GOVERNMENT OF MALAWI

MINISTRY OF AGRICULTURE, IRRIGATION AND WATER DEVELOPMENT

SHIRE VALLEY IRRIGATION PROJECT

FINAL FEASIBILITY REPORT

Technical Feasibility Study on Shire Valley Irrigation Project

March 2017

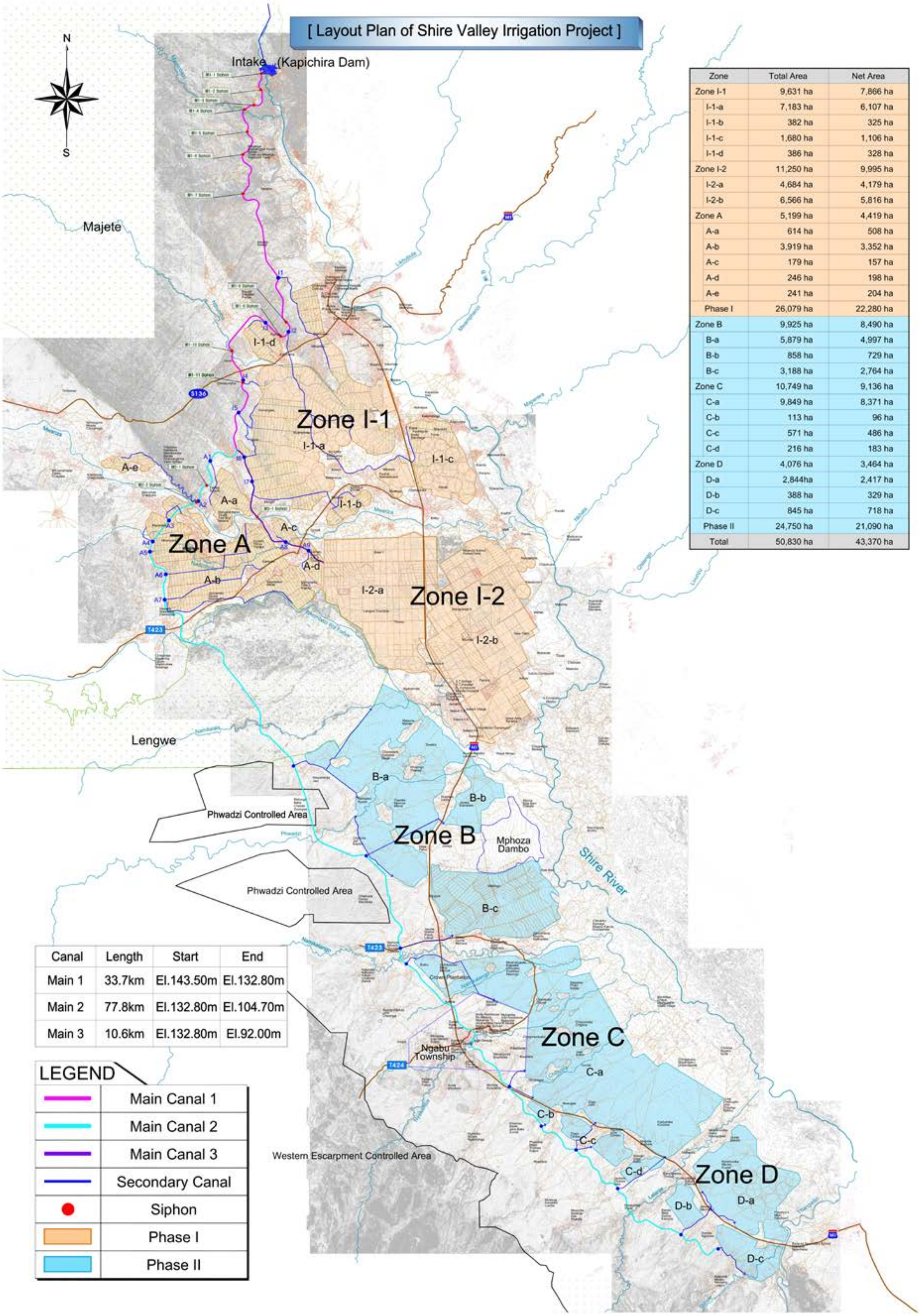
KOREA RURAL COMMUNITY CORPORATION

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	508 ha
A-b	3,919 ha	3,352 ha
A-c	179 ha	157 ha
A-d	246 ha	198 ha
A-e	241 ha	204 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

Canal	Length	Start	End
Main 1	33.7km	El.143.50m	El.132.80m
Main 2	77.8km	El.132.80m	El.104.70m
Main 3	10.6km	El.132.80m	El.92.00m

EXECUTIVE SUMMARY

BACKGROUND

Since the 1940s, the Government has been interested in the implementation of Shire Valley Irrigation Project. Since then, the proposed project has been the subject of a large number of surveys and studies. However, these studies have not resulted in the preparation of a detailed project proposal acceptable for funding by donor agencies. 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. The recommendations in the report have been endorsed and accepted by the Government of Malawi.

Since 6th July 2015 the Consultant - Korea Rural Community Corporation (KRC), in association with DASAN CONSULTANTS and GK Works - were tasked to undertake Technical Feasibility Study and has completed the tasks. During the implementation of their consultancy the detailed delineation of the project boundary was carried out resulting in adjusted project area. The initial project area was 42,500 ha and has now increased to 43,370 ha. The project is divided into two phases, Phase I is 22,280 ha and Phase II is 21,090 ha. Of the 43,370 ha to total area, the 15,757 ha are existing irrigated areas (see Table below).

[Table] Existing and New Irrigated Areas in Phase I and II

	Name of Farm	Total (ha)	Phase I (ha)	Phase II (ha)
Existing Area	Nchalo	9,995	9,995	
	Alumenda	2,764		2,764
	Sande Ranch	454	454	
	Phata	296	296	
	Kasinthla	1,429	1,429	
	Kaombe mcp	484		484
	Kaombe Trust	335		335
	Sub-total	**15,757**	**12,174**	**3,583**
New Area	New area	27,613	10,104	17,507
	Total	**43,370**	**22,280**	**21,090**

PROJECT AREA

The project area is in the southern part of Malawi within the administrative districts of Chikwawa and Nsanje. It is located on the west (right) bank of the Shire River in the Lower Shire River Valley which is 150 km long and 15-30 km wide. The Shire Valley has a high irrigation potential and is one of the most fertile areas in Malawi with a reliable source of water from the Shire River.

The 2016 population of Chikwawa, which is the principal area of SVIP, is estimated at 550,000. The population in the project area is about 223,000 from 48,400 households. Of these 95,000 people are residing in 21,000 households in the SVIP Phase 1 area and 128,000 people in 27,400 households in the SVIP Phase 2 area.

The Shire Valley is characterized by a generally low elevation where the relief profile ranges from 60 m to 150 above sea level. Temperatures in summer months range from 28°C to 35°C. The mean temperatures in winter months vary from 20°C to 35°Cwith an annual temperature range from 12°C to 15°C. The hottest period is from October - November when temperatures can reach 40°C. During the winter season, the area is under the influence of low equatorial pressures giving big clouds heavy with humidity and the north-east monsoon, which are the principal sources of rain. The average rainfall is 652mm with the rainy season falling from November to March. Analysis of monthly climate regimes indicates that the climate of the area is humid to semi-humid between December and March thereafter oscillating between semi-arid hyper arid in the period April to November.

Over the years the area has experienced famine and has relied heavily on relief food. Even during the periods of normal rainfall, the farming families in this area harvest food sufficient for only three months. This project will, therefore, alleviate the situation by improved irrigation and drainage infrastructure. The Shire Valley could be Malawi's breadbasket, capable of producing adequate food both for the Valley and also for the country with possibility for surplus which could be exported.

SCOPE OF TECHNICAL FEASIBILITY STUDY (TFS)

The objective of this assignment is to undertake a detailed technical feasibility study 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.

1) <u>Volume 1: Main Report</u>

- The main report (Volume 1) comprises four components, and they are:
  Main results of other SVIP Feasibility Study reports (6 reports): Communication, Community Participation, Land Tenure and Resettlement Policy Framework Study; Agricultural Development Planning Strategy; Public-Private Partnership (PPP); Environmental and social Impact Assessment; Hydraulic Modeling of Intake; Dam Safety
- Field survey: Topography Survey; Geotechnical Investigation; Hydrogeology; Soil Investigation; Flood Analysis; Development of GIS
- Main results of the First Stage Report: Assessment of technical options; Water requirement and water availability for SVIP;
- Preliminary design report: Environmental and social adaptation; Carbon finance potential; Preliminary design; Water supply and sanitation; Project costing and economic and financial assessment; Institutional framework and price setting; Project implementation time frame

2) <u>Volume 2: Drawings of design</u>

This volume contains the design drawings of SVIP. These drawings are provided in A3 format. They comprise two volumes: Volume 1: Drawings for project design; and Volume 2: Sample of GIS data.

- Volume 1 contains the drawings of design as below: Intake structures (plan view and section view); Longitudinal sections of Main canals; Longitudinal sections of Secondary canals; Main structures of canal and offtakes; Land consolidation plan; On-farm plan
- Volume 2 contains the sample of GIS data as follows: Image map; Digital map; Contour map; Digital Elevation Model (DEM); Road map; River & stream; Design layout of Project area; Soil map.

COMMUNICATION, COMMUNITY PARTICIPATION, LAND TENURE AND RESETTLEMENT POLICY FRAMEWORK STUDY

Gender and Youth Strategy

The Gender and Youth Strategy has identified gender and youth issues related to:

- Literacy and education rates of women are considerably lower than those of men.
- Access to and control over land is dominated by adult males over 35.
- Women and youth often left out in resettlement and reallocation processes.
- Only 4.2% of the household respondents obtained a loan in the last year.
- Decisions on large investments related purchases and important issues are made by men.
- 94% of the cultivated plots used women's labor. Only 23% have hired their labor input.

The Gender and Youth Strategy includes a goal, purpose and specific objectives as below:

- Incorporation and mainstreaming of gender and youth issues
- Easy reference SVIP gender and youth guidelines
- Facilitate approaches to the process of the Shire Valley Irrigation Project.

Communication strategy

Major conclusions drawn from the field study are presented below.

- The District Council meetings are an essential channel for the two phases of the SVIP.
- The District Executive Committee (DEC) meetings can be used for discussing sharing of information and for gaining a common understanding.
- Agricultural structures are an effective channel among stakeholders in the project area.
- It is best to contact NGOs working in Chikwawa District through either the DC's office or directly depending on the nature of the issue at hand.
- Letters are a reliable and official channel for communicating with Chiefs and villagers.
- Area Development Committee (ADC), Area Executive Committees (AEC) and Village Development Committee (VDC) meetings convey messages to the villages.

It is important to note that within Nsanje and Chikwawa Districts the proportion of literacy is respectively 73.8% and 80.2% for men and 54.9% and 49.1% for women.

The most common and popular media are as follows:

- After radio, newspapers are the next effective medium of communication in the country.
- MBC Television would be appropriate for communicating with other organizations.
- Mobile PA announcements are available for the leader group of villages.
- Public meetings are an effective way of communicating socio-economic issues in Malawi.
- Other printed materials such as posters are useful in passing on information.
- Theatrical performances are a popular way of conveying important information.
- But access to internet in rural areas is limited.

Grievance Redress Mechanisms

The objective of the SVIP Grievance Redress Mechanism (GRM) is to solve disputes at the earliest possible time, which will be in the interest of all parties concerned. The GRM implicitly encourages resolution of conflicts at the lowest level possible, in an amicable and participatory way. At every stage of the GRM, there will be somebody dedicated to handle and record complaints. The first step for a projected affected person who has a complaint is to notify their Local Leader, extension worker and/or project staff. If this is not successful, the case will be referred to the Group Village Grievance Redress Committee (GVGRC) to determine the validity of claims. If the complainant's claim is rejected, unsolved or not resolved satisfactorily, the matter shall be brought before the Area Grievance Redress Committee (AGRC) and subsequently before the District Grievance Redress Committee for settlement. Thereafter, the case can be presented to the MoAIWD/PTT.

Land Tenure Diagnostic, Allocation and Consolidation Strategy (LTDACS)

The results from the field survey show that 64% of the land within SVIP is customary and 36% is private land. The high percentage of private land is due to the large sugarcane estates such as Nchalo, Alumenda and Kaombe. In line with the just passed Customary Land Bill, land management matters for the cooperatives and associations may be under the organisational structures described in new law i.e. Land Management Committees and Land Tribunals. The new law provides an opportunity for the consolidated farms to get a customary estate title which is quasi-freehold and superior to a leasehold title.

Protection of the rights of the land owners in the various out-growers’ schemes is addressed in the constitution that includes detailed paragraphs regarding the division and transfer of shares, which can only be done within the families or within the scheme. The shares cannot be sold to a third party, thus preventing the taking over of the customary land by private companies. With the new law the cooperative or association can apply for a customary estate or leasehold title secure the rights and to establish a legal document as a basis for obtaining loans. Although not disaggregated by age, 7% of landholders rent their land rather than 'own' it. The majority (81%) of customary landholders in the SVIP area are male. The CCPL&TRPF survey found that 15% of landholders are female, and 4% hold the land jointly as spouses.

Resettlement Policy Framework (RPF)

The purpose of the Resettlement Policy Framework (RPF) is to provide a robust framework guiding land acquisition and resettlement issues from irrigation projects to be funded through the Shire Valley Irrigation Project. The need for the RPF emanates from two areas which will lead to displacement of people as a result of the construction of the main and branch canals and associated infrastructures.

It is recognized that project affected persons (PAPs) may be impacted by the involuntary taking of land resulting in relocation or loss of shelter. In all these cases PAPs are entitled to compensation. The RPF is based on principles which are consistent with policies and legal framework of the Government of Malawi (GoM) and the guidelines of Malawi’s development patterns, the WB (OP4.12), the AfDB (IDRP) and the FAO.

The determinant of the number of PAPs and quantities of assets loss will be limited to land taken up by the main canal, branch canals and area required for other infrastructure and construction purposes. The PAP or asset must have been located within this area before the cut-off date and baseline, and the PAP’s association with the location and asset must be registered or recognized in the local community.

In summary, an estimated 720 hectares of land will be acquired for the main canals and about 295 households will be affected in both phases. For phase 1, the affected area is estimated at 375 hectares and 121 houses. Some of these may be assimilated within the communities depending on the nature of their impact. However, others will have to be resettled elsewhere. In addition, about 198 ha will be required for construction purposes in Phase 1. The estimated costs for preparing and implementing the Resettlement Action Plan are about USD923,000 (Nine Hundred and Twenty Three Thousand United States Dollars only).

AGRICULTURAL DEVELOPMENT PLANNING STRATEGY

Overall Crop Production

The Shire Valley is well endowed to support the production of various crop and livestock commodities. The major limiting factors to crop production in the Shire Valley are the high temperatures (up to a maximum of 40 °C in November) and the unreliable rainfall pattern (ranging from 170 to 968 mm per year) resulting in low crop water availability. Crop yields as reported by the Shire Valley ADD are generally lower than what could be expected under large scale commercial production. The dry land crop yields reported can easily be doubled or trebled under irrigation.

The crop selection for the SVIP is based on the climate and soil considerations. The crops proposed for inclusion in the cropping program can grow very well on the soils identified as being suitable for irrigation in the project area. The main soil characteristics including: soil pH, depth (at more than 150 cm), structure, chemical properties (except for sodic areas) are all within range for all the recommended crops. Information gathered from available literature suggests that there could be issues pertaining to root pruning for some tree crops planted on Vertisols. However, it is also reported that this is not a serious problem for crops grown under irrigation since the cracking is bad when the soils are very dry.

Livestock production

In 2016, the population of cattle in the Shire Valley was estimated at 184,914. The sweet veld that dominates large tracks of land in the Shire Valley and the fairly large number of livestock currently raised in the project area present an opportunity for the development of a strong livestock sector. The improved availability of water that will be made possible by the Shire Valley Irrigation Project (SVIP) presents opportunities for enhancing the productivity of the grazing areas by establishing irrigated pastures. The SVIP presents an opportunity for the resuscitation of the fishing industry and the Kasinthula Fish Farm, in particular, in the project area.

Crop production models

Table below presents possible crop combinations/rotations during the first three years. In Phase I these crops are in addition to sugarcane which already covers 75 percent of the area. In terms of crop combinations there could be four options, namely:

- Option 1: Cotton and soya bean (summer) and beans, maize (winter);
- Option 2: Cotton and pigeon peas (summer) and beans, maize (winter);
- Option 3: Cotton and pigeon peas (summer) and soya beans, maize (winter); and,
- Option 4: Rice in summer in place of cotton rotated with fine beans in winter in place of maize.

The total irrigable area in Phase I is 22,400 ha. The area currently under sugarcane production is 12,275 ha. If the KAMA area is included under sugarcane production then the area under sugarcane becomes 14,535 ha; representing about 65% of the Phase I area. This leaves 7,865 ha (35 percent) for other crops. For Option 1 and 3, in Phase I, it is proposed to include the other crops of cotton, soya beans or pigeon peas in summer; and, maize, dry beans or soya beans, in winter.

A model farm unit covering an area of 500ha could realize a total gross margin of at least USD1.4 million/year from the proposed cropping program. The anticipated improvements with the introduction of the high value perennial crops in the program such as bananas, mangoes and citrus fruits increase the gross margin to USD1.5 million/year for a 500 ha farm.

Farmers' Organizations

The organization of farmers in the Shire Valley will be critical for the successful implementation and sustainability of the SVIP. The collective objectives of all stakeholders are, to: provide a conducive environment for participation of farmers' organizations and private investors that have the capacity to create value and jobs; limit transaction costs when dealing with a large number of farmers; allow smallholder farmers to effectively participate in the Project; and, allow farmers to enter into a fruitful dialogue and collaboration with private investors and get their voices heard, thus enabling the commercialization of farming in the Shire Valley.

Based on the assessment carried out it is recommended that at inception of the SVIP, Cooperatives should be established at each zone level depending on local setting of the zone, modeled along the lines of the Phata Cane Growers' Cooperative. This excludes already established institutions e.g. Illovo, KAMA Cooperative, Phata, Kasinthula, and Kaombe in Zone 1 and 2. These Cooperatives /Associations would have the power to: enter into contracts on behalf of its members; mobilize production; negotiate with suppliers for better input supply, credit facilities and produce prices.

SVIP Project Coordination Unit and Technical Assistants

The Project Coordination Unit (SVIP-PCU) is already in-place. It is therefore suggested that the functions of the PCU should still continue for the next five to ten years to coordinate the implementation of the AGDPS. The technical establishment of the PCU is composed of Project Coordinator, Community Mobilization Specialist, Irrigation Specialist, and Government counterpart staff (an Irrigation Engineer).

For successful implementation of the SVIP, in the next phase, the Project needs to hire technical assistants (TAs) who are experts engaged to assist in the implementation of such components as: irrigation development; irrigation water management; and capacity development. The specific areas that will require the inputs of technical assistants are: Irrigation Water Management; Crop Production; Community Mobilization and Farmer Organization; Aquaculture and Livestock; Credit and Input Supply; PPP; Marketing and Value Addition; and, Monitoring and Evaluation. The key roles of the SVIP and TAs, in implementation phase, in collaboration with the DEC would include the following:

- facilitating contracting arrangements for the development of irrigation systems in the SVIP;
- facilitating and coordinating community mobilization and formation of farmer organizational structures;
- facilitating and coordinating capacity building service provision of farm level institutions of the SVIP through service contracts;
- supporting the farm level institutions by putting in-place and developing appropriate governance and business management systems to effectively run their agricultural enterprises;
- facilitating and coordinating contract farming arrangements between farmer organization and agribusiness companies; and,
- linking the farm level institutions with the various Government and other service providing institutions.

SVIP Farmers' Union and farm based cooperatives/associations

The NIP 2016 advocates for well-managed irrigation schemes to sustain productivity. The NIP is aimed at:

- encouraging catchment management practices for the benefit of communities;
- developing farmer organizations through technical and administrative empowerment;
- exploring alternatives to handling and marketing of irrigated crops;

- facilitating in a coordinated manner, the formalization of land tenure rights;
- strengthening extension services for irrigated agriculture through irrigation technologies; and,
- supporting beneficiary communities where major rehabilitation, upgrading or modernization of irrigation infrastructure are required

1) The SVIP Farmers' Union

Specifically, the SVIP Farmers' Union would be responsible for:

a) Facilitating and coordinating community mobilization and sensitization; establishing irrigation block area management associations and cooperatives; providing assistance in the re-allocation of land; resettlement, and grievance redress; developing farm land ready for growing crops; advise on farm management and crop production; support to prepare and submit proposals for assistance. Initially project funding would be used for a period of five years. Over time this could grow into a farmers' membership organization providing the services on a demand driven basis.

b) Facilitating and coordinating capacity building service provision of farm level institutions of the SVIP through service contracts.

c) Supporting the farm level institutions putting in-place and develop appropriate governance and business management systems to effectively run their agricultural enterprises.

d) Facilitating and coordinating contract farming arrangements between farmers' organizations and agribusiness companies.

e) Linking the farm level institutions with the various Government and other service providing institutions.

f) Facilitating contracts for the development of irrigation systems in the SVIP area.

2) Farm based cooperatives

Farm based Cooperatives would be composed of beneficiaries from the same geographical area and based on the same GVH, following existing demarcations. The proposed area per farm based organization is 500-1,000ha. In case the irrigation system design layout cuts through boundaries, negotiations would be facilitated by the DEC, Farmers' Union and actual organizations involved. Membership would be drawn from land owners, who have aggregated land for irrigation development.

Implementation plan

The implementation of the farmers' organization component is anticipated to take five years. The first three years would be for sensitization, formation and operationalization of the associations and cooperatives. The next two years would be for intensive monitoring and evaluation of all aspects involved to make viable enterprises. It is anticipated that after this five-year period, the SVIP Farmers' Union would be an independent entity, receiving minimum assistance from SVIP PCU in terms of funding of its activities.

Recommended policy reforms

The macro and micro economic policies were analyzed, key challenges identified and the accompanying solutions provided to maximize the full potential of the identified product value-chains under the SVIP. The analysis focused on how GoM adopted and implemented policies to govern the economy as a whole (macro-economic policy), or those governing a particular economic sector (sector policies), in order to guide and modify the behavior and decisions of agents operating in the economy. The GoM influenced the economy by creating policies which regulate, incentivize/disincentivize or inform economic agents.

The key observations were as follows:

- Trade and market policies and overall performance resulted in producer disincentives of percent on average between 2005 and 2013.
- The exchange rate misalignment in place until 2012 and the inefficiencies in the value chain created additional disincentives of -29 percent on average between 2005 and 2013.
- Disincentives in the agricultural sector are mainly the result of poor price transmission between domestic and international owing to inadequate infrastructure and lack of negotiation capacities of producers.
- The implementation of trade and markets policies to contain domestic prices also depressed producer prices in some years.

PUBLIC-PRIVATE PARTNERSHIP (PPP)

PPP Options assessment

The study has assessed various PPP options that could be implemented in SVIP together with the risk allocation assessment in detail. To determine the relevancy of the PPP options proposed, a financial model has also been developed and the results of the analyses presented. The PPP options assessed include:

- Management contract
- Affermage (Fully private or semi Public)
- Lease (Fully private or semi Public)
- Concession and
- BOT

All PPP options have their own pros and cons and can be applied to involve the private sector in the project. Their difference is in the risks allocated to the government and the private partner.

The concession is the most demanding in terms of private involvement. It requires equity and debt financing of the infrastructure from the private partner who will bear all the commercial risks (ISC collection and water demand risks). According to the functions transferred to the private, this kind of concession is sometimes called DBOT (Design Build Operate Transfer), or DBTO, or any other acronyms that will indicate the functions transferred to the private.

The Consultant has proposed to structure the PPP for SVIP as a concessional arrangement, where the private sector will be in charge to operate and maintain the scheme and participate to the funding of the project. A concession would reduce the cost for the public sector and would guarantee a sustainable long term management of the scheme. A concession gives an operator the long-term right to use all utility assets conferred on the operator, including responsibility for all operation and investment while asset ownership remains with the authority.

Water Purchase Agreement (WPA)

In the case of SVIP, a WPA is a long term contract to deliver water to ILLOVO and other water users organized into trusts, to realize the dedicated infrastructure needed to fulfill this obligation and to define precisely the conditions to be respected by the parties. ILLOVO would account for at least 62% to 81% of the revenue of the projected PPP for Phase 1 of the SVIP according to WPA options negotiated. Therefore, the WPA with ILLOVO is the cornerstone of the project.

The first party is obviously ILLOVO and other existing trusts. The second one could be either the private partner of the PPP or the government of Malawi. In the second case, the government will enter the agreement to realize the dedicated infrastructure and to deliver the agreed amount of water, either through a PPP or directly if it decides so. In the first case, the WPA will be a part of the PPP contractual arrangement and the private partner will be obliged by it. In the second case, both parties, ILLOVO/other existing trust and the government, will be obligated by the WPA.

Conclusion and Recommendation on PPP and WPA

The preliminary report assessment shows that all types of PPP could be implemented for SVIP. The four types of PPP options have been analyzed in the PPP feasibility report. Although no decision has been taken by the government regarding the kind of PPP arrangement it is willing to set up, this study is proposing a concessional arrangement, where the private sector will be in charge to operate and maintain the scheme and participate in the funding. It is also recommended that the PPP model should adopt options of cash crops development (sugar cane and cotton) and organize farmers into a trust.

A concession would reduce the cost for the public sector and it would guarantee a sustainable long term management of the scheme. ILLOVO Sugar Group and other existing trusts in the basin should also be incorporated into the project under WPA.

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

Impact During Pre-construction Phase

The overall impact during the pre-construction phase is concentrated in the community organisation and the natural heritage front. This will include community reorganisation and resettlement, which will be addressed in the Resettlement Action Plan. In addition, the final decisions on canal design and alignment influenced the type of long-term consequences on the National Parks. Finally, the use of a tendering process for construction will need to be inclusive and closely monitored in order to ensure the adherence to the environmental mitigation recommendations determined in the ESIA and its ESMP. On the other hand, there will be no impacts on the physical environment or ecology during the pre-construction phase.

Impact During Construction Phase

Impacts on river geomorphology and water quality: the construction of the irrigation system will require extensive construction work around existing rivers, and as such will affect the geomorphology of rivers as well as the water quality.

Soil excavation and land leveling: the project will require extensive excavation work for canals, as well as rock blasting.

Impacts on workforce: the construction site will offer a number of job opportunities for the local populace, both skilled and unskilled.

Impacts on infrastructure agriculture and cultural heritage: the project will have manifold impacts on the human infrastructure, natural and cultural heritage throughout its construction.

Impacts wildlife parks and reserves: considering the passage of canals through Majete Natural Reserve (during Phase I) and Lengwe National Park (during Phase II), the impacts during construction in these areas are non-negligible.

Impacts on terrestrial biome: the construction will inevitably modify the current vegetative landscape, though much land area is already converted agricultural lands.

Impacts on aquatic habitats: Construction will lead to work on temporary rivers, which a number of fish use to migrate to spawning sites.

Impact During Operational Phase

Hydrological impacts: Increased demands on the reservoir will have compounded effects downstream, notably consequential decrease in flow at the Kapichira Falls.

Hydraulic transparency: due to the dynamic nature of this riverine landscape, poorly designed culverts and other infrastructures could lead to damming of tributary rivers and flooding of villages upstream.

Changes in soil properties: Irrigated agriculture sometimes trigger a series of changes in soil properties: salinization, sodicity, water logging.

Rapid social change and hinterland effect: the Installation of a modern irrigation scheme will necessitate the social acceptance and behavior modifications local communities in order to truly be successful.

Lack of proper maintenance of infrastructure: this ESIA requires that a number of mitigation infrastructures be installed (e g. bridges, wildlife passes) which will need to be adequately maintained in order to ensure their efficacy.

Changes and delays in agricultural development: whilst the project is designed to allow further agricultural development past subsistence agriculture, delays to the start of operation and or of behavioral shift could potentially postpone benefits, especially at a household (e g. food security) and community level (e.g. access to improved health and education facilities).

Livestock rearing: Livestock rearing practices will need to be adapted to the new conditions, as canals and command areas will represent obstacles to movement of cattle and grazing lands and water points will be reduced.

Decline in fisheries: Fisheries, which are already declining, may further be affected by the decrease in flows in the Elephant Marsh.

Health and Safety: the intricacy of the canal system will increase the risk of drowning and injuries, specifically for children as they are at risk even in the shallowest channels.

Tiger fish invasion: Kapichira Falls constitute a barrier between the Lower Shire to the Middle and Upper Shire. Currently, the Tiger Fish is present only in the Lower Shire, the gentle slopes of the main canals could allow downstream fishes (including the Tiger fish) to by-pass Kapichira Falls. The Tiger fish has the potentially of creating ecological havoc were it to be introduced to the rest of the basin; most notably, due to its piscivorous and aggressive nature. it has the potential to significantly affect the mainly endemic cichlid population of Lake Malawi. As such an effective fish barrier shall be put into place. Self-reliant and low maintenance are the two principles that should govern the fish barrier. Currently, the most viable option would be the creation of concrete wall along the Main canal 1 (Feeder canal), and to install it inside MWR because it is the farther upstream and because its access by community shall be restricted (to avoid damaged by cattle and people).

Reduction of aquatic habitat quality: With a reduction of flow, Elephant Marsh will be impacted; as such, there will be a decrease of suitable habitat for fish as well as a possible decline in quality due to siltation.

HYDRAULIC MODELING OF INTAKE

The model was calibrated based on the morphological evolutions of Kapichira reservoir from 2001 to 2016 and a full river discharge time-series were run, with realistic dam operations (including flushing) and realistic sediment loading. The computation of the hydro-sedimentary functioning of the reservoir with the first configurations/location of the Intake Structure was then carried out after the calibration is complete. The computation will continue for different other configurations listed as follows:

- *Configuration 1*: the intake is located just downstream of the spur dyke.
- *Configuration 2*: the intake is located just downstream of the spur dyke, and the whole right hand side deposit downstream of the spur dyke is dredged to a level of 141 m. The volume of dredging is 560,000 m^3.
- *Configuration 3*: the intake is located just upstream of the spur dyke.
- *Configuration 4*: the intake is located just upstream of the spur dyke, and the whole right hand side deposit upstream of the spur dyke is dredged to a level of 141 m. The volume of dredging is 640,000 m^3.

The main results obtained in this study are as follows: The impact of the SVIP intake on the intake of sediment transport at the power plant is very low. The amount of sediment entering the SVIP intake is quite large (in average 162,000 ton of clay and 26,500 ton of silt per year in the best C case with dredging). The dredging of the deposit downstream of the spur dyke enables to reduce significantly the amount of the silt fraction of this sediment. The largest part of the sediment entering the intake is composed of very fine, clayish, sediment that has a very low fall velocity.

Dredging of other areas in the reservoir does not reduce significantly the amount of sediment entering the SVIP intake and the power plant intake. All results thus show that dredging of the deposit downstream of the spur dyke is very beneficial for the project. In terms of the way of dredging downstream area of the spur dyke, two alternatives were proposed in the report.

DAM SAFETY

Field Observations

From the field visits, the experts have observed that:

- Weeds and bushes are growing on the upstream and downstream slopes of the embankment,
- Observations from the deck of the spillway indicated that:
  - The sloping chute of Bay 1 shows normal wear and tear.
  - Cracks are observed on chute of Bay 2.
  - Cracks are observed on Chute of Bay No 3. Some concrete near the toe has been washed away.
  - In Bay No. 4 reinforcement is exposed in one block.

The bottom seals of most of the gates are not effective and leakage is taking place.

Conclusions and Recommendations

- The first independent inspection should be conducted within a year of the report in 2015.
- The damages on the concrete chute should be repaired as per recommendation of a qualified civil engineer.
- Weeds and bushes growing on the upstream and downstream slopes should be removed taking care that the fill material and riprap are not disturbed.
- The POE is not seriously worried about the short term safety of the dam. However if the dam is never inspected and defects are not corrected then safety could ultimately be compromised

FIELD SURVEY

Topographic Survey

The topographic survey was carried out in order to facilitate the feasibility study and the preliminary design of Phase I of SVIP. SVIP has been divided into 6 zones, namely Zone I-1, Zone I-2, Zone A, Zone B, Zone C and Zone D, and these zones are serviced by 3 canals namely Main canal 1, Main canal 2, and Main canal 3.

In Phase I, the Main canal 1 route (33.7 km) starts from Kapichira Dam in Majete Game Reserve to a location in Supuni village, where it branches into two canals, Main canal 2 and Main canal 3. The Main canal 2 that serves the Phase I area runs for 18.4 km to NkombedziWaFodya River in the Lengwe National Park in Chikwawa District, whereas the Main canal 3 runs for 10.6km from the Supuni village to Tomali area where it joins the existing canals of the Illovo estate, also in Chikwawa District.

Geotechnical Investigation

Rock layers were found at BH-A, BH-4, BH-9, BH-13, 14, 15, situated 2 ~ 3m below the ground surface. The earth layer in each borehole is 2 m thick from the ground surface and comprises sand, silt, and clay. Granular material was found along the Main canal 1 section, and is equivalent to A-1(A-1-a, A-1-b), A-2(A-2-4~7) following the AASHTO Soil Classification System. Samples collected from this proposed site have been analyzed and fall into 5 (five) main soil subgroups of A-1, A-2, A-4, A-6 & A-7.The three soil subgroup of A-1, A-2 &A-7 are good quality of soil characteristics for civil works.

The first subgroups of A-4 & A-6 are poor soils which are plastic and having high volume changes, with fluctuating moisture content. Therefore, their expansive and contracting characteristics should be taken into account when designing structures. A-4(Silt), A-6(Sand) soil groups exist along the Main canal 1 and Main canal 2 sections, located within 3 m depth from the ground surface. These soils are recommended to be replaced or treated during canal construction for the persistence of structures. In terms of the construction conditions this will not be a substantial constraint.

The second subgroups of A-2-4, A-2-6 & A-2-7 are fairly to good soils which are not highly plastic, A-2-4 & A-2-5 have maximum plasticity index of 10%, and A-2-6 & A-2-7 soil subgroups have a minimum plasticity index of 11%.

The third subgroups of A-1-a & A-1-b are good to excellent soils which have very low plasticity index (PI) of not more than 6% or are Non Plastic (NP).

Eight borrow pits and 4 quarry sites were investigated to be a source of construction materials for the proposed Shire Valley Irrigation Project. Borrow pits investigated are Tomali, Nyaika, Sibale old pit, Nyamithuthu old pit, Chikhama, Moroko, Chikalumpha and Namiche. Quarry sites investigated are Kajawo, Thabwa existing quarry, Nzongwe and Ngabu.

Ngabu quarry site qualifies to be the source of construction material for the roads because the crushing value falls within the not more than 25% specification. Kajawo and Thabwa quarry sites can be used as sources of quarry for concrete works because the crushing values fall within the not more than35% specification for concrete works. Nzongwe quarry site is unsuitable as a source of construction materials because the crushing values fall outside the specification for both roads and concrete works.

Kajawo and Thabwa quarry sites shall be the main source of quarry material. These sites are near to each other and located at the bottom of the escarpment at the entrance into the Lower Shire Valley Plain from Blantyre. The distance between these sites and Majete Game Reserve, which is the farthest points of the main canals, is about 20 km.

Hydrogeology

The Lower Shire Valley is dominated by the alluvial aquifer system, with some sections consisting of Pre-Cambrian Basement Complex Aquifers. 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 $1x10^{-2}$ to $5x10^{-2}$. Annual groundwater recharge ranges from 15-80 mm. 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.

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.

Soil Survey

The study area administratively belongs to Chikwawa and Nsanje distiricts and its size is approximately 55,500 ha. In order to determine soil characteristics and classify soil types, field survey and soil analyses were carried out with reference to soil databases, CODA Report and commercial sugar farm data. Field soil investigations were conducted at 1,050 points and 1,003 soil samples were taken for further analysis. There are 11 RSGs in the Estates and 5 in the other part of SVIP Zones. Fourteen principle and 9 supplementary qualifiers were applied in the second level classification of RSGs and 218 soil types were classified. Soil erosion, flooding and ponding, poor drainage, heavy clayey or sandy texture, high levels of rock content on surface and/or subsoil, hard consistency, salinity and/or sodicity, and low fertility could be suggested as vital soil and terrain limiting factors.

- There are depressions (1,399 ha) and floodplains (2,601 ha) scattered in SVIP Zones
- Imperfectly or poorly-drained soils (16,146 ha) can lead to poor upland crop yield by root respiration hindrance and toxic reductants
- Arenosols (1,711 ha) are soils too sandy to hold enough water to grow crops, whereas Vertisols (12,151 ha) and Vertic Luvisols (1,500 ha) are so excessively clayey that they could be disadvantageous for tillage and drainage
- Dominant (>80%) or abundant (40-80%) gravels and/or stones are contained through or in the layers within 100 cm from the surface in the area of approximately 1,500 ha
- Saline and/or sodic soils occupy approximately 10% of Phase I zones (2,400 ha). The percentage of them in the entire SVIP area increases up to around 20% (11,000 ha)

Topsoil texture data and soil water deficit values by soil texturehave been used to determine the total readily available water in the soils within 30 cm from the surface within the soil survey area and this is approximately four million tonnes.

There are 24 map codes in SVIP Zones. 1Hcs (Rain-fed Herbaceous Crops with Small Sized Fields) occupies the greatest area of 21,125 ha (38%) and followed by 1SC (Sugarcane - Irrigated Herbaceous Crop(s)) over16,992 ha (31%), 1Hcs/2TO (Rain-fed Herbaceous Crops(s) Small (< 2ha)/Woodland Open General (15-65%) with Herbaceous Layer) over 3,938 ha (3%), and 1Hcs+2Ts (Rain-fed Herbaceous Crops(s) - Small Field(s) (< 2ha) with a layer of Sparse Trees) over 3,659 ha (3%).

Eight crops, including sugarcane in Estates, were being comprehensively cultivated in the fields during the present soil investigation. Sorghum and cotton were being grown under rain-fed traditional management at 137 out of 258 sites followed by cotton at 38 sites. Cereal crops such as sorghum, bulrush millet, maize, and rice were widely planted in single or mixed stands for subsistence production.

533 land units covering 36,771 ha in the soil survey area, except Estates, have been evaluated by use of ALES program. 67 land use types have been selected with a combination of managements (inputs and crops). Nine land qualities were determined through an inventory of relevant 22 land characteristics, which are attributes that can be measured or estimated. Due to unavailability of recent cropping data collected for SVIP, crop characteristics in the 1991 FAO Report were very usefully applied and modified for setting LURs in the present evaluation.

Comparing the land suitability classes of 15 crops through five models and averaging the areas of each class, maize (long cycle varieties) and rice, paddy, are found to have the highest percentage of N against the other crops: 90% and 92%, respectively. On the other hand, the crops with over 20% of (S1+S1/S2+S2) are bulrush millet, cotton, cashew, groundnuts (short cycle and long cycle varieties), sorghum and sunflower. However the areas which are not suitable for some crops could be suitable for other crops. Therefore there is no area which is not suitable for any crop.

Unsuitable land units, for instance, lots of lower clayey soils in Zone C, imperfectly to very poorly drained, are disadvantageous for cultivation. Therefore, some additional measures, such as soil amendments to improve soil properties, and site-specific irrigation/drainage plans, are necessary for them to be cultivated better.

The Saline and/or Sodic areas are largely distributed in areas of Kasinthula, Alumenda and Kaombe both of Illovo. TFS Consultant investigated ways of managing the soil properties of these areas, and they are summarized as below:

- Improving drainage: Deeper drainage channel system applied including subsurface drains
- Applying gypsum: In the early stage of the scheme soil shall be ploughed applying with gypsum (1 ~ 2 ton/ha)
- Using acid fertilizers (Ammonium Sulphate) to improve soil property
- Plating tolerant crops such as sun hemp, velvet beans, etc.

ASSESSMENT OF TECHNICAL OPTIONS

With / Without Illovo Estate

The first benefit (Release of up to 22.2MW to national grid) could be estimated in several ways such as construction cost of hydro-power station producing equivalent amount of electricity, etc. This benefit shall be considered as the main benefit to the GoM for including Illovo in the SVIP.

The GoM may control the water charge and adjust the economic feasibility of the project.

Irrigable Areas to be Developed

The boundaries of project areas were decided 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. Finally, the total project area was set to 43,370 ha.

In terms of topography, the following conditions were considered: slope, location, flooding, accessibility, etc. In terms of soil aptitude, the suitability of soils for agriculture production was considered. It is obvious that large estates such as Illovo and Kasinthula will continue to grow sugar cane even after the introduction of SVIP. Therefore the areal extent of the project area will not be disrupted by the existing farming system. Livestock rearing and growing crops are key agricultural production activities in the project area. There is no designated area for cattle grazing in the project area. Because the irrigation system will provide more favorable conditions of water supplying and passages for cattle breeding. Based on a 10-year flood, which is the standard for evaluating the vulnerability of farming land to flooding, most of the adjacent areas to the Mwanza River area are prone to flooding, in particular the area around Illovo Sugar Estate at Nchalo. In areas that are vulnerable to floods, there may be need to implement structural measures for flood mitigation to curb flooding.

With / Without Lining the Main canal 1

The main canals and the secondary canals were designed in lined canals considering the aspects below:

- Hydraulic Conditions: 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. Therefore the available head is about 40 m. only. The Main canal 1and Main canal 2 will have many structures such as drains, siphon and curved sections. These structures have to be carefully designed because they cause a lot of energy losses in the conveyance system.
- 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 Main canal 1. 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 Main canal1 with concrete.
- 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. This could be a major cause of high construction cost.

The geotechnical investigation carried along the Main canal 1 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 recommended.

Main Canal Optimization

SVIP consists of Phase I and Phase II. Zone A used to belong to Phase II in a feasibility assessment done before this TFS. Zone A is divided into the northern part and the southern part by Mwanza river. And the southern part cannot be irrigated by the Main canal 1. In order to supply water to this region, it is necessary to cross Mwanza river by connecting the Main canal 1 to the starting section of Main canal 2.

In order to reach Bangula, the canal has to cross Mwanaza river. Methods for crossing Mwanza river include connecting the canal along the contour line and crossing the river by the shortest distance. In Option 2 (open canal), the length of the canal increases by 23.6km and the development area also increases by 532ha. Both options have their own pros and cons. But Option 1 (Siphon) is more advantageous than Option 2, which would cause additional construction cost by extending the canal.

Phasing of the Project

Four alternatives for the phasing of the project, and they are:

- First Alternative for the Phasing: As it is possible to have inadequate water during dry periods, in some years, 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.

- 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. This alternative makes it possible to supply water to new region along the canal and also in Nsanje District.

- Third Alternative for the Phasing: 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.

- Fourth Alternative for the Phasing: This alternative involves excluding Illovo Sugar Estate and extending the Main canal 2 to Nsanje District. 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.

Type of Field Irrigation System

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. 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.

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.

Use of Other Resources

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. 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". Water balance analysis shows that at all the 10 places the storage capacities of dams are unable to supply water.

Nthumba, Phwadz, and Thangadzi are the most favorably located. However, there is 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.

WATER REQUIREMENTS ANDWATER AVAILABILITY FOR SVIP

The design water requirement for SVIP, 50.0m^3/s, is for the With Illovo condition.

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.

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,
- The completion of Kamuzu 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 m^3/sec flow would be sufficient to irrigate the whole potential irrigable areas (50,000 ha) in Shire Valley.

The design water requirements are based to satisfy the current crops, mostly sugarcane, in the already developed areas and the standard cropping pattern of dry beans, pigeon peas, cotton, soya bean, and maize for the new areas. It has also been assumed that the irrigation methods in the already developed areas remain the same and that new areas will be developed for surface irrigation. As such, the irrigation scheme has been designed for the most conservative scenario. In practice, a mix of irrigation methods, including surface and pressurized irrigation, is expected to be developed, based mostly on farmers' preferences, crop choice, land development cost considerations (with respect to soil and topography), and water productivity considerations. It is expected that a number of farm organizations will select sprinkler (central pivot) irrigation, which is more efficient. This will provide a buffer for possible climate change when higher crop water requirements can be expected and maybe reduced water availability. The total irrigation command area can also be adjusted during phase 2 when there is more clarity on the preferred on-farm irrigation methods.

Given the long term variability, since the 1960s the high level of regulation at Liwonde was radically changed the flow patterns. In terms of the data quality issues, we understand it isn't straightforward, but we just have to describe our best professional judgment. The lake levels are similar to the mid-1990s and still much above the lows of the early 20th century, which is after a series of dry years and particularly last year's drought. However with the upgrading of the barrage and most importantly the improved regulation regime, at least there will be less spillage and less intra-annual variation. In addition, a positive thing is, there is no climatic indication that points at long term drought conditions.

The cropping patterns were established to match water availability and avoid high demand in Oct-Dec. The KRCC and NORPLAN study are in general agreement on the availability of water and the impact on energy has been assessed.

ADAPTATION OF THE SCHEME TO ENVIRONMENTAL AND SOCIO-ECONOMIC CONSTRAINTS

The proposed intake for SVIP is to locate the intake on the western edge of the reservoir of Kapichira Dam. Another alternative (the other side of the spur dike) was considered.

