers. This would be an arrangement similar to what is currently happening at Kasinthula and Dwangwa. However, if this Trust is perceived as a government institution (with strong government representation), there is a risk of misconception of the transfer of ownership of the aggregated land from customary land tenure to the Government. This would spark wide spread conflict in the project area particularly if the issue is politicised.

Associations

In terms of farmer organizations for specific enterprises or in specific geographic areas within the proposed project impact areas, associations would work well. At the grassroots level, farmers would be organised into clubs. These are face-to-face groups for farmers working together on specific enterprises. Several clubs would be grouped into some zonal organisational structure and several of these zonal organisational structures would form an association. The entire project area would have 3 to 4 associations under one overall committee with equal representation from all the associations. Associations are easier to organise but are more informal with a less business focus by members particularly on mobilisation of resources.

Cooperatives

Despite the many practical problems associated with the institutionalisation of cooperatives in Malawi, the concept of cooperatives is attractive for the proposed SVIP. The focus on pooling resources for a joint enterprise is in-line with the focus of establishing commercial based agricultural systems for the SVIP. There are two key areas of the proposed SVIP where the concept of cooperatives is particularly relevant. The first, is the need to pool pieces of land owned by different households or families into big chunks of land suitable for irrigation development. Communities would be encouraged to form cooperatives that would pool their pieces of family land for irrigation development as their own business. Where households have no interest or capacity to participate in irrigation, they may still pool their land to earn income through sub-leasing or renting out to those who would use it for irrigation. Considering the complexities in the community, the processes to initiate cooperatives will need to be based on critical conversations involving as many stakeholders as possible in order to clear out any misconceptions and conflict and let community members start negotiating alliances as the basis of cooperatives.

Secondly, the agricultural systems currently prevailing in the proposed areas for the SVIP are predominantly subsistence, the proposed SVIP will replace this system with a commercially oriented approach, introducing a cooperative movement that focuses on entrepreneurship would be the most appropriate way for transforming the prevailing subsistence culture into commercializing agricultural production. "…cooperatives are economic organizations whose activities are devoted primarily to the promotion of economic and social welfare of members by providing services which enable them to realize and appreciate the objectives, benefits and values of their cooperative" Malawi Government (1997).

Furthermore most of the communities in the proposed SVIP project site are often affected by natural disasters – floods and droughts and have been frequently targeted by relief programs. These relief programs have also created another culture – a culture of dependency on handouts. Right from the outset, a cooperative movement in this area will also help to clear the dependency culture.

Through cooperatives, the farmers will not only pool together land but also the necessary capital and other resources required for commercial agriculture under irrigation. By mobilizing adequate savings/shares cooperatives in the proposed SVIP will be able to run input supply businesses to their members parallel to their commercial farming.

Considering the diversity of farmers and the geographical spread of the area, several cooperatives would be established with an apex governing body with representation from the various cooperatives. Different cooperatives would be engaged in contractual farming on different enterprises depending on farmer interests, availability of markets, and technical feasibility of the enterprises. Such an arrangement would contribute to development in terms of employment generation and boosting the condition of living of the majority of the people living in the proposed project impact areas.

Government should take a facilitatory and supervisory role in the formation and development of farmer organizations. The Phata and Dwangwa scenarios show that, with adequate capacity building, farmers could effectively manage their affairs with minimal assistance on technical issues. The Cooperative Act should be revised to allow for formation and registration of secondary organizations into Cooperatives.

The use of the criterion of land ownership to secure shares or membership to farmers' organizations excludes other citizens (currently without access to land) from benefitting from the project. Hence the project should consider development of farmers' organizations that would allow those without land to rent from those not willing to participate in irrigation activities.

Farming Models

The analysis in Table 2.6-14 shows that, in general, the existing farmer models are weak in such aspects as: production management, share of benefits, transparency and accountability and to a limited extent, cost management. Given this scenario the project needs to focus on supporting the farmer institutions through capacity building initiatives.

[Table 2.6-14] Assessment of Existing Farming Models in the Project Area

Model	Governance/ Organization structure	Land tenure /plot allocation	Production management	Share of benefits	Transparency and accountability	Costs
KAMA						
Kasinthula	2	4	4	1	2	2
Phata	4	3	3	2	3	2
Nkhate (Coop)	1	1	2	1	1	4
Nkhate (Ass)	4	4	4	5	3	4

5 = excellent, 4 = very good, 3 = good, 2 = fair, 1=poor

Note: KAMA is still under design

2.7. Development of GIS

TOR Requirements

The Consultant shall establish a geographical information system (GIS) that will be used all along the study and maintained beyond through the detailed design and implementation stages, residing in the end with the proposed Irrigation District as a kind of elaborate 'project life file'. The GIS shall be built upon the new aerial photography and digitized mapping that shall be prepared as a part of the feasibility study.

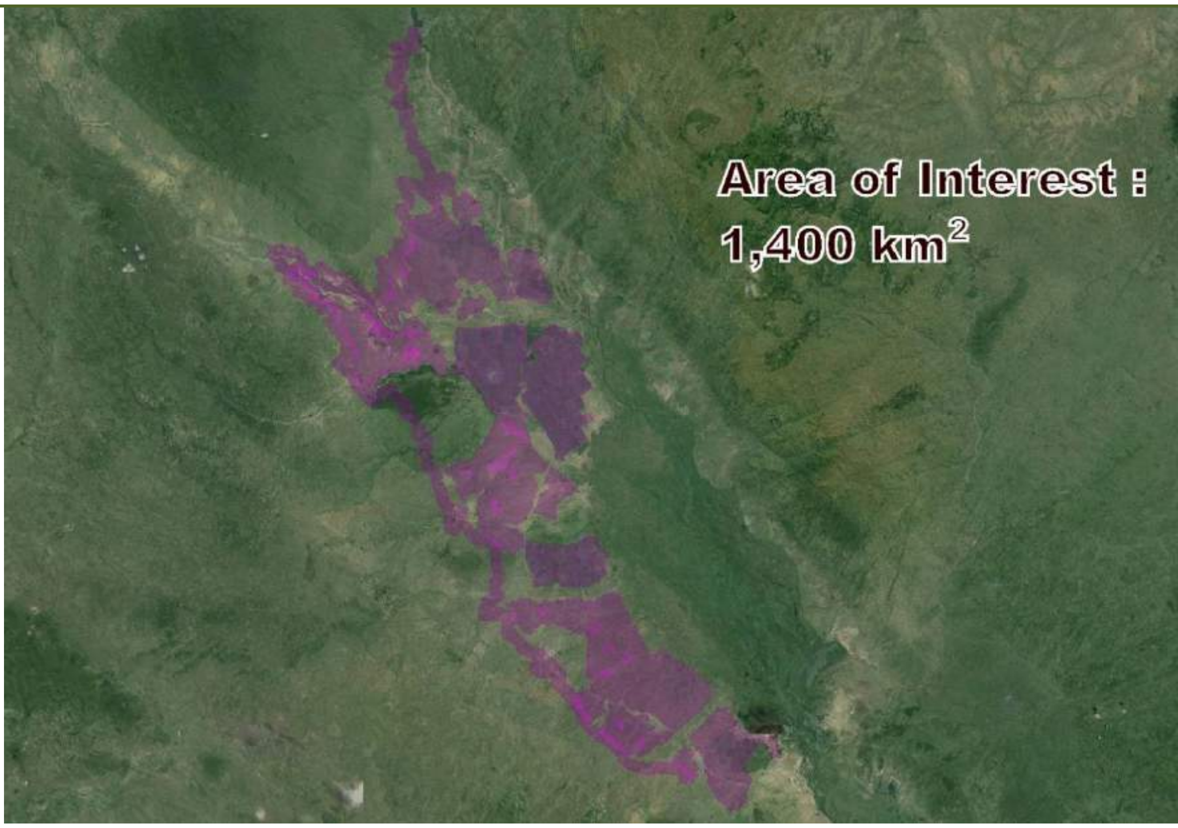
2.7.1. Work Scope

The scope of work of GIS development involved the following;

- Acquisition of 0.5m Satellite Images
- Ground Control Point surveying (about 20 points)
- Production of a 50cm Digital Elevation Model (DEM)
- Production of a 0.5m Contour Line - Vector Editing by Screen Digitizing
- Production of Orthophoto

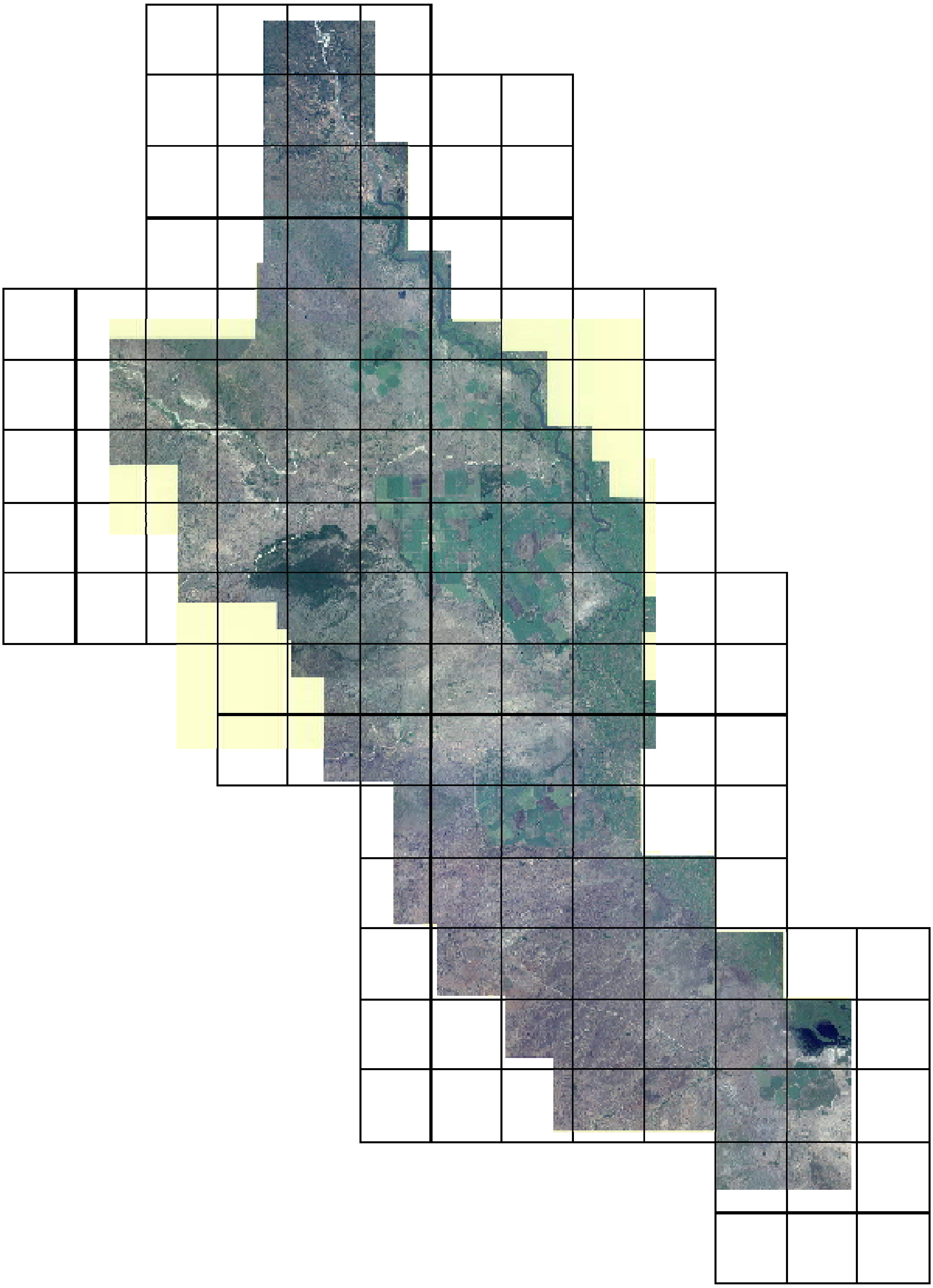
2.7.2. Area of Interest

Figure 2.7-1 shows the whole of Chikwawa area including the SVIP project area.



[Figure 2.7-1] Whole Chikwawa Area including the SVIP Project Area

Figure 2.7-2 shows the area of interest in the 1:5,000 scale map of Government of Malawi.

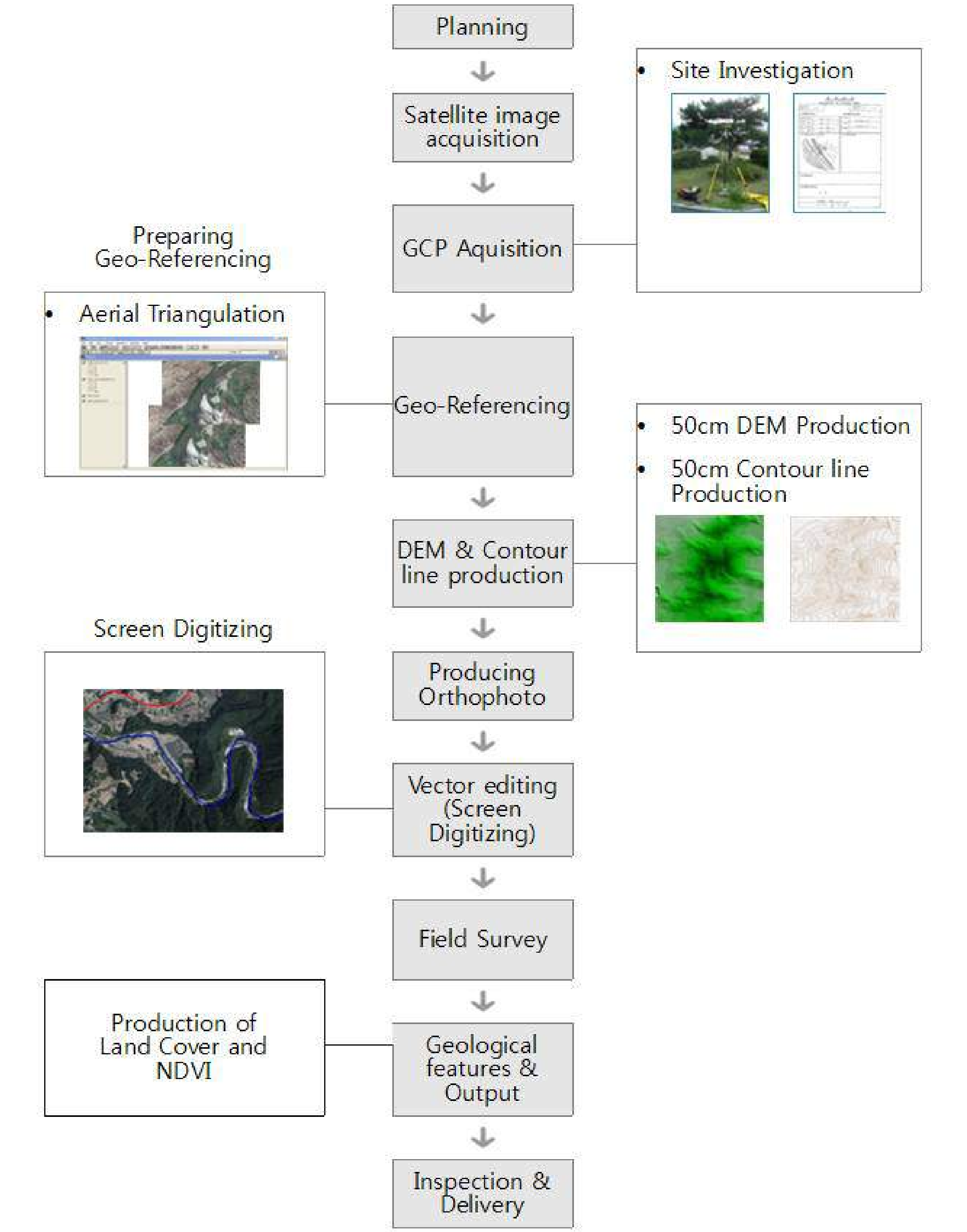


[Figure 2.7-2] Area of Interest in the 1:5,000 Scale Map of GoM

2.7.3. Methodology

Work Flow

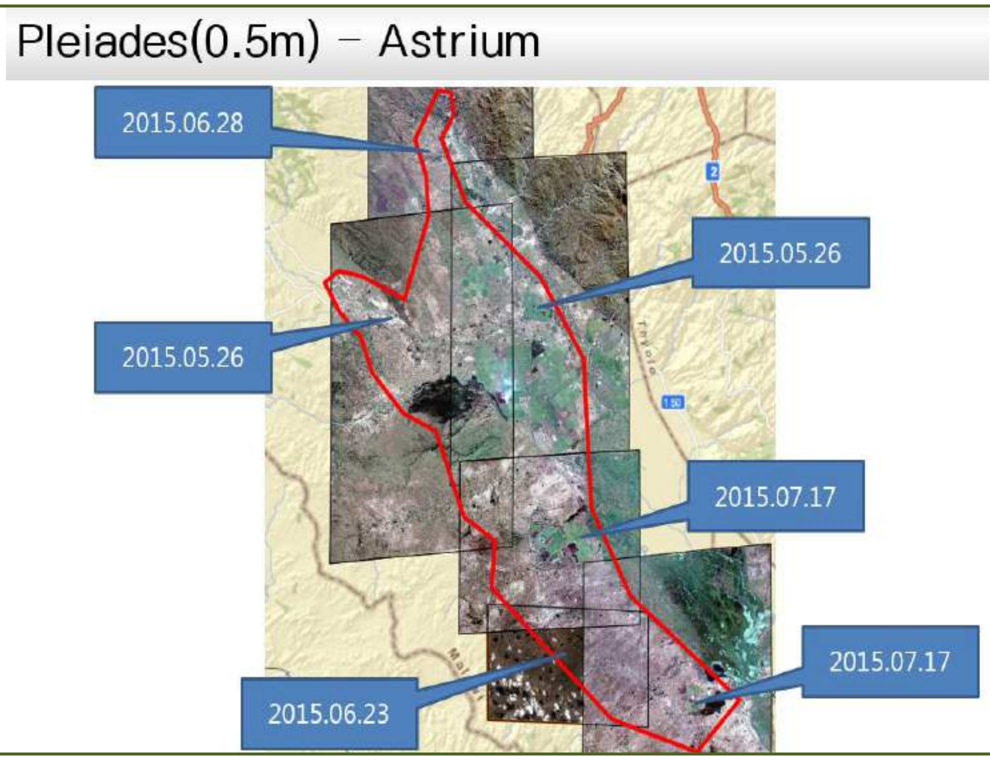
Figure 2.7-3 shows procedures adopted for GIS development.



[Figure 2.7-3] Procedures of GIS Development

0.5m Acquisition of Stereo Satellite Image

Recently acquired 0.5m high resolution satellite images were been used for this project. Figure 2.7-4 shows the satellite images with the dates on which they were taken.



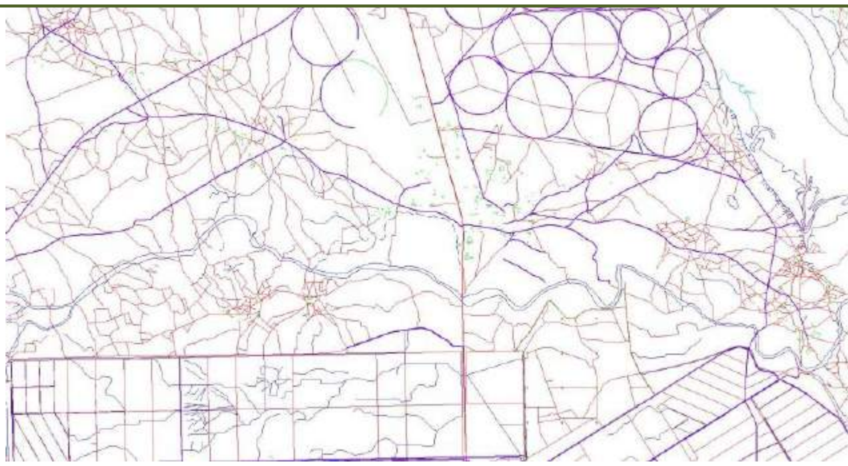
[Figure 2.7-4] Satellite Images with the Sates

Ground Control Point Survey

Ground Control Points (GCP) were acquired on site orthophotos for geo-processing work of this project.

Map Projection Evaluated by GPS Tracking Data(logged for 3 months long)

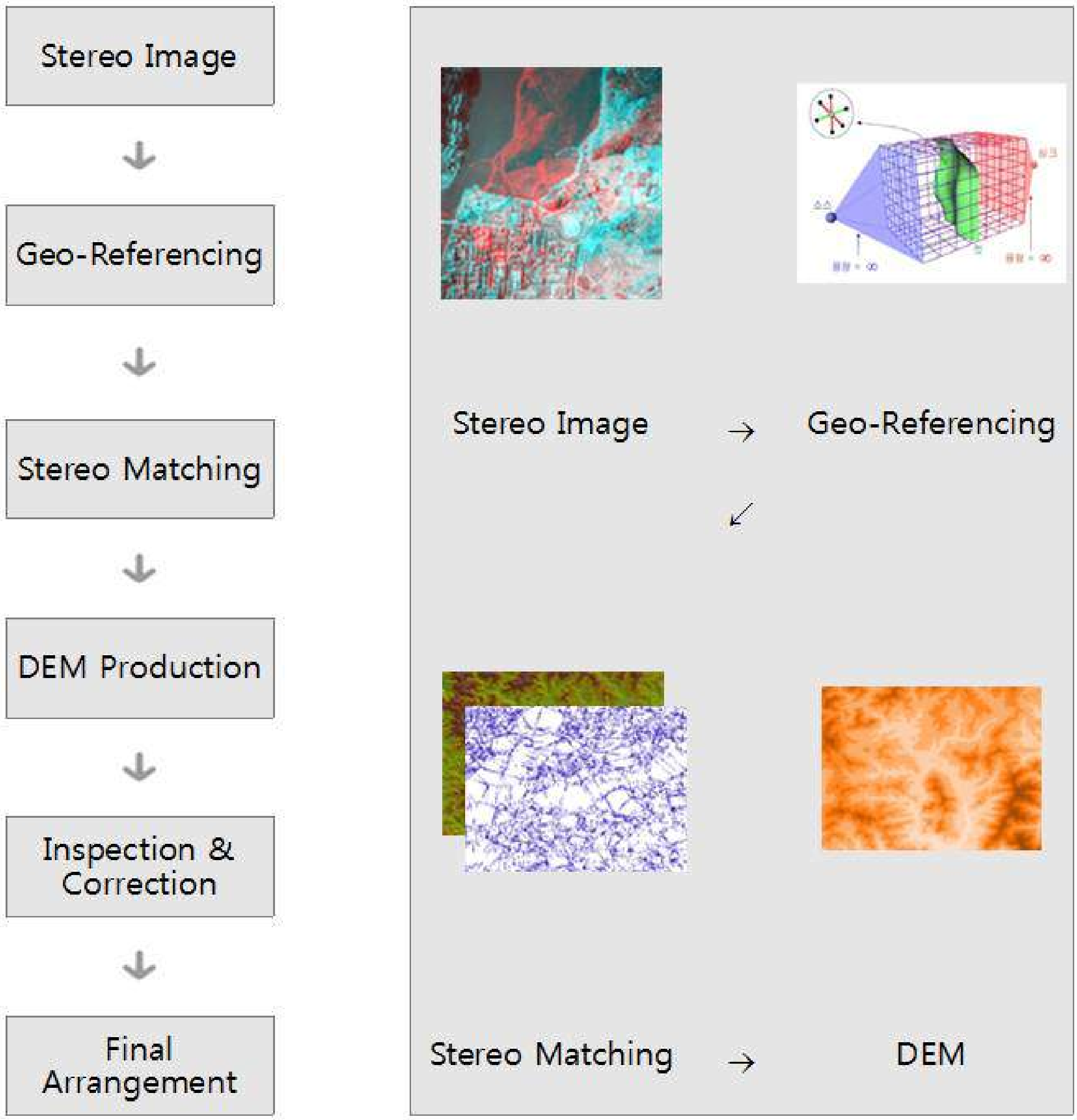
Projection is used ARC1950, and the purple line is the tracking data.



[Figure 2.7-5] Map Projection Evaluated by GPS

50cm Digital Elevation Model (DEM) Production

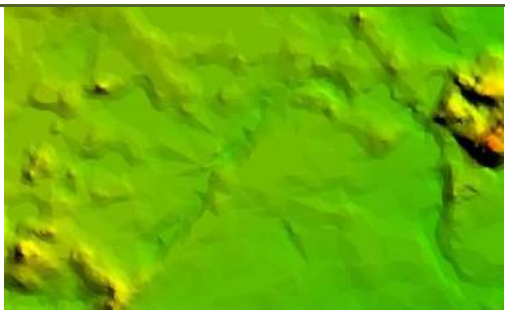
The DEM for the SVIP area was produced using existing elevation data and high resolution satellite images. Figure 2.7-5 shows the procedure adopted for the development of the DEM.

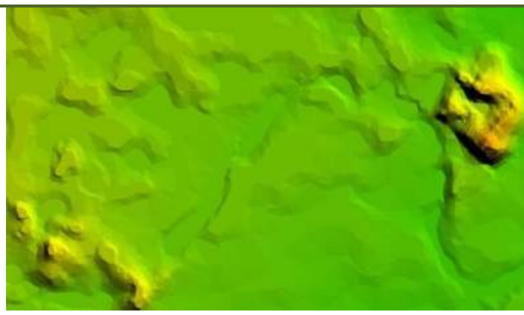


[Figure 2.7-6] Procedures of Digital Elevation Model Production

1m/5m Contour Line Production

The Index Contour Line (5m) and Intermediate Contour Line (1m) from DEM was then generated. And a Supplementary Contour Line (0.5m) was generated for very flat area. Finally, the contour lines generated were edited manually for cartographic output. TFS was carried out that the contour data got more accuracy for the GIS database.


Trees along the stream

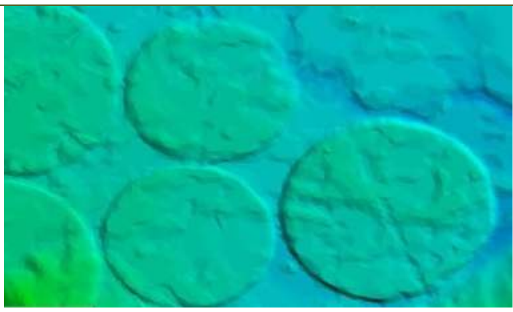

Removed

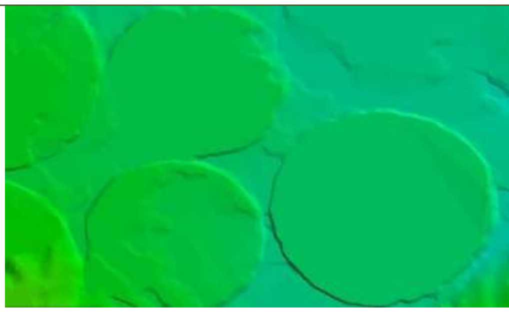

Trees on the top of mountains


Removed


Vegetation in farm


Removed


Sugarcane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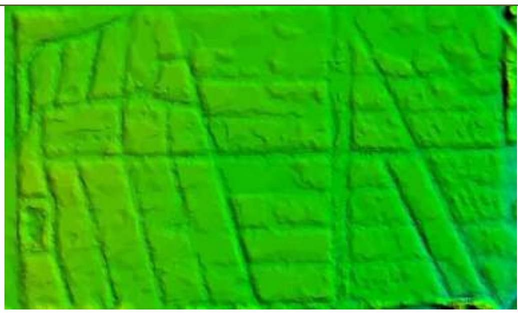
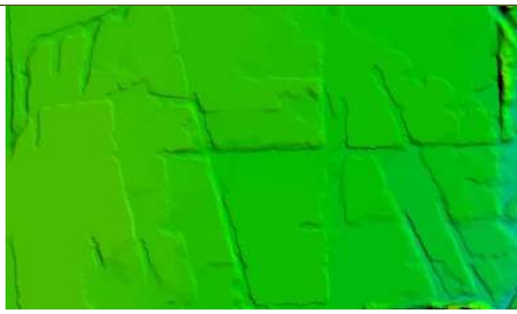

Many hills (tree) in town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[Figure 2.7-7] Contour (50cm interval) on the Bare Ground

0.5m Resolution Orthophoto Production

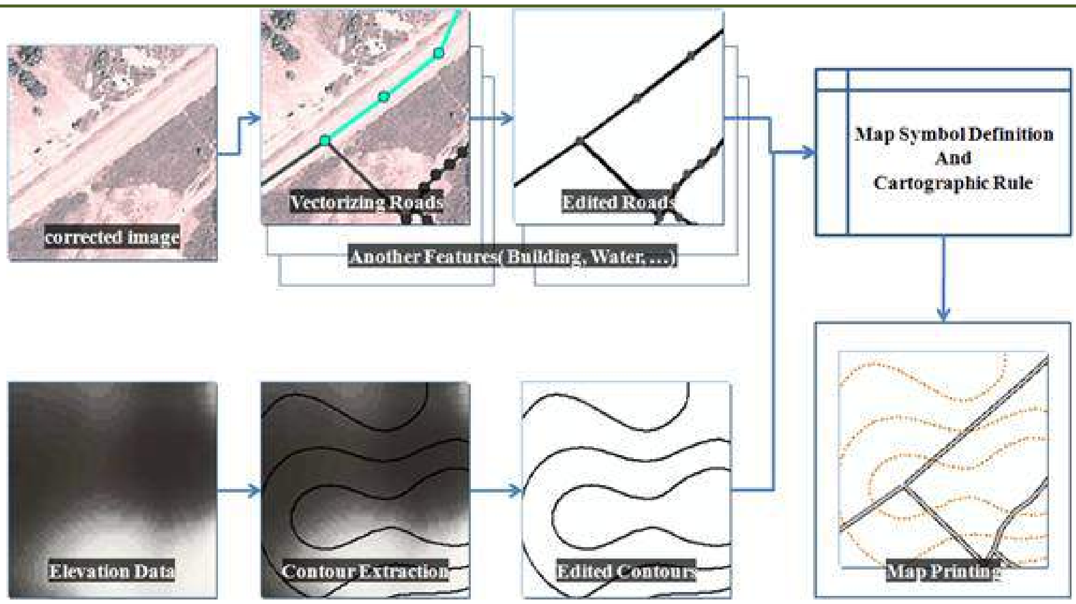
An orthophoto or orthoimage is an aerial photograph geometrically corrected ("orthorectified") such that the scale is uniform: the photo has the same characteristics as a map. Unlike an uncorrected aerial photograph, an orthophoto can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief lens distortion, and camera tilt. Table 2.7-1 shows the orthophoto production procedure.

[Table 2.7-1] Orthophoto Production Procedures

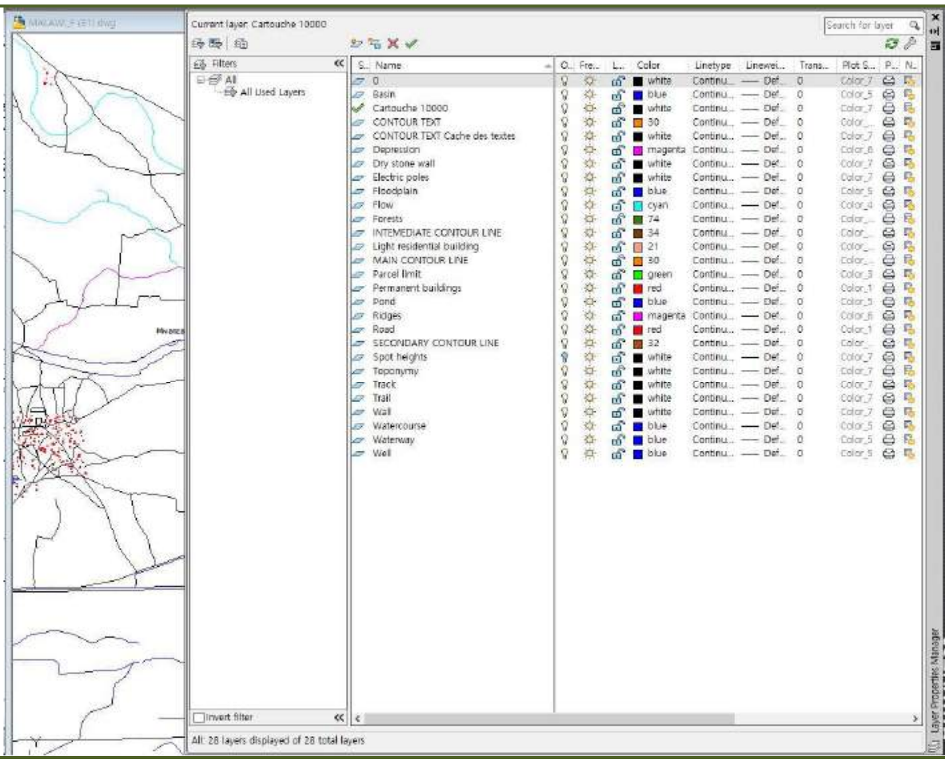
Process	Description
Planning and Preparation	- Collect aerial photograph and Aerial triangulation data - Use Direct Geo-referenced data interconnected with GPS/INS data
Input Images and Aerial Triangulation Data	- Set up coordinates - Input camera data - Input aerial photograph and Aerial triangulation data
GCP Entry	- Search clear GCP identifying geographical features - Identify and input common features of vicinity aerial photographs - Match aerial photograph and Aerial triangulation data
Orthographic Rectification	- Orthographic rectification with DEM - Minimize errors by taking center if photos are overlapped
Digital Orthophoto Production	- Primary data to carry out Screen Digitizing - Produce Digital Orthophoto with a consistent scale at all points in photos

Vector Editing by Screen Digitizing

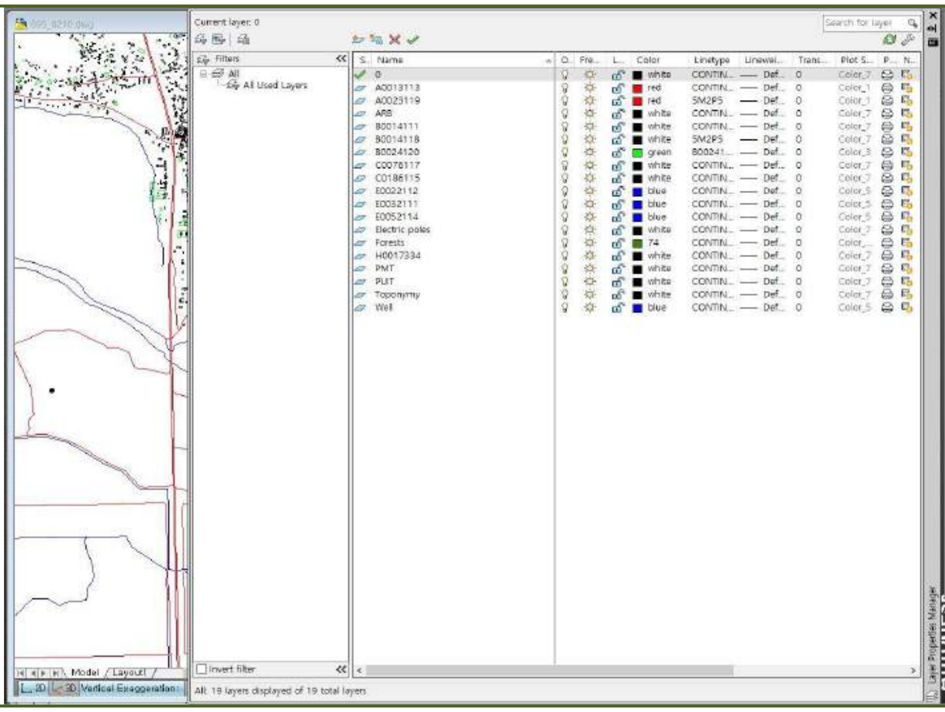
Screen digitizing is a critical process to identify features and information on images and determine extractable geographical features and to analyze correlations by using satellite images. Figure 2.7-8 shows the of vector editing procedure by screen digitizing. And the organized vector data (base map) for the GIS database is as following Figure 2.7-9 and Figure 2.7-10.



[Figure 2.7-8] Vector Editing Procedures by Screen Digitizing



[Figure 2.7-9] Digital Map Information without Layer



[Figure 2.7-10] Organized Base Map of Database (with 8 layer A~H)

2.7.4. GIS Development

The final GIS product will contain topograpghic map showing all physical features, such as, roads, rivers, soil types, land use, hills, etc and all relevant information that would be obtained from the Technical Feasibility Study and the other consultancies ; ESIA, CCPLT, HM and ADPS.

CHAPTER 3. ASSESSMENT OF TECHNICAL OPTIONS

3.1. With / Without Illovo Estate

TOR Requirements

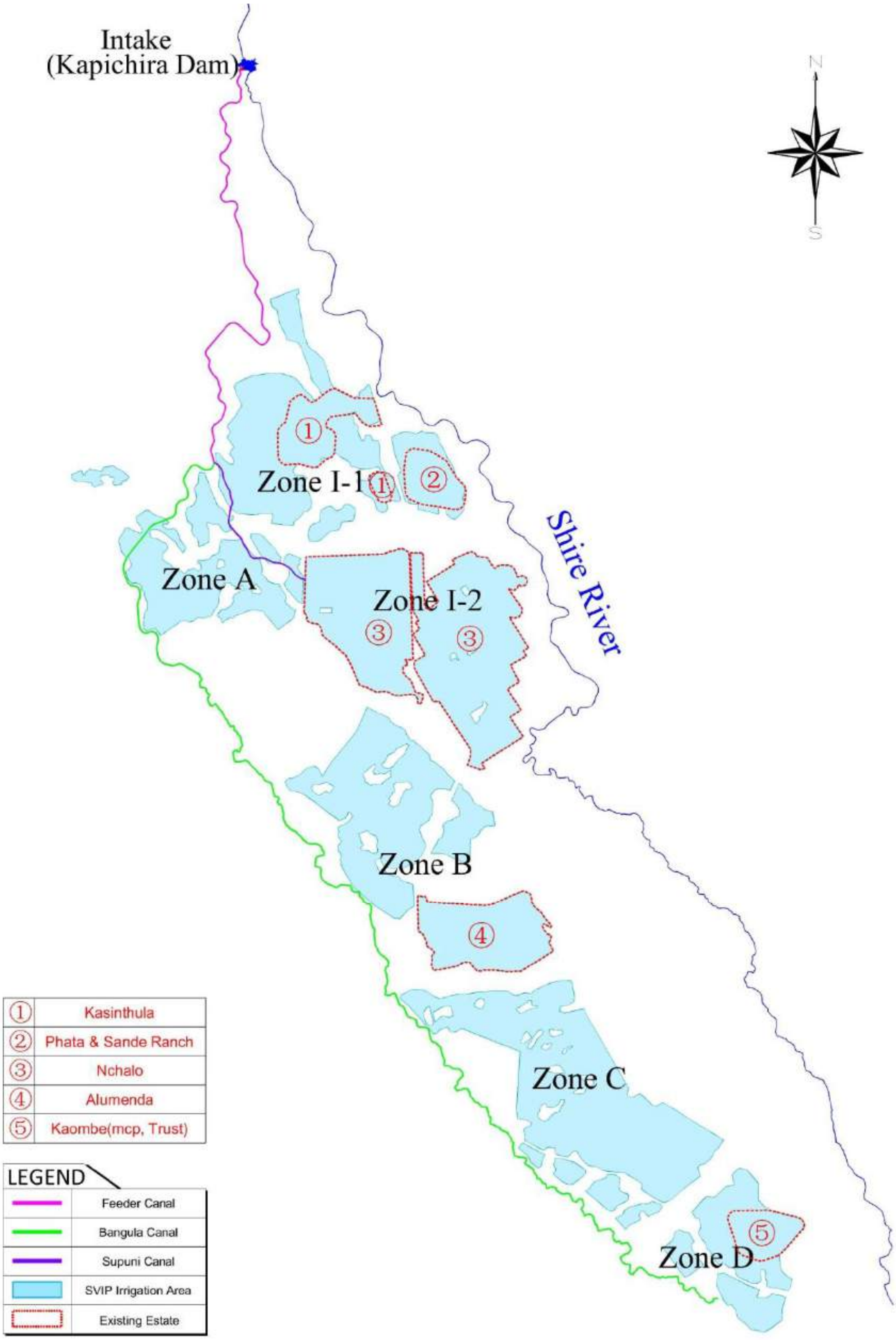
Extract from TOR : Including or not Illovo Estate in the scheme has major implications on the design, cost, profitability and institutional arrangements of the project. As Illovo Estate's position toward the project is not yet established, the Consultant shall assess both options and analyze to which extent a modification of the project scope may allow to preserve the economic profitability of the investment in the "without Illovo" option.

3.1.1. General Information about Illovo Estate

Illovo Sugar Estate, founded in 1956, is the largest sugar producing estate in Malawi. The estate gets its water from Shire River to irrigate 12,759ha of land planted with sugarcane. Illovo uses motorized submersible pumps to abstract water from the Shire. It is in light of the above that SVIP carried out a feasibility study to assess the possibility of supplying water to the Illovo by gravity by connecting the estate to SVIP water supply scheme which will abstract water for irrigation from Kapichira dam, located in the upper region of the project area.

[Figure 3.1-1] Aerial Photograph of the Illovo Estate

Illovo Sugar Estate would play an important role in planning, expense, profit and execution of the SVIP project if it were to be connected to the project's water supply scheme. However, the participation of Illovo estate has not been determined. As such, a consultant was hired by the project to compare each plausible scenario according to the participation of Illovo estate and examine its influence on validity and profitability of the business. The SVIP area includes large cane estates such as Illovo which covers 15,757ha, nearly 36% of the whole SVIP project area. The area of each estate is shown in Table 3.1-1.



[Figure 3.1-2] Location of the Existing Estate

[Table 3.1-1] Estate Areas in the Project Area

Estate	Total Area(ha)	2015 Cane Area(ha)	Non Cane Area(ha)
Nchalo	14,999.0	9,995.0	5,004.0
Alumenda	3,746.0	2,763.8	982.2
Sande Ranch	673.6	454.0	219.6
Phata	NA	296.1	NA
Kasinthula	NA	1,428.8	
Kaombe mcp	2,000.9	483.9	1,181.7
Kaombe Trust	NA	335.3	NA
Total	NA	**15,756.8**	NA

※ Non Cane Area : Roads, Drains, Canals, Dams, Villages and Wastelands

Illovo has expressed interest in getting connected to SVIP water supply scheme because of the high tariffs it pays to ESCOM as well as high annual maintenance expenses it incurs from pump maintenance costs. Consequently, gravity irrigation is more economic in the long run. In addition, SVIP's irrigation area will use the water of Kapichira dam, so the expense for constructing a new dam is not required. This seems to be an economically favorable condition for Illovo.

Table 3.1-2 suggests the comparison of the whole scale of project including the design water requirement between with and without Illovo Estate.

[Table 3.1-2] Work Scope by the With / Without Illovo Estate

Division	With Illovo Estate	Without Illovo Estate	Differences
Irrigation Area(ha)	43,370	30,611	▽12,759
Water Needs(m^3/s)	Q=50.0	Q=35.3	▽14.7
[1)]Length of Canal(km)	245.8	234.3	▽11.5
[2)]Land Consolidation(ha)	31,814	31,814	

※ 1) Length of Canal includes the total lengths of branch canals

2) Land consolidation is a total area without Illovo estate.

The decision to include Illovo Sugar Estate will be ascertained after consideration of various factors such as amount of available water resources, size of SVIP project cost, economy of project and other social aspects.

3.1.2. Water Availability Aspect

3.1.2.1. Introduction

The Shire River, with an annual mean flow of $395m^3/s$ at Kamuzu Barrage based on long-term average will provide water for the Shire Valley Irrigation Project. The irrigation water requirement for the 43, 370 ha of SVIP has been estimated to be $50.0m^3/s$ (See details in Chapter 5). This value is the peak requirement, which shall be required for about two weeks during the month of September. The value is obtained based on the cropping Pattern and assuming an overall irrigation efficiency of 52%. The intake structures and the feeder canal are designed for the maximum water requirement of the $50m^3/s$ in September. The first phase of the Project will require $25m^3/s$ for the irrigation, and the remaining $25m^3/s$ is required for phase II.

From records collected at Kapichira ESCOM Office, the required water for running all four generators is $270m^3/s$. In addition, there is also a need to provide for an environmental flow of $17m^3/s$. Thus the total water required for electricity generation, environmental flow and irrigation is $337m^3/s$.

The Shire River is the only outlet of Lake Malawi. Lake Malawi has a surface area of $28,769km^2$ according to a study conducted by UNDP in 1986 for the National Water Resources Master Plan. The study further gives the mean annual flow of the Shire River as $395m^3/s$. The flow of water in the Shire River from Lake Malawi passes through Lake Malombe and is partly controlled by Kamuzu Barrage at Liwonde before making its way to Kapichira Dam and the districts of Chikwawa and Nsaje where the proposed project will be. Nsanje District borders with Mozambique on the southern tip of Malawi,. The study further states that almost all the flow in Shire River ceased between 1915 and 1934. The report included a simulation study that showed the dependent flow with the barrage to be $170m^3/s$. The dependent flow of the Shire River can be increased by increasing the height of the barrage or construction of Kholombidzo high Dam. The Government made a decision to raise the height of the barrage at Liwonde by 400mm. This was considered to have less impact on the environment compared to Kholombidzo high dam.

Shire River flow studies have been conducted by many consultants for various uses including hydropower generation and irrigation. Available water for both power generation and irrigation was reviewed and the Government of Malawi directed that there should not be further development of power generation at Kapichira Dam. Hence, there will be no further power generation developments at Kapichira beyond Kapichira I and II. This decision was taken in order to save water for the development of the Shire Valley Irrigation Project by diverting water at Kapichira Dam.

3.1.2.2. Water Balance at at Kapichira Dam

The construction work of the SVIP is expected to start in 2018. The water will start to flow at the intake at Kapichira Dam towards the end of year 2022. Subsequent activities will follow as shown in Table 3.1-3. Based on the assumption that works for phase 1 start in 2018 and complete in 2022, it is also assumed that phase 2 starts after completion of phase 1 and will take 4 years to complete.

According to the National Water Resources Master Plan of 1986, the mean flow of water in Shire River over the period when the data started to be recorded, from 1890 to 1985, was 395 m^3/s at 1B1 which is the current site of the Kamuzu Barrage. The mean flow based on the data recorded from 1965 to 2015 is 342 m^3/s at Kamuzu Barrage. It should be noted that the mean water flow at Kamuzu Barrage is substantially lower than the flow at Kapichira Dam (Table 3.1.8). This is due to the many tributaries flowing into the Shire River downstream of Kamuzu Barrage.

As may be observed in Table 3.1.3, the water balance at Kapichira Dam, after taking into account hydro-power generation requirements, the environmental flow and the SVIP, is 55 m^3/s or better. This water balance is based on mean flows at Kamuzu Barrage (1B1) but, as already indicated, the water balance at Kapichira Dam is much higher than that recorded at 1B1. It is recognized that ESCOM uses 50 m^3/s for flushing during the rainy season to remove sediments near the intake but this flushing is not required during the dry season, from August to December, when the water has less sediments. Hence the flushing does not affect the flow in the critical months of September to November.

From the Shire River flow characteristics consolidated by the consultant and studies conducted by other consultants the trend of the characteristics are similar. Low flows were noted in the dry season months of September to November 1985 to 1987 and 1995 to 1997. At the time of writing this report, low flow of the Shire River is being experienced. This is expected to continue to 2017 and start to improve thereafter. The water balance from 2022 assumes normal mean water flow of 395 m^3/s.

[Table 3.1-3] Water Allocation at Kapichira Dam

Implementation Period	Flow	ESCOM Demand	Irrigation Demand	Environmental Flow	Total Demand	Remarks
2018-2020	m^3/s	270	0	17	287	Phase 1 under construction
2020-2022	m^3/s	270	0	17	287	Phase 1 under construction
2022-2024	m^3/s	270	25	17	312	Partial utilization of water
2024-2026	m^3/s	270	25	17	312	Full utilization of Ph 1 & Ph 2
2026-2028	m^3/s	270	50	17	337	Works for Ph 2 completed
2028-2030	m^3/s	270	50	17	337	Ph 1 & 2 being used

3.1.2.3. Review of previous Studies

Recently several hydrological studies have been implemented to estimate the amount of the Shire River runoff. Some of them are summarized below.

Study on Water Availability for Irrigation and Hydropower Production on Shire River at Kapichira Falls(Norplan, 2013)

The Norplan report estimated the required water quantity from the demand of 2016 and 2022 (2016:2,532GWh/y; 2022:2,892GWh/y). For SVIP irrigation demand, the report sets 3 cases of 30 m^3/s, 37m^3/s and 50m^3/s as the annual maximum required water quantity. Most of the analysis was done based on 37m^3/s. The report included analysis result from 30m^3/s and 50m^3/s in an appendix without explanation.

The report selects three time periods to establish 3 scenarios based on measurement data of Lake Malawi water level, and the followings are the scenarios:

a. Scenario 1 (1990-1919): Extremely dry season
b. Scenario 2 (1934-1953): Mean free water exceeding the required quantity
c. Scenario 3 (1990-2009): Recent days, mean free water exceeding the current average required quantity with dry years n between

The authors analyzed the water availability for the next 20 years on the assumption that water level pattern for the next 2 decades is recreated by setting the standard level as water level of Lake Malawi at 2013 Jan. 1st.

The analysis cases are as follows:

a. Case 1:Escom(I + II)

b.Case 2:Escom(I + II) and SVIP(with Nchalo) c.Case 3:Escom(I + II) and SVIP(without Nchalo)

The results of generation demand of 2022 (SVIP's demand: 37m^3/s) is as follows:

- *Scenario 1: meeting the demand for 7 months out of 240 months in total (Exceedance probability is lower than 10%)*
- *Scenario 2: meeting the demand for 231 months out of 240 months in total (Exceedance probability is lower than 97%)*
- *Scenario 3: meeting the demand for 97 months out of 240 months in total (Exceedance probability is lower than 48%)*

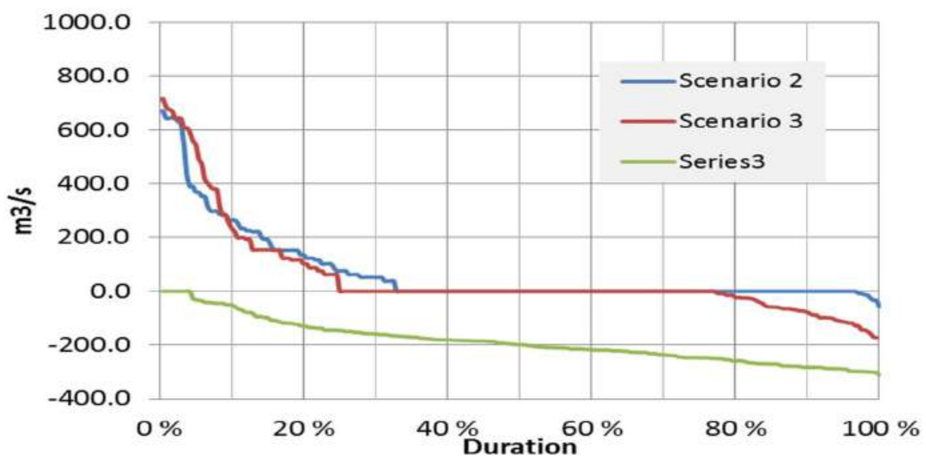
The mean free water as well as calculated water demand for 2013, for 2016 and 2022 are shown inTable 3.1-4 of Norplan Report reproduced below in part.

[Table 3.1-4] Hydrological Event Scenarios Used in the Simulation

Division	Period	Mean Freewater (m^3/s)
Complete 110 years	1900 - 2009	263
Wet interim period	1954 - 1990	>500
Scenario 1	1900 - 1919	-28.8
Scenario 2	1934 - 1953	321.2
Scenario 3	1990 - 2009	226.6

The Norplan Study confirms the UNDP estimate of an average year flow of about 300m^3/s. In fact under Scenario 2 (1934-1953), which represents a period with mean free- water higher than average water demand over the 20 year is 321.2m^3/s. Again, this is flow at Liwonde (Kamuzu Barrage [1B1]) is substantially lower than what would be obtained at Kapichira Dam.

Figure 3.1-3 shows the water balance curve for the generation demand of 2022 for the SVIP's demand is 50m^3/s. This figure shows that the irrigation and hydro power water demand (320m^3/s) shall be fulfilled 96% of exceedance probability for Scenario 2, and 78% of exceedance probability for Scenario 3. Suffice to note that the probabilities at Kapichira Dam would be higher because of the higher expected flows downstream.



[Figure 3.1-3] Water Balance Curve for Generation Demand of 2022 (SVIP's Demand: 50m^3/s)

Water Resources Investment Strategy, Component 1 – Water Resources Assessment (WRIS, 2011)

Based on the revised Malawi Growth and Development Strategy (MGDS; 2009), the Malawi government has led Water Resources Management Component of the Second National Water Development Project(NWDP II), and as a part of which, Water Resources Investment Strategy (WRIS) project was also performed.

Within this context, the specific objectives of WRIS are:

- To analyze the economic development objectives of the country and how water resources affect the country's achievements in economic growth and poverty reduction;
- To identify key water-related challenges for the country's economic development in the medium and long-term;
- To set-up priorities for the water sector interventions in time and geographically;
- To identify priority water resources sector investments.

Developing the WRIS and fulfilling these objectives comprises two major components:

- Component 1: A National Water Resource Assessment (WRAS)
- Component 2: Development of a National Water Resources Investment Strategy (WRIS)

This report sets out the key findings from Component I, the Water Resources Assessment (WRAS), and provides the foundations for developing the final Investment Strategy in Component II.

Specific conclusions or issues within WRA 1 (Shire River)
(This part is in the "Available Water Resources part; Annex II – Surface Water")

Summary statistics for the gauging stations are presented in Appendix D. These show average, maximum and minimum flows as well as flow frequency percentiles and flow statistics.

Station code	Q mean	Q min	Q max	S.D.	C of V	Q10	Q20	Q50	Q75	Q80	Q90	Q95	Specific runoff	Catchment runoff	Data coverage
	m^3/s	m^3/s	m^3/s			m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	l/s/km2	mm/year	%
1B1	431.6	134.3	963.0	234.1	0.5	732.5	666.8	419.4	181.8	176.3	164.3	154.0	3.3	104.8	99.2
1P2	532.1	42.9	979.5	230.8	0.4	800.1	744.5	555.5	377.3	325.7	180.4	144.2	4.0	125.3	68.1
1L12	538.8	162.0	1274.6	227.5	0.4	812.0	718.8	532.1	373.1	326.8	216.4	202.9	3.9	123.5	70.6
1G1	576.8	134.9	1818.1	258.4	0.4	860.2	751.7	561.3	390.5	347.0	269.0	205.1	3.9	122.4	92.2
1R3	4.9	0.0	96.2	8.6	1.8	12.3	7.4	1.6	0.6	0.4	0.2	0.0	6.6	215.1	91.7
2B22	1.2	0.0	8.4	1.7	1.4	3.2	1.9	0.5	0.2	0.1	0.0	0.0	4.0	133.0	66.9
2B33	1.2	0.0	9.3	1.7	1.4	3.1	2.1	0.5	0.2	0.1	0.0	0.0	4.6	151.3	66.9
2C3	2.4	0.1	23.0	3.5	1.5	5.8	4.0	0.9	0.3	0.3	0.2	0.2	38.3	1200.8	63.9
3E1	0.4	0.0	6.1	0.7	1.6	1.1	0.6	0.2	0.1	0.1	0.0	0.0	48.2	1519.8	94.2
3E2	2.1	0.0	20.0	3.3	1.6	6.5	3.0	0.7	0.3	0.2	0.1	0.0	16.4	693.1	51.7
3E3	3.9	0.0	33.2	5.3	1.4	10.9	6.1	1.6	0.7	0.6	0.4	0.3	8.5	277.6	58.9
3F3	1.9	0.0	18.3	2.6	1.4	4.7	2.9	0.9	0.4	0.3	0.2	0.1	8.4	325.2	66.7
4B1	33.6	0.0	318.9	48.4	1.4	107.3	67.7	9.5	2.6	1.8	1.0	0.3	4.2	134.2	84.2
4B4	8.2	0.0	99.2	13.6	1.6	27.7	13.3	1.9	0.4	0.3	0.1	0.0	5.8	182.7	93.1
4D4	10.0	0.0	128.5	18.2	1.8	25.4	14.2	2.6	0.8	0.6	0.3	0.1	5.5	178.2	95.6
4B9	14.8	0.0	137.8	21.4	1.4	45.4	31.4	4.1	1.2	0.9	0.4	0.1	5.0	160.5	84.2
5C1	40.3	0.0	320.1	62.0	1.5	129.4	69.1	8.7	2.1	1.5	0.3	0.0	3.8	118.8	79.4
5D1	28.6	0.0	270.2	50.2	1.8	97.9	43.7	5.5	1.1	0.6	0.1	0.0	3.2	100.1	59.7

ATKINS

Component 1 – Water Resources Assessment
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[Figure 3.1-4] Appendix D. Summary Flow Statistics (Atkins, 2011)

Figure 3.1-4 shows that 326.8m^3/s is 80% exceedance probability runoff of Shire River at 1L 12 point of Chikawa. Table 3.1-5 shows flows in Kapichira Dam, calculated on the basis of Liwonde (1B1) &

Chikwawa(1L12) discharge data. At the Kapichira Dam the 80% probability flow is estimated by 325.7m^3/s. It is greater than 320m^3/s, the water demand for both of Electricity (270m^3/s) and Irrigation (50.0m^3/s). It means that the Shire river runoff shall have the potentiality to satisfy the irrigation and hydropower water demand in 80% of probability.

[Table 3.1-5] Runoff Review at Shire River

Division	Liwonde(1B1) [1]WRIS	Kapichira Dam WRIS	Chikwawa(1L12) WRIS
Basin Area	130,200 km^2	138,031 km^2	138,600 km^2
Q mean(m^3/s)	431.6	536.6	538.8
Q max(m^3/s)	963.0	1269.4	1,274.6
Q50(m^3/s)	419.4	529.9	532.1
Q80(m^3/s)	176.3	325.5	326.8
Q95(m^3/s)	154.0	202.1	202.9
Q min(m^3/s)	134.3	161.3	162.0

※ 1) WRIS: Water Resources Investment Strategy(April 2011) Appendix D; Summary Flow Statistics

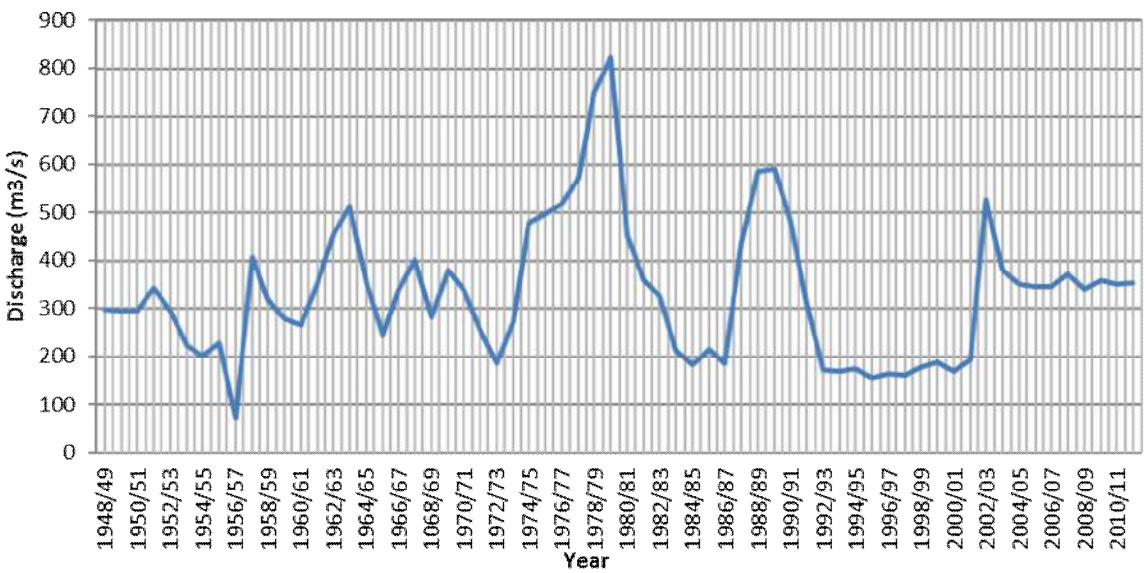
National Water Resources Master Plan in the Republic of Malawi (JAICA, 2014)

In the Fact Sheet for WRA1 (p.109 of Annex of main report), the summary for the 1L12 location (Shire at Chikwawa) is as follows: *monitored period; 33 years, drainage area;138,600 km2, average dry-season flows: Q75 = 464.894 m3/s & Q97 =390.158 m^3/s.*

This analysis supports the finding that the water availability in the Shire River at Kapichira Dam is sufficient to satisfy the water requirement for ESCOM, SVIP and environment 337 m^3/s.