In order to minimize the environmental impact within the Majete Reserve, the Main canal 1 was planned as a long underground siphon structure, which shall be constructed in this manner to provide the free access of animals to their drinking places. This will also avoid degrading of the natural landscapes in this area. On top of that, several mitigation measures requested by Majete Reserve, such as installation of brick walls around the open canal section, crossing roads and watering point, were considered in the canal design.

Lengwe National Park is located in the middle of the Main canal 2. In this area many animals have free movement in different paths and directions. The Main canal 2 crosses this area through an 11.5 km long open canal section. While the lined canal aggravates the environment, the earth canal improves the environmental condition. When the earth canal is constructed in this area, there will be no need for separate watering places or fencing along the canal. It is proposed therefore to design an open earth canal in this area in the Phase II procedure. The major issue which could be raised in terms of the earth canal is the infiltration loss through the bottom of canal. The geological survey results show that the average permeability at two locations in Lengwe Park is 8×10^{-4} cm/s, which shall be decreased after stabilizing the canal regime. This is a favorable condition for an earth canal.

One of the important environment issues is to protect the invasive fishes, such as Tiger fish, to migrate to the Lake Malawi through the irrigation canal. The design velocity in the siphon section of Main Canal is 2.1 m/s, and the flow velocity at the intake gate shall be 4.75 m/s with a 0.9 m head difference. These flow velocities are much faster than 1.35 m/s which is the maximum velocity that Tiger fish can overcome. Therefore, it is unlikely that Tiger fish will flow upward through the Main Canal and enter the main stream of the river. On top of that, there are some critical obstacles in the middle of Shire River. Between Matope Bridge and Kapichira Dam, there are two barrages constructed on Nkula and Tedzani Hydropower stations and steep rapids. Therefore there is no likelihood that they can enter the upper shire due to the long steep natural rapids and barrages at Tedzani and Nkula.

Even though the Consultant believes that Tiger fish cannot go upstream to Lake Malawi, in order to take extra precaution the installation of a drop structure was: It has 3.5 m height and is proposed to construct it inside Majete Game Reserve. A weir of 1 m height will be combined with the drop structure, which will create a clear fall of more than 2 meters which will be an efficient barrier for the Tiger Fish. This is a proposed measure by ESIA and ESMP studies.

There are many cattle that graze in the project area. Grazing places are communal but since cattle need not only grass but also water, they graze mainly along the river banks and roadside drainage channels. In this regard, farm areas have been planned not to include current grazing areas, and therefore the actual grazing area will not be reduced significantly due to the SVIP. Rather many types of plants will grow along the drainage channels throughout the year after the project, thus creating rather favorable conditions for grazing. Since many new roads will be constructed in the farm areas, in addition to the existing paths, much more grazing corridors shall be provided.

CARBON FINANCE POTENTIAL

Under the Kyoto Protocol developing countries are not obliged to reduce their GHG emissions, whereas industrialized countries have to fulfill specified targets. For developing countries the CDM is of most interest among the regulatory market mechanisms. An industrialized country implements an emission reduction project in a developing country. This can be an afforestation, an energy efficiency or a renewable energy project. Because of the uptake or savings of GHGs, carbon credits (CER) are generated.

So far five methodologies have been approved for agriculture, 11 for afforestation/reforestation(A/R) and six for agricultural residues/biogas 3. At the moment the rules for AFOLU(Agriculture, Forestry, and Other Land Use) projects in CDM only allow for specific types of projects in developing countries.

- Agriculture: Methane avoidance (manure management);Biogas projects; Agricultural residues for biomass energy
- Forestry: Reforestation; Afforestation

All crops absorb CO_2 from the atmosphere, yet this impact may be easily undone if the crops are harvested (and the organic matter is not permanently stored in the soil). Moreover disturbing the soil through tilling and weeding will remove extra CO_2 from the soil. Therefore only (semi-) permanent crops are considered to have a significant impact as Carbon sink. For the VISP the Fruit trees and Sugarcane are relevant.

Carbon sequestration of sugarcane may amount to 50 tons per ha, (Moundzeo et.al. (2011) in the Niari valley in Congo). The researchers conclude that "the sugarcane plantations contribute a great deal in the struggle against climate changes and their use in terms of bio fuel". This is in line what has been reported also by the sugar industries' research. With 44 % of the project area eventually under sugarcane, SVIP would contribute to approximately 955,000 tons of CO_2 sequestration.

The consultants did not find any carbon funding possibility for the SVIP. Additional projects of bio-fuels and co-generation could be supported by the CDM, but this would require that an industrialized country, such as Germany or the European Union, be found that is interested in assisting Malawi. Moreover, such a country should primarily be interested in receiving additional Carbon credits.

It is therefore recommended that the Ministry of Agriculture, Irrigation and Water contacts the EU delegation and German Embassy to explore their interest in funding ethanol production and co-generation based on sugar cane in Malawi.

PRELIMINARY DESIGN

Location of the Intake Structure

In terms of location of the intake structure, considering the pros and cons between the two locations in the Kapichira Dam, the closed area (Site A) with spur dike was selected. Selection of the appropriate site was done with the assistance of the Hydraulic Modeling study. The Hydraulic Modeling study recommends the site to be located at Site A.

The SVIP intake structure shall comprise a 46.5 m long intake sill, with 12 sluice gates each 3 m wide. The gates shall be operated by an automatic control system. When the operator inputs the required amount of water into the system, the system shall automatically operate the gates based on the relation between the flowrate, gate opening and water level variation.

Main Canal 1

The Main canal 1 is 33.7 km long from the intake at Kapichira Dam to the junction point where it divides into the Main canal 2 and Main canal 3. Five branch canals supply water to the Zone I-1 (6,126 ha) and are directly connected to the Main canal 1. The Main canal 3 is 10.6 km long and shall supply water to an area covering 12,090 ha, including 9,995 ha belonging to Illovo Nchalo Estate. The Main canal 2 starts at the end point of the Main canal 1 and shall reach the Bangula area, supplying water to part of Phase I and Phase II of SVIP. The total length is 88 km, of which 18.4 km shall supply water to 4,064 ha Zone A areas under Phase I including some areas under Illovo management.

The main canals shall have mild longitudinal slopes; Main canal 1: 1/8,000, Main canal 2: 1/5,000, Main canal 3: 1/3,000. The shorter the length of canal, the more economic and technical benefits are realized. In this regard, the crossing of Mwanza River shall be a siphon following the shortest route, thus reducing the canal length by about 20 km. The radius of curvature of the route was set in the range of 3~7 times of the top width of flow at maximum design discharge.

Canal Lining

According to the recommendations of concrete canal lining thickness based on USBR, the thickness of concrete lining for 50m^3/s is about 10cm. Based on this recommendation, the thickness of concrete lining has been set at 10 cm.

Canal Structures

Siphons are planned for crossing locations where large valleys and rivers which have important flooding and large roads are passing. The culverts are planned where topographic change is severe but flooding is small. Culverts are also planned where small scale of rivers and roads. The beginning section of Main canal 1 (about 1 km) shall be constructed within Majete Game Reserve area. This section was designed as a siphon structure in order to minimize adverse environmental impact from this project. The siphon shall have a rectangular cross section (8 m (B) x 3 m (H)) and a length of 755.4 m.

Control Gate Structures of Main canal 2 and Main canal 3

The Main canal 1 ends into the Main canal 2 and Main canal 3. Control gates shall be installed at the head of both canals. The control gate for the Main canal 2 has three gates (3 m width x 2.5 m height x 3), and the Main canal 3 has also three gates (1.8 m width x 2.5 m height x 3). An automatic flow measurement device shall be installed at the front side of the gates. The gates shall be operated using an automatic system.

Sediment Removal

The spur dike in the reservoir performs a great role to protect the intake structure from strong currents and sediment that flows down from upstream. Hydraulic modeling results (Artelia E&E) showed that all the sand particles will be settled down in the fore area of intake structure, but some silt and clay particles could be entered into the canal. Therefore a sedimentation basin at the intake structure is not necessary. Sediments entering into the canal will not emanate from the intake only, but also from the outside of canal with various reasons (Sometimes due to heavy rainfall the bank top could be severely scoured and the sediment will enter into the canal). These sediments could be coarser than those from the intake gates. To remove these sediments 5 sedimentation basins (3 basins for Main canal 1, 1 basin for Main canal 2, 1 for Main canal 3), and several other sedimentation basins are proposed to be constructed in front of the siphon structures, spaced every 10 km distance. The sedimentation basins are designed based on the particle size of 0.3 mm, and they have rectangular shape with 35 m of length and 4~6 m of width. This sedimentation basins will give a function for emergency spillways.

Canal Control and Regulation

For the Main canal 1, the calculations show that water depth is maintained higher than 1 m throughout the whole section for both the high water demand condition and also for the low water condition. This is mainly due to its gentle slope (1:8,000). However, since the Main canal 2 and Main canal 3 have steeper slopes, weirs shall be installed at the offtake structures. The water level in the Main canal 1 could also be regulated by operation of the entrance gates of Main canal 2 and Main canal 3. The 11 siphons in the Main canal 1 could also be used to regulate the water level of Main canal 1.

Water Intake Control and SCADA System

The SCADA (Supervisory Control and Data Acquisition) system enables a scientific and efficient water management. A complete supervisory control system comprises a tele-monitoring system and a tele-control system. From a practical point of view, a rather simplified system is recommended for SVIP. The intake gates at Kapichira Dam shall be operated by an automatic system, which also could be operated by a tele-control system. Considering the O&M cost and easiness of operation, the Main Canal 2 gate and Main Canal 3 gate shall be directly operated at the site (not tele-control system).

Irrigation Method and Night Storages

The daily time for irrigation depends on the irrigation methods. For pivot irrigation system, irrigation time is 24 hours, a whole day. For furrow irrigation, water application is normally 12 hours, during the daytime. Therefore, the branch canals shall be used only for 12 hours based on furrow irrigation methods. The main canal was designed for 24-hour continuous supply, for the whole year. Therefore, there is an operating time gap between the main canal and the branch canals. Night storages will therefore be provided in order to make up for the gap. Night storages shall be installed at all the head of each branch canal, 5 storages for Zone I-1 and 7 storages for Zone A.

Drainage Canals

For the on-farm drainage channel design, 5-year flood frequency was considered. And for the natural river the NRCS Synthesis Unit Hydrograph Method and the Rational Method have been used for drainage design, based on the 20-year of flood frequency.

On Farm Works

The longer the long side length of a land parcel, the more economical the project becomes. However, there will be some limitations such as available space, variation of topographic change, installation of roads and so on. Considering these factors, the length of long side of a standard parcel was decided as 800 m.

The length of short side depends on the irrigation method, furrow slope, and soil type, etc. For the furrow irrigation FAO recommends the maximum length of short side as 200 m for the clay soil, and 170 m for the loam soil when 0.3 % of furrow slope is applied. Since the representative soil type in the project area is Loamy Clay type, the length of short side of a standard parcel was decided as 200 m. In this way a standard parcel has the size of 800 m x 200 m. This parcel size can be changed easily to pivot system which has 800 m of diameter.

Land leveling is required for land consolidation suitable for furrow irrigation system. Since the land leveling cost depends on the amount of earth movement, it should be reflected in the design process. The furrow direction shall have a slope of 0.2~0.5% considering the required slope of furrows, soil erosion, amount of earth movement, etc. The field canal, 800 m length, which delivers water to furrows in a parcel, shall have a slope of 0.5 %.

Flood Protection

The areas which could be affected by a 10-year frequency flooding magnitude shall be protected by dikes. The dike has been planned to be constructer in selected areas in order prevent heavy damages to the villages. The beneficial area of the dike protection will be 1,069 ha. Some river training works are recommended as a fundamental measure for flooding.

Road Network

Zone I-1 is enclosed within the Main road M1 on the east boundary, S136 road on the north, and T423 road on the south. Mbaendelana, Chikhambi, Fombe villages are located around the S136 road, and Mbande, Mologeni, and Supuni villages are located around the T423 road.10 farm roads (6 m wide) connect from the northern area to the southern area, and 15 O&M roads (4 m wide) connect villages to farms. In the Zone A, 13 farm roads (6 m wide) connect from the northern area to the southern area, and 8 O&M roads (4 m wide) connect villages to farms.

WATER SUPPLY AND SANITATION

The water supply plan was to benefit residents within and around the Chikwawa Boma area, parts of TA Kasisi and TA Katunga. Applying the growth rate to the population estimated in 2008 gives the extrapolated population of 30,619 for 2016, and 41,335 for 2026, the target year.

The water treatment method proposed is either a compact sand filter system or membrane filter system, since the water demand is small scale. The proposed water treatment systems will treat water very efficiently and rapidly compared to the conventional WTP process. The water treatment system shall be installed near the cross point of the road T416 and S136. From where the treated water shall be delivered through the pipeline using overhead water tanks.

The water shall be taken from the Main canal 1. A compact sand filter system shall be installed at this location. The water taps shall be installed at every 250 m distance along the pipeline. A 150 mm diameter pipeline will convey water from the Main canal 1to the water treatment system over a distance of 4.6 km. Overhead tanks shall be installed near the water treatment works at a height of 25 m. A distribution pipeline of 125 mm diameter and 7.8 km long shall deliver treated water to a total of 15 well points installed at 500 m distance to each other. The water supplying capacity shall be 14.4 l/s.

PROJECT COSTING

The total cost of SVIP taking into account direct and indirect construction costs are estimated at 623,362 thousand USD (250,402 thousand USD for the Phase I, and 372,960 thousand USD for the Phase II). This figure could be reviewed in line with the budget allocation for Phase I works while costs for the design of the intake, Main canal 1 and all the canal systems up to crossing Mwanza River are based on a total hectarage of 43,370 ha of the project area.

The maintenance of the irrigation system amounts to 0.6 % of the construction cost for Phase 1 and 0.5 % for Phase 2. These are the weighted average of the maintenance cost for all separate components. Operation cost of the system depends on the Water Service Provider in charge of operating (and maintaining) the system up to water meters and Cooperatives that are responsible for operations (and maintenance) of the on-field systems between the water meters and the crops.

ECONOMIC & FINANCIAL ASSESSMENT

The financial and economic analysis of the project in Chapter 16 starts with the conversion factors needed to convert financial prices into economic prices that better reflect the efficiency of the investment for the country as a whole. A FAO study led to the conclusion that the economic price of maize is 17 % higher than the financial price, while for other agricultural goods the markets are sufficiently liberalised for the financial to represent the economic price. For fertilizers estimated border prices using World Bank's Commodity Price Projects (July 2016) were corrected from transportation cost. Fuel prices were corrected for excise duties and exchange rate imperfections.

Standard conversion rates were based on the same difference between official and market exchange rates. Shadow wage rates were set 50 % for unskilled, 1.25 for skilled labour on the basis of information pertaining to the labour market. For consultancy a conversion rate of 1.15 was used.

Thereafter it shows the total investments required to make the SVIP a success, including the compensation for resettlement and loss of income during construction, the construction cost, the cost of the organisation that is supposed to manage the infrastructure after its completion (the Water Service Provider (WSP), the cooperatives that will manage the newly irrigated lands as well as the improved agricultural extension. With 7.5 % physical contingencies and 6 % consultants' cost, the total investment required is estimated at USD226.9 million for Phase one, of which USD28.3 million is Value Added Taxes paid to the Government. Direct construction cost (excluding VAT) amount to USD199.9 million.

Among the potentially environmental impacts, the crossing of the Majete National Reserve stands out. It is proposed to mitigate the adverse impact through an 800 m long siphon. To avoid severe noise pollution during construction a sound absorbing wall could be installed at a cost of USD586,000. An alternative route for the first part of Canal 1 that would circumvent the Majete Reserve completely was also examined. However, the economic analysis supports the technical preference for the route through the reserve as the latter would reduce the EIRR with.

Measures are proposed to mitigate (or prevent) nuisance and pollution during construction in other areas as well as tree planting at the construction camps which will have a positive impact on the presence of animals after completion of the construction. The amount of USD2,320,000 for drop structures in the Main canal 1 look rather small to prevent fish species from invading Lake Malawi, where they could potentially do considerable harm to people's livelihood. The environmental impact on the Elephant Marsh has been insufficiently studied to include in this analysis.

The cost of investment for Phase 1 (with part of the cost of the Intake, Canal 1 and 3 reapportioned to Phase 2) amounts to USD10,493 and USD9,157 per ha in financial and economic cost respectively if the institutional cost and cost of compensation and an transformation strategy are included. Annual O&M cost will be between 8 and 10 % of the incremental income per ha produced by the irrigation scheme, which shows that the scheme is quite affordable for the ultimate beneficiaries.

The SVIP has different benefits. First and foremost, incremental agricultural production (and income), which are separated in sugar cane and other crops, revenue of the sale of (irrigation) water, reducing electricity consumption (and thus a saving of investment in production capacity), drinking water supply in Chikwawa Boma, improved livestock production and aquaculture. Moreover, the project also includes additional flood protect in works which may save irrigated land from 1:10 years floods, which has an EIRR of 17 %.

The project will also generate a considerable amount of paid employment through agricultural labour and staff of the cooperatives as well as the Service Water Provider. During the 3.5 years construction there will be a strong demand for workers generating considerable incomes. Malawi's Ministry of Labour hopes this will reduce the push factors for youth's migration to the Middle East as well as an opportunity to train Malawi's labour force. These developments have been quantified and included on the benefit side of the Benefit – Cost ratio. The projects Economic Internal Rate of Return amounts to 11.3 % and the Economic Benefit- Cost ratio to 1.63 over a 40 years period.

The project as a whole is expected to be major boast for the South of Malawi. The economic multiplier effect is likely to lead to an additional contribution and also educational and capacity development activity will also spread beyond the borders of the scheme. Reducing the time needed to fetch family's drinking water in Chikwawa Boma may reduce a major constraint for girls to attend school.

This chapter follows GoM's latest thinking of only 5 cooperatives in Phase 1 area in order to benefit from economies of scale. Approximately 40 % of the area of the 2 new cooperatives and KAMA will be used by the individual households to grow food crops. The remainder will be cultivated by the cooperatives for commercial purposes, which in KAMA's case will be sugarcane and for the non-cane cooperatives a mixture of cotton, food crops and fruit trees. Also at the level of the individual household, participating in the scheme, and joining one of the cooperatives that were the basis of this analysis, makes economically sense with a expected 6-fold increase in average income, originating from the food crops grown on their own plot, wages from the agricultural work they will do for their cooperative and considerable dividends they will receive from the cooperatives.

The cooperatives themselves are economically feasible with a financial Benefit-Cost ratio of 4.4 and in economic prices 4.8 if the households' production is included and 3.6 (or 3.8 in Economic prices) if the household's production is not included. After deduction of debt services and payment of 20.22 % profit tax, the Economic Benefit – Cost ratios is still around 3.8. All these ratios are computed under the assumption that the land is donated by the farmers (in exchange of some irrigated land for food production and payment of a dividend).

Sensitivity analysis showed that these findings are quite robust, which is primarily due to the large number of different benefits that this project will produce. However, simultaneous increase in the cost of the transformation strategy, the compensation for (permanent) loss of land and (temporary) loss of harvest, combined with higher Irrigation Service Charges may have a bigger impact on the project's EIRR

This chapter also observes that the sensitivity study did not include the study of the impact of lack of adequate maintenance on the benefits, the feasibility of the project in relation to the sustainability of the rather big investments.

INSTITUTIONAL FRAMEWORK AND PRICE SETTING

The focus on the institutional framework in the SVIP is on what the project can take for effective and sustainable delivery, through good farmer organizations, cooperatives in the value chains. The framework thus looks at the overall institutional set-up for the project, addressing water management in links with agricultural development and detailing for each organization. The emphasis has been on the structures, governance, cost of these farm organizations that will play a role in the sustainability of the project. The section looks at the legal framework, key players in the project and activities involved, Relating the Key players, the Organisations formed including Operation and Maintenance, Optimising Canals, and pricing.

The legal framework examines the implication of the land bills which were passed in August 2016 and are likely to replace the 1965 Land Act. It also looked at the Irrigation Act and the Water Resources Act. The former is amongst the most important legislative framework governing irrigation activities in Malawi and the latter provides for the creation of Catchment Management Authorities, association of water users and stakeholders in water resources, environmental conservation and management as it relates to water; and establishment of a water tribunal.

The section also discusses the key players and different roles. At national level there is the Ministry of Agriculture, Irrigation and Water Development and related coordinating unit for the project, the PTT (directly under the Ministry), Ministry of Trade and Industry, Ministry of Gender, Children, Disability and Social Welfare, and Ministry of Youth and Sports Development. At district level, apart from the district council, there are development committees (district, area and village), NGOs and other development initiatives in the area. All these have responsible undertaking in the value chains that will be created by the project. Among the private sector organisations, there is Illovo and other newer players e.g. Press Cane, Kaombe. Traditional leaders and organisations that will be created at a later stage within their geographical areas will also be key and form the main linkages with the rest of the population in the areas.

The main highlight for the section is the institutional set-up as the SVIP is being implemented. At coordination level, there will not be much change. The current situation will continue to ensure that government has some control on the project. Thus, the Steering Committee, a Technical Committee and Project Coordinating Unit will continue, with both the Ministry and district level involvement.

Operation and Maintenance

This will be operated by private operator, under PPP, eventually to be called Scheme Management Entity (SME). However, for proper operations and control, there will be a Monitoring Control Unit under the Ministry to oversee that the SME is working perfectly. The main role of the SME is to manage the Water Purchase Agreements with Water Users and ensure that different roles and functions that may be required are undertaken. These may include:

- Collect water fees from the organisations in the project area;
- Maintain and operate the canal to ensure that water is available throughout the year;
- Undertake refresher training workshops for the staff and members involved in operations and maintenance in the cooperatives so that OMEX downstream is working efficiently
- Provide other services to organization and institutions in the area, covering research, irrigation, technical irrigation advise etc

Farmer Organisations

The framework proposes that Farm Cooperatives covering between 500 and 1000 hectares will be the main organisations operating in the area. So far, the area has the following organisations/associations: Kama, Nchalo, Kasinthula and Phata. Altogether, these should be 6-7. The structure proposed depends on Phata Model, which seems successful and has been appreciated by the surrounding communities. As part of the governance structure, the model has a Board of Directors, an elected Executive, and a private operator that provides professional management services. The estimated costs to making such farm cooperatives a reality is at least USD1.5m.

Farmers' Union

A farmers' Union has also been proposed to deal with common issues for all the players benefiting from SVIP, including big firms such as Illovo. The main purpose is to periodically discuss the issues that are common to all of them. Any issue that requires redressing will be taken to the coordinating Unit.

A Grievances Committee

This is a Committee that will deal with grievances due to land issues, as well as problems in the membership within the Farmer Organisations. The committee has been proposed considering the number of households that will be affected in the construction of the Canals and the relocations within the Farmer Organisations.

Canal Optimisation

The canals designed in the project will need to be fully optimized. The proposed approach is for a branch (or several branches) serve a specific farmer organization. This will also help in water accountability.

Water Pricing

This is in line with Ch 16 (Economic and Financial Analysis). Weighing several factors including: the overall cost of the project; the farmers' ability to pay taking into account the activities they will be involved in; the operation and maintenance costs; the cost benefit analysis. The proposed cost would be charges of USD 6 for the cooperatives and USD 9 for the sugarcane growers (per 1000 cubic meters).

ABBREVIATIONS AND ACRONYMS

ADC	Area Development Committee
ADD	Agriculture Development Division
AEC	Area Executive Committee
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
CDM	Clean Development Mechanism
CEC	Cation Exchange Capacity
DAO	District Agriculture Office
DBO	Design – Build - Operate
DEM	Digital Elevation Model
DEC	District Executive Committee
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	Global 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
IRR	Internal Rate of Return
ITCZ	Inter Tropical Convergence Zone
KRC	Korea Rural Community Corporation
LCCS	Land Cover Classification System
MoAIWD	Ministry of Agriculture, Irrigation and Water Development
O&M	Operation & Maintenance
PC	Project Coordinator
PMF	Potential Maximum Flood
PPP	Public Private Partnership
PTT(C)	Project Technical Team (Coordinator)
RAP	Resettlement Action Plan
RAW	Readily Available Water
SCADA	Supervisory Control and Data Acquisition
SMEP	Soil Moisture Extract Pattern
SRBMP	Shire River Basin Management Program
STDEV	Standard Deviation

SVADD	Shire Valley Agriculture Development Division
SVIP	Shire Valley Irrigation Project
TA	Traditional Authority
TFS	Technical Feasibility Study
ToR	Terms of Reference
UNDP	United Nations Development Programme
VDC	Village Development Committee
WB	World Bank
WPA	Water Purchase Agreement
WRAS	National Water Resource Assessment
WRIS	Water Resources Investment Strategy
WSP	Water Service Provider
ZAB	Zaire Air Boundary

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CHAPTER 1. PROJECT DESCRIPTION

1.1. Project Overview

Since the 1940s, the administration has been interested in the implementation of SVIP, to develop an agricultural irrigation scheme in the Lower Shire Valley. Since then, the proposed project has been the subject of a large number of surveys and studies. However, 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, in 2011, 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.

The pre-feasibility study report recommends that approximately 42,500 ha can be developed into an agricultural irrigation project in two phases (Phase I and Phase II). Water for irrigation would be abstracted from the Shire River and conveyed by gravity mainly through open canals to the irrigable area. The intake would now be located at the right bank of the reservoir formed by the Kapichira Dam constructed for Hydroelectric Power generation (and therefore lower in elevation) as opposed to the previously recommended upstream site at the Hamilton Rapids.

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

Phase I of the project would extend over 21,408 ha, of which 9,995 ha and 750 ha have already been developed as sugarcane plantations by Illovo and Kasinthula out-growers respectively. 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, (d) new land in the Mthumba Valley and (e) new land between the Mwanza River and Lengwe National Park. Water for irrigating this area would be supplied through the Main Canal 1 and 3, and partly the Main Canal 2.

Phase II of the project would extend over (21,092 ha, which is 42,500 – 21,408 = 21,092 ha) between Lengwe National Park and Bangula trading centre, of which approximately 3,248 ha have already been developed as a sugarcane plantation by Illovo. Water for irrigating this area would be supplied entirely by the Main Canal 2.

This proposition implies that the existing Illovo pumped water supply would have to be converted to a gravity supply, and the remaining 17,844 ha would be allocated to smallholder farmers or their organizations.

Since 6th July 2015 the Consultant - Korea Rural Community Corporation (KRC), in association with DASAN CONSULTANTS and GK Works - is in the process of performing the tasks of the Technical Feasibility Study, and has completed the tasks for Stage 1. During the implementation of their consultancy the detailed delineation of the boundaries of each sector was done resulting in adjusted boundaries, and a slight increase in the total project area. The adjusted project area has now become 43,370 ha, of which 22,280 ha belong to Phase I, and 21,090 ha belong to Phase II. The adjusted project area has been approved by the Client and the preliminary designs have been implemented based on this adjusted area.

1.2. Project Area

Malawi is a landlocked country, bordered by Zambia to the west, Tanzania to the north and east, and Mozambique to the east, south, and west. Malawi occupies an area of 118,484 km^2, of which Lake Malawi covers an area of 28,750 km^2. The country has a diverse physical environment which includes a plateau where dambos are also found, an escarpment, and a floor of the Rift Valley where the Shire Valley is located. The prominent highlands include Nyika Plateau, Viphya Plateau, Zomba Mountain and Mulanje Mountain.

The project area is in the southern part of Malawi within the administrative districts of Chikwawa and Nsanje. It is located on the west (right) bank of the Shire River in the Lower Shire River Valley which is 150 km long and 15-30 km wide. The Shire Valley has a high irrigation potential and is one of the most fertile areas in Malawi with a reliable source of water from the Shire River. Phase One of the project covers 22,280 ha in Chikwawa District. This includes 10,106 ha of new development, 9,995 ha under ILLOVO.

The 2016 population of Chikwawa, which is the principal area of SVIP, is estimated to about 550,000. The population in the project area is about 223,000 in 48,400 households. Of these 95,000 people are residing in 21,000 households in the SVIP 1 area and 128,000 people in 27,400 households in the SVIP Phase 2 area.

Over the years the area has experienced famine and has relied heavily on relief food. Even during the periods of normal rainfall, the farming families in this area harvest food sufficient for only three months. This project will therefore ameliorate the situation. With improved irrigation and drainage infrastructure in place, the Shire Valley could be Malawi’s breadbasket, capable of producing adequate food both for the Valley and also for the entire country with possibility for surplus which could be exported.

The Shire Valley is characterized by a generally low elevation where the relief profile ranges from 60 m to 150 above sea level. Temperatures in summer months range from 28°C to 35°C. The mean temperatures in winter months vary from 20°C to 35°C with an annual temperature range from 12°C to 15°C. The hottest period is from October - November when temperatures can reach 40°C. During the winter season, the area is under the influence of low equatorial pressures giving big clouds heavy with humidity and the north-east monsoon, which are the principal sources of rain. The average rainfall is 652mm with the rainy season falling from November to March. Analysis of monthly climate regimes indicates that the climate of the area is humid to semi-humid between December and March thereafter oscillating between semi-arid to hyper arid in the period April to November.

For a country where agriculture is the mainstay of the national economy, scarcity of soil moisture limits crop production to only four months and thus poses a major constraint to attainment of the local and national agricultural potential. This consideration is by far, the single most important justification of the proposed irrigation initiative in the Shire Valley Area. The average annual potential evaporation based on Pan Evaporation data for Kasinthula Station averages 1969mm. Annual evaporation thus far exceeds the annual rainfall regime of 796mm implying that the SVIP area generally suffers a moisture deficit. With an aridity index (ratio of rainfall to Eo) of 0.4, the climate of the SVIP can generally be classified as semi-arid. The inadequacy of soil moisture imposes severe constraints to ecological productivity in the SVIP area.

1.3. Scope of the Technical Feasibility Study (TFS)

The objective of this assignment is to undertake a detailed technical feasibility study, which would upgrade 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 has completed the Stage 1 assignments, and now is performing Stage 2 assignments. The main tasks of this stage are as below:

- Topographic survey for the canal route and processing the base map for the preliminary design.
- Preliminary design for the Intake Structure, Main Canals, Canal Structures, Secondary Canals, Night Storage Ponds, Drainage Canals, and On Farm Works, etc. In the process of performing design tasks the Consultant shall take into consideration minimizing adverse impacts on the environment.
- Planning of the drinking water supply for residents served by the Southern Region Water Board and the rural community in the vicinity of the canal system, a separate supply network based on the irrigation water conveyed through the Main Canal 1. The Consultant proposes to present the most efficient water treatment and supplying system.
- Land consolidation, which will incorporate any adjustments in land tenure resulting from the layout of the plots and irrigation blocks.
- Estimation of the total project and O&M costs, and determination of the financial and economic analyses to attest to the feasibility of the project. Promotion of the project into the subsequent phases will depend upon the results of these analyses.
- Provision of the institutional framework that will include Water Management System, Institutional Framework of Organizations and local government institutions, and Revenue System for Organizations in the execution phase of the project.

It should be noted that while the feasibility study should focus on Phase I of the project, it will 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 of paramount importance because whether this phase will eventually proceed or not, will affect the design capacity of intake and Main Canal 1.

1.4. Reports to be Submitted

The First Stage Report

The First Stage Report, which is called the Option Report, was submitted and approved by the Client in September 2016. The main contents of the First Stage Report are:

- Preliminary investigations for Topography, Soil, Geology, Hydro-geology, Flood, Socio-economics, GIS development, etc.
- Assessment of technical options in terms of With / Without Illovo Estate, Irrigable Areas to be Developed, With / Without Lining the Main Canal 1, Main Canal Optimization, Phasing of the Project, Type of Cropping Patterns, Type of Field Irrigation System, Options to Mitigate

Environmental Impacts, Use of Other Resources, With / Without Maintaining Current Pumping System

- Financial assessment of Illovo Estate Participation which described Benefit of Illovo Estates, Capital Cost due to the Inclusion of Illovo Estates in the SVIP, Cost Recovery from Illovo Estates.
- Water requirements for SVIP
- Occurrence of a long series of dry years, and
- Cost estimation for the implementation of SVIP.

The Second Stage Report

The Second Stage Report is the major report of the Technical Feasibility Study. This report consists of 2 volumes:

- Volume 1: Main Report; and
- Volume 2: Drawings of design (A3 format).

1) Volume 1: Main Report

The main report (Volume 1) comprises four components, and they are:

- Main results of other SVIP Feasibility Study teams (6 teams):
  - Socio-Economic Study (Chapter 2);
  - Agricultural development planning strategy (Chapter 3);
  - Public-Private Partnership (PPP) (Chapter 4);
  - Environmental and social impact assessment (Chapter 5);
  - Hydraulic modeling of intake (Chapter 6);
  - Dam safety (Chapter 7)
- Field survey (Chapter 8):
  - Topography Survey;
  - Geotechnical Investigation;
  - Hydrogeology;
  - Soil Investigation;
  - Flood Analysis
  - Development of GIS
- Main results of the First Stage Report:
  - Assessment of technical options (Chapter 9);
  - Water requirement and water availability for SVIP (Chapter10);
- Preliminary design report:
  - Environmental and social adaptation (Chapter 11);

- Carbon finance potential (Chapter 12);
- Preliminary design (Chapter 13)
- Water supply and sanitation (Chapter 14);
- Project costing and economic and financial assessment (Chapter 15 and 16);
- Institutional framework and price setting (Chapter 17)
- Project implementation time frame (Chapter 18)

2) Volume 2: Drawings of design

This volume contains the drawings of design for SVIP. These drawings are provided in A3 format. It is comprise two parties:

- Part 1: Drawings for project design
- Part 2: Sample outs of GIS data

The Part 1 contains the drawings of design as below:

- Intake structures (plan view and section view)
- Longitudinal sections of Main canals
- Longitudinal sections of Secondary canals
- Main structures of canal and offtakes
- Land consolidation plan
- On-farm plan

The Part 2 contains the sample outs of GIS data as below:

- Image map
- Digital map
- Contour map
- Digital Elevation Model (DEM)
- Road map
- River & stream
- Design layout of project area
- Soil map

CHAPTER 2. SOCIO-ECONOMIC STUDY

2.1. Introduction

In 2016, it has been estimated that there is a population of 270,000 (62,790 households) in the Shire Valley Irrigation Project (SVIP) area. Of this population, 117,000 people (27,210 households) are residing in the SVIP Phase 1 area. The estimated population for the year 2021 is about 300,000 (70,000 households), of which about 130,000 (30,235 households) will live in the SVIP Phase 1 area. Most villages were established more that 100 years ago. There have been a regular influx of new settlers in the mainly for economic reasons. Integration of the newcomers was generally without problems.

According to the participants in the FGDs most people obtain their plot through inheritance within both Chikwawa and Nsanje Districts. About 22% of the plots are granted by the local leader and about 11% rented for a short period of usually one year or one growing season only. Land is mainly used for rain fed agriculture (69%) and settlement (28%). Only 2% of the land is irrigated and less than 0.5% set aside for grazing, business, renting and other uses. Over 70% of the respondents in the household survey use 3 to 4 parcels. The total area used by households is small, about one quarter use a total of 0.3 to 0.49 acres and 29% uses 1 to 1.5 acres.

IN terms of the economy and food security in the area, the main per capita consumption is lower than the national figure and below the poverty line of MK 37,002 in all TAs within Chikwawa and Nsanje Districts with the exception of TA Lundu (MK 37,820), in which Nchalo Estate (the Illovo Sugar estate) is located. The incidence of poverty and ultra-poverty in TAs in Chikwawa and Nsanje Districts is higher than the national average in all TAs, apart from TA Lundu and TA Katunga. These two TAs are where the Illovo Sugar estates are.

The average life expectancy at birth was 51 years in Malawi, 52.2 years for women and 49.6 years for men. In Chikwawa this was 51 years and in Nsanje 45 years. Infant Mortality, Child Mortality and Under-Five Mortality rates are higher in Chikwawa and Nsanje District than the national average reflecting the lower nutritional status and food security challenges in these two districts.

Whilst the overall literacy rate of Malawians in 2011 was 65%, the literacy rate in Chikwawa District was only 47% and in Nsanje it was even as low as 46%. These rates decrease with age and are lower in females than in males.

In terms of agriculture, the main types of crops grown in the SVIP area are maize (24%), sorghum (18%), and cotton (17%). Maize is more grown in the Phase 1 and sorghum in the Phase 2 area. Results of the SVIP baseline survey found that the average yields per hectare were 517 Kgs for maize, 297 Kgs for sorghum, 336 Kgs for cotton and 862 kg/ha for rice. The area has a large population of livestock and the most common types of livestock kept in the area are cattle, goats, pigs and chicken according to the FGDs.

Information has been obtained regarding community views on the Shire Valley Irrigation Project (SVIP). Almost all households (98%) are willing to participate in the SVIP; even if it is decided on their behalf what crops can be grown under irrigation. The main conditions for participating in the SVIP are that they should get financial support to develop their land and receive extension services. A large majority (88%) of the households are willing to pay for irrigation water.

People also generally agree with the idea of pooling land for the purposes of transforming agriculture from subsistence to commercial mechanized and intensive production. When pooling together land, two third of the FGDs were of the opinion that the size of an irrigation block should be determined by the number of farmers per block. The majority prefer that that when pooling land, reallocation should be proportionate to the area owned by an individual.

The Project Technical Team has studied Kasinthula and Phata models and is persuaded by the Phata model. The lessons learnt from the Tour of Swaziland also support the Phata model as the most promising smallholder farming model. The key success factors of this model are transparency, two-way communication, rule of law (constitution), strong organisation with leadership that is trusted and has integrity, land consolidation which opened access to finance and other opportunities, professional management of the farm and a ready market for the produce.

2.2. Gender and Youth Strategy

The purpose of the Gender and Youth Strategy for the SVIP is to enhance development effectiveness of the project by: (i) identifying project specific gender and youth dimensions and (ii) mainstreaming measures in the project planning and implementation to ensure gender and youth equity, sensitivity and inclusiveness. It has been developed through a mix of methods involving four interrelated data collection methods: review of documents and policies; key informant and focus group discussions with community members in the SVIP impact area; baseline household survey and national and district level individual in-depth interviews involving key stakeholders of the project.

The Gender and Youth Strategy has identified gender and youth issues related to:

- Education and literacy. Literacy and education rates of women are considerably lower than those of men, especially of the population above 35 years of age.
- Access to and control over land is dominated by adult males over 35, also in matrilineal societies.
- Resettlement. Experience shows that women and youth often loose out in resettlement and reallocation processes, especially when they are poor because they do not have sufficient power to attain their rights.
- Access to economic assets, credit and finance. Fewer high value assets and more lower value assets are owned by female headed compared to male headed households. Access to credit is problematic for the poor. Only 4.2% of the household respondents obtained a loan in the last year, 3.6% of the female headed and 7.1% of the male headed households. Fewer female (8.0%) than male (15.9%) headed households had a bank account in the SVIP survey.
- Decision making at household level. Often women are only allowed to make decisions on small and daily purchases for household needs. Decisions on large investments related purchases and important issues affecting the household are made by men. Results of the household survey show that married women made fewer decisions on their own compared with female headed households, while children generally did not make decision on most household activities. Generally the man takes control of all income from crop sales. This was confirmed by stakeholders interviewed in the SVIP impact area.
- Agricultural labour. The third integrated household survey showed that 94% of the cultivated plots used women to provide labour while a quarter used children in cultivating their plots. Only 23% reported to have hired their labour input.

The Gender and Youth Strategy includes a goal, purpose and specific objectives. The specific objectives are:

- Improve the sustainability and effectiveness of the Shire Valley Irrigation Project (SVIP) through incorporation and mainstreaming of gender and youth issues.
- Improve understanding and awareness of gender (women and youth) concepts through an easy reference SVIP gender and youth guidelines, and:
- Improve approaches to the planning, implementation, management, monitoring, financing and reporting of the Shire Valley Irrigation Project.

The strategy has identified activities for the preparatory stage of the project and the implementation stage. It also includes key stakeholders (both internal and external) from national to community level, stakeholder roles as well as sample indicators.

2.3. Communication Strategy

The development of the communication strategy started with a stakeholder and a SWOT analysis a desk research and a qualitative survey; interviewing respondents from the local government in Chikwawa to obtain a better understanding of its communication efforts as well as the communication landscape in the Lower Shire, particularly in Chikwawa.

Major conclusions drawn from the field study when it comes to possible effective communication channels to be used by the SVIP are presented below.

- The DC meetings provide a good opportunity to meet all elected representatives within the District as well as the Traditional Authority and co-opted members in one sitting for discussing options and strategic decision-making. Therefore, these meetings are an essential channel for the two phases of the SVIP.
- The District Executive Committee (DEC) meetings provide a good opportunity for project implementers to meet all government departments in the district at one sitting. These meetings can be used for discussing sharing of information and for gaining a common understanding.
- Agricultural structures are an effective channel for raising public awareness among stakeholders in the project area.
- It is best to contact NGOs working in Chikwawa through either the DC's office or directly depending on the nature of the issue at hand. NGOs outside Chikwawa can be reached directly through letters, e-mails and phone calls.
- Letters are a reliable and officially recognised channel for communicating with Chiefs and villagers.
- Area Development Committee (ADC), Area Executive Committees (AEC) and Village Development Committee (VDC) meetings provide a good opportunity to convey messages to the villages.
- Open days/field days could be utilised as part of public awareness campaigns.

These structures pave the way for a two-way communication flow. However, it can also be concluded that there is a need to strengthen the bottom-up flow of communication from the villagers to the SVIP Management. It is important to note that within Nsanje and Chikwawa Districts the proportion of literacy is respectively 73.8%and 80.2% for men and 54.9% and 49.1% for women.

The most common and popular media are as follows:

- The most popular media of communication are radio, newspapers, television, mobile public address (PA) system announcements, public meetings, printed materials and mobile phone communication.

- After radio, newspapers are the next effective medium of communication in the country. Among women, 11.8% of women read the newspaper at least once a week compared with 25.3% of men.
- In terms of television access, 33.4% of men aged 15-49 watch the television at least once a week compared with women at 15.9%. MBC Television would therefore be appropriate for communicating with corporates and other organisations involved in the SVIP.
- Mobile PA announcements are an ideal but expensive way to communicate with people at the village, group village and Traditional Authority levels.
- Experience has proven that public meetings with people at the village, group village and Traditional Authority levels are an effective way of communicating socio-economic issues in Malawi.
- Other printed materials such as posters are useful in passing on information about projects to the people in rural areas in Malawi.
- Phone calls and group SMSs are not the most effective way of reaching community members as only a small part of the population possesses mobile phones – not to mention the high illiteracy levels which would hinder people from reading the messages.
- Theatrical performances are a popular way of conveying important information to members of the general public in Malawi
- But access to internet in rural areas is limited.

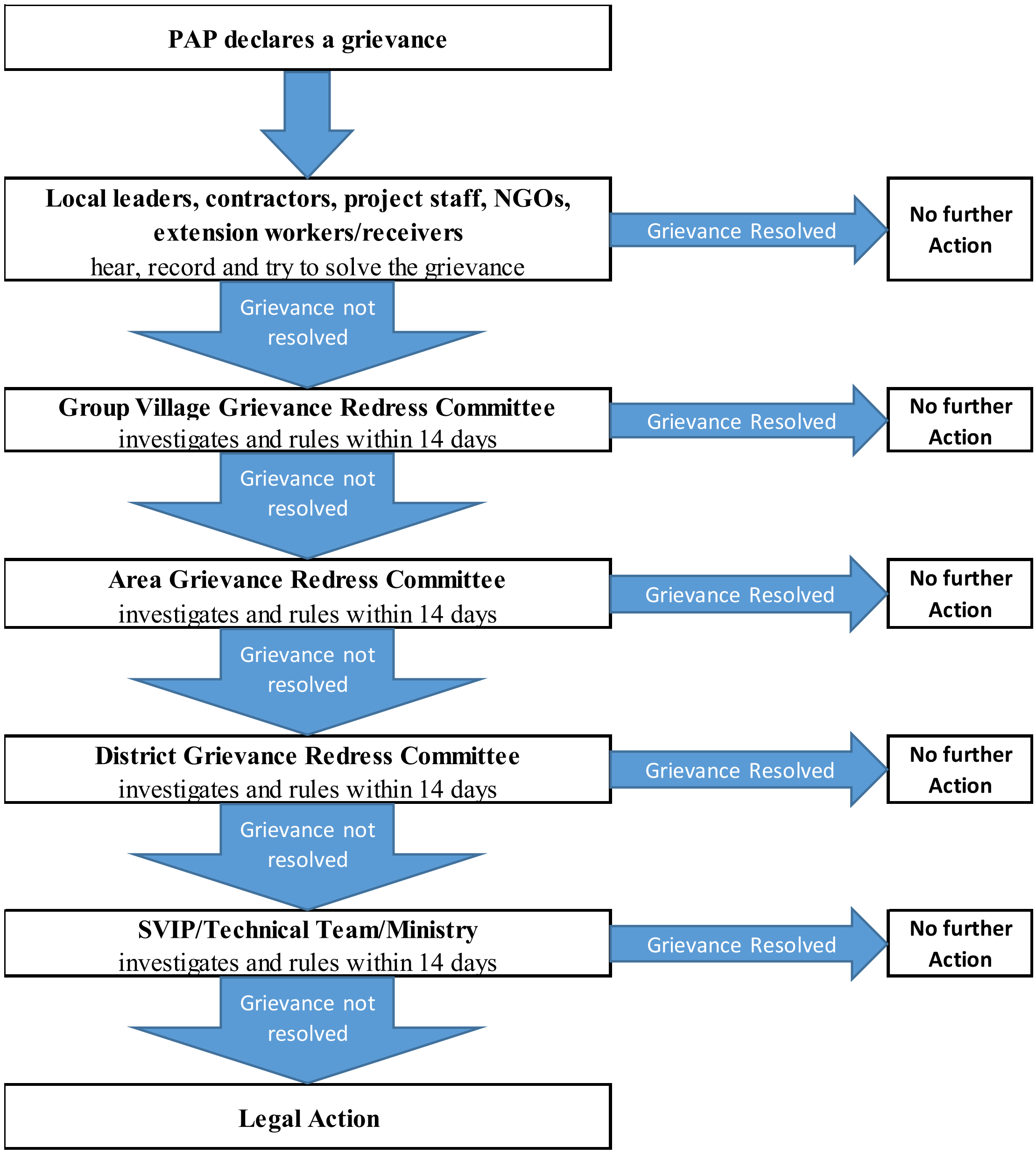
The main communication goals are to 1) build awareness and knowledge of the SVIP; 2) create a knowledge sharing and learning culture among project implementers; 3) encourage dialogue and create a two-way information flow; 4) keep key stakeholders informed regularly and on a timely basis; and 5) positively influence behaviour through capacity building and understanding.

The key messages if the communication strategy are 1) the need to transform farming from subsistence to commercial and market oriented farming; 2) the need to consolidate landholding; 3) need for farmers to get organized; 4) the need for the consolidated farms to be managed professionally; 5) the need for professional operation and maintenance of the irrigation infrastructure; 6) payment of a fee for the operation and maintenance of the infrastructure; 7) the advantages of partnering with private sector and other partners for financial and technical services; 8) the importance of storage and value adding; and the need to be linked to markets.

2.4. Grievance Redress Mechanisms

The objective of the SVIP Grievance Redress Mechanism (GRM) is to solve disputes at the earliest possible time, which will be in the interest of all parties concerned. The GRM implicitly encourages resolution of conflicts at the lowest level possible, in an amicable and participatory way. The SVIP GRM intends to provide clarity and predictability on how complaints will be received, assessed, sorted, and resolved, and monitored. The principles guiding the SVIP GRM’s procedures have been adapted from lessons learnt and documented by the World Bank from its funded projects and incorporate the Voluntary Guidelines of the FAO as a means to channel citizen feedback to the SVIP programme to enable it improve project outcomes for the people.

At every stage of the GRM, there will be somebody dedicated to handle and record complaints. The first step for a projected affected person who has a complaint is to notify their Local Leader, extension worker and/or project staff. These will record and try to solve the case, but if this is not successful, the case will be referred to the Group Village Grievance Redress Committee (GVGRC) to determine the validity of claims. If valid, the Local Leaders will notify the complainant and s/he will be assisted. If the complainant's claim is rejected, unsolved or not resolved satisfactorily, the matter shall be brought before the Area Grievance Redress Committee (AGRC) and subsequently before the District Grievance Redress Committee for settlement. Thereafter, the case can be presented to the MoAIWD/PTT. Figure 2.4-1 below provides an overview of the SVIP GRM.



[Figure 2.4-1] Proposed SVIP Grievance Redress Mechanism

The SVIP Project will be responsible for the operation of this GRM. A contact person for the GRM will be appointed. The main responsibilities of the contact person will include maintaining the grievance redress process, including the procedures; registration of complaints; capacity building of the grievance committee(s); outreach and external communications; tracking performance and monthly reporting

2.5. Land Tenure Diagnostic, Allocation and Consolidation Strategy (LTDACS)

Malawi faces a number of challenges including inequitable distribution, limited access to land and benefits arising from it, under resourced land administration institutions, insecure tenure regimes, weak institutional capacity, unsustainable utilization of land leading to different forms of degradation, limited investment, and conflicting sectoral land related policies The Land Governance Assessment Framework (LGAF) study of 2012 gives a detailed overview of these in the context of land governance and provides recommendations in support and addition to the recommendations of the Commission of Inquiry on Land Policy Reform, some of which are already implemented such as the MoLHUD.

The information from the Land Use and Tenure Inventory forms the basis for the Land Tenure Diagnostic, Allocation and Consolidation Strategy (LTDACS). This will guide the land re-arrangement process required for the implementation of the SVIP. This will generally be a process of land consolidation and reallocation with some limited resettlement. Closely related to the LTDACS is the Resettlement Policy Framework (RPF) which is covered in the next section and deals with how to develop fair and transparent resettlement processes to mitigate any loss of livelihood. Additionally, the Grievance Redress Mechanisms (GRM) presented earlier will define processes for those affected to raise concern and obtain feedback from the responsible agencies in a speedy, transparent and accountable manner.

The land inventory started with production of general land cover maps for both Phase I and II. These maps are based on the orthophotos provided by the Department of Surveys. Information from other sources was inserted to show physical features (i.e. roads, rivers, and lakes), registered land tenure, public facilities and enumeration areas. Orthophotos were used to identify the settlements and general land use.

The results from the field survey show that 64% of the land within SVIP is customary and 36% private is land. The high percentage of private land is due to the large sugarcane estates such as Nchalo, Alumenda and Kaombe. Apart from these large plantations/estates only a couple of small private leases exist in the project area, mostly located within the village areas. Another important result from the field investigations is that more than half of the customary land in phase 1 is already organised such as Kasinthula, Phata and Katunga-Maseya (KAMA) scheme which is in the process of being established. Knowledge and perception of these schemes are generally positive.

In line with the just passed Customary Land Bill, land management matters for the cooperatives and associations may be under the organisational structures described in new law i.e. Land Management Committees and Land Tribunals. The new law provides an opportunity for the consolidated farms to get a customary estate title which is quasi-freehold and superior to a leasehold title. Furthermore, the new law provides for the possibility of farmers to lease out land to private interests. Of course, if the consolidated farms are registered under the Registered Land Act, they will be no need for the involvement of the Land Management Committees or Land Tribunals; keeping in mind that customary estate title is better than leasehold title.

With relation to the resettlement and reallocation issues, it is important to note that all the schemes are established without any resettlement. Participating farmers obtain a share in the irrigation scheme in proportion to the land brought in, whereby the eligible area is broadly defined, i.e. incorporating the land required for the irrigation infrastructure as well as the surrounding land which may be used for resettlement.

Another important issue is the protection of the rights of the landowners. Protection of the rights of the land owners in the various out-growers' schemes is addressed in the constitution that includes detailed paragraphs regarding the division and transfer of shares, which can only be done within the families or within the scheme. The shares cannot be sold to a third party, thus preventing the taking over of the customary land by private companies. With the new law the cooperative or association can apply for a customary estate or leasehold title secure the rights and to establish a legal document as a basis for obtaining loans. The lesson from Swaziland in this matter is that the process of land consolidation involves a consultation process with all the land owners to ensure that all agree to consolidate the land. Once everyone has agreed, everyone's land is surveyed to determine the area of land brought to the consolidated farm by each member. The land is then surrendered to the chief. The chief then requests all the owners of the land that is being surrendered to sign against their names to signify their consent to surrender the land. Using this information, the chief's letter is issued to grant the land to the entity that will operate the farm; be it a cooperative, association or company.

In the SVIP area there is virtually no virgin land to be allocated by the chiefs. This lack of land for allocations inevitably means that persons without land must find alternative means of acquisition or access. Only 0.5% of landholders reported that they rent out land to others. Renting out, which may or may not require traditional authority consent, provides cash income for landholders who have excess land or are unable to cultivate the whole holding without employing casual labour. A recent study on Malawi land tenure revealed that active land rental markets are emerging in central and southern Malawi in response to increasing land scarcity, the skewed distribution of land, and imperfections in non-land factor markets. Although total landlessness is still at a very low level (3%) in Malawi, many near landless households attempt to access extra land through the land rental market where fixed-rent short-term contracts appear to dominate.

Land scarcity means opportunities for youth to acquire their own land are limited, although rental is an emerging option. Currently inheritance is the primary way to acquire or access land and it is not surprising that most landholders are over the age of 35 years. Although not disaggregated by age, 7% of landholders rent their land rather than 'own' it. The majority (81%) of customary landholders in the SVIP area are male. The CCPLTRPF survey found that 15% of landholders are female, and 4% hold the land jointly as spouses.

2.6. Resettlement Policy Framework (RPF)

The purpose of the Resettlement Policy Framework (RPF) is to provide a robust framework guiding land acquisition and resettlement issues from irrigation projects to be funded through the Shire Valley Irrigation Project. The need for the RPF emanates from two areas which will lead to displacement of people as a result of the construction of the main and secondary canals and associated infrastructures. This would trigger resettlement of some people. Policy and legal framework on resettlement in this project is drawn from the Constitution of Republic of Malawi, the National Land Policy and various pieces of legislation which include: the Land Act, the Land Acquisition Act, the Public Roads Act, the Town and Country Planning Act, the Water Resources Act, the Forestry Act and the Monuments and Relics Act.

It is recognised that project affected persons (PAPs) may be impacted by the involuntary taking of land resulting in: a) relocation or loss of shelter; b) loss of assets or access to assets; c) loss of income sources or means of livelihood whether or not the person should move to another location; or d) by the involuntary restriction of access to legally designated parks and protected areas resulting in adverse impacts on the livelihoods of the displaced persons. In all these cases PAPs are entitled to compensation. The RPF is based on principles which are consistent with policies and legal framework of the Government of Malawi (GoM) and the guidelines of Malawi's development patterns, the WB (OP4.12), the AfDB (IDRP) and the FAO. These guiding principles are that:

a. To the extent possible, involuntary displacement and land acquisition will be minimized.

b. A meaningful consultation and participation must take place.

c. A pre-resettlement data baseline must be established.

d. A fair and equitable set of compensation options must be negotiated.

e. Vulnerable social groups must be specifically catered for.

f. Monitoring and grievance procedure will be put in place.

g. Government to provide resettlement assistance to project affected persons.

h. Government should set up accessible grievance redress mechanisms.

i. RPF complies with relevant policies and laws.

j. Timing of start of construction work should be after harvest of the annual crop and full payment of all compensation dues.

k. Compensation should be adjusted to cover inflation rate.

The determinant of the number of PAPs and quantities of assets loss will be limited to land taken up by the main canal, secondary canals and area required for other infrastructure and construction purposes. The PAP or asset must have been located within this area before the cut-off date and baseline, and the PAP's association with the location and asset must be registered or recognized in the local community. Utmost care shall be exercised to verify claims so that vulnerable PAPs are not disadvantaged. Local authorities shall be consulted if a claim is in doubt.

In summary, an estimated 720 hectares of land will be acquired for the main canals and about 295 households will be affected in both phases. For phase 1, the affected area is estimated at 375 hectares and 121 houses. Some of these may be assimilated within the communities depending on the nature of their impact. However, others will have to be resettled elsewhere. In addition, about 198 ha will be required for construction purposes in Phase 1. The figures will be revised if need be during the preparation of the resettlement action plan.

Apart from loss of land and personal assets, the community may also suffer from loss of archaeological, cultural and religious sites which they hold dearly. These sites are not included in the RPF but reference is made to the Environmental and Social Action Plan that describes these sites and how these shall be treated. None of those have been identified along the current canal route in Phase 1.

Construction of the SVIP will require land for the infrastructure and construction purposes. The required land is owned and most used for income generating activities. This triggers involuntary resettlement, which establishes the need for a Resettlement Action Plan (RAP). Upon approval of this RPF, a RAP will be developed through consultative process between the District Executive Committee (DEC) and affected communities with assistance of the Consultant.

The estimated costs for preparing and implementing the Resettlement Action Plan are about USD 5 million (Five million US Dollars). The estimate is based upon the information of the Technical Feasibility Consultant on the area required for the construction of the canals and adjacent roads plus the area required for construction purposes and is most likely to change with changes in the canal route. Area required for additional irrigation infrastructures is estimated at 10%. Costs include the compensation for land, structures, crops and other developments on the land as well as some capacity development and other costs. This figure does not included costs for implementation of the Environmental and Social Action Plan as this is assumed to have its own budget.

The calculations of the estimated compensation are based on an assumption that the PAPs will get allocated a similar plot of land as the land lost. In the Land Tenure Diagnostic, Allocation and Consolidation Strategy the proposed approach for reallocation is based on the experiences from the existing out-growers schemes in the project area. If this approach is followed the PAPs will obtain a share in the irrigation scheme corresponding to their original plot sizes. Such an approach will reduce the need for a compensation of land, and also reduce the estimated figures.

CHAPTER 3. AGRICULTURAL DEVELOPMENT PLANNING STRATEGY

3.1. Key Elements of the AgDPS

The key elements of the Agricultural Development Planning Strategy (AgDPS) are:

- Organizational options to clearly map out the relationship among the various stakeholders, including linking the irrigation scheme management side and the agricultural production side;
- The various options to develop appropriate contractual arrangements between smallholder producers and agro-processors, to support an out-grower production scheme or any form of contract farming;
- The various institutional and contractual arrangements for the provision of agricultural services, including:
  - the various ways and means of minimizing post-harvest crop losses starting from timely harvesting of the produce in the field and appropriate drying techniques, chemical application and development of appropriate storage structures;
  - appropriate methods of value addition with a view to improving the marketing potential of the agricultural commodities;
- An appropriate and equitable mechanism to integrate larger private agri-business investors, in the development of the project area;
- A phased roll out of the strategy, including clearly identified activities for follow up work by different actors, including their objectives, linkages, indicative costs and respective timing; and,

Identifying specific reforms/conditions that need to be in-place to facilitate the roll out of the strategy, as well as other actions required to facilitate investment and smallholder engagement as detailed in the plan.

3.2. Objective

Malawi's economy is heavily dependent on the agricultural sector while at the same time the sector is dominated by the smallholder sub-sector. The smallholder sector relies mainly on rain-fed crop production. To address this weakness in the economic foundation of the country the Government of Malawi (GoM) has, since the 1940s, expressed an interest in developing the Shire Valley with the intention to exploit the huge potential that exists in the region for irrigated crop production.

The purpose of the AgDPS is to provide a clearly prioritised road map for improving Malawi's productivity through investment in irrigation infrastructure in the Shire Valley. The AgDPS aims to maximise the direct contribution of the Shire Valley to economic and social development as outlined under the thematic area of sustainable economic growth in the MGDSII. It aims to do this through the development of the Shire Valley in the manner that is balanced with the direct involvement of the private sector and the empowerment of the rural poor, smallholder farmers, the youth and women. The objective of the Agricultural Development Planning Strategy (AgDPS) is to lay the foundation for the implementation of this vision. The underlying objectives of the strategy are to:

- Develop a market oriented commercial farming project;

- Encourage a change of mindset to facilitate the transformation of the smallholder sector from a focus on subsistence production towards a commercial production mode;
- Contribute towards real value addition;
- Establish the institutional and contractual arrangements required to facilitate the transformation towards efficient; professional and market oriented agricultural production; and
- Identify the different building blocks; the timing; and investment levels required to achieve the objectives of the strategy.

3.3. Key Policies

The study has reviewed several policies, strategies and regulatory instruments that have been developed to establish a suitable framework that will facilitate the development of irrigated agriculture in the Shire Valley. The key policy and strategy documents that will influence the implementation of the SVIP and, in particular, the AgDPS include: the national constitution; Vision 2020; the Malawi Growth and Development Strategy (MGDS); the National Export Strategy (NES); the National Irrigation Policy (NIP); the Green Belt Initiative (GBI); the National Land Policy (NLP); the National Fertiliser Strategy (NFS); the Seed Policy; the Cooperative Development Policy; the Livestock Policy; the National Water Policy; and the New Alliance for Food Security and Nutrition in Malawi. In addition, the country is well integrated with others at both the regional and international level allowing it to pursue various options to access markets in the wider community of nations.

3.4. Overall Crop Production

Malawi has a total land area of 9.4 million ha and an additional 2.4 million ha covered by the waters of Lake Malawi and other smaller surface water bodies. The total population is currently estimated at 17 million people, 90 percent of whom live in the rural areas (National Statistical Office, 2008). The agricultural sector is divided into two main sub-sectors, namely: the relatively large scale, modern estates, located in high potential areas and primarily engaged in the production of export crops; and, smallholder farms operating on customary land or leasehold estates, engaged in small scale mainly subsistence, rain-fed farming.

It is estimated that of the 5.3 million ha that are arable, 3.7 million ha (70 percent of the land) are cultivated by smallholder farmers, engaged mainly in subsistence farming. Maize, cassava and rice are the major food crops and tobacco (particularly burley) is the major cash crop accounting for nearly 43 percent of the country’s export earnings. Food crops that are grown in the country include: millet, potatoes, pulses, sorghum, sweet potatoes and various types of fruit trees. Other important cash crops grown in the country include: cotton, sugar cane, tea, and tree nuts such as macadamia. The crops grown are mainly rain-fed with a small proportion of the agricultural land benefiting from the advances in irrigation practices

The Shire Valley is well endowed to support the production of various crop and livestock commodities. The Shire Valley is blessed with the right climatic conditions (temperature, humidity, sunlight and rainfall) and soil conditions to support the production of a wide variety of crops. The country also enjoys ready access to the markets in southern, central and east Africa.

The major limiting factors to crop production in the Shire Valley are the high temperatures (up to a maximum of 40^{o}C in November) and the unreliable rainfall pattern (ranging from 170 to 968 mm per year) resulting in low crop water availability. Although farmers grow some drought-resistant crops such as sorghum, millets and cotton which can withstand climate variability due to droughts and floods, the farming system's dependence on rainfall means that it remains vulnerable to variations in weather patterns. As a result crop productivity is well below the potential of the area, in the absence of irrigation facilities. The gap between potential and actual average farm crop yields suggests a huge scope for improvement in productivity and it is envisaged that the development of irrigation under the SVIP will facilitate the bridging of the gap.

Crop yields as reported by the Shire Valley ADD are generally lower than what could be expected under large scale commercial production. The dry land crop yields reported can easily be doubled or trebled under irrigation.

The crop selection for the SVIP is based on the climate and soil considerations. From the analysis several tropical and to some extent temperate crops can grow well in the Shire Valley either during summer, winter or all year round. The crops proposed for inclusion in the cropping programme can grow very well on the soils identified as being suitable for irrigation in the project area. The main soil characteristics including: soil pH, depth (at more than 150 cm), structure, chemical properties (except for sodic areas) are all within range for all the recommended crops. Information gathered from available literature suggests that there could be issues pertaining to root pruning for some tree crops planted on vertisols. However, it is also reported that this is not a serious problem for crops grown under irrigation since the cracking is bad when the soils are very dry. Secondly, soya beans and dry beans can experience emergence problems on soils with a high clay and silt content. This problem can be easily managed by applying "emergence irrigation" at the time the seeds are starting to emerge from the ground. This is normal practice on such soils.

The main AgDPS summarizes the results of a gross margin analysis carried out to assess the viability of the crops which are considered suitable, from an agronomic perspective, for growing in the Shire Valley. Other factors considered prior to carrying out the viability assessment include: availability of markets; ease of storing the commodities; availability of processing facilities; and, other related factors as detailed in the main document. From this list, the following six crops have been selected for inclusion in the cropping programme for the proposed SVIP during the first five years of scheme implementation: sugarcane; dry beans; pigeon peas; cotton; soya beans; and, maize for grain production. Sugarcane is already the major commercial crop in the project area with a well-developed value chain and it is envisaged that the crop will retain this status for the foreseeable future. Dry beans, cotton and soya beans are well established crops in Malawi in general, and are considered easy to grow, store and market.

The analysis also includes several high value crops which are capable of realizing much higher returns than those possible for the selection of crops described above. This includes such crops as: tomatoes; baby corn; sweet corn; and, chillies. These crops have not been included in the cropping programme to be adopted at inception to allow for the development of downstream industries that will be required to manage the logistics relating to the packaging, marketing and, or processing that has to be carried out before large volumes can be produced in the project area. For example, the type of tomatoes proposed for the project area will require a processing factory to be established first. The same applies for the cassava crop. It is envisaged that as scheme development progresses some of these crops will be included in the cropping programme.

There is also a group of crops which have been excluded from the programme after careful consideration of their agronomic requirements. For example, rice requires a lot of water and it is not easy to find other compatible crops for rotation purposes. The type of soils found in the project areas is not ideal for groundnut production mainly due to the relatively high clay content. At the other extreme, crops such as wheat, cow peas and sesame are estimated to realize fairly low gross margins returns and therefore have not been included in the proposed cropping programme.

The seed maize crop has been dropped from the cropping programme mainly because of the low gross margin returns as well as the serious reservations about the viability of the seed that can be produced under the high temperature conditions prevailing in the Shire Valley.

3.5. Livestock Production

In 2016, the population of cattle in the Shire Valley was estimated at 184,914. The sweet veld that dominates large tracks of land in the Shire Valley and the fairly large number of livestock currently raised in the project area present an opportunity for the development of a strong livestock sector. The improved availability of water that will be made possible by the Shire Valley Irrigation Project (SVIP) presents opportunities for enhancing the productivity of the grazing areas by establishing irrigated pastures. The SVIP presents an opportunity for the resuscitation of the fishing industry and the Kasinthula Fish Farm, in particular, in the project area.

3.6. Crop Production Models

The SVIP is anticipated to be a game changer in the way agriculture is practiced in Malawi. This is mainly because of the huge scale of the project (at 42,500 ha) and the great agronomic potential of the area. To achieve the game changer status there is need to ensure that the proposed production models are viable. This section briefly presents the strategic direction proposed for the successful implementation of the SVIP.

As proposed under Section 6.1.1 in the main report, during the early stages of the irrigation scheme the crop focus will be on easy-to-grow, easy-to-store crops as farmers' transition from a focus on subsistence to a commercial orientation. Table below presents possible crop combinations/rotations during the first three years. In Phase I these crops are in addition to sugarcane which already covers 75 percent of the area. In terms of crop combinations there could be four options, namely:

Option 1: Cotton and soya bean (summer) and beans, maize (winter);

Option 2: Cotton and pigeon peas (summer) and beans, maize (winter);

Option 3: Cotton and pigeon peas (summer) and soya beans, maize (winter); and,

Option 4: Rice in summer in place of cotton rotated with fine beans in winter in place of maize.

[Table 3.6-1] Possible Crop Rotations during the First Three Years

Option	Year 1		Year 2		Year 3	
	Summer	Winter	Summer	Winter	Summer	Winter
Option 1	Cotton	Beans	Cotton	Beans	Cotton	Beans
	Soya beans	Maize	Soya beans	Maize	Soya beans	Maize
	Sugarcane	Sugarcane	Sugarcane	Sugarcane	Sugarcane	Sugarcane
Option 2	Cotton	Beans	Cotton	Beans	Cotton	Beans
	Pigeon pea	Maize	Pigeon pea	Maize	Pigeon pea	Maize
	Sugarcane	Sugarcane	Sugarcane	Sugarcane	Sugarcane	Sugarcane

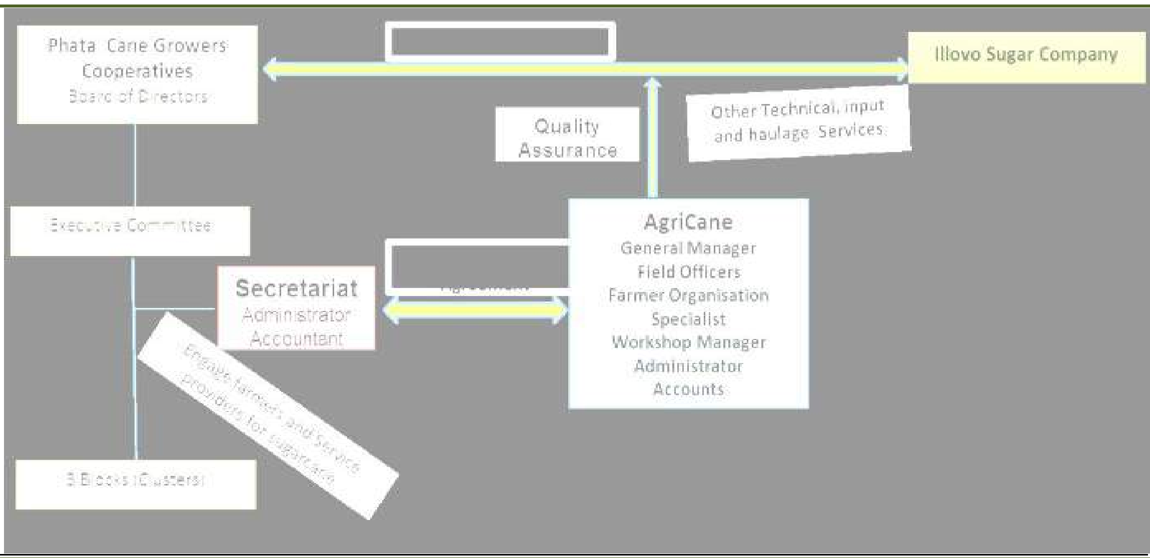
The total irrigable area in Phase I is 22,400 hectares. The area currently under sugarcane production is 12,275 hectares. If the KAMA area is included under sugarcane production then the area under sugarcane becomes 14,535 hectares; representing about 65% of the Phase I area. This leaves 7,865 hectares (35 %) for other crops. For Option 1 and 3, in Phase I, it is proposed to include the other crops of cotton, soya beans or pigeon peas in summer; and maize, dry beans or soya beans in winter. For details of the cropping pattern consult Chapter 6 of the main report. The cropping pattern proposed is compliant with the closed season for cotton.

A model farm unit covering an area of 500ha could realise a total gross margin of at least USD1.4 million/year from the proposed cropping programme. If this model was to be applied on the new area of 9,704 ha, the gross margin would be US$27 million per annum. This translates into MK2,100,00 per hectare per year. This is approximately six times the current gross margin in rain fed subsistence farming. In terms of poverty reduction, this project would put all participating farmers way above the World Bank poverty line. The introduction of perennial and high value crops in the cropping programme should be done with careful consideration of the ancillary investment that will be required to ensure that adequate support services are available in the project area. The anticipated improvements with the introduction of the high value perennial crops in the programme such as bananas, mangoes and citrus fruits increase the gross margin to USD1.5 million/year for a 500 ha farm.

3.7. Farmers' Organizations

The organisation of farmers in the Shire Valley will be critical for the successful implementation and sustainability of the SVIP. The collective objectives of all stakeholders are to: provide a conducive environment for participation of farmers' organizations and private investors that have the capacity to create value and jobs; limit transaction costs when dealing with a large number of farmers; allow smallholder farmers to effectively participate in the Project; and allow farmers to enter into a fruitful dialogue and collaboration with private investors and get their voices heard, thus enabling the commercialisation of farming in the Shire Valley.

The Phata model of organisation has been assessed to be the best model among the organisations in the area on the basis of governance, organization structure, land tenure /plot allocation, production management, share of benefits, transparency and accountability and costs of running business. The figure below shows the model in terms of how it follows a value chain approach to agricultural development. This institutional arrangement can be used as a generic arrangement recommended for the SVIP.



[Figure 3.7-1] Phata Institutional Arrangement

Based on the assessment carried out it is recommended that at inception of the SVIP, Cooperatives/Associations should be established at each zone level depending on local setting of the zone, modeled along the lines of the Phata Cane Growers' Cooperative. This excludes already established institutions e.g. Illovo, KAMA Cooperative, Phata, Kasinthula, and Kaombe in Zone 1 and 2. These Cooperatives/Associations would have the power to: enter into contracts on behalf of its members; mobilize production; negotiate with suppliers for better input supply, credit facilities and produce prices.

It is also proposed that SVIP Farmers' Union should be established to facilitate the coordination of irrigation development, management and capacity development initiatives. This arrangement is necessary given the vast expanse of the area covered by the Project and the existence of several farmers' organizations in the project area. This proposed Farmers' Union will provide a link between the farmers' organisations on undeveloped and existing irrigated areas (Associations/Cooperatives) and, the government agencies responsible for coordinating overall project implementation (the SVIP-PCU, Technical Assistants; and, the District Council). In addition, the SVIP Farmers' Union will be affiliated to the Farmers' Union of Malawi.

3.8. Service Provision

The low productivity levels currently achieved by farmers in the Shire Valley points to the need to ensure that the development of irrigation under the SVIP be supported by the strengthening of the institutions involved in supporting the smallholder farmer in his quest to achieve the envisaged transformation. Currently, most of the smallholder farmers operating in the project area rely on a seriously underfunded public sector. As a result, for all intents and purposes, the smallholder farmer has been left to fend for him/herself resulting in the common practice of adopting a low input-low return production system. However, the experience gained on the sugar estates currently operating in the project area shows that service provision can be enhanced with the active participation of other key stakeholders such as: development partners; non-governmental organisations; farmers' organisations (including clubs, associations and cooperative societies); and private sector companies.

3.9. SVIP Project Coordination Unit and Technical Assistants

The Project Coordination Unit (SVIP-PCU) would be the follow up to the Project Technical Team unit which is currently in charge of project preparation. This PCU will take on the functions of coordination of the implementation of the SVIP. It is therefore proposed that the functions of the PTT should still continue for the next five to ten years to coordinate the implementation of the AGDPS as a PCU. This would still be a Government unit comprising competitively recruited staff working with a wider taskforce of appointed senior staff from the relevant departments. The PCU would be the higher level body directing implementation. At the minimum, the PCU would comprise the Project Coordinator, Community Development Specialist, Irrigation Specialist, and Government counterpart staff (an Irrigation Engineer).

For successful implementation of the SVIP, in the next phase, the Project needs to hire technical assistants (TAs) who are experts engaged to assist in the implementation of such components as: irrigation development; irrigation water management; and capacity development. The specific areas that will require the inputs of technical assistants are: Irrigation Water Management; Crop Production; Community Mobilization and Farmer Organization; Aquaculture and Livestock; Credit and Input Supply; PPP; Marketing and Value Addition; and, Monitoring and Evaluation. The key roles of the

SVIP and TAs, in implementation phase, in collaboration with the DEC would include the following:

- facilitating contracting arrangements for the development of irrigation systems in the SVIP;
- facilitating and coordinating community mobilization and formation of farmer organizational structures;
- facilitating and coordinating capacity building service provision of farm level institutions of the SVIP through service contracts;
- supporting the farm level institutions by putting in-place and developing appropriate governance and business management systems to effectively run their agricultural enterprises;
- facilitating and coordinating contract farming arrangements between farmer organization and agribusiness companies; and,
- linking the farm level institutions with the various Government and other service providing institutions.

Two options are proposed for the recruitment of the TAs: 1) to recruit one Implementation Service Provider (ISP) on contract basis. This ISP would have a team leader, and a team of the following experts:

- Water Management Specialist;
- Agronomist;
- Farmer Organization Specialist;
- Aquaculture and Livestock Specialist;
- Inputs and Loans Specialist;
- PPP Specialist;
- Marketing and Value addition; and,
- Monitoring and Evaluation.

The second option would be for the PCU to recruit and engage these TAs on an as-and-when needed basis. The TAs would be required to facilitate capacity development of the farmers in general through the apex SVIP Farmers' Union and individual Associations or Cooperatives.

3.10. SVIP Farmers' Union and Farm Based Cooperatives/Associations

The NIP 2016 advocates for well-managed irrigation schemes to sustain productivity. The beneficiary community should operate and maintain the in-field infrastructure so that the designed capacities are maintained to support the desired crop production levels. The NIP is aimed at:

- encouraging catchment management practices for the benefit of irrigating and non-irrigating communities;
- developing farmer organizations through technical and administrative empowerment to ensure effective community participation;
- exploring alternatives to handling and marketing of farmers produce for maximum profitability of irrigated crops;
- facilitating in a coordinated manner, the formalization of land tenure rights that will ensure tenure security;
- strengthening extension services for irrigated agriculture through awareness and outreach of irrigation technologies; and,
- supporting beneficiary communities where major rehabilitation, upgrading or modernization of irrigation infrastructure are required

It is against this background that the existing and the proposed smallholder farmers' Associations/Cooperatives in the Project area would be encouraged to come together to establish the SVIP Farmers' Union. The role of the overarching farmers' organisation will focus on three main tasks, namely: to ease facilitation, coordination, and capacity building initiatives for the benefit of all targeted irrigation area beneficiaries or farmers' organizations throughout their value chains.

i. SVIP Farmers' Union

The membership of this Union would be drawn from the representatives of primary cooperatives/associations, for voting purposes. The areas of focus would be: training and extension; production planning; input supply and credit provision; establishment of stores and related outlets to meet the farmers' basic input needs; commodity marketing; mechanization and transport; general operation and maintenance; and overall scheme administration.

Specifically, the SVIP Farmers' Union would be responsible for:

a) Facilitating and coordinating community mobilization and sensitization; establishing irrigation block area management associations and cooperatives; providing assistance in the re-allocation of land; resettlement, and grievance redress; developing farm land ready for growing crops; advise on farm management and crop production; support to prepare and submit proposals for assistance. Initially project funding would be used for a period of five years. Over time this could grow into a farmers' membership organization providing the services on a demand driven basis.

b) Facilitating and coordinating capacity building service provision of farm level institutions of the SVIP through service contracts.

c) Supporting the farm level institutions putting in-place and develop appropriate governance and business management systems to effectively run their agricultural enterprises.

d) Facilitating and coordinating contract farming arrangements between farmers' organizations and agribusiness companies.

e) Linking the farm level institutions with the various Government and other service providing institutions.

f) Facilitating contracts for the development of irrigation systems in the SVIP area.

Daily management of the Union would be through an interim committee of selected members from existing associations and cooperatives and GVH or VDCs representatives. It is proposed that 11 members should be elected to steer the process.

ii. Formation of Cooperatives

The PTT held consultative meetings with all group village headmen in Phase I on the possibility of forming cooperatives. This was necessitated by the ADPS model of 500 – 1,000 ha irrigation blocks in SVIP area. It was noted that although 500-1,000 ha was clearly just a model for purposes of establishing the viability and profitability of irrigation farming in the SVIP area, the figure of 500-1000 ha has been interpreted as the recommended farm size and thus cooperative size. It is important to differentiate the concept of a farm from that of a cooperative. The two are not synonymous and should be discussed separately to avoid confusion.

The PTT was of the view that there are two important considerations to be kept in mind as we consider establishment of cooperatives. One aspect is farm management and the other is the water supply. It is assumed that the water supply side has been covered adequately and need not be repeated here. However, in terms of farm management, we can draw some lessons from the Phata Cooperative and Swaziland. Phata Cooperative shows that a farm size of 400 ha can be viable. On the other hand, the lessons in Swaziland showed that if a farm unit is too small, it becomes difficult to make ends meet due to large overheads. This is one of the reasons some companies combined to be managed as one unit. The other, of course, is to improve the economies of scale and increase the volumes of production and get better bargaining power. Both Phata and the Swazi farmers have dealt with the challenges brought by large and complex farms by bringing in professional managers. In this regard, it is possible to imagine one cooperative for the whole SVIP area with one manager at the top. Nonetheless, whether we are contemplating one or two or five cooperatives, it is possible to design a multi-tier farm management system on both the technical and the cooperative side. This is regardless of how many cooperatives are established. In this regard, the first tier can be at the block level or a combination of several blocks.

The idea would be for the area to be developed into farms determined by the design of the irrigation system i.e. the layout of the canals and irrigation blocks. Such farms can be managed by a field officer or whatever name found appropriate (botton tier). However, for efficiency purposes, smaller blocks can be combined to be managed by one field officer. It is possible to work out an optimal farm size that is efficient and cost-effective. Depending on optimal size of the farm, the whole area could be only 9-12 farms and be managed by 9-12 field officers. This is not known yet but will be the subject of discussion during the detailed design stage. Then the 9-12 farms can be grouped to form an area to be managed by a farm manager (the second tier of management). This may produce 3-4 areas, resulting in 3-4 farm managers. Finally, a general manager can be envisaged to manage the whole SVIP area (the top tier).

On the cooperative side, we can adopt what has been described in the Agriculture Development and Planning Strategy. At the farm (block) level, all smallholder farmers who have land in the block would be members of that unit. They would then form grass root level committees as the first tier of the cooperative structure. The crucial committees would include: Financen and Audit Committee, Irrigation and Crops Management Committee, Community Outreach and Liaison Committee, Disciplinary and Grievance Redress Committee and other committees as necessary. These may be at the block level or a combination of several blocks depending on the size of the blocks.

The next tier would then be the executive committee to deal with the day to day matters of the farm with the field officer. There would be executive committees at the block level and at the area level. Block level executive committees would be responsible for matters at block level and working closely with the field officers. Area level executive committees would be responsible for matters at area level and working closely with the farm managers. Preferably, the membership of the block level executive committees would come from the membership of the block level committees and the membership of the area executive committees would come from block level executive committees. Fourthly, there would be an overall executive committee comprising selected members of the area level executive committees. Finally, there would be a Board of Directors appointed by the Cooperative and the recommended composition would be 55% cooperative members and 45% outsiders selected on the basis of specialty expertise such as finance, legal, accounting and/or auditing. The underlying criterion for selecting the members of the Board of Directors would be integrity and honesty.

For purposes of ensuring that all voices of the cooperative members are heard the apex decision making body would be the Annual General Meeting which would be attended by adequate representatives of the general membership. It should be emphasized that this concept is applicable for any number of cooperatives. Hence if there were to be five cooperatives, then there would be five such organisations

However, the preference is to have fewer cooperatives in the SVIP. Too many cooperatives would create a complex system and will have a number of challenges including the following:

- Sharing of water will be a challenge as there will be competition for water access amongst different cooperatives.
- A need to require an independent water operator, to provide water as needed
- Small hactareage will entail having several cooperatives, and this will create problems in block sizing/land consolidation as this may impact land owners whose land is falling between two potential blocks before consolidation.
- Minimal bargaining power due to less total production
- It will take long time to finalise land consolidation.
- Amount of overheads is high because the management team has to be paid from resources from a small area

Each Cooperative would choose its enterprise (crop production, Livestock and aquaculture) based on factors as highlighted in Chapter 6, except for Zone 1 and partly 2 that are already into sugarcane production under contract farming with Illovo and PressCane. All enterprises would follow the whole value chain from production to marketing or value addition to marketing. This would be the main responsibility of the professional managers with the PCU providing oversight in the initial phase of the SVIP. Each Cooperative would be directly linked to the Water Service Provider identified for the Project depending on its irrigation water requirement.

The proposed institutional set up for sustainable development of the farmers' organizations are indicated in Figure 7.8 in the main document. The figure also shows the hierarchy of these institutions based on the services that would be provided and as discussed in previous sections.

3.11. Implementation Plan

The implementation of the farmers' organization component is anticipated to take five years. The first three years would be for sensitization, formation and operationalization of the associations and cooperatives. The next two years would be for intensive monitoring and evaluation of all aspects involved to make viable enterprises. It is anticipated that after this five-year period, the SVIP Farmers' Union would be an independent entity, receiving minimum assistance from SVIP PCU in terms of funding of its activities. For details of the implementation plan see Figure 7.9 in the main document which shows the farmer organization development process and Tables 7.5 and 7.6 which show a summary of the schedule of implementation and the current estimates of implementing the various components of the AGDPS.

3.12. Recommended Policy Reforms

The macro and micro economic policies were analyzed, key challenges identified and the accompanying solutions provided to maximise the full potential of the identified product value-chains under the SVIP. The analysis focused on how GoM adopted and implemented policies to govern the economy as a whole (macro-economic policy), or those governing a particular economic sector (sector policies), in order to guide and modify the behaviour and decisions of agents operating in the economy. The GoM influenced the economy by creating policies which regulate, incentivize/ disincentivize or inform economic agents.

The key observations were as follows:

- Trade and market policies and overall performance resulted in producer disincentives of percent on average between 2005 and 2013.
- The exchange rate misalignment in place until 2012 and the inefficiencies in the value chain created additional disincentives of 29 percent on average between 2005 and 2013.
- Disincentives in the agricultural sector are mainly the result of poor price transmission between domestic and international owing to inadequate infrastructure and lack of negotiation capacities of producers.
- The implementation of trade and markets policies to contain domestic prices also depressed producer prices in some years.

Reforming output markets and trade policies

With rapid population growth, demand for food will increase and will have to be met through market transactions. With favorable policies, Malawi's markets for food staples can grow in several ways. One is through increasing the competitiveness of the farmers so that they can compete better against food imports and capture bigger shares of their growing domestic and regional markets, especially for maize and rice. Key policy reforms GoM may pursue to expand trade include agro-processing investment policies, expansion of interregional trade, and price stabilization.

Agro-processing and value addition

Processing and value-addition will be needed to transform several of the crops produced into a wider range of products for which there is relatively high demand (e.g., processed cereals, processed foods targeted to growing local food markets, and livestock feed) in local, regional, and international markets. In terms of output, a significant share of Malawi's agricultural output is made up of bulky, perishable crops that are non-tradable in unprocessed form.

New policies are required to allow Malawi to create value from these staple crops, especially through value-added processing. Some of the policy interventions needed include investment in infrastructure (e.g., roads, electricity, communications, and water) to support rural processing zones in SVIP area. In general, these investments though huge, open up opportunities for public-private partnerships given the severe constraints on public-sector resources and capacity.

The GoM should intervene in the financing for businesses and reduce tariffs on processing equipment to promote agribusiness development. This should be accompanied by policies that support entrepreneurship, high-quality products, grades and standards, and certification of farmers are also important in promoting agricultural marketing on the continent. This is against the backdrop that the lack of finance is recognized widely as a perennial constraint to agribusinesses development. Formal lending to agriculture is limited severely by agriculture's seasonality and high risk, and banks are reluctant to deal with agriculture.

Promotion of intra-regional and cross-border trade

GoM should aim towards a more open intra-regional trade in view of Malawi's land-lockedness/land-linkedness to take advantage of differences in comparative advantages, achieve greater economies of scale in marketing, and help to stabilize food supplies in the face of adverse weather events at country levels, and act as a vent for surpluses. Intraregional trade can help to reduce the thinness of domestic markets and the likelihood of price collapse from increased agricultural productivity in the absence of wider markets.

Increasing the production of price-inelastic food crops in thin domestic markets, in the absence of regional trade outlets due primarily to high tariff and non-tariff barriers, ostensibly results in the reduction of producer prices for farmers.

Price stabilization

The GoM should ensure that the National Food Reserve Agency (NFRA) is fully funded to operate in earnest as strategic grain reserve in order to stabilize domestic grain prices. Liberalized markets have exposed many small farmers to significant price risks that can deter technology adoption and development of markets and agricultural lending. Surplus food producers are discouraged from intensifying production if they fear that increased output could lead to price collapse at harvest time, robbing them of any gains from productivity enhancement and possibly making them worse off overall. Inter-seasonal price troughs in years of particular abundance are the main concerns. Surplus producers generally have the resources to be able to hold back at least a proportion of their harvest and avoid the worst effects of normal intra-seasonal price falls immediately after harvest.

Market information and intelligence system

The GoM should develop a sound and robust market information system for the SVIP area. Price information is necessary to:

- Reinforce the spatial and temporal arbitrage capacity of producers and strengthen their bargaining power with potential buyers;
- Support producers decisions concerning investments, marketing opportunities or storage decisions;
- Systematically monitor and analyze the effects of market and price policies, contributing to the implementation of adequate price and market interventions that consider the effects on both consumers and producers as well as on export competitiveness.

The GoM should set up or improve market intelligence systems for the SVIP area. This may include the establishment of a central repository, which will cover all markets (domestic, regional and international). An appropriate agency should be identified to host the repository, and it will be charged with compiling, regularly updating and passing on up-to-the-minute market information and intelligence to agribusiness players.

Other complimentary measures

The GoM should encourage the emergence of competitive marketing systems through infrastructural investments, effective regulation, and providing incentives for marketing agents to serve the SVIP area.

Invest in infrastructure development

The creation of a flourishing agribusiness sector will not be possible without investment in key infrastructural facilities such as roads, railways, energy, communication and physical market areas. Upgraded facilities will reduce the transaction costs of doing business. Clear criteria for prioritisation of infrastructure projects will be developed to form the basis for all investment in infrastructure. The GOM should act on three levels to attract such investment. First, the GoM should encourage public-private partnerships where they are viable, and the government itself will invest in those projects where the consumer cannot - at the outset - pay. Second, the GoM should issue concessions and other tax relief to spur greater investment such as infrastructure bonds to raise funds for heavy investments, e.g. roads, electricity. Third, the GoM should make more financial resources available for infrastructure development, specifically the following:

- strengthening of the agro-machinery sub-sector;
- upgrading of rural access roads;
- improved agricultural water management to include expanded irrigation infrastructure;
- access to affordable fuel energy and other renewable energy;
- establishment of accessible and modern physical agri-food markets, especially in urban areas; and
- establishment of adequate storage and collection (e.g. pre-cooling) facilities in production areas.
- establishment of a National Single Window

The GoM should establish a "one-stop shop" mechanism for business development services, in which any number of services (technological, business development, financial, and input supply, for example) are offered in a central location. These services centers can have additional objectives of learning and training and are mostly run through public-private partnerships. These might include agribusiness centers, agribusiness incubators, and local economic development agencies, all of which could be designed to provide integrated SVIP development services for small-scale entrepreneurs and smallholder farmers. The specific services could include starting and registering a business, farm business planning, access to finance, training, and technical advice.