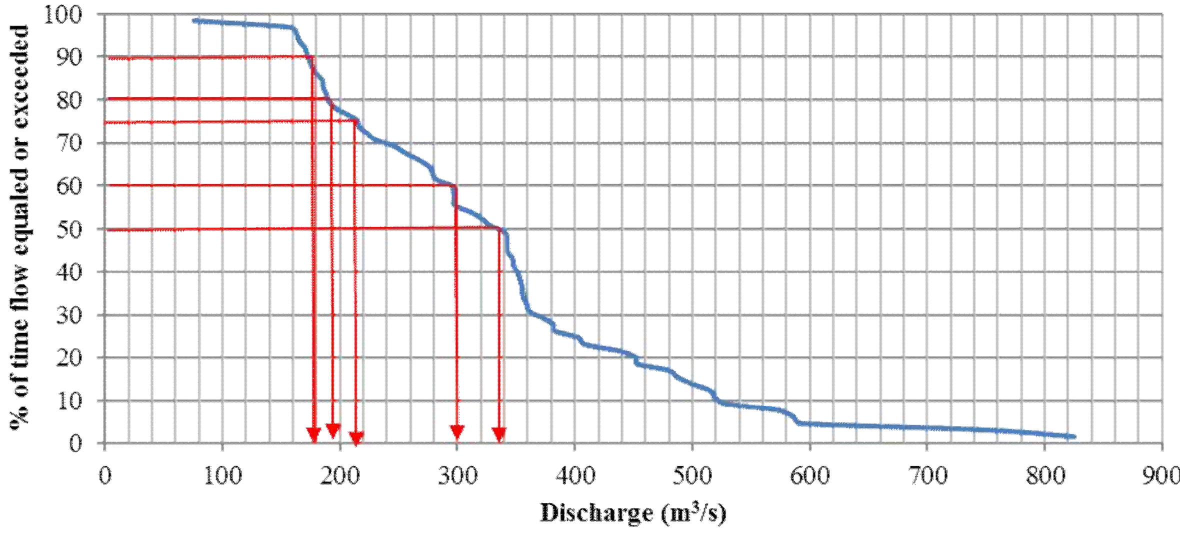
3.1.2.4. TFS - Dependability of Water Availability (80% probability)

Flow data for Shire River at Liwonde (1B1) and for the Shire at Chikwawa (1L12) was obtained from the Department of Water Resources in the Ministry of Agriculture, Irrigation and Water Development.



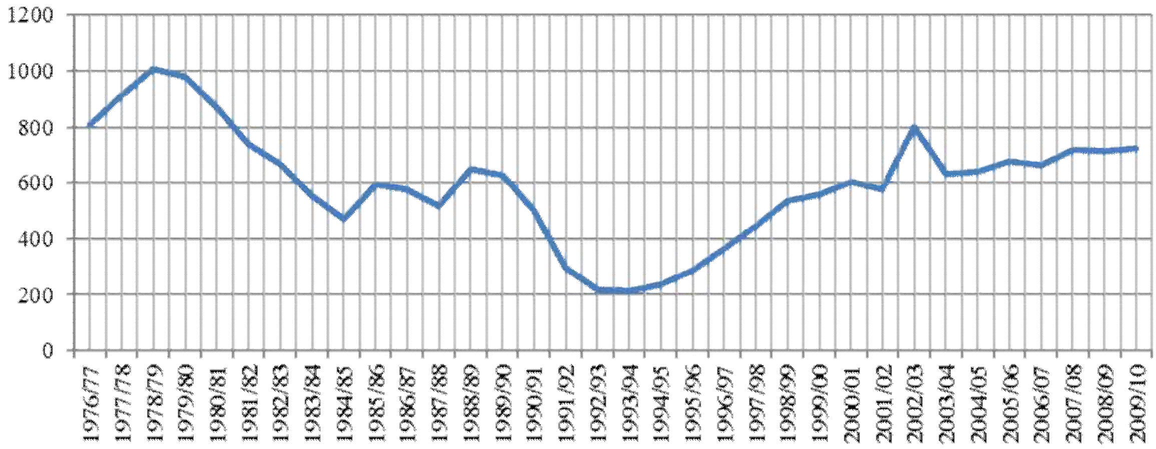
[Figure 3.1-5] Discharge at Liwonde 1B1 in 1948/49 ~ 2010/11

These data consisted of the annual mean flows from 1948/49 to 2010/11 for 1B1 and from 1976/77 to 2009/10 for 1L12. It is clear that there is no break in the cycle of flow from when the station was opened to 2011. Mean annual flows were then used to produce a flow duration curve as shown in Figure 3.1-6.



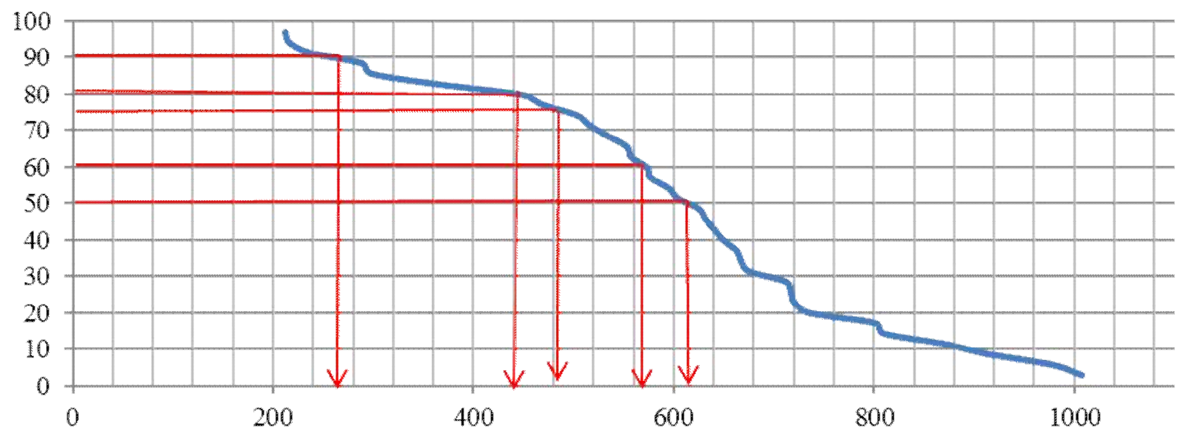
[Figure 3.1-6] Flow Duration Curve using Annual Mean Flows for Shire at Liwonde 1B1

The same process done for 1B1 was used to construct hydrograph of flows for 1L12. Examination of the hydrograph shows that annual mean flows for this station were higher prior to 1981/82 when they began to recede until 1984/85. Since then annual mean flows have not exceeded 800m^3/s except in 2002/03 when the annual mean flow reached 801.3m^3/s.



[Figure 3.1-7] Discharge at Chikwawa 1L12 in 1976/77 ~ 2009/10

Figures 3.1-8 is presentation of the flow duration curves for 1L12 for both annual mean flows and annual minimum flows.



[Figure 3.1-8] Flow Duration Curve using Annual Mean Flows for the Shire at Chikwawa 1L12

Comparison of findings can be made with WRIS' results using the three scenarios from which decisions can be made for the development of the Shire River Irrigation Project without compromising the needs of other water users. Table 3.1-6 and 7 shows the water availabilities at Liwonde location (1B1) and Chikwawa location(1L12). As may be observed, the water availability at Chikwawa location is much more favorable than Liwonde location. They make comparisons of the calculations of WRIS (2011) and TFS (2016). As can be seen, WRIS results are lower than TFS results; 326.8 m^3/s and 440.0 m^3/s, respectively for the 80% exceedance probability. The TFS result is sufficient the water requirements of ESCOM, environmental flow and SVIP.

[Table 3.1-6] Water Dependability at Liwonde 1B1

Researcher	Flow Station	Flow Equaled or Exceeded				
		90%	80%	75%	60%	50%
WRIS (2012)	Shire 1B1	164.3	176.3	181.8		419.0
TFS (2016)	Shire 1B1	178.0	195.0	213.0	300.0	335.0

[Table 3.1-7] Water Dependability at Chikwawa 1L12

Researcher	Flow Station	Flow Equaled or Exceeded				
		90%	80%	75%	60%	50%
WRIS (2011)	Shire 1L12	216.4	**326.8**	373.1		532.1
TFS (2016)	Shire 1L12	260.0	**440.0**	480.0	565.0	617.0

Furthermore, it should be noted that the design water requirement of 50 m^3/s is required only in the critical month of September and less water is required in other periods. It is interesting to see if the design water is available in September. Table 3.1-8 shows the flow rates of Shire River in September at the Liwonde (1B1) and Chikwawa (1L12) locations (data from the Department of Water Resources). At the two locations, 80% probable amount water is calculated to 170m^3/s and 413 m^3/s respectively, which is greater than 337 m^3/s.

[Table 3.1-8] Flowrates of Shire river in September at the Liwonde(1B1) & Chikwawa(1L12) locations

Year	1B1	1L12	Year	1B1	1L12	Year	1B1	1L12
1977	503.0	752.8	1989	679.4	643.2	2001	164.0	489.8
1978	617.2	905.3	1990	421.0	460.6	2002	216.4	547.1
1979	803.4	1,017.7	1991	462.8	457.9	2003	644.8	763.2
1980	801.8	858.6	1992	179.6	189.5	2004	384.9	614.1
1981	391.7	734.6	1993	170.9	216.4	2005	336.7	624.2
1982	337.2	662.5	1994	176.2	224.1	2006	350.1	654.3
1983	290.1	586.6	1995	169.8	203.0	2007	345.0	643.1
1984	152.5	418.5	1996	150.7	259.3	2008	349.9	672.9
1985	152.5	438.7	1997	161.5	347.4	2009	348.5	685.7
1986	221.9	552.6	1998	177.7	409.7			
1987	135.6	469.4	1999	189.5	497.8			
1988	393.2	463.4	2000	204.4	529.3			

As can be seen from Table 3.1.8, the flows at Chikwawa are greater than those of at Liwonde in almost all the years. This is obvious because of the larger catchment area and contribution of the many tributary rivers between Liwonde (1B1) and Chikwawa (1L12).

In the same way the available water for the other critical months of August to December has been calculated, and shown in Table 3.1-9. The water balance shows that there is sufficient water for both ESCOM, environmental flow and SVIP.

[Table 3.1-9] Water Balance for the Months of August, September and October

		August	September	October	November	December
80% Available Water		**442.3**	**413.2**	**385.8**	**349.8**	**356.5**
Demand (m^3/s)	**ESCOM**	270.0	270.0	270.0	270.0	270.0
	SVIP	48.0	50.0	36.8	38.3	24.0
	Environm.	17	17	17	17	17
	Total	**335.0**	**337.0**	**323.8**	**325.3**	**321.0**

3.1.2.5. Conclusion

As we have seen from the studies of WRIS (2011), Norplan (2013) and TFS (2016), the runoff of Shire River at Kapichira Dam shall fulfill the water demand for ESCOM, SVIP and Environment flow of 337m^3/s at 80% exceedance probability. Even though the design water requirement is set for the peak requirement, there are several ways to economize irrigation water as follows:

- Adjust farming program to set harvesting period and preparation period for next cultivation in September, which enable to use a small amount of water,
- Adjust cropping pattern to plant the crops which use less water in September,
- Reduce cultivating area during the dry period,
- Change the irrigation system from furrow irrigation to sprinkler/pivot irrigation system,
- Moreover, the completion of Kamuza barrage is expected to improve the water availability in the Shire river basin including SVIP.
- In general through proper design of the cropping pattern and improvement of the irrigation efficiency (through farmers training, changing of irrigation methods, etc) the 50 m3/sec flow would be sufficient to irrigate the whole potential irrigable areas (50, 000 ha) in Shire Valley.

3.1.3. Irrigation Water Requirement Aspect

With Illovo Estate (Net Irrigation Area : 43,370ha)

The design water requirement calculated by TFS is 50.0m^3/s. This quantity can satisfy the irrigation water demand for the whole project area (43,370ha) during both the rainy and dry seasons. The calculated water requirement for the project area including Illovo estate is shown in Table 3.1-10.

[Table 3.1-10] Irrigation Water Requirement with Illovo Estate

Division	Dry Season						Wet Season					
Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Monthly Rainfall(mm)	13.5	13.3	17.8	6.9	7.1	13.9	50.6	124.3	190.2	137.8	95.3	91.3
Daily Water Demand (m^3/day/ha)	66.7	70.5	88.0	97.7	102.1	96.8	76.2	52.4	40.9	45.6	50.7	54.8
Unit Water Requirement	0.001153 m^3/s/ha											
Irrigable Area	43,370 ha											
Crop Pattern	Sugarcane(44%) , Tropical Fruits(6%)											
	Maize(30%), Dry Bean(20%)						Cotton(30%), Soya Bean(20%)					
Irrigation Water Requirement	Q=50.0 m^3/s											

Without Illovo Estate (Net Irrigation Area : 30,611ha)

With Illovo excluded from the project area, the area and its design water requirement decrease so much so that the size of the canal and the expected total cost of construction will greatly decrease. Large estates within SVIP area are listed in Table 3.1-11.

[Table 3.1-11] Existing Large Estate in SVIP

Total	Illovo Estate		Sande Ranch	Phata	Kasinthula	Kaombe
	Nchalo	Alumenda				
15,757 ha	9,995 ha	2,764 ha	454 ha	296 ha	1,429 ha	819 ha

The whole area of project will become 30,611ha when the area of Illovo estate (Nchalo and Alumenda) is excluded. In this case, the design water requirement is 35.3m^3/s. Table 3.1-12 presents the estimated water requirement for the project area with Illovo excluded. For this brief comparison, the same cropping pattern as the case of With Illovo above was applied.

[Table 3.1-12] Irrigation Water Requirement without Illovo Estate

Division	Dry Season						Wet Season					
Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Monthly Rainfall(mm)	13.5	13.3	17.8	6.9	7.1	13.9	50.6	124.3	190.2	137.8	95.3	91.3
Daily Water Demand (m^3/day/ha)	66.7	70.5	88.0	97.7	102.1	96.8	76.2	52.4	40.9	45.6	50.7	54.8
Unit Water Requirement	0.001153 m^3/s/ha											
Irrigable Area	30,611 ha											
Crop Pattern	Sugarcane(44%) , Tropical Fruits(6%)											
	Maize(30%), Dry Bean(20%)						Maize(30%), Dry Bean(20%)					
Irrigation Water Requirement	Q=35.3 m^3/s											

As highlighted in the preceding discussion, not connecting Illovo to the water supply scheme for SVIP would reduce the water requirement to 35.3m^3/s, thereby saving irrigation water by 30%.

3.1.4. Rehabilitation of the Canal Structure of Illovo Estate

Water for Illovo Sugar Estate is supplied through 6 stages of pumping. The primary pumping is done at the lowest level of arable land from Shire River and then water is pumped to the next higher level in the remaining 5 stages based on the head that has to be overcome. The canal is constructed in such a way that its size decreases as the level at which the arable land is located increases.

In contrast to the situation described above, the main canal in SVIP will supply water to the whole arable land, starting from the highest level to the lowest level of arable land. Accordingly, the size of SVIP main canal is biggest at the highest level and smallest at the lowest level. Such discordance in irrigation structures makes it necessary to install many secondary canals for each block of arable land. This generates not only additional cost but also considerable loss of arable land for installing the secondary canal.

3.1.5. Electricity Supply Aspect

These estates supply water to the cane fields by pumping water from Shire River. Table 3.1-13 illustrates the pumpage and periods when the largest pumping discharges occurred between 2014 and 2015.

Cane Estates need a lot of electricity for pumping stations. According to data by Illovo, the amount of electricity needed for running the estates of Illovo (Nchalo + Alumenda + Sande + Kaombe) reaches its peak around September and October. The maximum monthly electricity consumption for pumping during this period is approximately 10,000,000Kwh.

This corresponds to daily use of about 333,333.3Kwh/day. If a pumping station is operated 15 hours a day the maximum amount of electricity used reaches as much as 22.2MW/yr. What this means is that if Illovo gets connected to the water supply scheme for SVIP this amount of electricity could be released to national grid.

[Table 3.1-13] Monthly Pumping Amount of Illovo Estate (2014~2015)

Division	Total	Nchalo	Alumenda	Sande Ranch	Kaombe Ranch
Peak Period		December	December	October	December
Peak River Abstraction(m^3)	31,306,439	22,584,578	6,323,866	1,185,235	1,304,760
Area (ha)	14,032	9,995	2,764	454	819

※ These data were provided by Illovo Estate

3.1.6. Financial Analysis

3.1.6.1. Including Illovo Case

Costs required to include Illovo

The cost part consists of construction costs and O&M cost. The construction cost consists of the cost for enlarging the feeder canal and Illovo canal cost. Tables 3.1-14 and Table 3.1-15 give this information.

[Table 3.1-14] Preliminary Cost Estimation by the With/Without Illovo Estate

Division	With Illovo (Q=50.0m^3/s)	Illovo (Q=14.7m^3/s)
Total Cost (thou. USD)	**37,100**	**11,130**
Intake (thou. USD)	4,000 (B=36m)	
Feeder Canal (thou. USD)	33,100	

※ The estimated cost is direct construction cost of open lined canal and adjacent roads.

[Table 3.1-15] Specification and Preliminary Cost of the Canal for only Illovo Estate

Division	Lining Canal	Concrete Canal	Pipe
Total (thou. USD)	5,900	16,700	34,600
Earth (thou. USD)	656	695	12,500
Structure (thou. USD)	5,244	16,005	22,100
Specification	b=3.6m B=8.4m H=1.6m L=11.5km	b=6.7m B=6.7m H=1.6m L=11.5km	D1,900mm@2 L=9.6km

※ The estimated cost is direct construction cost of open lined canal and adjacent roads.

Adding scale-up costs for Intake and Feeder canal and the lining cost for Illovo canal gives a total construction cost of 17,030,000 USD for the lined canal, and 45,730,000 USD for the pipe canal.

After the completion of the SVIP a separate dedicated organization will be configured to operate the waterways and irrigation systems. In general, the annual operating costs to manage the irrigation system are around 1% to 1.5% of the total Capital Cost at the planning stage. When 1.5% of O&M cost is applied, the O&M costs for the lined canal and pipe canal are 255,450 USD (17,030,000*1.5%) and 685,950 USD (45,730,000*1.5%), respectively.

Benefit from including Illovo

The Benefit part consists of:

- Release of up to 22.2MW to national grid
- Reduced Illovo Estates' pumping cost
- Water charge including the cost recovery of capital cost

The first benefit (Release of up to 22.2MW to national grid) could be estimated in several ways such as:

(1) generating cost with fuel,

(2) benefit from industry sector,

(3) construction cost of hydro-power station producing equivalent amount of electricity, etc.

Among these three options the construction cost of hydro-power station producing equivalent amount of electricity is the most objective and reasonable option.

In terms of option 3 (the construction cost of hydro-power station, the main idea was adopted from the "RENEWABLE ENERGY TECHNOLOGIES: COST ANALYSIS SERIES, *Volume 1: Power Sector,* Issue 3/5, Hydropower, June 2012 (IRENA: International Renewable Energy Agency), and it is as follows:

> *The total investment costs for hydropower vary significantly depending on the site, design choices and the cost of local labour and materials. The large civil works required for hydropower mean that the cost of materials and labour plays a larger role in overall costs than for some other renewable technologies. There is significantly less variation in the electro-mechanical costs.*

The total installed costs for large-scale hydropower projects typically range from a low of USD 1 000/kW to around USD 3 500/kW. However, it is not unusual to find projects with costs outside this range. For instance, installing hydropower capacity at an existing dam that was built for other purposes (flood control, water provision, etc.) may have costs as low as USD 500/kW. On the other hand, projects at remote sites, without adequate local infrastructure and located far from existing transmission networks, can cost significantly more than USD 3 500/kW.

Figure 4.2 presents the investment costs of hydropower projects by country/region. The cost of hydropower varies within countries and between countries depending on the resource available, site-specific considerations, cost structure of the local economy, etc., which explains the wide cost bands for hydropower. The lowest investment costs are typically associated with adding capacity at existing hydropower schemes or capturing energy from existing dams that do not have any hydropower facilities. The development of greenfield sites tends to be more expensive and typically range from USD 1 000 to USD 3 500/kW.

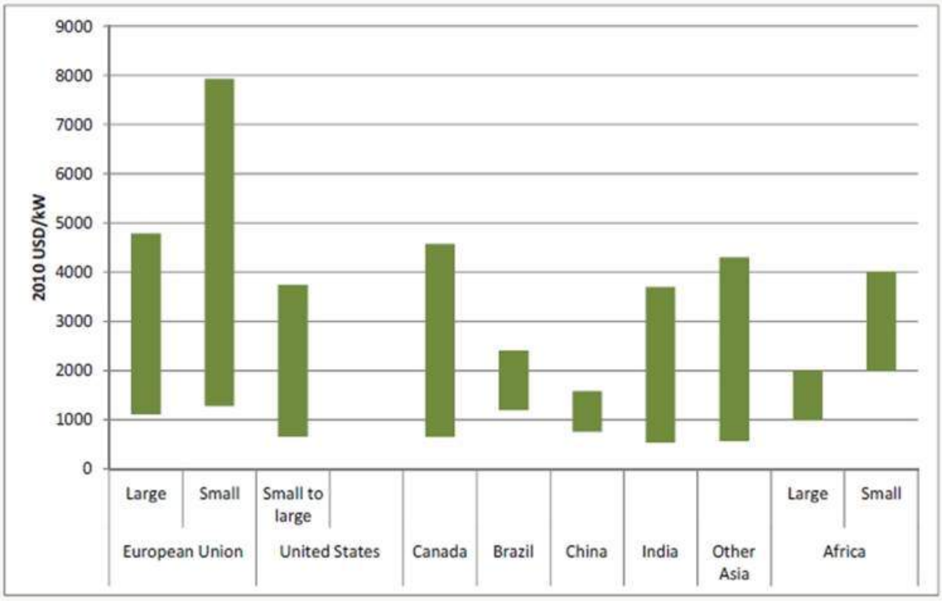


FIGURE 4.2: TOTAL INSTALLED HYDROPOWER COST RANGES BY COUNTRY

Sources: IRENA, 2011; IEA, 2010b; Black & Veatch, 2012; and IRENA/GIZ.

From the reference above, in the Africa region the hydropower cost varies from1,000 to 2,000 USD/kW for large scale of power station, and from 2,000 to 4,000 USD/kW for small scale power station. For a conservative estimation, hydropower cost of 2,000 USD/kW shall be considered as the benefit of release of 22.2MW to national grid. In this regard, the benefit shall be as follows:

- 2,000 USD/kW × 22,200 = 44,400,000 USD

This benefit shall be considered as the main benefit to the GoM for including Illovo in the SVIP.

The second benefit (Reduced Illovo Estates pumping cost) cannot be counted as economic benefit to Malawi because this benefit belongs to Illovo and not to the GoM.

The third benefit will be included in the Financial Analysis (Water charge including the cost recovery of capital cost). The GoM may control the water charge and adjust the economic feasibility of the project.

Benefit to Illovo Estates

Table 3.1-16 is an estimation of electrical charge for Illovo Estates (for more detail, refer to Chapter 4 "Financial Assessment of Illovo Estate participation")

[Table 3.1-16] Estimation of Electricity Charges of Illovo Estates

Division	'13 ~ '14	'14 ~ '15	Unit
Total Amount	86,446,227	80,348,170	KwHrs
On peak Unit charge	2,427,410	2,256,177	USD
Off peak Unit charge	2,102,372	1,954,067	USD
Total Charges	4,529,782	4,210,244	USD

Annual O&M cost of pumping station of Illovo Estates (Nchalo + Alumenda + Sande + Kaombe) is estimated at 296,075USD a year (for more detail, refer to Chapter 4 "Financial Assessment of Illovo Estate participation").

Benefit that Illovo can enjoy as Illovo Estates are integrated into SVIP is expected to largely come from cut in electrical charge and O&M cost of pump station. Therefore, the sum of the above two costs is 4,666,088 USD (an average of electrical charge for 2 years was applied). This is the benefit that Illovo can get.

Cost Recovery from Illovo Estates

Illovo has expressed the intention of long-term installment payment against the capital cost to be invested for Illovo inclusion. In this case, the cost recovery shall be implemented for 30 years, the life time of the project.

The capital cost for open canal was estimated at 17,030,000 USD. This amount was supposed to be invested evenly for three years as follows: 6,000,000 USD (1st year); 6,000,000 USD (2nd year); 5,030,000 USD (3rd year).

After completion of the SVIP, a separately dedicated organization will be configured to operate the canal and irrigation systems. In general, the annual operating costs to manage the irrigation system are around 1% to 1.5% of the total Capital Cost. For the open canal system, applying 1.5% of the capital cost, gives an annual O&M of 255,450 USD.

The capital cost for a pipe canal was estimated at 45,730,000 USD. The construction period could be shorter than that of an open canal. As such, most of the construction cost would be invested in the first two years as follows: 16,000,000 USD (1st years), 16,000,000 USD (2nd year), 13,730,000 USD (3rd year). For the pipe canal system, applying 1.5% of the capital cost, the annual O&M is 685,950 USD.

Cost and Benefit Flow for Open Canal

Table 3.1-17 shows the results of Financial Analysis for the different water fees. When the water fee is set at 8 USD/1000m3 for the amount of water used and the discount rate is set at 5%, the B/C ratio is 1.51 and FIRR is 8.62%. The discount rate of 5% is used by IMF and World Bank for loans longer than 15 years. From these results the break-even price for the water price is 5.3 USD/ 1000m^3. (See Chapter 4 "Financial Assessment of Illovo Estate participation")

[Table 3.1-17] Results of Financial Analysis for Different Water Fees

Water Fees (USD/1,000m^3)	FIRR	B/C
5	4.50%	0.94
5.3 (Break-even Price)	**4.98%**	**1.00**
6	6.03%	1.13
7	7.39%	1.32
8	8.62%	1.51
10	10.80%	1.88
12	12.73%	2.26
14	14.46%	2.64

(For more detail, refer to Chapter 4 "Financial Assessment of Illovo Estate participation")

The benefit to Illovo changes depending on the level of water fee. Table 3.1-18 shows the variation of benefit to Illovo based on water fee charged for the annual amount of water of 290,379,000 m^3.

[Table 3.1-18] Variation of Benefit to Illovo

Annual Benefit of Illovo (USD)	Water Fees (USD/1,000m^3)	Annual Water Charges (USD)	Annual Net Benefit of Illovo (USD)
4,666,088	5	1,451,895	3,214,193
4,666,088	6	1,742,274	2,923,814
4,666,088	7	2,032,653	2,633,435
4,666,088	8	2,323,032	2,343,056
4,666,088	10	2,903,790	1,762,298
4,666,088	12	3,484,548	1,181,540
4,666,088	14	4,065,306	600,782

From these results and for the case of water fee = 8 USD/1,000m^3, which is about 50% of the total annual benefit, Illovo can gain a benefit of 2,343,056 USD a year. This also gives a good B/C ratio of 1.51.When the water tariff is 10 USD/1,000m^3, the annual net benefit to Illovo Estate drops to 1,762,298 USD.

Cost and Benefit Flow for Pipe Canal

When the water fee is set at 8 USD/1000m^3 and the discount rate is set at 5%, the B/C ratio is 0.56 and FIRR is 0.39%. Table 3.1-19 shows the results of Financial Analysis for the different water fees. (See Chapter 4 "Financial Assessment")

[Table 3.1-19] Results of Financial Analysis for Different Water Fees

Water Fees (USD/1,000m^3)	FIRR	B/C
10	0.39%	0.56
12	2.13%	0.70
14 (Break-even Price)	**4.85%**	**0.98**
16	5.98%	1.12
18	7.01%	1.26
20	7.96%	1.40

(For more detail, refer to Chapter 4 "Financial Assessment of Illovo Estate participation")

The results show that the benefit to Illovo changes depending on the water fee. Table 3.1-20 shows the variation of benefit to Illovo due to changes in the water fee.

[Table 3.1-20] Variation of Benefit to Illovo

Annual Benefit of Illovo (USD)	Water Fees (USD/1,000m^3)	Annual Water Charges (USD)	Annual Net Benefit of Illovo (USD)
4,666,088	10	2,903,790	1,762,298
4,666,088	12	3,484,548	1,181,540
4,666,088	14	4,065,306	600,782
4,666,088	16	4,646,064	20,024
4,666,088	18	5,226,822	-560,734
4,666,088	20	5,807,580	-1,141,492

These results clearly show that in case of pipe canal, the benefit to Illovo shall be considerably reduced compared to the open canal. The pipe canal also gives no good B/C ratios.

Advantage in terms of Investment Recovery

As shown above, if Illovo Estates participates in SVIP project, it would be easier to recover the input capital and would contribute to increased benefits of the project. At the same time, the process of negotiating water price and capital recovery condition is important. The outcome of the negotiation has a bearing on the magnitude of the project benefits.

Conclusion of economic analysis for including Illovo

The additional capital cost for the inclusion of Illovo shall be recovered through a reasonable water pricing.

The benefit of release of 22.2MW to national grid was estimated at 44.4million USD. This benefit is the main benefit to the GoM for including Illovo in the SVIP.

3.1.6.2. Excluding Illovo Case

1) Financial Analysis for the Area of Phase I and II (43,370 ha)

On the other hand, it is desirable to discover new developable areas along the Feeder and Bangula canal. About 4,992ha could be newly included in the project. (See the detail in the Figure 3.5-2)

Therefore the new total irrigable areas of 4,992ha could be included in the project when Illovo estates are excluded.

The cost part of this option consists of the additional project cost for the two irrigation areas.. The estimated costs are:

- Southern area of Bangula: 88,476,000 USD
- Along the Feeder and Bangula: 74,114,000 USD
- Total additional cost: 162,590,000 USD

The benefit part of this option is the additional agricultural revenue coming from the new areas. Following the recent information of Kasinthula, the net income is approximately estimated at 1,000 USD/ha. If this reference is applied for the new areas, the additional agricultural revenue coming from this area shall be about 8,698,000 USD a year.

Considering the above cost and benefit, the cost and benefit flow is estimated for 30 years, and Table 3.1-21 present the results.

[Table 3.1-21] Cost and Benefit Flow for New Area Development

Year in Order	Year	Construction Cost	O & M Cost	Total Cost	Benefit (water fee)	Cash Balance
1	2018	60,000,000		60,000,000	-	(60,000,000)
2	2019	60,000,000		60,000,000	-	(60,000,000)
3	2020	42,590,000		42,590,000	-	(42,590,000)
4	2021			-	-	-
5	2022			-	-	-
6	2023		2,438,850	2,438,850	8,698,000	6,259,150
7	2024		2,438,850	2,438,850	8,698,000	6,259,150
8	2025		2,438,850	2,438,850	8,698,000	6,259,150
9	2026		2,438,850	2,438,850	8,698,000	6,259,150
10	2027		2,438,850	2,438,850	8,698,000	6,259,150
11	2028		2,438,850	2,438,850	8,698,000	6,259,150
12	2029		2,438,850	2,438,850	8,698,000	6,259,150
13	2030		2,438,850	2,438,850	8,698,000	6,259,150
14	2031		2,438,850	2,438,850	8,698,000	6,259,150
15	2032		2,438,850	2,438,850	8,698,000	6,259,150
16	2033		2,438,850	2,438,850	8,698,000	6,259,150
17	2034		2,438,850	2,438,850	8,698,000	6,259,150
18	2035		2,438,850	2,438,850	8,698,000	6,259,150
19	2036		2,438,850	2,438,850	8,698,000	6,259,150
20	2037		2,438,850	2,438,850	8,698,000	6,259,150
21	2038		2,438,850	2,438,850	8,698,000	6,259,150
22	2039		2,438,850	2,438,850	8,698,000	6,259,150
23	2040		2,438,850	2,438,850	8,698,000	6,259,150
24	2041		2,438,850	2,438,850	8,698,000	6,259,150
25	2042		2,438,850	2,438,850	8,698,000	6,259,150
26	2043		2,438,850	2,438,850	8,698,000	6,259,150
27	2044		2,438,850	2,438,850	8,698,000	6,259,150
28	2045		2,438,850	2,438,850	8,698,000	6,259,150
29	2046		2,438,850	2,438,850	8,698,000	6,259,150
30	2047		2,438,850	2,438,850	8,698,000	6,259,150
31	2048		2,438,850	2,438,850	8,698,000	6,259,150
32	2049		2,438,850	2,438,850	8,698,000	6,259,150
33	2050		2,438,850	2,438,850	8,698,000	6,259,150
34	2051		2,438,850	2,438,850	8,698,000	6,259,150
35	2052		2,438,850	2,438,850	8,698,000	6,259,150
Total		162,590,000	73,165,500	235,755,500	260,940,000	25,184,500
Internal rate of return (IRR): 0.79%						
Discount rate: 5%						
B/C: 0.59						

The applied benefit of 1,000 USD is a conservative estimation. The actual benefit is expected to be higher than this estimation. For purposes of decision making a series of sensitivity analyses were implemented, and Table 3.1-22 ~ Table 3.1-24 show the results of the sensitivity analyses with varying discount rates.

[Table 3.1-22] Results of Sensitivity Analysis (Discount Rate: 5%)

Annual Benefit /ha (USD)	Discount Rate	Internal Rate of Return (IRR)	B/C
1,000	5%	0.79	0.59
1,500	5%	3.99	0.88
1,700 (Break-even)	**5%**	**5.02**	**1.00**
2,000	5%	6.40	1.18
2,500	5%	8.40	1.47
3,000	5%	10.15	1.77

[Table 3.1-23] Results of Sensitivity Analysis (Discount Rate: 4%)

Annual Benefit /ha (USD)	Discount Rate	Internal Rate of Return (IRR)	B/C
1,000	4%	0.79	0.67
1,500 (Break-even Price)	**4%**	**3.99**	**1.00**
2,000	4%	6.40	1.33
2,500	4%	8.40	1.66
3,000	4%	10.15	2.00

[Table 3.1-24] Results of Sensitivity Analysis (Discount rate: 3%)

Annual Benefit /ha (USD)	Discount Rate	Internal Rate of Return (IRR)	B/C
1,000	3%	0.79	0.75
1,320 (Break-even)	**3%**	**2.96**	**1.00**
1,500	3%	3.99	1.13
2,000	3%	6.40	1.51
2,500	3%	8.40	1.89
3,000	3%	10.15	2.26

Comparison between Including and Excluding Illovo

For the inclusion of Illovo case, Table 3.1-17 shows that the assumption of water fee = 7 ~ 10 USD/1,000m^3 is favorable to the Project. This condition also generates good benefit to Illovo Estates.

For the exclusion of Illovo case, Table 3.1-22 shows that the assumption of annual benefit of 2,000 USD/ha with a discount rate of 5% gives B/C=1.18. It is also possible to get B/C = 1.13 with an annual benefit of 1,500 USD/ha and a discount rate of 5% (Table 3.1-21).

Thus, the economic feasibility depends on the water fee (for the inclusion of Illovo case) and, the benefit from new areas and the discount rate (for the exclusion of Illovo case). In general, the economic feasibility of SVIP is higher when Illovo estate is included.

For instance, for the inclusion of Illovo case, with a water fee of 8 USD/1,000m^3 the B/C ratio is 1.51. This is a very favorable condition for both GoM and Illovo Estates. However, in the exclusion of Illovo Estates case, the equivalent condition could be possible only when the annual benefit from new land is higher than 3,000 USD/ha. This is very difficult to realize under smallholder conditions.

It should however be noted that the non-measuring factors such as social influences and sustainability of resources were not considered. Generally the case of excluding Illovo gets more advantages in the non-measuring factors. Therefore GoM should carefully consider both cases.

2) Financial Analysis for the Area of Phase I (22,280 ha)

When the Illovo Estates are excluded from the project, the equivalent area (10,000 ha) could be developed instead of Illovo estates. The new area is found in Zones B and C (See the layout plan of SVIP). The area for Zone B-a and B-b is 5,727 ha. The rest (4,273 ha) are found in Zone C.

The project cost for Phase I for the exclusion of Illovo Estate was estimated at 220,764,000 USD. The project cost for the development of the new areas of Zone B and C was estimated at 396,320,000 USD. The difference of 175,556,000 USD shall be the additional cost for the alternative case.

The benefit part of this option is the additional agricultural revenue that comes from the new areas. Following the recent information obtained from Kasinthula, the net income is approximately 1,000 USD/ha. If this reference is applied for the new areas, the additional agricultural revenue coming from this area shall be about 10,000,000 USD a year.

Using the above costs and benefits, the cost and benefit flow is estimated for 30 years, and Table 3.1-25 shows the results.

[Table 3.1-25] Cost and Benefit Flow for New Area Development

Year in Order	Year	Construction Cost	O & M Cost	Total Cost	Benefit (water fee)	Cash Balance
1	2018	60,000,000		60,000,000	-	(60,000,000)
2	2019	60,000,000		60,000,000	-	(60,000,000)
3	2020	55,556,000		55,556,000	-	(55,556,000)
4	2021			-	-	-
5	2022			-	-	-
6	2023		2,633	2,633	10,000,000	9,997,367
7	2024		2,633	2,633	10,000,000	9,997,367
8	2025		2,633	2,633	10,000,000	9,997,367
9	2026		2,633	2,633	10,000,000	9,997,367
10	2027		2,633	2,633	10,000,000	9,997,367
11	2028		2,633	2,633	10,000,000	9,997,367
12	2029		2,633	2,633	10,000,000	9,997,367
13	2030		2,633	2,633	10,000,000	9,997,367

14	2031		2,633	2,633	10,000,000	9,997,367
15	2032		2,633	2,633	10,000,000	9,997,367
16	2033		2,633	2,633	10,000,000	9,997,367
17	2034		2,633	2,633	10,000,000	9,997,367
18	2035		2,633	2,633	10,000,000	9,997,367
19	2036		2,633	2,633	10,000,000	9,997,367
20	2037		2,633	2,633	10,000,000	9,997,367
21	2038		2,633	2,633	10,000,000	9,997,367
22	2039		2,633	2,633	10,000,000	9,997,367
23	2040		2,633	2,633	10,000,000	9,997,367
24	2041		2,633	2,633	10,000,000	9,997,367
25	2042		2,633	2,633	10,000,000	9,997,367
26	2043		2,633	2,633	10,000,000	9,997,367
27	2044		2,633	2,633	10,000,000	9,997,367
28	2045		2,633	2,633	10,000,000	9,997,367
29	2046		2,633	2,633	10,000,000	9,997,367
30	2047		2,633	2,633	10,000,000	9,997,367
31	2048		2,633	2,633	10,000,000	9,997,367
32	2049		2,633	2,633	10,000,000	9,997,367
33	2050		2,633	2,633	10,000,000	9,997,367
34	2051		2,633	2,633	10,000,000	9,997,367
35	2052		2,633	2,633	10,000,000	9,997,367
Total		175,556,000	79,000	175,635,000	300,000,000	124,365,000
Internal rate of return (FIRR): 1.28%						
Discount rate: 5%						
B/C: 0.63						

The applied benefit 1,000 USD is a conservative estimation, therefore the actual benefit is plausible to be higher than this estimation. For the convenience of decision a series of sensitivity analysis was implemented, and the Table 3.1-26 ~ Table 3.1-27 shows the results of sensitivity analysis with varying the discount rates.

[Table 3.1-26] Results of Sensitivity Analysis (Discount Rate: 5%)

Annual Benefit /ha (USD)	Discount Rate	Internal Rate of Return (FIRR)	B/C
1,000	5%	3.13	0.75
1,350 (Break-even)	**5%**	**5.13**	**1.02**
1,500	5%	5.89	1.13
2,000	5%	8.11	1.51
2,500	5%	10.03	1.89
3,000	5%	11.73	2.26

[Table 3.1-27] Results of Sensitivity Analysis (Discount Rate: 4%)

Annual Benefit /ha (USD)	Discount Rate	Internal Rate of Return (FIRR)	B/C
1,000	4%	3.13	0.87
1,150 (Break-even)	**4%**	**4.03**	**1.01**
1,500	4%	5.89	1.31
2,000	4%	8.11	1.75
2,500	4%	10.03	2.19
3,000	4%	11.73	2.62

[Table 3.1-28] Results of Sensitivity Analysis (Discount Rate: 3%)

Annual Benefit /ha (USD)	Discount Rate	Internal Rate of Return (IRR)	B/C
1,000 (Break-even Price)	**3%**	**3.13**	**1.02**
1,500	3%	5.89	1.53
2,000	3%	8.11	2.04
2,500	3%	10.03	2.55
3,000	3%	11.73	3.06

Comparison between Including and Excluding Illovo

For the inclusion of Illovo case, Table 3.1-17 showed that water fee = 7 ~ 10USD/1,000m^3 is favorable for the Project. These prices also generate good benefit for the Illovo estates.

For the exclusion of Illovo case, Table 3.1-23 shows that the scenario of annual benefit of 2,000 USD/ha with a discount rate of 5% gives B/C=1.51, which is higher than the case of whole project area (Financial Analysis for the Area of Phase I and II (43,370 ha)", where B/C=1.18 with the same conditions).

In general, the economic feasibility of the SVIP is higher when Illovo Estates is included. For instance, inclusion of Illovo and charging a water fee of 8 USD/1,000m^3, the B/C ratio is 1.51. This is a very favorable scenario for both GoM and Illovo Estates. However for the without Illovo Estates case, the equivalent condition is possible only when the annual benefit from new land is higher than 2,200 USD/ha. This is difficult to achieve under smallholder management.

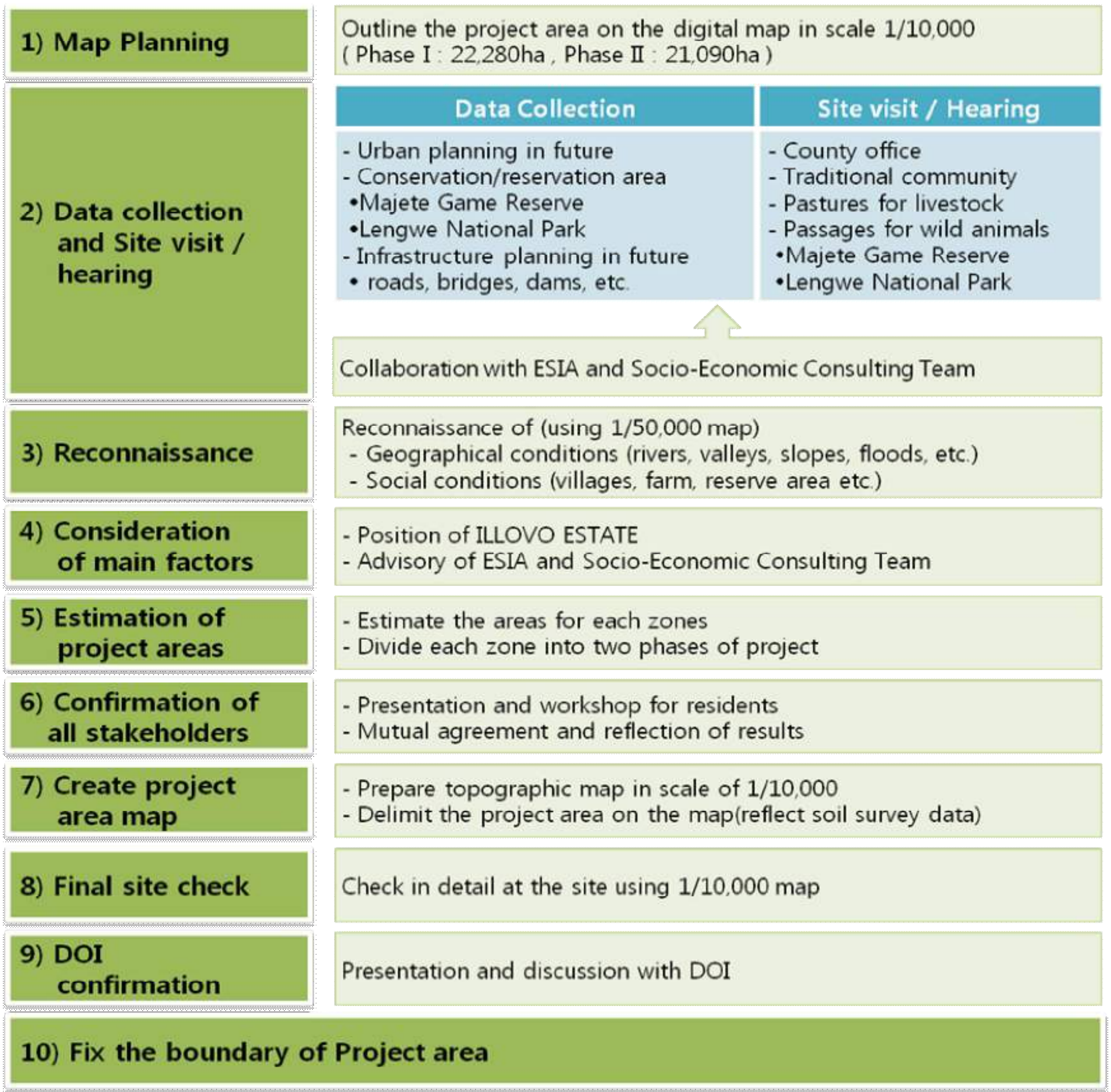
3.2. Irrigable Areas to be Developed

TOR Requirements

A broad analysis, based on available data, shall allow delimiting areas to be developed, based on soils aptitude, topography, existing farming systems, grazing areas, ecosystems to be protected, etc. The consultant shall use thematic mapping to demonstrate its conclusions.

3.2.1. Delimiting the Project Area

The project area and its cropping pattern are two major pillars to determine the water demand and the irrigation canal capacity. Even though the ToR of TFS provides the number of areas to be developed under SVIP, they are not the definitive values, and should be adjusted considering the natural conditions (such as geography, soil property, flood, etc.), social conditions (village, migration, reserve area, etc.), economic conditions, environmental conditions, and technical design considerations, etc. Figure 3.2-1 shows the Procedures for delimiting project areas.



[Figure 3.2-1] Procedures for Delimiting Project Areas

1) Map Planning

The first step in delineating the project area is to outline the area on the digital contour map of 1/10,000 scale obtained from GoM. This map provides adequate information to establish the project area for the initial stage of map planning.

2) Data Collection and Site Visit / Hearing

In order to delineate the project area successfully, more information which could not be found on the map were collected from other sources such as: Urban planning, Conservation/reservation area (Majete Game Reserve, Lengwe National Park), and Infrastructure planning (roads, bridges, dams, etc.).

The pastures for livestock, passages for wild animals in Majete Game Reserve and Lengwe National Park area were examined. Public officers and the leaders of communities will be consulted to provide input on how best to implement the SVIP.

3) Reconnaissance

Landmarks such as rivers and valleys identified from the map will be verified through the reconnaissance surveys. Other geographical conditions (e.g. topographic slopes and flooding range, etc.) will be sized during this survey. Social conditions such as village, farm, reserve area will be described to determine if they could be included in the project area.

4) Consideration of Main Factors

Determining the inclusion of Illovo Estate is the most important factor in the design, cost profitability and institutional arrangements of the project. The position of Illovo Sugar Estate was clarified in detail, and reflected in the procedure to delineate the project area. These procedures were implemented through close discussions with DoI.

Issues of land tenure/migration and environment are critical in determining the areal extent of the project area. These issues were reflected to adjust the boundaries of project area by adopting the advisories of ESIA and Socio-Economic Consulting Team.

5) Estimation of Project Areas

From the consideration of irrigation topographic conditions, the vulnerability to flooding and adequacy of soil aptitudes for agriculture, the tentative project areas are prepared. The tentative project areas are still larger than the final project areas (43,370 ha) because they include the non-farming areas such as roads, irrigation & drainage canal, etc. The net irrigation area was obtained excluding these non-farming areas.

Though there is no affirmative value on the reduction rate, 80~85% could be empirically acceptable in Asian areas. In this study the net irrigation areas was estimated at 85% of Gross areas except Illovo Estate zone. Table 3.2-1 shows the tentative project areas for each zone.

[Table 3.2-1] Tentative Project Areas of Each Zone

Division	Location	Total Area	Net Area
Zone I-1	Western area of Shire River (before Naphala stream) ~ Northern area of Mwanza River	9,631 ha	7,866 ha
Zone I-2	Illovo(Nchalo) Estate	11,250 ha	9,995 ha
Zone A	Western area of Naphala stream ~ Northern area of Nkombedzi River	5,199 ha	4,419 ha
Zone B	Southern area of Nkombedzi River ~ Northern area of D140, D130 Road	6,737 ha	5,726 ha
	Illovo(Alumenda) Estate	3,188 ha	2,764 ha
Zone C	Southern area of D140, D130 Road ~ Northern area of Lalanje River	10,749 ha	9,136 ha
Zone D	Southern area of Lalanje River ~ Northern area of Thangadzi River	4,077 ha	3,464 ha
TOTAL		**50,831 ha**	**43,370 ha**

3.2.2. Factors to be Considered

Topography

Malawi government provided the following topographical data for this project.

- High resolution digital terrain model
- Accurate orthophoto maps in digital formats
- Orthophoto map of scale of 1:10,000 for the project area
- Map of scale of 1:50,000 for the project area

By using these topographic maps outlines were drawn of developable irrigation areas, a canal line connecting each irrigation area with the feeder canal was designed, and then areas which irrigation water could reach were determined. Hence, the boundary of each project zone(I-1, I-2, A, B, C, D) was decided and an outline of irrigation canal system was been drawn in regard to the geographical features of the areas.

Figure 3.2-2 shows the map of project zones and main canals (Feeder canal, Bangula canal and Supuni canal).

[Figure 3.2-2] Tentative Project Areas and Main Canals

In order to determine irrigation areas in detail, the following conditions were considered.

(A) Land which could be supplied with water supply and has a gentle slope
(B) Land which has suitable soil properties for agriculture as ascertained by the soil survey
(C) Land which is located close to a village and could be conveniently cultivated
(D) Land which has good drainage condition and is not prone to flooding
(E) Land where sources of water supply such as dam or weir could be developed in its upper region
(F) Land which has good accessibility (i.e., with passable roads)
(G) Land where agricultural activity is vigorous

Table 3.2-2 shows criteria for the quantitative determination of land that could be included in the irrigation development area. And Table 3.2-3 shows the evaluation results of each zone.

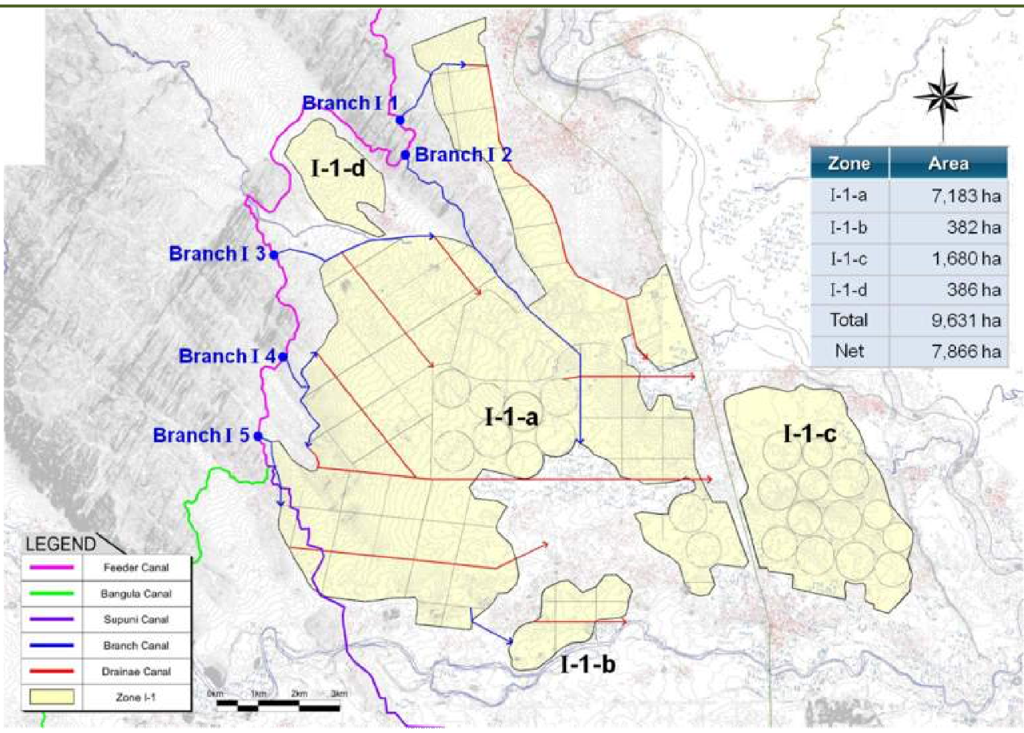
[Table 3.2-2] Selection Criteria of Irrigable Land

Item	Point	Point			
		Very Good	Good	Normal	Poor
A. Geographic condition	3.0	within 2% slope	within 3% slope	within 5% slope	over 5% slope
B. Soil characteristic	2.0	L, SL, SiL	CL, SiC, SC	LS, C	S, Gr
C. Farming activity	1.5				
D. Distance from village	1.0	within 0.5km form village	within 1km form village	within 2km form village	over 2km form village
E. Easy carrying out of production	1.0	within 1km from main road	within 2km form main road	within 3km from main road	over 3km form main road
F. Non-inundation land	0.5	-	1 time per 3 years	1 time per year	over 1 time per year
G. Possibility of irrigation water development	0.5	Dam site	Weir site	River	-
H. Positional distribution	0.5				
Total	10.0				

[Table 3.2-3] Evaluation Results of Each Zone

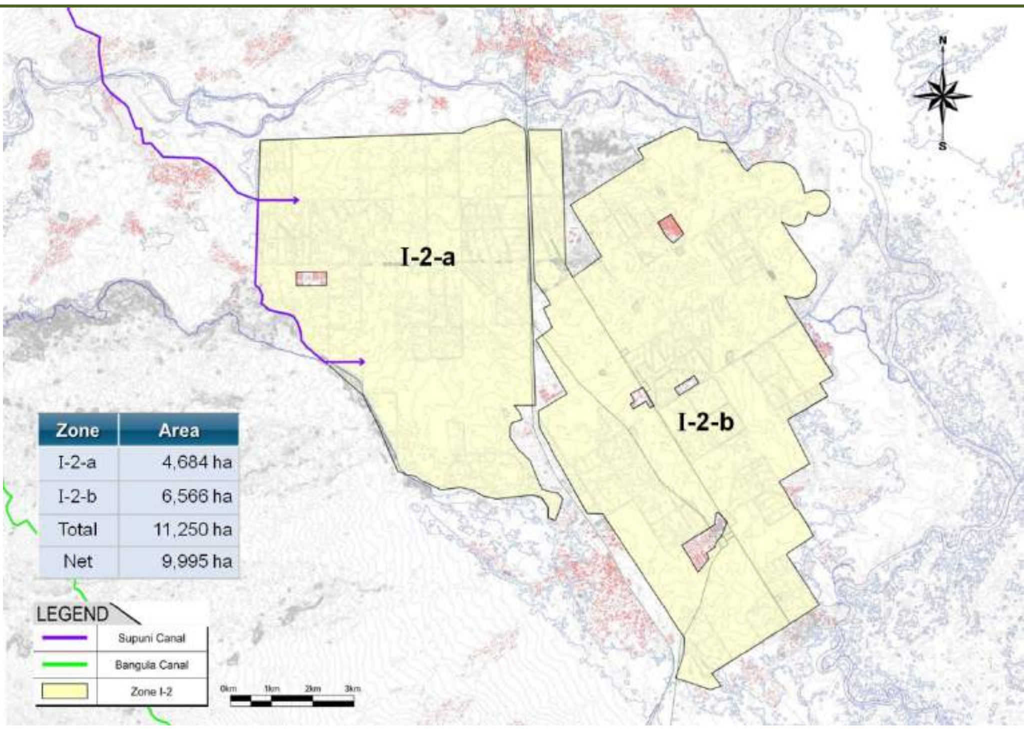
Item	Zone I-1	Zone I-2	Zone A	Zone B	Zone C	Zone D
A. Geographic condition	2.0	3.0	2.0	2.0	2.0	2.0
B. Soil characteristic	1.3	1.3	1.3	1.3	1.3	1.3
C. Farming activity	1.5	1.5	0.5	1.0	0.5	0.5
D. Distance from village	0.7	0.7	0.7	0.7	0.4	0.4
E. Easy carrying out of production	0.4	1.0	0.4	0.7	0.4	0.4
F. Non-inundation land	0.5	0.5	0.1	0.3	0.3	0.3
G. Possibility of irrigation water development	0.0	0.0	0.3	0.1	0.0	0.0
H. Positional distribution	0.5	0.1	0.3	0.3	0.3	0.1
Total	7.9	8.1	5.6	6.4	5.2	5.0

Detailed boundary of each project zone has been drawn in accordance with the above steps and criteria, and Figure 3.2-3 ~ Figure 3.2-8 show the determined boundaries, offtake position and connecting canal, and irrigation network in the each area.



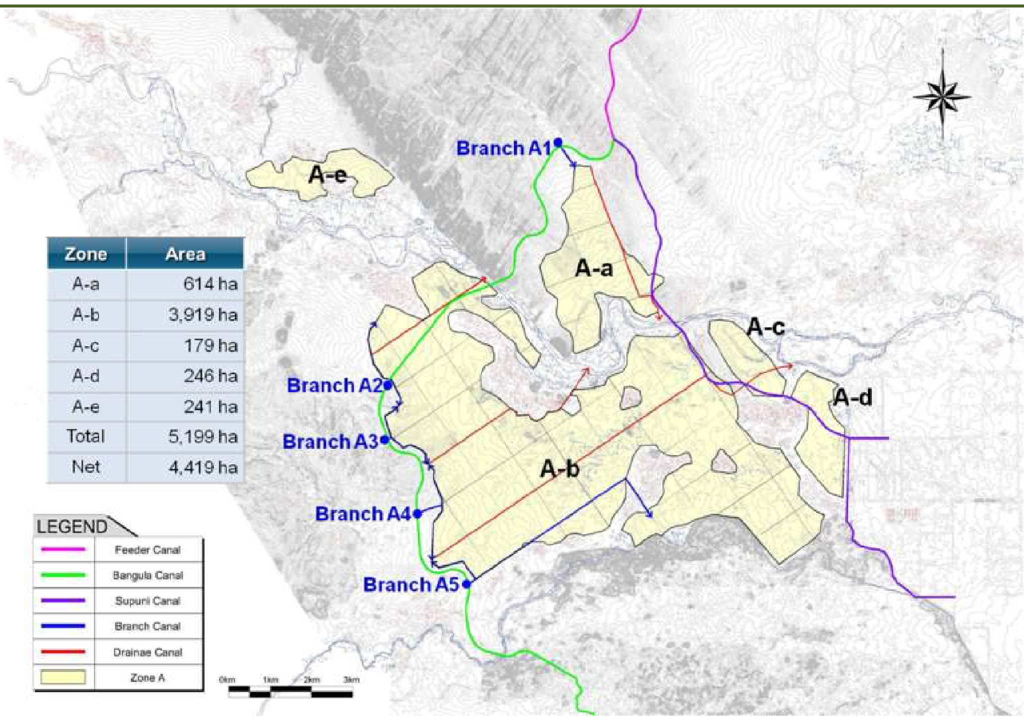
- Exclusion of the forest area around the village
- Exclusion of the inundation area nearby river
- Inclusion of the existing Estate(Kasinthula, Pahta and Sande Ranch)

[Figure 3.2-3] Tentative Project Area Zone I-1



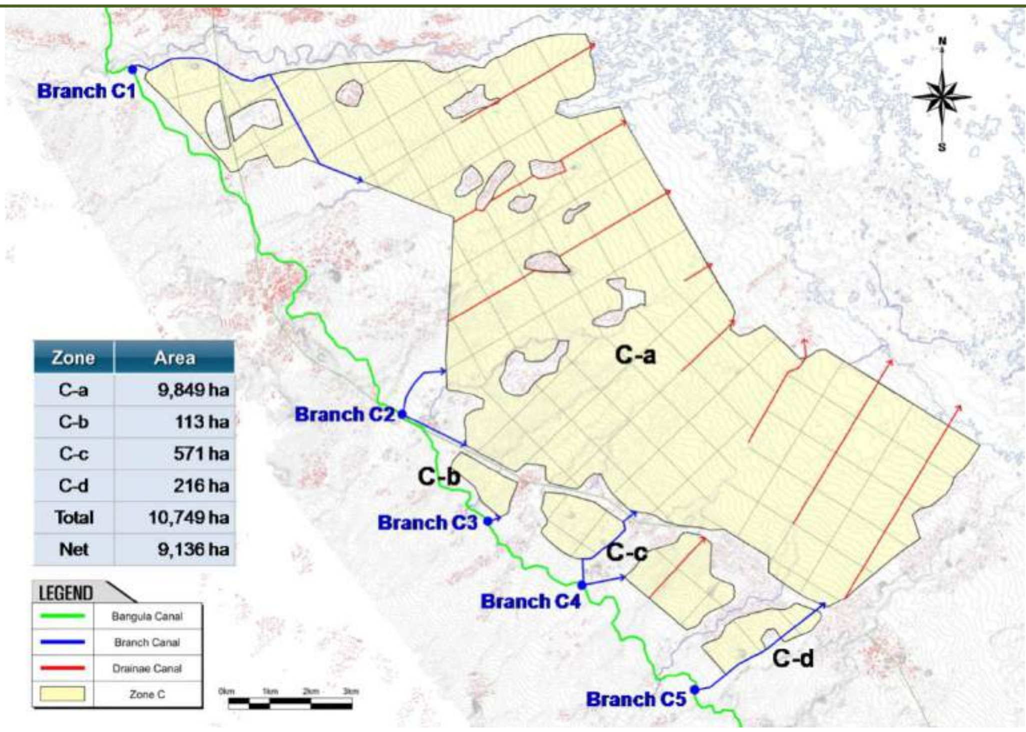
- Set up the existing Nchalo Estate totally (including scheme and infrastructure, etc.)