The GoM should ensure predictable and stable macroeconomic policies that enhance private sector competitiveness and encourage investment.

CHAPTER 4. PUBLIC-PRIVATE PARTNERSHIP (PPP)

4.1. Objective of the Assignment

In parallel to the TFS study, a PPP feasibility study is being conducted by BRLi of France. The objectives of this study are to advise MoAIWD and the PPP Commission on the financial, legal and organizational aspects of the proposed public-private partnership arrangements for irrigation services for SVIP. So far the Consultant has produced:

- Preliminary PPP Assessment Report (October, 2015)
- Revised PPP Feasibility Study Report (October, 2016)

Major findings of the study are highlighted as follows. The above reports have to be referred for more details.

4.2. PPP Options Assessment

The study has assessed various PPP options that could be implemented in SVIP together with the risk allocation assessment in detail. To determine the relevancy of the PPP options proposed, a financial model has also been developed and the results of the analyses presented. The PPP options assessed include:

- Management contract
- Affermage (Fully private or semi Public)
- Lease (Fully private or semi Public)
- Concession and
- BOT

4.2.1. Concessions and BOT

A concession gives an operator the long-term right to use all utility assets conferred on the operator, including responsibility for all operation and investment. Asset ownership remains with the authority. Assets revert to the authority at the end of the concession period, including assets purchased by the operator. In a concession, the operator typically obtains its revenues directly from the consumer and so it has a direct relationship with the consumer. A concession covers an entire infrastructure system (so may include the operator taking over existing assets as well as building and operating new assets).

A BOT Project (build operate transfer project) is typically used to develop a discrete asset rather than a whole network and is generally entirely new in nature (although refurbishment may be involved). In a BOT project, the project company or operator generally obtains its revenues through a fee charged to the utility/ government rather than tariffs charged to consumers.

4.2.2. Leases and Affermage Contracts

Leases and affermage contracts are generally public-private sector arrangements under which the private operator is responsible for operating and maintaining the utility but not for financing the investment.

In the case of a lease, the rental payment to the authority tends to be fixed irrespective of the level of tariff collection that is achieved and so the operator takes a risk on bill collection and on receipts covering its operating costs. In the case of affermage the operator is assured of its fee (assuming that the receipts are sufficient to cover it) and it is the authority that takes the risk on the rest of the receipts collected from customers covering its investment commitments.

Key Features of Leases and Affirmage Contracts

- Medium length - typically between 8 and 15 years;
- Collection risk passed to operator in lease;
- Lease operator will require assurances as to tariff levels and increases over term of lease, and compensation/ review mechanism if tariff levels do not meet projections;
- Cost of maintenance and some replacement passed to operator (operator takes some degree of asset risk in terms of the performance of the assets);
- Operator may be put in charge of overseeing capital investment program/ specific capital works;
- Employer is paid a fixed lease fee (lease)/ receives net receipts from customers (less affirmage fee) (affirmage);
- Review process every 4 or 5 years to review performance, costs, tariff levels, etc.;
- Employees seconded or transferred to the operator;
- Operator to maintain asset register and operation and maintenance manuals/ records, etc.;
- Typical to include minimum maintenance or replacement provisions towards the end of the contract, so that facilities are handed back in an operational state.

4.2.3. Management Contracts

The management contract is a soft Public-Private sector arrangements under which the participation of private operator in investment functions (Capital cost) is not required.

The service is paid to the private operator by the Public Authority, the private operator can however be in charge of the water fee collection. The management fees paid to the operator can be paid according to performance indicators. The main function of the private is Operation and Maintenance but it can also be involved in functions such as design and construction supervision of the investment works. The ownership of the assets remains with government and the operator acts as a service provider.

Key features include:

- Short term contract - typically between 3 and 8 years;
- The public sector is in charge of construction financing; Irrigation Service Fee Definition,
- The private sector will be in charge of the O&M of the scheme, but can also be in charge of design review and endorsement; construction supervision; capacity building,
- The construction is managed under another contract,
- the operator is paid a fixed fees by the Public sector to maintain and operate the infrastructures,
- Incentive remuneration through Key Performance Indicator (KPI) is usually required to guarantee that the operator will deliver the best services,

4.2.4. Applicability to the SVIP

All PPP options have their own pros and cons and can be applied to involve the private sector in the project. Their difference is in the risks allocated to the government and the private partner.

The concession is the most demanding in terms of private involvement. It requires equity and debt financing of the infrastructure from the private partner who will bear all the commercial risks (ISC collection and water demand risks). According to the functions transferred to the private, this kind of concession is sometimes called DBOT (Design Build Operate Transfer), or DBTO, or any other acronyms that will indicate the functions transferred to the private.

Affermage and leases put the burden of financing the infrastructure on the government, reducing the value for money of the PPP arrangement and increasing the public cost of providing the irrigation network. The private operator will bear the commercial risks. These are higher in the case of a lease compared to affermage. This model is less risky for the private partner (no financing functions).

In a management contract, the private partner will limit its risks (no financing role and revenues originated from the contracting authority and not from the users). The management contract is less demanding in that most of the risks are allocated to the contracting authority. This is the model of contract that has been recently set up in Ethiopia to develop two new important irrigation schemes. It has also been proposed in Bangladesh to rehab existing irrigation schemes.

In view of the above, the Consultant has proposed to structure the PPP for SVIP as a concessional arrangement, where the private sector will be in charge to operate and maintain the scheme and participate to the funding of the project. On the basis of the result of the financial model and sensitive analysis, the concession is a viable option. This recommendation has also been confirmed by the market testing that shows the interest of the private sector for such kind of PPP arrangement to build and operate the Shire Valley Irrigation Scheme. A concession would reduce the cost for the public sector and would guarantee a sustainable long term management of the scheme. A concession gives an operator the long-term right to use all utility assets conferred on the operator, including responsibility for all operation and investment while asset ownership remains with the authority.

4.2.5. Water Purchase Agreement (WPA)

In order to materialize the proposed PPP arrangement there must be a reliable Water Purchase Agreement with the water users of the project for securing a stream of revenue that allows to pay back the loans insured by the private partner for constructing the infrastructure.

In the case of SVIP, a WPA is a long term contract to deliver water to ILLOVO and other water users organized into trusts, to realize the dedicated infrastructure needed to fulfill this obligation and to define precisely the conditions to be respected by the parties. ILLOVO would account for at least 62% to 81% of the revenue of the projected PPP for Phase 1 of the SVIP according to WPA options negotiated. Therefore, the WPA with ILLOVO is the cornerstone of the project.

The first party is obviously ILLOVO and other existing trusts. The second one could be either the private partner of the PPP or the government of Malawi. In the second case, the government will enter the agreement to realize the dedicated infrastructure and to deliver the agreed amount of water, either through a PPP or directly if it decides so. In the first case, the WPA will be a part of the PPP contractual arrangement and the private partner will be obliged by it. In the second case, both parties, ILLOVO/other existing trust and the government, will be obligated by the WPA.

4.2.6. Options for WPA

Incomes of the private partner are strongly linked to (i) the Irrigation Service Charge (ISC), (ii) progressive increase in irrigated land and (iii) recovery rate. Various tariffs/ISC have been defined (in the framework of the WPA) for the different water users of SVIP, which include:

- Illovo Estate;
- Existing trust (Phata / Kasinthula / Sande Ranch),
- Water users in Zone I-1 new development land and
- Water users in Zone A new development land

In order to define the level of tariffs for the various water users, a specific assessment has been carried out using the preliminary project cost estimate prepared by the TFS team. To estimate the ISC for the various options, the investment costs have been shared between the areas irrigated/water users, based on the following assumptions/options:

- All investment costs are paid through the WPA (cost of the main infrastructures proportionally to the surface irrigated/ cost of secondary canals/ cost of on farm works (tertiary canal and infield surface/drainage/road);
- For the existing trusts (Phata / Kasintula and Sande Ranch) and new development land, the cost of on farm works are out of the water cost;
- For the existing trusts (Phata / Kasintula and Sande Ranch) and new development land, part of the cost of the main infrastructures (main canal and inlet) as well as the cost of on farm works, are not included in the ISC.
- For the existing trusts only cost of the main infrastructure is included in the water cost calculations.

Among the four options, the level of tariff proposed by the option 3 seems to be the most realistic for the various stakeholders. In this option Illovo state is paying ISC higher than the others water users based on the hypothesis that part of the investment costs required to provide them with water will be subject to subsidies (which is not the case for Illovo state). However, the best option need to be discussed and a decision needs to be taken by the public authority and then the WPA will have to be negotiated with the concerned parties.

In other terms, the result of the tariff assessment should allow the public authority to agree on the terms of the WPA with Illovo, Kasinthula / Phata / Sande Ranch, which would mean that a very important milestone has been achieved in view of realizing the PPP project for the SVIP.

The PPP feasibility study, among others, has also developed financial model and carried out financial analysis, risk analysis, value for money analysis for the various proposed PPP arrangements. For these and other details refer to PPP preliminary Assessment, BRLi, 2015 and PPP feasibility study, BRLi, 2016 repots.

4.2.7. Irrigation Service Charge

The PPP study has defined the level of the irrigation service charge that can be used in the financial model of the PPP arrangement. First of all it has been decided to propose a binomial tariff composed by a variable part per meter cubic consumed and a fixed part per ha.

- Variable part: the variable part must cover at least the O&M cost estimated, the renewal fund and big repair fund, the National Water authority fees;
- The fixed part; the fixed part must cover at least the financial cost of the private sector.

This assessment shows that the true estimation of water fees for each group of users, according to a strict sharing of CAPEX and OPEX based on the areas effectively irrigated by each of the parties would lead to have water service charge as follow:

Variable part: between 0.0076 USD/m^3 and 0.0086 USD/m^3 with the higher cost for the new land area I1 and zone A and the lower cost for Illovo. The cost for the existing trust (Kasintula/Phata/Sande Ranch) would be in the middle at around 0.0082 USD/m^3.

Fixed part: between 73 USD/ha and 150 USD/ha with the higher cost for the new land area I1 and zone A and the lower cost for Illovo. In this case also, the cost for the existing trust (Kasintula/Phata/Sande Ranch) would be in the middle at around 123 USD/ha.

The results obtain by this approach are logical as the infrastructures required for the new land development are much higher than the infrastructures required for the existing farm (additional drainage infrastructures + flood protection/etc.)

The application of those costs could nevertheless not be feasible at it goes against the social principle of the project that would recommend to have a lower cost for the smallholders organizations (existing trust and new development land) and the higher cost for the agribusiness such Illovo. Thus the true estimation of water fees have been adjusted as follows:

[Table 4.2-1] Estimation of Water Fees

	Illovo	Existing trusts (Kasinthula, Phata, etc)	New lands (Zone I-1 and Zone A)
Variable part (USD/1000 m^3)	8.6	8.6	8.6
Fixed part (USD/ha)	200	100	100
Average total cost/ha according to water requirements (USD2020)	389	289	281

As shows in the above table, for Illovo the variable and fixed part of the tariff has been increased, for existing trusts (Phata/Kasinthula/Sande Ranch) only the variable part has been increased whereas the fixed part has been reduced. For the new development area the variable part has been maintained and the fixed part has been reduced. The analysis on the capacity to pay has shown that the proposed tariff can be easily covered by the farmers.

4.3. Recommendation on PPP Option

The preliminary report assessment shows that all types of PPP could be implemented for SVIP. The four types of PPP options have been analyzed in the PPP feasibility report. Although no decision has been taken by the government regarding the kind of PPP arrangement it is willing to set up, the PPP feasibility study has proposed a concessional arrangement (a BOT), where the private partner will co-finance, design, construct and operate the infrastructure to distribute water in bulk. This option is preferred because it presents the best alignment in incentives. It solves the potential conflicts between designs, construction and operation through the PPP and it incentivize the private partner through its own investment in the operation. The second option to be considered is a DBO, a Design Build Operate contract, in order to reduce the potential conflicts between design, construction and operation. The private partner will have less incentive than a concession in that he is not committing equity to the project. In order to select the option to be implemented, it is essential to do a market test in order to estimate the interest of the private sector in a concession. If there is an obvious interest, therefore the government should consider pursuing the project through a concession. If not, a DBO contractor a traditional approach separating design, construction and operation should be considered.

4.4. Pros and Cons for Two Options Proposed

The advantage s and the disadvantages of two options are summarized in the following table:

[Table 4.4-1] Pros and Cons for Two Options Proposed

	Concession (BOT)	Design Built and Operate (DBO)	Management Contract
Advantage	• Co-financing • No cost overruns, on time delivery; • Result oriented with key performance indicators	• Better incentives to deliver a good project than traditional public procurement; • Cost control and costs overruns limited; • KPI and result oriented;	• Contractual obligation to have professional O&M, • Operational risk is shared, • Less risky for the private sector than other type of PPP (DBO, concession, etc) which make the project more attractive, • The private sector can be partly paid according to Key Performance Indicators which will guaranty the quality of its work and will reduce the risk for Public Authority • International experience can be gained,
Dis advantage	• Long term contract; • Costly separation; • Public guarantee over a long period	• More a public procurement than a public private partnership; • No co-financing; • More complex to procure	• Short time (3-8 years) contract that will require a new bidding process in few years,

CHAPTER 5. ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

5.1. Physical Environment Impact Assessment

5.1.1. Mitigation Measures for Geomorphology of Rivers

Impacts from water work

- Installing gabions or riprap on riverbanks to avoid having rivers shifting and no longer flowing through canals
- Not to cross a tributary river in a meander but rather where river are flowing in a straight line
- Avoid developing irrigated fields too close to any river and to take into account river mobility

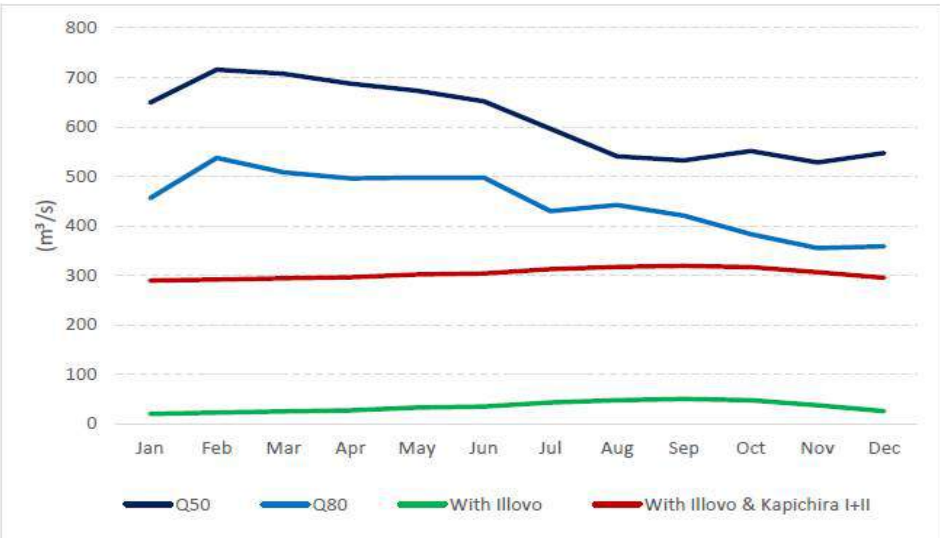
Siltation of Elephant marsh

- Limiting erosion and clear cutting of forests in the surround mountains (the Lower Shire River watershed management or the forestry department)
- Releasing more water from the Kamuzu barrage

5.1.2. Hydrology

Water availability

Figure 7 Water availability and demand at Kapichira Dam (using same hydrological data from DWR used in TFS)



[Figure 5.1-1] Water Availability and Demand at Kapichira Dam

The figure above shows that:

The availability of water by showing the 50% (Median Q50) and 80% (Quinquennial dry year Q80%) dependable monthly flows as well as the water requirement for SVIP without or with Illovo and with Kapichira I and II.

The water supply exceeds largely the irrigation requirement for SVIP without or with Illovo when taken alone.

5.1.3. Water Quality

Impacts from water works

- Carry out activities close to tributary river during the dry season when rivers are dry
- Implement best management practices for water work, such as :
  - Silt floating fences in the reservoir, silt fences when working close to rivers
  - Refueling activities away from any waterbody (at least 100 m)
  - Emergency spills containment kit in all vehicle and machinery
- Request in tender document that companies develop a method for environmentally friendly water work (reservoir and river) and spill containment.

Water quality impairment

- Drainage design to limit direct contact with Elephant marsh.
- Settling ponds could be designed to allow silt and attached pollutants to settle in ponds rather than reaching the marsh.
- Use of authorized pesticides (The Integrated Pest Management Plan)

5.1.4. Soil

Impacts from earthwork and leveling

- Some spoils from excavation could be used as soils for agriculture;
- No spoils can be stored even temporarily close to water bodies including Elephant marsh or parks;
- Unusable spoils shall not be left in mounds but shall be flattened and revegetated;
- Borrow pits shall have gentle slopes to minimize the risk of injuries and death;
- Borrow pits and quarries location shall be done in consultation of local authorities
- Borrow pits and quarries shall not be left unrestored and shall be filled with unusable soil

Changes in soil properties

- Monitoring of soil properties including soil water levels and salinity
- After the land evaluation exercise of the FS, other uses of unsuitable areas should be determined in land use plans, in which community preferences can be reflected.
- The planning of multi-purpose Reserve Areas has also to be incorporated in overall land use planning. This will be part of the outcome of the land evaluation exercise.
- Future use of Encompassing land with serious limitations or risks will have to be carefully planned.
- For poorly drained Vertisols, rice could be included as a crop, for which use the current Project areas of Zone B and C could even be slightly enlarged, extended down slope or sideways. Possibly even dambos could be reclaimed.

5.2. Impact on Socioeconomic, Cultural and Natural Heritage

5.2.1. Settlement, Community Organization and Land Tenure

Village reorganization and resettlement

The complete set of measures will be developed in the Resettlement Action Plan which is still to be produced once the Design study will start.

Workers influx

Recruitment policies

- That the tender document for the construction contractor specifies that a method for local employment shall be developed by bidding firms.
- Social preparation and the incorporation of eligibility for priority in employment into the RAP Entitlement Matrix, together with an official mechanism for providing names to the construction contractor and for follow-up to track the numbers of PAPs employed.
- The inclusion of appropriate wording in the construction contract.

Land occupation

LNP shall be aware of the risk of workers influx and encroachment in the park as some its western parts are already occupied by settlements. There is a risk of increase land occupation in Elephant marsh as well.

Workers code of conduct

In advance of any construction work, the code of conduct shall be taught to all workers and supplier during an induction training.

Sexually transmitted diseases

Reducing this risk will start by sensitizing staff and neighbouring population as well providing an easy access to condoms. Prohibition of prostitution will be enforced.

Rapid social changes

The Communication strategy report provides a tool to ensure social acceptability of the Project. It is recommended that the CCPLTRPF grievance redress mechanism encompasses the construction phase to allow community to communicate with the construction contractor about their concerns and grievances.

Hinter and effect

Mitigation for this impact are difficult to address in an ESIA as they involve many outside actors who already poorly performed at reducing unsuitable use of natural resources. Some measures of the SRBMP will in fact aim at improving use of natural resources

5.2.2. Infrastructures

Permanent loss building and other assets

Changes were proposed to avoid village areas and graveyards as much as possible. The result of the proposed changes is a reduction of affected villages from 19 to 6 and affected houses from 121 to 26 in Phase 1 (a similar investigation has not been done for phase 2 yet.) (COWI, 2016).

During construction, before blasting it will be important to assess risk to infrastructures by doing a groundtruthing survey

Disruption of access

- Bridges shall be built to allow for access across canals where existing footpaths and roads are impacted (10 tarred roads, 57 gravel roads and 17 footpaths will be severed by canals).

- Cattle bridges shall be built every km of main canal (133 cattle bridges, around 30,000 euros for a 23 m wide canal).
- Footpaths shall also be designed to allow people to cross secondary canals, these shall be 1.5 m wide. Spacing between these footpaths small not be more than 1 km.
- Whenever a canal crosses a seasonal river, box culverts shall be large enough to allow people to walk under the canal. It is not recommended to build cattle bridges in secondary or smaller canals as the presence of livestock in the command area will lead to conflicts.

In adequate maintenance of canals and infrastructures

It will be important to determine the responsibility of actors in order to allow infrastructures to function on the long term. Such structures include:

- Bridges (cattle, pedestrian and vehicle) ;
- Safety stairs for villagers to bath and wash and to exit in case of falls ;
- Wildlife passes ;
- Tiger fish barriers (or screens) ;
- Crocodiles fences ;
- Wildlife fences;
- A barrier against water hyacinth and debris at the water intake.

Maintenance shall be accompanied by some form of law enforcement to regulate the use of the canal. It will be also important to train farmers and irrigation water user associations (or water user associations) in maintaining their drains and canals as well as not to use the canal as a waste dump. This is a major responsibility and requires a significant level of managerial and technical skills and physical resources (facilities and equipment). Since water user associations membership will be compulsory, fees will be collected and in-kind contributions expected as well (maintenance of on farm channels). The creation and training of organizations for maintenance is a major task and will require;

(i) enactment of the relevant legislation,

(ii) significant social preparation,

(iii) intensive hands-on support and training at start-up and over the initial years of operation,

(iv) provision of facilities and equipment.

The current method to remove the water hyacinth at Kapichira reservoir (biocontrol using insects) shall continue on a regular basis to avoid having the plant invading drains, canals and night storages.

5.2.3. Economics

Disturbance to existing agriculture

- Loss of annual crops would be avoided by starting the project after the harvest.
- Bridges and footpaths across canal shall be built as the canal progresses and not at the end to avoid creating a long cutter with dangerous embankments.
- Land acquisition and land redistribution and the establishment of water user association shall be planned in advance of construction.

Job opportunities

- Job creation shall bring benefits to the community as long as local employment is favored.

Potential delays in irrigated agriculture development

Resources shall be provided to support the delivery of advisory services, adaptive research and development, the strengthening of research-extension-farmer linkages, the improvement of market linkages, and increased pluralism in market delivery. These resources could be provided by the Ministry of Agriculture, Irrigation and Water Development and the Proposed organizational setup presented in the Agricultural Development Planning Strategy study (PWC, 2016). Pilot trials shall also be put in place and Phase I success shall be tested prior to implementing Phase II.

Over supply of crops

In order to avoid oversupply of crops at local market, the project shall focus on exporting crops. In addition, the Project shall study the possibility to transform vegetable for the food industry

Benefits of irrigated agriculture

Positive side-effects can be numerous and relatively easily achieved :

- Greater food security than only rain-fed production and increase in the monetary income reducing poverty and food shortage.
- Change in behavior and acceptance of new attitudes particularly associated with health.
- Increased access to efficient health system.
- Better access to schools, etc.

Reduction of fisheries

Impacts on fisheries could be compensated by creating fish farms. Factors to consider for fish farming are presented in the "Agricultural Development Planning Strategy" study (PWC, 2016). In addition, the current study under the SRBMP called "Climate resilient livelihoods and sustainable natural resources management in the Elephant Marshes, Malawi" will provide (once available) more details on institutional measures to implement to ensure proper natural resources management.

Impacts on livestock rearing

The following mitigations reflect smallholder grievances:

- Construction of drinking spots along the main canals. A first estimate would be 40 cattle trough (20 on the western side and 20 on the eastern side). These troughs shall be made of concrete to limit seepage. Their size shall be around 5 by 5 meters.
- Phasing the installation of cattle bridges
- Construction of cattle bridges. Cattle bridges shall be installed at each km along the main canals (a total of 133 cattle bridges). Bridges shall be made of concrete and include high walls to avoid accident.
- Establishment of conflict management structures at village level and guidelines to deal with

farmer's conflicts.

- Formalization of the marketing of crop residues and organic manure to foster strong collaboration between livestock and irrigation farmers to ensure reciprocal gesture in the disposal of crop residues by crop farmers in exchange of manure.
- In order to ensure that crop residues are available to smallholder farmers, small scale farmers shall have access to the crop residues realized from crops grown on their traditional land parcels.
- Land that cannot be farmed shall be designated as grazing areas and, if possible, planted with Napier or Rhodes grass.

5.2.4. Health and Safety

Construction risk and nuisances

Dust and pedestrian on construction roads

- Spraying all gravel roads with sugar molasses or water on a regular basis
- Providing transportation to a designated place for workers at the end of their day of work.

Risk of workers not wearing any PPE

- In the call for tender document, bills of quantities shall request that answering firms provide cost estimates for safety equipment.
- In call for tender document, the method to ensure that PPE are returned to the employer shall be provided.

Risk due to poor hygiene and general state of workers camps

It is recommended to:

- Require the contractor to develop measures for the save evacuation of wastewater and wastes from the various camps, to forbid the evacuation of wastewater in watercourses and forbid burning wastes.

Risks due to workers lower standards

- In the call for tender document, a Health and Safety specialist shall be required
- Working close to water shall be subject to very high H&S standards given the fact that : the water intake in located in MWR, that there are a lot of crocodiles on site, and that the risk of electrocution is high when welding in a damp environment.

Other measures regarding generic health and safety on site are:

- Ensure that the project proponent and financier signal that best H&S standards should apply to this project (policy leadership).
- Include standard best practice health and safety provisions in the construction contract (and tender), together with :
  - appropriate Bills of Quantities items so that at least some elements of H&S are pay items (financial incentive),
  - a mechanism for withholding payments if the contractor is not compliant with the H&S provisions (especially PPE). Note that the provisions should include insurance to enable the contractor to pay for any and all treatments required by his workers including those of all subcontractors, together with any subsequent disability payments.
  - Include a specific task in the supervision contract concerning H&S supervision and compliance, together with the staff resources to carry this out, and including a training task for the employer's staff.
  - Require the contractor to implement an H&S program and training throughout the construction

period including an induction training.

- The construction contractor shall establish and enforce the code of conduct for drivers and suppliers. An induction training shall be provided (see previous section).
- Require the contractor to install speed breakers in all access roads. These shall be made of soil spoils and shall be compacted to last. One speed bump shall be installed every 200 m.
- Require the contractor to install construction fences around excavators and truck loading excavated earth.
- Require the contractor to have a small clinic and nurse available on-site all the time with first aid kits. This would also entail that a replacement nurse is available (on-call). In addition, one vehicle shall remain available at all time to drive wounded staff to Blantyre.
- When using dynamite for blasting local population shall be warned ahead through radios, public posters and local authorities. A safety patrol with an alarm has to ensure that all individuals are evacuated from quarries area prior to blasting.

The selection of the construction contractor will require a conscious decision by the project proponent and financing agencies prior to tendering for a construction contractor. In addition, many measures proposed in this ESIA involve a cost for the construction contractor, call for tender shall be clear on the requirement to quantify health and safety measures in the Bills of Quantities (PPE, speed breakers, construction fences, etc.)

In addition, in the call for tender for the PPP (scheme operator), it is recommended to require that firms provide a health and safety protocol for work in canals.

Bilharzias

The actions to reduce the burden of schistosomiasis are:

1) to reduce the contact between water and human by the use of boots and protective clothes. This reduction of the contacts with water is possible to do with farm workers but not feasible with children and adolescents.
2) to reduce the infection of the snail's fauna by avoiding defecating in or near water and avoiding urinating in water. Health sensitization is the only efficient way to reduce the release of feces or urine in water. It only can be obtained by a long-term strategy of education including scholar education.
3) the elimination of the snails by molluscicides. This action is neither realistic nor sustainable at the scale of hundreds hectares of irrigated area and hundreds kilometer of canals. However, the maintenance of the canals, particularly the elimination of aquatic plants, reduces the proliferation of snails. To dry up the canals during several weeks is also efficient but can rarely be done.
4) Preventive mass campaigns of chemotherapy with praziquantel. To be efficient, these campaigns have to be done with the entire population and repeated each year. Praziquantel is not an expansive drug and it is well-tolerated. It is effective against both urinary and intestinal schistosomiasis, resulting in a reduction of the severe forms but not in an interruption of their transmission.

Leptospirosis

Leptospirosis is prevented by the use of protective clothes and boots and avoiding contact with fresh water in the canals. Thus, this prevention is not different from that of schistosomiasis. Leptospirosis, however, is much rarer and much less transmissible. Before any excessive concern for this disease, it would be of interest to conduct a serological survey among the cane workers.

Other waterborne diseases not directly linked to irrigation schemes

Soil-transmitted helminthiasis

Measures against soil-transmitted helminthiasis are:

- use of pit latrines for defecation
- washing hand after defecation
- protection of the feet by shoes
- protection of the food from flies

Cholera

- Use of latrines for defecation or at least, defecation away from houses, paths, water pools and supplies, places where children play and covering feces with earth or sand ("The cat method" for ending open defecation).
- Hand washing with water and soap after defecation and before any contact with food or drink. Washing is efficient with any ordinary soap even with dirty water.
- Drinking safe water and safe water use for cooking, teeth brushing, children bathing. The easiest way to obtain safe water is to put 2 at 3 ppm of chlorine (five to ten drops of bleach for 10 liters of water). The disinfecting power of free chlorine persists from 24 to 48 hours.

To reduce the risk of cholera and at the same time of the other infectious diarrheas, providing people with safe drinking water is one of the most useful actions. From the Main canal 1, a main pipe can conduct the water by gravity to a treatment center (decantation and chlorination) then to the main villages and settlements (as developed in the FS). The biggest difficulty is not to construct this water transport network but its maintenance. To be sustainable, the water delivery by standpipes should be lucrative for the operator in charge of the distribution and also economically accessible for this poor population

Malaria

As mentioned in the Baseline report Malaria is not directly linked to irrigation schemes as the area is already surrounded by puddles, wetlands and dambos. However, the incidence of malaria attacks and their severity can be reduced. The main action to minimize the incidence is to reduce the contacts between Anopheles mosquitoes and human beings by the use of insecticide treated bed nets during the night. The nets should be in good condition, well bordered. Depending on the insecticide, the fabric and the manner of impregnation, this impregnation is efficient to repulse mosquitoes during six months to two years at best. Besides, the best way to reduce malaria attack severity is a prompt and exact diagnosis and a prompt treatment by an effective drug. The Malawian ministry of health guidelines prescribes to use an oral artemisin combined therapy like arthemeter plus lumefantrine for uncomplicated attacks and parenteral artesunate for the severe ones. However, nothing can be done regarding canal or drain design or the irrigation techniques to reduce the prevalence of malaria.

Onchocerciasis

Regarding Onchocerciasis, because of the strong link between the Simulium blackflies and running water in streams and rivers, there is no risk of invasion by these vectors of onchocerciasis in the lowlands along the bank of the Shire River and canals. The possible presence of Simulium larvae at the tiger fish barrier (if it involves a waterfall) is more anecdotic than of health interest.

Drownings

It is recommended to carry out sensitization at primary schools to inform children about the danger of canals. To allow people to access water without danger, it is also recommended to build large stairs at each village crossed by a main canal (Main Canal 1, 2 and 3). Stairs shall be built at village level only to maintain a certain level of control over the use of canal. To reduce the incidence of drowning, fixed ladder shall be fixed every 500 m on both side of the canal along the full length of the Main Canal 1, 2 and 3 (with alternating position). Fixed ladder shall be installed in night storages as well (as mentioned in the FS).

5.2.5. Cultural Heritage

Phase 1: Pre-construction data collection

- Artifact collection using hand excavated shovel pits or augers to assess the depth of sites and range of artifacts and controlled excavation of sites categorized as high priority. One elements is to be noted : many of these sites were identified in rivers in 2016. There is a chance that flash floods have washed them away;
- All artifacts collected shall be catalogued and described, and curated in Malawi through a governmental institution (MDoA);
- Appropriate analyses of collected artifacts such as ceramics, copper objects and slag, etc. will be completed as they are collected;
- A report will be issued describing and interpreting the cultural resources found and placing them within a broader cultural-historical framework; and
- Publication of results in peer-reviewed journals.

Phase2: Mitigation plan during construction

- Contractor Training and Awareness Program based on identified cultural sites, sacred sites and graveyards;
- An initial one or two months period of selective archaeological monitoring of surface clearing and earth work during construction in areas with poor surface visibility and/or a high probability for cultural resources buried below the surface; assessment of artifacts recovered during land transformation activities; training of Malawian students in archaeological monitoring;
- Salvage excavations at sites deemed as of high priority;
- Once the initial period of archaeological monitoring and salvage excavations is over, the Project will apply Chance Find Procedures (see the management plan for the details). Personnel from the MDoA should decide about necessary management measures;
- Avoid/minimize construction-related impacts to cultural resources.

5.2.6. Natural Heritage

5.2.6.1. Decision on the type of canal inside parks

African Parks has requested that vehicle and wildlife passes be installed. These mitigations require to provide water for wildlife and installing passages for:

- Wildlife (large passage) so that they can access drinking spots along the Shire (this measure is further detailed in another section),

- Vehicles (maintenance and park management) and pedestrians so that they can access viewpoints along the Shire (Kapichira falls, etc.)

All options of measures have to be studied in depth at either the current feasibility stage or at the design stage, in consultation with African Parks. In addition, all options have to be studied in light of recommended mitigations for ecological impacts

Changing the alignment route to reduce impacts(LNP)

Due to topographic constraints, the canal cannot shift further westward from the Old Lengwe. There is no possible measures to change the alignment route, siphons are not necessary since there are not steep slopes inside the park.

5.2.6.2. Decision on the status of canals inside parks

The canal shall remain within the MWR and LNP and shall not affect its status (no alienation of the canal right of way). How access to the intake and canal for maintenance will be managed shall be done in accordance with African Parks and LNP access restrictions (and inspection to avoid poaching). In case of wildlife passages (and other civil engineering infrastructures within the park), their status shall be clearly defined in order to clarify who will be responsible for maintenance of such passages and infrastructures. A Memorandum of Understanding between the project operator and African Parks/LNP will be necessary to ensure long-term commitments.

5.2.6.3. Tender process and selection of a construction contractor

- the tender document requires that the construction contractor has several references in work in parks and that these references be verified to ensure that work went well (reputation of the contractor shall be verified before the selection).
- the tender document includes all applicable environmental and social measures from the Environmental and Social Management Plan (ESMP).
- African Parks and LNP be involved in proof reading the tender document and the contractor's contract (or at least parts of it that relate to work within their boundaries).
- the tender document requires the contractor to have a wildlife or environmental specialist in its staff (in addition to a health and safety specialist) that reports to and consults with African Parks and LNP on a weekly basis.
- local law enforcement be involved in cases of serious unlawful activities such as poaching and prostitution.
- that the tender document and the contract clearly state roles and authority of African Parks and LNP during construction.

5.2.6.4. Impact on tourism

- Earth works shall be limited to the path of the canal and all bare soil shall be rehabilitated at post construction in consultation with African Parks (and based on local availability at plant nurseries, native plants shall be planted, see impacts on habitats section).
- Excavated materials shall be dumped in predetermined area such as a quarry, outside MWR or only in designated areas specified by African Parks.

- Temporary construction roads and tracks shall be limited to immediately adjacent site along the canal in the predefined footprint (10m) from the canal path, these roads and tracks shall be rehabilitated on completion of construction with indigenous plant species in consultation with African Parks (depending on local availability).
- The loss of the attractiveness of the boating trips shall be compensated by installing an alternative boat launch and mooring further upstream. To compensate for this impact will be challenging as river flows are faster away from the current site and small harbor dyke may have to be build upstream to mitigate against fast moving waters.
- The FS report has recommended that noise and dust barrier be installed close to MWR offices and community camps to reduce visual, air quality and noise impacts.

5.2.6.5. Impact on Majete buildings, roads and infrastructures

- To avoid causing disturbances to reserve buildings (and to keep canal as far as possible from them), it is recommended that an inverted siphon or a buried canal be designed to short cut the current alignment route (as discussed above).
- Roads (Hall Martin drive and start of Mkulumadzi road) will not be usable as tourism routes during and after construction due to disturbance and the changed environment. Compensation will be necessary to reroute roads and provide alternatives for tourists to avoid the Hall- Martin road and alternative routing to access southern portion of Mkulumadzi road. The previous map shows a proposed alternative road for tourists (diverted road). In addition, a vehicle bridge shall be installed at Kapichira falls road and on the road to Mwembezi Lodge (outside MWR fence)
- The Contractor shall regularly maintain Chikwawa to Majete main road (D135) in good condition, and the possibility of upgrading this road to asphalt should be considered.
- At a minimum, daily dust control interventions must be put in place along Chikwawa to Majete main road (and within the park). During the dry season (May to November), dust control shall be done every two hours (with water only). This will also ensure that villages close to the road are not impacted by dust. The source of water for dust control shall be taken from outside MWR and outside the Kapichira reservoir and in consultation with local communities. If water is pumped from the Shire, the access shall be stabilized to limit erosion in the river (concrete access ramp).
- Areas where fences will be affected will have to be compensated. Contractor will ensure there is no breach of the fence during construction. All repairs and newly required fence sections will be for the cost of the contractor but done by approved African Parks contractors

5.2.6.6. Impact on Kapichira falls attractiveness

To mitigate this major cumulative impact, the following measures shall be studied in depth, all of which involve many stakeholders. Regardless of mitigation, a maximum of 50 m^3/s will be withdrawn from Kapichira falls (between the dam and the tailrace).

- African Parks have to decide what is the desired environmental flow for touristic purposes at Kapichira falls. This ESIA recommends that additional release from Kamuzu barrage be equal to what SVIP will take on a seasonal basis (full compensation), so that once SVIP is in operation, there will be no reduction of flow at Kapichira falls from baseline situation.
- Based on this ESIA recommendation, the Government has to engage in discussion with Escom regarding management of Kamuzu barrage so that the dam releases more once Kapichira II is build. Based on this, the environmental flow shall be implemented and the government shall ensure that it is always respected (an agreement for water users regarding the environmental flow shall be produced by the Government)

5.2.6.7. Impact on Lengwe roads and infrastructures

Where the canal crosses roads, a vehicle bridge shall be installed. Based on available map of the park, there are four areas where a bridge shall be installed:

- North Thicket Drive,
- South Thicket Road,
- Makanga Drive
- Tsanya Drive

5.2.6.8. Loss of ownership of park management on the western side of Lengwe

Any form of mitigation measures shall be discussed with LNP management and shall be coherent with the activities of the current Shire River Basin Management Program and the new General Management Plan under SRBMP (GEF, 2106).

5.2.6.9. The presence of a canal inside parks will be long-term agent of changes

- Install a ranger scout along the canal close to a wildlife overpass ;
- Only install troughs on the western part of the canal (to keep cattle from entering the park to drink) (troughs are presented as a mitigation for wildlife in Chapter 7) ;
- To sort out all existing issues as described in the General Management Plan of LNP (GEF,2016) (poaching, illegal wood clearing, lack of reliable fence and buffalo entering Illovo field, current issue with Bailey Bridge at risk of collapsing, lack of field equipment, vehicles, communication equipment, etc.) before implementing any sort of mitigation or compensation measures as these existing issues could aggravate with the Project implementation. This implies that compensation for LNP due to impacts from SVIP could also be oriented to solve current issues:
  - Installing fences to keep buffalos from entering Illovo estate (part of SRBMP funds is currently oriented at installing new fences)
  - Building a new bridge across Nkombedzi Wa Fodya River to replace the current Bailey Bridge.
  - Improving existing infrastructures and equipment of the park
  - Improving existing drinking spots for wildlife,

5.3. Ecology Impact Assessment

5.3.1. Land Cover

Change to land cover is inevitable. However, impacts within park shall be compensated by planting the equivalent of affected trees (see next section). In addition, large baobab and communal forests shall be avoided (not cleared cut) when developing the command area. It is recommended, that before clearing trees or shrubs the following protocol be followed by the Engineer in charge of work plans and supervision of work:

- Make sure the forest or bush does not hide a graveyard by talking to village headman (part of the Code of Conduct),
- Make sure that there is no protected trees, shrubs or plants (National Parks and Wildlife Act (Act No. 11 of 1992) by requesting a clearance from the Department of National Parks and Wildlife (DPNW);
- Make sure that all cut trees return to their owners

5.3.2. Terrestrial Habitats and Wildlife

5.3.2.1. Disturbances of wildlife and vegetation

- Phasing the installation of wildlife passes as canal construction progresses is recommended to avoid creating a long trench in MWR and LNP without any passage
- Wildlife will have to be contained away from construction to avoid any casualties. Construction planning will have to consider and provide for materials and costs for the containment of animals for both LNP and MWR. Such costs include erecting temporary wildlife fences around construction sites. These fences have to be wildlife approved and electrified. They cannot be domestic animal fences.
- In MWR, construction vehicle will access the water intake site as far as possible from the east bank.
- Speed limits will be set at 15km/hour for all vehicles and trucks in MWR and LNP.
- The Department of National Parks and Wildlife (LNP) will be required to verify construction contractor fridges in their kitchen on a regular basis to ensure that contractors do not purchase any bush meat or animal parts.
- In MWR, anti-erosion practices shall be put in place. They shall be designed once the design study available. Silt fences on land and floating silt fence in the reservoir shall be installed.
- Machinery will be checked by reserve and park rangers at entrance to ensure that no mud is present on wheel and excavator. This is necessary to avoid invasion of the water hyacinth (or other plants). In case of presence of mud, the machinery or vehicle will be forbidden to enter.
- Access to the construction site must be restricted through controlled access points managed by African Parks, and operating hours shall be limited to 9am to 6pm. Peak game drive times are 6am – 9am and 3pm to 6pm, ideally work should avoid that timeframe. In LNP, work will take place between 6am and 6pm.
- Dredged spoils and excavated soils cannot be stored in MWR nor in LNP (even temporarily)
- Vegetation removal shall be limited to the canal path and a pre-agreed footprint either side of the canal during construction. All removed vegetation remains the property of MWR and LNP who will specify where this be stored and how.
- Post construction rehabilitation shall be mandatory and replanting of trees shall be done to ensure recovery of vegetation to African Park's and LNP specifications and standards (based on available plants in local nurseries). Rehabilitation shall take place at the end of work in MWR and not at the end of the contractor's contract to ensure that it is done and budgeted by the contractor (during tender). The same procedure applies to LNP during phase II.
- Regarding compensation for the losses of thicket and forest, we recommend the following revegetation measure:
  - To compensate for the 25 ha of forest cleared in MWR (mainly broad leave deciduous trees), an estimate number of trees proposed is 1 per 10meters (144 trees per ha) which represent 144 x 25 ha = 3,600 trees (square planting). Trees shall be planted inside the reserve in consultation with African Parks.
  - To compensate for the 60 ha of Thickets and forest cleared in LNP (mainly Pterocarpus antunesii), an estimate number of thicket species is 1 per 5meters (484 shrubs per ha) which represent 484 x 60 = 29,040 shrubs (square planting). Shrubs shall be planted in consultation with LNP management.
  - Wildlife and Environmental Society of Malawi (WESM) has the experience to carry out such planting. The nursery shall be located in the valley which will require land and irrigated water. In addition, each plant shall be between 2 and 5 years old to ensure success and shall be protected with cages to keep herbivores away. The full cost assessment is in the Environmental and Social Management Plan (ESMP).

5.3.2.2. Habitat fragmentation

Wildlife passes in MWR

The ESIA recommends that option 2 be implemented if a buried canal is not feasible and if additional flow is released from Kamuzu barrage to ensure an environmental flow at the Kapichira falls. If an agreement for additional flow release from Kamuzu barrage is not reached, than the falls and the Shire down the dam (before the tail race) will often be almost dry and will be less attractive to wildlife and tourist. Negotiation between the Government and Escom for additional flow release from Kamuzu barrage shall be undertaken as soon as possible as not implementing an environmental flow is not acceptable for African Parks and is a major impacts for Elephant marsh ecology as well. Option 1 could be interesting in terms of tourism since the isolated part would be free of wildlife and could be designed to allow tourist to walk secure and access the fall viewing area. All options have to be studied in depth at either the current feasibility stage or at the design stage, in consultation with African Parks.

Wildlife passes for LNP

In LNP where the canal will be open (see Natural Heritage section), it is suggested to install one wildlife overpass and one wildlife underpass. The overpass shall be located inside the thicket area. Troughs shall be installed on the western part of the canal only to avoid villagers bringing their cattle inside the park to fetch for water. The number of trough shall be discussed with LNP management. It is necessary to install bridges for vehicle at all location where an existing path crosses the canal. Based on actual map of LNP, the canal will cross paths at 4 locations (see maps on impact in LNP). There is no need to install specific pedestrian passes in LNP. All options have to be studied in depth at either the current feasibility stage or at the design stage, in consultation with Lengwe National Park management.

Buffer zones around LNP and encroachment

Any encroachment by the scheme inside LNP is not acceptable. In fact, the future zone A (The Nkombedzi Wa Foydya River along the LNP shall be protected from drainage water from the scheme and from any infrastructures.) and B (Zone B shall be moved back from the park boundary to allow for a buffer zone of at least 100 meters.) shall be designed to leave a large buffer zone between the park and the scheme where the scheme shall not be developed. The current Zone B is very closed (and some part is encroaching) to LNP, Zone B shall be reviewed to leave a buffer zone. The buffer zone shall be large enough to keep LNP from all impacts of surrounding activities and uses. Based on that, Zone B will be 342.6 ha smaller and the buffer zone will further reduce it by 74.9 ha

5.3.2.3. Drowning hazard for wildlife

- The design of the water intake shall be done to ensure no crocodiles and hippos can enter canal. For that, a strong net-cage shall be put in front of the water intake. Spaces shall allow to retain adult and juvenile crocodiles. However, having juvenile crocodiles entering the water intake will remain a risk.
- The issue of animal drowning is complex since:
  - Fencing the whole canal to avoid wildlife drowning will affect the natural landscape of both LNP and MWR. Fences requires maintenance. In addition, in the case of LNP, fences may be

stolen or vandalized (as it is the case today). Building a wall, using rocks in a concrete matrix will provide efficient protection against (for) large animals with little maintenance, will last longer and will have a better appearance. A wall is however more expensive than an electric fence as shown in the following table. This table presents several options including installing a wall around each vehicle bridge and wildlife pass to offer tourist with a pleasant view.