[Figure 3.2-4] Tentative Project Area Zone I-2



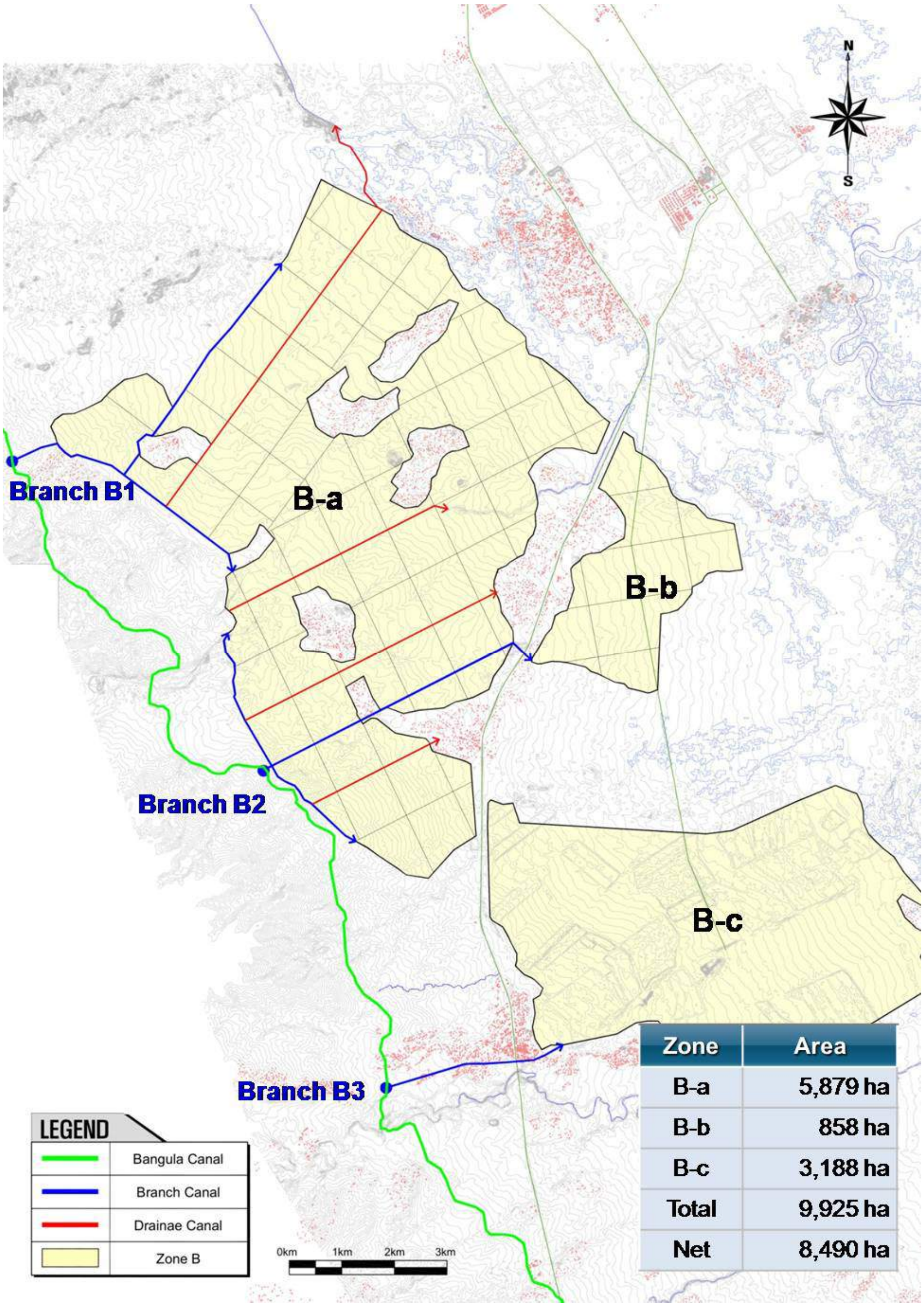
- Exclusion of the forest area around the village
- Exclusion of the inundation area nearby Mwanza River and Lengwe National Park
- Inclusion of a new area 425ha of TA Lundu reflecting the requests of farmers

[Figure 3.2-5] Tentative Project Area Zone A



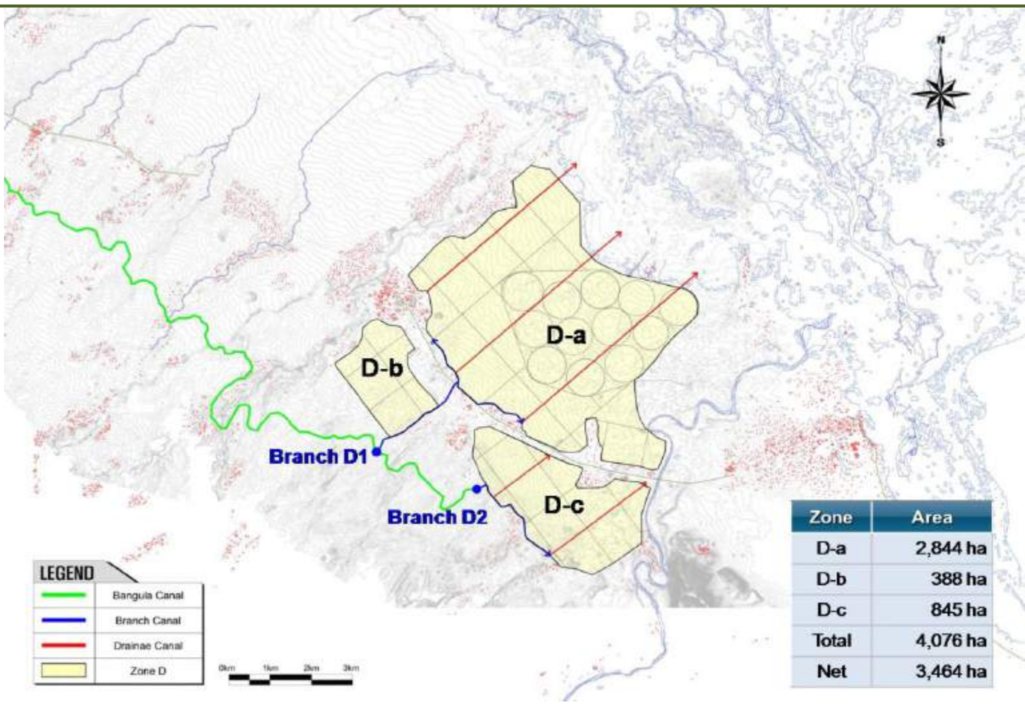
- Exclusion of the forest area around the village
- Exclusion of the inundation area nearby Shire River
- Exclusion of the Mphoza Dambo and the Ngabu township boundaries

[Figure 3.2-6] Tentative Project Area Zone C



- Exclusion of the forest area around the village
- Exclusion of the inundation area nearby Shire River

[Figure 3.2-7] Tentative Project Area Zone B



- Exclusion of the forest area around the village
- Exclusion of the inundation area nearby river
- Exclusion of the Lengwe National Park

[Figure 3.2-8] Tentative Project Area Zone D

Soil Aptitude

The soil survey for project area was done with a view to determining areas that could be placed under the SVIP. And where land was noted to be unsuitable for irrigation, such land was excluded from the project area. It was this principle that was adopted in the determing the extent of the project area on the basis of the suitability of soils for agriculture production.

Existing Farming Systems

Apart from large estates like Illovo and Kasinthula, most of the project area is owned by small holders. They do not have any irrigation facility which could tap surface or ground water, so they cultivate crops only during the rainy season major crops comprise corn, sorghum, cassava, cotton plant and soybean, all of which have a short cultivation period. They still use conventional farming systems which are labor intensive and very inefficient. Additionally, because of inadequate rainfall and frequent droughts, yields are generally very low.

In light of the above, it is clear that the introduction of irrigated agriculture in the project area, complemented with modern farming techniques, crop yields will be greatly enhanced thereby improving the quality of life of the local communities. This has the potential to change the existing simple cropping pattern of low value crops to high value crops.

It is obvious that large estates such as Illovo and Kasinthula will continue to grow sugar cane even after the introduction of SVIP. Also, it has been noted from field surveys that new project areas do not grow specific crops hence it would be easy to introduce new crops should the need arise. Therefore the areal extent of the project area will not be disrupted by the existing farming system.

[Figure 3.2-9] Maize Cultivation Area of Smallholder

Grazing Areas

Livestock rearing and growing crops are key agricultural production activities in the project area. Cattle are an additional source of income during the dry season when crop production is at its lowest because of water scarcity. There is no designated area for cattle grazing in the project area. As such, during the dry season almost every corner of the area is used for cattle grazing.

If SVIP project is implemented, crop production during the dry season will be possible, resulting in a significant reduction in cattle grazing area. But the impact will not be significant. Additionally, with the introduction of irrigated agriculture, some farmers will change from feeding their cattle using the current grazing system to keeping cattle in livestock pens since SVIP will boost crop production resulting in the production of abundant livestock feed. As such, the need for “free range” grazing will be greatly reduced. Similar sentiments have been expressed by local communities within the project area. Hence they did not demand reserved areas for pasture during the time of the field survey.

[Figure 3.2-10] Grazing Areas View in the Project Area

Flooding Areas

The 1:10,000 topographic map, the basis of delineating flood prone areas, was produced from satellite video of the flooding situation complemented by field surveys. Drawing identification number of flooding map uses 1:10,000 scale as GIS drawing identification number included in this project. Figure 2.5-13 shows flood pone areas by flood magnitude and associated return period.

Based on a 10-year flood, which is the standard for evaluating the vulnerability of farming land to flooding, most of Phase I project area is prone to flooding, in particular the area around Illovo Sugar Estate at Nchalo. A relatively small area under Phase II, particularly the area in Zone C. Most of the project area apart from the ones mentioned above is safe from 10 year floods.

In areas that are vulnerable to floods, there may be need to implement structural measures for flood mitigation to curb flooding.

3.3. With / Without Lining the Feeder Canal

TOR Requirements

Sogreah 1992's design concluded the feeder canal should be lined. The Consultant shall review this conclusion based on recent evolutions of the project scope, of lining techniques, partial lining options, and of the cost of works in similar conditions.

3.3.1. Factors to be Considered

The feeder canal has to be big enough to convey the design water requirement of 50.0m^3/s which will be supplied to the whole project area of 43,370ha including both the 1st and the 2nd phase areas. It has also been recommended that the canal should be lined to reduce seepage losses. Table 3.3-1 lists the details of each canal type.

[Table 3.3-1] Comparison of Earth Canal and Lined Canal

Items	Earth Canal	Lined Canal
Design factor	Large radius of curvature - more than 100m - canal length is long	Large radius of curvature - more than 50m - canal length is short
	Permissible maximum velocity is small - 0.7~1.0m/s - canal cross section is large	Permissible maximum velocity is large - 1.5~2.5m/s - canal cross section is small
	Gentle longitudinal slope for the erosion protection - 1/5,000 ~ 1/6,000 - canal length is long	Not being limited to longitudinal slope - canal length is short
	Gentle canal slope - 1:2.0~1:2.5 - canal cross section is large	Steep canal slope - 1:1.5~1:2.0 - canal cross section is large
	Friction loss of canal is large - n=0.025 - canal cross section is large	Friction loss of canal is small - n=0.015 - canal cross section is small
Loss	Canal loss is large - Conveyance Efficiency 80~85%	Canal loss is small - Conveyance Efficiency 89%
Cost	Less than lined canal	Higher than earth canal
O&M	Difficult	Easy
Rehabilitation	Easy	Difficult
Extendibility	Favorable	Unfavorable

[Figure 3.3-1] Earth Canal(left) and Lined Canal(right) of Illovo Estate

[Table 3.3-2] Benefit/Cost Analysis for Canal Linings

Type of Lining	Durability(Year)	Effectiveness (Seepage Reduction)	Construction Cost	B/C Ratio
Concrete	40~60	70%	1.92~2.33 USD	3.0~3.2
Exposed Geomembrane	20~40	90%	1.03~1.53 USD	3.0~3.9
Fluid-applied Geomembrane	10~20	90%	1.40~4.33 USD	0.2~1.8
Geomembrane with Concrete Cover	40~60	95%	2.43~2.54 USD	3.5~3.7

*Canal-Lining Demonstration Project (U.S. Department of the Interior)

3.3.2. Hydraulic Conditions

The length of the Feeder canal is set to be 33.8km. Bangula canal is 88.0km long running from the end point of the feeder canal to Bangula. The overall length of the canal is 121.8km, starting from Kapichira dam to Bangula. SVIP is based on a gravity fed irrigation system. The distance from the end of Bangula canal to the furthest point of the irrigation area is about 5km. In order to supply smoothly irrigation water to Bangula project area by using gravity, an effective head of 5m or more has to be maintained.

The intake at Kapichira dam is estimated to be 145.5~146.5m above sea level. In Bangula district (Zone D-c), the highest altitude is. 98m above sea level and the lowest altitude is 70m above sea level. Therefore an effective head of 103m above sea level or more has to be maintained at the end of Bangula canal. Thus, the altitude of the Bangula canal is supposed to be 104.7m above sea level. And, the head loss generated over a distance of 121.8km has to be below 40m.

The Feeder canal and Bangula canal will have many structures such as drains, siphon and curved sections. This is so because the terrain that will be traversed by the Feeder canal comprises complex mountainous environments. These structures have to be carefully designed because they cause a lot of energy losses in the conveyance system.

3.3.3. Ground Conditions

Field permeability test was performed at 10 locations where structures are to be installed in order to analyze the nature of soil in the sections of the feeder canal. Table 3.3-3 shows the locations where tests were done and the types of structures. Table 3.3-4 and Table 3.3-5 show the type of soil observed in the mentioned locations and the corresponding values of soil permeability.

[Table 3.3-3] Location of Soil Permeability Test and Structure Type

Division		Location	Type	Chain No.	Coordination(X,Y)
1	Feeder	Intake	Longitudinal Structure	0+000	687073.6, 8242379.0
2	Feeder	Road D135	Longitudinal Structure	2+854	686850.7, 8241561.7
3	Feeder	Road D135	Longitudinal Structure	5+706	686512.7, 8240341.4
4	Feeder	Mwambezi	Cross sectional drain structure	7+451	685546.3, 8240111.8
5	Feeder	Namkati	Cross sectional drain structure	15+207	685641.4, 8236817.1
6	Feeder	Masakale	Cross sectional drain structure	23+092	684964.2, 8234499.8
7	Feeder	Kadeya	Cross sectional drain structure	29+213	686951.3, 8232689.9
8	Feeder	Manjalende	Cross sectional drain structure	34+350	687303.0, 8229997.1
9	Feeder	Nthumba	Cross sectional drain structure	54+620	684998.1, 8224103.1
10	Feeder	Road D134	Longitudinal Structure	56+447	685678.0, 8222840.7

[Table 3.3-4] Description of Soil Profile at the Sampling Site

Site No.	Description of Soil Profile
1	0-400 mm, dark brownish soil, comprising clays, fine sands, and humus; >400 mm, reddish brown soil, containing clays and fine sands.
2	0-300 mm, black soil, consisting of clays, fine sands, and humus; >300 mm, loamy sandy soil
3	0-250 mm, reddish brown soil, comprising fine sands and clays; >250 mm, reddish brown sandy soil.
4	0-400 mm, dark brownish soil, containing fine sands and clays; >400 mm, brownish sandy soil.
5	0-300 mm, dark greyish soil, with fine sands and clay; >300 mm, decomposed metamorphic rock of gneiss origin, with feldspars
6	0-400 mm, dark brownish soils, containing fine sands and clays; >400 mm, brownish sandy soil
7	0-400 mm, decomposed rock of gneiss origin, with feldspars; >400 mm, decomposed rock
8	0-400 mm, dark brownish soil, comprising clays and fine sands; >400 mm brownish sandy soils
9	0-400 mm, decomposed lateritic rock; >400 mm, decomposed lateritic rock.
10	0-330 mm, dark brownish soil, comprising clays and fine sands; >330 mm, reddish sandy loam soils

[Table 3.3-5] Results of Soil Permeability

Sample No.	Hydraulic Gradient	Length of Sample (mm)	Volume (cm^3)	Time (min)	Coefficient of Permeability (mm/sec)
1	6.52	225	562	45	0.063
2	6.52	226	540	45	0.061
3	6.52	226	594	45	0.067
4	6.52	226	952	45	0.108
5	6.52	225	2580	45	0.291
6	6.52	225	1660	45	0.187
7	6.52	225	2160	45	0.244
8	6.52	226	584	45	0.066
9	6.52	226	844	45	0.095
10	6.52	226	440	45	0.050

As is shown in Table 3.3-4 and Table 3.3-5, the geology of the area comprises rock and sand. Soil permeability turned out to be very high. According to one the report on field surveys, water leakage in the canal will be very high. Therefore, there will be need to the feeder canal with concrete.

3.3.4. Canal Scale

In estimating a cross section of canal, earth canal has to be designed to have bigger cross section than lined canal, because the former induces more friction than the latter. The first thing to be determined when designing a canal is the depth of water. After determining an adequate flow depth, other specifications of the cross section were produced.

The deeper the canal is, the smaller its overall cross section is. This is one of the clear advantages. On the other hand, the hydraulic pressure may give rise to safety problems and also raise the construction cost, as the canal becomes deeper. In particular, the section of the feeder canal includes a long stretch of rocky terrain, so a lot of rock excavation will be required which will likely increase the construction cost.

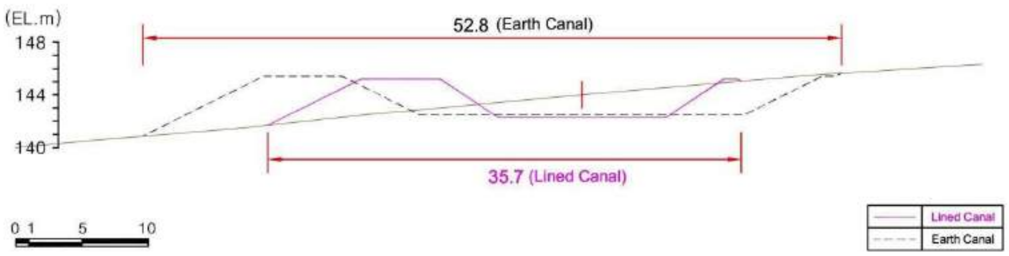
The design depth of the canal is decided h=2.1m consideration the permissible velocity of flow, maintenance, size of earthwork for cutting rocks, and safety.

Table 3.3-6 shows the results of modeling water conveyance by earth canal and lined canal under the condition that the design depth of water (h) is 2.1m, Q=50.0m^3/s, and the average hydraulic gradient(I) is 1/5,000. Table 3.3-6 is the comparison of the above two results.

[Table 3.3-6] Review of the Design Cross Section (Q=50.0m^3/S, I=1/5,000)

Type	Water Depth (m)	Bed Width (m)	Upper Width (m)	Velocity (m/s)	Area (m^2)
Earth Canal	2.1	24.6	33.0	0.83	60.5
Lined Canal	2.1	12.7	19.0	1.51	33.3

[Table 3.3-7] Comparison between Earth and Lined of Feeder Canal

<table>
<tr><th>Division</th><th>Earth Canal</th><th>Lined Canal</th></tr>
<tr><td rowspan="2">Cross Section</td><td colspan="2">
</td></tr>
<tr><td>Water Depth: 2.1m,
Excavation depth: 1.1~1.6m
Total Canal Width: 52.8m</td><td>Water Depth: 2.1m
Excavation Depth: 1.6~1.7m
Total Canal Width: 35.7m</td></tr>
<tr><td>Earth Volume</td><td>Excavation: 44.72 m^3
Embankment: 45.76 m^3

Total Earth Volume: 90.48 m^3</td><td>Excavation: 26.74 m^3
Embankment: 28.01 m^3
Lining: 2.32 m^3
Total Earth Volume: 54.75 m^3</td></tr>
<tr><td>Cost (total)</td><td>26,100 thou. USD</td><td>33,100 thou. USD</td></tr>
<tr><td>Cost(/m)</td><td>557 USD</td><td>707 USD</td></tr>
<tr><td>Selection Cause</td><td colspan="2">Lined canal is selected, because the earth canal have more earth volume(35.73m^3) and more wide width of canal.</td></tr>
</table>

※ The estimated cost is direct construction cost.

Conclusion

The geotechnical investigation carried along the feeder canal route revealed that the canal is passing through rocky and sandy soil areas which are highly permeable. Moreover the cross section of lined canal is smaller than that of the earth canal by $25m^2$(45%), which reduces excavation works and environmental impact particularly in Majete area. Thus the need of lining of canal is obvious.

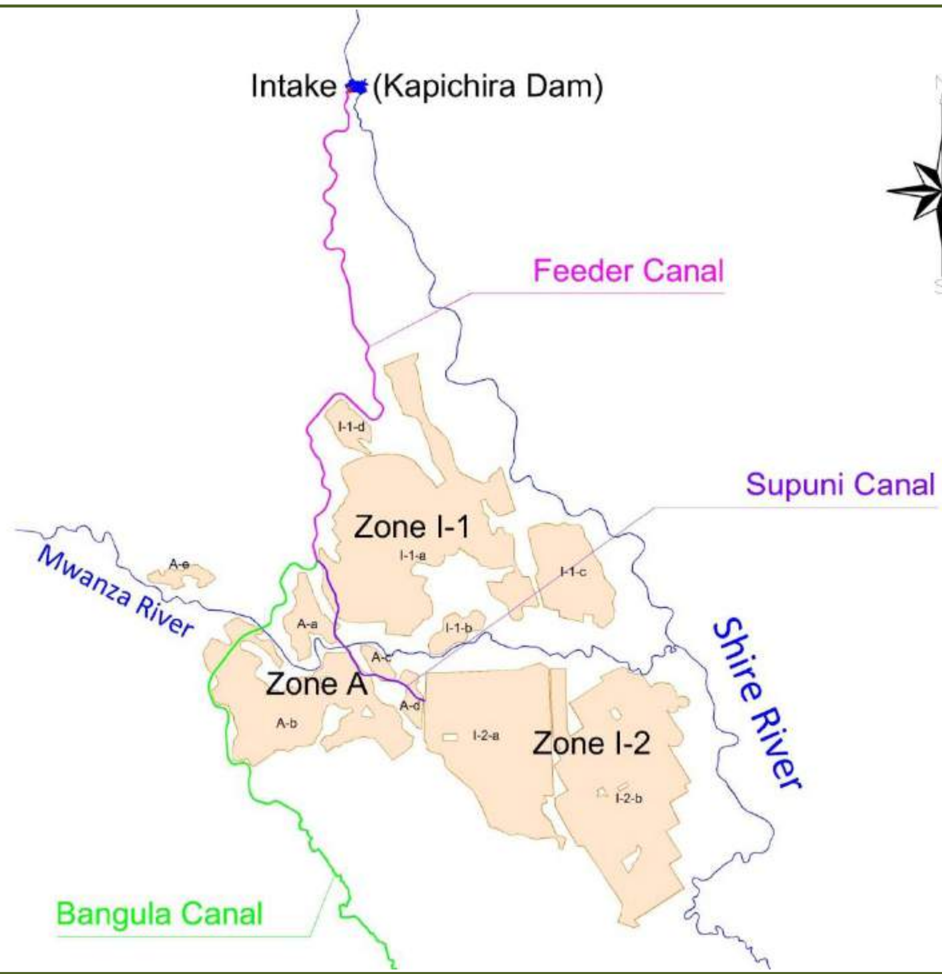
3.4. Main Canal Optimization

TOR Requirements

The possibility of commanding the entire area proposed for Phase I development (22,280ha) from the Main Canal (e.g. by locating additional irrigable land in the Kasinthula area) shall be assessed, to avoid the need to construct part of the Bangula Canal in Phase I; The Consultant shall also analyze the interest of a pressurized bulk conveyance to parts of the scheme for improved efficiency and enabling overhead irrigation without additional pumping cost.

3.4.1. Examination of Irrigation Methods for Zone A

SVIP consists of Phase I and Phase II. In order to enhance the economic feasibility of Phase I, it is necessary to consider the possibility of irrigating the area of Phase I (22,280ha) only by the Feeder canal without Bangula canal. Figure 3.4-1 shows the development zones of Phase I and 3 main canals. The length of these 3 canals is 33.8km (Feeder canal), 88.0km (Bangula canal), and 110.7km (Supuni canal).



[Figure 3.4-1] Layout Plan of Phase I

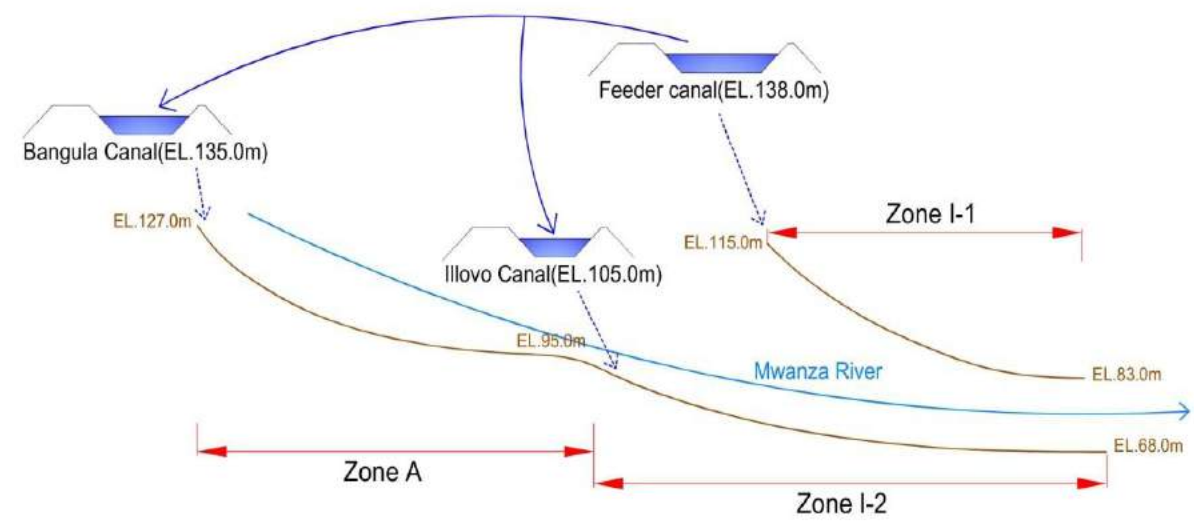
Zone A used to belong to Phase II in a feasibility assessment done before this TFS (see Table 3.4-1). If the irrigation plan of Phase I excludes Bangula canal while including zone A, the feasibility of Phase I will greatly increase, but things will become unfavorable to Phase II.

[Table 3.4-1] Project Areas for Phase I and II for CODA and TFS Studies

Division	CODA(2008)	TFS
Phase I	Zone I-1, Zone I-2	Zone I-1, Zone I-2, Zone A
Phase II	Zone A, Zone B, Zone C, Zone D	Zone B, Zone C, Zone D

Zone I-1 could be irrigated by feeder canal without any problem. Zone I-2 will be irrigated by Supuni canal connected to the end of Feeder canal. Zone A, however, is divided into the northern part and the southern part by Mwanza river. And the southern part cannot be irrigated by the Feeder canal. In order to supply water to this region, it is necessary to cross Mwanza river by connecting the Feeder canal to the starting section of Bangula canal. As an alternative, Supuni canal could cross Mwanza river and then furcate to supply water to zone A. In this case, however, the altitude of the canal becomes lower than that of the farmland and thus pumping facilities would need to be installed. Again, the increased size of Supuni canal would also raise the overall construction cost. If Phase II is implemented, the additional expense for increasing Supuni canal and pumping facilities cannot be recovered. Figure 3.4-2 shows the altitudes of feeding sites of 3 main canals and benefited regions.

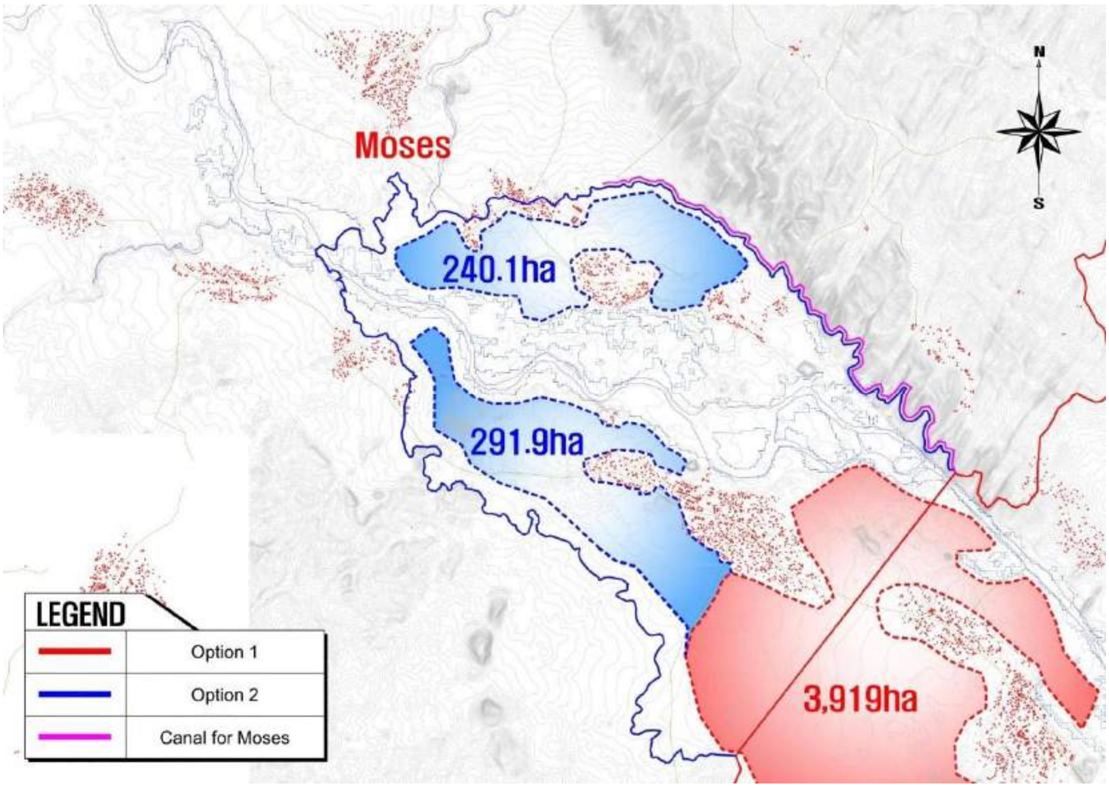
Another alternative is to incorporate only the northern part of zone A into Phase I and the southern part in Phase II. The development area of Phase I would then be reduced by 3,300ha. But the district of Zone A-c and A-d could be included in Phase I and gravity irrigation through Supuni canal could possible.



[Figure 3.4-2] Schematic Water Supplying Diagram of Phase I

3.4.2. Examination of Methods of Crossing Mwanza River by Bangula Canal

In order to reach Bangula region, the canal has to cross Mwnaza river. Methods for crossing Mwanza river include connecting the canal to a deep point of the valley along the contour line and crossing the river by the shortest distance.



[Figure 3.4-3] Options for the Bangula Canal Route

[Table 3.4-2] Comparison of Two Options for the Bangula Canal Route

Division	Option 1	Option 2
Irrigation Area	3,919.0 ha	4,451.0 ha (▲532.0 ha)
Canal Length	3.64 km	23.60 km
- Syphon	3.64 km	0.40 km
- Open Canal	-	23.20 km
Approximate Cost (estimation)	11,600 thou. USD	15,100 thou. USD

※ The estimated approximate cost is direct construction cost.

Figure 3.4-3 shows two ways of crossing Mwanza river. Table 3.4-2 compares the lengths of the canal and the development areas, estimated by the two alternative options. Option 1 is crossing Mwanza river by the shortest distance and Option 2 involves constructing the canal along the contour line of the valley. In Option 2, the length of the canal increases by 23.6km and the development area also increases by 532ha. Since the western border of Majete has a very steep rocky slope, it does not make sense to consider constructing a large-scale canal along such a slope (see Figure 3.4-4). Therefore, both options have their own merits and demerits. But option 1 is more superior to Option 2 which would cause additional construction cost by extending the canal.

The reduction of the development area by Option 1 could be compensated by constructing an independent and small-sized irrigation system running from the northern part of the canal to Moses village. Figure 3.4-3 illustrates such a small canal reaching the village. In this way, 240.1ha of Moses village could be irrigated.

[Figure 3.4-4] Steep Rock Zone of Majete Western Boundary

3.4.3. Optimization of Cross Section of Channel

Optimization of cross section of a channel means to configure the channel section hydraulically as well as economically, i.e., designing the best section. Hydraulically efficient cross section is able to convey maximum discharge with minimum cross sectional area within the range of calculated allowable velocity. The best section enables the conveyance of water with minimum infiltration and erosion, i.e., the erodibility of the channel is minimal. The followings are items to be considered when planning a hydraulically efficient cross section:

- The bigger the flow rate, the more wider and shallower the cross section
- The deeper the channel, the more costly the excavation works, It is economical to determine the maximum discharge within the allowable range of velocities
- Shallow cross section is better for a safe channel, easy to excavate, economical, less erosion of sediments

Table 3.4-3 ~ Table 3.4-6 are design criteria for drawing appropriate size of common type of irrigation ditches.

[Table 3.4-3] Appropriate Ratio of Depth and Bed Width of Canal

$Q(m^3/s)$	b/H	H	ß
Q>20	$ß * Q^{1/2}$	$ß* Q^{1/3}$	0.71~0.87

[Table 3.4-4] Appropriate Ratio of Gradient and Bed Width of Canal

$Q(m^3/s)$	B(m)	H(m)	b/H	V(m/sec)	Gradient(1:n)
30.0	12.0	2.20~2.70	5.8~3.9	0.65~0.95	3,000~5,000

[Table 3.4-5] Upper width (B) and Bed width (b) of Hydraulically Favorable Cross Section

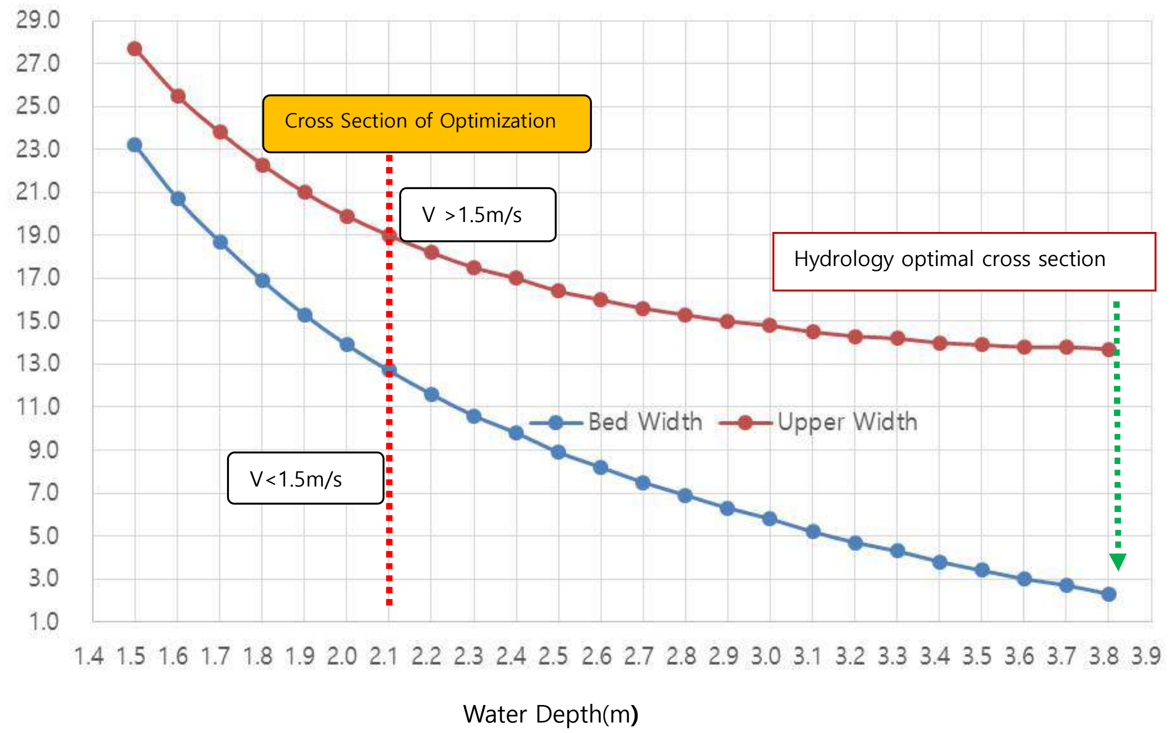
Division	1:1.5 Slope	1:2.0 Slope	Remark
B	3.606H	4.472H	
B	0.606H	0.472H	

[Table 3.4-6] Maximum Allowable Average Velocity of Canal

Division	Sandy	Clay	Lining	Concrete	Remark
V(m/sec)	0.45	1.0	1.5	3.0	

3.4.3.1. Optimization of Feeder Canal Cross Section

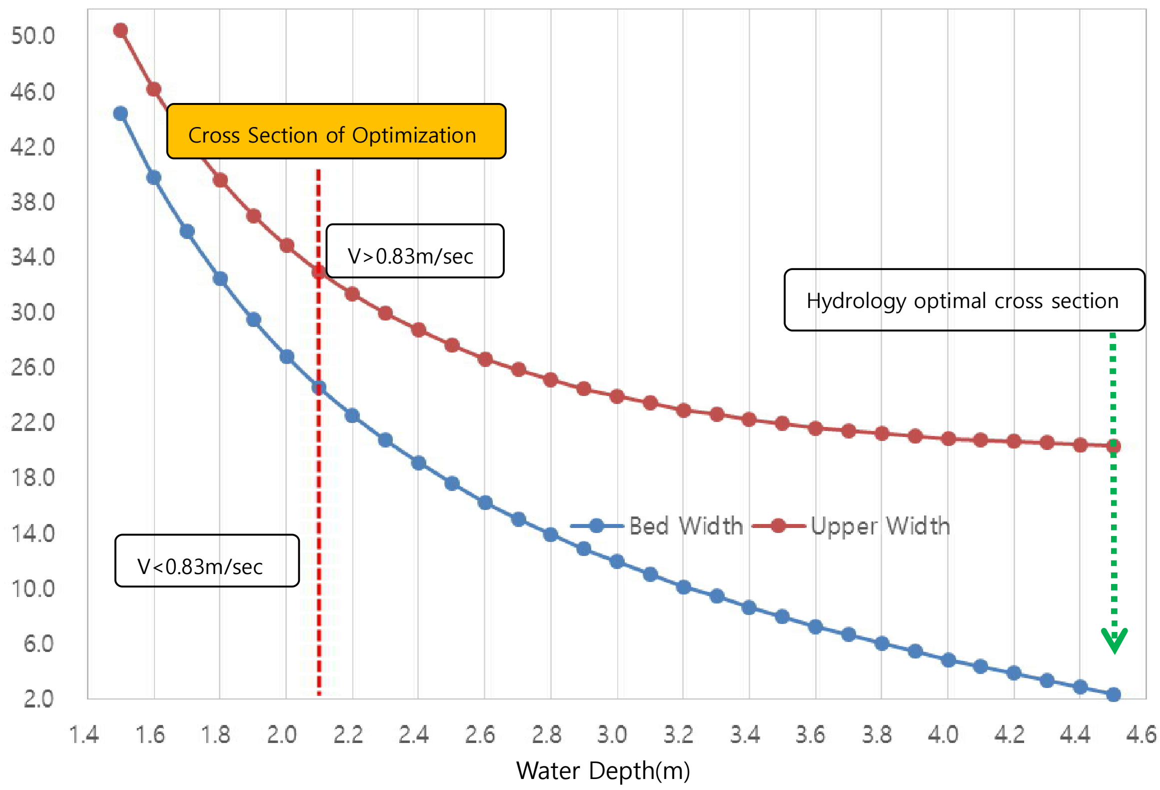
The best cross section of feeder canal may be achieved by selecting V=1.5m/s and a canal depth of H= 2.1m.



[Figure 3.4-5] Optimization of Cross Section of Lining Feeder Canal

[Table 3.4-7] Optimization of Cross Section of Lining Feeder Canal

Division	Optimization of Cross Section	Hydraulically Optimal Section
B: Upper Width(m)	19.00~19.10	13.70
b: Bed Width (m)	12.70~12.80	2.30
H: Water Depth(m)	2.10	3.80
V(m/sec)	1.50~1.51	1.65~1.67
1 : I	1:5,000~1:5,100	1:5,000~1:5,100



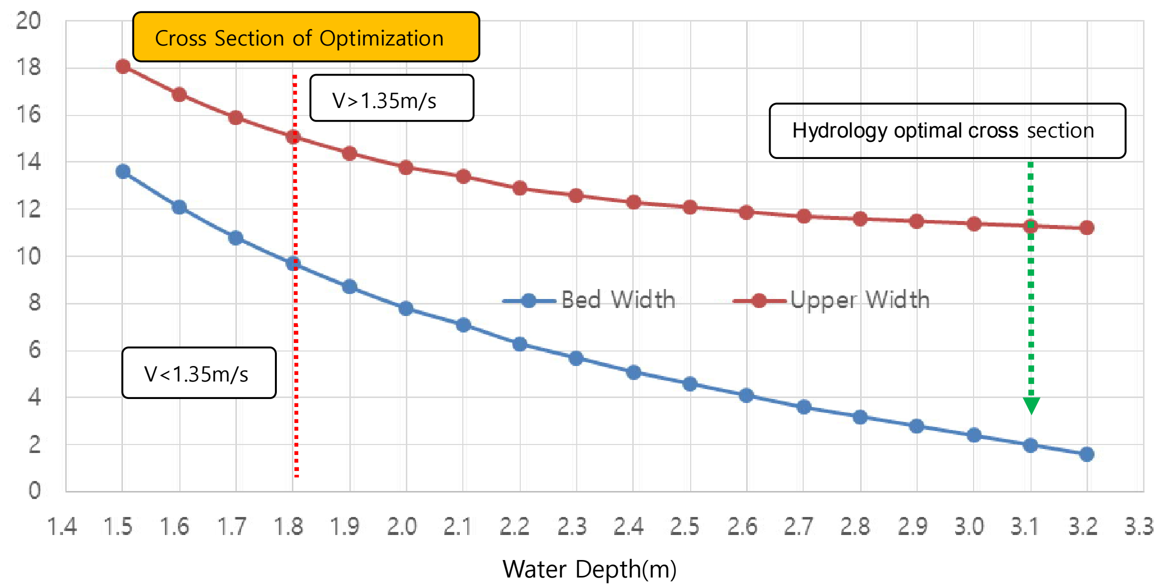
[Figure 3.4-6] Optimization of Cross Section of Earth Feeder Canal

[Table 3.4-8] Optimization of Cross Section of Earth Feeder Canal

Division	Optimization of Cross Section	Hydraulically Optimal Section
B: Upper Width(m)	33.00~33.30	20.40~20.50
b: Bed Width (m)	24.60~24.9	2.10~2.40
H: Water Depth(m)	2.10	4.50~4.60
V(m/sec)	0.82~0.83	0.97~0.98
1 : I	1:5,000~1:5,100	1:5,000~1:5,100

3.4.3.2. Optimization of Bangula Canal Cross Section

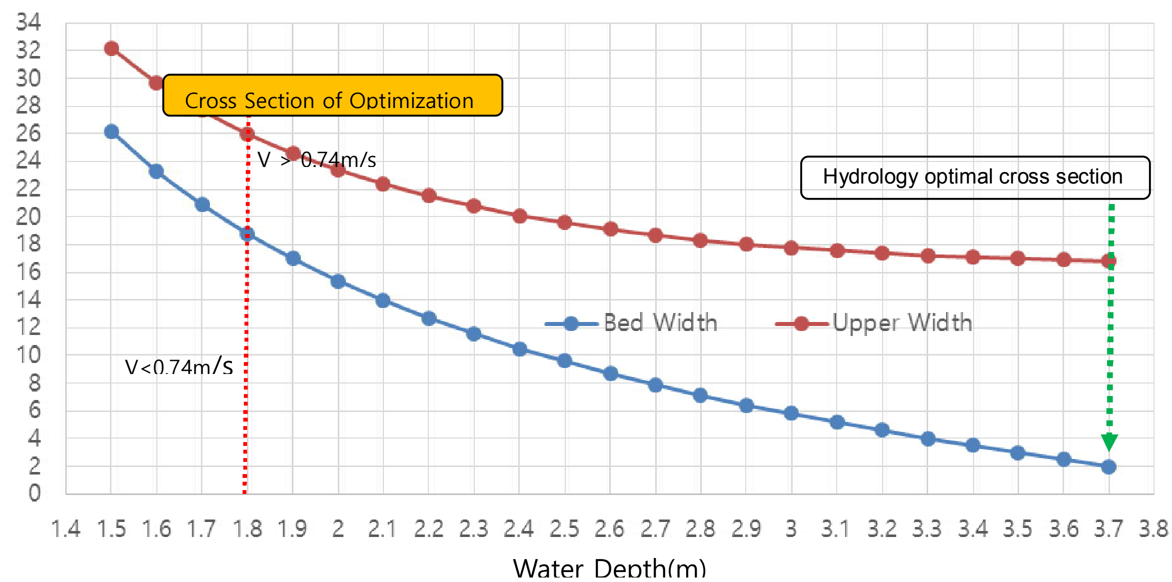
Bangula Canal has flatter traverse slope than the Feeder Canal. The best cross section for the Bangula Canal is achieved when is when V=1.35m/s for allowable velocity of lining canal and H=1.80m.



[Figure 3.4-7] Optimization of Cross Section of Lining Bangula Canal

[Table 3.4-9] Optimization of Cross Section of Lining Bangula Canal

Division	Optimization of Cross Section	Hydraulically Optimal Section
B: Upper Width(m)	14.00~15.10	10.80~11.20
b: Bed Width (m)	8.60~9.70	1.60~1.80
H: Water Depth(m)	1.80	3.00~3.10
V(m/sec)	1.35~1.48	1.47~1.59
1 : I	1:4,000~1:5,000	1:4,000~1:5,000



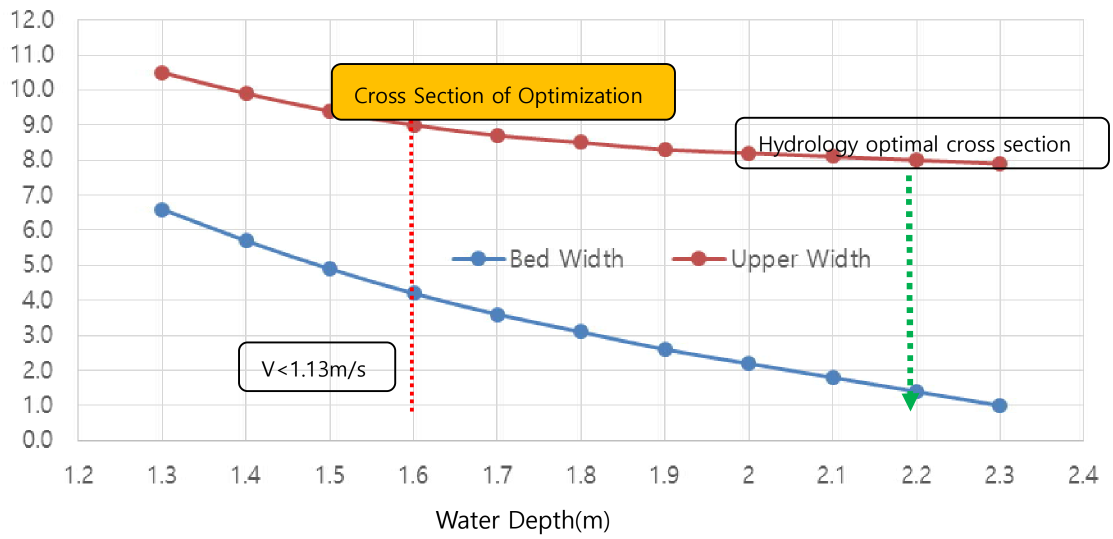
[Figure 3.4-8] Optimization of Cross Section of Earth Bangula Canal

[Table 3.4-10] Optimization of Cross Section of Earth Bangula Canal

Division	Optimization of Cross Section	Hydraulically Optimal Section
B: Upper Width(m)	23.90~26.00	16.10~16.80
b: Bed Width (m)	16.70~18.80	1.70~2.00
H: Water Depth(m)	1.80	3.60~3.70
V(m/sec)	0.74~0.82	0.86~0.94
1 : I	1:4,000~1:5,000	1:4,000~1:5,000

3.4.3.3. Optimization of Cross Section of Supuni Canal

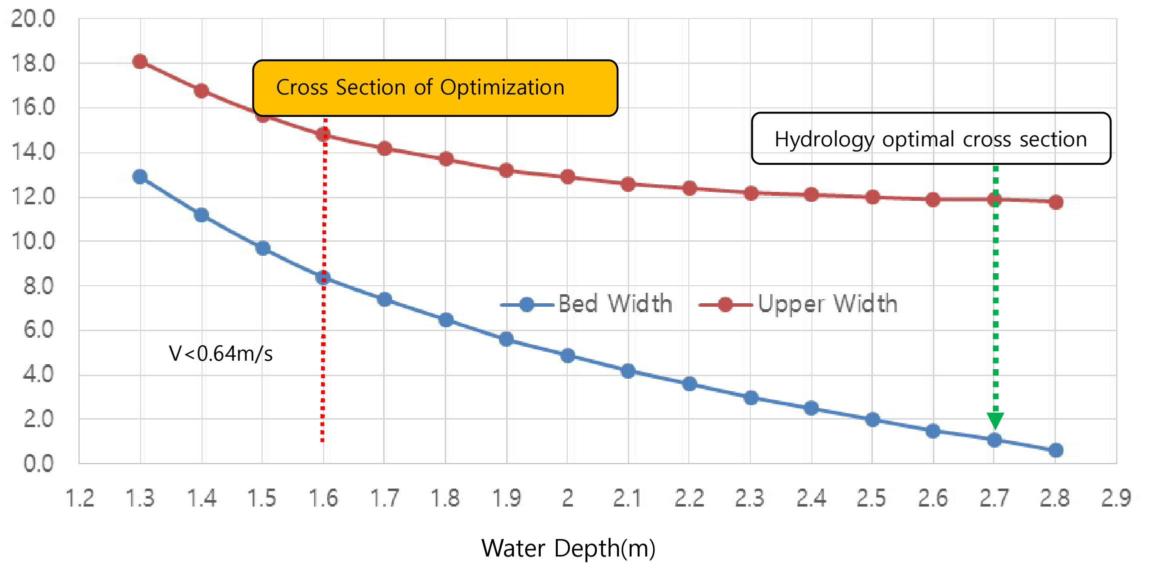
For Supuni Canal distributed from the Feeder Canal, the slope is designed at 1:3,000 ~ 1:5,000. Considering the drainage conditions of traverse drain facility of channel, water depth of H=1.60m was selected to optimize the cross section so as to achieve the best section.



[Figure 3.4-9] Optimization of Cross Section of Lining Supuni Canal

[Table 3.4-11] Optimization of Cross Section of Lining Supuni Canal

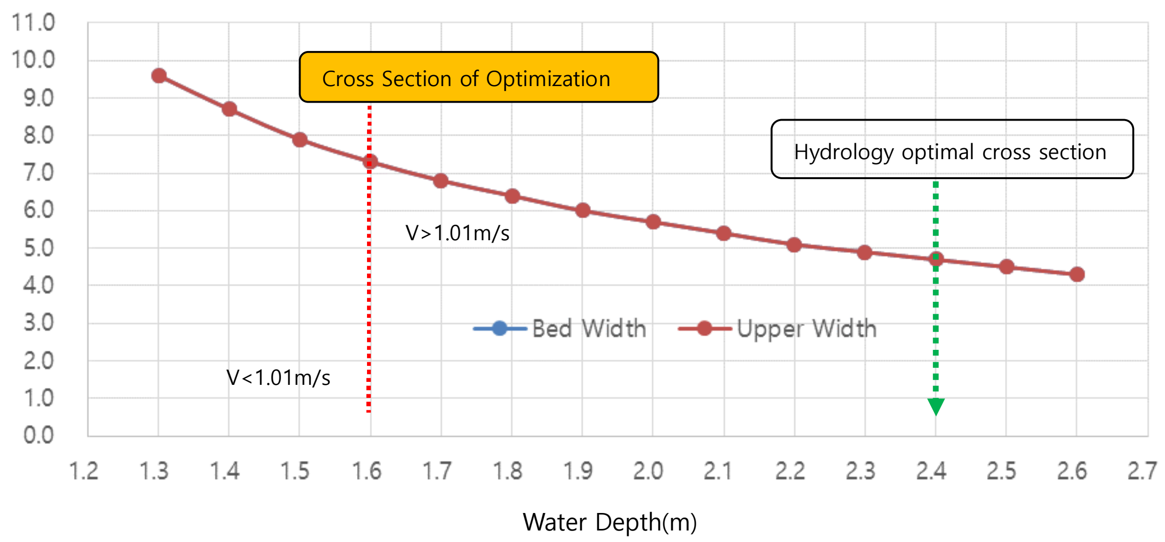
Division	Optimization of Cross Section			Hydraulically Optimal Section		
	1:3,000	1:4,000	1:5,000	1:3,000	1:4,000	1:5,000
B: Upper Width(m)	7.8	8.4	9.0	7.3	7.7	8.0
b: Bed Width (m)	3.0	3.6	4.2	1.3	1.4	1.4
H: Water Depth(m)	1.6	1.6	1.6	2.0	2.1	2.2
V(m/sec)	1.39	1.24	1.13	1.41	1.27	1.16



[Figure 3.4-10] Optimization of Cross Section of Earth Supuni Canal

[Table 3.4-12] Optimization of Cross Section of Earth Supuni Canal

Division	Optimization of Cross Section			Hydraulically Optimal Section		
	1:3,000	1:4,000	1:5,000	1:3,000	1:4,000	1:5,000
B: Upper Width(m)	12.6	13.8	14.8	10.8	11.4	11.9
b: Bed Width (m)	6.2	7.4	8.4	1.2	1.0	1.1
H: Water Depth(m)	1.6	1.6	1.6	2.4	2.6	2.7
V(m/sec)	0.79	0.70	0.64	0.83	0.74	0.68



[Figure 3.4-11] Optimization of Cross Section of Concrete Open Conduit Supuni Canal

[Table 3.4-13] Optimization of Cross Section of Concrete Open Conduit Supuni Canal

Division	Optimization of Cross Section			Hydraulically Optimal Section		
	1:3,000	1:4,000	1:5,000	1:3,000	1:4,000	1:5,000
B: Upper Width(m)	6.0	6.7	7.3	4.3	4.5	4.7
b: Bed Width (m)	6.0	6.7	7.3	4.3	4.5	4.7
H: Water Depth(m)	1.6	1.6	1.6	2.2	2.3	2.4
V(m/sec)	1.25	1.11	1.01	1.29	1.15	1.06

3.4.3.4. Optimization of Pipe Cross Section of Supuni Canal

Supuni Canal was reviewed against the possibility of installing a pipe line instead of an open channel. Pipe cross section was reviewed considering channel extension, elevation at start and end points of branching, design velocity by pipe diameter, friction loss of head:

1) Standard value of design velocity of 1.4-2.5m within the range of 1,600-3,000mm
2) Use velocity coefficient of 110-150 by pipe type
3) Use design velocity method, Hazen-Williams formula for flow and loss calculation

$Q=0.7854*(D^2)*V$, $D=(Q / (0.7854*V))^{1/2}$

$Q=0.27853\ C*(D^{2.63})*(I^{0.54})$, $D = 1.6258* (C^{-0.38})*(Q^{0.38})*(I^{-0.205})$

Head loss, $\triangle h=10.666\times(C^{-1.85})\times(D^{-4.87})\times(Q^{1.85})\times L$

4) Total cost would increase as pipe cost goes up for 900mm or larger diameter pipe ,

[Table 3.4-14] Optimization of Cross Section of Supuni Canal Pipe

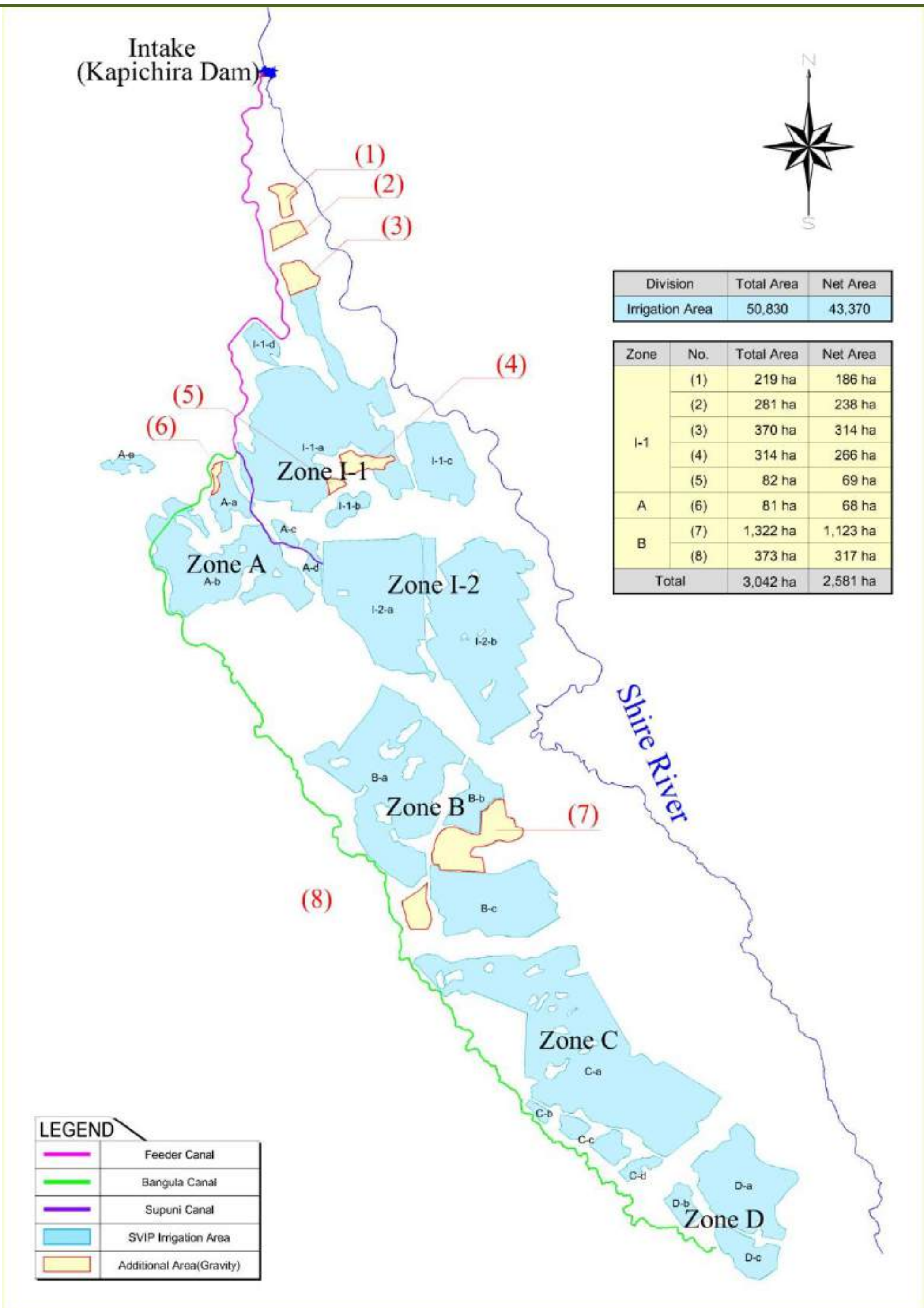
Pipe Type	Coated Steel Pipe	Centrifugal Reinforced Concrete Pipe	FRPM
Velocity Coefficient (C)	C = 110	C = 130	C = 150
Q(m^3/s)	11.81	11.81	11.81
Pipe Diameter (mm)	2,000@2	1,900@2	1,800@2
Design Velocity(m/s)	1.88	2.09	2.33
①Branch point EL.m	134.50	134.50	134.50
②End point EL.m	96.1	96.1	96.1
③ Loss of Head(m)	17.13	16.22	16.24
④Hydraulic Head(①-③)	117.4	118.3	118.3
⑤ Required Head(② +③)	113.2	112.3	112.3
Production Standard(mm)	80~3,000	150~2,000	200~3,000
Characteristics	- Good strength, durability - High water tightness - Good anti-vibration	- Anti-corrosion, high strength - Heavy - Low connection reliability	- Easy for carry and installation - High anti-corrosion, anti-shock - Good for soft ground
Pipe Cost	Mid	Average	High

3.5. Phasing of the Project

TOR Requirements

The project phasing should maximize profitability, inclusivity, and be favorable to a PPP implementation. The consultant will compare various phasing options.