- In MWR having a shallower and wider canal without fence rather than a narrow and deep canal to ensure that wildlife do not drown could be an interesting mitigation. However, several animals could use this canal as a pathway to travel (and not only to cross it), which in turn could affect the integrity of the canal. Elephants are large and heavy and travel in herds; they will cause damages to the canal. Therefore, some form of barriers are inevitable to keep elephant from entering the canal. In addition, regardless of the layout, the lined canal will always represent a drowning hazard. Based on return of experience from the Grootfontein–Omatako Canal in Namibia and discussion with M. Heyns, escape structures are not recommended as wildlife do not understand that these are exits (personal communication, 2016). If escape structures did not work with a canal much smaller than SVIP main canals (Grootfontein – Omatako Canal), they will probably not work with the Main Canal 1 and Main Canal 2.
- In LNP, an earth canal could reduce drowning hazard as long as slope are mild (milder than 1/1.5). The feasibility of an earth canal still needs to be assessed by the FS. In addition, buffalos in LNP will damage the earth canal, an intermediary solution would be an earth canal lined with prefabricated concrete mats which are flexible matrix of cellular concrete blocks. The cellular blocks are good grip for animals to exit canals.

5.3.3. Wetland Habitats and Wildlife

5.3.3.1. Long-term reduction of wetland area

This impact is non-avoidable as withdrawing water from the system is the basis of the Project. Building weirs in the marsh to maintain a certain level of water during the dry season is not recommended for several reasons:

- The severity of floods has shown how destructive the Shire can be, weirs may not sustain;
- Weirs will block sediment transport to downstream areas;
- Weirs will block fish movement;
- When Ruo River joins with Shire it creates a beneficial backflow that brings water to the marsh. Weir would block the flow of Ruo into the marsh.

5.3.3.2. Wildlife-human conflict

Elephant marsh is the most at stake when it comes to wildlife-human conflict.

Crocodiles

Crocodiles can move on land and in the water therefore there is little direct actions that can be undertaken, the risk will never be annihilated. To reduce the risk it is recommended to implemented the following measures (in order of cost):

- Sensitize people not to use drain canals to bath or to bring cattle for water.
- Design drains with steep slopes to keep crocodiles from exiting them and attacking people.

- With the installation of cattle troughs along the canal, the access to the Shire for livestock could be forbidden as part of a future wetland management.
- Install a crocodile fence across every connecting drains with the Shire. A crocodile fence shall be fixed to the drain bed and ground using concrete and shall be high enough to stand out during a flood. Wire mesh shall remain sharp at the top of the fence. On ground, it shall be wide enough to discourage crocodiles from moving on land and circulate around the fence to reach the drain.

Hippopotamus

Hippopotamus will be attracted to fields to forage, some measures can be proposed:

- Sensitize people not to stay late in their field, as hippopotamus are known to enter fields at night;
- Adapt crop in the command area so that cotton (non edible crop) is cultivated closer to the Shire and food crops further away;
- Install along irrigated fields thorny branches (acacia branches) to keep hippopotamus from entering. However, it has been reported that even barbed wire are not efficient against hippos. In fact, walls could be the only efficient measure (UNDP, 2016) given the size of the irrigation scheme, efficient actions are rather limited and death of hippopotamus due to conflicts will take place.

Buffalos entering fields

LNP will be surrounded by irrigated fields, to avoid all encounters with buffalos, it will be important to fence he whole Old Lengwe section of the park (or finalize the current fencing process).

5.3.4. Aquatic Habitats and Fish

Disturbance to fish migration to spawning sites

- Design appropriate permanent river crossings instead of earth dikes. The goal would be to foresee needs once the Project is operational and to install permanent crossings;
- Forbid ford crossings of rivers to avoid destroying banks. In case where ford crossing is the best option, banks shall be stabilized and the ford crossing and ramp shall be made of concrete.
- When installing a temporary dike to cross river (for machinery and construction vehicles), the following measures shall be implemented:
  - Install culverts that allow for hydraulic transparency (see section on hydraulic transparency).
  - Install culverts to allow for fish passages by :
  - ensuring that all culverts are installed partially under the river bed level;
  - avoiding creating water falls (perched culvert) or having a steep slope in the culvert;
  - avoiding increasing flow to a point where fishes can no longer swim;
  - stabilizing the culvert embankment with large riprap or gabion (given the strength of flash floods);
  - avoiding crossing at areas rich in vegetation (trees and tall grass) or with shallow rocky areas of as they are often valued spawning areas.
- All work in temporary rivers shall be prohibited from November to March and shall be concentrated between July and October to minimize impacts on migrating fishes.

Risk of tiger fish invasion in the upper Shire

Kapichira falls are the only proven and absolute barriers to the upstream migration of the Tiger fish. Other falls along the Shire have characteristics that makes them difficult to pass, but are not all-year around absolute barriers to fish. In addition, due to their locations upstream from Kapichira falls they were never proven to be reliable physical barriers to Tiger fish migration.

Allowing non-native fishes to move up the Middle and Upper Shire, one step closer to Lake Malawi, is also a risk because any future development along the River could provide new paths for fish movement (for example: a new gravity irrigation scheme using another hydropower reservoir, etc.).

Mitigation Measures for Tiger fishes

The following options are not based on any return of experience on Tiger fish barriers as this situation is unique. It is only based on bibliographical analysis on invasive fish issues in North America. In addition, the FS report does not provide reliable assessment on canal or siphon infrastructures that are planned and that could be modified to design a physical barrier. The following description of options has been carried out with these limitations and take into account that the Tiger fish is known to jump out of the water to catch birds (barn swallows), it is also known to gain speed deeper before surfacing out of water (O'Brien et an 2013).

[Option 1] High Concrete Wall: The Most Efficient But Not Technically Feasible

<u>Technical aspects</u>

To be efficient, the fish barrier shall have the following characteristics from upstream to downstream.

A waterfall high enough to keep the fish from jumping over. This wall shall be vertical and made of concrete. The height shall at least 2 meters which exceeds the leaping abilities of the Tiger fish.

A long area of shallow water of about 30 cm deep (called an apron) to keep fish from gaining speed and energy to jump. The length of the apron shall be a few meters. To convey $50m^3/s$, the apron will need to be several hundred meters wide.

An area of gradual slope leading to the canal which, at this point, will have its normal shape.

The fish barrier shall be installed in Majete Wildlife Reserve for the following reasons.

- To intercept all risks as the further downstream the structure is installed, the higher the risk of invasion;
- To take advantage of the buried canal or inverted siphons exit and available land to install the fish barrier;
- To take advantage of an area with lesser population density and to avoid having people using it to wash clothes (on the apron), bringing cattle to drink and to bath.
- To rely on African Parks as a well-managed organization for surveillance.

<u>Pros</u>

This option involves building a high wall to create a waterfall, impassible obstacle to the Tiger fish (adult, fry and juveniles). This option would, in theory, be the most efficient to block the fish. In addition, it is a simple civil engineering infrastructure that could be built by the construction contractor, and it is a low maintenance structure which efficiency will last regardless of maintenance.

<u>Cons</u>

The fish barrier represents a 2 m head loss and will require major expenses to compensate for the 2 m head loss, either by building a pumping station or by reducing the slope of the feeder canal to compensate for the loss (and therefore increasing the width of the canal as well). Without a pumping station or slope adaptation, the irrigation scheme will lose irrigated surfaces especially in Zone C and D of Phase Il but also in Phase l. A pumping station requires a reliable energy source and adds to the overall risk in terms of maintenance of the irrigation infrastructures. In addition, the pumping station would have to function at all time as the canal does not store water. Reducing the slope to recuperate the 2 m head loss will also be a challenge as the current canal slope and water velocity is very low.

[Option 2] Fish Screens: High Risk If Built By The Scheme Construction Contractor

<u>Technical aspects</u>

Fish screens are actual screens with small mesh size that retain fishes from moving along a canal or water intake. Fish screens should remain outside of the Shire flood risk zone (this is valid for all options). The following figure overlays flood assessment maps (BRLi, Wems, Aurecon, 2015) with the Project layout to show the area prone to floods. From this map, it is obvious that, in order to minimize the risk of floods overlapping fish screens, they have to be installed upstream from Mwanza River (this is valid for all options). Installing fish screens upstream of the scheme reduces the risk of sabotage as people could be tempted to stock fish in the canal, a fish screen could be seen as an obstacle to fisheries. It is not recommended to install the screens along a canal since there is a probability that people use the canal as a waste dumpster (it is observed in many countries where the consultant has worked) blocking the flow at screen location and creating localized floods leading to potential Tiger fish passage around the fish screens;

The mesh shall be small enough to exclude all tiger fish life stages except for eggs as tiger fish is not likely to spawn in the canal (especially in the buried canal) and that the risk of passage is based on movement (fish swimming upstream) and not flow (eggs do not swim).

Fry sizes at hatching varies from 5-8 mm but fry grows very fast in warm temperatures (above 28^0C) to reach 15mm in length within 2-3 days (with good nutrition).

Adult size is up to 1,050mm (standard length, i.e., exclude the caudal fin, only the body) in the wild, in captivity they grow up to 750 mm ; their life span is 10 to 15 years and can weigh up to 28 kg. Males are larger than females.

Fish screens with 5 mm mesh size could be installed at the water intake.

The cost for fish screens varies greatly. But the average price in the US is about 35,000 USD per m^3/s (Oregon Department of Fish and Wildlife Fish Screening Program: Fish Screen Types and Costs, 2016). A cost estimate for a fish screen with automatic cleaning device was provided by an USA based firm; based on current design of the Project, the cost of a fish screen would be 1.2 million USD including installation and shipment to South Africa of the screens (IWS International Water Screens, 2016) but excluding land transport to Malawi, which would cost around 25,000 USD (quotation from Savino Del Bene, 2017). Custom fees and are unknown. Each replacement screen is 75,000 USD.

The fish screens shall have automatic cleaning mechanism to remove debris using a traveling belt, with the belt moving in an endless loop powered by electricity. In front of the traveling belt a trash rack would be installed removing larger debris (logs, etc.). An inspection and maintenance plan shall be developed to ensure that the screens are operating well and that there is no breach.

<u>Pros</u>

Installing fish screens will have lesser economic impact on the Project than option 1 (due to option 1 important head loss) because it will lead to insignificant head loss (about 30 cm head loss, based on actual calculations from IWS with a fish screen at the SVIP water intake, 2016). It will be efficient to prevent the Tiger fish from moving upstream only if a specialized firm is involved in designing and installing the screen.

Cons

The risk of defect, breach or obstruction of the screens is very important for the following reasons.

There is a high risk of water hyacinth bloom in the Kapichira reservoir leading to blockage of screens at the water intake, unless a reliable trash rack is installed.

Unless a specialized firm is involved in designing, producing and installing the screen, it will probably have defects and will not prevent fish passage (in fact in many countries such as the US, fish screens have to follow regulations and norms and must be built by certified firms). Many specialized firms are located on the Pacific coast of North America where there are Issues with invasive migratory fishes. This expertise is absent in Africa and there is no return of experience in Africa.

The fish screen is not a simple civil engineer infrastructure and will require constant effort and maintenance. Maintenance of this technology may fail in the medium term for a number of reasons (change in the scheme operator, budgets cut back. lack of spare parts. etc.). Maintenance of the screen at the water intake would require to remove debris (water hyacinth), logs, etc. in an area crawling with crocodiles. A self-cleaning device is highly recommended.

[Option 3] A Low Concrete Wall: An Intermediary Option

This infrastructure shall not be installed outside MWR otherwise people will use it as area to wash clothes (on the apron) to bring cattle to drink and to bath. This will lead to damages to the infrastructure.

Pros

Since option 1 represents an economic constraint (due to important head loss of the wall), a lower wall could be designed. In that case, the lower height of the “wall" could be compensated by a fence along it to keep adult fish from jumping, the height of the wall would still be efficient to keep adults. Fry and juveniles away and the apron will keep Tiger fish from gaining speed to jump. The fence could be either vertical or horizontal (as shown in the following pictures). This option is economically advantageous while ensuring high efficiency. However, as the dam is low any damages to the structure would reduce it efficiency. The fence could simply be repaired in case of damages.

Cons

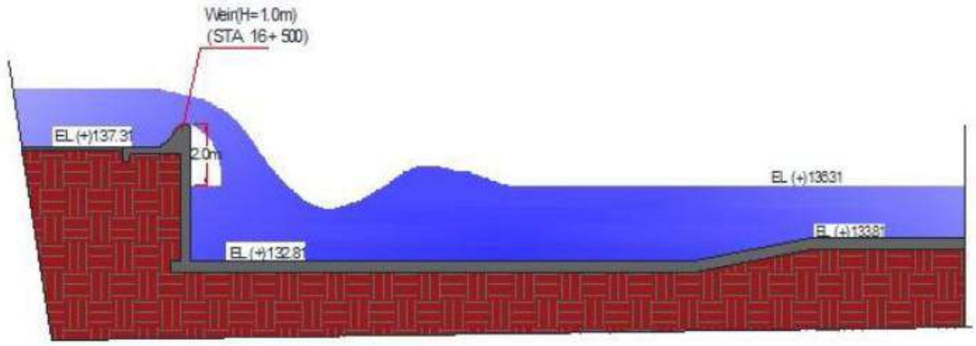
For this option, the Design or FS consultant has to decide what is an acceptable head loss, canal slope reduction, width augmentation and flow reduction. The height shall however not be lower than one meter.

As for option 1, the apron would require large space, which is a disadvantage. The fence shall be designed, produced and installed by a specialized firm.

[Option 4] The Tiger Fish Weir Designed By KRC

Several discussions were held after the ESIA Mitigation Workshop (November 2016) on measures to avoid invasion of the Tiger fish upstream of Kapichira falls. In March 2017, a document called "Second proposal for mitigating the Tiger Fish Issue" was produced by the FS consultant presenting an infrastructure to stop Tiger fish migration upstream. This section presents the infrastructure and its main characteristics.

The infrastructure involves a fall with a 1 meter high broad crested weir across the Main canal 1 (feeder canal) combined with a 3.5 meters drop structure as shown in the following figure.



[Figure 5.3-1] KRC Proposal for a Tiger Fish Barrier

<u>Pros</u>

The height of the fall provides sufficient protection against fishes trying to jump.

<u>Cons</u>

The proposal from KRC seems to be efficient; however, it will have to be completed by more detailed plans and technical description in order to assess its efficiency. In addition, a ramp must be installed to allow removing deposited silts.

KRC has provided in its document two location, one inside MWR and one at STA.16+600 (as shown in the picture). The STA.16+600 is too far downstream and will not catch all risks. In addition, at this location, there is a risk of damages from people using the falls for domestic use or to bring their cattle to drink. The weir has to be located inside MWR.

5.4. Impact Assessment Conclusion

Tender process for a construction contractor

The selection of the construction contractor will require a conscious decision by the project proponent and financing agencies prior to tendering. In addition, many measures proposed in this ESIA involve costs for the construction contractor, call for tender shall be clear on the requirement to quantify measures in the Bills of Quantities. It is highly recommended to require that the contractor has experience in work in wildlife parks and that its reputation be assessed.

Fate of Shire environmental flow

Based on this ESIA and the identified impacts, maintaining an environmental flow at Kapichira falls is necessary for the following reasons:

- to safeguard Elephant marsh current size;

- to safeguard crocodiles and hippopotamus habitat and food supply and to minimize conflicts with farmers (and casualties);
- to safeguard fisheries;
- to maintain Kapichira falls attractiveness for tourists;
- to help designing appropriate mitigation measures for MWR (the fate of the falls could influence mitigation regarding wildlife passes) ;
- to compensate for the impact on an international waterway.

Type of canal associate infrastructure in MWR and LNP

In order to achieve maximum efficiency in mitigation while remaining economically feasible (and realistic), we recommend that the canal in MWR shall be design as follow (Option C-2):

- From KP O to 1.5 (inside the reserve fences): a buried canal with sufficient concrete to allow all wildlife to cross including elephants (and vehicles), no fences would be necessary ;
- From KP 1.5 to 3.24 (outside the reserve fences): an open lined canal with a vehicle bridge across the road to Mwambezi lodge;
- Fencing from KP 1.5 to 3.24 shall be regular electric fence, but 100 m of both sides of the vehicle bridge ramp, fences shall be replaced by a wall made of rock in a concrete matrix (for esthetical purposes);
- From KP 3.24 to KP 8.1 (inside the fences and across the Mwambezi River): a buried canal with sufficient concrete to allow all wildlife to cross including elephant (and vehicles), no fences would be necessary.

Type of fish barrier

This ESIA recommends that Option 3 be implemented, as it is a mix of several techniques and does not involve major head losses. Option 3 would require installing the fish screens at the water intake with a self-cleaning device (traveling belt) and a small dam along the Main canal 1 with a fence across it to keep tiger fish from jumping. The mesh of the screen shall be small enough to exclude all tiger fish life stages. We strongly recommend that the fish screen be designed by a specialized firm and not just by installing a wire mesh across the water intake. The biggest challenge in the fish screen is that this device will required a high level of maintenance and will require specific expertise to design and install the fish screen. In the US, fish screens cost around 35,000 USD per m^3/s. This cost excludes maintenance and electricity.

5.4.1. Conclusion on Infrastructures to Build to Mitigate

Canal options in MWR

The Design and FS shall study the economic feasibility of the following options:

- Option B-1: 1,200m inverted siphon to convey 50m^3/s
- Option B-2: 600m inverted siphon to convey 50m^3/s
- Option C-1: a buried canal all along MWR (4,400m long) and Option C-2: a buried canal inside MWR fences (2,700 m long) to convey 50m^3/s with the following dimensions:
  - 25 m (width)
  - 2.5 m (height)

- 0.5 m (concrete thickness)
- 0.5 m (diameter of supporting poles inside the canal for ensure elephant passage)
- 5 supporting poles per meter

Canal options in LNP

If the canal is an earth canal, the design shall study the cost of installing prefabricated concrete mats along the 13 km of LNP which are flexible matrix of cellular concrete blocks that safeguard canal integrity from animals.

Fence options in MWR and LNP

The Design and FS shall study the economic feasibility of the following options:

- Unit cost per meter for a wall made of rock in concrete matrix (with a 0.5 cm thickness and a height of 2 meters)

Passes

The Design and FS shall study the economic feasibility of the following options:

- Unit cost for a wildlife overpass in concrete able to sustain the weight of a herd of elephant or buffalos (20+ individuals) with the following dimensions:
  - Slope for the access ramps: 1:8
  - Width : 50 m
  - Height: 2 m above the canal
  - Length to cross the Main canal 1: 23 m (without the length of the ramp on both site of the canal)
  - Wall on the pass: 2 m high
- Additional cost to enlarge a box culvert to allow for dry passages of small to medium size animals (wildlife underpass).
- The unit cost for vehicle bridges across main canals
- The unit cost for footpaths across main canals (and secondary canals)
- The unit cost for cattle bridge across main canals
- The unit cost for 1 km prefabricated concrete mats made of flexible matrix of cellular concrete blocks to install in the Main canal 2

Crocodile fence

The Design and FS shall study the economic feasibility of the following measure:

- The unit cost for a crocodile fence made of wire mesh with the following dimensions:
  - Height: 2 m
  - Width : 5 m

Tiger fish barrier

The design and FS shall study the economic feasibility of the following options:

- The cost for “Option 1: High concrete wall”, with the following characteristics:

- Dam height : 2m
- Apron length : 10m
- Apron width : 150m (or large enough to sustain the flow and not have water depth above 30cm)
- Flow 50m^3/s
- Potential pumping station (and other expenses) to compensate for the 2m head loss

• The unit costs for "Option 2: Fish screens", with the following characteristics:

- Large fish screen for the water intake of 46.5 m long and 3 m high
- Medium fish screen for the Main canal 1 of 23 m wide and 3m high
- Small fish screen for secondary canal (or night storages) of 4m wide and 1.5m high
- Automatic screen cleaning devices on all screens (self-cleaning drum screen for secondary canal, traveling belt screen for the water intake)

• The unit cost for "Option 3: Fish screen and low concrete wall", with the following characteristics:

- Dam height : 1m
- Apron length : 10m
- Apron width : 150m (or large enough to sustain the flow and not have water depth above 30cm)
- Flow 50m^3/s
- Large fish screen for the water intake with traveling belt screen to allow for maintenance of 46.5 long and 3 meter high

CHAPTER 6. HYDRAULIC MODELING OF INTAKE

6.1. Introduction

It is planned to abstract the required water for irrigation using the existing dam at Kapichira constructed for hydro power generation. The intake for the hydropower is located on the right side of the dam whereas the intake for SVIP is proposed to be located on the right bank of the head pond for Kapichira Hydropower Station. A couple of hundred metres upstream of the dam there is a bund/spur, stretching several hundred metres from the right bank of the river to the middle of the reservoir/river (Figure 6.1-1). It is believed that the morphology of the head-pond is highly sensitive to the incoming flow, the pond geometry, the sediment particle size and the flushing regime that has been established over the years. The construction of an intake in the right bank of the head pond would certainly modify the morphology and, if not carefully sited, could have an adverse impact on the sediment flushing efficiency.

The objective of Hydraulic Modeling study among others is, therefore, to:

- Recommend the optimum site of the intake structure using the preliminary design of the intake general location and range of design discharges provided by the technical feasibility consultants,

Study the likely impacts of introducing the SVIP intake structure on the hydraulic behavior (incl. sedimentation) in the head-pond area and around the intake to iteratively determine the most optimal and efficient sediment exclusion and/or sediment ejection works to ensure safety and operational flexibility.

[Figure 6.1-1] Intake Structure in the Kapichira Dam

Accordingly, Artelia Eau & Environment (France) was engaged to undertake a 3D numerical modeling of the Shire river and Kapichira reservoir, including the existing power plant intake and the future SVIP intake to solve the problems related with the dynamics of sediment transport and river (reservoir area) morphology, in close consultation with the Technical Feasibility Study Consultant; KRC.

6.2. Data Exploration

Data exploration activities undertaken by Artelia include bathometric survey and sediment sampling and analysis at the existing Kapichira head pond/reservoir.

6.2.1. Bathymetric Survey

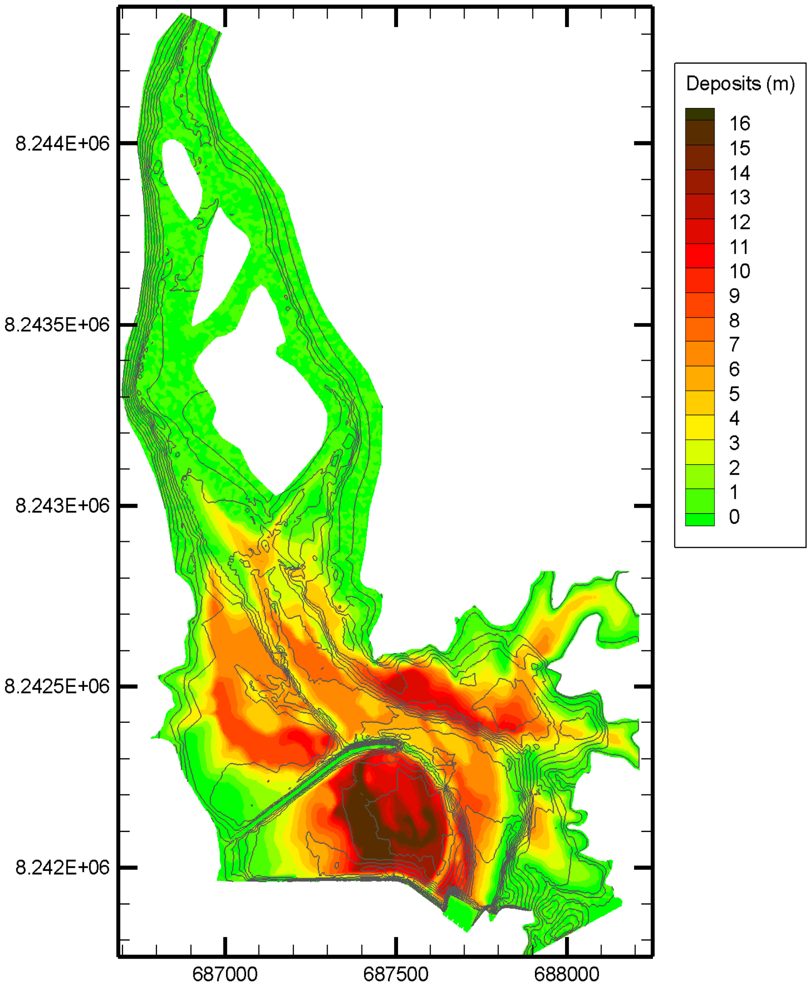
The bathymetric survey was conducted to determine the amount and configuration of silt accumulated in the reservoir since the construction of the dam. It includes undertaking transverse and longitudinal profiles covering the reservoir area and ten meters into both sides of the bank (Figure 6.2-1). The survey was not conducted in shallow areas where navigation was not possible and in the areas some 120 meters above the spill way for safety reasons.

[Figure 6.2-1] Locations of Surveyed Areas

The initial topographic condition of the area was taken from the topographic map prepared in 2001. DTM has been prepared using the two data sets (the 2001 topographic map and the present bathymetric survey) to determine the volume of silt deposited.

The volume of sediment deposited in the reservoir since the construction of the dam has been computed from the differential of the two DTMs and is estimated to be 4,700,000 m^3.

The map of the differential of the two DTMs, which shows the thickness of the sediment deposits, is presented in Figure 6.2-2. The figure shows up to 16 meters of sediment in some part of the reservoir.



[Figure 6.2-2] Sediment Deposit since Construction of Kapichira Dam

6.2.2. Sediment Sampling

Suspended Sediment

Suspended sediment samples were collected at strategic locations during the wet and dry seasons. The samples in suspension were taken at different depth and analyzed at Malawi Poly technic. The concentrations measured during the wet season are much larger that the concentrations from the dry season. It indicates a strong decrease of the suspended sediment concentration at the end of the rainy seasons. According to African Parks at Majete, the turbidity of the water decreases during the dry season, and the water is clearer at the end of the dry season. It was also noted that, the concentrations at the same location but different depth are close to each other, which show that the vertical stratification of sediment in suspension is weak.

The results from the wet season sampling show a decrease of concentration of sediment in suspension between the upstream end of the reservoir (average concentration of 240 g/l) and the middle of the reservoir (average concentration of 100 g/l). Between the middle and the end of the reservoir, there seems to be no decrease of concentration in suspension.

The results from the dry season sampling do not show a decrease of concentration in the reservoir, which indicates that there is very little settling of sediment in the reservoir during that time. The value of suspended sediment concentration entering the reservoir during the wet season is of about 0.25 g/l, which is consistent with the literature which mentions a value of suspended load during the rainy season (but outside floods) of about 0.3 g/l.

These data have been used to build time-series of sediment concentration entering the reservoir for the numerical modeling.

Bed Sediment

Sampling on bed loads were taken at the same time when the suspended samples were taken using different equipment. The results of the analysis show a clear pattern of sediment sorting in the reservoir: the sediment from the channel in the middle of the reservoir is sandy, while sediment on the banks is finer.

The sieving curves indicate a clear sand mode in most samples. The D50 of this mode is very consistent between the different samples of the wet season samples: except for few, the D50 of all samples ranges between 0.11 and 0.17 mm (average 0.14 mm). The correlation between grain size and depth indicates that deeper sediment tends to be slightly coarser, but this tendency is rather weak. For all most all samples from the wet season, the amount of coarse sand is negligible.

For more information on data collection and analysis refer to: Data exploration Report, Artelia, 2016.

6.3. Numerical Modeling

6.3.1. Software Used

The software used by Artelia for computation is TELEMAC-3D, which is a part of the TELEMAC-MASCARET system. TELEMAC-3D solves the three-dimensional hydraulics equations (non-hydrostatic Navier-Stokes equations in laminar or turbulent conditions), the transport-diffusion equations for tracers, using finite element or finite volume-type methods.

TELEMAC-3D also simulates the transport of suspended cohesive and non-cohesive sediment. To do so, it solves the suspended sediment transport and bed change equations. Exchanges with the bed are represented by the erosion and deposition flow terms.

6.3.2. Model Calibration and Operation

The model was calibrated based on the morphological evolutions of Kapichira reservoir from 2001 to 2016 and a full river discharge time-series were run, with realistic dam operations (including flushing) and realistic sediment loading. The computation of the hydro-sedimentary functioning of the reservoir with the first configurations/location of the Intake Structure was then carried out after the calibration is complete. The computation will continue for different other configurations listed as follows:

- *Configuration 1*: the intake is located just downstream of the spur dyke.
- *Configuration 2*: the intake is located just downstream of the spur dyke, and the whole right hand side deposit downstream of the spur dyke is dredged to a level of 141 m. The volume of dredging is 560,000 m^3.
- *Configuration 3*: the intake is located just upstream of the spur dyke.

- *Configuration 4*: the intake is located just upstream of the spur dyke, and the whole right hand side deposit upstream of the spur dyke is dredged to a level of 141 m. The volume of dredging is 640,000 m^3.

For details of the numerical modeling results which among others include:

- The various configurations (A,B,C,D and E) tested to determine effect of dredging,
- Long term Impact of the Intake and Role of Dredging
- Hydraulic capacity of the intake structure; refer to Hydraulic Modeling of Intake Structure Final Report, 3rd march 2017, ARTELIA Eau & Environment.

6.4. Conclusion

6.4.1. General

A detailed three-dimensional numerical model of Kapichira reservoir has been set up. It enables to compute flow, sediment transport (with sand, silt and clay) and bed evolution for long-term time series.

It has been calibrated on the long-term morphological evolution of the reservoir since the building of Kapichira dam.

A methodology to assess the hydro-sedimentary functioning of the reservoir taking into account the SVIP intake has then been set-up.

In a first step, different locations of the intake have been tested. The results show that the location proposed by the Technical Feasibility Consultant, i.e. downstream of the spur dyke, is preferable.

Then, longer tests (on a 10-years hydrological scenario) have been run in order to assess the morphological and sedimentary functioning of the reservoir in the future, with or without the SVIP intake. In all cases, the large sediment deposit downstream of the spur dyke continues its aggradation. When the SVIP intake is in place, a channel remains through this deposit, and enables the feeding of the intake during the 10-years period.

The impact of the SVIP intake on the intake of sediment transport at the power plant is very low. A small increase of the intake of sand is computed for some configurations. The configuration which includes dredging of the deposit downstream of the spur dyke does not show this increase.

The amount of sediment entering the SVIP intake is quite large (in average 162,000 t of clay and 26,500 t of silt per year in the best C case with dredging). The dredging of the deposit downstream of the spur dyke enables to reduce significantly the amount of the silt fraction of this sediment. But the largest part of the sediment entering the intake is composed of very fine, clayish, sediment that has a very low fall velocity. This kind of sediment can hardly settle, and its concentration at the intake is not reduced by the dredging.

Dredging of other areas in the reservoir does not reduce significantly the amount of sediment entering the SVIP intake and the power plant intake.

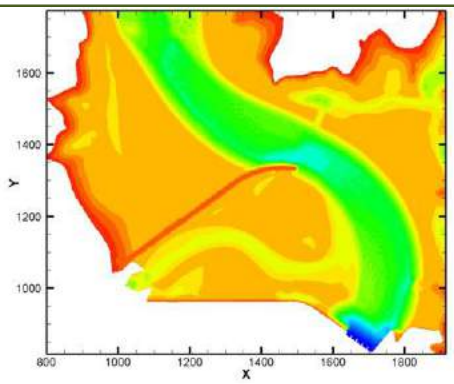
A worrying issue has been raised concerning hydraulic conveyance. Hydraulic computations indeed show that without maintenance of low bed levels in the reservoir upstream of the SVIP intake, the target discharge cannot be reached in the future for low water levels in the reservoir.

All results thus show that dredging of the deposit downstream of the spur dyke is very beneficial for the project. Ideally, the low bed level should be maintained permanently through continuous dredging. If not, the dredged area will progressively fill up, and the gains of the dredging will progressively disappear. Most of the effect of the dredging is lost after 4 years.

6.4.2. Conclusion on Dredging

<u>Alternative 1:</u> if ESCOM does not perform a large scale dredging of the reservoir and continues to operate at a high water level (minimum of 146.0/146.5 m).

In this case a frequent but limited dredging of the supply channel would be the most cost-effective option. The channel widths that form in the downstream RHS deposit in the computation with configuration A, B and C (see figure below for configuration A) and its associated conveyance can provide guidance for this minimal channel to be dredged.



[Figure 6.4-1] Bathymetry after 10 Years – Configuration A

- At the end of the computation with the 25 m^3/s intake discharge (run with configuration A), the channel through the deposit is about 50 meters wide (30 m at the bottom and 60 meters at the top) and has a bed level of about 145 m.
- At the end of the other computations (with configurations B,C, D and E), that are run with a 50 m^3/s intake discharge, the channel through the deposit is about 80 meters wide (70 m at the bottom and 100 meters at the top) and has a bed level of about 144.5 m.

It is thus recommend for the first step of the SVIP construction (discharge around 25 m^3/s) to dredge a channel, with a width of 40 meters at the bottom and a bed level set up at 144 m to secure the intake functioning.

The location and maintenance of this approach channel is discussed below (see § 11.2.2). Artelia's recommends in conclusion:

<u>A. For the SVIP</u>

- to dredge the approach channel up to the intake within the deposit at the convenient depth and with the appropriate width,
- to set down this dredged sediment along the dam embankment
- to monitor the channel location along the year and to dredge any deposit which could happen within this channel

<u>B. For EGENCO</u>

- to keep clean the main river channel up to the spillway by periodic flushing

- to control the water level in the reservoir during each flushing to avoid too high velocities at the spur dyke head and along the dam embankments close to the spillway abutments

Alternative 2: ESCOM agrees that they will undertake a large scale dredging of the reservoir.

In this case, ESCOM will be able to operate at lower water levels (although the target water level will probably remain 147 m), which would endanger the proper feeding of the SVIP intake. In order to counteract this, the dredging (initial dredging but also maintenance dredging) should involve in priority the whole RHS downstream deposit, up to the intake. According to the Technical Feasibility Consultant, the definition of the initial dredging is the whole RHS downstream deposit at a 141 m bed level (as implemented in the model in configuration C), which is perfectly adequate. Maintenance dredging would be necessary, and its rate can be estimated from the results of the run with configuration C. The dotted violet line from figure 34 indicates that the rate of deposition in this area is of about 100,000 m^3 per year. At the end of the present study, EGENCO (ex ESCOM seems to rule out this alternative).

CHAPTER 7. DAM SAFETY

The Ministry of Agriculture, Irrigation and Water Development has retained the services of Dam Safety Panel of experts to undertake periodic, comprehensive and independent reviews with the objective of evaluating features and actions pertaining to the safety of critical water infrastructure in Malawi and providing recommendations of actions that may be needed to upgrade the existing infrastructure and/or construct new dams and appurtenances to acceptable safety standards in compliance with relevant national and international water infrastructure safety guidelines.

The panel contains one Dam Expert and another Hydraulic Engineering Specialist. The experts visited Kapichira Dam three times in the past to assess the existing situations and give recommendations. Their last visit was made in January, 2017. Their major findings and recommendations of their consecutive visits are presented as follows:

7.1. Kapichira Dam

The Kapichira Dam comprises an 830 m long rock fill dam with a clay core, with a maximum height of 30 m at the foundation. A ski jump concrete spillway on the left bank with five openings controlled by sluice gates (each 15.24 m wide and 13.50 m high) has discharge capacity of 8,750 m³ per second. From the dam there is an 8.8 m square to circular tunnel (with the downstream 76 m long section steel lined) which leads to the power station via a surge shaft/tower. The dam was designed by TAMS of New York and Knight Piesold of UK and was completed in 1999.

Adjacent to the right abutment there is a fuse plug spillway integral with the dam. The spillway and fuse plug operating together can pass the Potential Maximum Flood (PMF). The crest at this point is about a meter or so lower than the crest of the main dam and is located across the old bed of the river.

The spillway has 5 radial gates, which are power operated. The standby generator is operated three times a week to ensure availability when it is needed. One of the gates (gate 3) is presently out of operation due to breaking of rope, which is being replaced.

The operation of the gates is decided by the Station staff based on reservoir levels. The staff has no access to hydro metrological data from upstream. Sensors are installed to open the gates automatically in case of high flood. It is desirable that there should be written instructions to the operating staff with regard to the operation of the spillway gates.

The Power house has 4 units of 32 MW each, which require 67 cumecs for generating 32 MW. The total discharge required by 4 units is 268 cumecs to produce 128 MW.

From various discussions with stakeholders, the experts have also noted that:

- No formal inspection of the dam and other works has been carried out since its completion,
- Piezometer readings are taken by staff of central office and are said to be stable although no readings have been taken recently. No feedback is given to the local office. No report on the analysis of piezometric data was available at site,
- No seepage was observed downstream. Seepage is not measured by the Project staff. The spillway gallery is also reported to have little seepage,
- There is no programme for monitoring settlement along the dam crest or at other structures,

It was reported that erosion occurred on the upstream face of the embankment in 2004 near its junction with the spillway. The damage was repaired. It was pointed out that the cofferdam for construction of the spillway was not removed and is submerged in the water. At the time of erosion part of the old coffer dam was also washed out.

7.2. Field Observations

From the field visits, the experts have observed that:

- Weeds and bushes are growing on the upstream and downstream slopes of the embankment,
- Observations from the deck of the spillway indicated that:
  - The sloping chute of Bay 1 shows normal wear and tear.
  - Cracks are observed on chute of Bay 2.
  - Cracks are observed on Chute of Bay No 3. Some concrete near the toe has been washed away.
  - In Bay No. 4 reinforcement is exposed in one block.

The bottom seals of most of the gates are not effective and leakage is taking place.

7.3. Conclusions and Recommendations

- The Kapichira Dam is a large dam as per ICOLD Guidelines. In accordance with International Commission of Large Dams (ICOLD) Bulletin No. 59 on Dam Safety Guidelines, dams require periodic safety inspections. A dam safety inspection plan incorporates (1) routine dam safety inspections to be undertaken by the Dam Operation Staff of the owner, (ii) Annual and 5-yearly (comprehensive) dam safety inspections to be undertaken by experienced Dam Safety Experts together with the Dam Operation Staff of the owner, (iii) special inspections to be undertaken following major floods, earthquakes etc., (iv) Dam Safety Reviews, (v) Potential Failure Modes Analysis (PFMA) and (vi) Risk Assessments. It is recommended that a programme for dam safety inspection be implemented for the Kapichira dam. The first independent inspection should be conducted within a year of the date of this report,
- The Owner should produce an annual inspection report on the dam and instrumentation monitoring
- The dam and other structures are being managed by the Power House staff. It is recommended that a qualified civil engineer be appointed by ESCOM for operation and maintenance of the dam and other structures.
- The requirements for freeboard should be reviewed and, if necessary, increased. The freeboard seems to have been significantly encroached,
- At present there is no Emergency Preparedness Plan (EPP) for the Kapichira dam. POE recommends that an EPP may be prepared.
- The damages on the concrete chute should be repaired as per recommendation of a qualified civil engineer. This should be done within a year of the date of this report.
- Weeds and bushes growing on the upstream and downstream slopes should be removed taking care that the fill material and riprap are not disturbed.

The Panel of Experts is not seriously worried about the short term safety of the dam. However if the dam is never inspected and defects are not corrected then safety could ultimately be compromised.

CHAPTER 8. FIELD SURVEY

8.1. Topographic Survey

8.1.1. Introduction

The topographic survey was carried out in order to facilitate the feasibility study and the preliminary design of Phase I of SVIP. SVIP has been divided into 6 zones, namely Zone I-1, Zone I-2, Zone A, Zone B, Zone C and Zone D, and these zones are serviced by 3 canals namely Main canal 1, Main canal 2, and Main canal 3.

In Phase I, the Main canal 1 route (33.7 km) starts from Kapichira Dam in Majete Game Reserve to a location in Supuni village, where it branches into two canals, Main canal 2 and Main canal 3. The Main canal 2 runs for 18.4 km to Mkombedzi Wa Fodya River in the Lengwe National Park in Chikwawa District, whereas the Main canal 3 runs for 10.6 km from the Supuni village to Tomali area where it joins the existing canals of the Illovo estate, also in Chikwawa District. The detailed scope of topographic survey is as shown in Table 8.1-1.

[Table 8.1-1] Scope of Topographic Survey Work

Item	Canal Survey	Structure Area Survey	Remark
Intake Area		A=10,000 m^2	
Main Canal 1	L=33.7 km	L=6.215km, A=728,600 m^2	
Main Canal 2	L=18.4 km	L=2.830km, A=316,000 m^2	Serving Phase I
Main Canal 3	L=10.6 km	L=2.960km, A=343,600 m^2	
Total	L=62.7 km		

8.1.2. Methodology

8.1.2.1. Survey Equipment

The following are the survey equipment that were employed on the exercise.

- Leica GPS Receivers, System 1200, GNSS plus : 1 set
- Kolida GPS Receivers, K9T : 2 sets
- Leica Total Station, System 1201AX : 2 sets

Figure 8.1-1 shows topographical surveys being done using some of the equipment listed above.

[Figure 8.1-1] Survey Equipment and Survey Team

8.1.2.2. Method

Site surveys included topographic, longitudinal, and cross sectional with survey points located at specific intervals depending upon the detail of information required. Structures and obstructions such as roads, embankments, electric poles, buried structures, water supply facilities, etc. were picked and are included in the topographic, longitudinal and cross section maps. Details of how the surveys were done are as shown in Table 8.1-2.

[Table 8.1-2] Details of the Survey Work

Survey Method	Canal Survey	Structure Survey
Topographic Survey	X	O
Longitudinal Survey (intervals of survey points)	50 m	20 m
Cross Section Survey (width / intervals)	80 m / 20 m	120 m / 5 m

8.1.2.3. Data Collection and Processing

Data collection was done using Leica GPS and Kolida GPS Receivers in real time kinematic (RKT) mode and Total Station. The establishment of survey controls, determination, pegging and surveying of the centre lines as well as surveying of topographic points and other features were also done using GPS Receivers in RTK mode. The Total Station was used in transferring orthometric heights of survey control points.

Data processing was done using the Leica Geo-Office and Engineering Star of the Kolida version. Production of topographic and layout maps was through the use of ArcGIS, whereas contours, profiles and sections were produced using a combination of the Terramodel, AutoCAD and Civil-3D - AutoCAD software.

8.1.2.4. Coordination System

The coordination system used in the surveying of this project was as follows.

- Projection : UTM Zone 36
- Local Ellipsoid : Clark 1880 (Modified), Arc 1950
- Local Transformation : Blantyre Coordinate System, 7 Parameter
- Reference Coordinates : Trig Pillar from National Triangulation

8.1.3. Survey Result

8.1.3.1. Establishment of Survey Control Stations

A total of 67 control points were established, properly distributed along the canal route. These control points were established from the existing trigonometric station as reference points. A total of 7 trig pillars were used for surveying and checking of the established controls. Details of the trigonometric station are as shown in Table 8.1-3. Trig pillar and control point are indicated in Figure 8.1-2.

[Table 8.1-3] List of Trigonometric Stations used as Reference Points

Point ID	Easting	Northing	Orth. Height	Remarks
318 NYS	713143.734	8171425.864	84.030	Surveys Dept. Trig Pillar
328 NYS	689720.799	8223958.325	147.570	Surveys Dept. Trig Pillar
331 MWS	676296.919	8201902.613	211.590	Surveys Dept. Trig Pillar
333 MWS	683491.275	8195219.126	186.880	Surveys Dept. Trig Pillar
335 MWS	681515.276	8237230.016	291.649	Surveys Dept. Trig Pillar
338 MWS	692472.042	8246384.115	608.569	Surveys Dept. Trig Pillar
358 MWT	692325.736	8229209.571	112.120	Surveys Dept. Trig Pillar

Some control points were placed on existing permanent structures such as steel poles and big rocks while others were beacons placed on the ground comprising a 12 mm diameter Iron Rod embedded on the middle of 30 cm by 20 cm by 30 cm concrete. Details of the control points established are shown in Table 8.1-4.