3.5.1. Proposed Phasing of the Project



Division	Total Area	Net Area
Irrigation Area	50,830	43,370

Zone	No.	Total Area	Net Area
I-1	(1)	219 ha	186 ha
	(2)	281 ha	238 ha
	(3)	370 ha	314 ha
	(4)	314 ha	266 ha
	(5)	82 ha	69 ha
A	(6)	81 ha	68 ha
B	(7)	1,322 ha	1,123 ha
	(8)	373 ha	317 ha
Total		3,042 ha	2,581 ha

[Figure 3.5-1] Proposed Phasing of the Project and Areas of Each Zones

[Table 3.5-1] Proposed Phasing of the Project and Areas of Each Zones

Phase	Zone		Total Area	Net Area
Phase I	Zone I-1		**9,631 ha**	**7,866 ha**
		I-1-a (including Kasinthula)	7,183 ha	6,107 ha
		I-1-b	382 ha	325 ha
		I-1-c (including Phata & Sande Ranch)	1,680 ha	1,106 ha
		I-1-d	386 ha	328 ha
	Zone I-2 (Nchalo)		**11,250 ha**	**9,995 ha**
		I-2-a	4,684 ha	4,179 ha
		I-2-b	6,566 ha	5,816 ha
	Zone A		**5,199 ha**	**4,419 ha**
		A-a	614 ha	522 ha
		A-b	3,919 ha	3,331 ha
		A-c	179 ha	152 ha
		A-d	246 ha	209 ha
		A-e	241 ha	205 ha
	Sub-Total (Phase I)		**26,080 ha**	**22,280 ha**
Phase II	Zone B		**9,925 ha**	**8,490 ha**
		B-a	5,879 ha	4,997 ha
		B-b	858 ha	729 ha
		B-c (Alumenda)	3,188 ha	2,764 ha
	Zone C		**10,749 ha**	**9,136 ha**
		C-a	9,849 ha	8,372 ha
		C-b	113 ha	96 ha
		C-c	571 ha	485 ha
		C-d	216 ha	183 ha
	Zone D		**4,077 ha**	**3,464 ha**
		D-a(including Kaombe)	2,844ha	2,417 ha
		D-b	388 ha	329 ha
		D-c	845 ha	718 ha
	Sun-Total (Phase II)		**24,751 ha**	**21,090 ha**
TOTAL			**50,831 ha**	**43,370 ha**

The implementation of SVIP will be divided into Phase I and Phase II. Figure 3.5-1 and Table 3.5-1 describe the zones and areas of each phase presented in ToR. Large agricultural estates which can cultivate crops even in dry season are Kasinthula, Phata, Sande Ranch of Zone I, Nchalo of Zone I-2, Alumenda of Zone B and Kaombe of Zone D. These estates cultivate sugarcane by pumping water from Shier river. Table 3.5-2 shows project zones which include those large agricultural estates and cultivated area of each group.

[Table 3.5-2] Existing Large Estate in SVIP

Total	Zone I-1			Zone I-2	Zone B	Zone D
	Kasinthula	Sande Ranch	Phata	Nchalo	Alumenda	Kaombe
15,757 ha	1,429 ha	454 ha	296 ha	9,995 ha	2,764 ha	819 ha

3.5.2. Alternatives for the Phasing of the Project

3.5.2.1. First Alternative for the Phasing

As it is possible to have inadequate water during dry periods, an efficient method of using water resources has to be considered. In this regards the first alternative for the Phasing of the Project considers to exclude the Nchalo area (9,995 ha) in the Phase I, and Alumenda area (2,764 ha) in the Phase II. In this case the canal construction cost shall be reduced by 9,100 thousands USD. If Nchalo and Alumenda area are excluded in the project area, the overall project area will decrease to 29,741 ha. The design water requirement will be also be reduced to 35.3m^3/s. In the original plan, the area of Phase I is 22,280ha, and it will be reduced to 12,285ha when the Nchalo is excluded. The size of Phase II shall be 18,326 ha.

3.5.2.2. Second Alternative for the Phasing

According to the first alternative suggested above, the reduction of the project area to 12,285 ha will also cut down the project cost of Phase I, thereby allowing the possibility of incorporating Zone B into Phase I. In this case, the development area of Phase I will become 18,011 ha and that of the Phase II will be decreased to 12,600 ha. This alternative makes it possible to supply water to new region along the canal and also in Nsanje District.

3.5.2.3. Third Alternative for the Phasing

Figure 3.5-1 shows the potential area for new development. According to the location of the potential area, the additional area was decided 6 sites of Phase I and 2 sites of Phase II, in the lower section of the canal.

As mentioned in the second alternative, it is desirable to discover new developable areas and incorporate them into the project area. Conditions seem to allow a net irrigation area of about 3,042ha (Phase I: 1,347ha, Phase II: 1,695ha) to be newly included in the SVIP.

Therefore, if the net area is estimated at 85% of the whole area, then net irrigable area is 2,581ha (Phase I: 1,141ha, Phase II: 1,440ha). In this case, net irrigable area will be 33,192ha and the design water requirement will be 40.4m^3/s.

3.5.2.4. Summary of Alternatives for the Phasing of the Project

The summary of alternatives for the phasing of the project is presented in Table 3.5-3. The most appropriate alternative will be chosen after examining various factors such as economy, policy direction, and social consensus.

[Table 3.5-3] Summary of Alternatives for the Phasing of the Project

Division		TFS & DOI	Alternative 1	Alternative 2	Alternative 3
Phase I	Zone	Zone I-1, Zone I-2, Zone A	Zone I-1, Zone A	Zone I-1, Zone A, Zone B	Zone I-1, Zone A, Zone B, New Zone (1,141ha)
	Area(ha)	22,280	12,285 (9,995)	18,011 (12,759)	19,151
Phase II	Zone	Zone B, Zone C, Zone D	Zone B, Zone C, Zone D	Zone C, Zone D	Zone C, Zone D, New Zone (1,440ha)
	Area(ha)	21,090	18,326 (2,764)	12,600	14,041
Total Area(ha)		43,370	30,611 (12,759)	30,611 (12,759)	33,192
Design Water Requirement(m^3/s)		50.0	35.3	35.3	38.3

※ Without Illovo: Nchalo(Zone I-2) 9,995ha, Alumenda(Zone B) 2,764ha

[Table 3.5-4] Summary of Alternatives for the Phasing of the Project (unit: thousand USD)

Division		TFS & DOI	Alternative 1	Alternative 2	Alternative 3
Total	Cost	527,449	508,801	508,801	540,191
	Area(ha)	43,370	30,611	30,611	33,192
	Cost/ha	12.162	16.622	16.622	16.275
Phase I	Cost	229,094	214,250	311,101	324,968
	Area(ha)	22,278	12,283	18,010	19,151
	Cost/ha	10.283	17.443	17.274	16.969
Phase II	Cost	298,355	294,551	197,700	215,223
	Area(ha)	21,092	18,328	12,601	14,041
	Cost/ha	14.145	16.071	15.689	15.328

※ ToR: With Illovo; Alternative 1 & 2: Without Illovo; Alternative3: New areas are included

Total cost for new area 2,581ha was calculated using unit cost for With Illovo case, and was found to be 12,162 USD/ha.

[Table 3.5-5] Summary of Alternatives for the Phasing of the Project

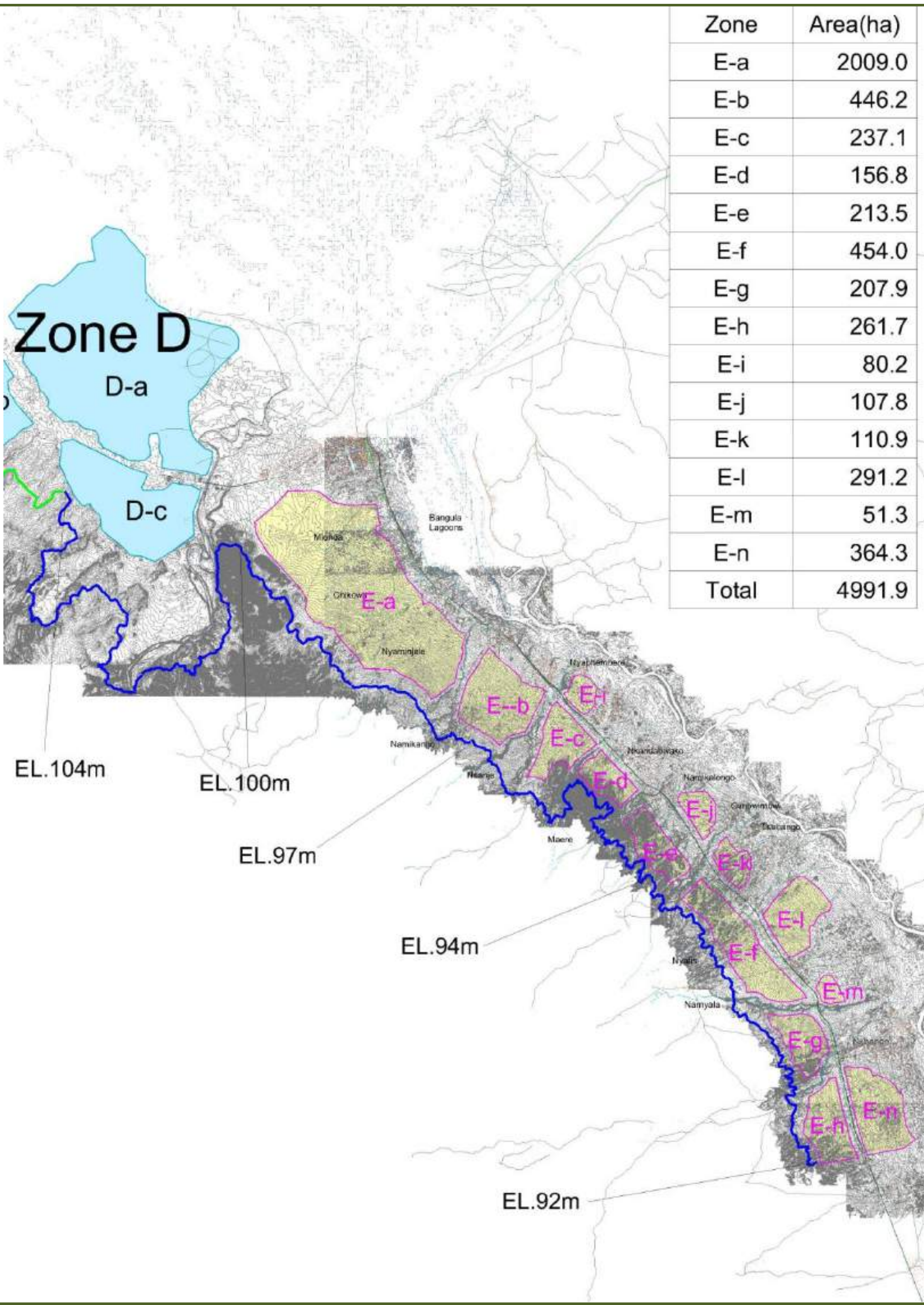
Total Project Cost	New Area	Cost / ha
31,390,000 USD	2,581 ha	12,162 USD/ha

[Table 3.5-6] With / Without of Total Project Cost

Descriptions	With Illovo		Without Illovo	
	Quantities	Cost(USD)	Quantities	Cost(USD)
I. Direct Total Cost		418,610,000		403,810,000
1) Inlet works	**B=36m**	4,000,000	**B=25m**	3,380,000
2) Feeder Canal	**L=33.80km**	33,100,000	**L=33.80km**	29,900,000
3) Supuni Canal	**L=10.70km**	5,900,000		-
4) Bangula Canal	**L=88.00km**		**L=88.00km**	
Zone A Canal	L= 3.64km	11,600,000	L= 3.64km	10,800,000
Bangula Canal A	L=12.51km	7,800,000	L=12.51km	7,250,000
Bangula Phase II	L=71.85km		L=71.85km	
Zone B	L=23.95km	14,100,000	L=23.95km	13,150,000
Zone C~D	L=47.90km	17,700,000	L=47.90km	16,420,000
5) Branch Canal	**L=93.20km**		**L=88.20km**	
Branch- Phase I	L=40.80km	5,800,000	L=35.80km	5,090,000
Branch- Phase II	L=52.40km		L=52.40km	
Zone B	L=25.10km	3,350,000	L=25.10km	3,350,000
Zone C	L=19.30km	2,580,000	L=19.30km	2,580,000
Zone D	L= 8.00km	1,070,000	L= 8.00km	1,070,000
6) Land Consolidation	**A= 33,395ha**		**A= 33,395ha**	
Zone I-1	A= 7,452ha	65,170,000	A= 7,452ha	65,170,000
Zone A	A= 5,199ha	48,450,000	A= 5,199ha	48,450,000
Zone B	A= 6,737ha	60,370,000	A= 6,737ha	60,370,000
	L=7.1km	790,000	-	-
Zone C	A=10,749ha	105,000,000	A=10,749ha	105,000,000
Zone D	A= 3,258ha	31,830,000	A= 3,258ha	31,830,000
II. Contingency (20% of direct cost)		83,772,000		80,762,000
III. Consultant (6% of direct cost)		25,116,600		24,229,000
IV. Total Project Cost		527,448,600		508,801,000

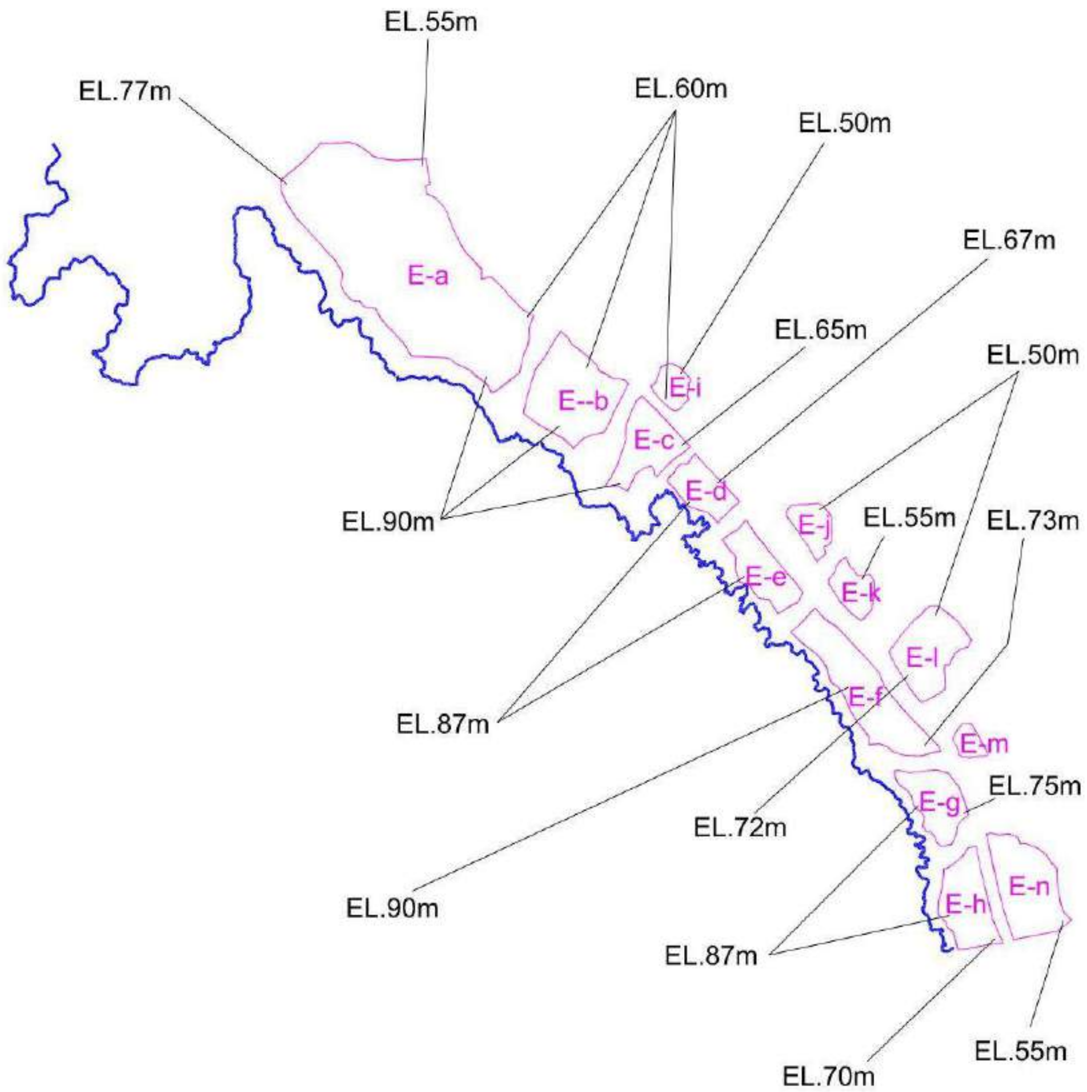
3.5.2.5. Fourth Alternative for the Phasing

This alternative involves excluding Illovo Sugar Estate and extending the Bangula canal to Nsanje District. Figure 3.5-2 and Figure 3.5-3 shows the potential irrigable areas in Nsanje District and canal route. This alternative would bring 4,992 ha (net irrigable area = 4,243 ha) of the new irrigable areas in the Nsanje District in the SVIP. It is up the GoM to decide whether to include this irrigable land in SVIP or not.



Zone	Area(ha)
E-a	2009.0
E-b	446.2
E-c	237.1
E-d	156.8
E-e	213.5
E-f	454.0
E-g	207.9
E-h	261.7
E-i	80.2
E-j	107.8
E-k	110.9
E-l	291.2
E-m	51.3
E-n	364.3
Total	4991.9

[Figure 3.5-2] Potential Irrigable Areas in the Nsanje District and Canal Route (1)



[Figure 3.5-3] Potential Irrigable Areas in the Nsanje District and Canal Route (2)

[Table 3.5-7] With/ Without +4,992ha of Total Project Cost

Descriptions	Without Illovo		Without Illovo + 4,992ha	
	Quantities	Total	Quantities	Total
Ⅰ. Direct Total Cost		**403,810,000**		**532,850,000**
1) Inlet works	**B=25m**	**3,380,000**	**B=33m**	**3,490,000**
2) Feeder Canal	**L=33.80km**	**29,900,000**	**L=33.80km**	**31,900,000**
3) Bangula Canal	**L=88.00km**	**47,620,000**	**L=153.20km**	**74,760,000**
Zone A Canal	L= 3.64km	10,800,000	L= 3.64km	12,800,000
Bangula Canal A	L=12.51km	7,250,000	L=12.51km	8,600,000
Bangula PhaseⅡ	L=71.85km		L=71.85km	
Zone B	L=23.95km	13,150,000	L=23.95km	16,050,000
Zone C~D	L=47.90km	16,420,000	L=47.90km	20,050,000
Zone E			L=65.20km	17,260,000
4) Branch Canal	**L=88.20km**	**12,090,000**	**L=88.20km**	**12,090,000**
Branch- PhaseⅠ	L=35.80km	5,090,000	L=35.80km	5,090,000
Branch- PhaseⅡ	L=52.40km		L=52.40km	
Zone B	L=25.10km	3,350,000	L=25.10km	3,350,000
Zone C	L=19.30km	2,580,000	L=19.30km	2,580,000
Zone D	L= 8.00km	1,070,000	L= 8.00km	1,070,000
Zone E	-	-	-	-
5) Land Consolidation	**A= 33,395ha**	**310,820,000**	**A= 37,887ha**	**410,610,000**
Zone Ⅰ-1	A= 7,452ha	65,170,000	A= 7,452ha	80,830,000
Zone A	A= 5,199ha	48,450,000	A= 5,199ha	53,660,000
Zone B	A= 6,737ha	60,370,000	A= 6,737ha	76,920,000
Zone C	A=10,749ha	105,000,000	A=10,749ha	118,600,000
Zone D	A= 3,258ha	31,830,000	A= 3,258ha	31,830,000
Zone E	-	-	A= 4,992ha	48,770,000
Ⅱ. Contingency(20% of direct cost)		80,762,000		106,570,000
Ⅲ. Consultant(6% of direct cost)		24,229,000		31,971,000
Ⅳ. Total Project Cost		508,801,000		671,391,000

- Total additional cost: 162,590,000 USD
  = Without Illovo + 4,992ha(671,391,000) - Without Illovo (508,801,000)
  (=Southern area of Bangula: 88,476,000 USD + Along the Feeder and Bangula: 74,114,000 USD)
- Southern area of Bangula: 88,476,000 USD
  = 70,220,000(Direct cost) + 18,256,000(Contingency+ Consultant 26%)
  70,220,000 = 17,260,000(Bangula Canal Zone E) + 48,770,000(Land Consolidation Zone E) + 4,190,000(Intake + Canal Increasing)
- Along the Feeder and Bangula: 74,114,000 USD
  = 58,820,000 + 15,294,000(Contingency+ Consultant 26%)
  58,820,000 = 51,020,000(Land Consolidation) + 7,800,000(Intake + Canal Increasing + Pumping facilities)

3.6. Type of Cropping Patterns

TOR Requirements

The type of cropping pattern and farming systems to be promoted is obviously a major element that will affect profitability, financial sustainability, inclusivity as well as the environmental impacts of the project. The Consultant will determine (a) potential crops, cropping patterns and crop rotations; (b) corresponding appropriate field-level irrigation technologies; (c) optimum crop-specific husbandry and management practices including agrochemical and other input quantity; and (d) corresponding yield, cost of production and financial return expectations (crop budgets); all on the basis of agro-climatic conditions, soil and land suitability evaluations, agricultural statistics and research findings, farmer preferences and capabilities, and market and other considerations. The Consultant shall carefully study corresponding options for smallholders, outgrowers, and Illovo Estate.

3.6.1. Chikwawa and Nsanje Districts

The Shire Valley Irrigation Project (SVIP) is aimed at improving agricultural productivity and food security through irrigation farming. The Shire river basin is divided into three sections: the Upper Shire; the Middle Shire and the Lower Shire. The Shire Valley Agriculture Development Division (SVADD) covers two districts, Nsanje and Chikwawa.

The main tasks as indicated in the TORs were to:

a) determine suitable crops and cropping patterns
b) identify preferred crops by farmers
c) recommend crop-specific husbandry practices
d) determine costs of production and corresponding yields

Chikwawa and Nsanje districts are located in southern region of Malawi. According to the NSO report (2008), the projected population for two districts in 2010 was 461,705 and 250,159 for Chikwawa and Nsanje, respectively. The main occupation is farming. The main sources of income are sales of crop produce (60%), livestock (20%) and ganyu (40%). There are 11 Extension Planning Areas (EPAs) in SVADD with 6 EPAs in Chikwawa and 5 in Nsanje.

SWOT analysis of the area is presented in Table 3.6-1. In relation to agriculture, the strengths in this area include fertile alluvial soils that are favorable for production of most arable crops, livestock ownership, human resource capacity at agriculture offices, availability of land for cultivation, water resources for irrigation, and presence of NGOs. Most households own livestock and this offers an opportunity for integrated crop-livestock farming systems for enhancing agricultural productivity and other ecosystem services.

Another advantage of the SVIP is its proximity to the Shire river and other water bodies which offers potential for irrigation farming. In addition, availability of land for cultivation and the flat topography makes it suitable for irrigation farming. The presence of NGOs such as CADECOM, World Vision Goal Malawi and companies such Illovo and Presscane provide an opportunity for collaboration to improve agricultural productivity. These organizations work hand in hand with the District Agriculture Office (DAO) on various projects.

Another strength of the project is the availability of qualified staff at the DAO both at district level and EPA level. Consultations with key informants and FGDs revealed that most farmers are hardworking and are willing to learn new farming technologies that improve agriculture productivity. The main challenges to increased agricultural productivity are low rainfall, dry spells, high temperatures (Shire Valley Agriculture Development Project, 1975). However, with adequate water supply, the area has high potential for agriculture. The SVIP can help to address some of these challenges and increase crop productivity through irrigation farming during the dry season and support rainfed crops during dry spells or short rains.

In terms of weaknesses and threats, the main challenges are weather conditions experienced in the area and specifically the high temperatures that negatively affect agriculture production as well as welfare of staff and communities, dry spells and frequent flooding during rainy season. However, floods can also be considered an opportunity for agriculture intensification as they provide eater and residual moisture for irrigation farming in dry season. Other weaknesses include poor road networks connecting to other areas specifically in the East bank in Chikwawa leads to inaccessibility of farm inputs such as improved crop varieties and fertilizer. Furthermore, the discussions also suggested that relief services from NGOs and government has breed a culture of dependency amongst some farmers.

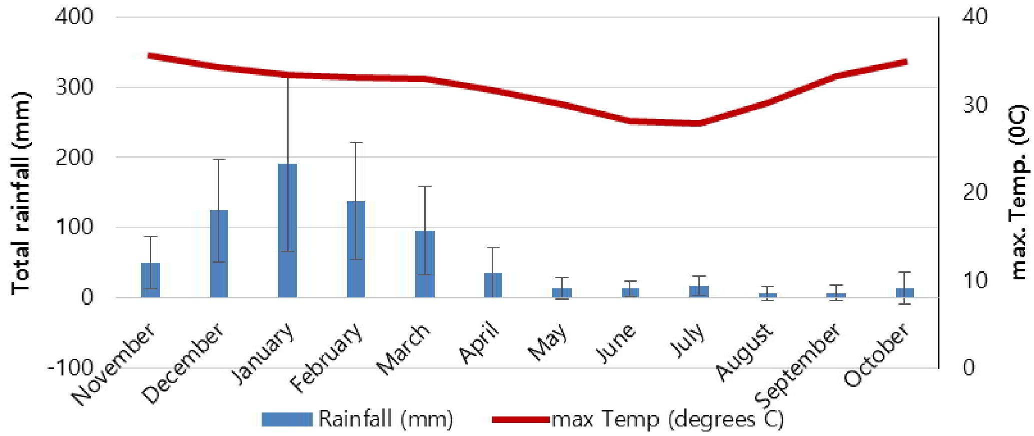
[Table 3.6-1] SWOT Analysis of Shire Valley ADD (Chikwawa and Nsanje Districts)

Strengths	Weaknesses
- Fertile soils (alluvial soils) for agricultural production - High ownership of livestock - The hot weather in the lower shire is conducive for growing cash crops such as sugarcanes and cotton - Human resources : Availability of qualified staff at District Agriculture office and EPA offices - Innovative and hardworking farmers - Different institutions (government and NGOs) working in the area on agriculture or other development projects. These institutions can help to link farmers to markets, value addition.	- High temperatures increase evapotranspiration and are not suitable for cool season crops - Poor road networks - The Lower Shire Valley is prone to flooding which makes it a disaster risk area - Unreliable markets for some crops
Opportunities	**Threats**
- Fertile soils - Proximity to Shire river and other water bodies offers potential for irrigation farming - A variety of crops grown in the area - Hard working farmers - High temperatures are favorable for cash crops cotton and sugarcane; and livestock production. - Floods support irrigation farming and rice production. - Existing structures from the district level to village level committees. These committees can help in coordination of development projects and dissemination of information - Presence of the sugarcane factory (Illovo)	- Natural disasters such as floods. Floods reduce agricultural productivity and also negatively affects livelihoods in general, and the environment

3.6.2. Agro-Ecological Characteristics of the Shire Valley Region

3.6.2.1. Altitude, Rainfall and Temperature

The Shire Valley agroecological zone comprises upland areas and low altitude areas. The areas lie at 70-600m above sea level. The rainfall pattern is unimodal with precipitation starting in November and ending in May. Annual rainfall is in the range of 600-800mm for low altitude areas and 800-1200mm in the upland areas (Shire Valley Irrigation project, 1975). Figure 3.6-1 shows the mean monthly rainfall and temperatures in Nchalo over a 45 years period. The average annual rainfall is 706.8± 41.70mm received between November and March. Rainfall distribution within the growing season (January-March) is highly variable between years and this affects timing of agronomic practices, crop growth and overall productivity. Temperature is another ecological factor that affects plant growth and productivity. The temperatures in SVADD are generally very hot ranging from 18 to 370C. High temperatures increase evapotranspiration.



※ Error bars are standard deviations (*Source of data*: Department of Climate Change and Meteorology)

[Figure 3.6-1] Mean Monthly Rainfall and Temperatures in Nchalo over 45 Years

3.6.2.2. Soil Characteristics

The soils in lower Shire valley are generally fertile alluvial soils with the dominance of 2:1 clays. The soils are moderately deep to very deep and are classified as calcimorphic alluvials (Fluvisols) with a pH of 6.5-8.5 (neutral to alkaline) (Malawi Government, Ministry of Agriculture and Food Security, 2012). According to a study of soil characteristics conducted by FAO in the SVADD, the soils have low to medium levels of total nitrogen (0.08-0.12%), phosphorus, and cation exchange capacity (CEC) and variable texture (sandy loam, clay loam to sandy clay loam). Soil pH is within a range of 5.5-6.5 and this is suitable for production of most arable crops. In terms of topography, most areas are flat (slope of 0-2%) with a few uplands zones having gentle slopes (2-6%). As for the proposed areas for SVIP program, a study was conducted by the Technical Feasibility Study team in 2015 to characterize the soils in the proposed SVIP areas in Phase I and II. A total of 907 soil samples were collected from top and sub soils, and these were analyzed for various chemical and physical properties. Results on soil characteristics for the Phase I and Phase II zones are presented in Table 3.6-1. The dominant soil types are Fluvisols and Vertisols in Phase I and Phase II zones respectively. In the phase I zones, 70% is under Dystric Fluvisols and 30% Gleyic Solonchaks. The soils in Phase I zones are largely fine textured with high cation exchange capacity (CEC). Soils with high CEC have higher capacity to hold nutrients and water. Soil bulk density ranged from 1.31 to 1.53 kg/dm^3. Salinity affects plant growth and development due to water stress on plants and injury to plant cells. The results show that the soils are non-saline (0.1 dS/m) and non sodic (2-3% ESP). However, there potential problem soils of salinity (14.5 dS/m) and sodic soils (46% ESP) are reported on 30% of the hectarage in Phase I zones with Gleyic Solonchaks soils.

[Table 3.6-1] Soil Characteristics in Phase I Zones, SVIP

Variable	Phase I		Phase II	
	Value/comment	Rating *	Value/comment	Rating*
Dominant Soil Group	Fluvisols (70%)		Vertisols	
Soil Unit Name (FAO74)	Dystric Fluvisols		Vertisols	
Drainage class (0-0.5% slope)	Very Poor		Poor	
AWC (mm)	150		125	
Topsoil Sand Fraction (%)	19		18	
Topsoil Clay Fraction (%)	49		56	
Soil Texture	clay		clay	
Topsoil Bulk Density (kg/dm^3)	1.31		1.42	
Topsoil Organic Carbon (%)	1.26	Medium	0.95	Medium
Topsoil pH (H_2O)	6.4	Slightly acid	7.3	Neutral
Topsoil CEC (clay) (cmol/kg)	38	Very high	70	Very high
Topsoil CEC (soil) (cmol/kg)	27	High	43	Very high
Topsoil Base Saturation (%)	93		100	
Topsoil Sodicity (ESP) (%)	1	Non sodic	1	Non sodic
Topsoil Salinity (ECe) (dS/m)	0.1	Non saline	0.1	Non saline
Subsoil Sand Fraction (%)	21		18	
Subsoil Clay Fraction (%)	47		58	
Subsoil Texture	clay		clay	
Subsoil Bulk Density (kg/dm^3)	1.4		1.53	
Subsoil Organic Carbon (%)	0.55	Low	0.55	Low
Subsoil pH (H_2O)	7	Neutral	7.8	Slightly alkaline
Subsoil CEC (clay) (cmol/kg)	41	Very high	72	Very high
Subsoil CEC (soil) (cmol/kg)	22	High	43	Very high
Subsoil Base Saturation (%)	100		100	
Subsoil Sodicity (ESP) (%)	3	Non sodic soil	2	Non sodic soil
Subsoil Salinity (ECe) (dS/m)	0.1	Non saline	0.1	Non saline

Source: Technical Feasibility Study Soils Report, SVIP (2016);
AWC: available water holding
*Rating based on the critical soil test values used for soil fertility recommendations in Malawi (Chitedze Agriculture Research Station, Lilongwe, Malawi)

3.6.3. Cropping Pattern for SVIP

3.6.3.1. Crop Selection

The crop recommendations are based on the following considerations:

- suitability to climate and soils;
- crop viability – gross margin analysis (see Table 2.6-12);
- market analysis – agribusiness and supply chain issues; and
- Processing or value addition opportunities.

Consideration is also made in respect of government policy, ease of crop storage, farmer familiarity with the crops and current relevant government strategies, such as the National Export Strategy, and the Buy Malawi Strategy. The current recommendations are for crops that can be grown as soon as the irrigation scheme is commissioned. These are crops that will be relatively easy to manage and market as the farming system transforms from subsistence to commercial. After this initial stage the farmers can diversify into other crops such as vegetables, spices, tropical fruits and other. Sugar cane can be introduced at the initial stage or at a later stage depending on the immediate demand from Illovo and Presscane who are likely to be the buyers of sugar cane.

3.6.3.2. Potential Crops for SVIP

Crop productivity is a function of the genotype and the environment. Under favorable climate, crop yield can be optimized through use of appropriate genotypes, cropping systems that minimize competition, and good agronomic practices. A cropping system can be defined as the cropping patterns or the arrangement of crops in space and over time and the management practices that are used on a particular field and their interaction with farm resources and technology (Palaniappan and Sivaraman, 1996). Factors that should be considered in selection of crops are adaptation to the environment, yield potential, water requirement, irrigation requirement, gross margins, market potential, storage characteristics and farmer preferences. Based on the environment characteristics in this area, potential crops are those that are drought tolerant, early maturing and adapted to high daytime temperatures. The recommended crops based on the environmental characteristics (soils and climate factors) are presented in Table 3.6-2. The crops include sugarcane, maize, sorghum, cotton, pigeonpea, common beans, sweet potatoes, vegetables and tropical fruits (bananas and mangoes). In terms of land allocation, 44% of the area can be allocated to sugarcane and the remaining 56% to the other crops (Table 3.6-3). Crops such as maize and rice can be grown under rainfed and irrigation. However for rice, the type of varieties should be considered as some varieties (e.g. Faya) are sensitive to photoperiod and as such can only be planted in rainy season. Common beans can be grown in winter (April-July) under irrigation when temperatures are cooler.

Cereals

The cereals which we focused on are maize, sorghum, rice and wheat and from this list **maize is recommended** to be grown especially during times of rainfed maize deficits. Based on gross margin analysis rice has the highest gross margin followed by maize but current rice production meets local demand and exports into the region are under pressure from the cheap imports from Asia. Rice exports and imports fluctuate considerably from year to year, but show an overall declining trend between 2006 and 2011.

Oil Seeds

The oil seed crops that we looked at are sunflower, groundnuts, and soybeans. Groundnuts and soya beans have the highest and similar gross margins. However the soils in the Shire valley are mainly clay soils and not suitable for groundnuts. Therefore the **recommended oil seed crop is soya beans**. Soya beans will produce both oil and animal feed leading to a reduction of animal feed imports. CP Feeds Company Limited reported that the domestic market for soya beans only satisfy about 40% of their need for the production of both oil and livestock feed. It has been reported that local demand for soybean increased by over 40% between 2002 and 2013.

Pulses

The pulses that we focused on are dry beans, *(Phaseolus vulgaris* L*)* and pigeon pea. The two crops have got very good gross margins to the extent that **dry beans is be recommended for winter production and pigeon pea for summer production**. However, there is need for a more detailed market analysis.

Fibre Crops

The only fibre crop that we focused on is cotton. Currently cotton is only grown under rainfed conditions and over the past three years production has decreased from about 100,000 MT to 25,000 MT (discussions with Quton Seed Company). The capacity of ginning companies is about 215,000 MT of seed cotton. Using the current varieties available on the market, irrigated cotton can yield as much as 4.0 t/ha compared to about 1.0 t/ha obtained under rainfed conditions. Cotton production is strongly supported by government through the Cotton Act and the establishment of the Cotton Council will greatly improve cotton marketing within the country. **Cotton is therefore recommended** as a crop that can be grown in summer. Its gross margin is good and can bring good returns to investment.

Sugarcane

Illovo has little extra capacity for processing sugar cane. However, the demand for sugar cane for ethanol production is still relatively high and although PressCane is currently involved in carrying feasibility studies to establish 2,000 ha of sugar cane they still need a further 4,000 ha to make maximum use of their ethanol plants. Therefore **sugar cane is one of the recommended crops**.

[Table 3.6-2] Potential Crops for Irrigated and Rainfed Production

Period	Cropping calendar	Potential crops	Traits of crops or varieties	Trade offs/challenges
Perennial	All year	Sugarcane	Adapted to high temperatures	High water requirement
		Bananas, mangoes	Adapted to high temperatures	Long term benefits depending on varieties
Rainfed + Supplimentary irrigation	Nov-April/May	Maize, cotton, sorghum, vegetables, pigeonpea	Drought tolerant, early maturity varieties adapted to low attitude areas, grain quality	Early maturing varieties have lower yield potential compared to long duration varieties
	Nov-May	Cotton	Preferred by market; quality of lint, yield	Pests may reduce yield. Need for a pest management plan
	Nov-July	Pigeonpea	Wide adapted, drought tolerant	Pests
	Dec- May	Rice	Some varieties are aromatic varieties with good cooking quality e.g. Faya, Kilombero; high demand (markets); sensitive to photoperiod	Low yield potential; production can be increased with more acreage and good agricultural practices
Irrigation	April-July and July-October	Maize	Plant both early and medium duration maize varieties	- long duration variety may need high amounts of irrigation water
	April –July	Beans	Yield, varieties resistant to bean stem maggot	Pests
	April - November	Different types of vegetables	Short season crops, market potential	High demand for irrigation water when temperatures are very high
	June –Oct	Rice		High water requirement; varieties not sensitive to photoperiod

[Table 3.6-3] Proposed Hectarage to be Allocated to Different Crops under the SVIP

Proportion of Land	Crop	Life Cycle	Rainfed	Irrigation
44%	Sugarcane	Perennial	Perennial	Perennial
50%	Maize	Annual	Yes	Yes
	Cotton	Annual	Yes	No
	Sorghum	Annual	Yes	Yes
	Pigeonpea	Annual	Yes	No
	Cowpea	Annual	Yes	Yes
	Beans	Annul	No	Yes*
	Other potential annual crops	Annual	Yes	Yes
6%	Bananas, mangoes	Perennial	Perennial	Perennial

Characteristics of Recommended Crops and Ecological Requirements

Table 3.6-4 shows ecological requirements and yield of potential crops. Crop water requirement varies with crop species, climate, season of growth and soil type. Sugarcane has the highest water requirement, followed by cotton, maize, sorghum and beans.

[Table 3.6-4] Ecological Requirements of Selected Crops and Potential Yield

Crop	Temperature	Soil characteristics	Life cycle & days to mat urity	Water requirement (mm)	Other characteristics	Potential yield (kg/ha)	Source
Sugarcane	High temperatures	Well drained loam soils; optimum pH 6.5but can tolerate pH 5-8	Perennial; 12-18 months	1,500-2,500	High water requirement.		3
Maize	High temperatures	Well drained soils with a pH of 5.5-6.5; non saline; medium to high fertility	Annual; 3-4 months	500-800	Sensitive to drought	6000-10000 (for improved varieties)	1, 3
Cotton	High temperature	Well drained soils	Annual	700-1,300	Drought resistant;	2,500-3,000	1
Sorghum	High temperatures (21-35^{0}C)	Clay loam soils; Adapted to a wide range of soil fertility gradients; soil pH 6.0-8.5	Annual	400-650	Drought resistant; Moderately tolerant to salts	3000	1, 2
Pigeonpea	warm to high temperatures	Well drained soils. Wide adapted to soil fertility types; pH 5.0-8.5	Annual or perennial		Drought resistant, Biological nitrogen fixation, wide adaptation to soils	2,000-2,500	
Beans	Cool temperatures (C3 plant)	well drained soils	Annual	300-500	High temperatures reduce yield	2,000-2,500	1
Tomatoes	Cool to warm temperatures (18-25^{0}C).	well drained soils, high soil organic matter; pH 5-7	Annual	400-600	High temper atures reduce yield	18,000-50,000	1, 3
Bananas	Warm to high temperature	Well drained fertile soils (high organic matter); soil	Perennial	>1,200mm annual rainfall	Drought tolerant	-	1
Mangoes	Warm to high temperature; altitude		Perennial			200-500 fruits/tree	1

Proposed Cropping Patterns and Rotations

As indicated, 44% of the land is proposed to be allocated to sugarcane. The remaining 56% will be allocated to other crops (6 % of which will be allocated to fruit orchard). In order to sustainably intensity crop production on the 50 % of land, a proposed crop rotation plan for rainfed and irrigated conditions is outlined in Table 3.6-5. Crop rotation is growing of different crops in an ordered sequence on the same the field year to year. The benefits of a well-planned crop rotation include control of pest and disease management and soil fertility improvement. The choice of crops in the rotation system is based on principles that optimize positive interactions and productivity. These principles include complementarity in terms of rooting habits, nutrient demand, allelopathy, susceptibility to pests and diseases

[Table 3.6-5] Proposed Crop Rotations over a Two Years Period

Type of crop	% of Hectar	Year 1-Rainfed (Nov-April)				Year 1-Irrigation (April-July; August -October)			
		Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4
Annual	50%	Maize	Cotton	Sorghum	Pigeonpea	Beans or cowpea	Maize	Beans or cowpea	Different types of fruit and vegetables
		Year 2-Rainfed (Nov-April)				**Year 2-Irrigation (April/May-October)**			
		Cotton	Sorghum	Pigeonpea	Maize	Beans or cowpea	Sweet potatoes	Maize	Different types of fruit and vegetables
Perennial	44%	Sugarcane				Sugarcane			
	6%	Fruit orchard – Bananas and mangoes				Fruit orchard – Bananas and mangoes			

* Vegetables include tomatoes, leafy vegetables, cabbage and onions and choice will depend on market analysis in a particular year

Cropping Calendar

Timing of agronomic practices is important for optimizing crop yields. Table 3.6-6 presents a calendar for the different agronomic practices. A specific cropping calendar will be developed for the each of the potential crops.

[Table 3.6-6] Cropping Calendar

Season	Period	Operations
Summer	November/December	Planting, fertilizer application
	January	Weeding, fertilizer application, pest/disease management
	February	Weeding, harvesting on early maturing crops
	March	Sowing tomatoes
	April	Harvesting soybeans, beans, transplanting tomatoes
Cool Dry Season	May	Harvesting, planting beans, leafy vegetables
	June	Harvesting; planting rice
	July	Post-harvest activities, marketing
Hot Dry Season	August	Land preparation, crop residue management, planting, marketing
	September	Harvesting winter crops, marketing
	October	Harvesting winter crops, marketing, land preparation
	November	Harvesting, land preparation, planting

3.6.3.3. Crop Production Constraints

The main challenges to increasing crop productivity in this area include: unpredictable weather, high temperatures, floods, short rainfall season, pests and poor agricultural practices (Table 3.6-7). Climate variability can be defined as the spatial and temporal variations in the mean, standard deviation and occurrences of extreme events of the climate (IPCC, 2001). Short rainfall season, dry spells and poor rainfall distribution reduce crop productivity. Floods also destroy houses and agricultural fields during the rainy season Another constraint is pests. The discussions with key informants and FGDs revealed that the main pests are armyworms in all cereal crops. However, this season, a new pest, cotton mearly bug, was observed in the district and this attacked cotton and all other green plants.

[Table 3.6-7] Constraints to Crop Production

Crop	Constraints
Cross cutting constraints	– Weather patterns: droughts, dry spells or floods occur every year. – High labor costs especially in cotton and maize. – Some farm inputs such as herbicides are not available in local shops – Pests such as army worms – Need for a generator to supply energy for pumping water – Lack of treadle pumps
Maize	– Poor rainfall distribution; – Low soil fertility in some areas, termites especially when there are dry spells or drought – Pests: Stalkborer, army worms – Maize streak virus is common in irrigated maize
Cotton	– Pests such as bollworms, aphids, jassids and cotton merely bug. Cotton merely bug is a new pest observed in the district the current season 2015/2016) and it attacks all green plants. – Poor markets/low prices – High pest incidences. Pesticides are expensive – High cost of inputs – Lack of credit facilities – Lack of resilient varieties
Sorghum	Witch weed
Pearl millet	Too much rainfall reduces yield; no reliable markets
Sesame	Pests, no reliable markets
Rice	High temperatures increase water requirement for rice
Tomatoes	Pests and Diseases

[Table 3.6-8] Gross Margin Estimates for a Selection of Crops

No	Crop	Average Yield (kg/ha)	Average Price (MK/kg)	Estimated Income (MK)	Total Variable Costs (MK)	Gross Margin (MK/ha)
1	Beans (dry)	2,000	700	1,400,000	476,345	923,655
2	Cassava (dry)	2,000	100	200,000	118,151	81,849
3	Cassava (wet)	22,000	70	1,540,000	88,451	1,451,549
4	Chillies	1,500	650	975,000	226,345	748,655
5	Cotton	4,000	200	800,000	380,301	419,699
6	Cow peas	2,200	140	308,000	219,923	88,077
7	Groundnuts(shelled)	2,500	500	1,250,000	745,676	504,324
8	Groundnuts(unshelled)	4,170	200	834,000	722,775	111,225
9	Maize (irrig)	5,000	160	800,000	499,954	300,046
10	Maize (seed, irrig)	3,500	339	1,188,032	996,619	191,413
11	Pigeon peas	2,500	500	1,250,000	244,663	1,005,337
12	Rice (polished)	2,500	500	1,750,000	496,304	1,253,696
13	Rice (unpolished)	3,500	300	1,050,000	496,304	553,696
14	Sesame	1,100	180	198,000	155,015	42,985
15	Sorghum	5,000	120	600,000	483,372	116,628
16	Soya beans	3,100	185	573,500	347,138	226,362
17	Sugar cane	120,300	47	5,665,817	3,675,539	1,990,279
18	Tomatoes	45,000	185	22,500,000	2,009,799	20,490,201
19	Wheat	3,000	180	540,000	497,074	42,926

Source: ADPS Interim Report

3.6.4. Conclusions and Recommendations

This study was conducted to: determine suitable crops and cropping patterns; identify preferred crops by farmers; recommend crop-specific husbandry practices; determine costs of production and corresponding yields. There is a wide range of crops that are grown in SVADD including cereals, grain legumes, oil seeds, cash crops, vegetables and fruits. The top four preferred crops by farmers are sorghum, maize, cotton and millet. Other preferred crops are cowpea, sweet potatoes, pigeonpea, beans, sesame and cassava. These crops are grown primarily for food except cotton, a cash crop. Other preferred crops are cowpea, sweet potatoes, sesame, beans and different types of vegetables.

Potential crops recommended for SVIP based on ecological requirements and farmer preferences are sugarcane, maize, cotton, sorghum, pigeonpea, sweet potatoes, cowpea, beans, vegetables, bananas and mangoes. These crops are adapted to high temperatures except for beans that are recommended for winter production only. In terms of hectarage, it is proposed that 44% of the area should be allocated to sugarcane, 6% to fruits (bananas and mangoes) and the remaining 50% to annual crops.

For the annual crops, production can be intensified through a proper planned crop rotation systems under rainfed and irrigation. Crop rotations should consider the complementarity of different crops to minimize the negative interaction. Some of the crop characteristics to be considered are rooting habits and nutrient demand, susceptibility to pests to diseases, allelopathic effects and crop duration. Legumes such as pigeonpea should be followed by cereal crops (maize and sorghum) in order to benefit from nitrogen fixed by legumes. High crop productivity can be achieved with use of improved varieties, adequate water supply and good agronomic practices. Therefore, in the design process, there is need to consider the irrigation water requirement for the potential crops.

- Cotton is a cash crop and was listed among the top three preferred crops by farmers. Productivity of cotton can be enhanced by growing varieties that are pest resistant to reduce costs associated with pest management; and identification of markets with suitable varieties.
- Maize is recommended for both grain and seed maize production under rainfed and irrigation. Gross margins are higher with seed maize than grain production. At least two crops can be harvested in a year and there is high potential for high yield with good management and adequate water supply.
- Pigeonpea is a grain legume that is drought tolerant and adapted to wide environment conditions. As a legume, the can fix atmospheric nitrogen into inorganic forms thereby improving soil fertility. There are different varieties (short, medium and long duration) that can be grown to suit different needs. The crop has high market potential.
- Other crops that can be grown at small scale during specific times of the year are cowpea, beans and vegetables (fruit and leafy vegetables).

It is recommended that an orchard should also be established for bananas and mangoes of 6% of the land. Fruit production should supported with investment in processing plants for value addition, diversification of products and to reduce postharvest losses.

3.7. Type of Field Irrigation System

TOR Requirements

Irrigation systems should be adapted to the farming systems as well as to the financial capacity of the farmers. Options should allow differentiating the recommended irrigation systems for Illovo Estates, out-growers, and small holders.

3.7.1. Current Situation

3.7.1.1. Illovo Estate

There are 6 large estates within SVIP area. These are Nchalo, Alumenda, Sande Ranch, Phata, Kasinthula and Kaombe. All of them cultivate sugarcane. Types of irrigation they are adopting are furrow irrigation, pivot irrigation and sprinkler irrigation. Table 3.7-1 shows the distribution of area by the types of irrigation for each estate. Furrow irrigation is most widely used (52% of the overall area), and sprinkler irrigation using dragline occupies 31% of the overall area, and then pivot irrigation is used in 17% of the area. Figure 3.7-1 ~ Figure 3.7-3 provide panoramic views of 3 types of irrigation as applied in Illovo estate.

[Table 3.7-1] Estate Irrigation Systems

Estate	Total (ha)	Furrow Irrigation(ha)	Pivot Irrigation(ha)	Sprinkler Irrigation	
				Dragline(ha)	Semisolid(ha)
Nchalo	9,995.0	3,962.5	1,174.3	4,803.2	55.0
Alumenda	2,763.8	2,763.8			
Sande Ranch	454.0	454.0			
Phata	296.1	296.1			
Kasinthla	1,428.8	748.8	680		
Kaombe mcp	483.9		483.9		
Kaombe Trust	335.3		335.3		
Total	15,756.9	8,225.2	2,673.5	4,803.2	55.0

[Figure 3.7-1] View of the Furrow Irrigation(Illovo Estate)


[Figure 3.7-2] View of the Pivot Irrigation(Illovo Estate)

[Figure 3.7-3] View of the Sprinkler Irrigation

3.7.1.2. Out Growers

The out-growers who cultivate sugarcane by contract with Illovo estate are rewarded availing them with generally good irrigation systems provided by Illovo. But those who cultivate cotton plant and corn by contract do not have infrastructures such as farm road and irrigation canal. These crops are difficult to cultivate in dry season.

The crops which are sowed and cultivated in rainy season and are harvested in dry season are cotton, maize, sorghum, millet and bean.

3.7.1.3. Small Holders

Small holders have no irrigation facility. They cultivate crops only in rainy season. Their major crops include cotton, maize, sorghum, millet, and bean.

3.7.2. Suggestion of Irrigation System

The new development areas are the region of small holders, where two crops other than sugarcane in a year are planned. As various kinds of crops are going to be grown, the type of irrigation method adopted will differ in accordance with kinds of crops and size of irrigation block.

Furrow irrigation, pivot irrigation, and sprinkler irrigation can be applied to corn, bean and sorghum. Sprinkler irrigation and furrow irrigation can supply water to cotton, fruits and vegetables.

This region is susceptible to shortage of water during the dry season. Thus, intermittent irrigation scheme can be adopted in order to use water more efficiently. Apart from efficient use of water, intermittent irrigation scheme also help with sound growth of crops.

Irrigation type must consider soil condition, crop, topography, and fiscal condition of farming household. For a farmer to select between center pivot irrigation and drip irrigation serious consideration should paid to the management condition as they have good application efficiency with high installation cost. Sprinkler irrigation is beneficial to saving irrigation water, showing rain-like penetration, no forming solid surface caused by irrigation but, at the same time, vulnerable to wind. As both center pivot and sprinkler irrigations need certain degree of pressure, it requires installation and operation cost of pressure device. In case of center pivot irrigation, biggest advantage is the ability to irrigate for 24 hours.

[Table 3.7-2] Irrigation Systems of Application Efficiency

Division	Furrow	Sprinkler	Pivot	Drip
FAO	60 %	70 %	80 %	95 %
CODA	60 %		80 %	
Coyn & Bellier	65 %		80 %	

Furrow irrigation is the cheapest type with lowest application efficiency. However, it is advantageous to use natural slope to deliver irrigation water to farther locations using gravity. In fact, 52% of Illovo Estate areas adopt furrow irrigation. While this method consumes large amount of water, the water supplied to the field is well used to keep the soil condition good. SVIP project plans to apply furrow irrigation to the whole area. Accordingly, it gives allowances to water requirement calculation to make it possible for the plantation to modify the irrigation types based on the condition.

3.8. Options to Mitigate Environmental Impact

TOR Requirements

Especially on designing alternatives for crossings through protected areas, and to identify preliminary biodiversity reserves/hotspots within the gross irrigation area, to be weighed in the overall concept design later.

3.8.1. Key Issues

As mentioned in the Terms of Reference (Shire Valley Irrigation Project Technical Feasibility), ESIA Inception Report, and ESIA Draft Baseline Report ('the Baseline Report'), major challenges of SVIP are that it will affect the current ecosystem such as Majete Game Reserve ('the Reserve), Lengwe National Park ('the Park'), Elephant Marsh, and other valued ecosystems. Constructing canals will increase pressure on the current ecosystems. The feeder canal will pass through Majete Game Reserve and Lengwe National Park, the most valuable ecological areas. However, the project will also benefit the community and the country at large. For example, the people of Chikwawa and Nsanje districts generally have inadequate food due to practicing rain-fed agriculture in an area with erratic rainfall, hence the implementation of SVIP will ease this problem and enhance food security in the area. To attain sustainable development and minimize negative impacts of the Project, major challenges and other environmental issues of the Project have been taken into account in the feasibility study and Environmental and Social Impact Assessment. Appropriate mitigation measures have been devised in accordance with ESIA done by BRL ingénierie. Presented in this section are mitigation options for major environmental challenges.

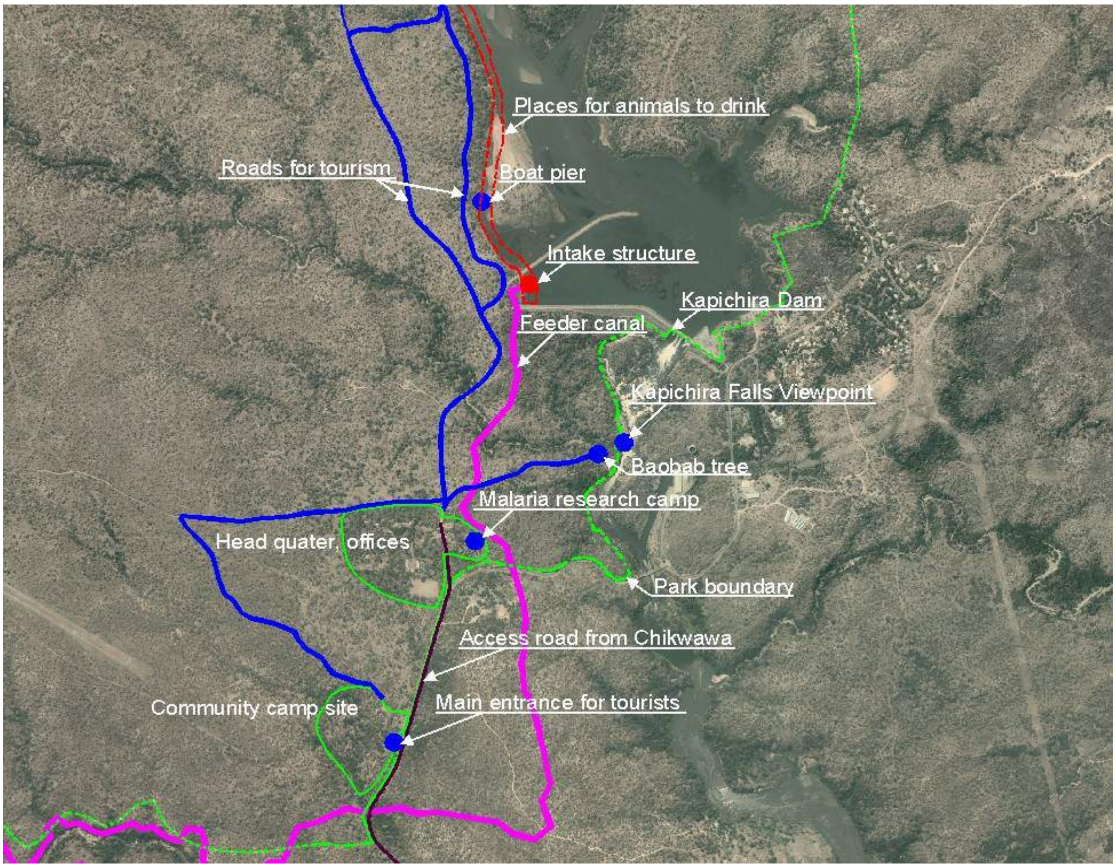
3.8.2. Majete Game Reserve

Majete Game Reserve located in northern area of Chikwawa is a wildlife sanctuary but also the main tourist attraction in the Lower Shire valley. The Reserve has been managed by African Parks since 2003. As described in the Baseline Report, "the Reserve that had once lost most of its large mammals was restocked with the following mammals: leopard, lion, black rhino, elephant, buffalo, zebra, sable antelope, Lichtenstein’s hartebeest, common waterbuck, eland, impala, nyala, warthog, bushpigs, hippopotamus. All of these species populations are increasing. The reserve along Majete and the Shire River represent highly valuable aquatic habitats since they provide vast permanent water resources for many animals and the only large water body during the dry season (elephant, hippopotamus, lion and crocodile are frequent in these areas). Birds also forage in the Shire."

[Figure 3.8-1] Wildlife in Majete Game Reserve

As zoned in the Baseline Report, the headquarters and offices of Majete Game Reserve are located in the Utility Zone. Major tourist attractions in the Reserve are located in the High Intensity Tourism Zone close to Kapichira falls and along Shire River as shown in Figure 3.8-2. Roads from the community camp site connect tourist attractions such as the Hamilton Rapids, the baobab tree, Kapichira falls viewpoint, boat pier, and sites to game viewing activities. Since the Shire River is the only perennial water body in the area, animals are easily observed along it during the dry season.

As shown in Figure 3.8-2, the Intake Structure is supposed to be located at the right bank of Kapichira Dam. From the intake the feeder canal will cross about 1 km of the Majete Game Reserve to the south passing by Malaria research camp and then turn to the west passing by community camp site. Installation of the canal and the intake will affect the scenery of Reserve and also the life of animals.