[Table 8.1-4] Details of Control Points

Point ID	Easting	Northing	Orth. Height	Remarks
SIVP4X	685855.651	8239420.642	146.881	Beacons
SVIP 1	687399.607	8242288.826	150.786	Beacons
SVIP 3C	687013.887	8241235.600	139.691	Beacons
SVIP 3D	687074.210	8241211.417	133.930	Beacons
SVIP 3X	686797.235	8241565.994	150.083	Beacons
SVIP10A1M	681372.983	8213269.236	117.224	Beacons
SVIP10A2M	681340.242	8213180.982	117.417	Beacons
SVIP10M	681282.201	8213211.348	117.778	Beacons
SVIP11M	681560.806	8206823.972	126.724	Beacons
SVIP12A1M	681968.485	8206369.488	125.551	Beacons
SVIP12A2M	681745.720	8206263.642	126.359	Beacons
SVIP12M	682004.914	8206234.995	125.840	Beacons
SVIP2BM	686808.492	8241609.062	149.407	Beacons
SVIP2M	687024.846	8242405.332	150.289	Beacons
SVIP3A1M	686882.475	8241563.466	143.802	Beacons
SVIP3A3M	686936.023	8241006.665	154.391	Beacons
SVIP3AM	687164.242	8235024.221	127.754	Beacons
SVIP3AXM	687164.246	8235024.224	127.745	Beacons
SVIP3E	687013.224	8240348.738	149.780	Beacons
SVIP3F	686974.157	8240316.107	151.188	Beacons
SVIP3G	686486.928	8240308.437	142.572	Beacons
SVIP3M	686801.784	8241559.504	150.362	Beacons
SVIP4A1M	686842.066	8234009.575	140.363	Beacons
SVIP4A2M	686729.391	8233747.755	142.974	Beacons

SVIP4M	686508.468	8233450.821	147.815	Beacons
SVIP4V	686112.796	8238649.579	147.424	Beacons
SVIP4Z	686098.254	8238631.973	146.582	Beacons
SVIP5M	685662.659	8232133.553	179.335	Beacons
SVIP6A1M	688025.964	8228712.420	138.898	Beacons
SVIP6A2	688206.635	8228691.180	134.691	Beacons
SVIP6M	687162.385	8228785.787	164.027	Beacons
SVIP7A1M	688419.737	8227625.631	143.010	Beacons
SVIP7A2M	688296.877	8227509.547	161.461	Beacons
SVIP7M	688410.763	8227669.001	144.075	Beacons
SVIP8A1M	685261.270	8222794.239	146.531	Beacons
SVIP8A2M	685562.770	8222770.208	139.702	Beacons
SVIP8M	685097.274	8222595.650	156.151	Beacons
SVIP9A	685243.979	8217841.779	142.658	Beacons
SVIP9M	685114.700	8217885.133	152.281	Beacons
SC1	686016.853	8237226.833	148.453	Beacons
SC10	681569.414	8206848.677	126.346	Beacons
SC1A	685995.666	8237267.794	150.224	Beacons
SC2	688422.549	8227041.883	141.322	Beacons
SC2A1	689416.059	8224518.097	129.859	Beacons
SC3	689408.155	8224509.289	129.191	Beacons
SC3A1	688860.478	8225052.243	142.683	Beacons
SC4	689081.813	8225079.798	133.326	Beacons
SC4A1	687643.493	8225720.614	151.814	Beacons
SC5	687604.241	8225724.752	141.572	Beacons
SC6	685103.403	8222603.494	155.739	Beacons
SC6A1	686169.622	8220675.968	139.597	Beacons
SC7	683577.412	8216842.769	137.353	Beacons
SC8	683289.465	8214347.783	129.235	Beacons
SC8A	682812.923	8214542.357	144.619	Beacons
SC9	679846.995	8210718.373	124.792	Beacons
SC9A	679823.215	8210690.877	124.448	Beacons
SC11	686336.089	8215961.536	112.030	Beacons
SC11X	686336.087	8215961.562	111.863	Beacons
SC12	686399.408	8215962.959	110.520	Beacons
SC13	687866.125	8211938.147	108.822	Beacons
SC13A	686406.972	8215945.524	110.743	Beacons
SC13B	687873.672	8211920.719	109.073	Beacons
SC13C	687878.122	8211900.085	108.873	Beacons
SC14	686655.026	8213427.806	107.740	Beacons
SC15	688631.402	8211565.777	97.470	Beacons
SC15A	688630.629	8211591.987	97.153	Beacons
SC16	691138.892	8210273.200	94.343	Beacons

[Figure 8.1-2] Trig Pillar 318 NYS (Left) and Control Point Example (Right)

8.1.3.2. Centre Line Pegging and Clearing

Centre line coordinates were established using the GPS, and wooden pegs were placed at every 50 m interval along the centre line of the canal route. The whole length of the canal centre line (62.7 km) was cleared of trees and bushes, and well pegged. Approximately 1,300 painted wooden pegs measuring 90 cm tall and 20 cm girth were fixed 30 cm deep, while at some locations arrows painted on a tree indicate the point of survey on the centre line of the canal. A 3m wide clearing also left a corridor that was easy to identify and move along.

[Figure 8.1-3] Example of Wooden Pegs and Arrow Painted on a Tree along the Canal Centre Line

8.1.3.3. Survey Points Within the Command Area

About 70,000 points were surveyed covering an approximate area of 5,356,200m^2 and their coordinates were then fed into various software for generating various products such as topographic maps, contour lines, profiles and various map features.

8.1.3.4. Topographic Map

The topographic survey data were fed into AutoCAD software to produce topographic maps and contour lines with a contour interval of 0.2 m. Topographic maps also depict all physical features along the canal route, such as houses, roads, rocks, big trees, and rivers and so on.

8.2. Geotechnical Investigation

Geotechnical investigation was implemented two times: January 2016 and March 2016. The first geotechnical investigation was limited to Phase I area and work scope was also limited to obtain the basic information for the Option Report.

8.2.1. First Geotechnical Investigation

8.2.1.1. Percussive Drilling and Auger Boring

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 Main canal 1 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 8.2-1 ~ Table 8.2-4 show the location of investigation sites.

[Table 8.2-1] Coordination of Percussive Drilling and Auger Boring (Main Canal 1)

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 8.2-2] Coordination of Percussive Drilling and Auger Boring (Main Canal 2)

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 8.2-3] Coordination of Percussive Drilling and Auger Boring (Main Canal 3)

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 8.2-4] 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.

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.

8.2.1.2. Determining Seepage Losses in the Main Canal 1

The geotechnical tests on the Main canal 1 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 Main canal 1 (Table 8.2-5), starting with Point 1 at the Intake of the Main Canal 1 and ending with Point 10 close to Road D134, an alternative method involving digging pits was adopted.

[Table 8.2-5] List of the Main Structures

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

The 10 points along the Main canal 1 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;

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

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

(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; and thereafter

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

Geotechnical Assessment

Presented in Table 8.2-6 are brief descriptions of soil profiles exhibited by the pits excavated at the 10 selected points along the Main canal 1.

[Table 8.2-6] 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 Main canal 1 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 Main canal 1 is highly recommended to minimize the seepage loss. In this regard a buried concrete siphon could be considered as another option. During the preliminary design the pros and cons of the two alternatives shall be carefully assessed, and the better one selected.

Presented in Table 8.2-7 and Table 8.2-8, respectively, are the results of the percolation and soil permeability tests conducted at Points 1 to 10 on the Main canal 1.

[Table 8.2-7] 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 8.2-8] 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

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 8.2-9), with coefficient of permeability in the range of 10^{-2} to 10^{-4}.

[Table 8.2-9] 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

Conclusion

Study findings show that the area that will be traversed by the Main canal 1 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.

8.2.2. Second Geotechnical Investigation

Second geotechnical surveys were carried out for the proposed SVIP. The purpose of the geotechnical surveys was to determine the surface and subsurface conditions at specific points within the project area including the physical, chemical and mechanical properties of subsurface materials in order to;

- Evaluate the geotechnical engineering conditions of the project area in order to assist in the design and construction of the most suitable and economical structures.
- Evaluate the corrosiveness of the site materials to assist in the selection of most suitable construction materials and protection measures.
- To evaluate the permeability of the ground to come up with economical treatment.
- Determine the soil parameters for safe and economical design of the structures.

8.2.2.1. Scope of Geotechnical Survey

Geotechnical surveys involved field activities and laboratory work. Field activities were carried out in accordance with BS 5903 of 1990, and the laboratory activities were carried out in accordance with BS 1377 of 1991. Details of field and laboratory activities are given in Table 8.2-10.

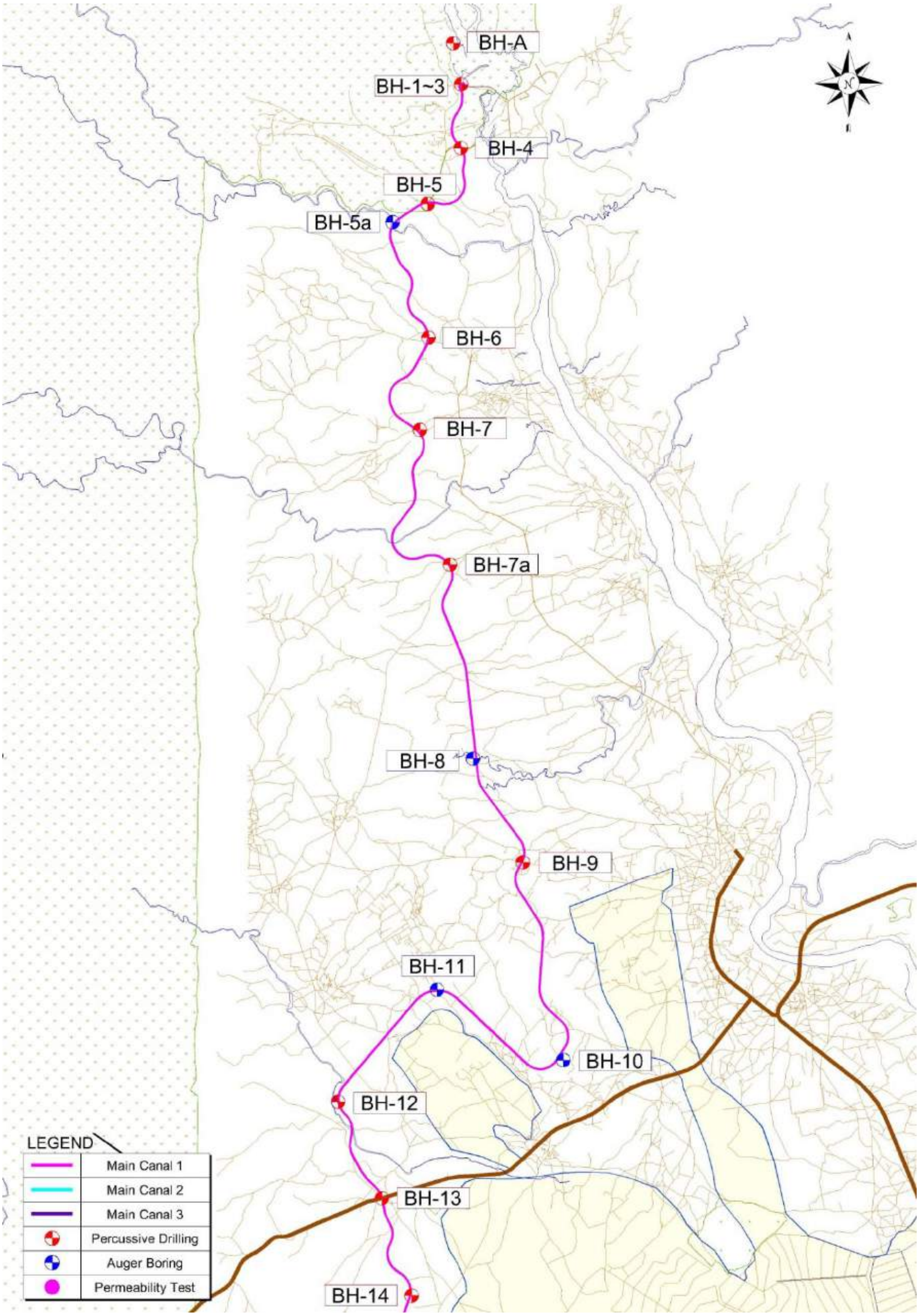
[Table 8.2-10] Details of Field and Laboratory Activities

Item	Tasks
Field Activities	Location of borehole positions
	Drilling of 19 boreholes
	Collection of disturbed & undisturbed samples
	Carrying out standard penetration tests at an interval of 1.5 m
	Excavation of Permeability pits to maximum of 1.0 m
	Collection of samples for permeability test
	Logging of each borehole and each permeability pit
	Carrying out of 3 sand replacement tests
	Carry out 9 Auguring holes
	Carrying out G/pits surveys
	Carrying out quarry surveys
	Carrying out of unit weight tests
Laboratory Activities	Determination of sieve analysis
	Determination of atterberg limits
	Permeability test
	Specific gravity
	Natural moisture content
	Determination of Maximum dry density
	Determination of Aggregate Crushing Value

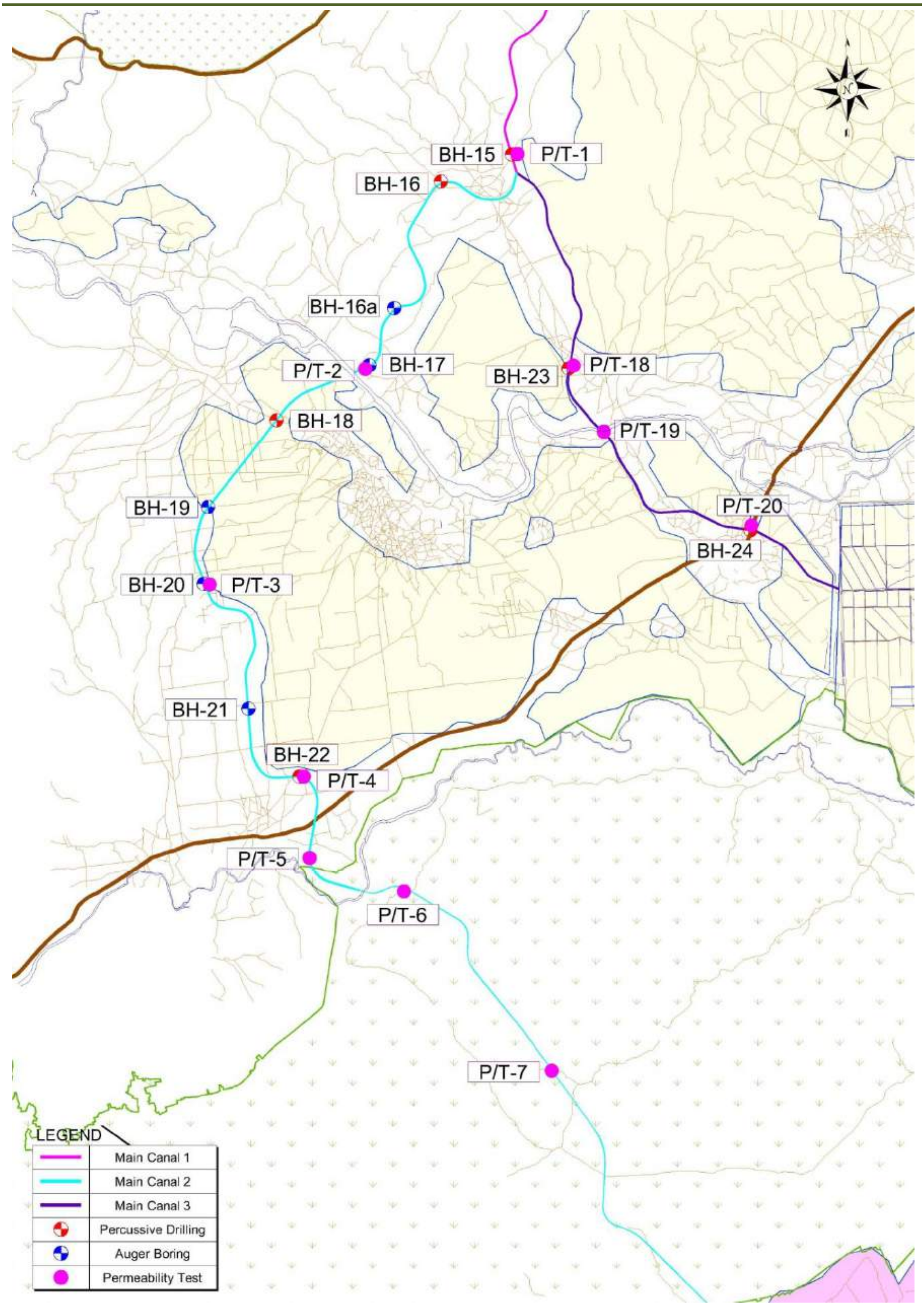
8.2.2.2. Survey Result

The geological map of Malawi reveals that the proposed Shire Valley Irrigation Project is partly within the Shire Highlands and mostly within the Lower Shire Valley Plains. From the intake site, soil characteristics reveal the existence of charnockitic suite: banded pyroxene granulites and gneisses, and hyperthene-granite of precabrian palaezoic late origin. Alluvium of quarternary origin occurs from the foot of the escarpment to Kamuzu Bridge to Majete and Bangula.

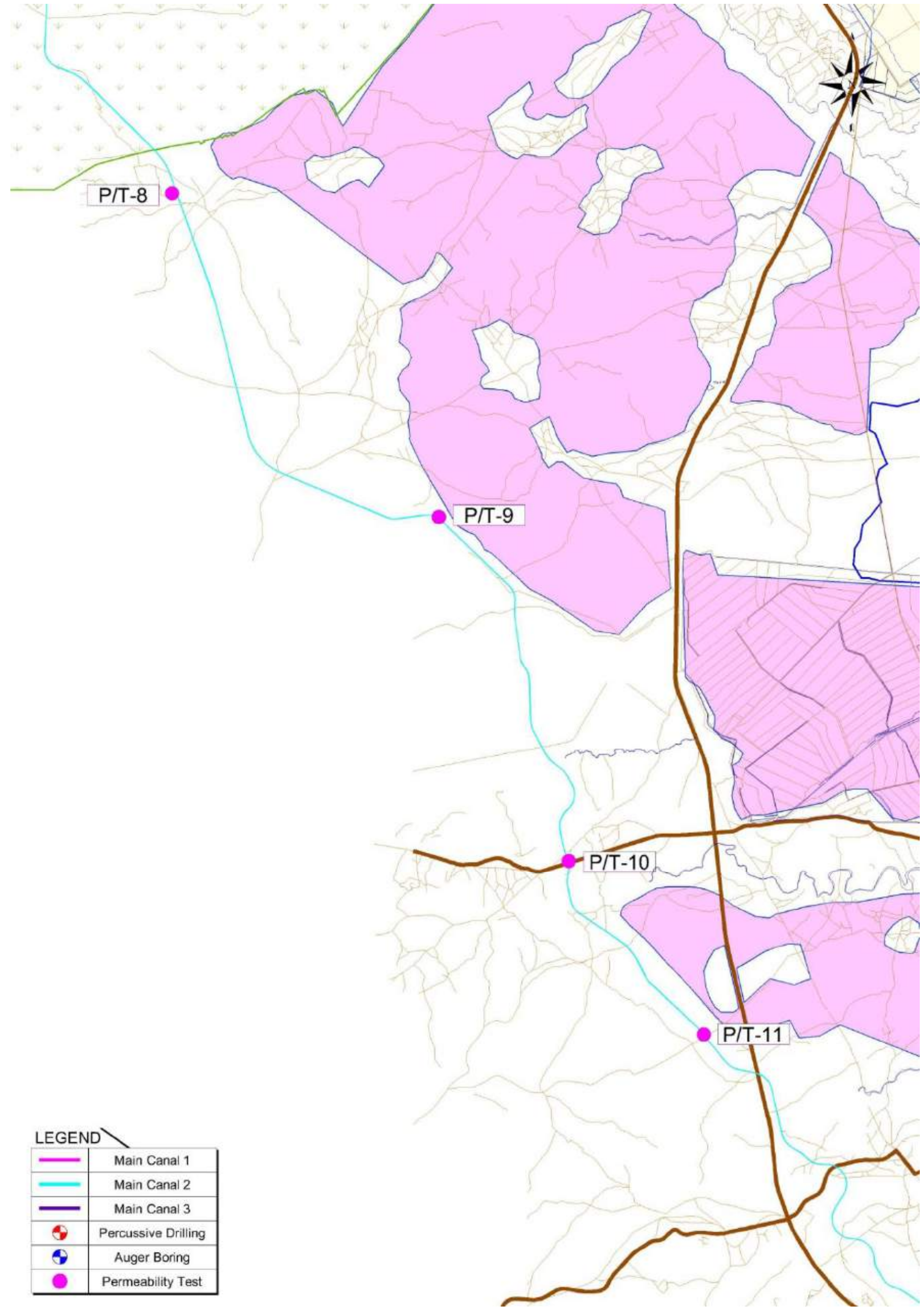
The composition of field activities during the operation of the survey included the following: 19 boreholes were drilled, 20 permeability pits were excavated, 9 Auguring holes were sunk, 89 disturbed samples were collected for sieve analysis and atterberg limit tests, 40 Natural moisture content tests were performed in the laboratory, 20 permeability tests were conducted in the laboratory, and 3 sand replacement test were done. These activities were done along the proposed canal lines and within the command area. The various locations are depicted in Figure 8.2-1~8.2-4.



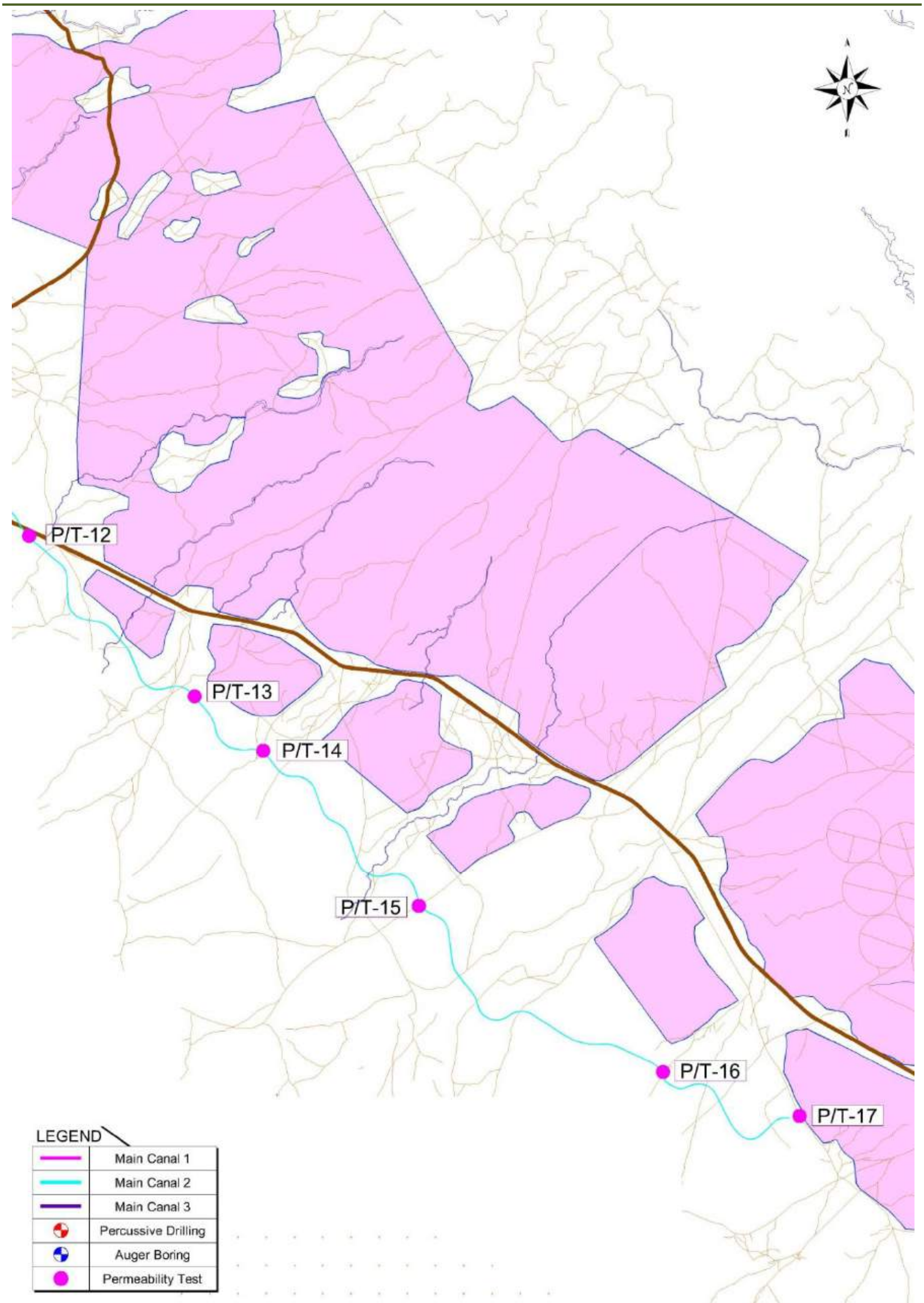
[Figure 8.2-1] Location Map of Geotechnical Investigation -1



[Figure 8.2-2] Location Map of Geotechnical Investigation -2



[Figure 8.2-3] Location Map of Geotechnical Investigation -3



[Figure 8.2-4] Location Map of Geotechnical Investigation -4

The drilling depths of the boreholes were decided based on the bed elevations of canal, and the drilling were executed up to the 1 m below those elevations.

Boreholes: the following boreholes were drilled at various strategic points along the canal lines and within the command area:

- BH A Comprises of 2 layers and it was drilled to maximum of 2.65m.
- BH 1 Comprises of 6 layers and it was drilled to maximum of 6.47m.
- BH 2 Comprises of 6 layers and it was drilled to maximum of 6.5m.
- BH 3 Comprises of 3 layers and it was drilled to maximum of 9.70m.
- BH 4 & 5 were drilled to maximum of 2.235m on average.
- BH 7a Comprises of 3 layers and it was drilled to maximum of 1.30m.
- BH 6, 7 & 9 were drilled to maximum of 3.45m on average.
- BH 12, 13 & 14 were drilled to maximum of 4.15m on average.
- BH 15 & 16 were drilled to maximum of 3.45m each.
- BH 18 Comprises of 6 layers and it was drilled to maximum of 6.45m.
- BH 22 was drilled to maximum of 3.0m.
- BH 23 & 24 were drilled to maximum of 3.175m on average

[Figure 8.2-5] Drilling of Borehole (left) and Laboratory Test (right)

Rock layers were found at BH-ABH-4, BH-9, BH-13, 14, 15, situated 2 ~ 3m below the ground surface. The earth layer in each borehole is 2 m thick from the ground surface and comprises sand, silt, and clay. Granular material was found along the Main canal 1 section, and is equivalent to A-1 (A-1-a, A-1-b), A-2 (A-2-4~7) following the AASHTO Soil Classification System. Samples collected from this proposed site have been analyzed and fall into 5 (five) main soil subgroups of A-1, A-2, A-4, A-6 & A-7. The three soil subgroup of A-1, A-2 and A-7 are good quality of soil characteristics for civil works.

The first subgroups of A-4 & A-6 are poor soils which are plastic and having high volume changes, with fluctuating moisture content. Therefore, their expansive and contracting characteristics should be taken into account when designing structures. A-4 (Silt), A-6 (Sand) soil groups exist along the Main canal 1 and Main canal 2 sections, located within 3 m depth from the ground surface. These soils are recommended to be replaced or treated during canal construction for the persistence of structures. In terms of the construction conditions this will not be a substantial constraint.

The second subgroups of A-2-4, A-2-6 & A-2-7 are fairly to good soils which are not highly plastic, A-2-4 & A-2-5 have maximum plasticity index of 10%, and A-2-6 & A-2-7 soil subgroups have a minimum plasticity index of 11%.

The third subgroups of A-1-a & A-1-b are good to excellent soils which have very low plasticity index (PI) of not more than 6% or are Non Plastic (NP).

Borrow Pits: the following borrow pits were dug and quarry sites investigated for determining appropriate sites as sources of construction materials:

8 borrow pits and 4 quarry sites were investigated to be a source of construction materials for the proposed Shire Valley Irrigation Project. Borrow pits investigated are Tomali, Nyaika, Sibale old pit, Nyamithuthu old pit, Chikhama, Moroko, Chikalumpha and Namiche. Quarry sites investigated are Kajawo, Thabwa existing quarry, Nzongwe and Ngabu. Characteristics of all the sites investigated are as follows:

- Tomali gravel pit: 2 main soil subgroups of A-2-4 and A-2-6 were identified, with CBR values of 16 % at 95 and 18% at 98
- Nyaika gravel pit: 2 main soil subgroups of A-2-6 and A-2-7 were identified, with CBR values of 30 % at 95 and 74% at 98
- Sibale gravel pit: 1 main subgroup of A-1-a was identified, with CBR values of 54% at 95 and 65% at 98
- Nyamithuthu old pit: 2 main subgroups of A-1-a and A-2-4 were identified, with CBR values of 54 % at 95 and 74% at 98
- Chikhamba, Namacha and Chikalimba borrow pits: 3 main subgroups of A-1-a, A-2-4 & A-2-6 were identified, with CBR values of 22 % at 95 and 48% at 98, 34 %at 95 and 42% at 98 & 16 % at 95 and 27% at 98 respectively
- Moroko gravel pit: 3 main soil subgroups of A-6, A-2-6 & A-2-7were identified, with CBR values of 24 % at 95 and 25% at 98
- Kajawo quarry site produces aggregate with a crushing value of 35.3%
- Thabwa quarry site produces aggregate with a crushing value of 30.1%
- Nzongwe quarry site produces aggregate with a crushing value of 43.0%
- Ngabu quarry site produces aggregate with a crushing value of 22.0%

Ngabu quarry site qualifies to be the source of construction material for the roads because the crushing value falls within the not more than 25% specification. Kajawo and Thabwa quarry sites can be used as sources of quarry for concrete works because the crushing values fall within the not more than 35% specification for concrete works. Nzongwe quarry site is unsuitable as a source of construction materials because the crushing values fall outside the specification for both roads and concrete works.

Kajawo and Thabwa quarry sites shall be the main source of quarry material. These sites are near to each other and located at the bottom of the escarpment at the entrance into the Lower Shire Valley Plain from Blantyre. The distance between these sites and Majete Game Reserve, which is the farthest points of the main canals, is about 20 km.

Environmental conditions play an important role in the design assumptions. Presented are some of the metrological data for the area.

- Mean temperature : 25 °c
- Mean rainfall : 800 mm
- Mean pressure : 889 hpa
- Mean wind speed : 4.9 m/s

8.3. Hydrogeology

8.3.1. Location and Climate

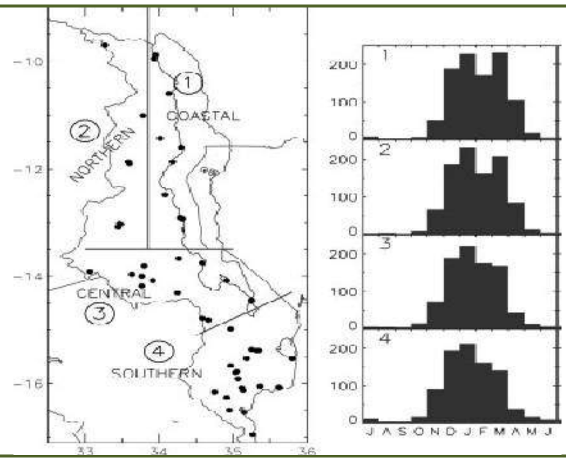
The Lower Shire Valley is located at the extreme southern part of Malawi (Chavula, 1989). More than 70% of the area lies in Chikwawa District and the rest falls within Nsanje District. The Lower Shire Valley is bounded on the east by the Thyolo Escarpment which marks the edge of the lift faulting at 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).

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 are three large-scale (synoptic) systems that bring rainfall to the Lower Shire Valley (Kululanga and Chavula, 1993).

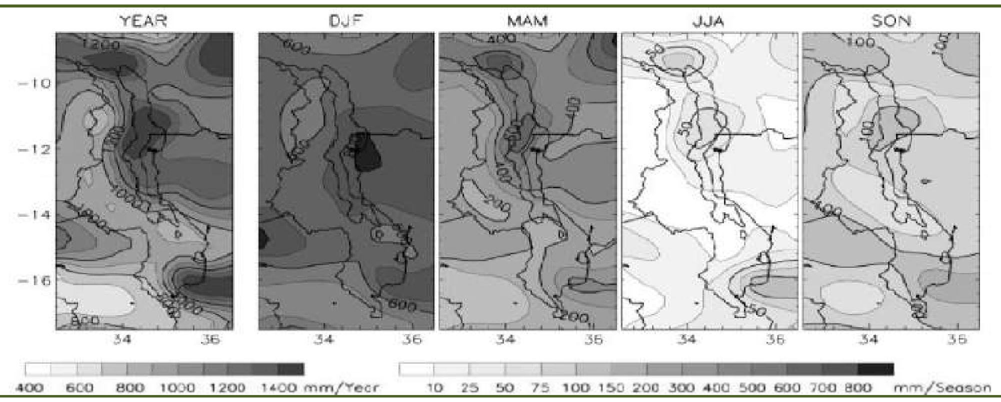
Figure 8.3-1 shows four homogeneous rainfall regions in Malawi, with the stations within them and the typical seasonal cycle of rainfall (mm per month) in each region; whereas Table 8.3-1 shows rainfall onset, end, and duration (Nicholson et al, 2013). Chikwawa and Ngabu Meteorological Stations, main weather stations in the Lower Shire Valley, are indicated in Table 1 as Stations 20 and 21 respectively. Figure 8.3-2 shows mean annual and seasonal rainfall in mm (based on the period 1962 - 2009).

[Table 8.3-1] 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 8.3-1] 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 8.3-2] 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).

8.3.2. 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.

8.3.3. Geology

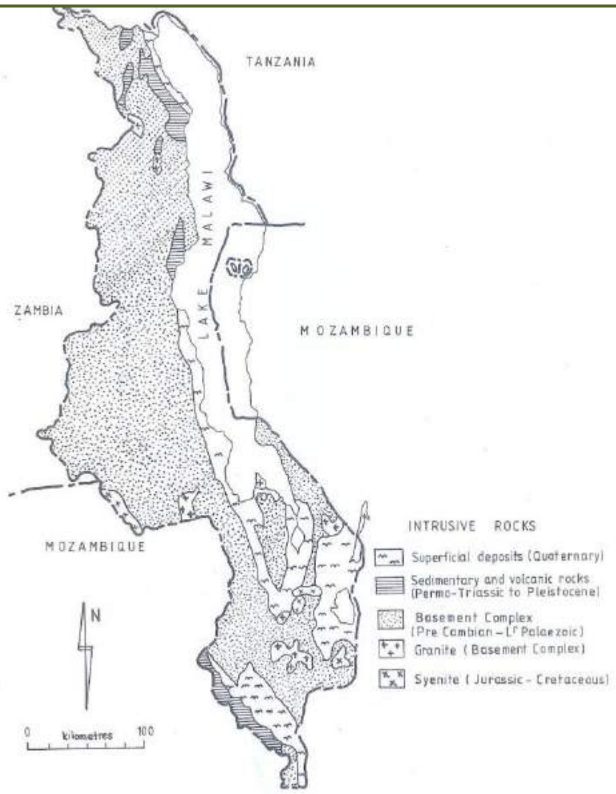
Most of the area is underlain by gneisses and granulites of the basement complex or by sedimentary and volcanic rocks of Karroo age (Figures 8.3-3 ~ Figure 8.3-6). Over large areas on the floor of the Lower Shire Valley these rocks are observed by colluvium and river alluvium (Chavula, 1989; Monjerezi, 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).

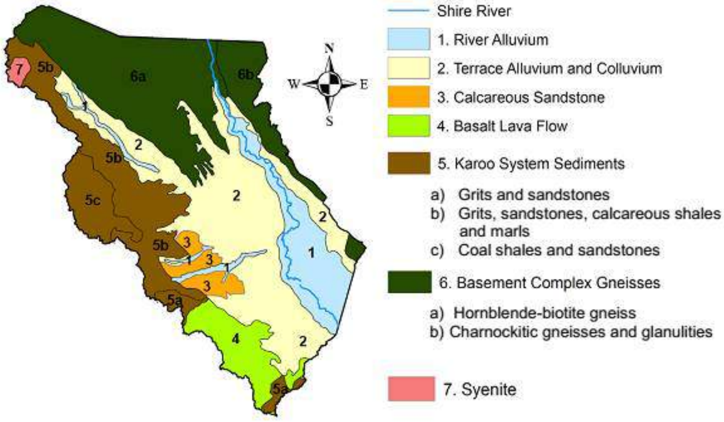
The deposition of these sediments was followed by a period of vulcanicity of late Karroo age. Basalt lava flows outcrop south and west of Ngabu and minor intrusions of dolerite are found throughout the Karroo sediments and the basement complex.

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.

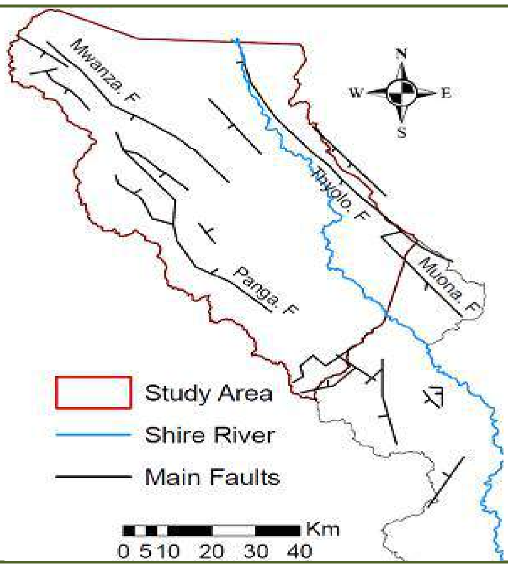
Faulting has been very severe in the Lower Shire Valley mostly associated with the development of the Great East African Rift Valley System. The eastern margin of the rift is represented principally by the Thyolo Fault (Figure 8.3-5). West of the Shire River the Karroo rocks down faulted against the basement complex along the Mwanza Fault.



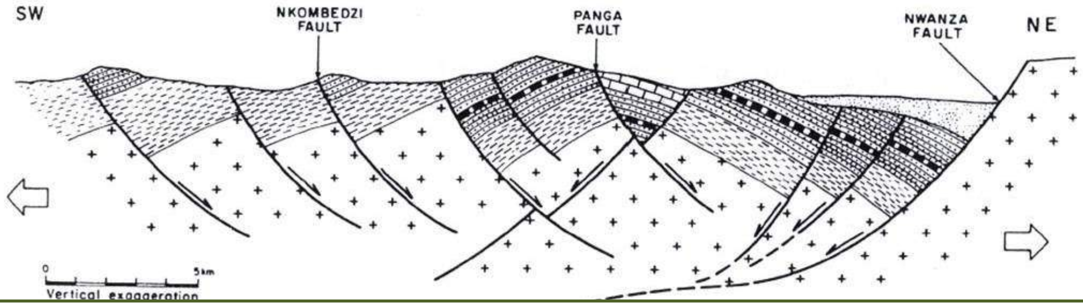
[Figure 8.3-3] General Geology of Malawi (Source: Water Dept/UNDP, 1986)



[Figure 8.3-4] Detailed Geology of the Lower Shire Valley (Source: Monjerezi, 2012)



[Figure 8.3-5] Main Faults in the Lower Shire Valley



[Figure 8.3-6] Schematic Cross-section of the Lower Shire Valley showing the Effects of the Faults within the Basin (Source: Castaing, 1991)

8.3.4. 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.

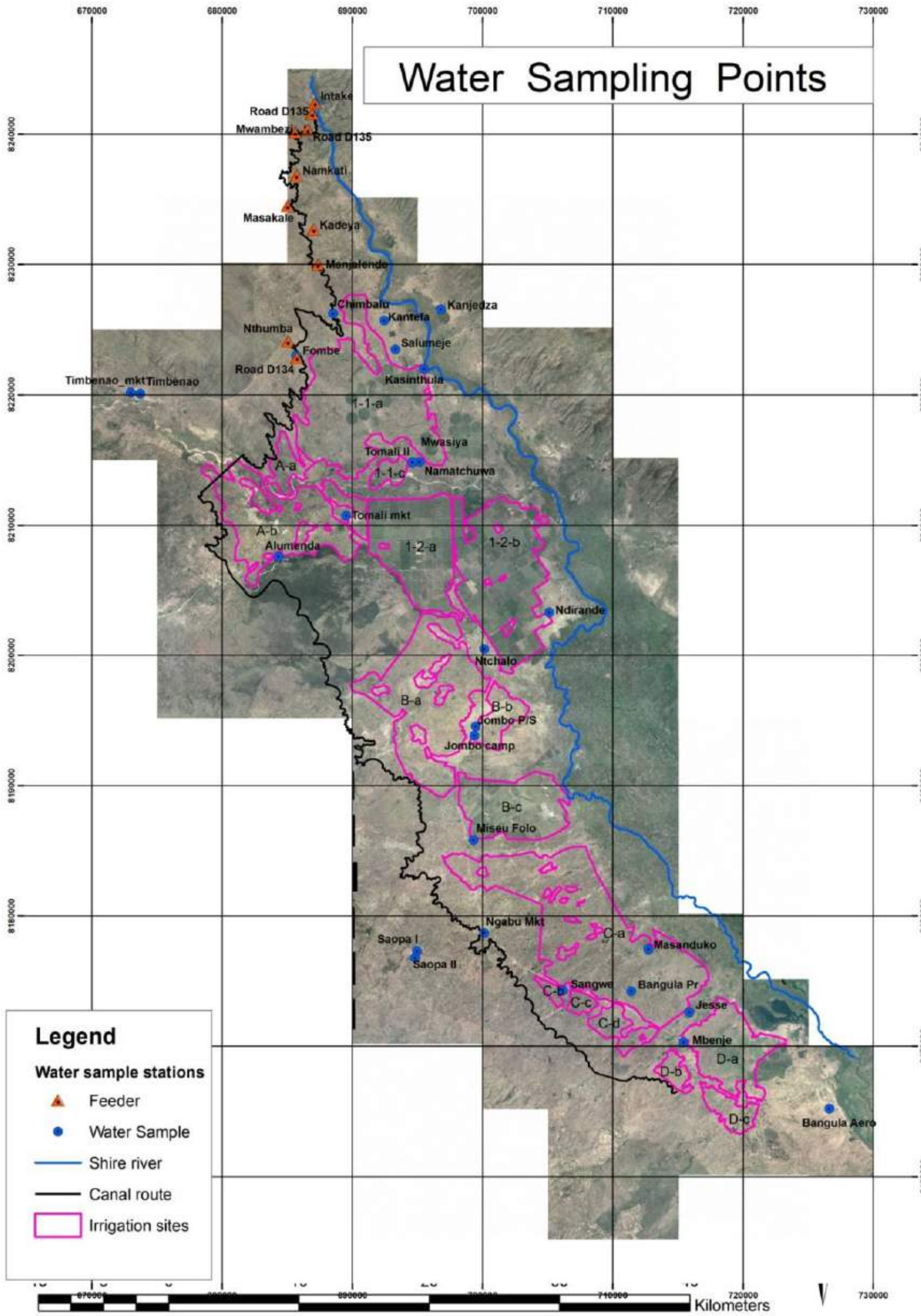
Apart from the Mwanza River, the following are some of the rivers that arise from the west of the Lower Shire Valley: Mkombedzi wa Fodya, Phwadzi, Namikalango, Mafume, Dandi, and Thangadzi. Their channels are well defined in the middle reaches but generally disappear as the Shire is approached. These 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.

8.3.5. 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 (Tables 8.3-2, Figure 8.3-7) 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 8.3-2] Location of Water Quality Sampling Points

Sample No.	Name	Type	Easting	Northing	Above Limit of Sodium
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	√



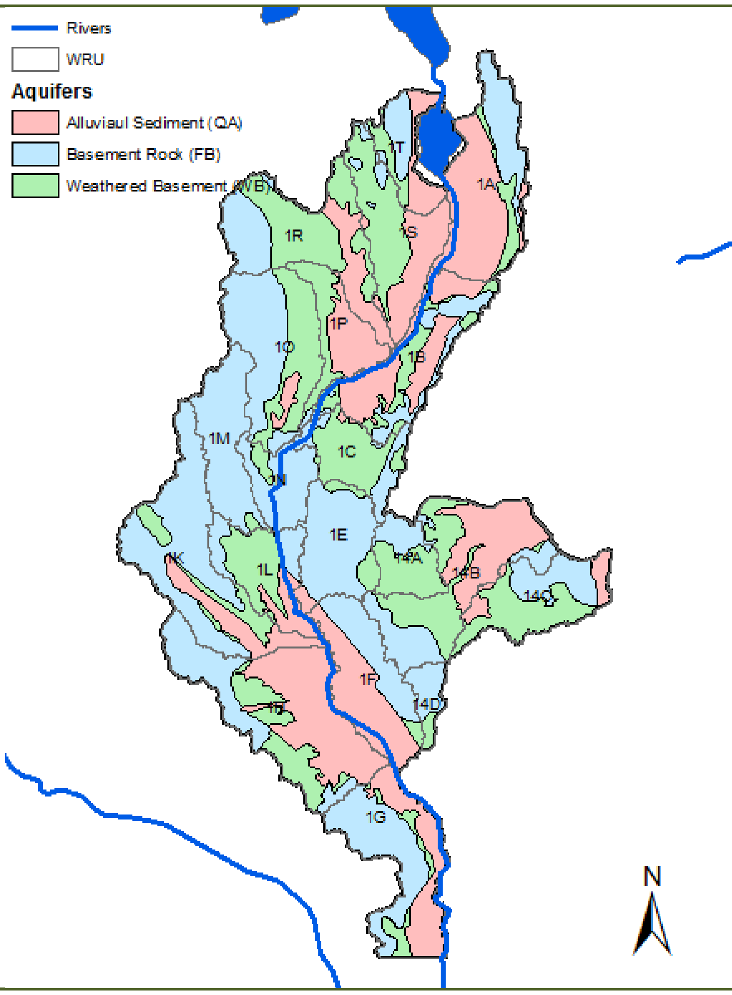
[Figure 8.3-7] Water Sampling Blocks

8.3.6. Evaluation of Water Balance

Evaluation of the water balance of the Lower Shire Valley was mostly done through literature review, involving studies done the Water Department/UNDP in 1986, Chavula in 1989, Monjerezi in2012, and DHI in 2015.

8.3.7. 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 8.3-8). The alluvial aquifers are fluvial in nature, but highly variable in character in both vertical sequence and lateral extent. Most litho logical records obtained from boreholes provide very little information about the successions.



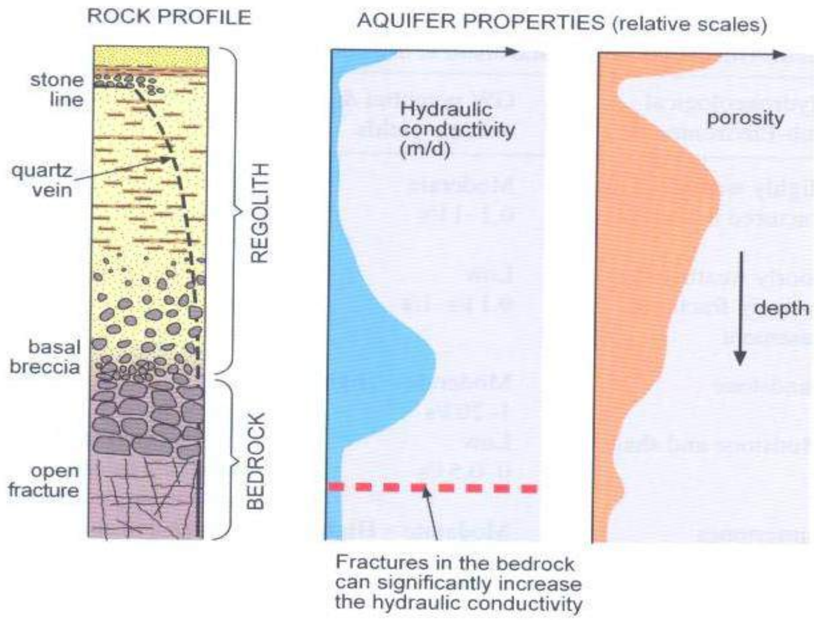
[Figure 8.3-8] Various Aquifer Types in the Shire River Basin (Source: Monjerezi, 2012)

Generally, alluvial 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 meters per day. Storage coefficient values normally lie in the range of $1*10^{-2}$ to $5*10^{-2}$ (Water Department/UNDP, 1986).

The Pre-Cambrian Basement Complex aquifers are not as dominant and extensive in the Lower Shire Valley (Figure 8.3-8) 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 8.3-9) 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 8.3-9] Profile of Precambrian Basement Complex Aquifer (Chilton and Foster, 1995)

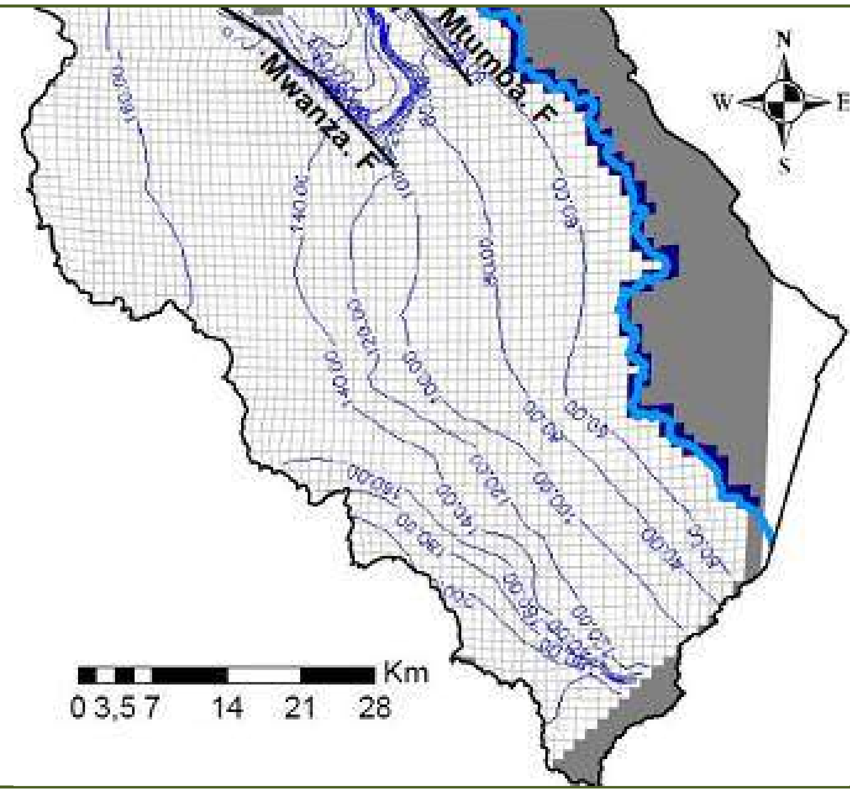
It is clear from the preceding discussion that the alluvial aquifers of the Lower Shire Valley are very rich in groundwater resources, adequate for drinking as well as irrigated agriculture.

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

8.3.8. 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 8.3-10 shows that groundwater flow is generally towards the Shire River (Chavula, 1989; Monjerezi, 2012), making the Shire an influent river.



[Figure 8.3-10] Piezometric Surface of the Lower Shire Valley

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.

8.3.9. 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.

8.3.10. 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.

8.4. Soil Survey

8.4.1. 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.

8.4.2. Methodology

Field investigation

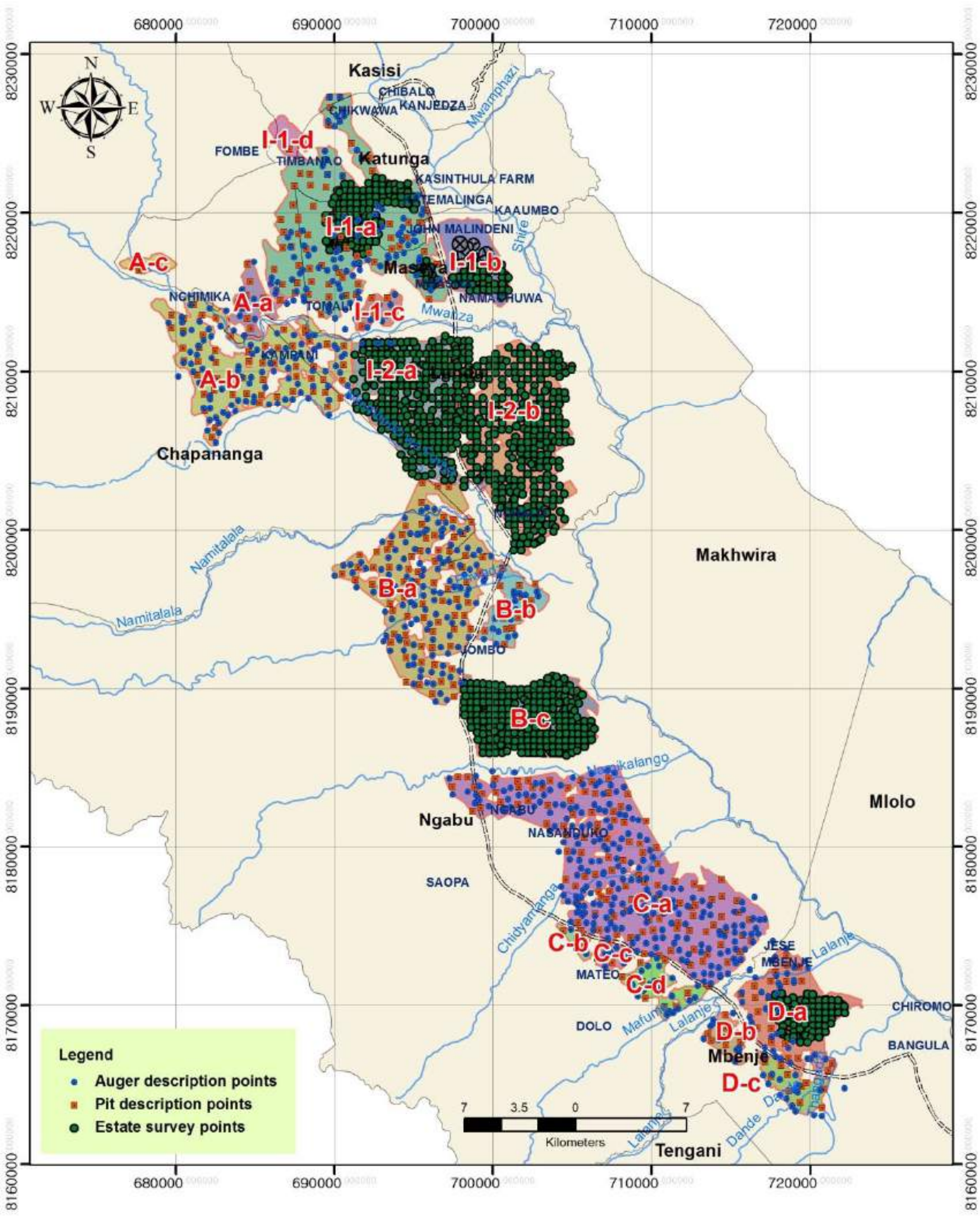
An ArcGIS aerial photo map of scale 1:10,000 taken in 2013 was used to select survey reference points. These reference points were selected using a ratio of one point to one hundred hectares cell and on a grid of 1km x 1km within the zones to be surveyed, except Illovo Nchalo Estate. The spacing of the points was in consideration of accessibility and spatial evenness. Soil sampling was done at 1-3 points in a cell. In total, soil survey points amounted to 1,050. For the commercial farm areas, soil survey had recently been done over 1,226 points, and it was decided that the detail was adequate to warrant no additional surveys.

The survey area was divided into six zones, which were further subdivided into 19 sub-zones stretching on both sides of the M1 road from the uppermost zone of I-1-a to the lowermost sub-zone of D-c. The total area covered is around 55,500 ha, including the commercial farms of Kasinthula, Phata, and Nchalo Estate.

Parameters to be investigated during the survey, description and sampling methods were determined with reference to the Korean Field Book (KRC, 2013), the American Field Book (USDR, 2012) and the FAO Guidelines (FAO, 2006). On-site observations were recorded on profile description sheets at every survey point and summarized in soil information sheets.

Soil profile descriptions were done either as soil pit profiles or through soil augering as per the FAO Guidelines. As of 6th January 2016, routine profile description had been executed at 391 pit sites and at 659 soil augering sites.

Percolation is a phenomenon in which water seeps through the soil by gravity and keeps moving until it reaches the groundwater table. It is similar to permeation, it is an important soil characteristic when determining the soil water holding capacity for calculating the water requirement of crops, especially for paddy rice. Soil percolation rates were determined in the field using the Cylinder Method at 19 sites. Two open cylindrical PVC pipes 30-50 cm long and 100mm in diameter were hammered into the saturated soil to a depth of between 20-40 cm where a hard soil layer was encountered, in soils where the groundwater table was at ≥ 50 cm. Additional water was poured into the cylinder on which was mounted a hook gauge. After a period of time, usually 24 hours (one day), the water level change in the cylinder was measured and converted to mm/day.



[Figure 8.4-1] Location Map of Soil Survey Points

For other crops, except rice paddy, total readily available moisture (TRAM) was also calculated from the following formula below. TRAM is the maximum readily available water (RAW) that a soil can store within an effective depth from the ground surface, which is theoretically the daily maximum irrigable water.

$$\mathrm{TRAM} = (FC_{24} - ML)H\frac{1}{Cp}$$

FC_{24}: soil moisture at field capacity 24 hours after waterlogging (%), ML: soil moisture at wilting point, *H*: the depth (mm) of limiting layer, *Cp*: soil moisture extract pattern (SMEP) of limiting layer. The limiting layer is a layer which has the minimum TRAM value. Field capacity (FC) was determined at 17 sites from core samples taken from wet soil a day after waterlogging.

At 17 sites, undisturbed core samples were taken at the depths of 0-10 (H1), 10-20 (H2), 20-30 (H3), and 30-40 cm (H4) from soils saturated with ground water. Then they were weighed before and after oven-drying to calculate bulk density.

Readily available water (RAW) is the soil moisture held between field capacity and a nominated refill point for unrestricted plant growth. In this range of soil moisture, plants are neither waterlogged nor water-stressed. RAW for horticultural crops is usually the amount of water between field capacity and -20 to -60kPa. RAW for various soil types has been standardises from detailed field and laboratory studies on lots of samples (Agriculture NSW Water Unit, 2014).

Each crop has a particular root zone. Root zone RAW was determined at the same sites where TRAM was determined, regardless of SMEP. To calculate root zone RAW, the RAW of each soil horizon (in centimetres) in the root zone was multiplied by the thickness of that horizon. The values for each soil horizon were then summed up to get the total root zone RAW.

Soil analysis

One 1003 soil samples were taken from topsoil and subsoil horizons. After carbonate reaction test in the laboratory of KARS, all samples from soil pits were entrusted to the Bvumbwe Agricultural Research Station (BARS), located 13 km south east of Blantyre, to determine soil texture, soil reaction (pH), organic carbon (OC), available phosphorus (P_2O_5), electrical conductivity (EC), cation exchange capacity (CEC), base saturation (BS), sodium absorption ratio (SAR), exchangeable sodium percentage (ESP), and bulk density (BD). The analysis was based on the FAO analytical procedures for determination of chemical-physical characteristics and the final soil classification (FAO, 2014).

Soil texture was determined as percentage of sand, silt, and clay by the hydrometer method. Soil reaction was measured with a pH-meter in a soil suspension of one-part soil and five-part distilled water by dilution method.

Organic carbon was obtained by Walkley and Black method; wet combustion of the organic matter with a potassium chromate/sulphuric acid mixture and titration of residual dichromate with ferrous sulphate.

Total nitrogen was analyzed by Kjeldahl method. A soil sample is digested with concentrated sulphuric acid. The digest is distilled and the distillate is titrated against a weak hydrochloric acid.

Available phosphorus was quantified by Bray (I) method. An extracting solution is used, consisting of a mixture of hydrochloric acid and ammonium fluoride. After filtering the soil suspension, an aliquot is taken. Then, phosphorus in the soil extracts is determined using a spectrophotometer and a stannous chloride indicator.

Exchangeable cations were extracted with a natural ammonium acetate solution. After filtering the suspension, aliquots are taken which are passed onto a flame photometer for determination of sodium and potassium. Another aliquot is taken and passed onto an atomic absorption spectrophotometer for magnesium and calcium determination.

Cation exchange capacity was determined using spectrophotometer by measuring Sodium in the percolate. After percolation with ammonium acetate at pH 7, the sample is percolated with sodium acetate at pH 7, washed free of excess salt and percolated with ammonium acetate.

Electrical conductivity was measured with an electrical-meter that was used in determining the soil's total soluble salt content. The conductivity of the saturation extract is widely used as a convenient means of assessing soil salinity.

Exchangeable sodium percentage was used as a measure of the "alkali hazard" of a saline soil. ESP is represented by the ratio of Na+ ions to the cation adsorbed on the soil. ESP = (Na^+/CEC) * 100, Units of the CEC and Na^+ is cmol/ kg.

Sodium absorption ratio is determined from analysis of water extracted from the soil. The formula for calculating sodium adsorption ratio is:

$$\text{S.A.R.} = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

where sodium, calcium, and magnesium are in milliequivalents/litre.

Base saturation is closely related to cation-exchange capacity, which is the fraction of exchangeable cations that are base cations (Ca, Mg, K and Na). It can be expressed as a percentage, and called percent base saturation. Bulk density was the mass per unit volume expressed as g/cm^3. Once the bulk density is known, measurements of soil mass, volume or percentages can be expressed interchangeably or in absolute terms.

Soil classification

World reference base for soil resources (WRB) 2014 is a revised version of the previous WRB (FAO, 2006) and a classification system for naming soils and creating soil map legends (FAO, 2014). It was the main reference consulted to identify soil types at survey points.

Field classification was carried out by professionals based on profile/landscape photos, the soil description sheets and soil information sheets. At arbitrarily set soil pit description sites, comparative survey was also done by Korean soil survey team to compare and confirm the identity of survey of four teams.

One by one assignment of a WRB to a soil type at each point, was done in collaboration with KARS and BARS, based on diagnostic horizons, properties, and materials, and confirmed from field investigation and soil analyses as well.

KARS produced its soil survey report and submitted it to the Consultant in accordance with the required format of summary, methodology, results, and annexes containing soil profile description sheets, soil information sheet, and related photos.

8.4.3. Updated Soil Classification

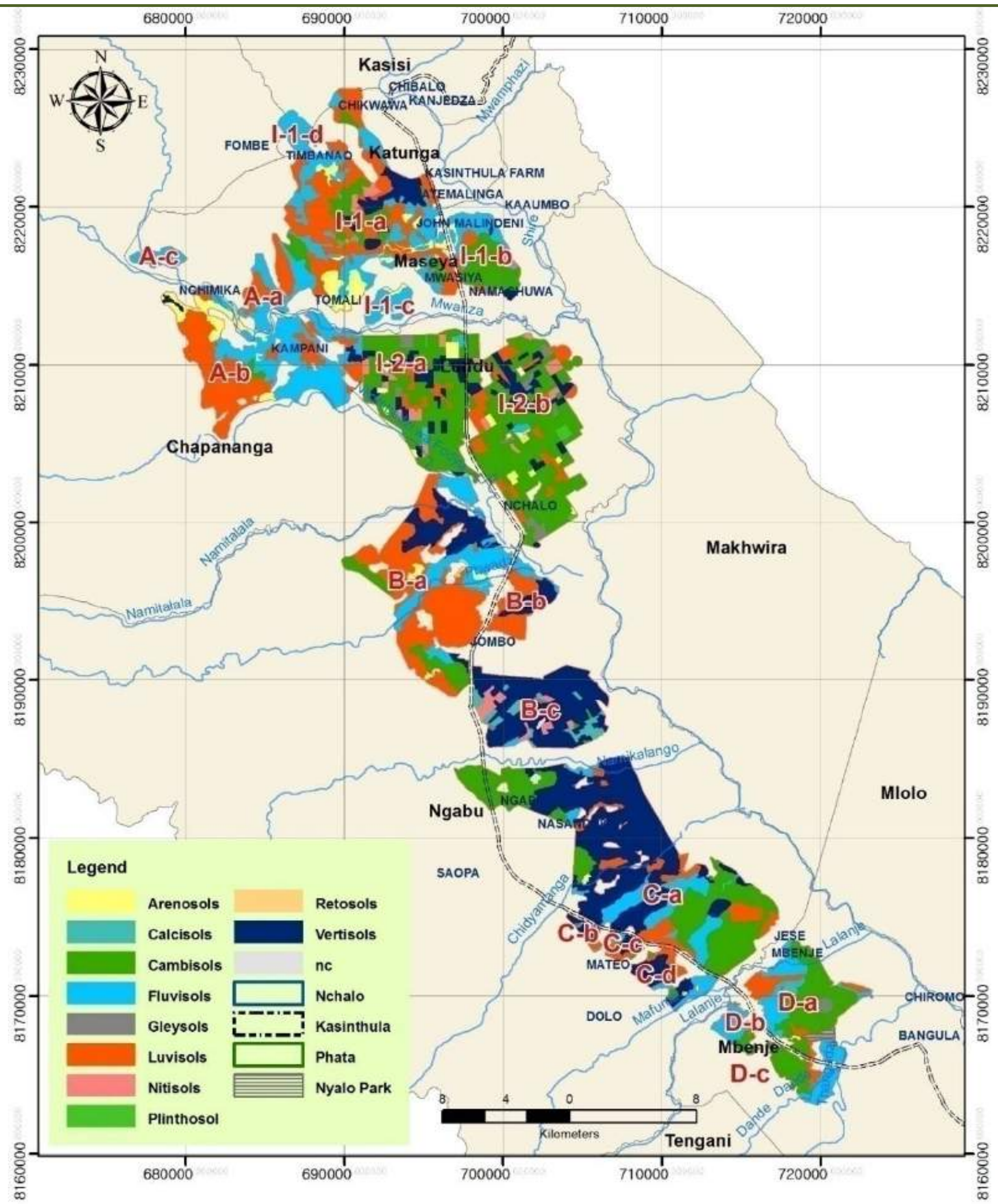
From the current on-site observation and soil analysis in the survey area, there are 11 applicable RSGs and 17 qualifiers that classify the soils considering soil texture, rock fragments, drainage, flooding and ponding, carbonate content, erosion, crack development, etc.

[Table 8.4-1] Applicable RSGs and Qualifiers

RSG	Principal Qualifiers	Supplemented Qualifiers	Remarks
Arenosols	Rubic Fluvic Salic Dystric		
Calcisols	-	-	Estates
Cambisols	Gleyic Stagnic Fluvic Vertic Skeletic Salic Sodic Calcaric Dysric/Eutric	Arenic/Clayic/Loamic	
Ferralsols	-	-	Estates
Fluvisols	Gleyic Stagnic Skeletic Sodic Calcaric Dystric/Eutric	Arenic/Clayic/Loamic Salic	
Gleysols			Estates
Luvisols	Abruptic Gleyic Stagnic Vertic Calcic Skeletic Endocalcaric	Clayic/Loamic Salic Sodic	
Nitisols	-	-	Estates
Plinthosols	-	-	Estates
Retisols	-	-	Estates
Vertisols	Salic Sodic Calcic Skeletic Haplic	Calcaric Gleyic Stagnic	

Reference soil groups

There are 11 RSGs in the Estates and 5 in the other parts of the project zones. The first level soil classification is presented in Figure 8.4-2 which shows the occurrence of the RSGs.



[Figure 8.4-2] Soil Map Classified in the First Level

The characteristics of 11 RSGs are summmarized as follows.

1) Arenosols (AR)

Arenosols comprise deep sandy soils. This includes soils in residual sands after in situ weathering of usually quartz-rich sediments or rock, and soils in recently deposited sands. Parent materials are unconsolidated, in places calcareous, translocated materials of sandy texture. In the dry zone, there is little or no soil development.

The characteristic that all Arenosols have in common is their coarse texture, accounting for their generally high permeability and low water and nutrient storage capacity. On the other hand, Arenosols offer ease of cultivation, rooting and harvesting of root and tuber crops.

[Table 8.4-2] Characteristics of Arenosols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a, b, c I-2-a, b B-a / C-a / D-a	1,795		0-4	well	None-slight	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

2) Calcisols (CL)

Calcisols accommodate soils with substantial accumulation of secondary carbonates. Calcisols are widespread in arid and semi-arid environments, often associated with highly calcareous parent materials. Parent materials are mostly alluvial, colluvial and aeolian deposits of base-rich weathering material. Typical Calcisols have a pale brown surface horizon; substantial accumulation of secondary carbonates occurs within 100 cm of the soil surface.

[Table 8.4-3] Characteristics of Calcisols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a / I-2-a B-c / D-a	564		0-2		slight	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

3) Cambisols (CM)

Cambisols combine soils with at least an incipient subsurface soil formation. Transformation of parent material is evident from structure formation and mostly brownish discoloration, increasing clay percentage, and/or carbonate removal. Parent materials are medium and fine textured materials derived from a wide range of rocks. Cambisols are characterized by slight or moderate weathering of parent material and by absence of appreciable quantities of illuviated clay, organic matter, Al and/or Fe compounds.

Cambisols also encompass soils that fail one or more characteristics diagnostic for other RSGs, including highly weathered ones. Cambisols generally make good agricultural land and are used intensively.

[Table 8.4-4] Characteristics of Cambisols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a, b / I-2-a, b A-b / B-c C-a, b, c, d D-a, b, c	15,710		0-8	Poorly-well	Slight-moderate	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

4) Ferralsols (FR)

Ferralsols represent the classical, deeply weathered, red or yellow soils of the humid tropics. These soils have diffuse horizon boundaries, a clay assemblage dominated by low-activity clays (mainly kaolinite) and a high content of sesquioxides. Parent materials are strongly weathered material on old, stable geomorphic surfaces. Deep and intensive weathering has resulted in a residual concentration of resistant primary minerals (e.g. quartz) along with sesquioxides and kaolinite. This mineralogy and the relatively low pH explain the stable microstructure and yellowish (goethite) or reddish (hematite) soil colors.

Most Ferralsols have good physical properties. Great soil depth, good permeability and stable microstructure make Ferralsols less susceptible to erosion than most other intensely weathered tropical soils. Moist Ferralsols are friable and easy to work. They are well drained but may at times be droughty because of their low available water storage capacity.

[Table 8.4-5] Characteristics of Ferralsols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-b	57		0-2		slight	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

5) Fluvisols (FL)

Fluvisols accommodate genetically young soils in fluvial, lacustrine or marine deposits. Parent materials are predominantly recent fluvial deposits. Profiles with evidence of stratification; weak horizon differentiation but a distinct topsoil horizon may be present. The good natural fertility of most Fluvisols and attractive dwelling sites on river levees were recognized in prehistoric times.

Paddy rice cultivation is widespread on tropical Fluvisols with satisfactory irrigation. Many dryland crops are grown on Fluvisols as well, normally with some form of water control.

[Table 8.4-6] Characteristics of Fluvisols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a, b, c, d I-2-a, b / A-a, b, c B-a, b, c C-a, b, c, d D-a, b, c	20,246		0-4	Poorly-very well	None-severe	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

6) Gleysols (GL)

Gleysols comprise soils saturated with groundwater for long enough periods to develop reducing conditions resulting in gleyic properties, including underwater soils. Parent material: A wide range of unconsolidated materials, mainly fluvial sediments. Evidence of reduction processes with segregation of Fe compounds starts within 40 cm of the soil surface.

For many Gleysols, the main obstacle to utilization is the necessity to install a drainage system to lower the groundwater table. Adequately drained Gleysols can be used for arable cropping, dairy farming and horticulture. Soil structure will be destroyed for a long time if soils are cultivated when too wet.

[Table 8.4-7] Characteristics of Gleysols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-2-a, b B-c / D-a	412		0-2	Poorly	slight	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

7) Luvisols (LV)

Luvisols have a higher clay content in the subsoil than in the topsoil, as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. They have high-activity clays throughout the argic horizon and a high base saturation in the 50–100 cm depth. Parent materials a wide variety of unconsolidated materials including aeolian, alluvial and colluvial deposits. Luvisols have pedogenetic differentiation of clay content, with a lower content in the topsoil and a higher content in the subsoil without marked leaching of base cations or advanced weathering of high-activity clays.

Most of them are fertile soils and suitable for a wide range of agricultural uses. Luvisols with a high silt content are susceptible to structure deterioration where tilled when wet or with heavy machinery. Luvisols on steep slopes require erosion control measures. In places, the dense subsoil causes temporarily reducing conditions with stagnic properties.

[Table 8.4-8] Characteristics of Luvisols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a, b / I-2-a, b A-a, b / B-a, b C-a, b, c, d D-a, b, c	14,640		0-8	Imperfectly-somewhat excessively	None-severe	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

8) Nitisols (NT)

Nitisols are deep, well-drained, red tropical soils with diffuse horizon boundaries and a subsurface horizon with at least 30 percent clay and moderate to strong angular blocky structure breaking into polyhedral or flat-edged or nut-shaped elements with, in moist state, shiny aggregate faces. Weathering is relatively advanced but they are far more productive than most other red tropical soils. Parent materials are finely textured weathering products of intermediate to basic parent rock.

Nitisols are red or reddish-brown clayey soils with a nitic subsurface horizon of high aggregate stability. The clay assemblage of them is dominated by kaolinite/(meta) halloysite. Nitisols are rich in Fe and have little water-dispersible clay. The deep and porous solum and the stable soil structure of them permit deep rooting and make these soils quite resistant to erosion. The good workability of Nitisols, their good internal drainage and fair water holding properties are complemented by chemical (fertility) properties that compare favorably with those of most other tropical soils.

[Table 8.4-9] Characteristics of Nitisols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a / I-2-a, b B-c	817		0-2		slight	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

9) Plinthosols (PT)

Plinthosols are soils with plinthite, petroplinthite or pisoliths. Plinthite is a Fe-rich (in some cases also Mn-rich), humus-poor mixture of kaolinitic clay (and other products of strong weathering such as gibbsite) with quartz and other constituents. It usually changes irreversibly to a layer with hard concretions or nodules or to a hardpan on exposure to repeated wetting and drying. They are a continuous or fractured sheet of connected, strongly cemented to indurated concretions or nodules or concentrations in platy, polygonal or reticulate patterns. Pisoliths are discrete, strongly cemented to indurated concretions or nodules. Both petroplinthite and pisoliths develop from plinthite by hardening. Parent material is plinthite more common in weathering material from basic rock than in acidic rock weathering.

Plinthosols present considerable management problems. Poor natural soil fertility caused by strong weathering, waterlogging in bottomlands and drought on Plinthosols with petroplinthite or pisoliths are serious limitations.

[Table 8.4-10] Characteristics of Plinthosols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a / I-2-b	107		0-2		slight	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

10) Retisols (RT)

Retisols have a clay illuviation horizon with an interfingering of bleached coarser textured soil material into the illuviation horizon forming a net-like pattern. The interfingering bleached coarser-textured material is characterized by a partial removal of clay and free iron oxides. There may be also bleached coarser-textured material falling from the overlying horizon into cracks in the illuvial horizon. Parent materials are materials of fluvial origin and aeolian deposits. A thin, dark surface horizon over a layer with coarser-textured albic material interfingers as a net into an underlying brown argic or natric horizon. The agricultural suitability of Retisols is limited because of their acidity, low nutrient levels, tillage and drainage problems.

[Table 8.4-11] Characteristics of Retisols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a / I-2-b	28		0-2		slight	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

11) Vertisols (VR)

Vertisols are heavy clay soils with a high proportion of swelling clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years. Parent materials are sediments that contain a high proportion of swelling clays. Alternate swelling and shrinking of expanding clays results in deep cracks in the dry season, and formation of slickensides and wedge-shaped structural elements in the subsurface soil.

Large areas of Vertisols in the semi-arid tropics are still unused or are used only for extensive grazing, wood chopping, charcoal burning and the like. These soils have considerable agricultural potential, but adapted management is a precondition for sustained production. The comparatively good chemical fertility and their occurrence on extensive level plains where reclamation and mechanical cultivation can be envisaged are assets of Vertisols. Their physical soil characteristics, and notably their difficult water relations, cause management problems. Buildings and other structures on Vertisols are at risk and engineers have to take special precautions to avoid damage.

[Table 8.4-12] Characteristics of Vertisols in the Project Zones

Location	Area (ha)	Land Use	Slope (%)	Drainage	Erosion	Texture (top/sub)
I-1-a, b I-2-a, b A-b / B-b, c C-a, b, c, d	14,973		0-4	Poorly-well	None-severe	
pH	**EC (dS/m)**	**ESP (%)**	**OM (%)**	**N (ppm)**	**P (ppm)**	**Limitations**

<u>Principle Qualifiers</u>

The definitions of the qualifiers for the second-level units relate to RSGs, diagnostic horizons, properties and materials, attributes such as colour, chemical conditions, texture, etc.

Subqualifiers may be used in the soil name instead of the qualifier listed in the Key. Subqualifiers that cannot replace a listed qualifier are found in alphabetical order.

Qualifiers that have depth requirements can be combined with the specifiers Epi-, Endo-, Amphi- and Panto- to create subqualifiers (e.g. Epicalcic, Endocalcic) further expressing the depth of occurrence.

<u>1) If a qualifier refers to a horizon or layer (e.g. Calcic, Arenic):</u>

- Epi-: the horizon or layer has its lower limit (e.g. Calcic, Arenic):ocalcic surface.
- Endo-: the horizon or layer starts between > 50 and Calcic, Arenic):ocalcic soil surface.
- Amphi-: the horizon or layer starts < 50 cm of the (mineral) soil surface and has its lower limit > 50 cm of the (mineral) soil surface.
- Panto-: the horizon or layer starts at the (mineral) soil surface and has its lower limit ≥ 100 cm of the (mineral) soil surface.

<u>2) If a qualifier refers to the major part of a certain depth range (Dystric and Eutric):</u>

- Epi-: the characteristic is present in the major part between the (mineral) soil surface (or the specified upper limit) and 50 cm from the (mineral) soil surface and is absent in the major part between 50 and 100 cm from the (mineral) soil surface or between 50 cm from the (mineral) soil surface and continuous rock, technic hard material or a cemented or indurated layer, whichever is shallower.

- Endo-: the characteristic is present in the major part between 50 and 100 cm from the (mineral) soil surface or between 50 cm from the (mineral) soil surface and continuous rock, technic hard material or a cemented or indurated layer, whichever is shallower, and absent in the major part between the (mineral) soil surface (or the specified upper limit) and 50 cm from the (mineral) soil surface.
- Panto-: the characteristic is present from the (mineral) soil surface to a depth of 100 cm from the (mineral) soil surface throughout.

3) If a qualifier refers to a specified depth range throughout (e.g. Sodic, Calcaric):

- Epi-: the characteristic is present throughout between the (mineral) soil surface (or the specified upper limit) and 50 cm from the (mineral) soil surface and is absent in some layer between 50 and 100 cm from the (mineral) soil surface.
- Endo-: the characteristic is present throughout between 50 and 100 cm from the (mineral) soil surface or between 50 cm from the (mineral) soil surface and continuous rock, technic hard material or a cemented or indurated layer, whichever is shallower, and is absent in some layer ≤ 50 cm from the (mineral) soil surface.

Fourteen principle qualifiers applied in the second level classification of RSGs are defined as follows.

1) **Abruptic (ap)**: having an abrupt textural difference within ≤ 100 cm of the mineral soil surface.
2) **Calcaric (ca)**: having calcaric material throughout between 20 and 100 cm from the soil surface, or between 20 cm and continuous rock, or a cemented or indurated layer, whichever is shallower.
3) **Calcic (cc)**: having a calcic horizon starting ≤ 100 cm from the soil surface.

   Hypercalcic (jc): having a calcic horizon with a calcium carbonate equivalent in the fine earth fraction of ≥ 50% (by mass) and starting ≤ 100 cm from the soil surface.

   Hypocalcic (wc): having a calcic horizon with a calcium carbonate equivalent in the fine earth fraction of < 25% (by mass) and starting ≤ 100 cm from the soil surface.

   Protocalcic (qc): having a layer with protocalcic properties starting ≤ 100 cm from the soil surface and not having a calcic or petrocalcic horizon starting ≤ 100 cm from the soil surface.

4) **Dystric (dy)**: having a base saturation of < 50% in the major part between 20 and 100 cm from the mineral soil surface or between 20 cm and a cemented or indurated layer, whichever is shallower, or in a layer ≥ 5 cm thick, directly above a cemented or indurated layer, if the cemented or indurated layer starts ≤ 25 cm from the mineral soil surface.
5) **Eutric (eu)**: having a base saturation of ≥ 50% in the major part between 20 and 100 cm from the mineral soil surface or between 20 cm and a cemented or indurated layer, whichever is shallower, or in a layer ≥ 5 cm thick, directly above a cemented or indurated layer, if the cemented or indurated layer starts ≤ 25 cm from the mineral soil surface.
6) **Fluvic (fv)**: having fluvic material ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface.
7) **Gleyic (gl)**: having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that has gleyic properties throughout and reducing conditions in in some parts of every sublayer.
8) **Haplic (ha)**: having a typical expression of certain features (typical in the sense that there is no further or meaningful characterization) and only used if none of the preceding qualifiers applies.
9) **Rubic (ru)**: having within ≤ 100 cm of the soil surface, a subsurface layer ≥ 30 cm thick, with a Munsell colour hue redder than 10YR and/or a chroma of ≥ 5, both moist (in Arenosols only).
10) **Salic (sz):** having a salic horizon starting ≤ 100 cm from the soil surface.

    Hypersalic (jz): having an ECe of ≥ 30 dS m-1 at 25 °C in some layer within ≤ 100 cm of the soil surface.

Protosalic (qz): having an ECe of ≥ 4 dS m-1 at 25 °C in some layer within ≤ 100 cm of the soil surface and not having a salic horizon starting ≤ 100 cm from the soil surface.

11) **Skeletic (sk)**: having ≥ 40% (by volume) coarse fragments averaged over a depth of 100 cm from the soil surface or to continuous rock, technic hard material or a cemented or indurated layer, whichever is shallower.

12) **Sodic (so)**: having ≥ 15% exchangeable Na plus Mg and ≥ 6% exchangeable Na on the exchange complex, in a layer ≥ 20 cm thick, starting ≤ 100 cm from the soil surface and not having a natric horizon starting ≤ 100 cm from the soil surface.

13) **Stagnic (st)**: having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil surface, that does not form part of a hydragric horizon and that has:

- stagnic properties in which the area of reductimorphic colours plus the area of oximorphic colors is ≥ 25% of the total area, and
- reducing conditions for some time during the year in the major part of the soil volume that has the reductimorphic colors.

14) **Vertic (vr)**: having a vertic horizon starting ≤ 100 cm from the soil surface.

Protovertic (qv): having a protovertic horizon starting ≤ 100 cm from the soil surface and not having a vertic horizon starting ≤ 100 cm from the soil surface.

Supplementary Qualifiers

Nine supplementary qualifiers are introduced in order to complement principle qualifiers.

1) **Arenic (ar):** having a texture class of sand or loamy sand in a layer ≥ 30 cm thick, within a texture class of sand or loamy sand in a layer ≥ 30 cm thick,inciple quali a cemented or indurated layer, whichever is shallower.

2) **Calcaric (ca)**: having calcaric material throughout between 20 and 100 cm from the soil surface, or between 20 cm and continuous rock, or a cemented or indurated layer, whichever is shallower.

3) **Clayic (ce)**: having a texture class of clay, sandy clay or silty clay, in a layer il surface, or between 20 cm and continuous rocoil surface or between the mineral soil surface and a cemented or indurated layer, whichever is shallower.

4) **Fluvic (fv)**: having fluvic material of clay, sandy clay or silty clay, in a layermineral soil surface.

5) **Gleyic (gl)**: having a layer aterial of clay, d starting ≤ 75 cm from the mineral soil surface, that has gleyic properties throughout and reducing conditions in in some parts of every sublayer.

6) **Loamic (lo)**: having a texture class of loam, sandy loam, sandy clay loam, clay loam or silty clay loam in a layer ≥ 30 cm thick, within ≤ 100 cm of the mineral soil surface or between the mineral soil surface and a cemented or indurated layer, whichever is shallower.

7) **Salic (sz)**: having a salic horizon starting sandy loam, sandy clay loam, cl

Hypersalic (jz): having an ECe of ≥ 30 dS m-1 at 25 °C in some layer within ≤ 100 cm of the soil surface.

Protosalic (qz): having an ECe of ving an -1 at 25 g an ECe of ving an ECe ≤ 100 cm of the soil surface and not having a salic horizon starting ≤ 100 cm from the soil surface.

8) **Sodic (so)**: having so): ECe of ving an ECe ≤ 100 cm of the soil surface and not having a salic horizon starting ≤ 100 cm from the soil surface. of the mineral soil surface or between the mineral soil surface and a cemented or indurated l

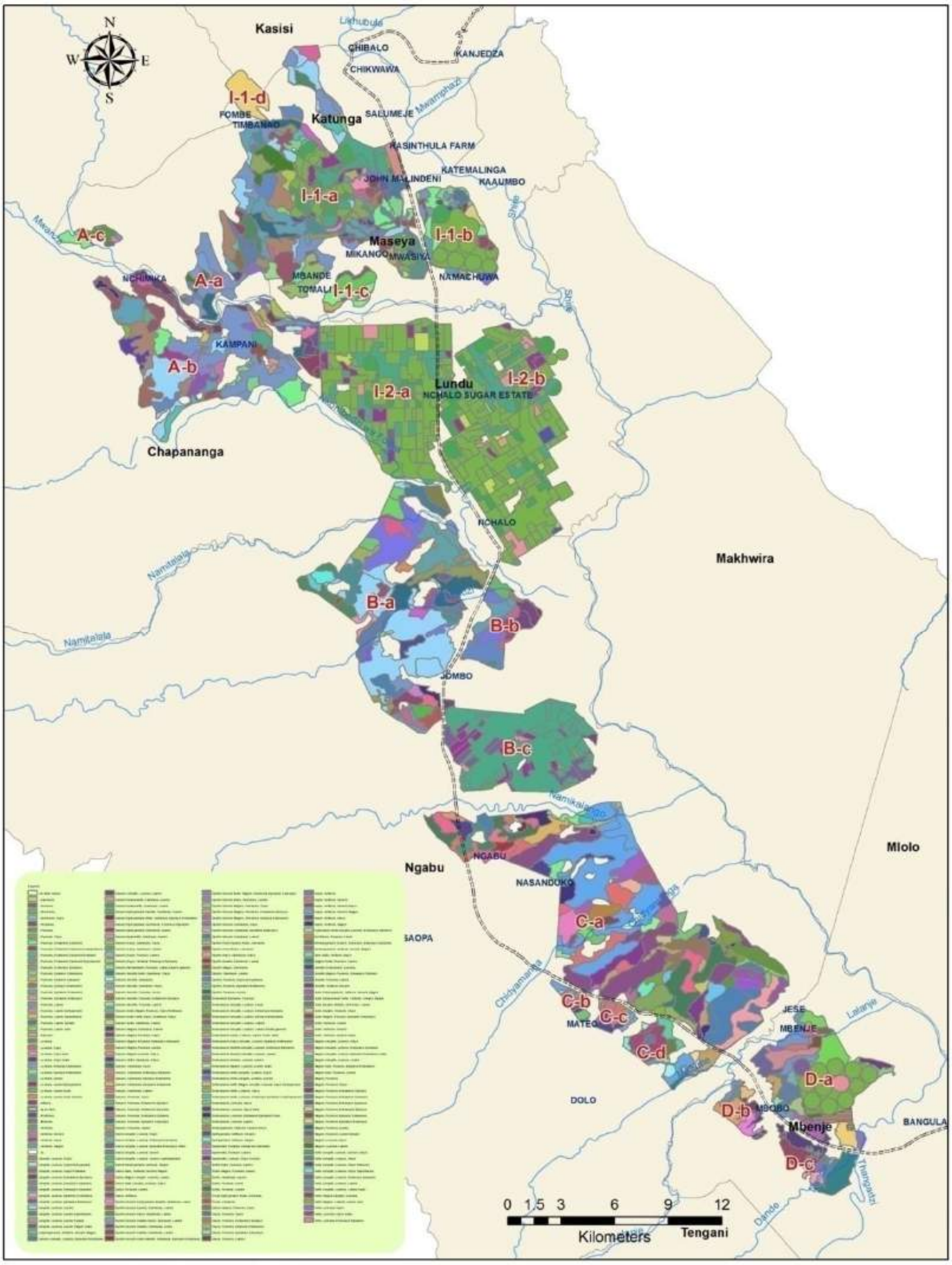
9) **Stagnic (st)**: having a layer ≥ 25 cm thick, and starting ≤ 75 cm from the mineral soil

surface, that does not form part of a hydragric horizon and that has:

- stagnic properties in which the area of reductimorphic colours plus the area of oximorphic colors is ≥ 25% of the total area, and
- reducing conditions for some time during the year in the major part of the soil volume that has the reductimorphic colors.

Soil Units

Soil units sum up to 222 in the survey zones when classified by the applicable RSGs, qualifiers, and specifiers.



[Figure 8.4-3] 2016 Soil Map of Soil Survey Zones

Soil Limitations

Soil limiting factors for cropping examined in the CODA report and the FAO map. In the 2008 CODA report, they were investigated in soil texture, effective depth, water holding capacity, topography, fertility potential, alkalinity, and salinity. Meanwhile, the FAO map considered soil depth, occurrence of flooding, salinity, drainage, texture, topsoil consistence, presence of free lime, and inherent chemical fertility of the upper 50 cm of the soil.

From the present soil survey, similarity, flooding and ponding, erosion, heavy clayey or sandy texture, high levels of rock content on surface and/or subsoil, poor drainage, hard consistence, salinity and/or sodicity, low fertility could be suggested as vital soil limiting factors.

1) Slope

Except for part of the western uplands and footslopes, the project area is flat so has no limitation in slope for irrigated cultivation.