[Figure 3.8-2] Facilities and Tourist Attractions in Majete Game Reserve

[Figure 3.8-3] Kapichira Falls and Viewpoint

[Figure 3.8-4] Main Entrance for Tourists and Access Road from Chikwawa

[Figure 3.8-5] Baobab Tree and Boat Pier

3.8.2.1. Mitigation Options in the Majete Game Reserve

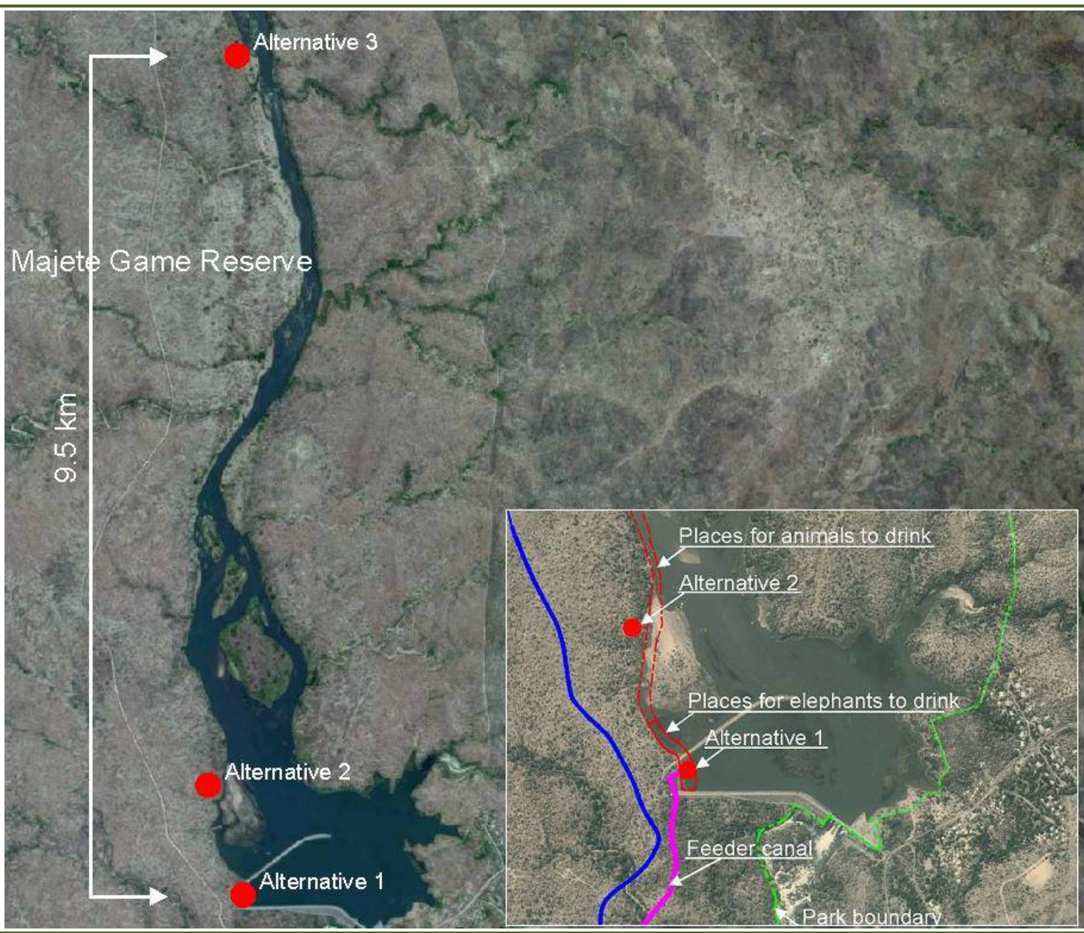
In the feasibility study, main mitigation measures involve the selection of an appropriate site for the intake structure and to choose the shortest route and type of the feeder canal. Since the Shire River is the only large water body in the area during the dry season, the canal will be an impassible obstacle for animals to access to the Shire River. It will thus reduce the aesthetic nature of the reserve. Therefore, the location of the intake and the canal route should be chosen to minimize this negative impact.

<u>Location of the Intake Structure</u>

Concerning the location of the intake structure, initially it was proposed to be located at Hamilton rapids upstream of Kapichira Dam as described in the CODA report (2008). However, the current location of the intake is at the reservoir of Kapichira Dam as shown in Figure 3.8-6. The advantage of the current location is that water can be abstracted easily, economically, and is effective for O&M due to the shortest length of the canal. In view of environmental impacts, the current location (Alternative 1) of the intake is highly recommended.

[Table 3.8-1] Comparison of Alternative Locations of the Intake

Items	Alternative 1(TFS) Current location	Alternative 2(TFS)	Alternative 3(CODA)
Location (Figure 3.8-6)	15°53′38″ 34°44′49″	15°53′17″ 34°44′44″	15°51′10″ 34°44′49″ Hamilton rapids
Canal length in the Reserve	About 1.5km	About 2km	More than 15km
Environmental impact	Minimized impacts on animal movement to Shire river	More impacts on animal movement to Shire river than Alternative 1	Serious impacts on animal movement to Shire river
	Minimized impacts on the scenery of the Reserve	More impacts on on the scenery of the Reserve along the Shire river	Serious impacts on the scenery of the Reserve along the Shire river
Merits and demerits of Irrigation scheme	- Low sediment inflow - Stable water abstraction - O&M condition is better	- High sediment inflow - Hydraulic investigation in progress	- High sediment inflow - Unstable water abstraction - O&M condition is worse
Cost	Least	Medium	Highest
Feasibility	VG	G	NG



[Figure 3.8-6] Alternative Locations of the Intake

Feeder Canal Route

In order to minimize the environmental impact inside the Reserve, the shortest route along the road for tourists (Figure 3.8-2) will be adopted and other alternative routes of the canal will not be considered in the option assessment report.

The type of the Feeder canal will be the main factor to consider in conserving the current ecology in the reserve. Since the Feeder canal will be an impassable obstacle for animals not to cross and will reduce of the attractiveness of the scenery in the Reserve, it is recommended that steel or concrete pipes should be installed instead of an open canal. However, it is almost impossible to cover the whole canal inside the reserve due to the physiographic constraint and head loss. This issue will be studied further after the preliminary vertical design of the Feeder canal inside the Reserve is completed.

Through the interview with the park manager, it was noted that there are two passages that elephants use in this area. In case of open type canal, which should be designed with at least two overpass structures and fences along the canal to allow for wildlife to cross and to avoid animal drowning. Another issue raised by the Majete Game Reserve management was that as the canal scheme abstract water at the reservoir, the feasibility of the falls as a tourist sight may be compromised in the longer term with reduced flows etc. This issue has been dealt with in section 3.8.4.

3.8.2.2. Mitigation Measures during the Construction

One of the main impacts of implementing the Project inside the Reserve is disturbance caused by construction activities, which could be a stressful to wildlife as well as severely disturb tourism operations. Noise, visual disturbance, dust, disturbance of vegetation and scaring of game will be caused by construction activities such as blasting, machine operations and construction vehicles. Appropriate mitigation measures will be applied and these are highlighted in the ESIA. Additionally, Majete Game Reserve management has to be engaged and be assured of effective mitigation measures and compensation of any negative impacts of this project on the Reserve.

Closing of the Construction Area during the Construction

Due to the likely disturbance to be caused by construction activities, animals may move upstream during the construction, and that human and wildlife conflicts may take place in the construction area, it is recommended to close the area during the construction of the feeder canal. However, access to Kapichira falls viewing site and the baobab tree should be possible. Since construction works will affect tourism, any reduction of the Park’s revenue shall be compensated appropriately.

Construction Machinery Deployment and Movement

It has been proposed in ESIA inception report that the construction machinery will have to cross the dam in order to get to the location of the intake instead of crossing the reserve as a mitigation measure. However, crossing the dam from tESCOM side could affect the stability of the dam structure. Therefore, an alternative access road from the start of the Kapichira tar road along the intended path of the canal has been suggested in order to minimize disruption to the operations of the Reserve (Figure 3.8.2-7). However, the reserve's management raised concerns about the heavy machinery on the main access road from Chikhwawa to Majete entrance gate because construction vehicles could affect the condition of the road and visitors' travelling to Majete. To minimize this effect, mitigation measures such as repairing of damaged road, speed limit have been proposed.

Construction Period

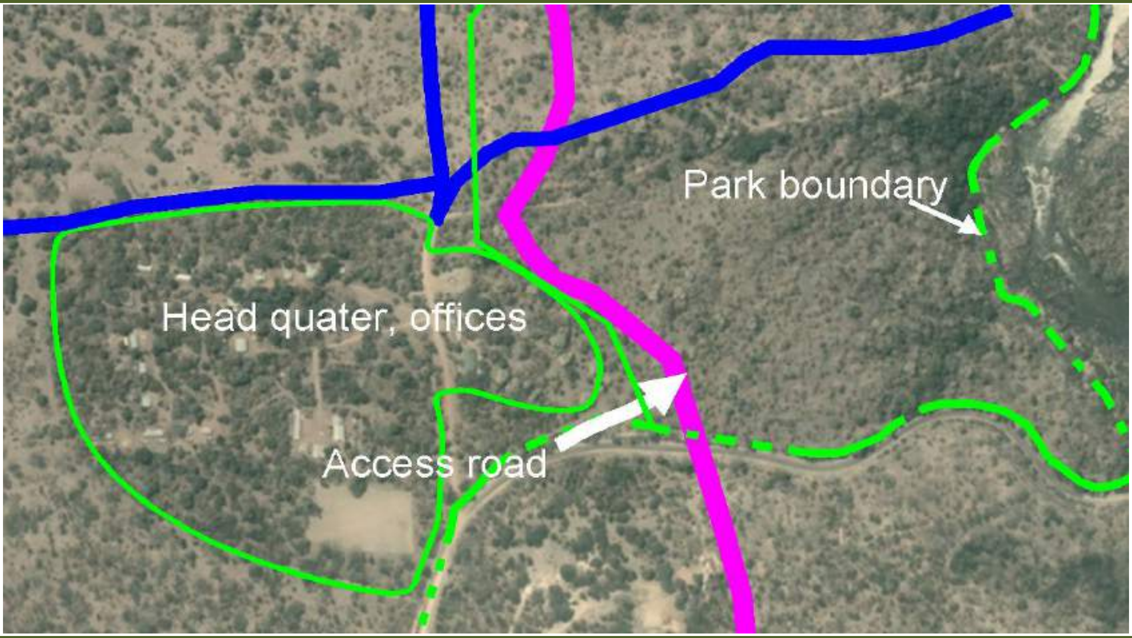
Shortening the entire construction period inside the Reserve will be an ideal mitigation measure to negative effects on tourism and wildlife. It is worth noting that tourists visit the Reserve in large number during the dry season which in principle starts from May and ends in November. But the dry season is also the suitable season for the implementation of construction works. Therefore, the period of construction activities that creates high level of noise will be negotiated with the management of the Reserve, and so will the working hours on a daily and weekly basis.

Minimal Forest Clearing

Clearing and construction activities will be confined only to areas covered by the project site to minimize the threat to wildlife and ensure minimal forest clearing in along the canal route.

Other Mitigation Measures and Compensation

Noise barriers and dust screen will be installed at the area of the facilities close to construction site such as the Head office, Malaria research camp, community camp site and boat pier to mitigate noise and dust disturbance. As mentioned in the preceding discussion, mitigation measure has been suggested and prepared under the Reserve management's confirmation before the commencement of construction works. In addition, any form of compensation to offset costs incurred by disrupting Reserve operations shall be discussed with the Reserve management.

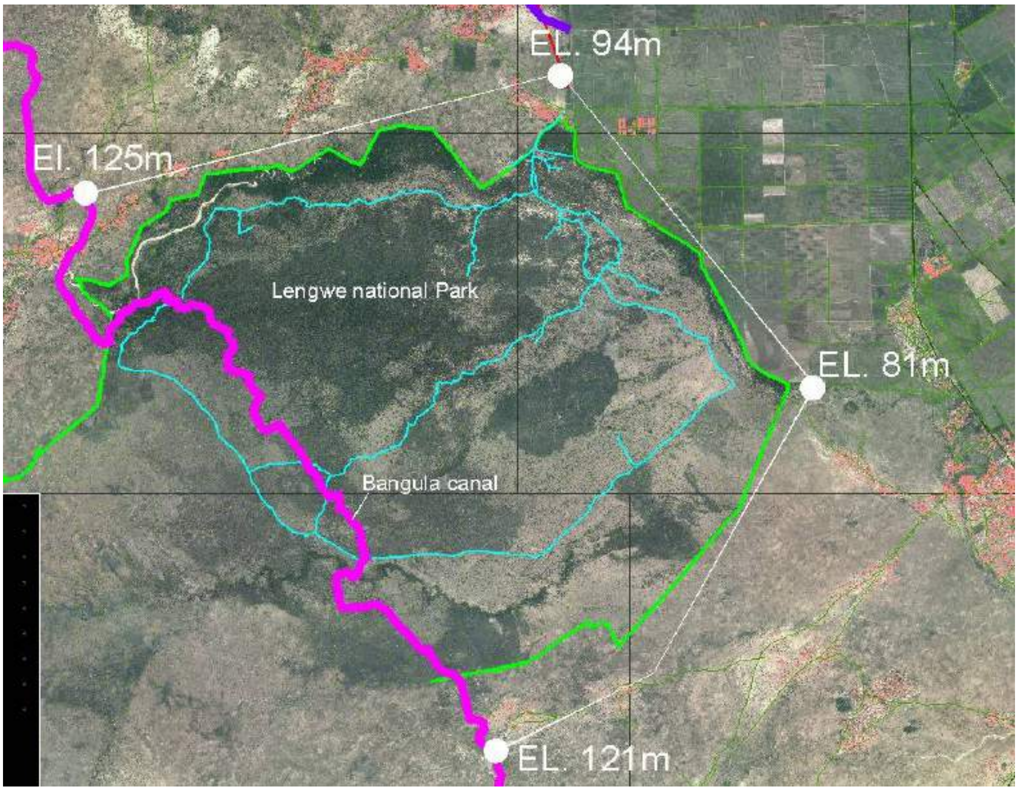


[Figure 3.8-7] Alternative Access Road to the Construction Site

3.8.3. Lengwe National Park

The park was established as a game reserve in 1928 and declared a national park in 1970. As described in the Baseline report. "Lengwe, and especially its eastern part, is highly valued for having one of the last Nyala population in the region confined in the rare thicket ecosystem. The almost total disappearance of thicket vegetation in the Shire Valley outside wildlife reserves means that thickets in Lengwe and Mwabvi are of the utmost importance for the survival of relatively rare species and the Nyala."

One major challenge that the park faces is to supply water for animals to drink during the dry season. Since the area between the park and the Shire River, which is the only large water resource in the area but is covered by sugarcane plantation, animals in the park suffer lack of water. The park has currently provided water by electrical pumping system from Illove. But Due to the unreliable supply of electricity, it does not provide enough water for animals and it is recommended that water be supplied to the park by gravity. Buffalos are frequently reported to enter Illovo estate and destroy hectares of plantation looking for water and food during dry months as mentioned in the Baseline study. If the Park provides adequate water to wild animals, the population of Nyala could be restored. Since the Bangula canal is supposed to cross the park over a distance of 14km, it could cause habitat fragmentation and will be an impassible obstacle for animals to cross. However, there are no other alternative routes for the canal except for passing through the park (Figure 3.8-9). The type of canal and other mitigation measures will be considered for implementation in order to minimize the effect on the park.



[Figure 3.8-8] Current Condition of Altitude above Sea Level around the Lengwe National Park

[Figure 3.8-9] Wildlife in Lengwe National Park

3.8.3.1. Mitigation Options in the Lengwe National Park

As presented above, the canal is supposed to cross the Park, the most valuable ecosystem, for about As discussed above, the canal is supposed to pass through the park for about 14km, with the width of 14~26m. In principle a closed type canal is recommended and it is also proposed in the ESIA Inception Report as a mitigation measure. However, as shown in Table 3.8-2, a closed canal cannot provide water by gravity. Also, it will seriously aggravate negative effects of the project economically. The construction cost of the closed canal is 5 times higher than the lined canal. If an overpass structure for animals to cross the canal is installed appropriately, it can mitigate negative impacts on the park. The number and length of the overpass structure will be discussed with ESIA team and the park management. To prevent animals from drowning, fences will be installed along the canal.

[Table 3.8-2] Comparison of Canal Type

Items		Open Canal		Closed Canal
		Earth Canal	Lined Canal	Culvert
Length of canal (Inside the Park)		14.1km	14.1km	14.1km
Q(m/s)		24.91	24.91	24.91
Specification	Upper Width	20.9 ~ 22.7m	12.9 ~ 13.30m	3.3m x 2m @ 3
	Bed Width	13.7 ~ 15.5m	7.5 ~ 7.9m	
	Water depth	1.8m	1.8m	1.8m
Slope		1:2.0~1:2.5	1:1.5	underground
Cost($)	Canal	4,850,400	6,147,600	44,922,600
	Overpass structure	3,186,000 (5places @ 200m length)	3,186,000 (5units @ 200m length)	-
	Total	8,036,400	9,333,600	44,922,600
O&M		Difficult	Easy	Easy
Rehabilitation		Easy	Difficult	Difficult
Environmental impact		Mitigating habitat fragmentation and animal movement by overpass structures: 5 places @ 200m length	Mitigating habitat fragmentation and animal movement by overpass structures: 5 places @ 200m length	No habitat fragmentation after construction
		Providing water by gravity for animals to drink	Providing water by gravity for animals to drink	Providing water by Electrical pumping system for animals to drink Additional cost for the Park's maintenance
Feasibility		G	VG	NG

3.8.3.2. Mitigation Measures during the Construction

Tourism and management infrastructure are located on the Eastern end of the Park close to the Park entrance gate while the canal route is located at the end area of the road network used for wildlife viewing. If access road to construction site is constructed along the canal avoiding the main utility area and an alternate route for tourists is constructed, tourism operations of the Park shall not be seriously disturbed. Animals in the Park will be scared by construction activities and their movement will be restricted. Although it could increase construction costs, the construction needs to be phased in order to mitigate negative impacts.

Construction Period

As stated in the preceding discussion, shortening the entire construction period inside the Park will be an ideal mitigation measure on tourism and wildlife. It will take at least two years to construct the canal inside the Park. It is recommended to phase the construction in two or three sections inside the Park. After fishing the construction of one section, passages for animal movement has to be prepared and then the other construction section has to be started. The period of construction activities that create high level of noise will be negotiated with the Park management

Minimal Forest Clearing

Clearing and construction activities will be confined only to areas covered by the project site to minimize the threat to wildlife and ensure minimal forest clearing in the canal right-of-way.

Compensation

As mentioned above, mitigation measure have been suggested and prepared with the Park management's agreement prior to the construction of the canal. In addition, any form of compensation to detrimental effects of the project to the Park operations was discussed with the Park management.

3.8.4. Elephant Marsh

Elephant marsh is one of the distinctive landscapes in Malawi. According to the ESIA Baseline report, "The Elephant Marsh hydrological behaviour during the dry season is almost entirely driven by the upstream basin of the Shire River at Kapichira (95% of the inflow) and consequently the main leverage for action to satisfy the minimum environmental flow for Elephant Marsh is the Kamuzu Barrage. During the wet season, the Elephant Marsh's inundation is mainly caused by the Shire River and the Ruo River.

The abstraction of water by the scheme would reduce the water supply to this wetland, with some potential shrinkage in its area. One of the main reasons for protecting the Elephant marsh is to sustain flows in the Shire River. Table 3.8-4 shows the exceedance probability data of Shire river discharge at Kapichira Dam which were published in the WRIS. For example, Q80 indicates the discharge of Shire River which will occur over 80% annually. According to the this report, Q80 is 326 m^3/s, which is greater than 319.4m^3/s, the water demand for both of electricity generation (269.24m^3/s) and Irrigation (50.0m^3/s). This means that Shire's runoff will potentiality satisfy the water demand for both.

However, since Lake Malawi is the major source of water for Shire River during the dry season, however, since Lake Malawi is the major source of water for Shire River during the dry season, inflow into Kapichira Dam mostly depend on the runoff from Lake Malawi and Liwonde Barrage. In light of the above, water deficit will be severe in SVIP area and in the Elephant Marsh if outflow from Lake Malawi is sharply reduced.

[Table 3.8-3] Probability of Water Supplying as the Discharge of Shire River

Classification	ESCOM I (m^3/s)	ESCOM II (m^3/s)	SVIP (m^3/s)	Total Water Demand(m^3/s)	Probability of Water Supplying for SVIP (%)
Case I	134.6	134.6	50.0	319.4	80
Case II	134.6	67.3	50.0	252.1	88
Case III	134.6	0	50.0	184.8	97

[Table 3.8-4] Exceedance Probability Discharge at Kapichira Dam (unit: m^3/s)

Division	Q mean	Q max	Q50	Q75	Q80	Q95	Q min
WRIS	537	1,269	530	371	326	202	161
Water Demand	for Electricity(269.2) and Irrigation(50.0) = 319.2m^3/s						

3.8.5. Aquatic Ecology

As explained in the Baseline report, Shire River is divided into 3 distinctive aquatic ecological zones: the upper Shire, the Middle Shire and the Lower Shire. The upper Shire extends from the outlet from Lake Malawi which was declared a natural heritage site for fish biodiversity in the world by UNESCO to Matope Bridge. The Middle Shire extends from Matope Bridge to Kapichira while the Lower Shire extends from Kapichira to the point where it exits Malawi to join the Zambezi. The Lower Shire fish fauna shares the same ecology with the lower Zambezi fish species because of the absence of any physical barrier between the Lower Shire and the Zambezi River.

Based on the aquatic ecology research of ESIA, three fish species, namely: Tilapia, African Catfish and Chikano contribute to 90% of the total fish catch in the Lower Shire. And Tilapia constitutes about 51%. Although Tilapia and Catfish are categorized as invasive and potential invasive species, they are native in the Lower Shire. These two are not able to climb or negotiate against physical obstacles and rapids. The other species (Straightfin Barb, S. njassae, Tiger fish Lake Salmon, Redeye labeo, Barbus eurystomus, Barbus johnstonii, Marcusenius macrolepidotus) are native and not invasive. They also do not have the ability to pass through physical obstacles and rapids except for Lake Salmon, Redeye labeo.

It is clear from the ESIA that the project will not affect aquatic ecology noticeably in Lake Malawi and the Middle shire because fish species in the Lower Shire are native and not invasive. In addition, fish will not be able to migrate to the upstream due to the presence of Kamuzu Barrage at Liwonde and the rapids in the Middle Shire.

3.8.6. Cultural Heritage

Among cultural resources that are listed in the Cultural Heritage Impact Assessment, no cultural resources are located along the current route of the. Currently twelve cultural resources among

CK46~CK86 were identified in the area of the project. Depending on the outcome of Cultural Heritage Impact Assessment, further survey or mitigation measure such as sub surface screening, extensive excavations, rescue archaeology will be implemented. Graveyards that are affected by the irrigation project will be relocated or preserved in consultation with stake holders and according to the related laws and regulations.

3.8.7. Other Environmental Impacts and Mitigation Measures

As the canal crosses several villages, the life of these villages will be disturbed seriously by noise, dust, traffic inconvenience during the construction phase. To minimize these impacts, mitigation measures such as speed limit of construction vehicles, limitation of working hours, have been prepared In case any damage to facilities in a village occurs, it has to be avoided or compensated in consultation with stakeholders.

Mitigation measures and management plan will be suggested and prepared about other environmental and social issues such as health related issues, resettlement plan, pest management plan, etc. The feasibility study will review these measures.

3.9. Use of Other Resources

TOR Requirements

The consultant shall investigate and recommend feasibility and options for augmenting the SVIP surface water supply with ground water and conjunctive use of surface and ground water in the command area to reduce risk of irrigation water scarcity during dry spells; also investigate options for within system storage and beneficial use of rivers other than the Shire passing through the command area for nested/conjunctive systems within SVIP.

3.9.1. Surface Water Resources

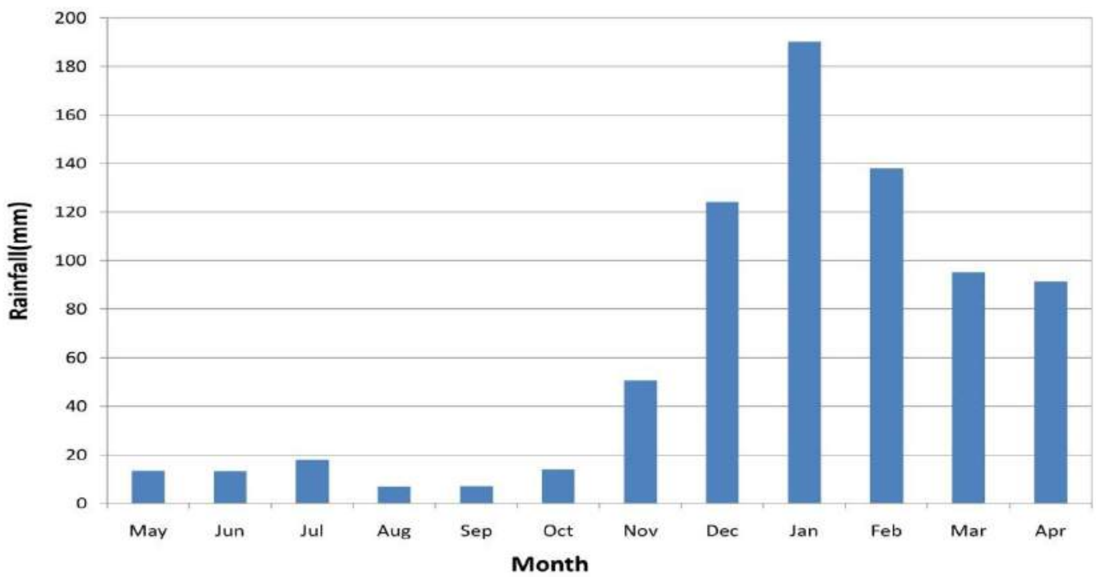
3.9.1.1. Climatic Condition of Chikwawa Area

Table 3.9-1 and Figure 3.9-1 shows a long-term monthly rainfall record of Chikwawa. The annual rainfall in the project area is 761 mm. As shown in the data, little rainfall takes place in the project area and hence many rivers do not flow during the dry season. Therefore, abstracting water from surface water bodies is possible only between November and April, and the hence the water sourced during that period has to be used also during the dry season.

The demand for irrigation water reaches its peak between August and October, and the water resources obtained during the rainy season must meet the water requirement for agriculture during this period. Consequently it is very important to determine whether the water obtained from rainfall is adequate to last for 4~5 months (despite a large amount of evaporation and infiltration) during the dry season or not.

[Table 3.9-1] Monthly Average Rainfall (1971~2014) in Chikwawa Area

Division	Dry Season						Wet Season					
Month	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Monthly Rainfall(mm)	13.5	13.3	17.8	6.9	7.1	13.9	50.6	124.3	190.2	137.8	95.3	91.3



[Figure 3.9-1] Monthly Average Rainfall (1971~2014) in Chikwawa Area

An investigation was conducted on river flows during the dry season (between September and October). Figure 3.9-2 ~ Figure 3.9-3 describe the state of rivers at the time of the investigation. All the rivers were dry like Mwanza river and there was no sign of flow at that time during the field visits.


[Figure 3.9-2] Mwanza River (Dry Season)



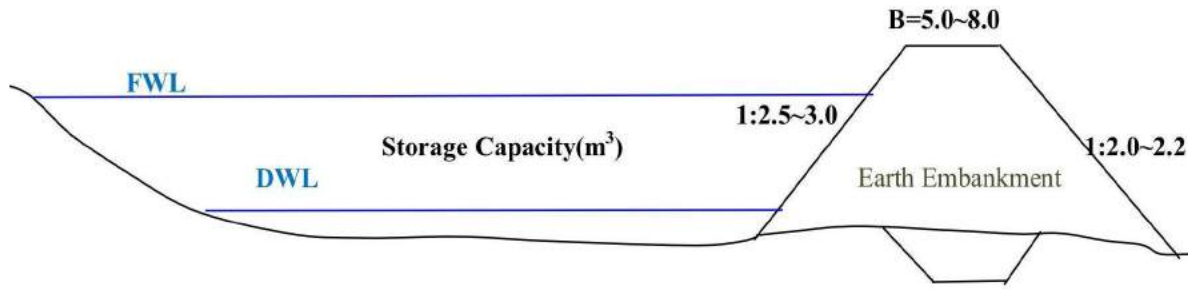
[Figure 3.9-3] Mwanza River (Dry Season)

3.9.1.2. Required Conditions to Develop the Surface Water Resources

When planning dam construction for surface water development, many conditions must be reviewed. Out of the many, the most important factor is topography. In particular, the ratio of irrigation area of project site to basin is a key factor as the ratio has an effect on the economics of dam construction. Local runoff of 10~15 times is considered appropriate.

Another key factor is how short the length of dam can be. In many cases, economic validity fails to be achieved as dams require longer lengths due to topographical characteristics which raise construction costs. The shorter the dam body is, and the higher the dam is, and the better economically.

Climatological factors play an important role in the construction of dams. If rainfall is evenly distributed over a year, there is no need for the reservoir to store lots of water at one time. So the size of the dam does not need to be big. However, if the area has a clear distinction between dry and wet seasons, and that the dry season is longer than the wet season, the size of dam must be big in order to store adequate water during the rainy season for use up until the end of dry season. Chikwawa region of SVIP project area experiences short wet season, low rainfall, long dry season, and high evaporation. Despite these unfavorable conditions, TFS selected 10 candidate areas for dam construction. TFS considers building common earth fill dams as shown in Figure 3.9-4.



[Figure 3.9-4] Typical Fill Dam Section

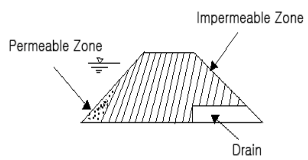
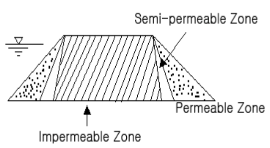
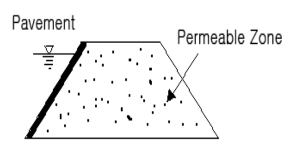
In general, civil engineering considers dams with 15m or lower height as small dam. Shown below is the categorization according to Estimating design floods for small earth dam in Malawi (M. P. McCartney et al. FRIEND Conference 2002, Regional Hydrology: Bridging the gap between Research and Practice)

[Table 3.9-2] Classification of Dam

Dam Size Classification	Very Small	Small	Medium	Large	Major
Reservoir Capacity(1,000m^3)	< 50	50~1,000	1,000~5,000	5,000~20,000	> 20,000
Height (m)	< 4.5	4.5~8	8~15	15~30	> 30

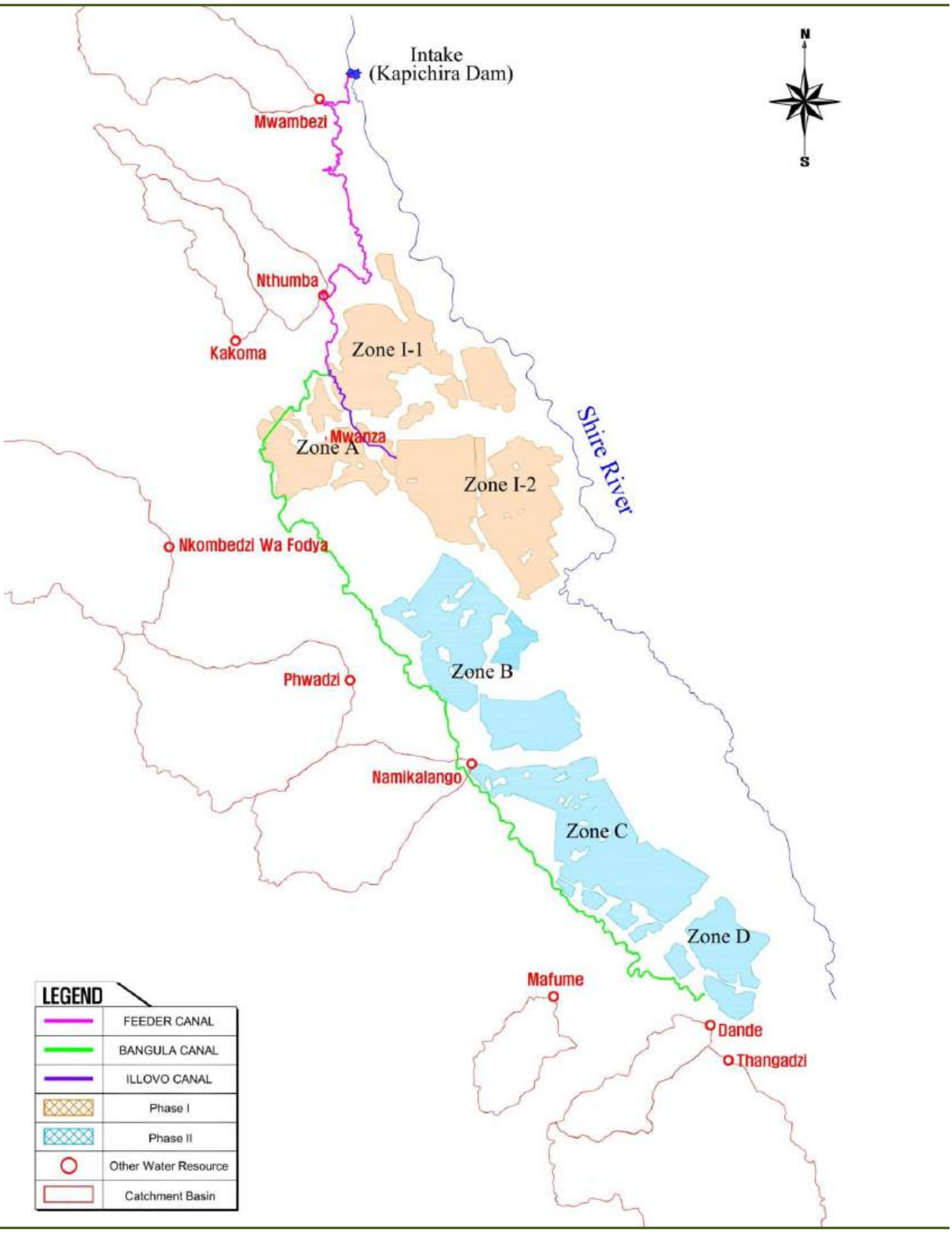
After considering not only topographical, geographical, hydrological and natural situation but also economic factors, the construction of earth dams was considered as the most appropriate option for the 10 selected sites in the project area. Generally, earth dams can be classified into three type categories, homogeneous type, zone type and surface waterproof type (Table 3.9-3). Homogeneous type of dam is that most of embankment (over 80% of dam body) is constructed by single material with earth or gravel.

[Table 3.9-3] Comparison of Fill Dam Type

Class	Homogeneous Type	Zone Type	Surface Waterproof Type
Dam Height	Low	High	High is not good
Topography	Unsuitable for Stiff Slope	Suitable for Stiff Slope	Unsuitable for Stiff Slope
Geological Features	Suitable for soil foundation	Suitable for Permeable foundation	Unsuitable for the soft or porous rocks
Weather Condition	Suitable for cold and wet regions	Limited construction Period	Nothing
Section			

3.9.1.3. Potential Locations of Dams in the SVIP Area

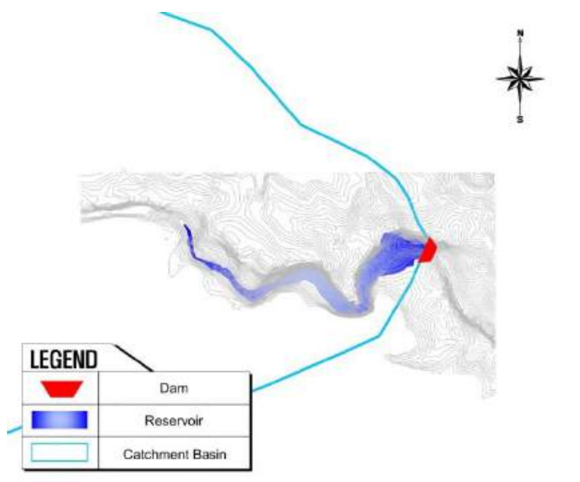
Small catchments with rivers flowing into the SVIP area were investigated for potential dam sites both on the map and in the field. Ten (10) promising catchments were selected and analyzed. They are small catchments located in the sections through which the main canal of SVIP will pass. Table 3.9-4 shows the name of river, location, basin area, and type and size of structure to be installed. Figure 3.9-5 describes the location of catchments and their boundaries with respect to each dam. Figure 3.9-6 ~ Figure 3.9-14 show the storage areas at the position of each dam except Mwanza river.



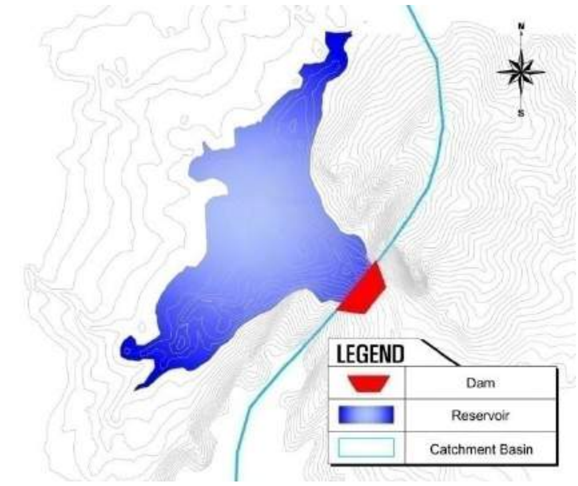
[Figure 3.9-5] Location of the Other Water Resources

[Table 3.9-4] Potential Areas to Develop the Surface Water Resources

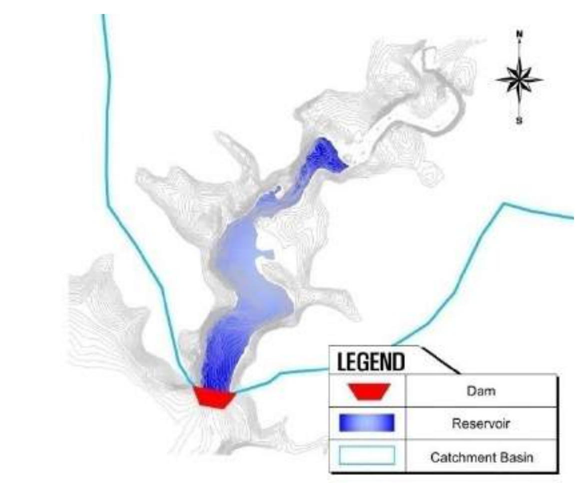
River	Catchment Area(km^2)	Type	Specification		Crest Height (a.m.s.l m)	Storage Capacity(m^3)
			Length(m)	Height(m)		
Mwambezi	156.3	Dam	74	13	156	275,100
Nthumba	69.4	Dam	184	7	139	918,300
Kakoma	50.0	Dam	123	14	163	771,600
Mwanza	1,618.1	Intake Barrage				
Nkombedzi	244.1	Dam	112	18	168	17,066,247
Phwadzi	188.4	Dam	254	7	137	835,300
Namikalango	142.6	Dam	294	6	114	595,400
Mafume	44.8	Dam	106	8	183	2,308,582
Danje	53.0	Dam	395	36	94	454,500
Thangdzi	307.6	Dam	142	17	91	8,658,200



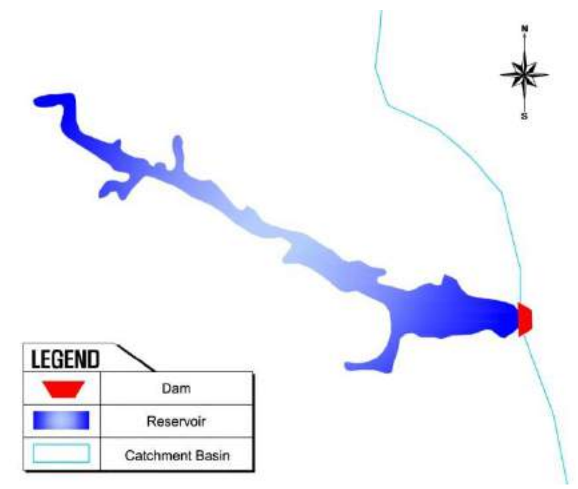
[Figure 3.9-6] Mwambezi Dam



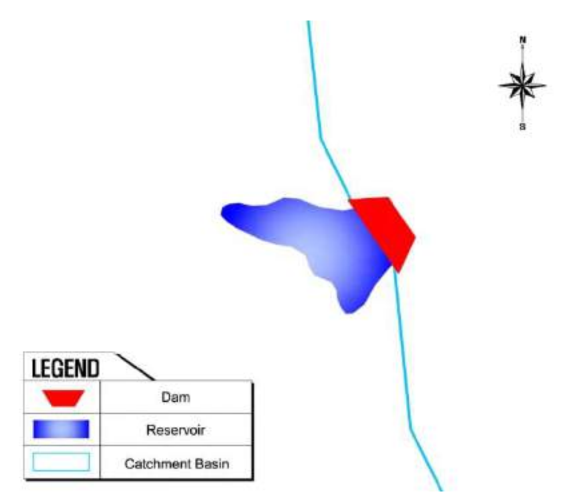
[Figure 3.9-7] Nthumba Dam



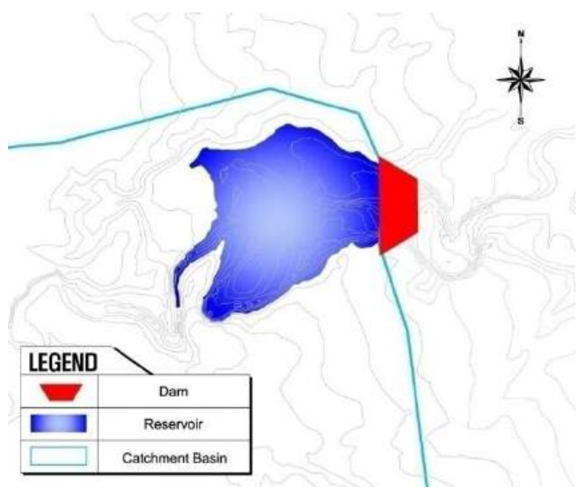
[Figure 3.9-8] Kakoma Dam



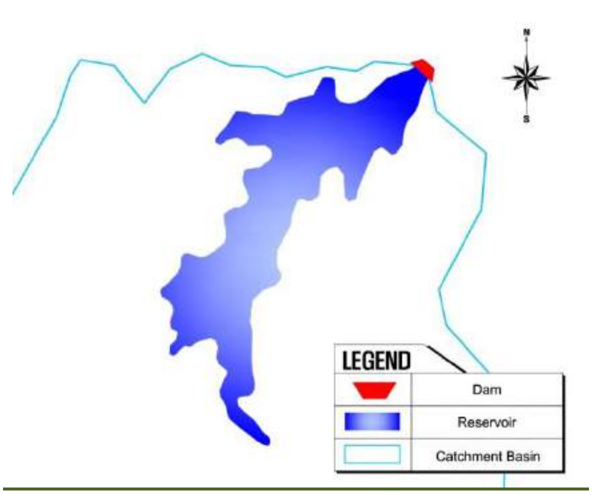
[Figure 3.9-9] Nkombedzi Dam



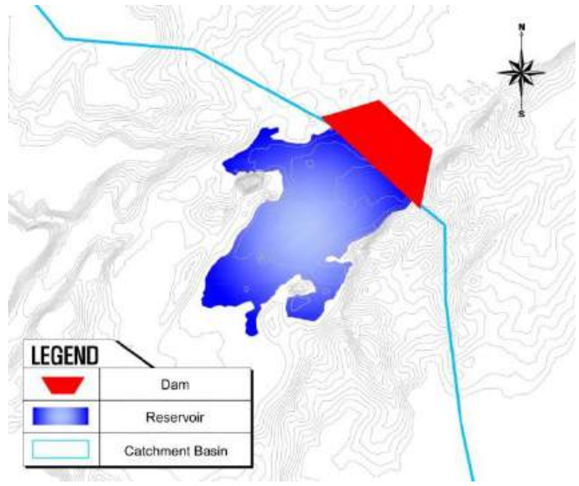
[Figure 3.9-10] Phwadzi Dam



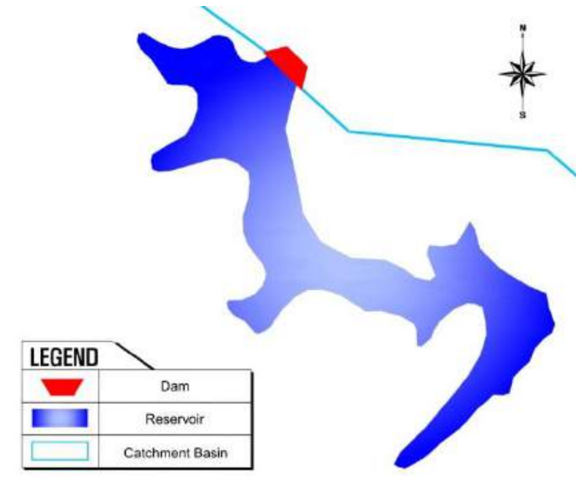
[Figure 3.9-11] Namikalango Dam



[Figure 3.9-12] Mafume Dam



[Figure 3.9-13] Danje Dam



[Figure 3.9-14] Thangdzi Dam

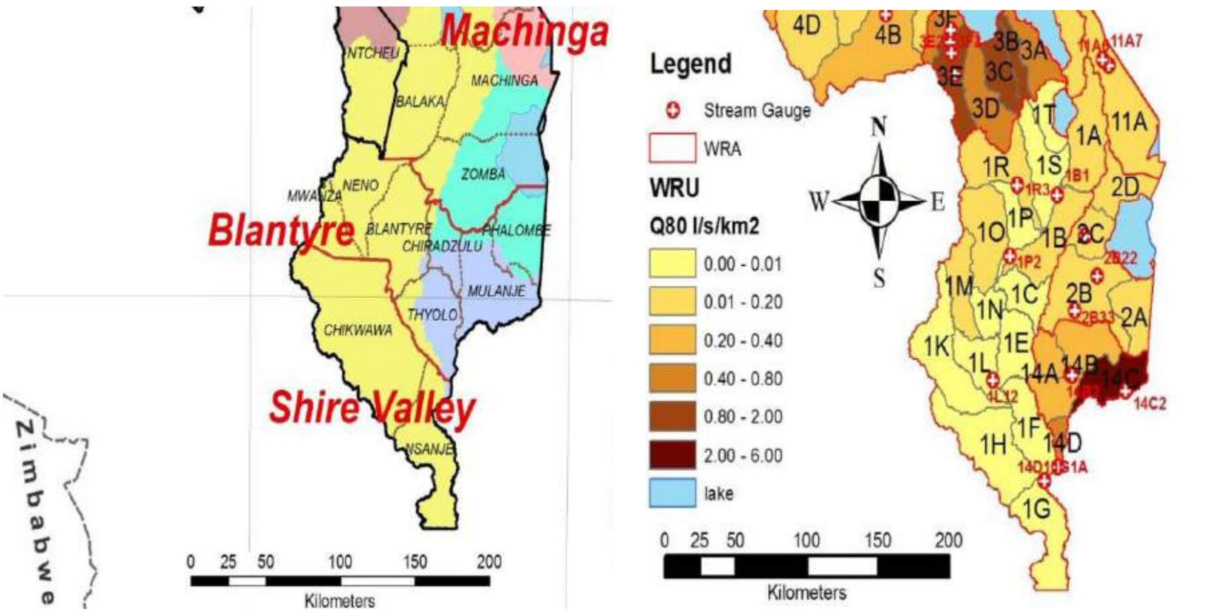
3.9.1.4. Water Balance of Reservoirs

Runoff Estimation of SVIP Project Area

Chikwawa has almost zero runoff during the dry season and has some runoff when it rains during the wet season. Monthly runoff is decided to consider stream flow of Chikwawa region.

The IMP (Irrigation Master Plan) estimates the PIA (Potential Irrigation Area) based on available surface water resources and deducts domestic water demand and environmental flows. For this purpose, the NWRMP (National Water Resources Master Plan) has made available stochastic generation of monthly flows for 30 years (Nov 1980 to Oct 2010).

These data have been analyzed to determine the 80% reliable flows (Q80) used in the assessment of available water resource for irrigation. This represents the one in five year drought, or to say that four years in five will have flows exceeding the Q80 flow. From the Q80 results, the unit minimum flows for each WRU have been computed in l/s/km^2, and when represented geographically, show the areas of abundant water and those with less water (see Figure 3.9-15).



[Figure 3.9-15] Water Resource Unit Area with District Boundaries(Irrigation Master Plan, 2015)

Mwanza River has the largest basin area of 2,110km^2 in Chikwawa region. Although it sustains flows in its upper reaches, the flows disappear when the Mwanza approaches the Shire. SVIP area belongs to 1H, 1G (water resource unit boundaries.).

Table 3.9-5 describes monthly 80% flow per unit area and runoff and Table 3.9-6 shows monthly stochastic data.

[Table 3.9-5] Monthly 80% Flow Per Unit Area of 1H Region (m^3/s/km^2)

Division	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
80% Flow (m^3/s/km^2)	0.00137	0.00295	0.00122	0.00058	0.00026	0.00012	0.00005	0.00002	0.00001	0.00001	0.0	0.0	0.00659

[Table 3.9-6] Monthly Stochastic Data by WRU

1H	Column K			2117.89km^2							1,000m^3	
Year	1	2	3	4	5	6	7	8	9	10	11	12
1979	26417.1	31408.5	18079.2	8286.6	3798.0	1739.2	798.2	364.3	168.5	77.7	36.3	16.1
1980	8.0	2.4	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38060.1
1981	17441.7	46247.8	21194.2	9712.2	4451.5	2039.9	934.8	428.5	197.0	91.1	41.5	18.7
1982	102572	166753	76414.8	35020.5	16049.0	7356.1	3372.1	1545.4	707.6	324.1	147.7	67.0
1983	32.1	23904.1	10954.7	5020.7	2300.7	1054.9	482.	222.3	101.1	45.5	20.7	42037.5
1984	19263.1	113579	61940.7	28385.0	13009.0	5961.6	2732.0	1253.5	572.8	262.5	121.8	120565
1985	67926.9	83164.8	118500	54305.0	24885.0	11404.8	5228.2	2394.5	1099.0	503.5	230.7	56270.5
1986	98741.9	120568	55252.7	25321.2	11605.5	5318.8	2437.3	1116.9	513.2	235.7	108.9	48.2
1987	6688.0	3065.1	1403.5	642.8	294.6	134.8	61.6	29.5	13.0	5.4	2.6	0.0
1988	34125.5	143836	90184.4	41329.4	18939.0	8680.6	3977.4	1824.0	834.6	383.0	176.3	80.4
1989	28983.0	139058	119173	54613.4	25027.0	11469.6	5257.7	2410.6	1104.2	506.2	233.3	107.1
1990	60414.0	27685.3	12687.6	5813.9	2665.0	1220.8	559.8	257.1	116.6	53.6	25.9	10.7
1991	5.4	3261.8	51430.6	23569.1	10802.0	4950.7	2268.6	1039.2	476.9	219.6	101.1	45.5
1992	21.4	9.7	5.4	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11929.6
1993	152701	69975.4	32068.5	14696.6	6736.2	3087.1	1414.2	648.2	298.1	136.6	62.2	29.5
1994	7751.3	3551.4	1628.5	746.5	342.8	155.5	72.3	32.1	15.6	8.0	2.6	2.7
1995	82459.9	37787.9	17315.9	7936.7	3637.3	1666.7	763.3	350.9	160.7	72.3	33.7	58699.8
1996	48666.5	92965	44124	20220.2	9267.3	4248.3	1947.2	891.9	409.5	187.5	85.5	40.2
1997	83737.5	181989	83397.3	38219.0	17514.1	8027.4	3680.1	1687.4	772.4	353.5	163.3	75.0
1998	40513.5	18564.9	8506.6	3898.4	1786.5	819.1	375.0	171.4	77.8	34.8	15.6	93610.1
1999	128973	78227.3	35847.7	16428.1	7529.0	3450.0	1580.3	725.8	331.8	152.7	70.0	32.1
2000	68701	66131.3	77941.4	35717.8	16367.7	7501.2	3439.1	1574.9	723.2	332.1	152.9	69.6
2001	126329	178130	81629.6	37407.7	17144.4	7856.4	3599.8	1649.9	756.9	345.5	158.1	62272.8
2002	77732.5	35622.7	16324.8	7480.5	3428.4	1570.8	720.5	329.4	150.3	69.6	31.1	13.4
2003	62789.7	46100.3	211272	9681.1	4438.1	2034.7	932.1	425.9	197.0	91.1	41.5	18.7
2004	3827.4	7797.1	3701.5	1695.2	776.7	355.1	163.4	75.0	33.7	16.1	7.8	16997.1
2005	7788.8	3568.3	1636.5	749.1	342.8	158.1	72.3	32.1	15.6	8.0	2.6	73875.6
2006	33852.3	15514.3	32400.6	14847.0	6805.8	3118.2	1430.3	656.2	300.7	136.6	62.2	29.5
2007	251100	145169	66526.1	30487.1	13973.2	6404.8	2935.5	1344.6	616.9	283.9	129.6	111060
2008	21424.5	94793.9	44991.8	20619.4	9449.4	4331.2	1984.7	910.7	417.3	190.2	88.1	72094.5
2009	33038.1	15139.4	6937.1	3180.4	1457.0	668.7	305.3	139.3	64.8	29.5	13.0	5.4
80% Flow m^3/s	2.9	6.3	2.6	1.2	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0
80% Flow m^3/s/km^2	0.00137	0.00295	0.00122	0.00058	0.00026	0.00012	0.00005	0.00002	0.00001	0.00001	0.00000	0.00000

(Irrigation Master Plan and Investment Framework, Appendix 4: Hydrology, Final Version February 2015/ Page 26)

According to Table 3.9-5, total quantity of monthly 80% flow per unit area of 1H region amounts to 0.00659m^3/s/km^2. Table 3.9-6 shows the monthly rainfall and distribution of SVIP region. It estimates monthly runoff distribution of 80% flow of 1H region by dividing the total quantity of monthly 80% flow of 0.00659m^3/s/km^2. Likewise, 80% flow which is redistributed against 1H region to divide them by total quantity of rainfall per monthly unit area to estimate monthly runoff ratio per monthly rainfall for 1H region. Runoff (%) for calculated monthly rainfall is used as standard to estimate the runoff by basin area of total secondary head work for water sources.

[Table 3.9-7] Monthly Rainfall and 80% Flow($m^3/s/km^2$) Distribution and Runoff Ratio of SVIP

Division	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Rainfall (mm)	190.2	137.8	95.3	91.3	13.5	13.3	17.8	6.9	7.1	13.9	50.7	124.3	762
(%)	24.96	18.08	12.50	11.98	1.77	1.75	2.34	0.91	0.93	1.82	6.65	16.31	100
80% Flow (㎥/s/㎢)	0.00174	0.00127	0.00088	0.00084	0.00012	0.0	0.0	0.0	0.0	0.00013	0.00047	0.00114	0.00659
Runoff (%)	2.46	2.22	2.46	2.38	2.46	0.0	0.0	0.0	0.0	2.46	2.38	2.46	19.30

Water balance factor of dam consists of inflow caused by runoff from dam basin, loss from evaporation of reservoir, water requirement of crop, and reservoir draft. In other words, “water balance of dam = quantity of possible to store out of runoff from dam basin - loss from dam - water requirement of crop” whose result is captured in the following.

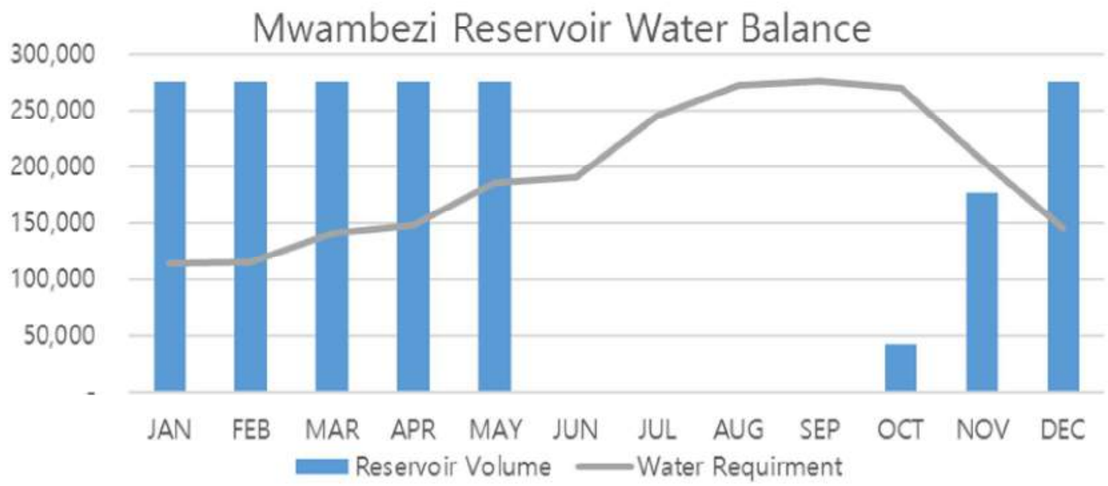
1) Mwambezi Dam

Mwambezi dam site is located at the lower reach of Mwambezi river before it joins Shire River. Its catchment area is 156.3km^2, length 74m, height 13m, irrigation area 90ha, and storage capacity 275,100m^3. As it is located higher than feeder canal, it will able to supply water to feeder canal.

Table 3.9-8 and Figure 3.9-16 are the estimation result of water balance of Mwambezi Reservoir. Storage capacity of dam becomes lowest during June to October while inflow between September to August reaches zero. Thus, even though water requirement of field is largest, the dam is unable to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-8] Water Balance of Mwambezi Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	731,932	723,967	275,106	7,965	114,111	334,750
Feb	478,967	472,145	275,106	6,822	114,912	82,127
Mar	366,735	359,182	275,106	7,553	141,453	-
Apr	340,009	333,364	275,106	6,645	147,960	-
May	51,951	46,184	-	5,767	186,093	-
Jun				4,917	190,350	-
Jul				5,355	245,520	-
Aug			-	7,003	272,583	-
Sep			-	8,904	275,670	-
Oct	53,490	42,504	42,504	10,986	270,072	-
Nov	188,438	177,540	177,540	10,898	205,740	-
Dec	478,334	469,545	275,106	8,789	146,196	48,243



[Figure 3.9-16] Water Balance of Mwambezi Dam

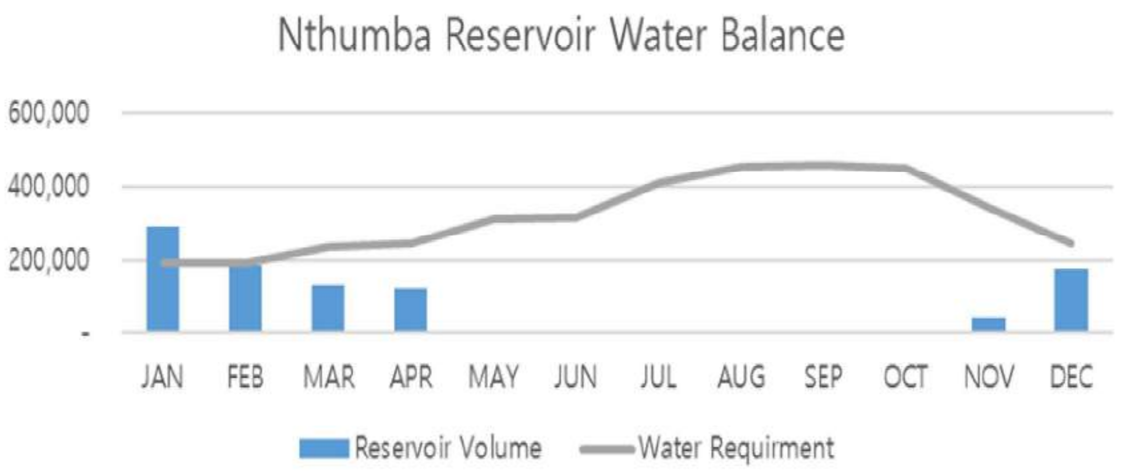
2) Nthumba Dam

Nthumba dam is located on the lower reach of Nthumba River before it joins Shire River. Its catchment area is 69.4km^2, length 184m, height 7m, irrigation area 150ha, and storage capacity 918,328m^3. It is conveniently located to supply water to feeder canal.

Table 3.9-9 and Figure 3.9-17 are the estimation result of water balance of Nthumba Reservoir. Storage capacity of dam becomes lowest during May to November while inflow between August to October reaches zero. Thus, even though water requirement of field is largest, the dam will not be able to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-9] Water Balance of Nthumba Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	324,991	293,124	293,124	31,867	190,185	-
Feb	212,670	185,376	185,376	27,294	191,520	-
Mar	162,837	132,618	132,618	30,219	235,755	-
Apr	150,970	124,384	124,384	26,586	246,600	-
May	23,067			23,076	310,155	-
Jun				19,673	317,250	-
Jul				21,428	409,200	-
Aug				28,021	454,305	-
Sep				35,625	459,450	-
Oct	23,750			43,955	450,120	-
Nov	83,670	40,069	40,069	43,601	342,900	-
Dec	212,389	177,225	177,225	35,164	243,660	-



[Figure 3.9-17] Water Balance of Nthumba Dam

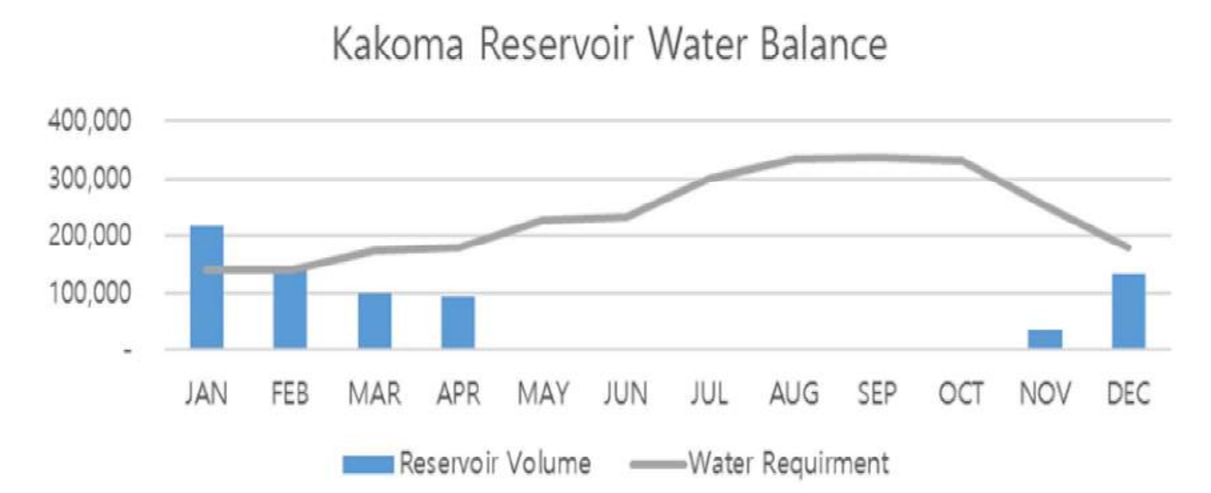
3) Kakoma Dam

Kakoma dam is located at the middle reach of Kakoma River before it joins Shire River. Its catchment area is 50.2km^2, length 123m, height 14m, irrigation area 110ha, and storage capacity 771,600 m^3. It is located to be able to supply water to feeder canal.

Table 3.9-10 and Figure 3.9-18 are the estimation result of water balance of Kakoma Reservoir. Storage capacity of dam becomes lowest during May to October while inflow between August to October reaches zero. Thus, even though water requirement of field is largest, dam is unable to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-10] Water Balance of Kakoma Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	235,080	217,145	217,145	17,935	139,469	-
Feb	153,833	138,472	138,472	15,361	140,448	-
Mar	117,787	100,780	100,780	17,007	172,887	-
Apr	109,203	94,241	94,241	14,962	180,840	-
May	16,685	3,698	3,698	12,987	227,447	-
Jun				11,072	232,650	-
Jul				12,059	300,080	-
Aug				15,770	333,157	-
Sep				20,049	336,930	-
Oct	17,179			24,738	330,088	-
Nov	60,522	35,984	35,984	24,538	251,460	-
Dec	153,630	133,840	133,840	19,790	178,684	-



[Figure 3.9-18] Water Balance of Kakoma Dam

4) Mwanza Barrage

Mwanza Barrage would store the water flowing from upstream by building barrage at the upper reach of Supuni canal. Mwanza River has a basin of 1,618km^2.

From water resources use perspective, it is fine to obtain water resources by constructing a barrage at the lower reach. However, as sediments have accumulated so much thereby raising the bed of the channel, the actual effective storage is not expected to be big. In such cases, effective management is only possible if the stream has adequate flows. As Mwanza River is generally dry in it is lower reach, the selected site is not ideal for the construction of a barrage.

At the same time, it discharges huge volumes of water for very periods during the rainy season, leading to frequent flooding in the lower reach. It also causes flooding in SVIP project area, as the cross sectional area of flow small. If a barrage were constructed, it would increase flood damage. All in all, the disadvantages of construction of the barrage would outweigh the advantages.

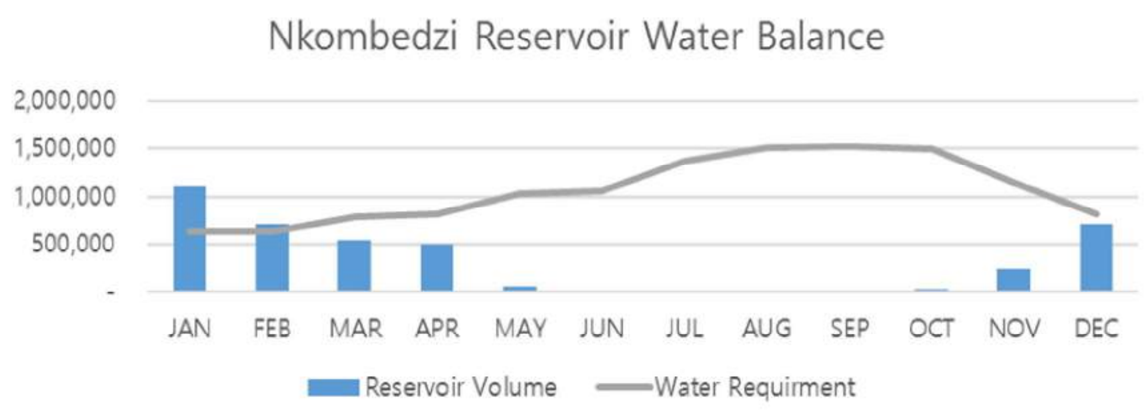
5) Nkombedzi Dam

Nkombedzi dam is located before at the Middle of Mkombedzi before it joins the Shire River. Its catchment area is 244.1km^2, length 112m, height 18m, irrigation area 500ha, and storage capacity 17,987,247 m^3. It is located to be able to supply water to Bangula Canal.

Table 3.9-11 and Figure 3.9-19 are the estimation result of water balance of Nkombedzi Reservoir. Storage capacity of dam becomes lowest during May to October while inflow between August to October reaches zero. Thus, even though water requirement of field is largest, dam is unable to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-11] Water Balance of Nkombedzi Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	1,143,088	1,106,048	1,106,048	37,040	633,950	-
Feb	748,022	716,297	716,297	31,725	638,400	-
Mar	572,746	537,622	537,622	35,124	785,850	-
Apr	531,006	50,0105	50,0105	30,901	822,000	-
May	81,134	54,312	54,312	26,822	1,033,850	-
Jun				22,867	1,057,500	-
Jul				24,906	1,364,000	-
Aug				32,570	1,514,350	-
Sep				41,408	1,531,500	-
Oct	83,537	32,447	32,447	51,090	1,500,400	-
Nov	294,292	243,614	243,614	50,678	1,143,000	-
Dec	747,033	706,161	706,161	40,872	812,200	-



[Figure 3.9-19] Water Balance of Nkombedzi Dam

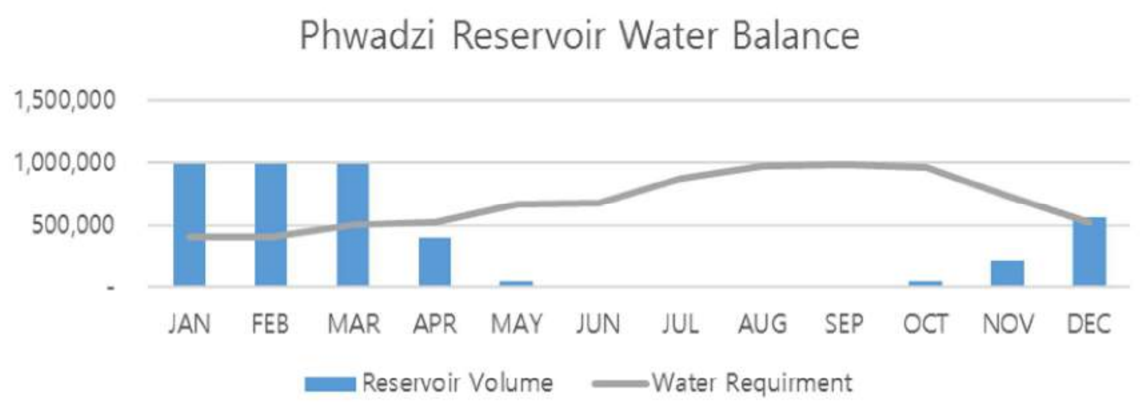
6) Phwadzi Dam

Phwadzi dam is located at the middle of Phwadzi River. Its catchment area is 188.4km^2, length 254m, height 7m, irrigation area 320ha, and storage capacity 988,892 m^3. It is located at a place where it could be able to supply water to Bangula Canal.

Table 3.9-12 and Figure 3.9-20 are the estimation result of water balance of Phwadzi Reservoir. Storage capacity of dam becomes lowest during June to October while inflow between August to October reaches zero. Thus, even though water requirement of field is largest, dam is unable to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-12] Water Balance of Phwadzi Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	882,252	870,396	835,300	11,856	405,728	-
Feb	577,335	567,181	835,300	10,154	408,576	-
Mar	442,053	430,811	835,300	11,242	502,944	-
Apr	409,838	399,947	835,300	9,891	526,080	-
May	62,620	54,035	54,035	8,585	661,664	-
Jun				7,319	676,800	-
Jul				7,972	872,960	-
Aug				10,425	969184	-
Sep				13,253	980,160	-
Oct	64,475	48,122	48,122	16,353	960,256	-
Nov	227,139	210,918	210,918	16,221	731,520	-
Dec	576,571	563,489	563,489	13,082	519,808	-



[Figure 3.9-20] Water Balance of Phwadzi Dam

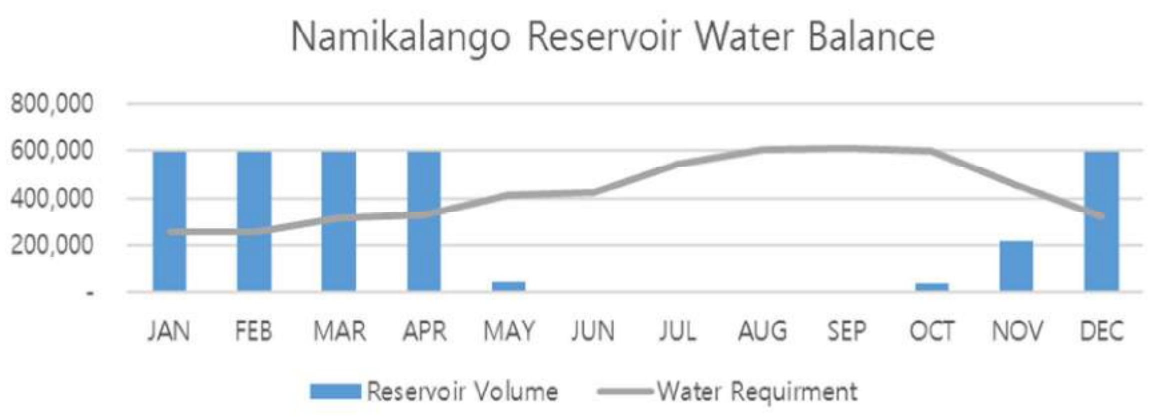
7) Namikalango Dam

Namikalango dam is located at the middle of Namikalango River. Its catchment area is 142.6km^2, length 294m, height 6m, irrigation area 200ha, and storage capacity 595,407 m^3. As it is located at the lower reach of Bangula Canal route, it is not possible to gravitate water to Bangula Canal. Instead it will be required to supply water directly from the dam to the lower reach.

Table 3.9-13 and Figure 3.9-21 are the estimation result of water balance of Namikalango Reservoir. Storage capacity of dam becomes lowest during June to October while inflow between August to October reaches zero. Thus, even though water requirement of field is largest, dam is unable to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-13] Water Balance of Namikalango Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	667,777	660,327	595,407	7,450	253,580	-
Feb	436,985	430,604	595,407	6,381	255,360	-
Mar	334,590	327,525	595,407	7,065	314,340	-
Apr	310,208	303,990	595,407	6,216	328,800	-
May	47,397	42,002	42,002	5,395	413.540	-
Jun				4,599	423,000	-
Jul				5,010	545,600	-
Aug				6,551	605,740	-
Sep				8,329	612,600	-
Oct	48,801	38,524	38,524	10,277	600,160	-
Nov	227,139	216,945	216,945	10,194	457,200	-
Dec	436,407	428,186	595,407	8,221	324,880	-



[Figure 3.9-21] Water Balance of Namikalango Dam

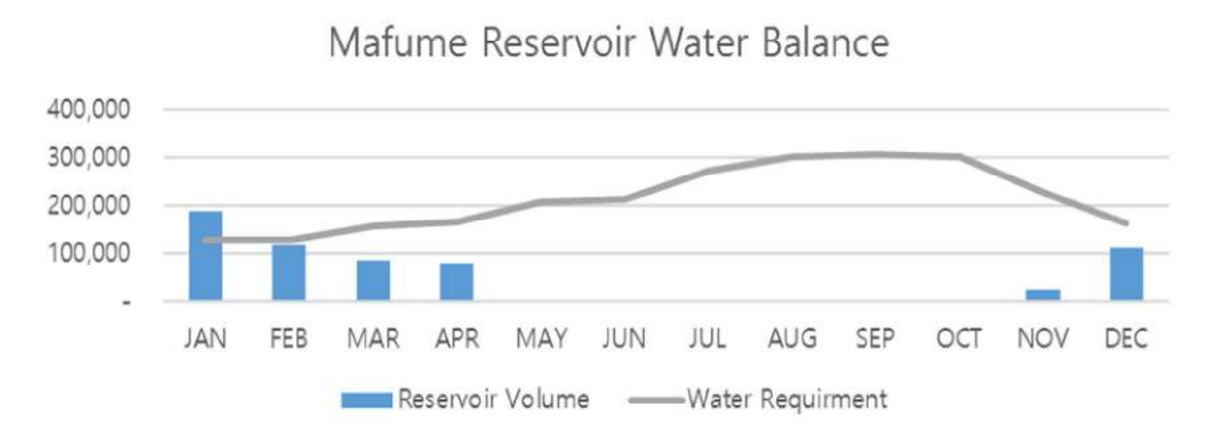
8) Mafume Dam

Mafume dam is located at the middle of Mafume River. Its catchment area is 44.8 km^2, length 106 m, height 8 m, irrigation area 100 ha, and storage capacity 2,308,582 m^3. It is located at a place where it could be able to supply water to Bangula Canal.

Table 3.9-14 and Figure 3.9-22 are the estimation result of water balance of Mafume Reservoir. Storage capacity of dam becomes lowest during May to November while inflow between August to October reaches zero. Thus, even though water requirement of field is largest, dam is unable to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-14] Water Balance of Mafume Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	209,792	186,597	186,597	23,195	126,790	-
Feb	137,285	117,418	117,418	19,867	127,680	-
Mar	105,116	83,120	83,120	21,996	157,170	-
Apr	97,456	78,105	78,105	19,351	164,400	-
May	14,890			16,797	206,770	-
Jun				14,320	211,500	-
Jul				15,597	272,800	-
Aug				20,396	302,870	-
Sep				25,931	306,300	-
Oct	15,331			31,994	300,080	-
Nov	54,011	22,275	22,275	31,736	228,600	-
Dec	137,104	111,509	111,509	25,595	162,440	-



[Figure 3.9-22] Water Balance of Mafume Dam

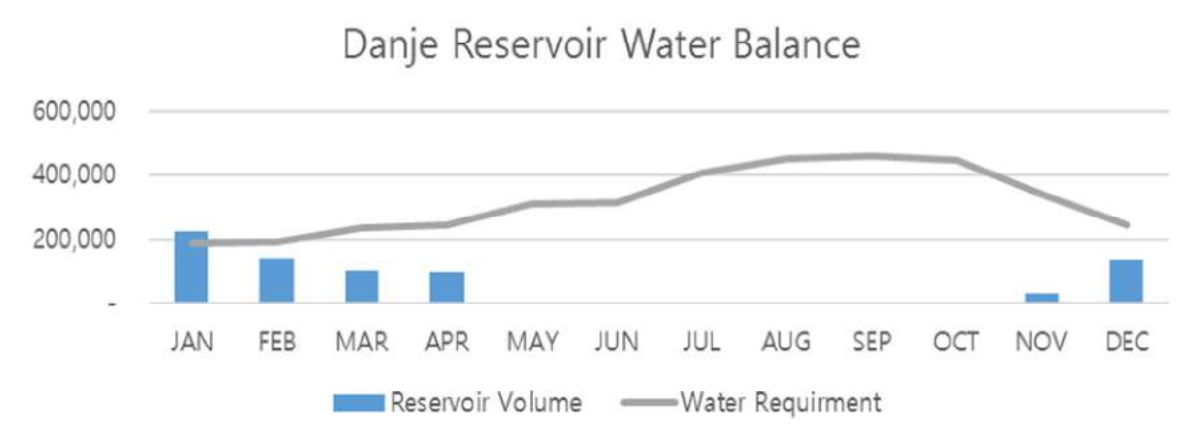
9) Dande Dam

Dande dam is located at the middle of Dande River. Its catchment area is 53.0 km^2, length 395 m, height 36 m, irrigation area 150 ha, and storage capacity 454,566 m^3. It is located at a place where it could supply water to irrigation area more favorably than to Bangula Canal.

Table 3.9-15 and Figure 3.9-23 are the estimation result of water balance of Dande Reservoir. Storage capacity of dam becomes lowest during June to October while inflow between August to October reaches zero. Thus, even though water requirement of field is largest, dam is unable to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-15] Water Balance of Dande Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	248,192	224,997	224,997	23,195	190,185	-
Feb	162,413	142,546	142,546	19,867	191,520	-
Mar	124,356	102,360	102,360	21,996	235,755	-
Apr	115,294	95,943	95,943	19,351	246,600	-
May	17,616	819	819	16,797	310,155	-
Jun				14,320	317,250	-
Jul				15,597	409,200	-
Aug				20,396	454,305	-
Sep				25,931	459,450	-
Oct	18,138			31,994	450,120	-
Nov	63,898	32,162	32,162	31,736	342,900	-
Dec	162,199	136,604	136,604	25,595	243,660	-



[Figure 3.9-23] Water Balance of Dande Dam

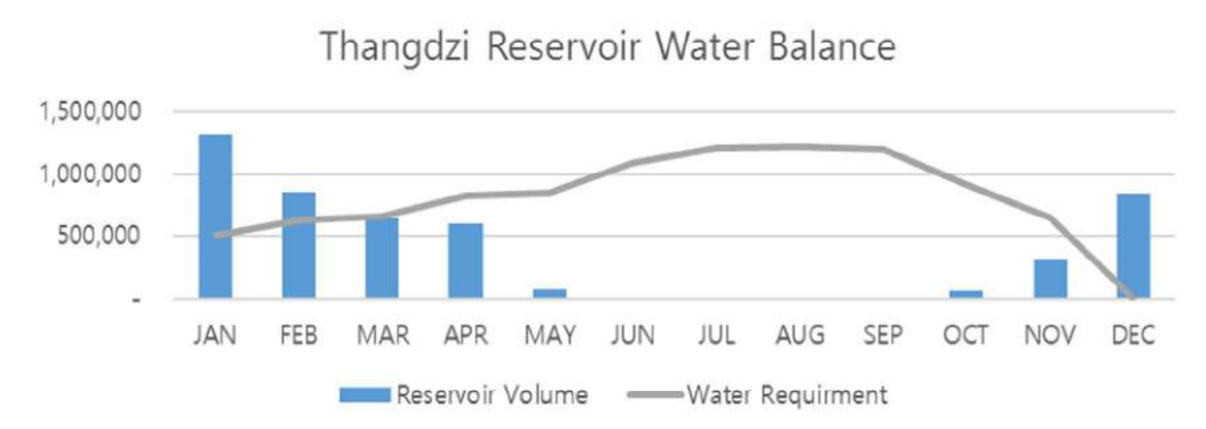
10) Thangadzi Dam

Thangadzi dam is located at the middle of Thangadzi River. Its catchment area is 307.6 km^2, length 395 m, height 17 m, irrigation area 400 ha, and storage capacity 8,658,287 m^3. It is located at a place where it could supply water to irrigation area more favorably than to Bangula Canal.

Table 3.9-16 and Figure 3.9-24 are the estimation result of water balance of Thangadzi Reservoir. Storage capacity of dam becomes lowest during May to October while inflow between August to October reaches zero. Thus, even though water requirement of field is largest, dam is unable to supply water. Detail calculation of water balance is described in Annex 6.

[Table 3.9-16] Water Balance of Thangadzi Dam

Division	Watershed Runoff (m^3)	Reservoir Volume (m^3)			Field Water Requirement (m^3)	Out Flow (m^3)
		Inflow	Total	Water Loss		
Jan	1,334,617	1,311,422	1,311,422	23,195	507,160	-
Feb	873,357	853,490	853,490	19,867	510,720	-
Mar	668,712	646,716	646,716	21,996	628,680	-
Apr	619,978	600,627	600,627	19,351	657,600	-
May	94,728	77,931	77,931	16,797	827,080	-
Jun				14,320	846,000	-
Jul				15,597	1,091,200	-
Aug				20,396	1,211,480	-
Sep				25,931	1,225,200	-
Oct	97,535	65,541	65,541	31,994	1,200,320	-
Nov	343,602	311,866	311,866	31,736	914,400	-
Dec	872,202	846,607	846,607	25,595	649,760	-



[Figure 3.9-24] Water Balance of Thangadzi Dam

3.9.1.5. Developability of Surface Water Resources in the SVIP Area

In case of the dam construction, the direct construction cost of irrigational area is the most important factor in conducting the economic viability of a dam. Table 3.9-17 shows the calculation result of direct construction cost of irrigational area of 9 dams. Unit construction costs of 9 dams vary widely, with Mkombedzi requiring lowest cost and Dande the highest. In case of the comparison between unit construction cost of dam and canal construction cost of SVIP, Nkombedzi dam and Dande dam are estimated at 2.3 and 33.6 respectively. It means that it is cheaper to supply water via SVIP water canal than to build supplementary dams. It is obvious for SVIP that there is no need to build additional head work for water resources.

[Table 3.9-17] Cost Analysis of Dam Construction

River	Catchment Area(km²)	Specification		Area (ha)	Cost		Rate
		Length(m)	Height(m)		(USD)	(2)(USD/ha)	(2)/(1)
Mwambezi	156.3	74	13	90	1,544,000	17,156	6.8
Nthumba	69.4	184	7	150	1,440,000	9,600	3.8
Kakoma	50.2	123	14	110	1,735,000	15,773	6.3
Nkombedzi	244.1	112	18	500	2,862,000	5,724	2.3
Phwadzi	188.4	254	7	320	2,403,000	7,509	3.0
Namikalango	142.6	294	6	200	2,186,000	10,930	4.3
Mafume	44.8	106	8	100	944,000	9,440	3.7
Dande	53.0	395	36	150	12,708,000	84,720	33.6
Thangadzi	307.6	142	17	400	3,495,000	8,738	3.5
# (1) Cost of SVIP(Intake & Canal)				43,370	107,000,000	2,518	1.0

Many factors are considered in order to determine the viability of dam construction including its economic viability. TFS qualitatively evaluated the viability from 3 perspectives; economic factor described above, capability of water provision to main canal by using gravity irrigation, and the length of branch canal from dam to canal. And the evaluation result is presented in Table 3.9-18.

[Table 3.9-18] Evaluation Summary of Other Water Resource Candidates

River	Economy	Possibility of Gravity Water Supplying	Connect Canal	Evaluation
Mwambezi	NG	VG	VG	NG
Nthumba	**G**	**VG**	**VG**	**G**
Kakoma	NG	VG	NG	NG
Nkombedzi	VG	VG	NG	NG
Phwadzi	**G**	**VG**	**G**	**G**
Namikalango	NG	NG	NG	NG
Mafume	G	VG	NG	NG
Dande	NG	VG	G	NG
Thangadzi	**G**	**VG**	**G**	**G**

※ Evaluation Criteria:
1) Economy = Ratio of unit cost of dam to unit cost of SVIP: below 3.0 (VG), 3.0~4.0 (G), above 4.0 (NG)
2) Possibility of gravity water supplying: above the main canal (VG), below the main canal (NG)
3) Connect canal: short than 1 km (VG), 1~3 km (G), longer than 3 km (NG)
4) Overall assessment: 1 NG: NG; 1 G: G; all VG: VG

Table 3.9-18 shows that Nthumba, Phwadz, and Thangadzi are most favorably located. However, it is only comparative evaluation result between candidate dams. In general, candidate areas cost more than SVIP, have no inflow during dry season so that storage run out of in a month from the end of rainy season. As a result, it is not valid to secure additional surface water resources with the supplementary dam.

3.9.1.6. Sediment

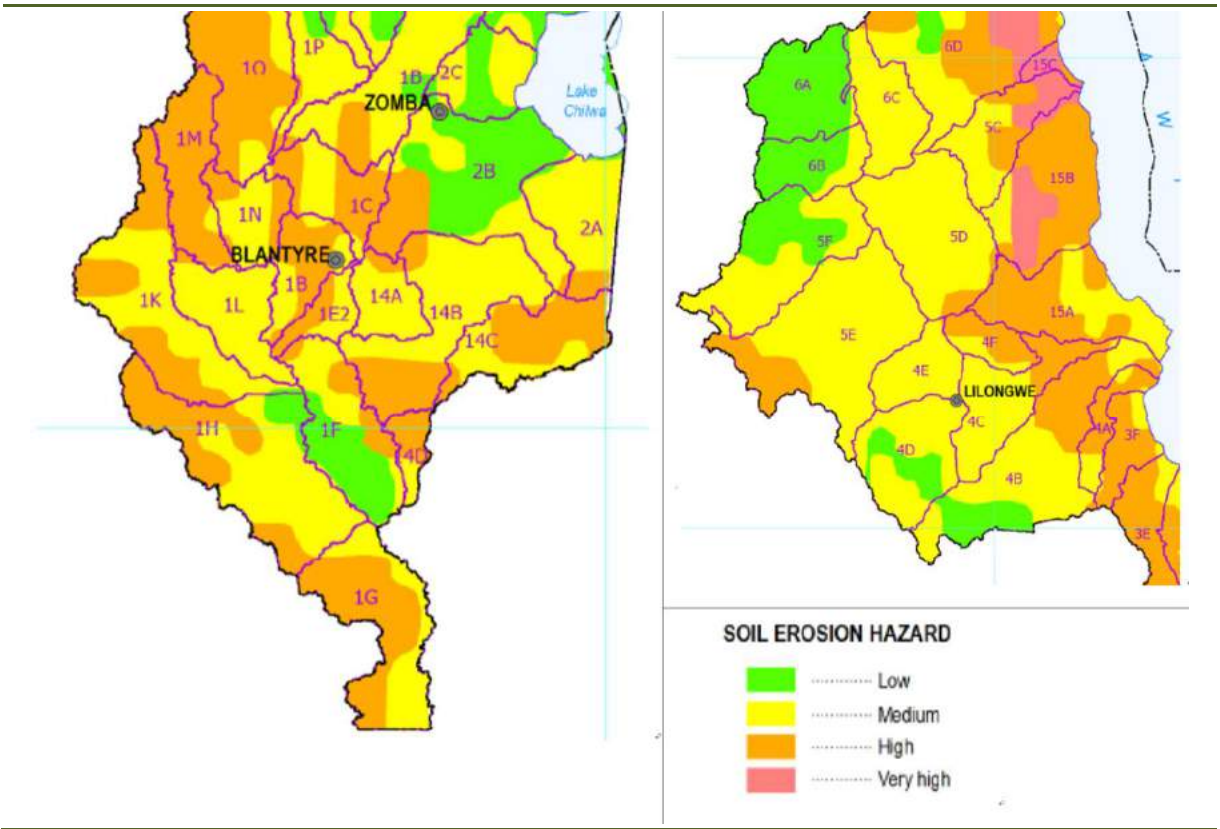
Storage volume of the reservoir is decreased by sediment inflow from the basin, and the extent of decrease in the storage volume is very different depending on the rainfall intensity, geographical features and geological condition as well as the vegetation type of basin.

The sediment volume is estimated by desktop analysis considering the slope, slope length, rainfall, land use and soil which seem to be related to produce sediment volume. Because the measurement data of sediment inflow is not in the SVIP basin, TFS reviewed the data “National Water Resources Master Plan (Part II. Chapter 6)(NWR Master Plan)”. According to the NWR Master Plan, the basin condition is as the following Table 3.9-19.

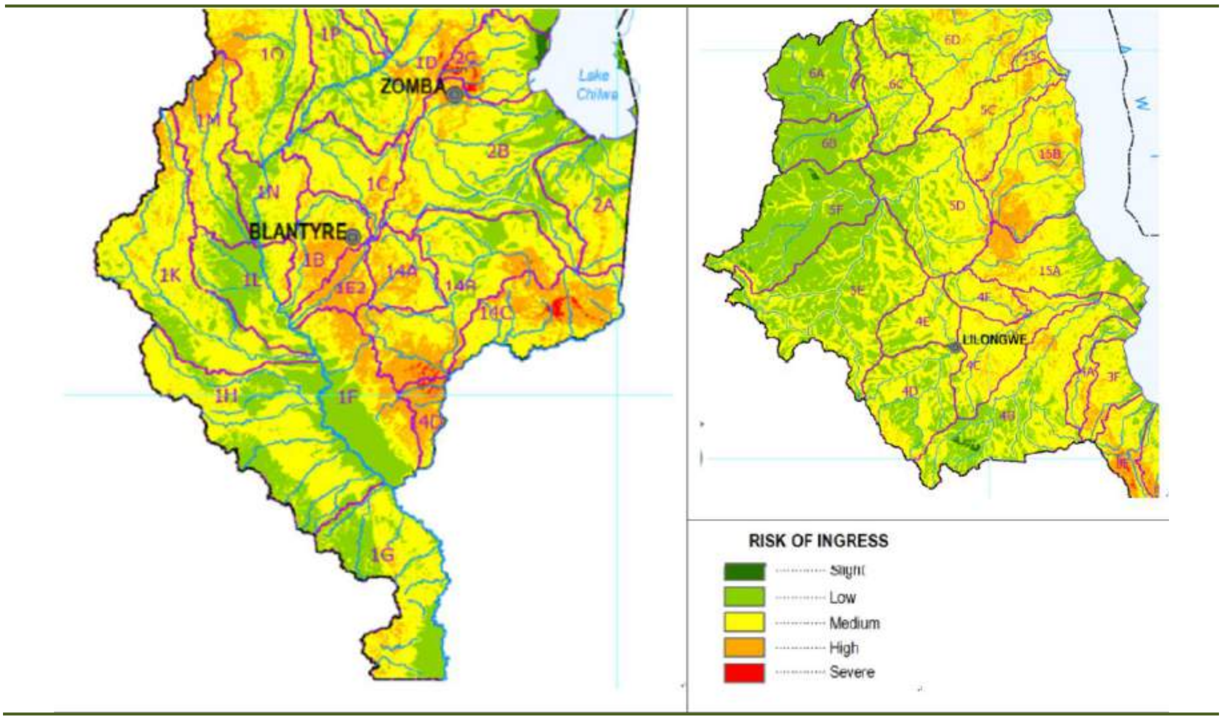
[Table 3.9-19] Sampling Sites (Stations) and Target Basins(NWR Master Plan)

Target Area			Represented WRU
Station	Catchment Area(km^2)	Coverage Ratio of Forest	
4E1	943	0%	4E
5F1	2,347	18%	5F
6C1	2,866	67%	6A & 6B
4D21	180	64%	4D

※ Source: National Water Resources Master Plan (Part II. Chapter 6)



[Figure 3.9-25] Soil Erosion Hazard Map, 1986 (NWR Master Plan)



[Figure 3.9-26] Risk of Sediment Ingress to Watercourses (NWR Master Plan)

Result of Survey (NWR Master Plan)

The survey result is summarized in Table 3.9-20. From the result below, it can be said that the volume of suspended sediment is inversely proportional to forest coverage ratio and its volume is bigger in the rainy season than in the dry season. In case that the above-mentioned finding is converted into an annual soil erosion rate, though the result only includes suspended sediment, converted soil erosion rate is very small in the order of 10^{-3} to 10^{-5} mm/year.

[Table 3.9-20] Survey Result on Suspended Sediment (NWR Master Plan)

Target Area			Severy Result		
Station	Catchment Area(km^2)	Coverage Ratio of Forest	Suspended Sediment(mg/l)	Discharge(m^3/s)	Estimated Volume of SS($g/sec/km^2$)
4E1 (4E)	943	0%	32	4.92	0.167
			30	0.64	0.020
5F1 (5F)	2,347	18%	1	18.75	0.008
			< 0.10	0.89	NA
6C1 (6A&6B)	2,866	67%	11	0.77	0.003
			(4.7)	0	NA
4D21 (4D)	180	64%	To be measured	Ditto	To be estimated
			< 0.10	0.35	NA

※ ( ) : Repersented WRU

The survey regarding sediment runoff was conducted in the feasibility study for the stabilization of the course of the Songwe River, 2003. In the survey, suspended sediment and discharge that are the same items as the survey in the Project were measured in five sites in the Songwe River basin. One site is in the upper stream of the Songwe River, three sites are in the lower stream of the Songwe River, and one site is in the Kyungu River, a tributary of Songwe River. The measurement was conducted once or twice a month from December 2002 to June 2003.

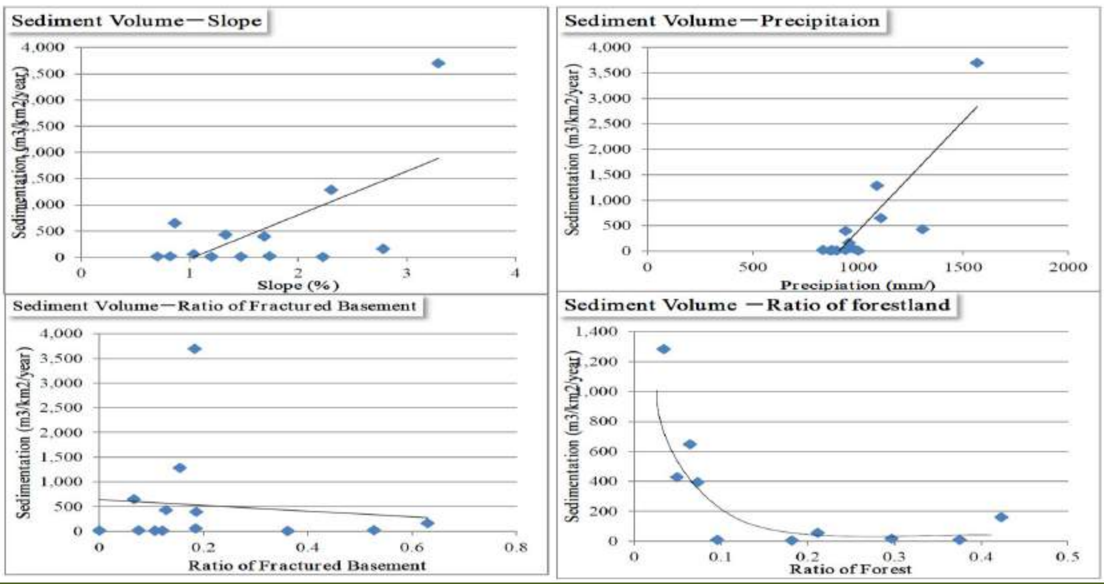
From the above survey, the result of Mwandenga site, which is located in the lower stream of the Songwe River and is a site of existing gauging station of 9B7 with a catchment area of 3,864km^2 including area in Tanzania, is summarized in Table 3.9-21.

[Table 3.9-21] Songwe River of Suspended Sediment (NWR Master Plan)

Station	Catchment Area(km^2)	Suspended Sediment(mg/l)	Discharge(m^3/s)	Estimated Volume of SS(g/sec/ km^2)	Remark
9B7	3,864	2,855	68.5	50.613	Dec
		2,650	165.1	113.229	Feb
		1,089	37.7	10.625	Mar
		3,670	57.7	54.803	
		346	32.7	2.928	Apr
		94	24.1	0.586	
		235	28.5	1.733	May

Assessment of Sediment Volume (NWR Master Plan)

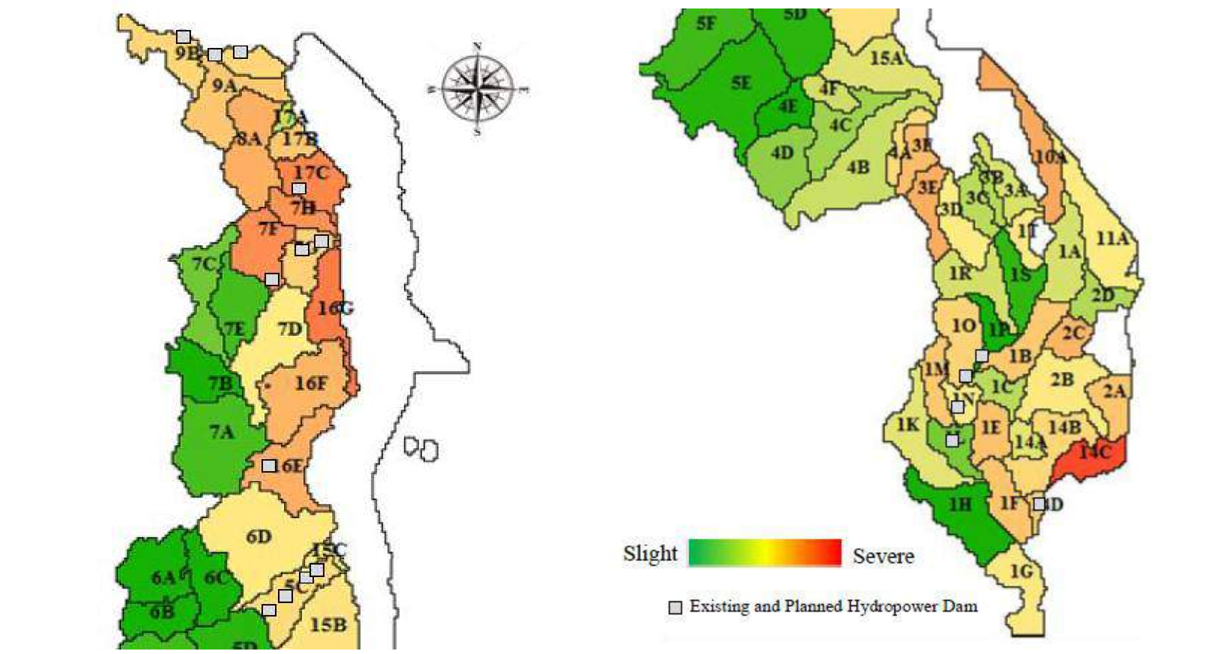
The sediment volume is estimated by desktop analysis considering slope, slope length, precipitation, land use and soil which seem to be related to produce sediment volume. There is some degree of correlation between sediment volume and other factors shown in Figure 3.9-27. Considering the correlation, the sediment yield in Malawi is estimated by WRU and shown in Figure 3.9-28. There are relatively severe sediment volumes in the northern and southern regions and along Lake Malawi because of the steep slope and severe precipitation. On the other hand, there are relatively slight sediment volumes in the central region because there is a gentle slope and sediment is considered to be caught by dambos. Among the factors related to sediment volume, only the ratio of forest is changed by mainly human activities. Therefore, forest land should be conserved to control sediment in the watershed. However, since this is the only desktop analysis under the limited data, a field survey is required for more appropriate findings.



[Figure 3.9-27] Relationship between Factors and Sediment Volume(NWR Master Plan)

[Table 3.9-22] Relationship between Factors and Sediment Volume

Sediment ($m^3/km^2/year$)	Slope (%)	Rainfall (mm)	Basement (%)	Forest (%)
3,700	3.40%	1700	18%	
1,280	2.30%	1150	15%	4%
650	0.80%	1150	8%	7%
420	1.30%	1300	12%	6%
390	1.60%	950	18%	8%
180	2.80%	1000	63%	43%
90	0.70%	800	52%	22%
0	0.80%	870	38%	37%
50	1.05%	810	19%	30%
0	1.20%	880	12%	18%
0	1.45%	900	10%	11%
0	1.75%	820	8%	
0	2.20%	1100	0%	
AVE. 516 $m^3/km^2/year$	1.6%	1,033	21%	15%



[Figure 3.9-28] Estimated Sediment Yields in Malawi(NWR Master Plan)

As the Figure 3.9-27, the sedimentation is most affected by the factor such as the slope, rainfall and ratio of forest. And, Chikwawa 1H region is reviewed the slight sediment yield that is the estimated sediment yields by the NWR Master Plan (see the Figure 3.9-28).

According to the Figure 3.9-25, there is not a similar station with the Chikwawa 1H among the WRU 4E, 5F, 6A, 6B and 4D region. Therefore, TFS is analyzed using the average sediment of 516 $m^3/km^2/year$ by the using of the Table 3.9-19.

[Table 3.9-23] Sediment Inflow into the Dam

River	Catchment Area(km^2)	1) Storage Capacity(m^3)	2) Sediment		2) / 1)
			m^3/km^2/year	m^3/year	
Mwambezi	156.3	275,100	516	80,651	29.3%
Nthumba	69.4	918,328	516	35,810	3.9%
Kakoma	50.2	771,600	516	25,903	3.3%
Nkombedzi	244.1	17,987,247	516	125,955	0.7%
Phwadzi	188.4	988,892	516	97,214	9.8%
Namikalango	142.6	595,407	516	73,581	12.3%
Mafume	44.8	2,308,582	516	23,116	1.0%
Danje	53.0	454,566	516	27,348	6.0%
Thangdzi	307.6	8,658,287	516	158,721	1.8%

Generally, according to the international data, the sediment has a large range of 10m^3/km^2/year ~ 3,000m^3/km^2/year per the basin of 1km2. Also, when the water level of reservoir is the lowest in 10 years return period of drought, the sediment is dredged.

The reservoir storage is decided to assume the sediment inflow that is 7% of the total storage volume. Mostly, because it is considered the sediment inflow that the dead storage capacity of the 10% below the dead storage water level is secured.

3.9.2. Ground Water Resources

Ground water resources investigation was implemented by hydro-geologists of KRC and Malawian experts. The results of hydro-geological survey are described in the Chapter 2.4.

3.10. With / Without Maintaining Current Pumping System

TOR Requirements

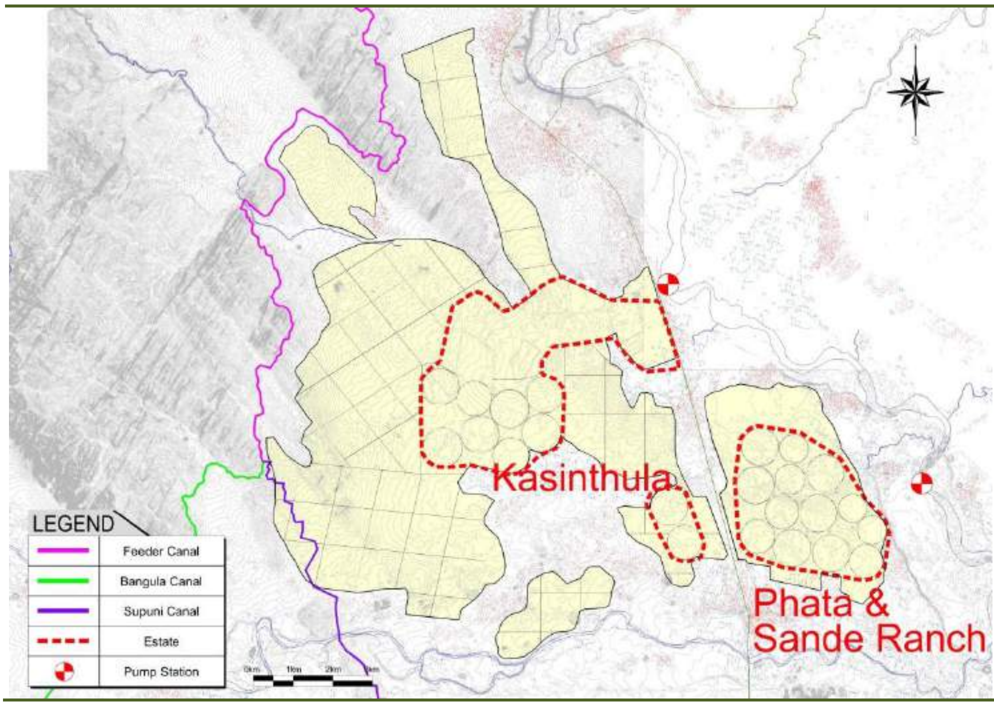
The Consultant shall carry out technical, financial and economic assessment of options for maintaining current pump based systems for use in times of peak demand/water scarcity, and their impacts on scheme design, construction and operations cost, as well as on other uses (mainly hydropower).

3.10.1. Current Pumping Systems

Large estates located within SVIP area are equipped with pumping stations which are sufficient for irrigation. An agricultural estate like Phata has a plan to install additional pumping station to extend its estate.

3.10.1.1. Kasinthula Association and Sande Ranch

Kasinthula (1,429 ha) and Sande Ranch (750 ha) are located in Zone I-1 and pumps water for agriculture from Shire River.



[Figure 3.10-1] Location of Kasinthula Association, Sande Ranch and Pump Station

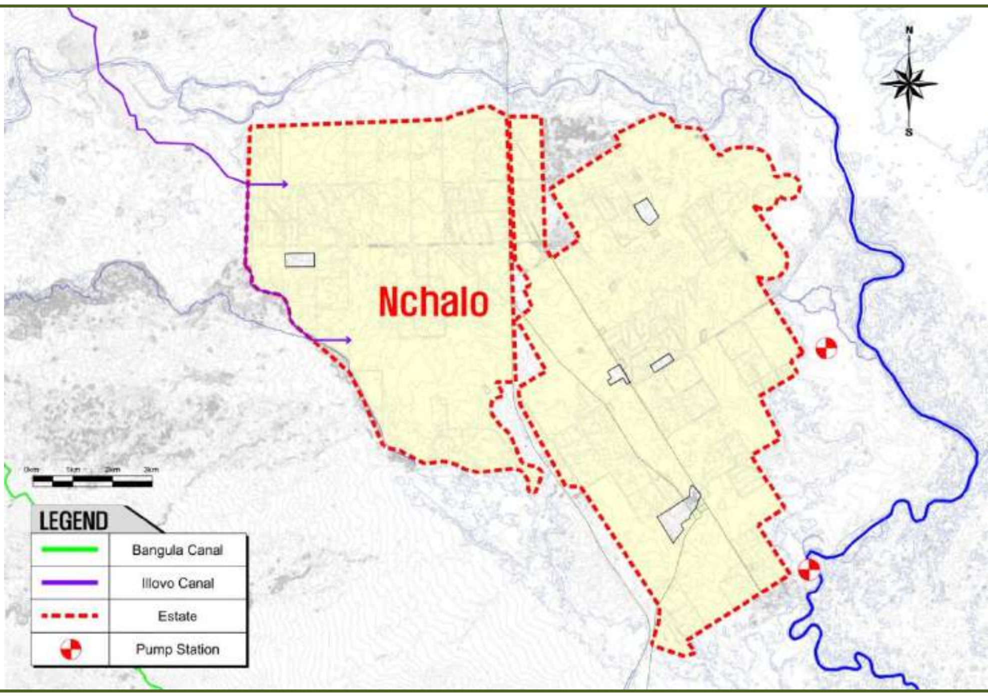
[Figure 3.10-2] First Pump Station of Kasinthula (Intake from Shire River)

[Figure 3.10-3] Sand Trap of First Pump Station of Kasinthula

[Figure 3.10-4] Lined Canal and Second Pump Station of Kasinthula

3.10.1.2. Nchalo Estate

Nchalo estate (9,995 ha) of Illovo is located in Zone I-2 and pumps water for agriculture from Shire river.

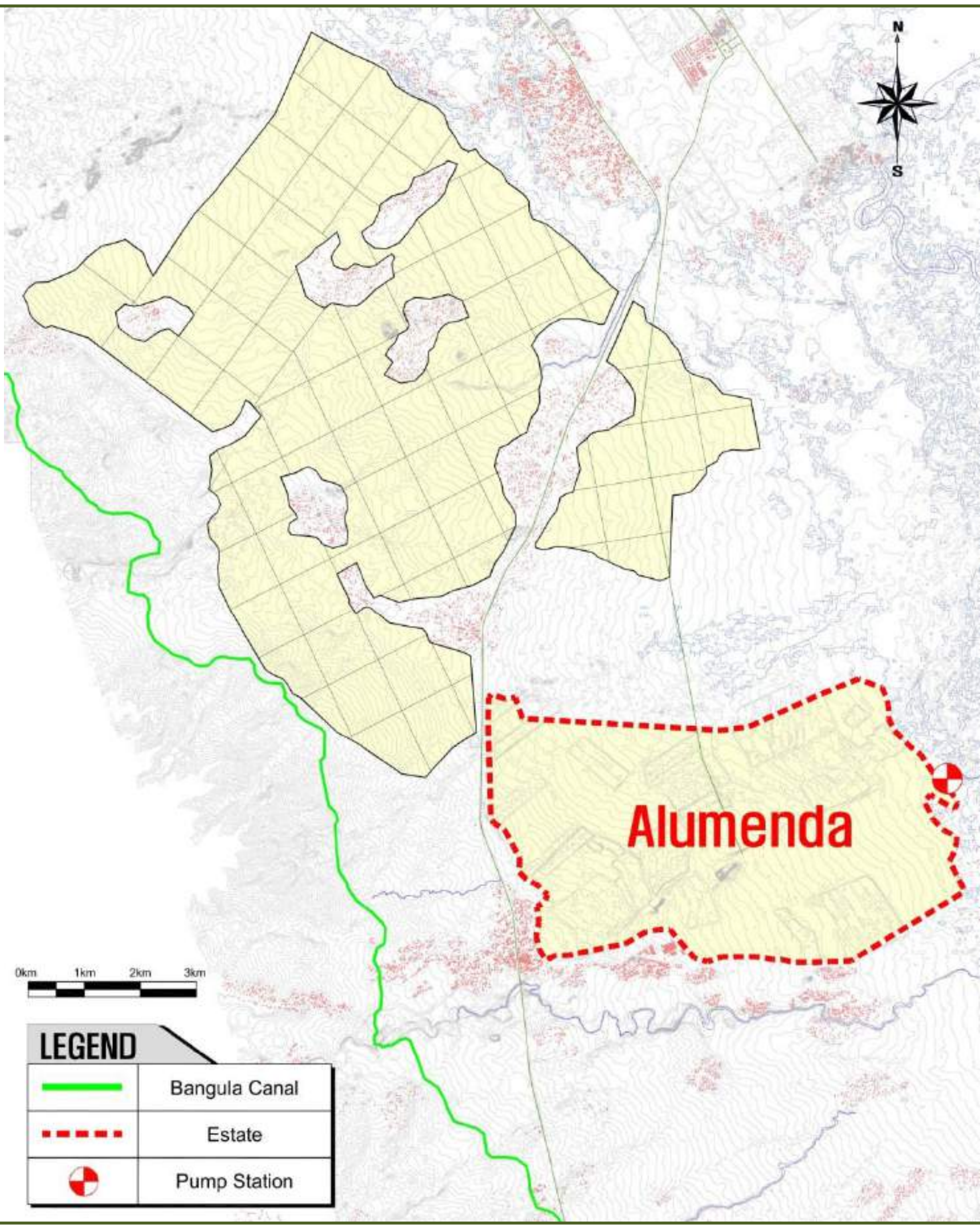


[Figure 3.10-5] Location of Nchalo Estate and Pump Station

[Figure 3.10-6] First Pump Station (M1) of Nchalo (Intake from Shire River)

3.10.1.3. Alumenda Estate

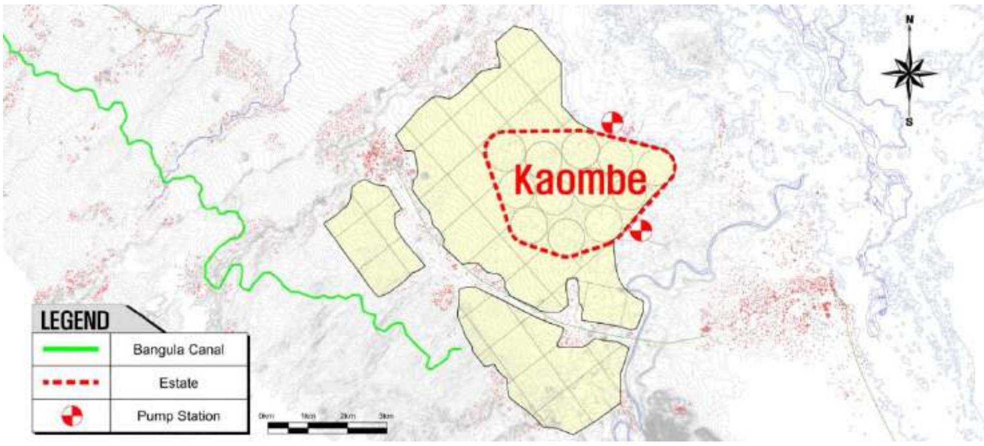
In zone B, Alumenda Estate (2,764 ha) pumps the irrigation water from Shire River.



[Figure 3.10-7] Location of Alumenda Estate and Pump Station

3.10.1.4. Kaombe Estate

In zone D, Kaombe Estate (819 ha) pumps irrigation water from Shire river.



[Figure 3.10-8] Location of Kaombe Estate and Pump Station

3.10.1.5. Pumped Water of Estates

Table 3.10-1 shows the monthly pumping water volume for all Estates (Nchalo, Alumenda, Sande & Kaombe) from the Shire river during 2008~2015.

[Table 3.10-1] Pumped Water Amount for the Whole Estates

Mon	08~09	09~10	10~11	11~12	12~13	14~15	Average
Jan	11,239,009	37,986,606	20,876,722	13,699,259	14,814,830	906,523	16,587,158
Feb	25,695,040	22,845,622	23,838,282	33,419,944	4,257,828	4,919,532	19,162,708
Mar	28,133,784	22,235,749	27,764,611	25,344,056	25,608,839	15,866,645	24,158,947
Apr	26,295,544	21,581,341	26,097,865	26,268,754	22,437,570	21,090,144	23,961,870
May	24,781,226	20,053,699	22,216,887	24,225,598	27,803,012	21,832,519	23,485,490
Jun	18,736,653	19,731,690	19,967,574	27,605,481	25,012,199	20,466,221	21,919,970
Jul	19,389,889	17,616,233	18,924,750	19,493,666	22,318,207	20,719,177	19,743,654
Aug	20,049,897	23,306,980	17,213,190	23,753,577	22,692,915	23,487,176	21,750,623
Sep	24,478,784	31,079,287	27,352,645	29,947,608	26,252,706	23,973,404	27,180,739
Oct	33,849,907	19,742,929	32,812,689	30,431,117	34,217,584	29,431,530	30,080,959
Nov	36,058,594	32,409,216	33,251,484	36,454,296	35,198,680	29,866,768	33,873,173
Dec	25,505,082	29,828,225	20,047,833	36,274,931	28,213,991	30,976,475	28,474,423

3.10.1.6. Electric Power Consumption

Table 3.10-2 shows the amount of electricity used for pumping agricultural water by Nchalo, Alumenda, Sande Ranch and Kaombe estate, all of which belong to Illovo..

[Table 3.10-2] Amount of Electricity Used at Nchalo, Alumenda, Sande Ranch and Kaombe

Division	Total Power Used at Illovo	
	2013~2014 (kWh)	2014~2015 (kWh)
April	9,045,486	7,928,224
May	8,029,816	6,872,879
June	5,879,581	5,694,752
July	5,764,472	6,374,136
August	6,673,517	7,329,560
September	6,953,463	7,747,074
October	9,148,317	8,822,189
November	9,622,275	8,729,932
December	7,668,330	9,616,679
January	5,732,599	2,460,860
February	4,034,110	3,055,129
March	7,894,261	5,716,756
Total	**86,446,227**	**80,348,170**
Average	**7,203,852**	**6,695,681**
MWh (GWh)	**86,446 (86.45)**	**80,348 (80.35)**

3.10.2. Technical Aspects

3.10.2.1. Water Resource Availability

Table 3.10-3 shows the exceedance probability data of Shire river discharge at Kapichira dam, which were published on the report of WRIS. For example, Q80 indicates the discharge of Shire river which will occur over 80% annually. According to the this report, Q80 is 326m^3/s, which is greater than 319.4m^3/s, the water demand for both of Electricity (269.2m^3/s) and Irrigation (50.0m^3/s). It means that the Shire river runoff has the potential to satisfy the water demand in 80% of probability.

[Table 3.10-3] Exceedance Probability Discharge at Kapichira Dam (unit: m^3/s)

Division	Q mean	Q max	Q50	Q75	Q80	Q95	Q min
WRIS	537	1,269	530	371	326	202	161
Water Demand	for Electricity(269.2) and Irrigation(50.0) = 319.4m^3/s						

※ Water Resources Investment Strategy (April 2011)

According to the discharge statistics of Shire river at Kapichira dam of Table 3.10-3, the probability of supplying irrigation water is as shown in Table 3.10-4. As Table 3.10-4 shows, the water demand for ESCOM exceeds the water requirement for irrigation, as such the probability of supplying to the project might vary greatly depending on how many turbines are operational. As the demand of electricity will continue to increase in the future, power supply in dry season will also increase. As a result, water requirement for irrigation in dry season will not be met quite often. In this case, the existing pumping facilities need to be used. In respect of the availability of water resources, it seems to be necessary to maintain the existing pumping facilities.

[Table 3.10-4] Probability of Water Supplying as the Discharge of Shire River

Classification	ESCOM I (m^3/s)	ESCOM II (m^3/s)	SVIP (m^3/s)	Probability of Water Supplying for SVIP (%)
Case I	134.6	134.6	50.0	80
Case II	134.6	67.3	50.0	88
Case III	134.6	0.0	50.0	97

3.10.2.2. Economical Aspects

In terms of the economic aspect, TFS was reviewed broadly as to whether existing pumping stations should be kept or not. It was possible to get the related information of costs during the field survey, therefore it was reviewed using secondary information.

According to the report of Illovo, Kasinthula Estate Plan Report(National and Shire Irrigation Study, Second Interim Report, 1980), the direct construction cost of irrigation facilities for 7,400ha was about 4.75 million GBP in 1969. Generally, the construction cost of pumping facilities takes about 40% of total construction cost in the irrigation project that the pumping station is used for water resource. Thus, it is estimated that the construction cost of pumping facilities was about 1.9 million GBP. At the time, the ratio of GBP to USD was 2.4, the cost was equivalent to 4.56 million USD.

The correct inflation data are required to convert the past value of the currency into the present one. Using a rough estimation, TFS applied 1% inflation as a matter of convenience, and the amount came to 7.82 million USD. Commonly, the yearly O&M cost of machinery facilities is determined about 2% of the machinery facility cost. But, in this case, TFS decided that the O&M ratio was 0.5% for maintaining equipment condition without the operation of equipment. Therefore, the yearly O&M cost was estimated to be 39,100 USD. In consideration of the cost about the irrigation area of 7,400ha, the yearly O&M cost per ha was estimated to be 5.3 USD.

Because it was also was difficult to get the relevant data of Estate profit, TFS reviewed the profit by a secondary information. According to the manager of Kasinthula Association, the yearly net income per ha is about 1,000 USD. In the case of Illovo Estate case, it is expected to be much higher

SVIP Project is designed at a frequency of irrigation water requirement of 5 years. Thus, it is assumed that drought episodes cause crop damage once in every 5 years in theory. The drought of such a magnitude decrease income by about 30%, equivalent about 300 USD decrease. In this case, the O&M cost during 5 years is estimated to be about 26.5 USD. Therefore, the O&M activities are estimated to cost less than 273.5 USD

According to the above process, TFS recommended retaining the pumping station which could be operated when drought is expected once in 5 years.

CHAPTER 4. FINANCIAL ASSESSMENT OF ILLOVO ESTATE PARTICIPATION

TOR Requirements

Illovo Estate participation in the project funding is a major element impacting the design and profitability of the project. The Consultant shall estimate, based on previous studies, the part of the project cost that is linked to Illovo estate water supply, and based on the expected savings and other advantages that Illovo would benefit from the scheme, estimate, in close collaboration with the PPP advisor, the level of financial participation that should be acceptable by the company. The Consultant shall assist the DoI during negotiations with Illovo, in particular by refining its financial assessment based on information given by Illovo Estate during negotiations.

4.1. Benefit of Illovo Estates

These are basically foregone costs which Illovo get by switching to SVIP. The benefits accrue from costs associated with use of ESCOM power for irrigation and O&M costs for the pumping station.

4.1.1. Estimation of Electricity Cost of Illovo Estates

If the water is supplied by gravity from SVIP, the most important benefit which Illovo Sugar Estate would gain from closing down its pumping station is a reduction in cost of electricity. Presented in Table 4.1-1 is the amount of power used by Illovo during the period 2013-2014 and 2014-2015.

[Table 4.1-1] Electricity Consumption of Illovo Estates (Nchalo + Alumenda + Sande + Kaombe)

Month	’13 ~ ‘14	’14 ~ ‘15
April	9,045,486	7,928,224
May	8,029,816	6,872,879
June	5,879,581	5,694,752
July	5,764,472	6,374,136
August	6,673,517	7,329,560
September	6,953,463	7,747,074
October	9,148,317	8,822,189
November	9,622,275	8,729,932
December	7,668,330	9,616,679
January	5,732,599	2,460,860
February	4,034,110	3,055,129
March	7,894,261	5,716,756
Total KwHrs	**86,446,227**	**80,348,170**
Average KwHrs	**7,203,852**	**6,695,681**
Mwhrs	**86,446**	**80,348**
Gwhrs	**86.45**	**80.35**

※ Illovo Estate provided

Since it was difficult to get detailed power usage fees for Illovo, current electricity tariffs by ESCOM were applied to estimate the power usage. Presented in Table 4.1-2 are current electricity tariffs by ESCOM as of February 2016.

[Table 4.1-2] Standard Electric Charges of ESCOM (Feb., 2016)

Tariff Code	Description	Type of Charge per Month	Rate(MK)	Rate(USD)
ET1	Domestic, Prepaid, Single Phase Supply	Unit charge per KWh	41.35	0.062
ET2	Domestic, Postpaid, Single Phase Supply	Fixed Charge	2795.75	4.173
		Unit charge per KWh	35.79	0.053
ET3	Domestic, Prepaid, Three Phase Supply	Unit charge per KWh	64.04	0.096
ET4	Domestic, Postpaid, Three Phase Supply	Fixed Charge	7987.84	11.922
		Unit charge per KWh	57.37	0.086
ET5	General, Prepaid, Single Phase Supply	Unit charge per KWh	71.17	0.106
ET6	General, Postpaid, Single Phase Supply	Fixed Charge	5591.48	8.345
		Unit charge per KWh	85.41	0.127
ET7	General, Prepaid, Three Phase Supply	Unit charge per KWh	74.71	0.112
ET8	General, Postpaid, Three Phase Supply	Fixed Charge	7987.84	11.922
		Unit charge per KWh	71.18	0.106
ET9	Maximum Demand - Low Voltage Supply (Large power for industrial users, supplied at three phase supply and metered at 400 Volts)	Fixed Charge per Month	27950	41.716
		On peak Unit charge per KWh	78.48	0.117
		Off peak Unit charge per KWh	21.5	0.032
		Capacity Charge per KVA based on the customers annual declared demand	3306.97	4.936
		Demand Charge per kVA based on actual monthly demand reading	5351.39	7.987
ET10	Maximum Demand - Low Voltage Supply (Large power for industrial users, supplied at three phase supply and metered at 11kV or 33kV)	Fixed Charge per Month	27950	41.716
		On peak Unit charge per KWh	69.88	0.104
		Off peak Unit charge per KWh	19.35	0.029
		Capacity Charge per KVA based on the customers annual declared demand	2996.72	4.473
		Demand Charge per kVA based on actual monthly demand reading	5074.75	7.574
ET11	Public Service, Prepaid, Three Phase Supply, High Current Metering	Unit charge per KWh	85.69	0.128

※ Cited from ESCOM internet homepage
1) Off peak hrs is from Monday to Friday from 00:00hr to 7:00hr, from 12:00hr to 17:00hr and from 20:00hr to 24:00hr
2) On peak Hrs are from Monday to Friday from 7:00 hr to 12:00hs and from 17:00 hr to 20:00hr
3) All Saturday, Sundays and Public holidays are Off peak hours

ET9 was applied for the Tariff code, and selected "On peak Unit charge per KWh" and "Off peak Unit charge per KWh" for the Type of Charge per month. "On peak Unit charge per KWh" was applied for 5 days during the week, and 8 hours in a day. This means that it was applied for 40 hours (24%) in a week. For the remaining 128 hours (76%), the "Off peak Unit charge per KWh" was used. Because detailed information on the running time of the pump station was not available, "On peak Unit charge per KWh" was applied on 24% of total power consumption and "Off peak Unit charge per KWh" was applied on 76% of the total power consumption. Presented in Table 4.1-3 is the estimated power fee for Illovo Sugar Estate.

[Table 4.1-3] Estimation of Electricity Charges of Illovo Estates

Division	'13 ~ '14	'14 ~ '15	Unit
Total Amount	86,446,227	80,348,170	KwHrs
On peak Unit charge	2,427,410	2,256,177	USD
Off peak Unit charge	2,102,372	1,954,067	USD
Total Charges	**4,529,782**	**4,210,244**	**USD**

4.1.2. Estimation of O&M cost of Illovo Estates

According to the planning report of Kasinthula (National and Shire Irrigation Study, Second Interim Report, 1980), the direct cost of irrigation for a 7,400 ha area in 1969 was 4.75 million pounds (detailed cost was not presented in the report). In general, in the irrigation project area where pumping is the only water resource, the percentage of the construction costs related to pumping facilities is about 40% or so of the total direct cost. Therefore, the construction costs related to pumping facilities are estimated to have been approximately 1.9 million pounds. At that time, the exchange rate was 2.4 dollars to the pound. With this exchange rate the equivalent pump construction cost was about 4.56 million US dollars.

Correct inflation data are needed to translate the past into the present value of the currency. However, for purpose of rough estimation, we apply a 1% inflation rate on each year. With this adjustment the construction cost for the pump facilities is approximately 7.82 million USD. Yearly O&M costs for use of mechanical facilities are about 2% of the facility possession. Applying this rate, the yearly O&M costs are approximately 156,400 USD for 7,400 ha, or 21.1 USD per ha.

Total area of Illovo Estates (Nachalo + Alumenda + Sande + Kaombo) is 14,032 ha. Thus, the yearly O&M costs for the pumping stations for the 14,032 ha are estimated at 296,075 USD.

4.1.3. Marginal Benefit of Illovo Estates

The above analysis therefore shows that if Illovo Estate is included in the SVIP, the Estate would benefit from foregone cost of electricity and the O & M costs for the pump stations. The combined marginal benefit is 4,666,088 USD.

4.2. Capital Cost due to the Inclusion of Illovo Estates in the SVIP

4.2.1. Intake Facilities and Feeder Canal

With Illovo estate included, intake structure and feeder canal would have to be designed in such a way that they meet the above water requirement of 50.0m^3/s in which the water requirement of 14.7 m^3/s for Illovo estate was included. The total construction cost of intake structure and the Feeder canal was estimated to 37,100,000 USD. If Illovo estate is included in the project area, this cost should be allocated in proportion to the amount of water between the government and Illovo. In accordance with such criteria, the amount of expenses which is responsible for Illovo is 11,130,000 USD. Table 4.2-1 shows the details of the allocation.

[Table 4.2-1] Allocation of Construction Cost of Intake Structure and the Feeder Canal

Division	With Illovo (Q=50.0m^3/s)	Illovo (Q=14.7m^3/s)
Total Cost (thou. USD)	**37,100**	**11,130**
Intake (thou. USD)	4,000 (B=36m)	
Feeder Canal (thou. USD)	33,100	

※ The estimated cost is direct construction cost.

4.2.2. Main Canal for Illovo Estate

With Illovo Sugar Estate included, a dedicated waterway would have to be constructed to supply Illovo with water from the feeder canal. This conveyance system would either be an open channel or a pipeline. In case of an open channel, the length of the canal would be 11~12 km, while the length would be 9~10km for pipeline. Table 4.2-2 shows required specifications and estimated cost for each case.

[Table 4.2-2] Specification and Preliminary Cost of the Canal for only Illovo Estate

Division	Lining Canal	Concrete Canal	Pipe
Total (thou. USD)	5,900	16,700	34,600
Earth (thou. USD)	656	695	12,500
Structure (thou. USD)	5,244	16,005	22,100
Specification	b=3.6m B=8.4m H=1.6m L=11.5km	b=6.7m B=6.7m H=1.6m L=11.5km	D1,900mm@2 L=9.6km

※ The estimated preliminary cost is direct construction cost.

With Illovo estate excluded, such a dedicated waterway would not be built, hence the project cost would be reduced.

4.2.3. Capital Marginal cost of Inclusion of Illovo Estates in the SVIP

Adding scale-up marginal costs for Intake and Feeder canal and the lining marginal cost for Illovo canal gives a total construction marginal cost of 17,030,000 USD. The marginal cost for pipe canal is 45,730,000 USD.

4.3. Cost Recovery from Illovo Estates

4.3.1. Cost Recovery of Capital Cost with O&M Cost

Illovo has expressed the intention of long-term installment payment against the capital cost to be invested for its inclusion. In this case, the cost recovery shall be implemented for the 30 year life time of the project.

Open Canal

The capital cost for open canal was estimated at 17,030,000 USD. This amount was supposed to be invested evenly for three years as follows: 6,000,000 USD (1st year); 6,000,000 USD (2nd year); 5,030,000 USD (3rd year).

After completion of the SVIP, a separately dedicated organization will be configured to operate the canal and irrigation systems. In general, the annual operating costs to manage the irrigation system are around 1% to 1.5% of the total Capital Cost. For the open canal system, applying 1.5% of the capital cost, gives an annual O&M of 255,450 USD.

Pipe Canal

The capital cost for a pipe canal was estimated at 45,730,000 USD. The construction period could be shorter than that of an open canal. As such, most of the construction cost would be invested in the first two years as follows: 16,000,000 USD (1st years), 16,000,000 USD (2nd year), 13,730,000 USD (3rd year).

For the pipe canal system, applying 1.5% of the capital cost, the annual O&M is 685,950 USD.

4.3.2. Water Pricing for Illovo Estates

After an irrigation project is finished and the water supply stage is entered, one of the most important steps is to make a decision regarding the appropriate water charges. There are frequently large differences in charges and charging mechanisms within a single country reflecting different objectives, different water sources, different degrees of water scarcity and irrigation schemes with different technologies, farm types or socio-economic objectives. Statements describing irrigation water charging at a national level must be regarded as indicative.

Examples of Water Charging for Irrigated Agriculture

In terms of water charging, generally two methods are being used: Charge per cubic metre and Charge per hectare. “Water charging irrigated agriculture” (FAO, 2004) explained these methods as shown below:

> *Price per cubic metre: There is a very large range in the reported volumetric price of water for irrigation. Prices as high as 18 to 29 US cents / m^3, applied as a rising block tariff, are reported in Israel. Spain reports prices of 16 US cents/m^3 on schemes drawing from deep aquifers. In the market garden sector of Holland, where growers irrigate greenhouse crops from a municipal supply, the price per cubic metre may be as high US$1.30, but this is an extreme case. At the lowest end of the range Canada and Romania report prices below 0.1 cent/m^3. A price of about 2 US cents/m^3 (US$20/1 000$m^3$) is a common ‘average’ volumetric price charged for irrigation water, but these other values show the extent of the range.*
>
> *Charge per hectare: Where irrigated area is used as the charging basis, comparison is made more difficult as it is not always clear in the literature whether figures quoted are seasonal or annual. Japan reports a figure of US$246/ha; China and Greece report ranges of US$92–210 and 50–150 respectively. US$40–50 /ha/year is a more representative ‘average’ charge in*

more developed countries. In India many states charge no more that US$10 /ha/year. Figures 3 and 4 in the text present the range of charges reported. Moreover, there is often considerable variation between theoretical or target rates and those actually charged in the field.

In Georgia (United States), a water charge of 247 ~ 1,236 USD per ha is imposed based on arable land area supplied, and the average charge is 337 USD per ha. This amount is equivalent to 44 USD per 1,000m^3 when the charge is based on the amount of water supplied.

Table 4.3-1 shows the various cases of water charging for several countries in the world. This data are cited from “Cost recovery and water pricing for irrigation and drainage projects” (World bank, 2005).

[Table 4.3-1] Examples of Water Charging for Several Countries in the World

Country	Project	Year	Water Pricing	Remarks
Brazil	Jaiba Project	1995	$3.69/ha/month	Capital cost
			$10.11/1,000$m^3$	O&M cost
Bulgaria	öKo Inc.	2001	$0.01~$0.085/m^3	water prices depend on the source of irrigation: gravity or pump
China	North Plain, Nanyao and Bayi irrigation districts	1993	1.5 yuan/mu ($3.45/ha)	Fixed area fee
			7.11 yuan/m^3 ($1.09/$m^{3)}$	Volumetric fee
Egypt		1995	$52/ha	no effect on the choice of crop or technology
India	Haryana	2003	$8/ha	Full cost recovery
Iran	Zayandeh Rud Basin, Esfahan Province	2001	$20~$50/1,000m^3	Full recovery for O&M
Morocco	Tadla Scheme	2003	$150/ha	Full cost recovery
	Haouz Scheme	2003	$54/ha	Full cost recovery
Niger	Niger	2000	$124/ha	Full cost recovery

Additional issues considered in the water price calculations for the Illovo Estates are presented below:

- Benefits Illovo reaps when included in the SVIP
- Recovery of capital costs and O & M costs spent for the required facilities; and
- Illovo's fair profits guarantee

As mentioned above, the estimated annual benefit to Illovo that is expected to come from inclusion in the SVIP is 4,666,088 USD.

Table 4.3-2 shows monthly pumped water amount for the whole Estates (Nchalo, Alumenda, Sande Ranch & Kaombe) during 2008~2015 from the Shire river.

[Table 4.3-2] Pumped Water Amount for the Whole Estates (Unit: m^3)

Mon	08~09	09~10	10~11	11~12	12~13	14~15	Average
JAN	11,239,009	37,986,606	20,876,722	13,699,259	14,814,830	906,523	16,587,158
FEB	25,695,040	22,845,622	23,838,282	33,419,944	4,257,828	4,919,532	19,162,708

MAR	28,133,784	22,235,749	27,764,611	25,344,056	25,608,839	15,866,645	24,158,947
APR	26,295,544	21,581,341	26,097,865	26,268,754	22,437,570	21,090,144	23,961,870
MAY	24,781,226	20,053,699	22,216,887	24,225,598	27,803,012	21,832,519	23,485,490
JUN	18,736,653	19,731,690	19,967,574	27,605,481	25,012,199	20,466,221	21,919,970
JUL	19,389,889	17,616,233	18,924,750	19,493,666	22,318,207	20,719,177	19,743,654
AUG	20,049,897	23,306,980	17,213,190	23,753,577	22,692,915	23,487,176	21,750,623
SEP	24,478,784	31,079,287	27,352,645	29,947,608	26,252,706	23,973,404	27,180,739
OCT	33,849,907	19,742,929	32,812,689	30,431,117	34,217,584	29,431,530	30,080,959
NOV	36,058,594	32,409,216	33,251,484	36,454,296	35,198,680	29,866,768	33,873,173
DEC	25,505,082	29,828,225	20,047,833	36,274,931	28,213,991	30,976,475	28,474,423
Total	294,213,409	298,417,577	290,364,532	326,918,287	288,828,361	243,536,114	290,379,714

Cost and Benefit Flow for Open Canal

The purpose of this cost and benefit flow analysis is to estimate a break-even price which gives the With Illovo case in the SVIP zero profit. The break-even price shall be the starting point to estimate the most plausible water price for GoM and Illovo Estate.

When calculating the breakeven water price, the annual water prices are estimated using the average Illovo water consumption (290,379,714m^3). Table 4.3-3 shows the cost and benefit flow for open canal under the condition of water fee = 8 USD /1,000 m^3.

[Table 4.3-3] Cost and Benefit Flow for Open Canal (Water fee = 8 USD /1,000 m^3)

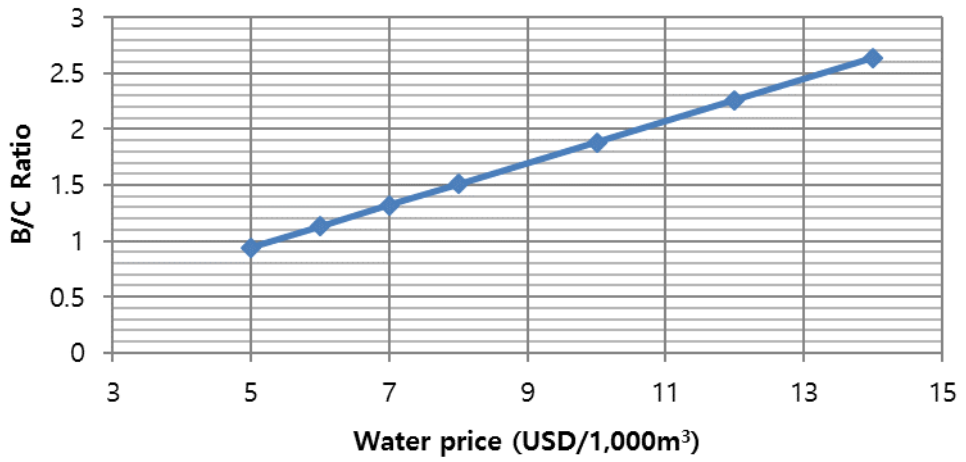
Year in Order	Year	Construction Cost	O & M Cost	Total Cost	Benefit (water fee)	Cash Balance
1	2018	6,000,000		6,000,000	-	(6,000,000)
2	2019	6,000,000		6,000,000	-	(6,000,000)
3	2020	5,030,000		5,030,000	-	(5,030,000)
4	2021			-	-	-
5	2022			-	-	-
6	2023		255,450	255,450	2,323,032	2,067,582
7	2024		255,450	255,450	2,323,032	2,067,582
8	2025		255,450	255,450	2,323,032	2,067,582
9	2026		255,450	255,450	2,323,032	2,067,582
10	2027		255,450	255,450	2,323,032	2,067,582
11	2028		255,450	255,450	2,323,032	2,067,582
12	2029		255,450	255,450	2,323,032	2,067,582
13	2030		255,450	255,450	2,323,032	2,067,582
14	2031		255,450	255,450	2,323,032	2,067,582
15	2032		255,450	255,450	2,323,032	2,067,582
16	2033		255,450	255,450	2,323,032	2,067,582
17	2034		255,450	255,450	2,323,032	2,067,582
18	2035		255,450	255,450	2,323,032	2,067,582
19	2036		255,450	255,450	2,323,032	2,067,582
20	2037		255,450	255,450	2,323,032	2,067,582

21	2038		255,450	255,450	2,323,032	2,067,582
22	2039		255,450	255,450	2,323,032	2,067,582
23	2040		255,450	255,450	2,323,032	2,067,582
24	2041		255,450	255,450	2,323,032	2,067,582
25	2042		255,450	255,450	2,323,032	2,067,582
26	2043		255,450	255,450	2,323,032	2,067,582
27	2044		255,450	255,450	2,323,032	2,067,582
28	2045		255,450	255,450	2,323,032	2,067,582
29	2046		255,450	255,450	2,323,032	2,067,582
30	2047		255,450	255,450	2,323,032	2,067,582
31	2048		255,450	255,450	2,323,032	2,067,582
32	2049		255,450	255,450	2,323,032	2,067,582
33	2050		255,450	255,450	2,323,032	2,067,582
34	2051		255,450	255,450	2,323,032	2,067,582
35	2052		255,450	255,450	2,323,032	2,067,582
Total		17,030,000	7,663,500	24,693,500	69,690,960	44,997,460
Internal rate of return (FIRR): 8.62%						
Discount rate: 5%						
B/C: 1.51						

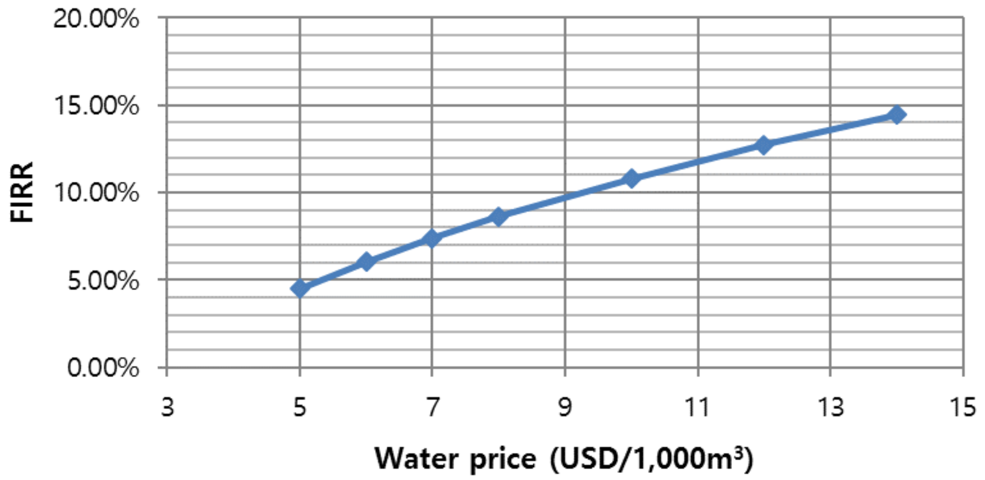
When the water fee is set at 8 USD/1000m^3 for the amount of water used and the discount rate is set at 5%, the B/C ratio is 1.51 and FIRR is 8.62%. The discount rate of 5% is used by IMF and World Bank for loans longer than 15 years. Table 4.3-4 shows the cost and benefit flows for the different water fees, and Figures 4.3-1 and 2 show the relation between the water prices and B/C ratios, and the relation between the water prices and FIRR, respectively. **From these results the break-even price for the water price is 5.3 USD/ 1000m^3.**

[Table 4.3-4] Results of Economic Analysis for Different Water Fees

Water Fees (USD/1,000m^3)	FIRR	B/C
5	4.50%	0.94
5.3 (Break-even Price)	**4.98%**	**1.00**
6	6.03%	1.13
7	7.39%	1.32
8	8.62%	1.51
10	10.80%	1.88
12	12.73%	2.26
14	14.46%	2.64



[Figure 4.3-1] Relation between the Water Prices and B/C Ratio

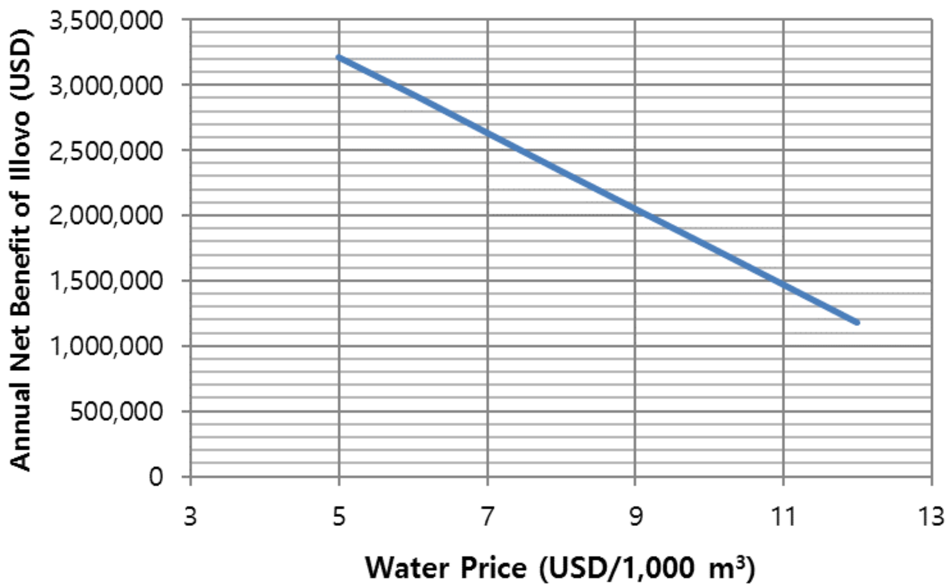


[Figure 4.3-2] Relation between the Water Prices and FIRR

The benefit to Illovo changes depending on the selected water fee. Table 4.3-5 shows the variation of benefits to Illovo when the water fee is changed for the annual amount of water of 290,379,000 m^3. Figure 4.3-3 shows the relation between the water prices and the annual net benefits of Illovo Estate.

[Table 4.3-5] Variation of Benefit of Illovo

Annual Benefit of Illovo (USD)	Water Fees (USD/1,000m^3)	Annual Water Charges (USD)	Annual Net Benefit of Illovo (USD)
4,666,088	5	1,451,895	3,214,193
4,666,088	6	1,742,274	2,923,814
4,666,088	7	2,032,653	2,633,435
4,666,088	8	2,323,032	2,343,056
4,666,088	10	2,903,790	1,762,298
4,666,088	12	3,484,548	1,181,540
4,666,088	14	4,065,306	600,782



[Figure 4.3-3] Relation between the Water Prices and the Annual Net Benefit of Illovo Estate

From Table 4.3-5, it is clear that when the water fee = 8 USD/1,000m^3, which is about 50% of the total annual benefit, Illovo can gain a benefit of 2,343,056 USD a year. This also gives a good B/C ratio of 1.51. When the water tariff is 10 USD/1,000m^3, the annual net benefit to Illovo Estate drops to 1,762,298 USD. The consultant recommends therefore that the plausible range of water price shall be 7~10USD/1,000m^3.

(PPP team proposed 16USD/1,000 m^3, which is almost near to what Illovo is currently paying for power. PPP team thinks that Illovo will have better quality of water and less O&M charge, so it is still interesting in a long term perspective.)

In terms of the cost recovery period, Table 4.3-6 shows the relation between the water price and cost recovery period. When the water price = 4 USD/1,000m^3, it shall take 17 years to recover the cost input. On the other hand, when water price = 8 USD/1,000m^3, it shall take only 6 years.

[Table 4.3-6] Relation between the Water Price and Cost Recovery Period

Water Fees (USD/1,000 m^3)	Cost Recovery Period
6	23
7	18
8	15
10	11
12	9

Cost and Benefit Flow for Pipe Canal

Table 4.3-7 shows the cost and benefit flow for the pipe canal under the condition of water fee = 4 USD /1,000 m^3.

[Table 4.3-7] Cost and Benefit Flow for Piped Canal (Water fee = 8 USD /1,000 m^3)

Year in Order	Year	Construction Cost	O & M Cost	Total Cost	Benefit (water fee)	Cash Balance
1	2018	16,000,000		16,000,000	-	(16,000,000)
2	2019	16,000,000		16,000,000	-	(16,000,000)
3	2020	13,730,000		13,730,000	-	(13,730,000)
4	2021			-	-	-
5	2022			-	-	-
6	2023		685,950	685,950	2,323,032	1,637,082
7	2024		685,950	685,950	2,323,032	1,637,082
8	2025		685,950	685,950	2,323,032	1,637,082
9	2026		685,950	685,950	2,323,032	1,637,082
10	2027		685,950	685,950	2,323,032	1,637,082
11	2028		685,950	685,950	2,323,032	1,637,082
12	2029		685,950	685,950	2,323,032	1,637,082
13	2030		685,950	685,950	2,323,032	1,637,082
14	2031		685,950	685,950	2,323,032	1,637,082
15	2032		685,950	685,950	2,323,032	1,637,082
16	2033		685,950	685,950	2,323,032	1,637,082
17	2034		685,950	685,950	2,323,032	1,637,082
18	2035		685,950	685,950	2,323,032	1,637,082
19	2036		685,950	685,950	2,323,032	1,637,082
20	2037		685,950	685,950	2,323,032	1,637,082
21	2038		685,950	685,950	2,323,032	1,637,082
22	2039		685,950	685,950	2,323,032	1,637,082
23	2040		685,950	685,950	2,323,032	1,637,082
24	2041		685,950	685,950	2,323,032	1,637,082
25	2042		685,950	685,950	2,323,032	1,637,082
26	2043		685,950	685,950	2,323,032	1,637,082
27	2044		685,950	685,950	2,323,032	1,637,082
28	2045		685,950	685,950	2,323,032	1,637,082
29	2046		685,950	685,950	2,323,032	1,637,082
30	2047		685,950	685,950	2,323,032	1,637,082
31	2048		685,950	685,950	2,323,032	1,637,082
32	2049		685,950	685,950	2,323,032	1,637,082
33	2050		685,950	685,950	2,323,032	1,637,082
34	2051		685,950	685,950	2,323,032	1,637,082
35	2052		685,950	685,950	2,323,032	1,637,082
Total		45,730,000	20,578,500	66,308,500	69,690,960	3,382,460
Internal rate of return (FIRR): 0.39%						
Discount rate: 5%						
B/C: 0.56						

When the water fee is set at 8 USD/1000m^3 and the discount rate is set at 5%, the B/C ratio is 0.56 and FIRR is 0.39%. Table 4.3-8 shows the cost and benefit flow for the different water fees.

[Table 4.3-8] Results of Economic Analysis for Different Water Fees

Water Fees (USD/1,000m^3)	FIRR	B/C
10	0.39%	0.56
12	2.13%	0.70
14 (Break-even Price)	**4.85%**	**0.98**
16	5.98%	1.12
18	7.01%	1.26
20	7.96%	1.40

The benefit to Illovo again changes depending on the selected water fee. Table 4.3-9 shows the variation of benefits to Illovo as water fee changes.

[Table 4.3-9] Variation of Benefit of Illovo

Annual Benefit of Illovo (USD)	Water Fees (USD/1,000m^3)	Annual Water Charges (USD)	Annual Net Benefit of Illovo (USD)
4,666,088	10	2,903,790	1,762,298
4,666,088	12	3,484,548	1,181,540
4,666,088	14	4,065,306	600,782
4,666,088	16	4,646,064	20,024
4,666,088	18	5,226,822	-560,734
4,666,088	20	5,807,580	-1,141,492

Table 4.3-9 clearly shows that the benefits to Illovo with pipe canal are largely reduced.

In terms of the cost recovery period, Table 4.3-10 shows the relation between the water price and cost recovery period. In the case of pipe canal the cost recovery period shall be much longer than the open canal case (See 4.3-6).

[Table 4.3-10] Relation between the Water Price and Cost Recovery Period

Water Fees (USD/1,000 m^3)	Cost Recovery Period
15	27
16	24
17	21
18	19

CHAPTER 5. WATER REQUIREMENTS FOR SVIP

TOR Requirement
- Calculation of requirement by crop and supply amount of irrigation requirement
- Calculation of irrigation water requirement(CROPWAT) considering crop cultivation and system

5.1. Assessment Factors for Water Requirement

Water requirements by crops depend not only on climate, field and farming practice but also on the shape of the irrigation canal and stages of crop growth.

5.1.1. Climate

Climate is the prime factor for determining crop water requirements. It includes key parameters such as precipitation, evaporation, sunlight, humidity and wind speed. Climate significantly affects stages of crop growth that may influence variations in crop water requirements. Most of the SVIP area falls under Chikwawa District. Temperature may be as high as 40 ℃ during summer, with correspondingly high evapotranspiration rates. Climatic factors are essential in determining crop water requirements using CROPWAT developed by FAO.

5.1.2. Field Condition

In general, field conditions necessary for determining crop water requirement include osmotic coefficient, depth of fresh water, management loss and hectarage of irrigated area. The variables listed above significantly affect water resources management at the field level. Most of the SVIP area comprises sandy soil; as such, it is difficult for the soil to retain water in the root zone after irrigation. Sandy soil lowers the irrigation efficiency and increases irrigation frequency. On the contrary, where loam soil is prevalent, it can dramatically reduce the irrigation frequency as it has better water holding capacity than sandy soil.

5.1.3. Cropping Pattern

An assessment should be made of the different crops grown under irrigation. Furthermore, information on the various crop characteristics such as length of the growing cycle, crop factors and rooting depth should be collected. A local survey should be carried out in the irrigation scheme to assess crops grown under rain-fed as well as under irrigation in order to estimate water requirement under the existing cultivation situation. Through field observations, interviews with extension agents, farmers and additional information from other agencies, for instance a revenue department, an assessment could be made of the present cropping pattern.

Since the TFS was tasked to determine the design water requirement for the whole project area, including existing large scale sugarcane plantations, appropriate type of crop and cultivation area were selected. Given that existing plantations will continue to grow sugarcane, it was necessary to select the right crop for the new areas of the project. At this stage, it was important to select crops most favored including sugarcane even though it was difficult to know the crop that would be grown and the corresponding size of the area.

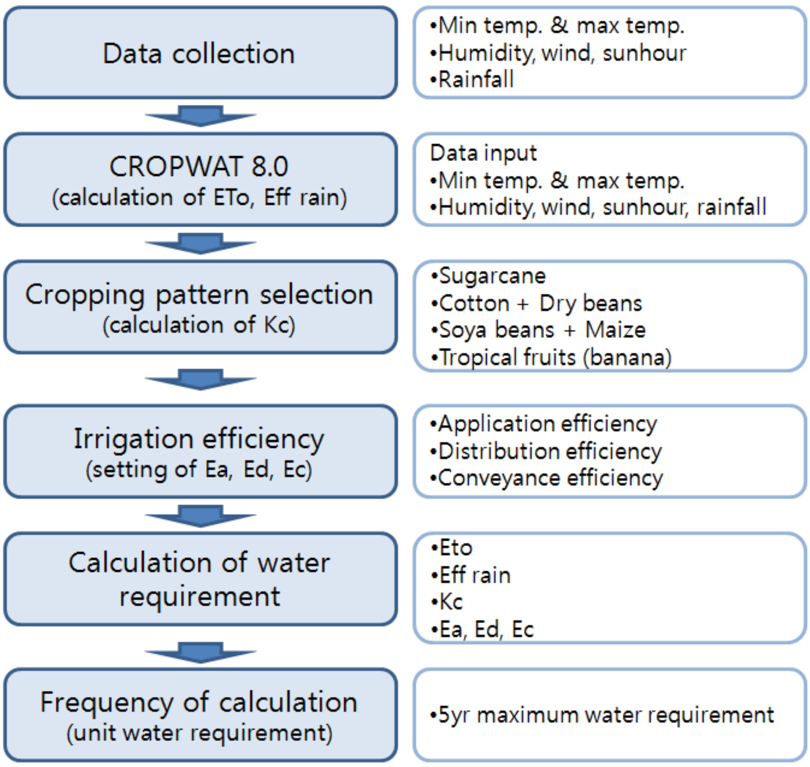
5.1.4. Irrigation Methods

Common irrigation systems include: surface irrigation (furrow, basin, etc.), overhead irrigation (sprinkler, etc.), subsurface irrigation, and drip irrigation. Accordingly, irrigation efficiency and crop water requirements vary depending on the type of irrigation system adopted. For SVIP area, large Estates such as Illovo, Kasinthula, Phata, and Sande Ranch are growing sugarcane using furrow, sprinkler, and pivot irrigation systems. Among the three, both sprinkler and pivot irrigation systems have higher efficiency than furrow irrigation. However, in these estates, furrow irrigation is most widely used (i.e., it covers 52% of the overall area), sprinkler irrigation using dragline covers 31%, and pivot irrigation is used in 17% of the area. Illovo Sugar Estate operates furrow irrigation for 8 hours in a day. And during the time that irrigation is not operational, the water is stored within the canals and storage reservoirs. Illovo Sugar Estate has a total of 46 night storage facilities. Pivot irrigation is operated on a 24 hours/day basis, drawing water directly from the secondary canal.

5.2. Water Requirement Analysis

Water demand for an irrigation project is estimated by adding the efficiencies to the water requirement in the field. Water requirement in the field is related to the cropping pattern, climatic conditions and soil percolation characteristics. The procedure adopted to estimate water demand for the project was as follows:

i) Collected climatic data for Chikwawa and Nchalo areas;
ii) Calculated effective rainfall;
iii) Selected cropping pattern (obtained from Agriculture Development Team);
iv) Calculated crop water requirement using CROPWAT;
v) Applied irrigation efficiency; and
vi) Calculated water demand for a 5-year frequency



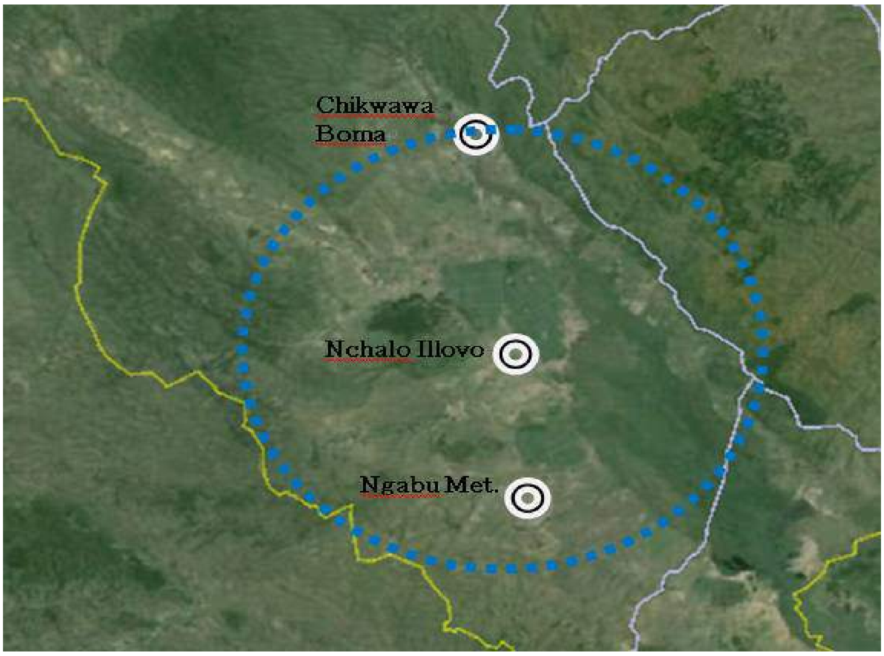
[Figure 5.2-1] Procedure of the Water Requirement Estimation

5.2.1. Climate Data Collection

SVIP has 3 meteorological stations, one located at Chikwawa Boma, another at Nchalo Illovo and the third at Ngabu. Chikwawa Boma meteorological station is located at a distance of 27.1km away to the north of Nchalo and Ngabu meteorological station is 18.21km away to the south from Nchalo Illovo station at Nchalo (Table 5.2-1).

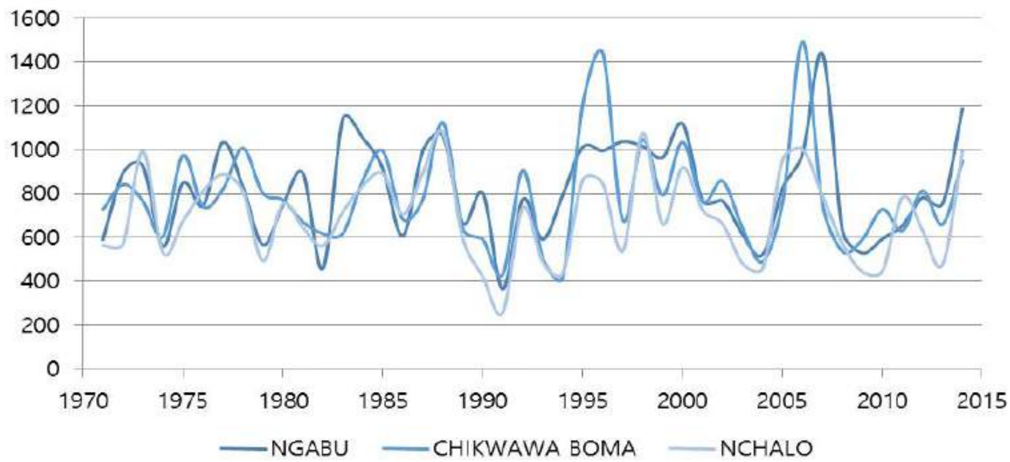
[Table 5.2-1] Data Status of Meteorological Station

Division	Chikwawa Boma	Nchalo Illovo	Ngabu Met.
Long. / Lat.	34.7833 / -16.0333	34.9333 / -16.2333	34.95 / -16.5
Rainfall	1950~2014	1971~2014	1961~2014
Humidity	1981~2014		1972~1989
Temperature		1971~2014	
Wind Run		1971~2014	
Sunhours		1971~2014	



[Figure 5.2-2] Location of Meteorological Station at SVIP

Meteorological stations at Chikwawa Boma, Nchalo Illovo, and Ngabu show rainfall data distribution as presented in Figure 5.2-3. It is most convenient to use the data from Nchalo Illovo as it is located at the center of the three meteorological stations.



[Figure 5.2-3] Rainfall Distribution of 3 Meteorological Station

In some cases, when the scheme is large, more than one station may be established but often no suitable stations with sufficient climatic data are located in the scheme. In such a case a careful selection of the data that is required should be made.

If the irrigation scheme is very large, more than one meteorological station may be installed for data collection; but more often than not, no stations within the scheme will have adequate climatic data for use in calculating crop water requirements. In such a case, a careful selection of the existing data is required.

In the current study the following data sources were used:

a) Temperature: Nchalo Illovo (1971-2014)
b) Humidity: Chikwawa Boma (1981-2014), Ngabu Met. (1972-1989)
c) Wind: Nchalo Illovo (1971-2014)

The above climatic data are presented in Annex 9.

5.2.2. Climate and Rainfall Data Sets

Data for the Estimation of Evapotranspiration (ETo)

Evapotranspiration (ETo) represents the potential evaporation of a well-watered grass crop. The water needs of other crops are directly linked to this climatic parameter. Although several methods exist for determining ETo, the Penman-Monteith Method is recommended as the appropriate combination method to determine ETo from climatic data such as temperature, humidity, sunshine and wind speed.

In order to calculate ETo, the respective climatic data should be collected from the nearest and most representative meteorological station. Several institutions and agencies may keep climatic records such as Irrigation Departments, Meteorological Services, nearby Agricultural Research Stations, etc. These organizations may provide data on stations inside or in the vicinity of the irrigation scheme of interest which may then be used in calculating crop water requirements (CWR).

In the current study, data on climate used for calculating ETo were collected from Nchalo Illovo station and spans a period of 44 years from 1971 to 2014. Nchalo Illovo station data were the most reliable, easy to collect, and in close proximity to the project area. Detailed results of ETo are presented in Annex 7.

Rainfall Data

Average monthly rainfall data were collected from Nchalo station. Effective rainfall was calculated using CROPWAT 8.0 based on the FAO empirical formula (FAO/AGLW formula) to estimate dependable rainfall: the combined effect of dependable rainfall (80% probability of exceeding normal rainfall) and estimated losses due to runoff and deep percolation.

For purposes of planning irrigation water supply and management, rainfall data of normal, wet and dry years were used. An estimate of the respective rainfall data could be obtained by computing and plotting probabilities from the rainfall records. The different steps involved were as follows:

i) Tabulating yearly rainfall totals for a given period;

ii) Arranging data in descending order of magnitude;

iii) Tabulating plotting position according to:

$$Fa = 100 * m / (N + 1)$$

Where; N = number of records, m = rank number, Fa = plotting position

Details of rainfall data treatment procedures are presented in Annex 7.

5.2.3. Effective Rainfall Estimation

To account for the losses due to runoff or percolation, a choice can be made of one of the four methods given in CROPWAT 8.0 (Fixed percentage, Dependable rain, Empirical formula, USDA Soil Conservation Service).

In general, the efficiency of rainfall will decrease with increasing rainfall. For most rainfall values below 100 mm/month, the efficiency will be approximately 80%. Unless more detailed information is available for local conditions, it is suggested to select the Option “Fixed percentage” and give 80% as requested value. In the water balance calculations included in the irrigation scheduling part of CROPWAT, a possibility exists to evaluate actual efficiency values for different crops and soil conditions. Details about calculation of effective rainfall and associated results are presented in Annex 7.

5.2.4. Cropping Pattern

Large estates grow sugarcane in several locations within SVIP area. Table 5.2-2 shows sugarcane cultivation area of the large estates.

[Table 5.2-2] Status of the Large Estate in Project Area

Total Area	Nchalo	Alumenda	Sande Ranch	Phata	Kasinthula	Kaombe
15,757 ha	9,995 ha	2,764 ha	454 ha	296 ha	1,429 ha	819 ha

Existing estates grow sugarcane in 15,757 ha, accounting for 36% of SVIP’s total area of 43,370ha. In addition, each estate is expanding the sugarcane plantation area. The areas not occupied by existing estates are taken up by smallholder farmers. The smallholder farmers do not have the capacity to expand their plantation areas by buying more land. There is need to encourage smallholder farmers to grow sugarcane on contract basis by forming associations, just like the way Phata did.

Presscane, located in the project area, produces ethanol from molasses and sugarcane. Illovo supplies molasses to Presscane for use in the production of ethanol. But in order to increase production, the company is planning to produce its own sugarcane rather than depending on Illovo. According to Presscane, it succeeded to secure additional area of 2,270 ha by signing contracts with small holder farmers within the existing T/A Maseya area. The company plans to grow sugarcane by using of an out-growers association arrangement.

Most of the project areas, except for large scale estates, are engaged in traditional farming activities. Traditional farmers grow their crops during the rainy season only, but are vulnerable to drought episodes. As a result, yields by traditional farmers are generally very low. These farmers mainly grow maize, sorghum and millet. Cotton is another crop grown over many areas of the project. It was noted during field surveys that the farmers' primary goal in growing crops is to enhance food security at household level. Therefore, even after the completion of SVIP development, farmers are expected to grow these food crops, but with improved yields.

Based on field survey results, five main crops, namely: sugarcane, maize, beans, cotton and tropical fruits were selected in calculating crop water requirements. Currently, sugarcane takes up 37% of the total project area. About 44% of the area is designated for sugarcane, considering the future expansion of Presscane and plantation development.

Sugarcane requires 12 months to mature and be ready for harvest; as such, the 44% area designated for sugarcane cannot be shared with other crops. With the completion of SVIP, it is envisaged that some of the crops that were only grown during the rainy season could also be grown during dry season under irrigation. Thus, SVIP will enable farmers to do double-cropping. TFS has set up cropping pattern for the whole development area and the results are presented in Table 5.2-3 and Figure 5.2-4.

[Table 5.2-3] Areas of Crops for the Water Requirement Estimation

Total	Sugarcane			Cotton, Maize, Bean, Tropical Fruits		
	Total	Existing	New	Total	Existing	New
43,370 ha	19,083 ha	15,757 ha	3,326 ha	24,287 ha		24,287 ha
100%	44%			56%		

<table>
<tr><td>Division</td><td>Nov</td><td>Dec</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Apr</td><td>May</td><td>Jun</td><td>Jul</td><td>Aug</td><td>Sep</td><td>Oct</td></tr>
<tr><td>Pattern Ⅰ</td><td colspan="12">Surgacane(44%)</td></tr>
<tr><td rowspan="3">Pattern Ⅱ</td><td colspan="6">Cotton(30%)</td><td colspan="6">Dry Bean(20%)</td></tr>
<tr><td></td><td colspan="5">Soya Beans(20%)</td><td colspan="5">Maize(30%)</td><td></td></tr>
<tr><td colspan="12">Tropical Fruits(6%)</td></tr>
</table>

[Figure 5.2-4] Cultivation Plan for the Crops

5.2.5. Crop Coefficient

The calculation of water demand depends on evapotranspiration ETc, a parameter which is determined by multiplying ETo by a crop coefficient Kc. Kc varies predominantly with the specific crop characteristics and crop stage. The Kc for each crop has been defined by using FAO guidelines (FAO – Guidelines for computing crop water requirements – paper 56 / chapter 6 and FAO website – Water Development and Management Unit – Crop information) and Nchalo climate data. Detailed crop coefficients for each crop are presented in Annex 7.

In view of the fact that sugarcane requires 12 months to mature and be ready for harvest, the total sugarcane area has been divided into seven blocks, and each block has different growing period to minimize the maximum water requirements. Table 5.2-4 shows monthly crop coefficient distribution of sugarcane when adopting the above seven block planting schedule.

[Table 5.2-4] Distribution of Monthly Crop Coefficient Average

Season	Sugarcane		Cotton + (Dry Bean)		Soya Bean + (Maize)		Tropical Fruits		Average	
	Kc	Area	Kc	Area	Kc	Area	Kc	Area	Kc	Area
Jan	0.82	44%	1.10	30%	0.71	20%	0.50	6%	0.86	100%
Feb	0.80	44%	0.94	30%	0.99	20%	0.50	6%	0.86	100%
Mar	0.82	44%	0.78	30%	0.92	20%	0.50	6%	0.80	100%
Apr	0.80	44%	0.62	30%	0.85	20%	0.60	6%	0.74	100%
May	0.82	44%	(0.42)	(20%)	(0.42)	(30%)	0.70	6%	0.61	100%
Jun	0.80	44%	(0.76)	(20%)	(0.76)	(30%)	0.80	6%	0.77	100%
Jul	0.82	44%	(1.09)	(20%)	(1.11)	(30%)	0.90	6%	0.96	100%
Aug	0.80	44%	(0.70)	(20%)	(1.03)	(30%)	1.00	6%	0.85	100%
Sep	0.82	44%	(0.30)	(20%)	(0.96)	(30%)	1.10	6%	0.77	100%
Oct	0.80	44%	0.42	30%	0.00	20%	1.05	6%	0.53	100%
Nov	0.82	44%	0.64	30%	0.00	20%	1.00	6%	0.61	100%
Dec	0.80	44%	0.86	30%	0.42	20%	0.00	6%	0.69	100%

[Table 5.2-5] Distribution of Monthly Crop Coefficient of Sugarcane for 7 Blocks

Season	Kc1	Kc2	Kc3	Kc4	Kc5	Kc6	Kc7	Average
Jan	0.65	0.98	1.15	1.15	1.15	0.66	0.00	0.82
Feb	0.00	0.81	1.15	1.15	1.15	0.90	0.42	0.80
Mar	0.00	0.65	0.98	1.15	1.15	1.15	0.66	0.82
Apr	0.42	0.00	0.81	1.15	1.15	1.15	0.90	0.80
May	0.66	0.00	0.65	0.98	1.15	1.15	1.15	0.82
Jun	0.90	0.42	0.00	0.81	1.15	1.15	1.15	0.80
Jul	1.15	0.66	0.00	0.65	0.98	1.15	1.15	0.82
Aug	1.15	0.90	0.42	0.00	0.81	1.15	1.15	0.80
Sep	1.15	1.15	0.66	0.00	0.65	0.98	1.15	0.82
Oct	1.15	1.15	0.90	0.42	0.00	0.81	1.15	0.80
Nov	1.15	1.15	1.15	0.66	0.00	0.65	0.98	0.82
Dec	1.15	1.15	1.15	0.90	0.42	0.00	0.81	0.80

5.2.6. Irrigation Efficiency

Irrigation water may experience conveyance losses (seepage, evaporation, etc.). Therefore, calculation of crop water requirement must consider conveyance losses and irrigation efficiency at the field level.

Application Efficiency

Application efficiency is the ratio of water stored in a particular soil layer to the amount of water arrived at paving from source for cropping. It is an important factor in deciding the timing of irrigation.

$$E_a = \frac{W_s}{W_f} \times 100(\%)$$

Where, Wf: Quantity arrived at paving, Ws: Water stored in effective soil layer through irrigation

Application efficiency is 60% or higher for surface irrigation and 70-80% for sprinkler irrigation. Table 5.2-6 is the standard application efficiency.

[Table 5.2-6] Standard of Application Efficiency by Type of Irrigation (FAO)

Irrigation Method	Field Application Efficiency
Border, Furrow, Basin irrigation	60%
Sprinkle irrigation	70%
Drip irrigation	95%

The TFS team has agreed with the client to estimate water requirement using furrow irrigation to the whole SVIP area by setting the application efficiency at 52%.

Conveyance Efficiency

Conveyance efficiency is the ratio of water arrived at paving to water drawn from the source.

$$E_c = \frac{W_f}{W_r} \times 100(\%)$$

Where, Wf: quantity arrived at paving, Wr: drawn water from source

Concrete conduit has 90-95% of conveyance efficiency and pipeline 95%. Presented in Table 5.2-7 is a general standard of conveyance efficiency for earth canal and lined canal. TFS has proposed 89% for conveyance efficiency through lined canal.

[Table 5.2-7] Standard of Conveyance Efficiency for Earth Canal and Lined Canal

Division	Earth Canal			Lined Canal
	Sand	Loam	Clay	
Long (> 2000m)	60	70	80	90~95
Medium (200-2000m)	70	75	85	90~95
Short (< 200m)	80	85	90	90~95

Irrigation Efficiency

Irrigation efficiency is the ratio of water stored in specific layer of soil to water drawn from source.

$$E_s = \frac{E_a}{100} \times \frac{E_c}{100} \times 100(\%)$$

Storage Efficiency

Storage efficiency is the ratio of water stored in specific soil layer after irrigation to water required by specific soil layer before irrigation.

$$E_s = \frac{W_s}{W_n} \times 100(\%)$$

Where, Wn: Requirement of effective soil layer before irrigation (=field moisture capacity=moisture content before irrigation), Ws: water stored in effective soil layer by irrigation

Distribution Uniformity

Distribution uniformity is ratio of average of 25% of the smallest penetration to average penetration of paving.

$$E_d = \frac{h_m}{h_a} \times 100(\%)$$

Where, Ed: distribution uniformity, ha: average penetration, hm: average of 25% of smallest penetration

The distribution uniformity is usually 80% or higher. The TFS has chosen 90% for distribution uniformity.

Applied Irrigation Efficiencies for SVIP

TFS has selected the following irrigation efficiency considering standards described above and many local conditions: Ea=64%, Ed=90% and Ec=90%. According to FAO standard, it is considered to be appropriate efficiency if the value obtained by multiplying Ea by Ec falls within a range of 50 to 60%. If Ea is multiplied by Ec of the irrigation efficiency that TFS selected, the result so obtained is 52%, which meets the FAO standard.

Irrigation Efficiencies for Several Cases

Table 5.2-8 shows irrigation efficiency applied to previous studies and the current project.

[Table 5.2-8] Irrigation Efficiencies for Several Cases

Irrigation Efficiency	TFS	FAO	CODA	C & B
Application Efficiency Ea	64%	60~90%	60~80%	65~80%
Distribution Efficiency Ed	90%		70%	99%
Conveyance Efficiency Ec	90%	95%	80%	94%
Canal types	Lining canal	Lining canal	Earth canal	Pipe canal

Table 5.2-9 shows the design water requirement varies depending on the irrigation efficiencies.

[Table 5.2-9] Design water requirements under different irrigation efficiencies

Irrigation Efficiency	Overall Efficiency	Net Area	Unit CWR	CWR
Ea=70%, Ed=95%, Ec=95%	63.2%	42,500 ha 43,370 ha	0.000950 m^3/s/ha 0.000950 m^3/s/ha	40.09 m^3/s/ 41.21 m^3/s/
Ea=75%, Ed=95%, Ec=95%	67.7%	42,500 ha 43,370 ha	0.000950 m^3/s/ha 0.000950 m^3/s/ha	37.68 m^3/s/ 38.45 m^3/s/
Ea=65%, Ed=95%, Ec=90%	55.6%	37,000 ha 35,000 ha	0.000950 m^3/s/ha 0.000950 m^3/s/ha	40.01 m^3/s/ 37.80 m^3/s/
Ea=65%, Ed=99%, Ec=90%	57.9%	38,580 ha 36,450 ha	0.000950 m^3/s/ha 0.000950 m^3/s/ha	40.01 m^3/s/ 37.80 m^3/s/

5.2.7. Calculate Water Demand

5.2.7.1. Calculate Water Demand in 5 Year Frequency

TFS provided data for CROPWAT 8.0 to calculate monthly requirement for the period 1971 to 2014 by using yearly meteorological data from January to December.

- ✓ Monthly Meteorological Data Collection
  - i. Rainfall , Humidity, Wind Run, Sunhours : Monthly Data(1971~2014)
  - ii. Temperature : Max Temp, Max Temp Monthly Data(1971~2014)
- ✓ ETo , Effective Rainfall , Kc Data Calculation Input by using CROPWAT 8.0
  - i. Climate / ETo → Monthly Climate input → Climatic Data and ETo Calculation
  - ii. Rain → Monthly Rainfall input → Rainfall and Effective Rainfall Data
  - iii. Crops → Kc selection by FAO → Crop Coefficient Kc Data

[Table 5.2-10] Input Data for the Monthly Water Demand

Division			Unit	September			October		
				1971	~	2014	1971	~	2014
DATA	①	Mean Temp	℃	24.9		25.3	27.3		26.9
	②	Humidity	%	54		38	53		37
	③	Wind	Km/day	197.1		162.5	221.9		209.9
	④	Mean Rainfall	mm	0.0		1.8	0.0		39.7
	⑤	Crop Coefficient Kc=		0.77		0.77	0.53		0.53
	⑥	ETo	mm/day	5.82		5.68	6.17		6.82
	⑦	Mean ET: ⑥* month days	mm	174.6		170.4	191.3		211.4
	⑧	Consumptive use: ⑦*⑤	mm	134.4		131.2	101.4		112.1
	⑨	Land Preparation	mm	0		0	0		0
	⑩	Preparation Losses	mm	0		0	0		0
	⑪	Nursery Requirement	mm	0		0	0		0

In general, a 5-year frequency was applied for the water demand estimation. The procedure for doing this work is presented in Table 5.2-11 ~ Table 5.2-13. The unit water requirement was estimated to be $0.001153m^3/s/ha$ (1.153L/s/ha), with total water requirement of $50.0m^3/s$.

[Table 5.2-9] Input Data for the Monthly Water Demand

Division			Unit	September			October		
				1971	~	2014	1971	~	2014
CALCULATION	1)	Total Water Demand: ⑧+⑨+⑩+⑪	mm	134.4		131.2	101.4		112.1
	2)	Effective Rain	mm	5.82		5.68	6.17		6.82
	3)	Net Irrigation Requirement : 1) - 2)	mm	128.6		125.5	95.2		105.2
	4)	Application Efficiency (Ea)		0.6		0.6	0.6		0.6
	5)	Distribution Efficiency (Ed)		0.9		0.9	0.9		0.9
	6)	Filed Irri. Requirement : 3) / 4) * 5)	mm	222.6		195.5	164.8		182.1
	7)	Conveyance Efficiency (Ec)		0.9		0.9	0.9		0.9
	8)	Gross Irri. Requirement : 6) / 7)	mm	247.3		217.3	183.1		202.4
	9)	Gross Daily Irri. Requirement	mm/day	8.245		7.242	5.906		6.528
	10)	Monthly Demand	m^3/m/ha	2473		2173	1831		2024
	11)	Daily Demand	m^3/day/ha	82.45		72.42	59.06		65.28

- 5 year frequency water demand is calculated by the formula “AVERAGE + Gamble-Chow frequency Coefficient × STDEV” using the Gamble-Chow method
- Design unit water demand takes the maximum monthly value in the year

[Table 5.2-10] Monthly Water Demand for the Whole Period of Data

No	Years	Months(m^3/day/ha)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1971	0.0	71.5	61.7	77.0	38.4	62.3	79.8	86.0	82.4	59.1	47.0	0.0
~	~												
N	2014	12.0	3.0	70.6	41.8	35.5	43.7	57.2	75.4	72.4	65.3	76.6	35.3
AVERAGE		17.8	28.5	42.3	58.3	50.1	58.0	74.5	83.2	87.1	64.2	60.7	27.3
STDEV		24.37	30.59	27.99	17.6	10.06	10.39	17.58	17.25	17.26	12.67	21.69	28.46

[Table 5.2-11] Monthly Maximum Water Demand in Various Frequencies

Frequency	Frequency Coef.	Months(m^3/day/ha)											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2.33 year	0.0011	17.9	28.6	42.4	58.4	50.1	58.0	74.6	83.3	87.2	64.3	60.8	27.4
3 year	0.2538	24.0	36.3	49.5	62.8	52.7	60.7	79.1	87.7	91.6	67.5	66.2	34.6
4 year	0.5214	30.5	44.5	56.9	67.5	55.4	63.4	83.8	92.3	96.2	70.9	72.1	42.2
5 year	0.7195	35.4	50.6	62.5	71.0	57.4	65.5	87.2	95.7	**99.6**	73.4	76.4	47.8

Water requirement of SVIP was calculated through the process described above. In the Table 5.2-13 the 5 year maximum water requirement is 99.6 m^3/day/ha, which is quivalent to 0.001153m^3/s/ha. Since the whole net irrigation area is 43,370 ha, the total water requirement for the project is estimated to 50.0m^3/s (0.001153m^3/s/ha x 43,370ha = 50.0m^3/s , Sep.).

5.2.8. Review of Water Requirement

Review of water requirement considered the data applied to water requirement calculation of SVIP, pumping data from 2008 to 2015 from all estates (Nchalo, Alumenda, Sande Eanch & Kaombe) that are growing crops in huge scale agricultural facility.

5.2.8.1. Pumped Water of Estates

Table 5.2-14 is monthly data of pumping from Shire River during 2008 to 2015 by all estates (Nchalo, Alumenda, Sande Ranch and Kaombe)

[Table 5.2-12] Pumped Water Amount for the Whole Estates

Mon	08~09	09~10	10~11	11~12	12~13	14~15	Average
Jan	11,239,009	37,986,606	20,876,722	13,699,259	14,814,830	906,523	16,587,158
Feb	25,695,040	22,845,622	23,838,282	33,419,944	4,257,828	4,919,532	19,162,708
Mar	28,133,784	22,235,749	27,764,611	25,344,056	25,608,839	15,866,645	24,158,947
Apr	26,295,544	21,581,341	26,097,865	26,268,754	22,437,570	21,090,144	23,961,870
May	24,781,226	20,053,699	22,216,887	24,225,598	27,803,012	21,832,519	23,485,490
Jun	18,736,653	19,731,690	19,967,574	27,605,481	25,012,199	20,466,221	21,919,970
Jul	19,389,889	17,616,233	18,924,750	19,493,666	22,318,207	20,719,177	19,743,654
Aug	20,049,897	23,306,980	17,213,190	23,753,577	22,692,915	23,487,176	21,750,623
Sep	24,478,784	31,079,287	27,352,645	29,947,608	26,252,706	23,973,404	27,180,739
Oct	33,849,907	19,742,929	32,812,689	30,431,117	34,217,584	29,431,530	30,080,959
Nov	36,058,594	32,409,216	33,251,484	36,454,296	35,198,680	29,866,768	33,873,173
Dec	25,505,082	29,828,225	20,047,833	36,274,931	28,213,991	30,976,475	28,474,423

5.2.8.2. Water Requirement for Estates

Crop water requirement estimated for SVIP was calculated from the total water requirement for 14,032 ha of all estates (Nchalo, Alumenda, Sande Ranch & Kaombe). Presented in Table 5.2-15 are comparisons between the quantity of water pumped from Shire River from 2008 to 2015 by all estates (Nchalo, Alumenda, Sande Ranch & Kaombe) to water requirement calculated for SVIP. Figure 5.2-5 shows a graphical presentation of the results.

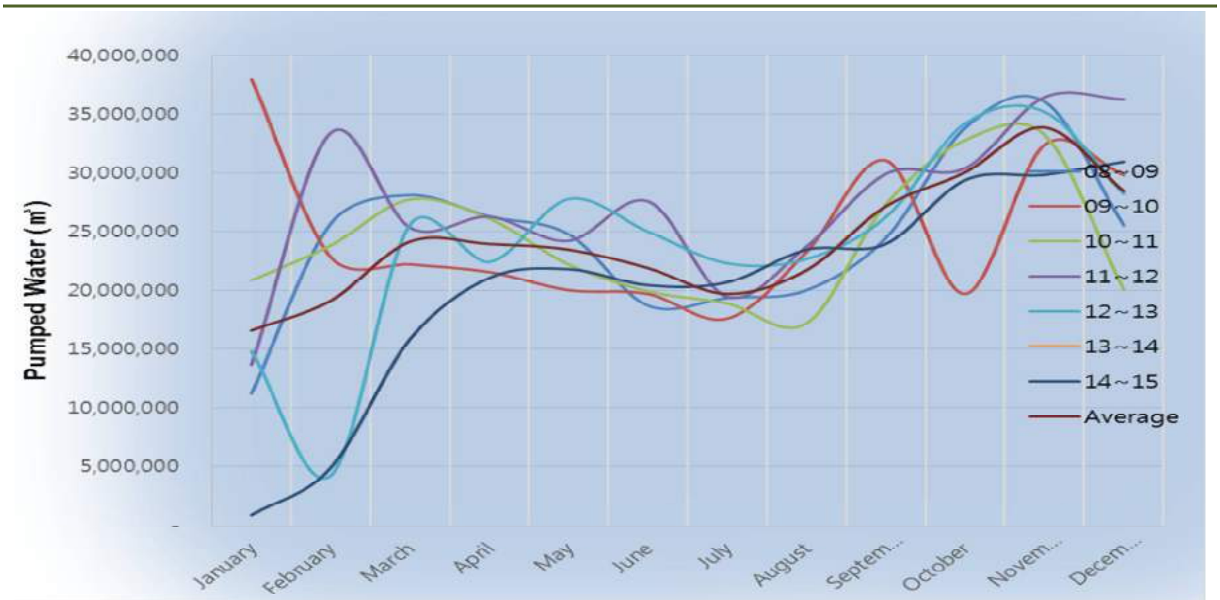
During the rainy season, the two values show similar results. However, during the dry season (May to October), calculated water requirement for SVIP is larger than actual water pumped. There are several possible reasons to explain this scenario. One possible reason could be the unstable power supply in the country. Water requirement would be reduced as area for smaller crop coefficient is getting larger from April to November when sugarcane has been harvested. However, it cannot be the basis for proposing larger amount of water requirement.

[Table 5.2-13] Pumped Water & Water Requirement

Month	Water Pumped (08~15)		Water Requirement (TFS)		
	Average(m^3/s)	Area(ha)	m^3/s	m^3/day/ha	Days
Jan	16,587,158	14,032	15,398,717	35.4	31
Feb	19,162,708		19,880,538	50.6	28
Mar	24,158,947		27,187,000	62.5	31
Apr	23,961,870		29,888,160	71.0	30
May	23,485,490		24,968,541	57.4	31

Jun	21,919,970		27,572,880	65.5	30
Jul	19,743,654		37,931,302	87.2	31
Aug	21,750,623		41,628,734	95.7	31
Sep	27,180,739		41,927,616	99.6	30
Oct	30,080,959		31,928,413	73.4	31
Nov	33,873,173		32,161,344	76.4	30
Dec	25,505,082		20,792,618	47.8	31

[Figure 5.2-5] Pumped Water & Water Requirement



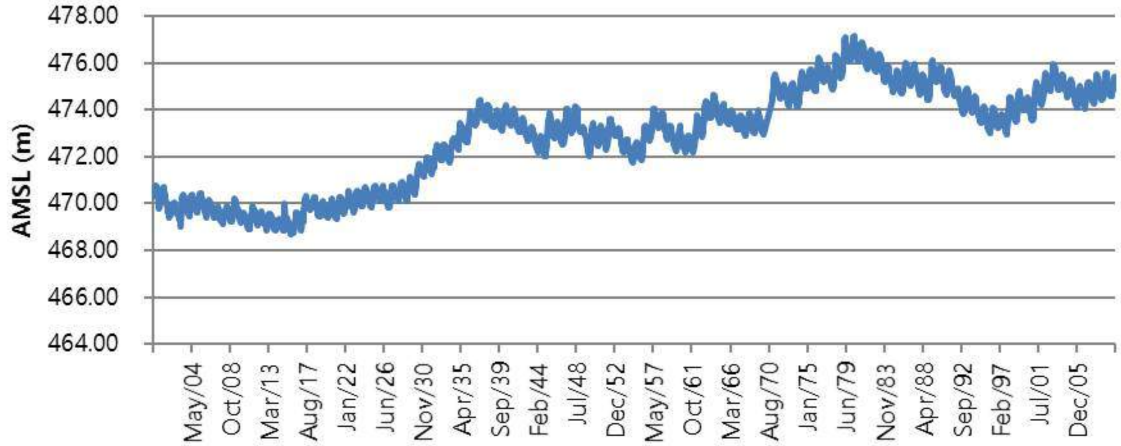
[Figure 5.2-6] Pumped Water Amount for the Whole Estates

The records and graphs show that data on pumping from Shire River at the estates are not reliable as they are affected by many factors which are not used in determining crop water requirement.

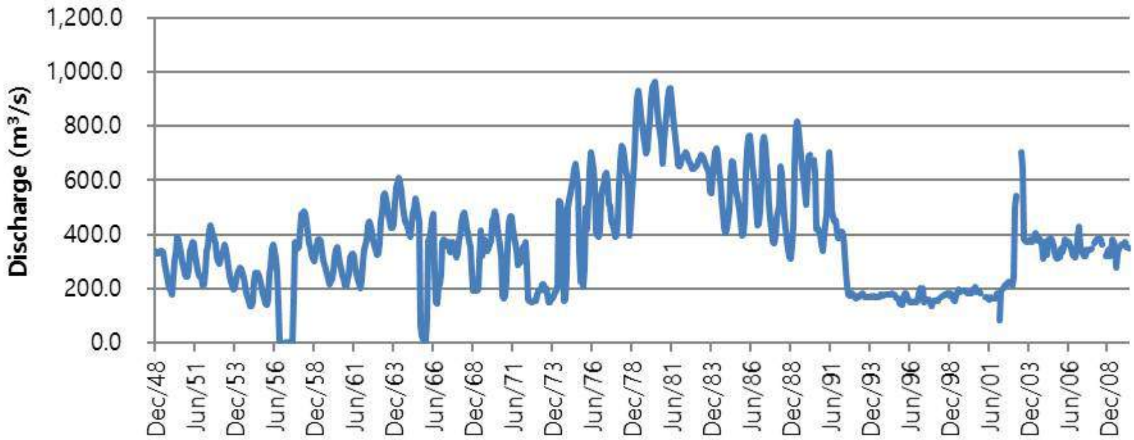
CHAPTER 6. OCCURRENCE OF A LONG SERIES OF DRY YEARS

6.1. Water Level Fluctuation of Lake Malawi and Discharge Changes of Shire River

Water level fluctuations of Lake Malawi and discharge of Shire River have been observed since 1896. As water level of Lake Malawi has fluctuated as shown on the Figure 6.1-1, Shire River has shown wide range of changes in discharge (Figure 6.1-2). Since the average water level was 470.3min 1900 the water level of Lake Malawi has decreased gradually to break record low of 469.0m in 1915. Since 1915, it has continued to increase to 471.2m in 1930 and reached 473.9m in 1937. Water level fluctuation of Lake Malawi is affected by the changes of rainfall in the catchment area.



[Figure 6.1-1] Water Level of Lake Malawi (1900~2010)



[Figure 6.1-2] Discharge of Shire River (1948~2010)

Shire River at Liwonde has does not have runoff data prior to 1948. However, runoff from the lake into the Shire was observed between 1915 and 1935. Increased rainfall from 1930 to 1935 raised the water level of Lake Malawi, thereby breaching the sand bar that had blocked the lake outflow into the Shire.

The high rainfall that occured between 1979 and 1980 caused water level of Lake Malawi to rise above 477m above sea level, resulting in runoff in excess of 900m^3/s in the Shire and trigered severe flooding in the Lower Shire Valley. However, a decrease in lake level from the 1990s resulted in a reduction of runoff in the Shire. Heavy rainfall that took place between 2000 and 2003 caused increase of runoff of more than 700m^3/s in the Shire.

6.2. Causes of "No outflow" from Lake Malawi

More recently (Atkins, 2011a) it has been recognised that anthropogenic activities coupled with climate change are likely to have profound impacts on the Lake Malawi ecosystem that could determine lake volumes and levels as well as outflow from it. They particularly single out changes in precipitation and evapotranspiration but further than these two parameters, it should be pointed out that as has happened to Lake Chad, Lake Malawi could indeed be at risk to anthropogenic activities especially land use within its catchment.

Studies on the levels of the lake have been carried out by a number of researchers and an account of these levels is provided by Norplan (2011a) and is presented in Table 6.2-1.

[Table 6.2-1] History of Lake Levels of Lake Malawi

Period	Description	Period	Description
1800–1809	Levels were "so low that local inhabitants traversed dry land where a deep lake now resides". The Ruhuhu tributary was completely desiccated.	1910–1919	No outflow. Minimum level of 470.1m reached in 1915 following which levels rose by 0.5 m to 1919.
1810–1819		1920–1929	No outflow. Levels rose by 1.75 m over the decade.
1820–1829	Levels may have been about 465m at the start of the century (Nicholson and Yin 2001).	1930–1939	Levels rose by 2.5 m from 1930 to a peak in 1937. Outflows resumed from 1935.
1830–1839		1940–1949	Country-wide drought in 1949.
1840–1849		1950–1959	Temporary bund in place at the outlet from the lake from October 1956 to July 1957.
1850–1859	Lake level very high from 1857.	1960–1969	Bund placed across the Shire at Liwonde in 1965 during construction of the Kamuzu Barrage, which was also commissioned in 1965.
1860–1869	Lake level very high to 1863.	1970–1979	Peak annual levels of 476.9–471.2 reached in the years 1978, 1979 and 1980 with inundation of lakeshore areas and high flows in the Shire.
1870–1879	Lake level high in 1873 (~475 m; Kidd 1983), but falling in 1875–78.	1980–1989	
1880–1889	Lake level high in 1882 (~474 m; Kidd 1983).	1990–1999	Levels declined from 474 m to 473m from 1991 to 1997, affecting Shire flows and hydropower generation.
1890–1899	Lake level very low in 1890 but rising in 1892–95.	2000–2009	Unusual rainfall patterns in the 2001/02 crop season caused both drought and flooding. Country-wide drought following rainfall deficits in the 2004/05 wet season.
1900–1909	Lake levels dropped with the outflow stopped by a sandbar in 1908.	2009-2016	

In another study (Shela, 2000) reasons for the sudden drop of water levels in both Lake Malawi and Shire River is discussed. The failure of Lake Malawi to release water to the Shire in 1915 when the river is said to have dried up, has been a subject of many theories. One such theory is that there must havebeen tectonic movements within the region, causing the lake basin to drop and change the level at which it releases water to the Shire. This theory is supported by records of earth tremors within the Rift Valley. Another reason given for this event above the theory is that low rainfall within the catchment during the period prior to 1915 was responsible for the lowering of lake levels even though no reference is given to this assertion. Other reasons that are associated with the lake's failure to maintain its levels and release water to the Shire River during 1915 include:

- Channel blockage at Samama where the Shire begins;
- Vegetation overgrowth and piling of sedimentation from small tributaries near the lake.

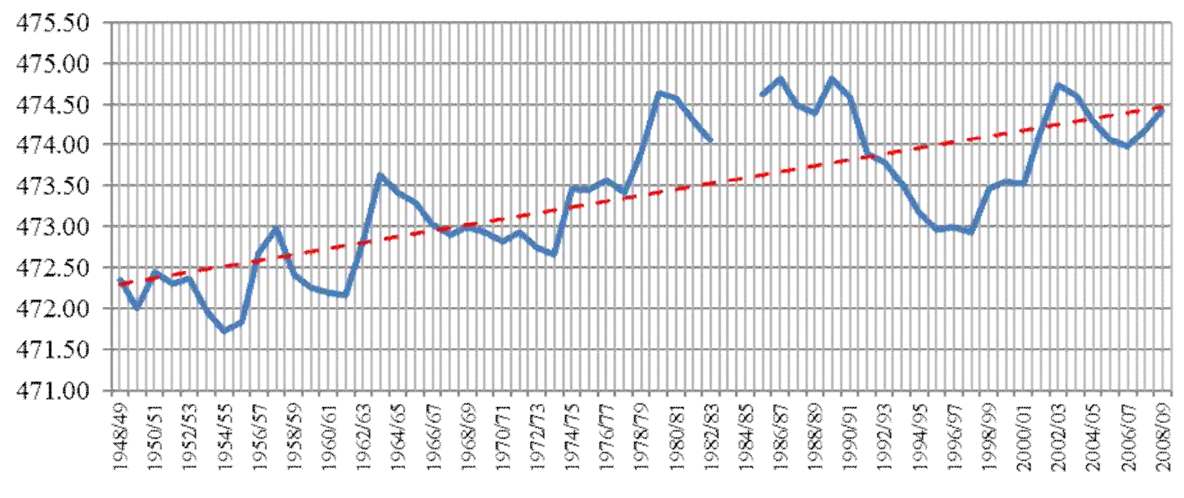
Any comprehensive reason given to the causes of "no outflow" from the lake must take into account the lake water balance model which is of the form:

$$\mathbf{L_p = L_a + I + P_d + g - O - E}$$

Where
- $\mathbf{L_p}$ is the present lake level;
- $\mathbf{L_a}$ is the antecedent lake level;
- $\mathbf{I}$ is the inflow to the lake from its catchment;
- $\mathbf{P_d}$ is direct precipitation over the lake;
- $\mathbf{g}$ is groundwater flow to the lake;
- $\mathbf{O}$ is outflow from the lake; and
- $\mathbf{E}$ is evaporation from the lake's surface.

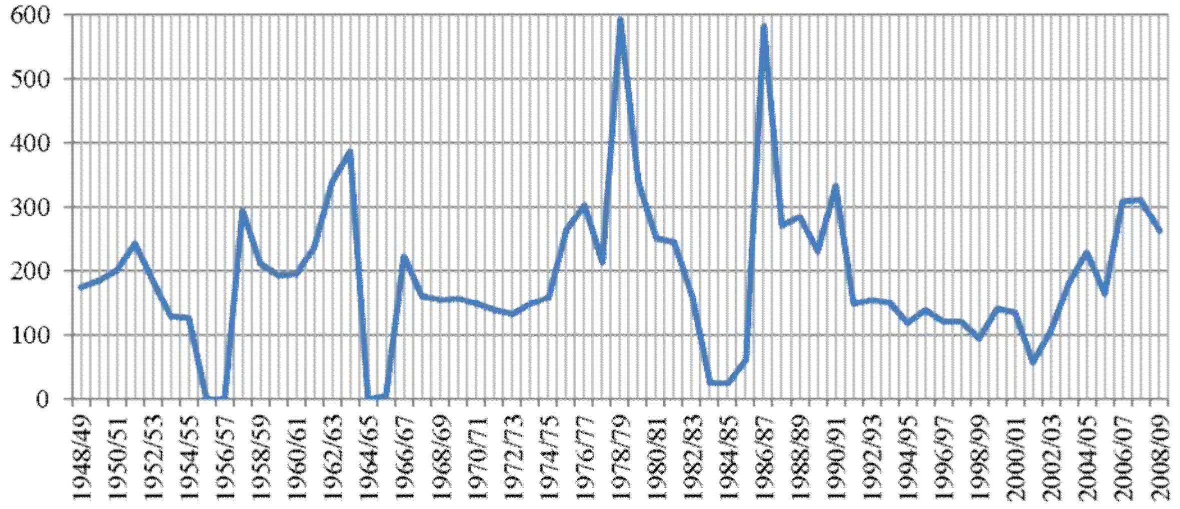
It therefore must be noted that unless values of the above parameters are known based on long-term data, a reasonable judgment can be obtained as to why the lake level must have been so low as to cause the cessation of flow in the Shire River. It is currently not known as to what the total inflow into the lake is due to a number of ungauged rivers and streams that flow into it and so, it cannot be possible even to give a value of inflow in the equation.

In order to understand the behaviour of the lake as regards to its minimum lake levels, annual minimum lake levels from 1948/49 to 2008/09 were plotted in series from data obtained from the Water Department and appearing in Figure 6.2-1. It shows the trend of annual minimum lake levels that depict a general rise.



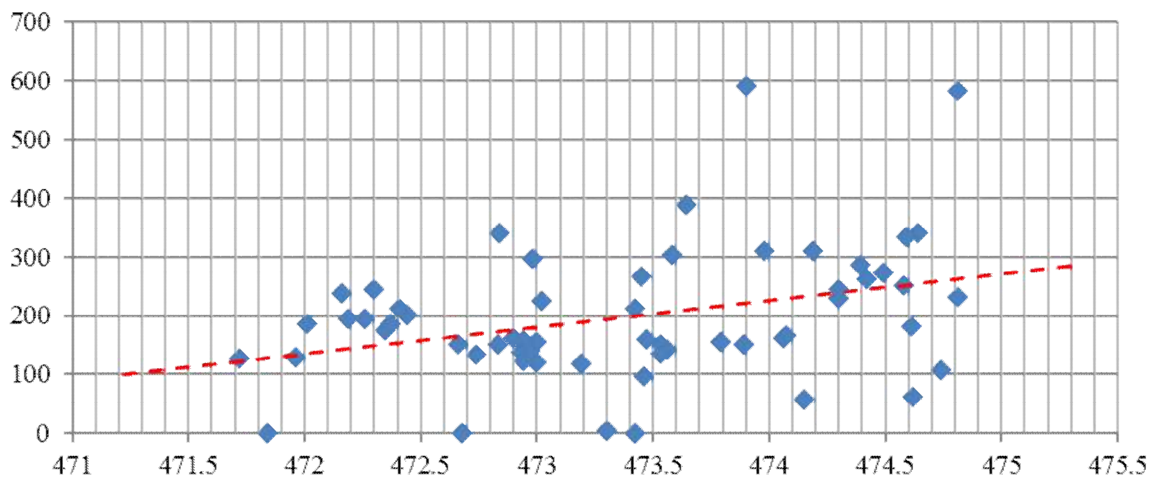
[Figure 6.2-1] Annual Minimum Lake Levels (1948/49 to 2008/09)

It cannot however be said as to why there is that rise in annual minimum lake levels whether it is due to sedimentation at the lake's bottom, increase in precipitation, reduced evaporation or other reason. A comprehensive study on this subject is therefore required to understand fully the linkage between lake levels and outflow through the Shire. A plot of the annual minimum flows for the Shire River at Liwonde (1B1) was also made as seen in Figure 6.2-2. The unbroken record of flows at this station shows two very high flows in 1978/79 which corresponded to the high lake levels of that year and in 1986/87. The lowest flows were recorded in 1955/56 and in 1964/65.



[Figure 6.2-2] Annual Minimum Flows of the Shire at Liwonde (1B1) from 1948/49 to 2008/09

A plot of the annual minimum lake levels and the annual minimum flows of the Shire at Liwonde was also performed as seen in Figure 6.2-3. There is no direct relationship between the two which shows that there are a number of factors that are responsible for both the lake level and the flow at the gauging station in Liwonde. The regulation of the Kamuzu Barrage is one of the factors that may also be responsible for this poor relationship.



[Figure 6.2-3] Relationship between Annual Minimum Lake Levels and Annual Minimum Flows of the Shire at Liwonde (1B1)

6.3. Topographic Factor Affecting the Discharge of Shire River

Shire river takes off from Mangochi District in the southern part of Lake Malawi, and flows through Upper Shire Valley, Middle Shire and Lower Shire Valley before joining the Zambezi in Mozambique. Upper Shire Valley stretches from Mangochi to Matope Bridge. The area is characterised by very gentle slope of the river bed. The lowest bed level in Mangochi is at 471maslwhile the elevation of the bed level at Matope Bridge is at 465m above sea level. The distance between the two points is around 134km. Kamuzu Barrage at Liwonde is located at a distance of 72km away from Mangochi, with the lowest bed level at 468m above sea level. Thus, there is only 3m elevation difference between Mangochi and Liwonde Shire River beds.

During the topographic studies in this area TFS found the bend section between Mangochi and the upper reach of Lake Malombe could be another determining factor to Shire river discharge. This area includes a sharp bend at Chipalamawamba village, TA Mponda. This type of bend shape of river course is often occurred in the coastal areas when the river discharge is reduced. As the flow velocity reduces at the bend, it leads to sediment deposit accumulating at the river bend and river bed. It in turn blocks the river course and reduces the velocity again. Figure 6.3-1 ~ Figure 6.3-3 shows the whole view of the bend area and the sediment deposited in the channel.

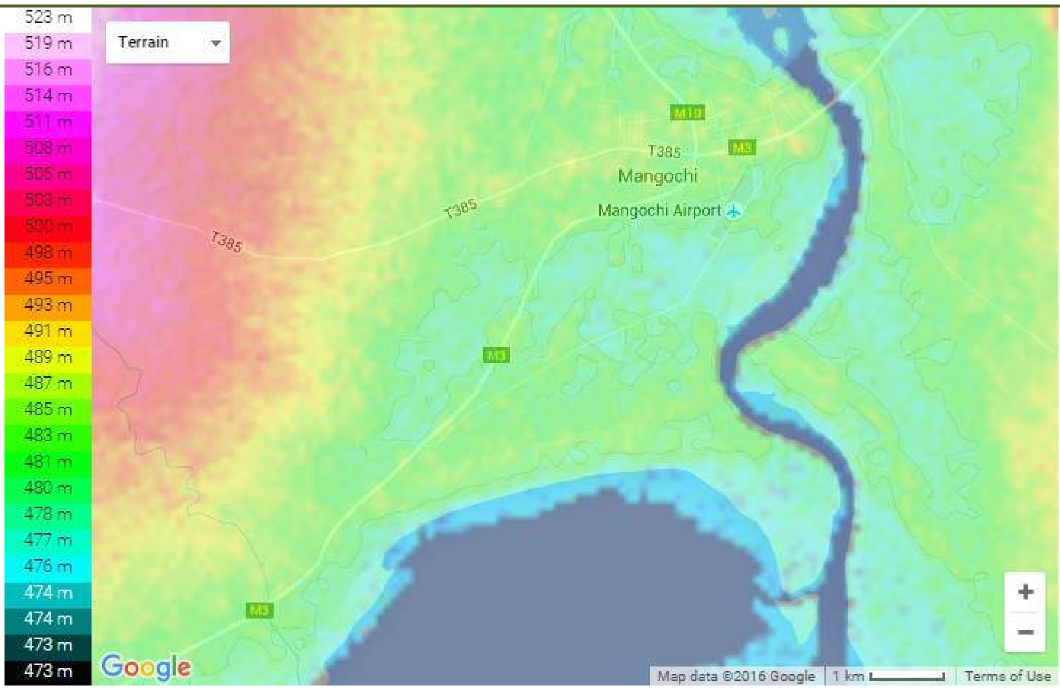
When severe floods take place, sediments deposited at the bend scour along the high river flows thereby increasing the width of the river at the bend. Once the width of the channel increases, the river runs smoothly. However, if decreasing precipitation lasts for several years, sediments start accumulating at the bend, making the river course narrow. When the river course decreases, the difference between water level of Lake Malawi and Shire River runoff increase (Figure 6.3-7~ Figure 6.3-12). (Source data: Water Resource Investment Strategy (2011) & National Water Resources Master Plan,1986)

During the period between 1970 and 1990, the rainfall was high, and the river course was well developed at the bend section, so that a linear relation between the water level of Lake Malawi and Shire River discharge was set up (Figure 6.3-7 and 8). This linear relation was maintained by 1992 in some extent (Figure 6.3-9) but enough. It is deduced that sedimentation has been started at the bend section.

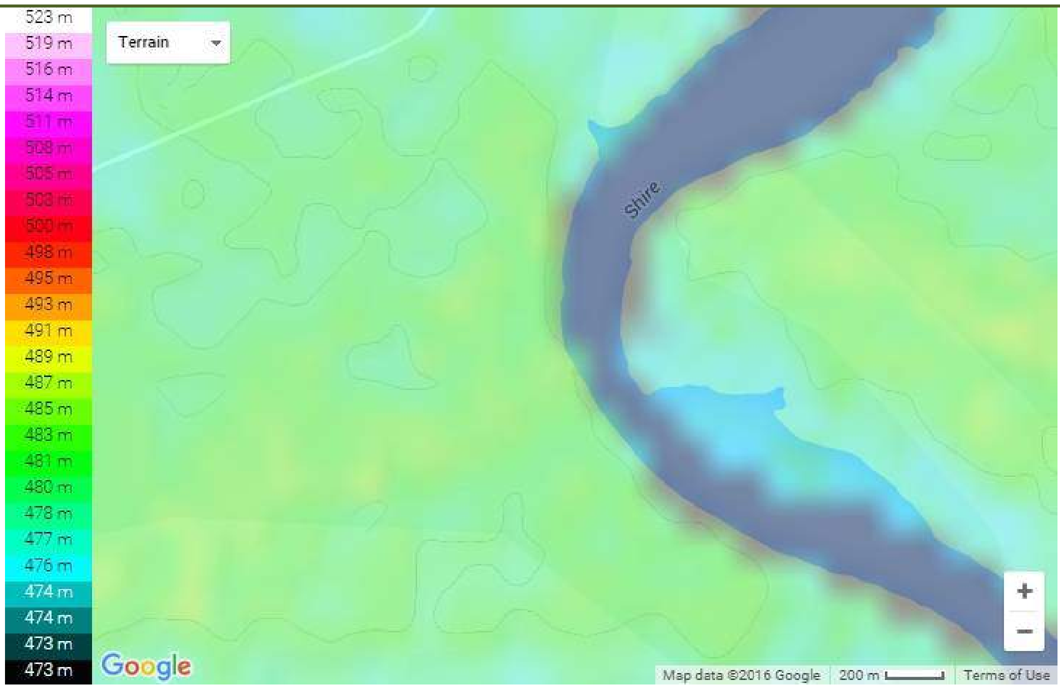
As rainfall between 1993 and 2001 was lower than the average, sediments accumulated at the bend. From 1993 to 2001, runoff remained at the level of 150~200m^3/s without increase regardless of water level change from 473 to 475 masl. It is because once the river course is narrowed, increasing water level cannot raise the runoff proportionately.

However, the flow changed when the flow of water increased between 2002 and 2003. In this period, water level reached as high as 476 masl for a longer period, removing accumulated sediments at the bend. Figure 6.3-11 shows that the discharge was changed from 198.95m^3/s (April 2002) to 704.5m^3/s (July 2003) while the water level in the lake was maintained at 475.6masl.

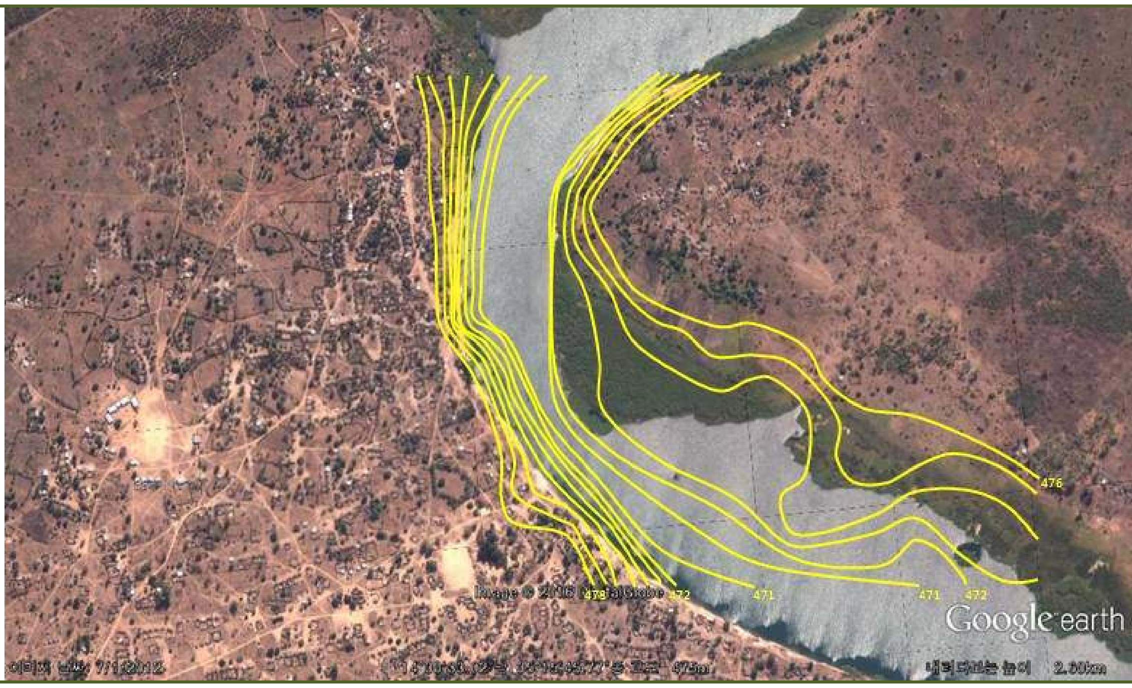
Once enlarged bend section, the sedimentation is slowly progressed up to now. Figure 6.3-12 shows the situation clearly. The water level of Lake Malawi changes from 474 masl to 475.6 masl as runoff remains within the range of 300~400m^3/s. This pattern is similar to that of 1993 and 2001 (Figure 6.3-10). This pattern is assumed to occur when only limited removal of sediments occurs at the bend and increase in water level makes little changes in removal of the sediments.



[Figure 6.3-1] Bend Section between Mangochi and Lake Malombe (Google map)



[Figure 6.3-2] Enlarged View of the Bend Section (Google map)

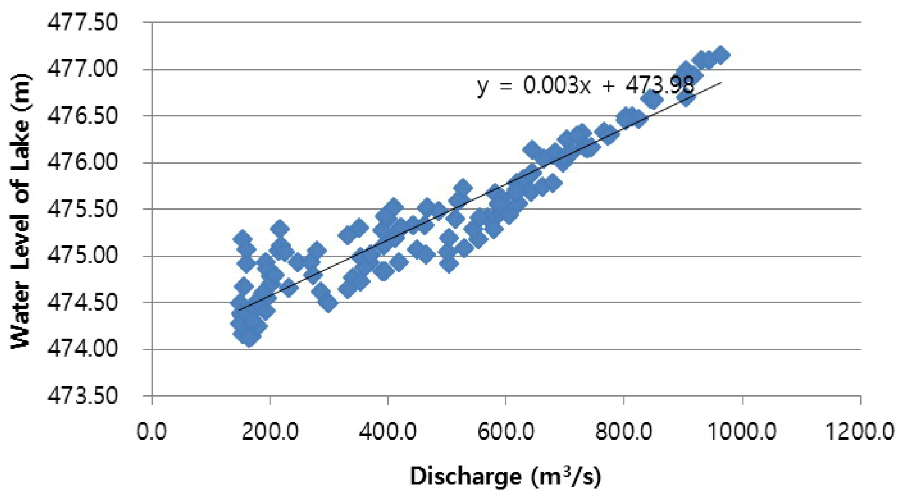


[Figure 6.3-3] Depth Status of Shire River Bend Section (Google map)

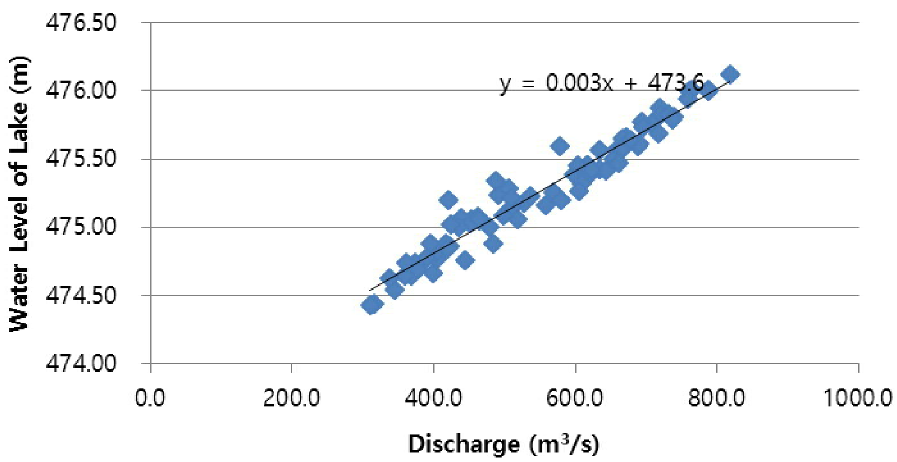
[Figure 6.3-4] View of Shire River Bend Section (1)

[Figure 6.3-5] View of Shire River Bend Section (2)

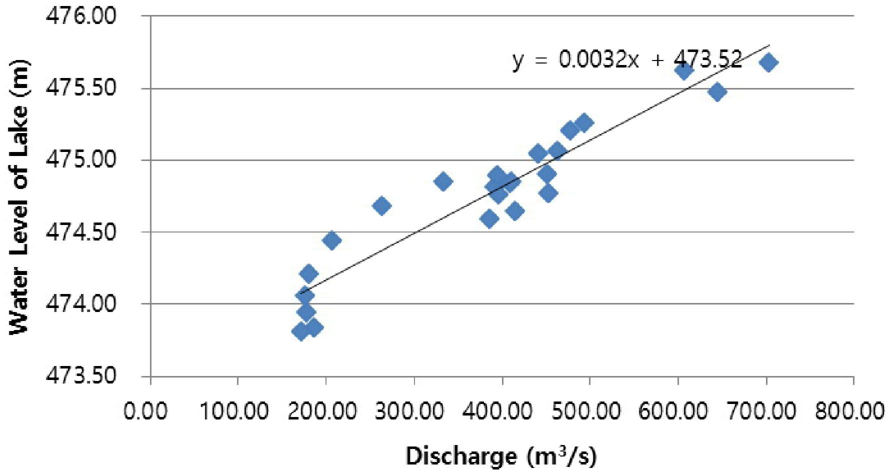
[Figure 6.3-6] View of Sediment Deposit at Shire River Bend Section



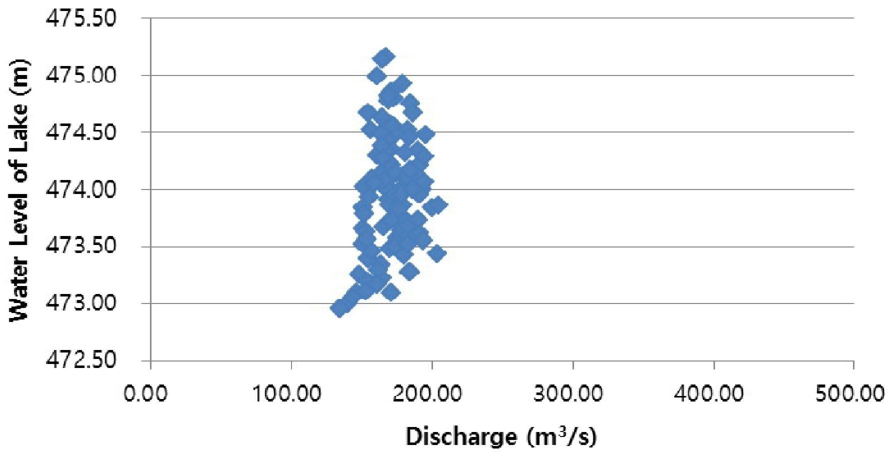
[Figure 6.3-7] Relation of Water Level of Lake Malawi and Shire River Discharge (1970~1980)



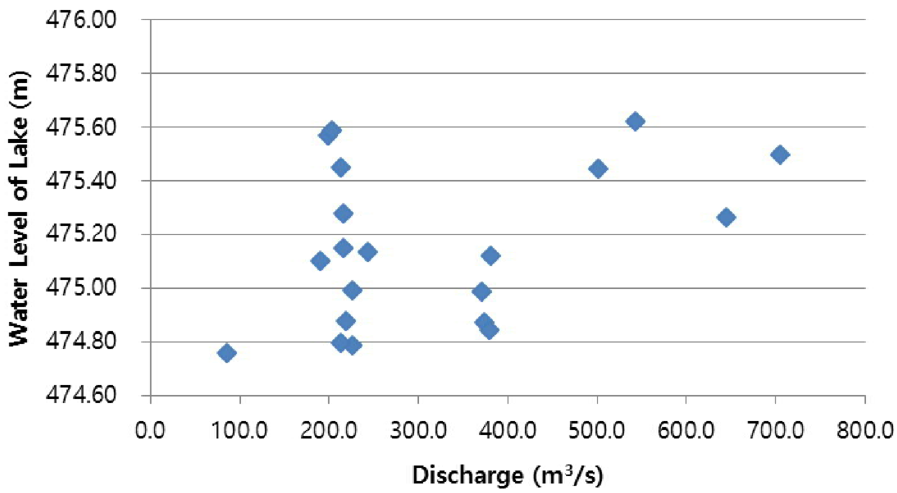
[Figure 6.3-8] Relation of Water Level of Lake Malawi and Shire River Discharge (1981~1990)



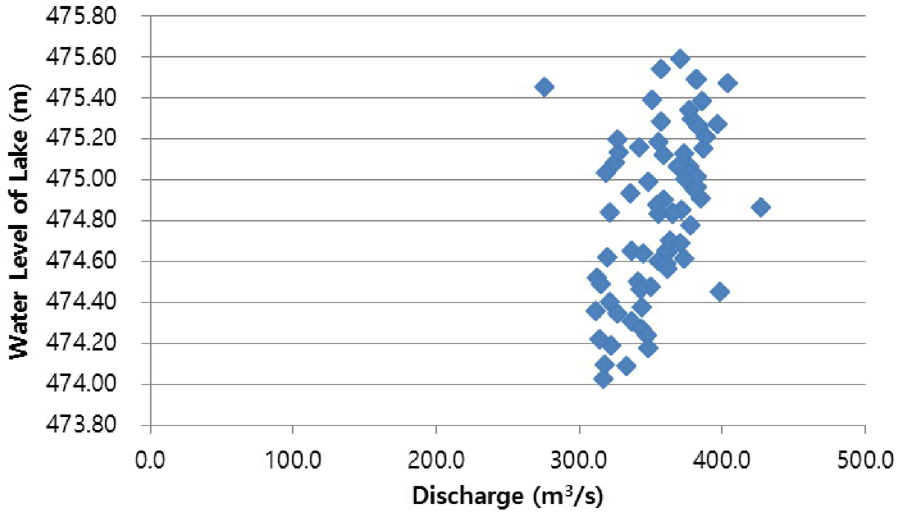
[Figure 6.3-9] Relation of Water Level of Lake Malawi and Shire River Discharge (1991~1992)



[Figure 6.3-10] Relation of Water Level of Lake Malawi and Shire River Discharge (1993~2001)



[Figure 6.3-11] Relation of Water Level of Lake Malawi and Shire River Discharge (2002~2003)



[Figure 6.3-12] Relation of Water Level of Lake Malawi and Shire River Discharge (2004~2010)

6.4. Management of Hydrological Stable Discharge of Shire River

Figures 6.2-11 and Figure 6.2-12 help to show how to ensure stable runoff from a hydrological perspective. According to Figure 6.2-11, 700m^3/s runoff can occur from the lake when the water level is at 475.6m above sea level, with sediments at the bend removed. Therefore, it is important to maintain the sectional area of channel at the bend free of sediments.

In order for Kamuzu Barrage at Liwonde to function as planned, the linear relationship between water level in Lake Malawi and runoff in the Shire should be maintained. To do so, the cross sectional area of flow at the channel bend should be maintained within a fixed range. Although sediments deposited at the bend can be removed by high water flows, it becomes difficult to scour such sediments if they are allowed stay in place for a long period of time. Thus, it is absolutely necessary to dredge this section of the channel on a regular basis in order to maintain the cross sectrional area of flow and hence sustain flows in the Shire.

In terms of the source of sediment, the consultant assumes that the influential area shall be confined in the catchment areas of outlet of Lake Malawi. Because the Lake Malawi maintains very standstill state all through the year, the sediment sources far from the outlet of the lake will not migrate up to this point. Therefore it would be rather easier to implement the mitigation measures in some limited influential areas.

In this way, preservation, conservation and sustainable utilization of the system's resources would be another way of ensuring that river course is maintained. In this regard, some of the mitigations measures that could be proposed include:

- Implementing afforestation projects in the catchment of Lake Malawi and Shire River system;
- Improving agricultural extension services in the two catchments in order to enhance good agricultural practices;
- Implementating policies regarding land use practices and imposing stiff penalties for violation thereof;
- Strengthening environmental impact assessments for all projects that may have a negative impact on the Lake Malawi/Shire River system;

- Providing incentives for “good practices” related to land use and land husbandry practices;
- Encouraging civil society organizations and Community Based Organizations to take part in promoting good land use practices;

6.5. Risk of Recurrence of the Scenario

The risk of recurrence of “no outflow from Lake Malawi is difficult to confirm against a background of the absence of very long period of records of water levels and flows of the Shire River. The observation that the flow of the Shire River ceased only occurred once and it is therefore not possible to judge the frequency of such events. However, Scholz et al (2015) provided some insight on the behaviour of the lake in the past 1 million years. Scholz and his fellow researchers observe that the variations in lake level may be an explanation for the lake's diversity in fish species hosting about 1,000 unique species of brightly colored fish called cichlids. Using data from the lake’s core at various points throughout its history, the lake has cycled down to less than half its current 700-meter depth, the researchers conclude. They indicate that during these times, “a significant portion of the lake was not covered with water, but in grasslands or even deserts”.

Scholz states that, “there were times when there were two distinct water bodies, which would have further promoted geographic separation of groups of fish and enhanced the generation of new species.” They determined past lake levels by looking for sediment traits associated with modern-day shallow lakes in the Rift Valley. By looking at how well preserved carbon debris is in different depths of the core, the researchers can determine whether lake levels in the past were deep enough for two or just one layer. In their conclusion of the research they state, “This paper will pave the way for future publications from collaborators on the project. It provides a foundational data set for other researchers to build upon”. They do not state when or how many times the lake levels were lowest or highest.

6.6. Further Study Required

The causes of topographical changes at the bend and its relation to Shire River runoff have been inferred from a combination of observed data analysis and field observations. Systematic and theoretical supports are required to apply to reality. To do so, it requires precise measurement of bend topography, exact data collection of the history of topographical conditions, measurement of sediment discharge and sedment characteristics. In addition, it is also necessary to sample velocity and distribution of current direction during the rainy and dry seasons. All the data should be used as input to the 3D hydrological model, including sediment behavior, in order to run simulations of many different cases to find out the cause of changes of the cross sectional area of flow of the channel and its effect of the maintenance of the river course.

6.7. Existing Regulation Range of Kamuzu Barrage

According to the Detailed Design Report Volume 1 Final by Nonplan, in association with Willy and Partners Engineering Services, the existing Kamuzu Barrage has a control range corresponding to water levels of Lake Malawi, defined as “Lake Level”, between 473.5 masl (LRW) and 475.32 masl (HRW). The report further states that the present operation rules for the Kamuzu Barrage provide that once Lake Level falls below 473.5 masl the gates should be fully opened. Lake Level above 475.32 masl will also require fully open gates. The corresponding water levels at the barrage vary depending on flow and Lake Levels. Flow simulations carried out for the Lake Level Control Feasibility Study in

2003 (by Norconsult) and for the Shire River Flow Augmentation Study in 2003 (NORPLAN) showed that the water level at the barrage was between approximately 0.15 m and > 1 m lower than the Lake Level. The lowest difference was calculated at a discharge of approximately 180 m^3/s whereas the highest difference was calculated to for high Lake Levels and flow of >600 m^3/s.

The results of the hydraulic simulations for different hydraulic conditions are presented in Table 6.7-1. In the column "Condition" "Unreg" means that all gates are open, while "Reg" means that the flow through the barrage is regulated.

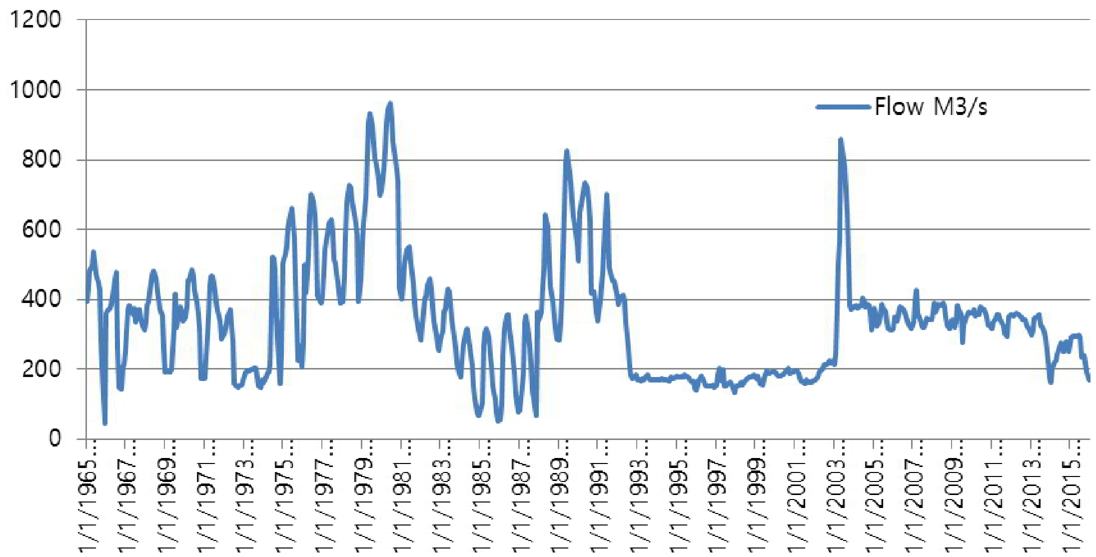
The most interesting values are scenario 5, where there is a large local inflow, and low demand for additional release from Kamuzu Barrage to cover the demand of the downstream stakeholders. Then there is hardly any head between the Barrage and the Lake.

[Table 6.7-1] Hydraulics of the Shire River

Scenario	1	2	3	4	5	6	7	8	9	10
Flow through Barrage (m^3/s)	Q=10	Q=70	Q=130	Q=170 (LL=474)	Q=170 (LL=HRWL)	Q=260	Q=630	Q=900	Q=1,600	Q=2,400
Tributary Inflow	none	small	none	small	large	small	none	large	large	large
Condition	Unreg.	Unreg.	Reg.	Reg.	Reg.	Unreg.	Unreg.	Unreg.	Unreg.	Unreg.
Lake Malawi	472	472.9	473.5	474	475.72	474.38	475.72	476.5	477.63	478.79
Lake Malombe	471.96	472.83	473.4	473.92	475.72	474.25	475.58	476.33	477.49	478.63
Barrage Headwater	470.74	471.57	472.17	473.4	475.69	473.11	474.6	475.58	476.64	477.93
Barrage Tailwater	470.73	471.55	472.15	472.44	472.6	473.08	474.54	475.2	476.45	477.61
Station 1B1	470.62	471.43	472.05	472.35	472.52	472.99	474.44	475.09	476.36	477.53
d/s Railway Bridge	470.6	471.41	472.03	472.32	472.5	472.97	474.04	475.02	476.14	477.12
Upstreams rapids	465.48	466.06	466.4	466.57	466.95	466.98	468.64	469.34	470.37	471.11

6.8. Flow Regime at Kamuzu Barrage

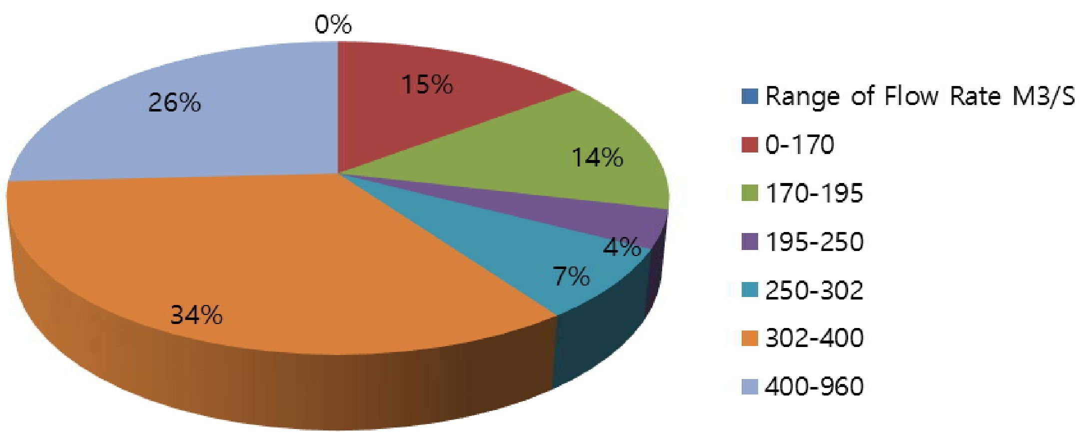
Shire River flow records at Kamuzu Barrage, from 1965 when the barrage was constructed to end 2015, were collected from the MoAIWD and ESCOM. Trend of cyclic occurrence are noted in Figure 6.8-1.



[Figure 6.8-1] Shire River Flow at Kamuzu Barrage Station 1B1

The mean flow from 1965 to 2015 is 342.46 m^3/s. The highest flow was observed in 1980 when it reached 963 m^3/s. The average flow in the same year was 802.9 m^3/s. There were other high flows such as in 2003 when the flow reached 860.42 m^3/s S. On the lower side of the flows, low flows were noted between 1985 to 1987 and 1995 to 1997. In these years where the flows were low, the lowest average flow was in 1996 where it was 157.96 m^3/s. In the year 2015 the average flow was 259.77 m^3/s. Although the trend is showing a repetition of 1985 to 1987 and 1995 to 1997, the average is increasing as noted from the average flow of 2015 compared to 1985 and 1995.

The data collected was also used to develop a pie chart that would show the extent of range of flows in order to help the project appreciate the plan that can be developed for O&M of SVIP and Kapichira power generation. There was a good average flow between 2003 and 2012 which was 370.30 m^3/s. It is expected that there will be better minimum flow after completion of the rehabilitation of Kamuzu Barrage.



[Figure 6.8-2] Range of Flow Regime

The pie chart shows that most of the flows are within the range 302 to 400 m^3/s followed by the range between 400 and 960 m^3/s.

The minimum flow that can be used to run the generators at Kapichira Generation Station is not less than 170 m^3/s. The flow of 170 m^3/s. at Kamuzu Barrage, including the flows from tributaries between Kamuzu Barrage and Kapichira Dam, barely enable the operators to run all the generators. The four generators at Kapichira Power Station require a flow of 268 m^3/s and it is assumed that the tributaries between Kamuzu Barrage and Kapichira Dam add up to 98 m^3/s. Therefore, to run all four generators at Kapichira Power Station and provide a minimum 50% for SVIP, which is equivalent to only phase I, the flows at Kamuzu Barrage should be 195 m^3/s. It is possible to have a deliberate arrangement where one generator is on standby or undergoing rehabilitation while SVIP is in full operation and both systems using the 170 m^3/s. This shows that the possibility of running SVIP and three generators can be planned in years with low flows. It is noted that the low flows experienced so far last for three consecutive years and are worse from September to December. Therefore, in such difficult years there would still be enough water for one growing season and the second growing season can be done but the crops would be stressed by about 40%.

CHAPTER 7. COST ESTIMATION OF SVIP

Generally, the construction budget comprises direct construction cost, consulting service fees (design and construction inspection), public charges and tax, and usually includes a contingency component to take care of unexpected expenses. For SVIP, direct construction cost consist of intake, canal, road, and land consolidation costs in line with planned irrigation facilities.

7.1. Calculation Condition of Direct Construction Cost

In preparing direct costs of any project, it is absolutely necessary to conduct investigations about existing local prices in order to gain knowledge about labor expenses, material costs, and construction machinery cost with a view to calculating the direct construction cost of the project. Price investigations for SVIP were conducted between October and November 2015 when the exchange rate was 650MK to 1 USD.

Labor Costs

As highlighted in the preceding discussion, estimates for labor costs for the intake, canal, and land consolidation for SVIP were done using data collected from the local price investigation exercise.

[Table 7.1-1] Labor Costs in Malawi (2015)

Descriptions	Unit	Investigation	
		Malawi(MK)	USD
Unskilled Labourer	m.d	1,000	1.538
Skilled Labourer	m.d	*2,500	3.846
Concrete work	m.d	3,000	4.615
Steel worker	m.d	2,500	3.846
Carpenter	m.d	2,000	3.076
Scaffolding man	m.d	2,000	3.076
Stonemason	m.d	1,700	2.615
Plumber	m.d	2,000	3.076
Supervisor	m.d	3,500	5.384
Machine main operator	m.d	4,000	6.153
Machine Supervisor	m.d	8,000	12.307
Truck driver	m.d	4,000	6.153
Machine driver	m.d	4,000	6.153
Painter	m.d	*2,000	3.076
Welder(general)	m.d	2,000	3.846

* Application of labor cost of similar discipline

Materials Costs

Cost of main materials that could be procured locally such as reinforcement bars, aggregate, cement, and oil were based on data obtained from the local price investigation.

[Table 7.1-2] Materials Cost in Malawi (2015)

Descriptions	Sub Explain	Unit	Investigation	
			Malawi(MK)	USD
Cement	50kg	EA	6,500	10.000
Rebar	All size	ton	800,000	1,230.769
Sand	Include transportation	m^3	20,000	30.769
Gravel	Include transportation	m^3	25,000	38.461
Plywood	12mm *121* 242cm	m^2	*8,000	12,307
Wire	#20 D=0.9mm	kg	1,500	2.307
Nail	N50	kg	1,500	2.307
Farm oil		ℓ	*3,000	4.615
Super		ℓ	800	1.230
Diesel		ℓ	800	1.230
Wire Mesh	#6 150*150	m^2	13,000	20.000

* Application of material cost of similar discipline

Construction Machinery Cost

Construction machinery costs presented in Table 7.1-3 were prepared following the price investigation carried out in October 2015.

[Table 7.1-3] Construction Machinery Cost

Descriptions	Sub Explain	Unit	Investigation	
			Malawi(MK)	USD
Bulldozer	19ton	day	260,000	400.000
Bulldozer	32ton	day	300,000	461.538
Wetland Bulldozer	13ton	day	200,000	307.692
Excavator(Caterpillar)	1.0 m^3	day	179,000	275.385
Excavator(Caterpillar)	0.7m^3	day	180,000	276.923
Loader(tire)	1.72 m^3	day	200,000	307.692
Motor grader	3.6m	day	200,000	307.692
Dump truck	10ton	day	60,000	92,308
Dump truck	15ton	day	75,000	115.385
Tire roller	8~15ton	day	75,000	115.385
Vibration roller	10ton	day	95,000	146.154
Water tank(water-cart)	16000 ℓ	day	50,000	76.923
Concrete mixer	0.10 m^3	day	*15,000	23.077
Concrete mixer	0.45 m^3	day	35,000	53.846
Concrete mixer	1.0 m^3	day	70,000	107,692
Caterpillar crane	15ton	day	20,000	30,769
Motor generate	50kw	day	20,000	30,769
Concrete vibrator	Ø45, 2.6kw	day	12,000	18.462

* Application of construction machinery cost of similar discipline

7.2. Calculation of Conditions of Indirect Cost

Contingency Cost

Contingency cost is an amount of money intended to compensate the unexpected increase in expenses arising from the difference between the time of preparation of the engineer's draft cost estimate and the actual implementation of the works. A contingency of 20% was proposed for SVIP based on the locally collected data during the local price investigation exercise and advice from the DoI.

Consultant Cost

The consultancy cost can be broken down into the following costs: design costs during the implementation phase, costs pertaining to support to the bidding process, and construction supervision and operation cost. The ratio of cost for consultancy to total budget should either amount to the locally accepted 6.5% or be less than 6% given the size of the SVIP.

7.3. Calculation of Project Cost

The total cost of SVIP taking into account direct and indirect construction costs is estimated at 532,882,000 USD. But this figure has to be reviewed in line with the budget allocation for Phase I works while costs for the design of the intake, feeder canal and all the canal system up to crossing Mwanza River are based on a total hectarge of 43,370 ha of the project area.

[Table 7.3-1] SVIP Investment Cost

Descriptions	Quantities	Total (USD)	Remarks		
I. Direct Total Cost		**418,610,000**	Sum of [1) + 2) + 3) + 4) + 5) + 6)]		
1) Inlet works		**4,000,000**			
2) Feeder Canal	**L=33.80km**	**33,100,000**	Lined canal		
3) Supuni Canal	**L=10.70km**	**5,900,000**	Lined canal		
4) Bangula Canal	**L=88.00km**	**51,200,000**			
-Zone A Canal	L= 3.64km	11,600,000	Syphon		
-Bangula Canal A	L=12.51km	7,800,000	Lined canal		
-Bangula Phase II	L=71.85km	31,800,000	Lined canal		
5) Branch Canal	**L=93.20km**	**12,800,000**			
-Branch- Phase I	L=40.80km	5,800,000	Lined canal		
-Branch- Phase II	L=52.40km	7,000,000	Lined canal		
6) Land Consolidation		**311,610,000**	**Second & Tertiary**	**Land Leveling**	**Roads & Drainage**
Sub-total	**A= 33,395ha**	**311,610,000**	**47,430,000**	**211,340,000**	**52,840,000**
-Zone I-1	A= 7,452ha	65,170,000	9,780,000	44,310,000	11,080,000
-Zone A	A= 5,199ha	48,450,000	7,270,000	32,940,000	8,240,000
-Zone B	A= 6,737ha	61,160,000	9,060,000	41,050,000	10,260,000
	L=7.1km		790,000		
-Zone C	A=10,749ha	105,000,000	15,750,000	71,400,000	17,850,000
-Zone D	A= 3,258ha	31,830,000	4,780,000	21,640,000	5,410,000
II. Contingency(20% of direct cost)		**83,722,000**	= 1) * 0.2		
III. Consultant(6% of direct cost)		**25,116,600**	= 1) * 0.06		
IV. Total Project Cost		**527,448,600**	= I + II + III		

* All the canal construction cost includes the cost of roads that will be constructed adjacent to the canals.
* Land Consolidation comprises Second & Tertiary, Land Leveling and Roads & Drainage.

7.4. The Financial Plan for Project of Phase I

The implementation of Phase I of SVIP will utilize financial resources from AfDB-WB/FAO(WB-P158805). The total funding comprises 160,000 thousand USD from WB and 50,000 thousand USD from AfDB, with a total of 210,000 thousands USD. However, Phase I will require 235,527 thousand USD for the implementation of various activities, leaving a short fall of 36,527 thousand USD.

[Table 7.4-1] Financing of AfDB-WB/FAO(WB-P158805) (thousand USD)

Total	WB	AfDB	Remark
210,000	160,000	50,000	

[Table 7.4-2] SVIP Investment Cost of Phase I

Descriptions	Quantities	Total	Remarks		
I. Direct Total Cost		**181,820,000**	Sum of [1) + 2) + 3) + 4) + 5) + 6)]		
1) Intake Works		**4,000,000**			
2) Feeder Canal	**L=33.80km**	**33,100,000**	Lined canal		
3) Supuni Canal	**L=10.70km**	**5,900,000**	Lined canal		
4) Bangula Canal	**L=16.15km**	**19,400,000**			
-Zone A Canal	L= 3.64km	11,600,000	Syphon		
-Bangula Canal A	L=12.51km	7,800,000	Lined canal		
5) Branch Canal	**L=40.80km**	**5,800,000**			
-Branch- Phase I	L=40.80km	5,800,000	Lined canal		
6) Land Consolidation		**113,620,000**	**Second & Tertiary**	**Land Leveling**	**Roads & Drainage**
Sub-total	**A= 12,651ha**	113,620,000	17,050,000	77,250,000	19,320,000
-Zone I-1	A= 7,452ha	65,170,000	9,780,000	44.310.000	11,080,000
-Zone A	A= 5,199ha	48,450,000	7,270,000	32,940,000	8,240,000
II. Contingency(20% of direct cost)		36,364,000			
III. Consultant(6% of direct cost)		10,909,200			
IV. Total Project Cost		229,093,200			

* All the canal construction cost includes the cost of roads that will be constructed adjacent to the canals.

*Land Consolidation comprises Second & Tertiary, Land Leveling and Roads & Drainage