[Table 8.4-13] Slope Distribution in the Soil Survey Zones

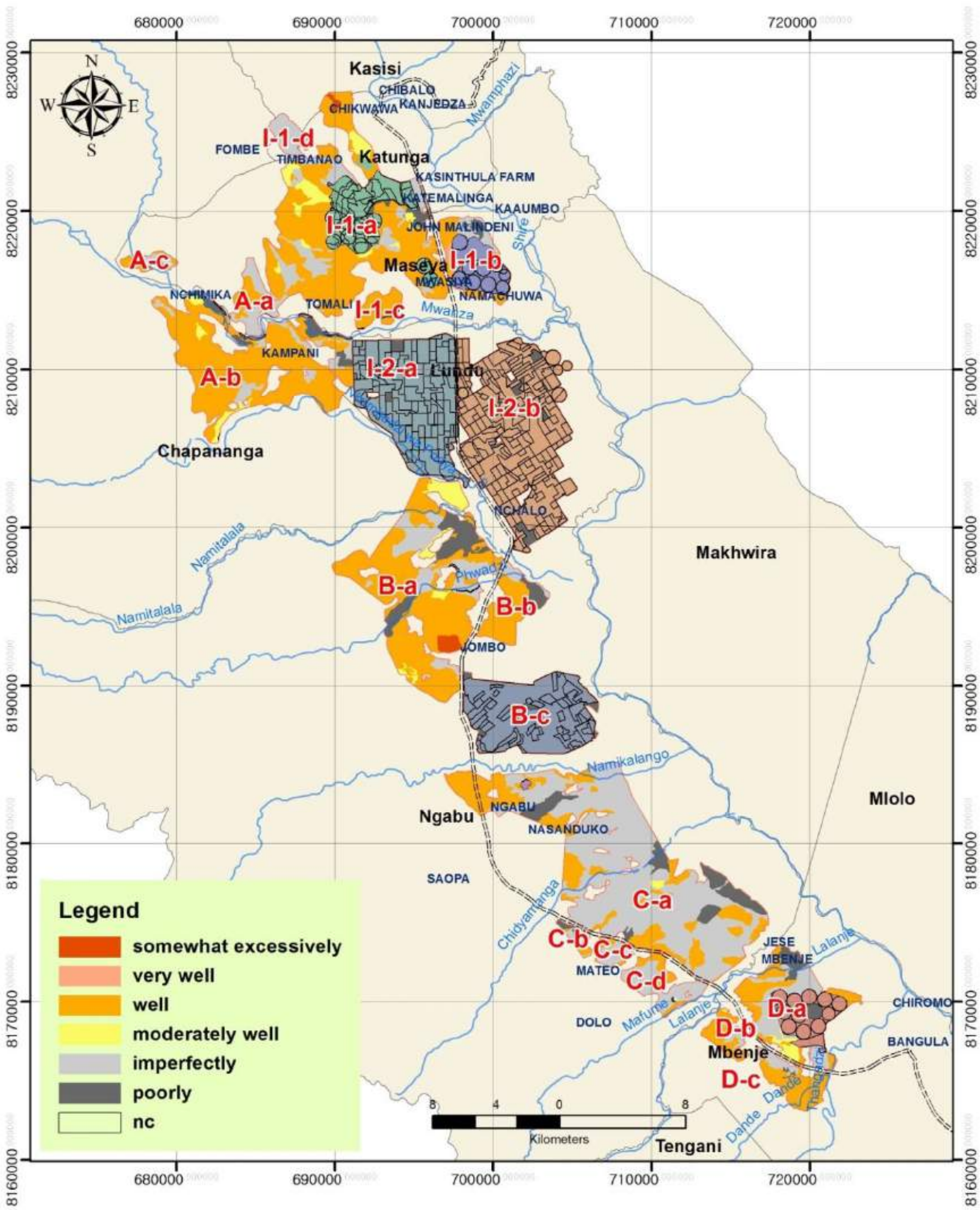
Slope	0-2%	2-4%	4-8%	N/C	Sum
Acreage (ha)	53,491	1,457	455	140	55,543

2) Erosion

Like in the case of slope, the project area has low erosion hazard overall.

3) Drainage

The bad soil drainage of project area, espcially Zone C, could have a large area of depressed fields inundated in the rainy season. Measures such as canal amendment, land reclamation, and agricultural draining management are indispensable for reducing the damage.



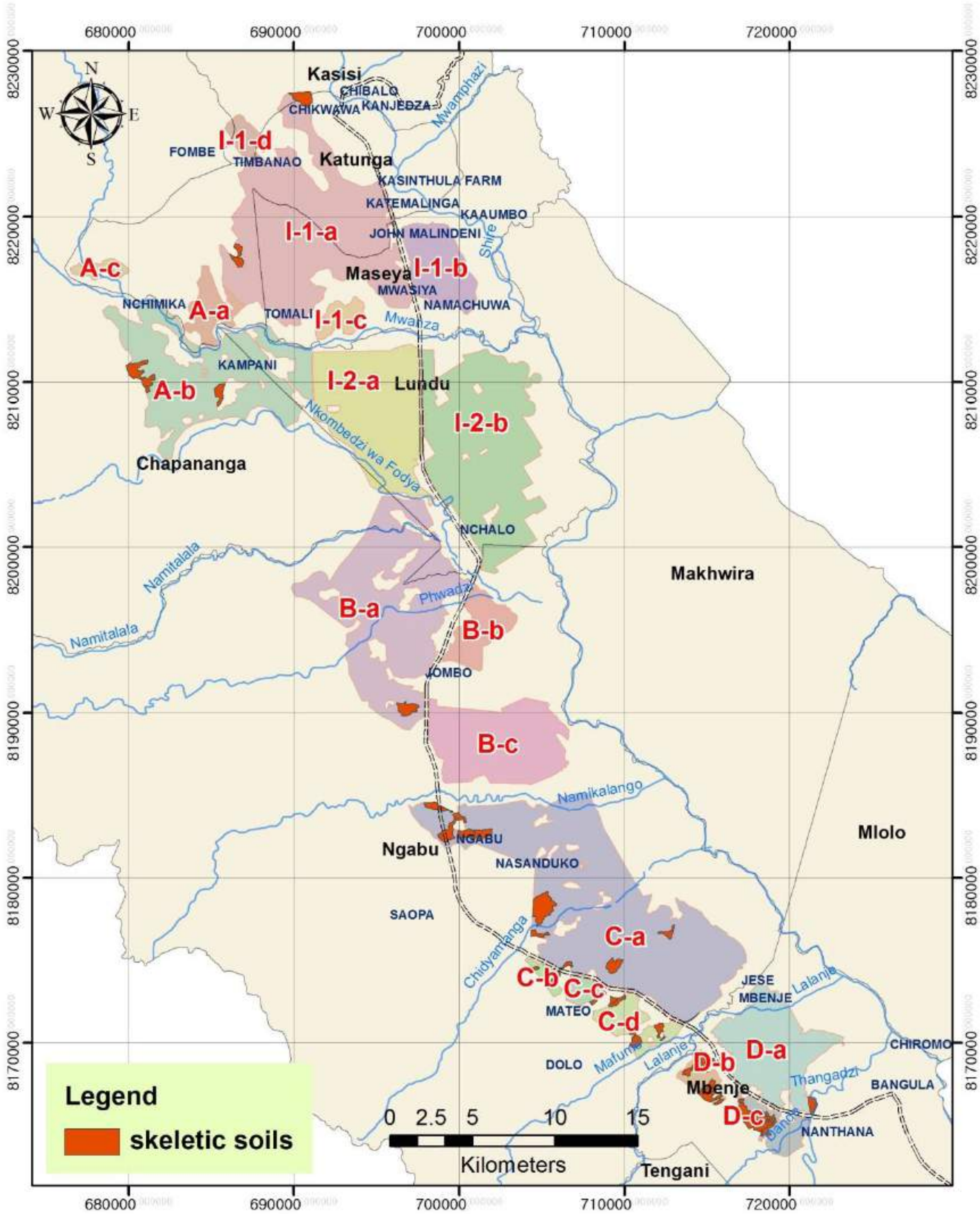
[Figure 8.4-4] Drainage Classes of Soil Survey Zones

4) Soil texture

Arenosols are too sandy soils to hold enogh water to grow crops, whereas Vertisols and Vertic Luvisols excessively clayey are disadvantageous for tillage and drainage.

5) Rock fragments

Dominant or abundant gravels and/or stones are contained through or in the layers within 100 cm from the surface in the area of approximately 1,500 ha. These rock fragments reduce the effective rooting depth of crops so that induce low water holding capacity, loss of nutrients, and finally worsen crop yields.



[Figure 8.4-5] Skeletic Soils of Soil Survey Soils

6) Consistency

In the area of soils with heavy clay content in topsoil, it would be desirable to cover and mix original soils with a sandy soil and to steadily introduce machinery such as tillers and tractors in order to facilitate farmers' agricultural activities and to help crops with efficient uptake of essential nutrients from soil.

7) Salinity and sodicity

According to the 1969 FAO Soil Map, salt-affected zones were A-b, A-e, I-2-a, I-2-b, B-b, and D-a, the hectarage of which was 1,480 ha. They changed to I-1-a, I-1-b, I-2-b, B-b, B-c, C-a, and D-a of 1,803 ha in total in 1991. The 2008 CODA Map presents that salt-affected zones was I-1-a and I-1-b in Phase I Area and areaed only 754 ha.

The findings from the present study is that salt-affected zones expand to I-1-a, I-1-c, A-a, A-b, B-a, C-a, C-d, D-a, and D-b not including Estates. Actually, saline and/or sodic soils occupy approximately 10% of Phase I Zones (2,400 ha). The percentage increases up to around 20% (11,000 ha) for the entire.

Causes and Measures

Rain or irrigation, in the absence of leaching, can bring salts to the surface by capillary action. Salinity from irrigation can increase in soil over time wherever irrigation is implemented, since almost all water (even natural rainfall) contains some dissolved salts. When the plants use the water, the salts are left behind in the soil and eventually begin to accumulate.

Since soil salinity makes it more difficult for plants to absorb soil moisture, these salts must be leached out of the plant root zone by applying additional water. This water in excess of plant needs is called the leaching fraction. Salination from irrigation water is also greatly increased by poor drainage and use of saline water for irrigating agricultural crops.

The Saline and/or Sodic areas are largely distributed in Kasinthula, Alumenda of Illovo and Kaombe of Illovo areas. TFS Consultant (with Kasinthula Research Station; DR. I.R. Fandika) investigated the ways of managing the soil property of these areas, and they are summarized as below:

- Improving drainage: Deeper drainage canals system applied including subsurface drains
- Applying gypsum: In the early stage of the scheme soil shall be ploughed applying with gypsum (1 ~ 2 ton/ha) (The required cost for 8,000 ha will be about 1.5 million USD)
- Using acid fertilizers (Ammonium Sulphate) to improve soil property
- Plating tolerant crops such as sun hemp, velvet beans, etc.

The following recommendation was provide by DR. I.R. Fandika (Kasinthula Research Station) for a sustainable salinity management:

(1) Land reclamation by adding soil amendments

The sodic soil conditions will require two management steps: (1) replacing the exchangeable Na with a more favorable ion such as calcium and magnesium and (2) leaching the soluble Na that has been replaced on the soil colloid, by applying excessive irrigation water during irrigation. Therefore, it's advisable that all the area spotted sodic be ploughed and be applied with gypsum at the early stage of the scheme establishment. Usually no more than 1 to 2 tons of gypsum per ha should be applied at one time. Lighter, more frequent application of gypsum tends be more effective than a single heavy application.

(2) Use of Tolerant Crops

Cotton has been identified as the highest salt tolerant crop which has the highest percent yield potential in some irrigation scheme. Rice, wheat, sorghum, millet, and soybeans were identified as medium tolerant crops to the salinity levels. It is a practical option, therefore, during the recovery or reclamation process of the proposed irrigation scheme saline or sodic land to use either the high or medium salt tolerant crops. It should be noted that maize will not be an economic crop during the reclamation period of the irrigation scheme as is sensitive to the salinity levels.

(3) Good Drainage Infrastructure

An increase in the salinity for the irrigation scheme is often associated with water logging (Dougherty and Hall, 1995) and with water table that has low hydraulic conductivity and low porosity. Therefore an appropriate and well maintained drainage network will effectively mitigate the problem by removing salts from the field.

(4) Use of Raised Beds

It is also recommended that upland crops around this part of the scheme be grown on raised beds to ensure favorable condition for plant roots.

(5) Application of Organic Manure

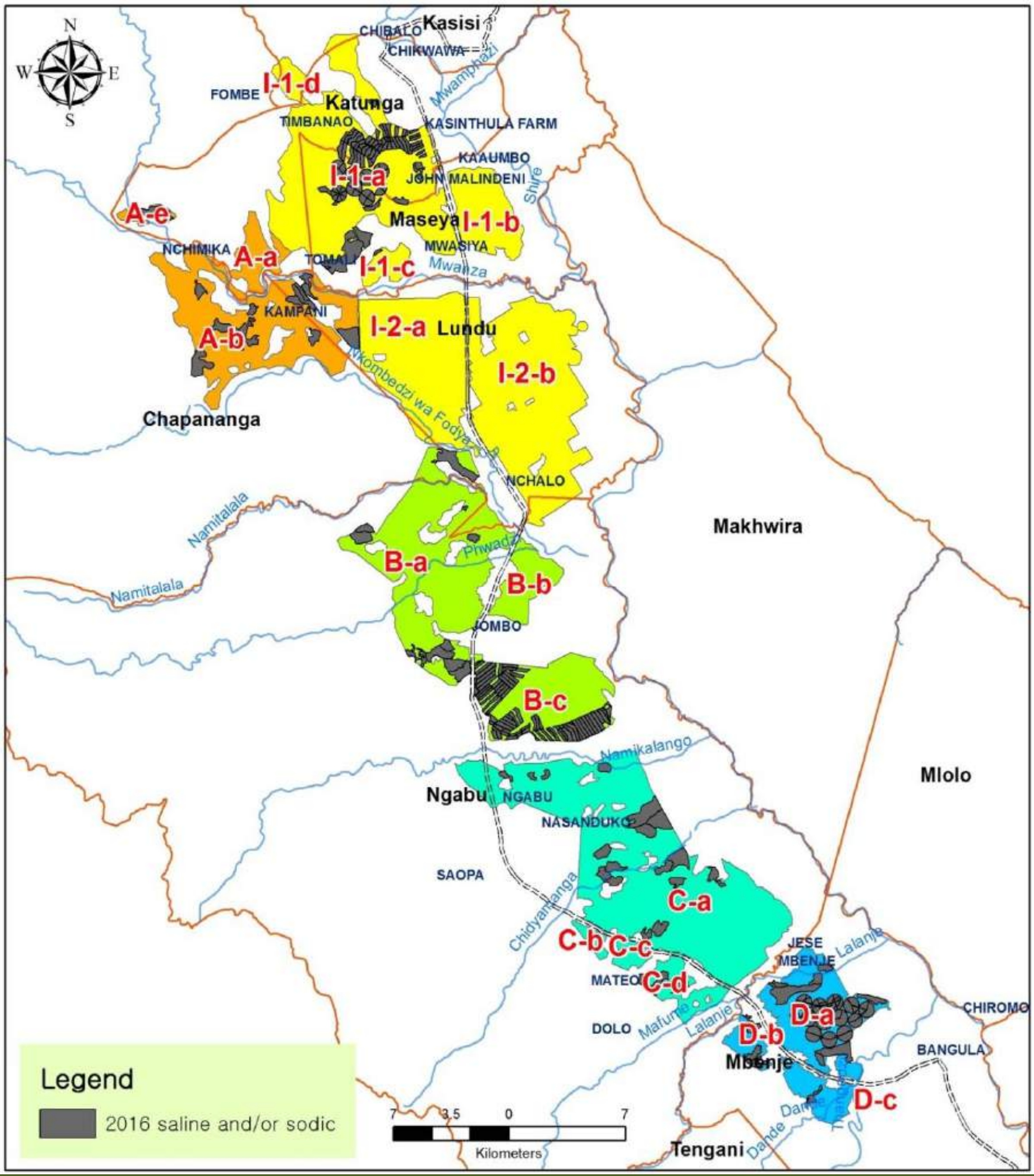
An addition of organic manure to soils at the scheme will serve as a binding agent for soil colloids and buffer for soil pH and salinity thereby creating favorable condition for crop growth. The organic manure sourced from compost and farmyard manure need to be encouraged during the reclamation of the irrigation scheme.

(6) Annual Saline Monitoring

Following the soil verification survey of the irrigation scheme, soil changes for the scheme will need to be monitored (Dougherty and Hall, 1995) annually so that potential problems can be managed. Annual monitoring of the scheme can involve annual soil analysis to be complemented by field research of the potential tolerant crops to determine the actual yield potential with different management system that will be applied.

(7) Conclusion

It can be concluded that saline and sodic soils are spatially distributed at far end (South east and west) of the irrigation scheme. And that the land can be easily reclaimable by applying gypsum before irrigation farming starts and through initial use of tolerant crops such as cotton, rice, sorghum, millet, soybeans and wheat. Rice is highly recommendable as is already being grown around the area by smallholder farmers.



[Figure 8.4-6] 2016 Saline and/or Sodic Soils in the SVIP Zones

8.4.4. Land Suitability

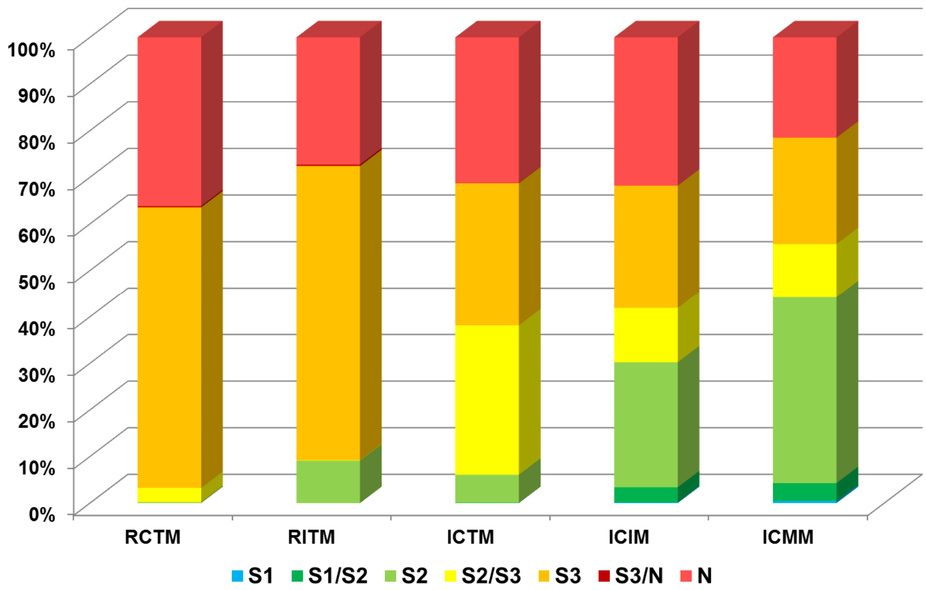
Land suitability has been assessed for 533 land units of 36,771 ha in the soil survey area except Estates by use of ALES program. LUT/Crop models were determined in consideration of water sources, management levels, and crops cultivated now or potentially growing well in the future as per Table 8.4-14. Due to no recent cropping data collected for SVIP, crop characteristics in the 1991 FAO Report (FAO, 1991a) were very usefully applied and modified for setting LURs in the present evaluation.

[Table 8.4-14] LUT/Crop Description

LUT/Crop	Water Source	Management Level	Crop
RCTM-BM	rain-fed	traditional	bulrush millet
RCTM-CA2	rain-fed	traditional	cassava, long cycle varieties
RCTM-CA1	rain-fed	traditional	cassava, short cycle varieties
RCTM-CS	rain-fed	traditional	cashew
RCTM-CO	rain-fed	traditional	cotton
RCTM-CP	rain-fed	traditional	cowpea
RCTM-GN1	rain-fed	traditional	groundnuts, short cycle varieties
RCTM-GN2	rain-fed	traditional	groundnuts, long cycle varieties
RCTM-MA2	rain-fed	traditional	maize, long cycle varieties
RCTM-MA1	rain-fed	traditional	maize, short cycle varieties
RCTM-RI	rain-fed	traditional	rice, paddy
RCTM-SO	rain-fed	traditional	sorghum
RCTM-SB	rain-fed	traditional	soya beans
RCTM-SP	rain-fed	traditional	sweet potato
RCTM-SU	rain-fed	traditional	sunflower
RITM-BM	rain-fed	improved	bulrush millet
RITM-CA2	rain-fed	improved	cassava, long cycle varieties
RITM-CS	rain-fed	improved	cashew
RITM-CO	rain-fed	improved	cotton
RITM-CP	rain-fed	improved	cowpea
RITM-GN1	rain-fed	improved	groundnuts, short cycle varieties
RITM-MA1	rain-fed	improved	maize, short cycle varieties
RITM-SO	rain-fed	improved	sorghum
RITM-SB	rain-fed	improved	soya beans
RITM-SU	rain-fed	improved	sunflower
ICTM-BM	irrigated	traditional	bulrush millet
ICTM-CA2	irrigated	traditional	cassava, long cycle varieties
ICTM-CA1	irrigated	traditional	cassava, short cycle varieties
ICTM-CS	irrigated	traditional	cashew
ICTM-CO	irrigated	traditional	cotton
ICTM-CP	irrigated	traditional	cowpea
ICTM-GN1	irrigated	traditional	groundnuts, short cycle varieties
ICTM-GN2	irrigated	traditional	groundnuts, long cycle varieties
ICTM-MA2	irrigated	traditional	maize, long cycle varieties
ICTM-MA1	irrigated	traditional	maize, short cycle varieties
ICTM-RI	irrigated	traditional	rice, paddy
ICTM-SO	irrigated	traditional	sorghum
ICTM-SB	irrigated	traditional	soya beans
ICTM-SP	irrigated	traditional	sweet potato
ICTM-SU	irrigated	traditional	sunflower
ICIM-BM	irrigated	improved	bulrush millet
ICIM-CA2	irrigated	improved	cassava, long cycle varieties
ICIM-CA1	irrigated	improved	cassava, short cycle varieties
ICIM-CS	irrigated	improved	cashew
ICIM-CO	irrigated	improved	cotton

ICIM-CP	irrigated	improved	cowpea
ICIM-GN1	irrigated	improved	groundnuts, short cycle varieties
ICIM-GN2	irrigated	improved	groundnuts, long cycle varieties
ICIM-MA2	irrigated	improved	maize, long cycle varieties
ICIM-MA1	irrigated	improved	maize, short cycle varieties
ICIM-SO	irrigated	improved	sorghum
ICIM-SB	irrigated	improved	soya beans
ICIM-SP	irrigated	improved	sweet potato
ICIM-SU	irrigated	improved	sunflower
ICMM-BM	irrigated	modern	bulrush millet
ICMM-CA2	irrigated	modern	cassava, long cycle varieties
ICMM-CA1	irrigated	modern	cassava, short cycle varieties
ICMM-CS	irrigated	modern	cashew
ICMM-CO	irrigated	modern	cotton
ICMM-CP	irrigated	modern	cowpea
ICMM-GN1	irrigated	modern	groundnuts, short cycle varieties
ICMM-GN2	irrigated	modern	groundnuts, long cycle varieties
ICMM-MA2	irrigated	modern	maize, long cycle varieties
ICMM-MA1	irrigated	modern	maize, short cycle varieties
ICMM-SO	irrigated	modern	sorghum
ICMM-SB	irrigated	modern	soya beans
ICMM-SU	irrigated	modern	sunflower

Unsuitable (N) land averages approximately 11,000 ha (30%) out of the whole assessed area. Land suitability classes depend greatly on management levels and crop types. Except for Class N, S3 are generally dominant under RCTM (22,138 ha on average for all crops) and RITM (23,165 ha). S2 is predicted to increase obviously from 2,300 ha to 14,666 ha as land suitability classes become divided further through ICTM, ICIM, and ICMM. Detailed land suitability results are presented in Table 8.4-15 and Figure 8.4-7.



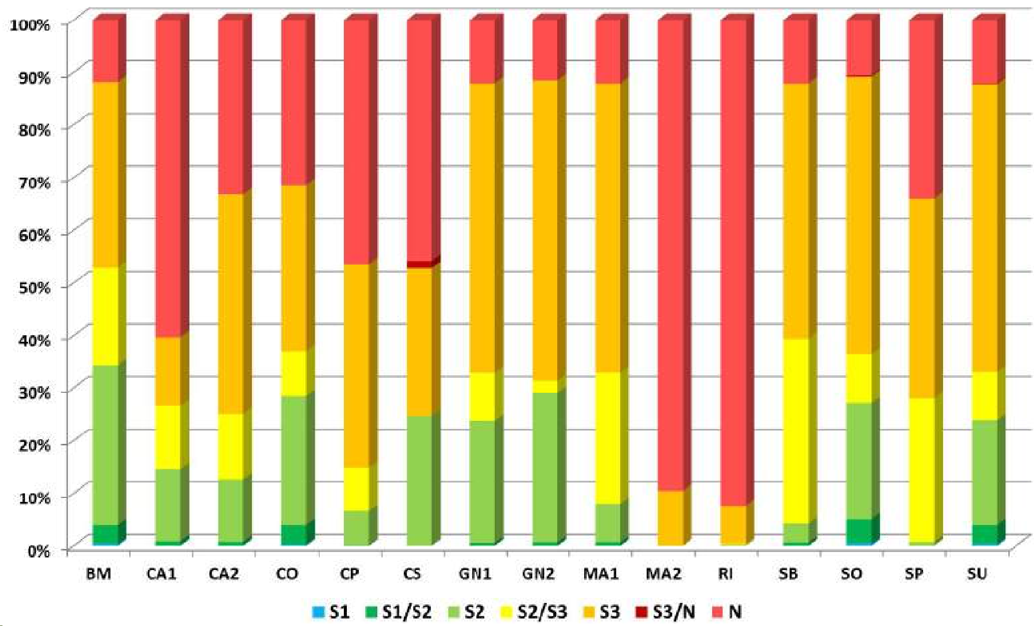
[Figure 8.4-7] Composition of Land Suitability Classes by LUT

[Table 8.4-15] Land Suitability Classes by LUT/Crop

LUT/Crop	Land Suitability (ha)							
	S1	S1/S2	S2	S2/S3	S3	S3/N	N	Sum
RCTM-BM	0	0	985	16,493	14,014	0	5,219	36,711
RCTM-CA2	0	0	0	0	23,941	0	12,770	36,711
RCTM-CA1	0	0	0	0	3,777	0	32,934	36,711
RCTM-CS	0	0	0	0	16,953	1,160	18,598	36,711
RCTM-CO	0	0	0	0	24,572	0	12,139	36,711
RCTM-CP	0	0	0	0	31,492	0	5,219	36,711
RCTM-GN1	0	0	0	0	31,492	0	5,219	36,711
RCTM-GN2	0	0	0	0	31,492	0	5,219	36,711
RCTM-MA2	0	0	0	0	3,777	0	32,934	36,711
RCTM-MA1	0	0	0	0	31,492	0	5,219	36,711
RCTM-RI	0	0	232	188	20	0	36,271	36,711
RCTM-SO	0	0	0	0	31,938	189	4,584	36,711
RCTM-SB	0	0	0	0	31,492	0	5,219	36,711
RCTM-SP	0	0	0	0	24,237	0	12,474	36,711
RCTM-SU	0	0	0	0	31,381	111	5,219	36,711
RITM-BM	0	0	17,766	294	13,432	0	5,219	36,711
RITM-CA2	0	0	0	0	23,941	0	12,770	36,711
RITM-CS	0	0	0	0	16,593	1,160	18,578	36,331
RITM-CO	0	0	15,607	183	8,782	0	12,139	36,711
RITM-CP	0	0	0	0	10,998	0	25,713	36,711
RITM-GN1	0	0	0	0	31,492	0	5,219	36,711
RITM-MA1	0	0	0	0	31,492	0	5,219	36,711
RITM-SO	0	0	0	0	31,938	0	4,773	36,711
RITM-SB	0	0	0	0	31,492	0	5,219	36,711
RITM-SU	0	0	0	0	31,492	0	5,219	36,711
ICTM-BM	0	50	935	16,493	14,014	0	5,219	36,711
ICTM-CA2	0	0	116	12,533	11,292	0	12,770	36,711
ICTM-CA1	0	0	74	2,773	930	0	32,934	36,711
ICTM-CS	0	0	12,456	0	5,657	0	18,598	36,711
ICTM-CO	0	50	398	15,060	9,064	0	12,139	36,711
ICTM-CP	0	50	348	14,984	16,110	0	5,219	36,711
ICTM-GN1	0	0	935	16,301	14,256	0	5,219	36,711
ICTM-GN2	0	0	166	2,806	28,520	0	5,219	36,711
ICTM-MA2	0	0	0	0	3,777	0	32,934	36,711
ICTM-MA1	0	50	885	16,379	14,178	0	5,219	36,711
ICTM-RI	0	46	14,384	8,268	5,029	0	8,984	36,711
ICTM-SO	0	50	935	16,493	14,460	189	4,584	36,711
ICTM-SB	0	0	166	23,016	8,310	0	5,219	36,711
ICTM-SP	0	0	398	15,062	8,777	0	12,474	36,711
ICTM-SU	0	50	935	16,415	13,981	111	5,219	36,711
ICIM-BM	238	3,280	14,412	294	13,268	0	5,219	36,711
ICIM-CA2	0	172	2,481	10,168	11,120	0	12,770	36,711
ICIM-CA1	0	1,040	14,481	183	8,237	0	12,770	36,711
ICIM-CS	0	0	12,456	0	5,657	0	18,598	36,711

ICIM-CO	66	3,452	12,089	183	8,782	0	12,139	36,711
ICIM-CP	0	63	4,577	148	6,210	0	25,713	36,711
ICIM-GN1	0	485	17,281	183	13,543	0	5,219	36,711
ICIM-GN2	0	485	17,281	183	13,543	0	5,219	36,711
ICIM-MA2	0	0	0	0	3,777	0	32,934	36,711
ICIM-MA1	0	604	4,524	12,821	13,543	0	5,219	36,711
ICIM-SO	238	3,280	20,355	253	7,812	0	4,773	36,711
ICIM-SB	0	485	3,292	20,271	7,444	0	5,219	36,711
ICIM-SP	0	0	398	15,062	8,777	0	12,474	36,711
ICIM-SU	238	3,280	14,334	183	13,457	0	5,219	36,711
ICMM-BM	544	3,189	21,687	364	10,162	0	765	36,711
ICMM-CA2	0	1,146	19,172	190	6,288	0	9,915	36,711
ICMM-CA1	0	172	5,619	14,717	6,288	0	9,915	36,711
ICMM-CS	0	0	20,259	0	6,722	0	9,730	36,711
ICMM-CO	372	3,361	16,856	190	6,648	0	9,284	36,711
ICMM-CP	0	63	6,948	155	6,026	0	23,519	36,711
ICMM-GN1	0	485	24,304	253	10,458	0	1,211	36,711
ICMM-GN2	0	485	24,304	253	10,458	0	1,211	36,711
ICMM-MA2	0	0	0	0	3,998	0	32,713	36,711
ICMM-MA1	0	604	7,852	16,586	10,458	0	1,211	36,711
ICMM-SO	692	5,045	19,237	253	10,719	0	765	36,711
ICMM-SB	0	602	3,256	21,291	10,351	0	1,211	36,711
ICMM-SU	544	3,189	21,163	253	10,351	0	1,211	36,711

Comparing the land suitability classes of 15 crops through five models and averaging the areas of each class, maize (long cycle varieties) and rice, paddy are found to have the highest percentage of N against the other crops: 90% and 92%, respectively. On the other hand, the crops with over 20% of (S1+S1/S2+S2) are bulrush millet, cotton, cashew, groundnuts (short cycle and long cycle varieties), sorghum and sunflower (Figure 8.4-8).



[Figure 8.4-8] Composition of Land Suitability Classes by Crop

Besides, Unsuitable land units, for instance, lots of lower clayey imperfectly to very poorly-drained ones in Zone C are disadvantageous for cultivation, therefore some additional measures such as soil amendments to improve soil properties, site-specific irrigation/drainage plans are necessary for them to be cultivated better.,

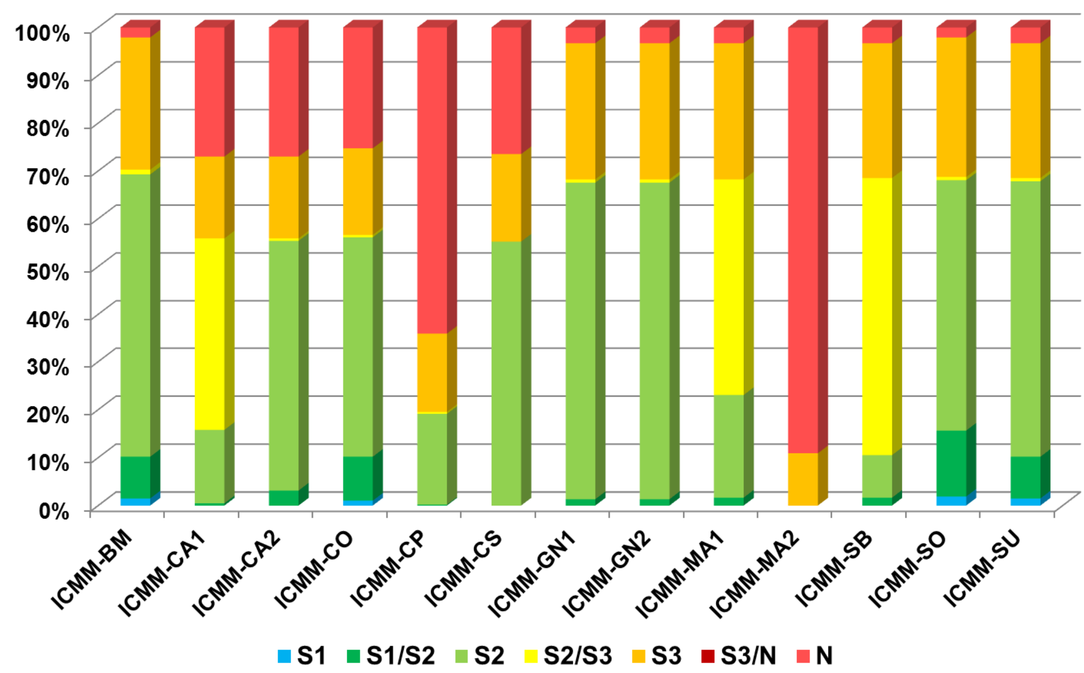
Land suitability for irrigated cultivation under modern management

Irrigated cultivation under modern management (ICMM) adds proper embankment and drainage channel construction to ICIM model suppose that land units are safe from flooding and drainage can become better after construction. The suitability of 13 LUT/Crops have been studied for ICMM (Table 8.4-14). A total of six land qualities is used in the ICTM model, defined by 14 land characteristics.

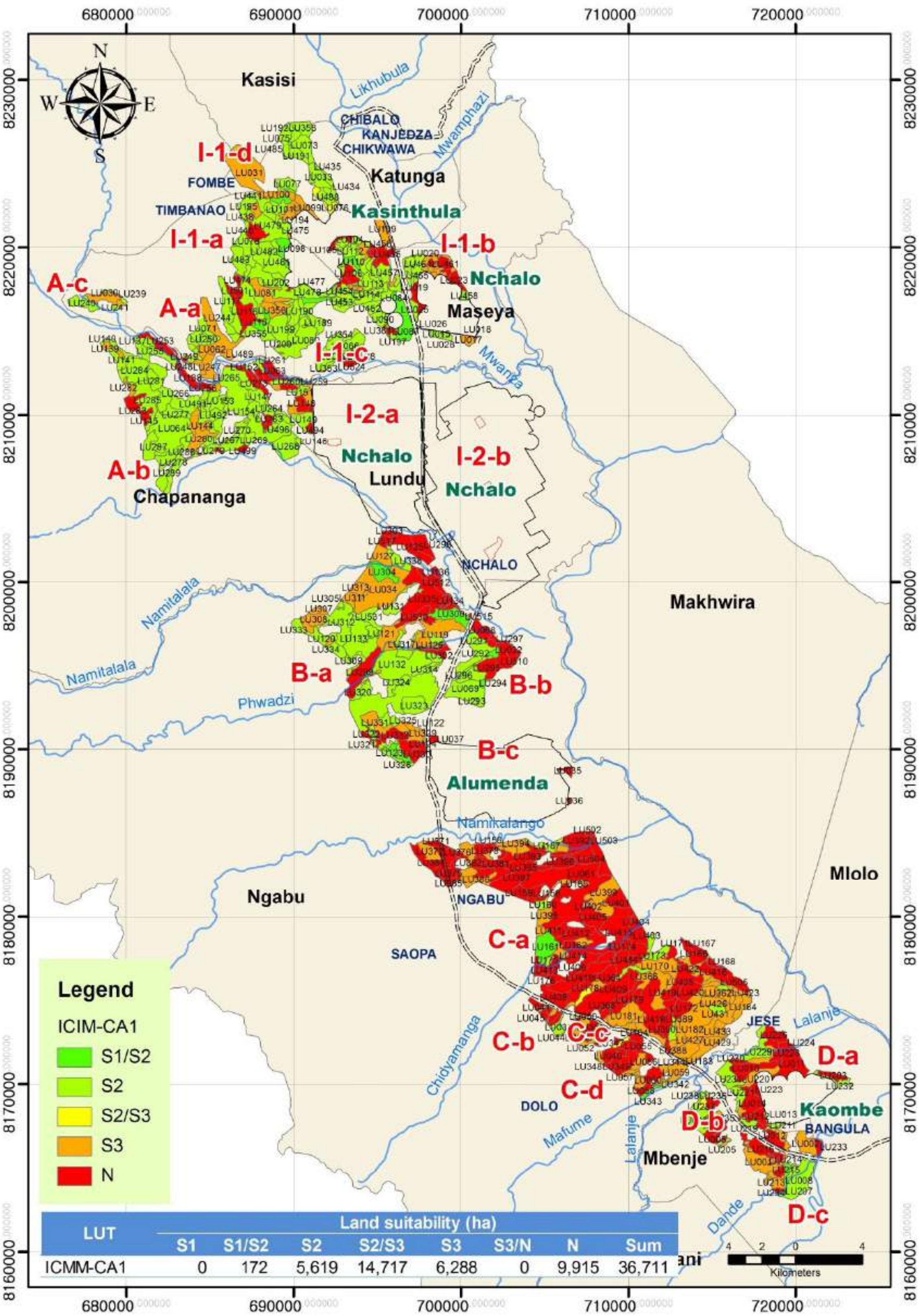
The area of Class N drops down below 20% of 7,897 ha on average for 13 LUT/Crops, which is much less proposition in comparison with the other four models. S1/S2 (highly to moderately suitable), S2 (moderately suitable), S2/S3 (moderately to marginally suitable) and S3 (marginally suitable) is 4, 40, 11 and 23%, respectively. The propositions of both S1/S2 and S2 continue to increase as S3 and N fall down, even when compared with ICIM model.

However the areas which are not suitable for some crops could be suitable for other crops. Therefore there is no area which is not suitable for any crop.

For cassava (short cycle varieties), the proposition of S2 plus S2/S3 exceeds 50% of 18,859 ha. For sunflower, groundnuts, sorghum as well as bulrush millet, the proposition of (S1+S1/S2+S2+S2/S3) is over 60% (Figure 8.4-9). S1/S2 and S2 areas of cassava and sunflower distribute mainly in Zones I-1, A, and B but they are found also in Zones C and D (Figures 8.4-10 and 8.4-11).

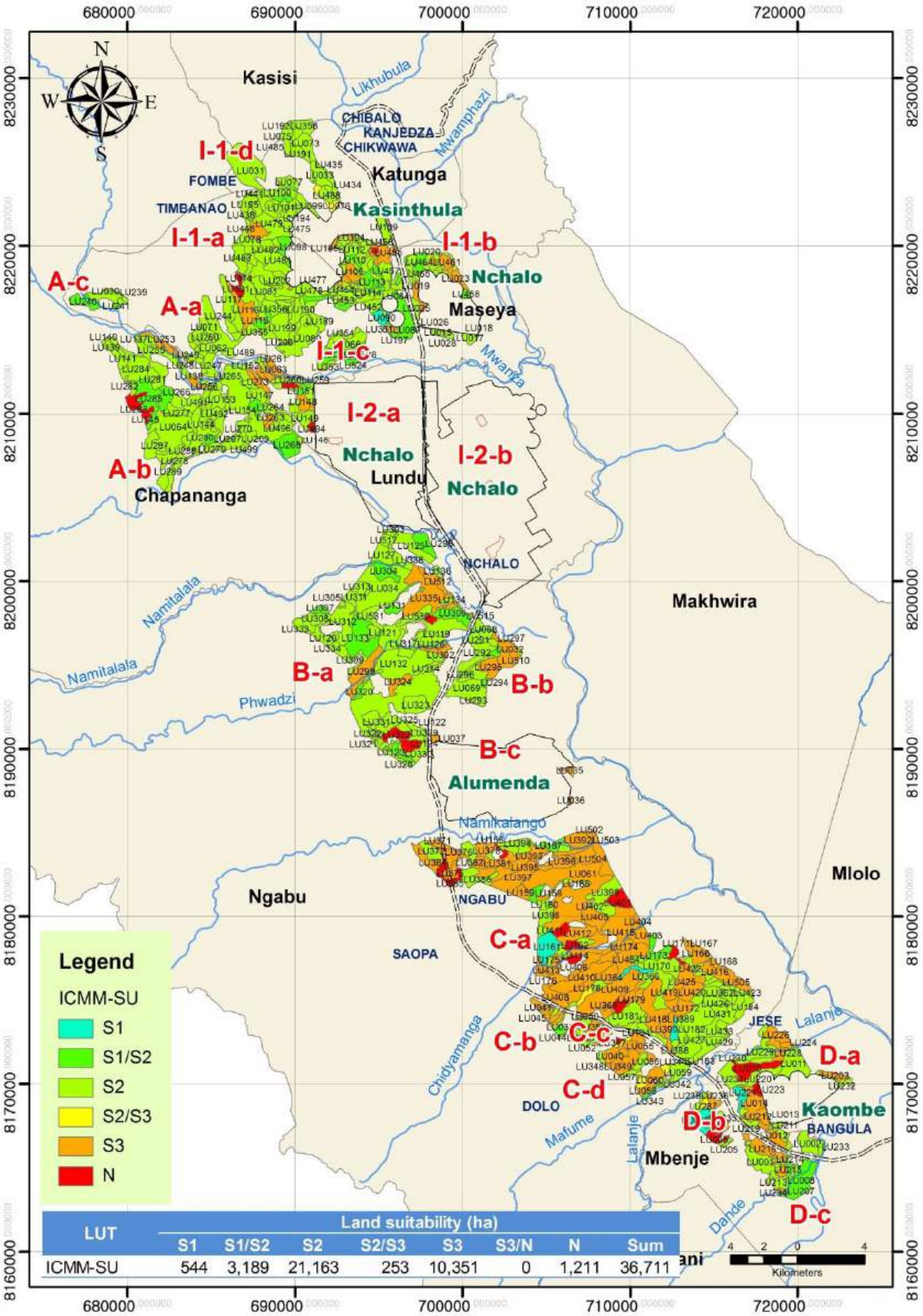


[Figure 8.4-9] Composition of Land Suitability Classes by Crop for ICMM Model



LUT	Land suitability (ha)							
	S1	S1/S2	S2	S2/S3	S3	S3/N	N	Sum
ICMM-CA1	0	172	5,619	14,717	6,288	0	9,915	36,711

[Figure 8.4-10] Land Suitability Map for ICIM-CA1



LUT	Land suitability (ha)							
	S1	S1/S2	S2	S2/S3	S3	S3/N	N	Sum
ICMM-SU	544	3,189	21,163	253	10,351	0	1,211	36,711

[Figure 8.4-11] Land Suitability Map for ICIM-SU

8.5. Flood Analysis

8.5.1. 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. The location and status of the four meteorological stations are shown in Table 8.5-1.

[Table 8.5-1] 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	

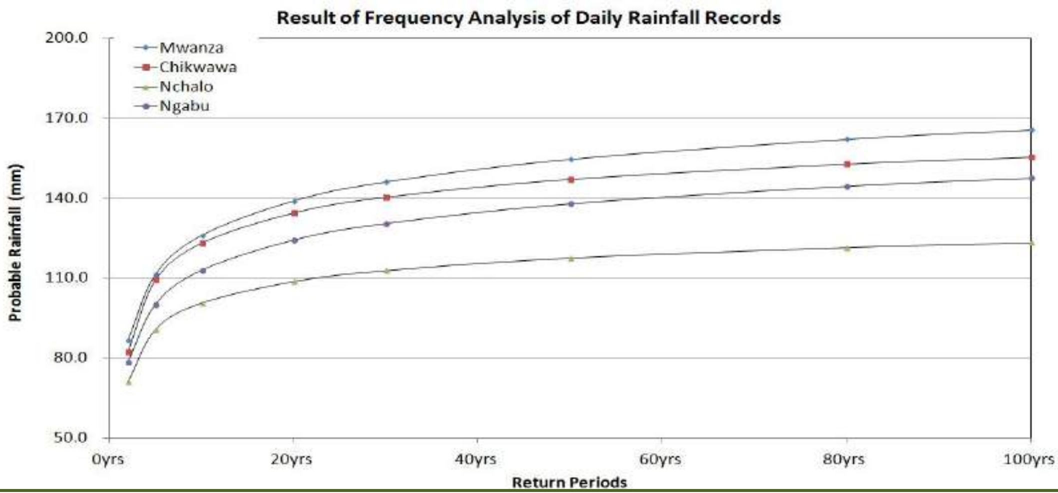
Table 8.5-2 shows monthly average and monthly maximum rainfall data from 1971 to April of 2015 at Nchalo meteorological station. It is clear from the table that the highest rainfall at Nchalo was recorded in Jan. 2015, with an average rainfall value of 706.8mm.

[Table 8.5-2] 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	0.0	0.0	0.0	0.0	1.3	8.6

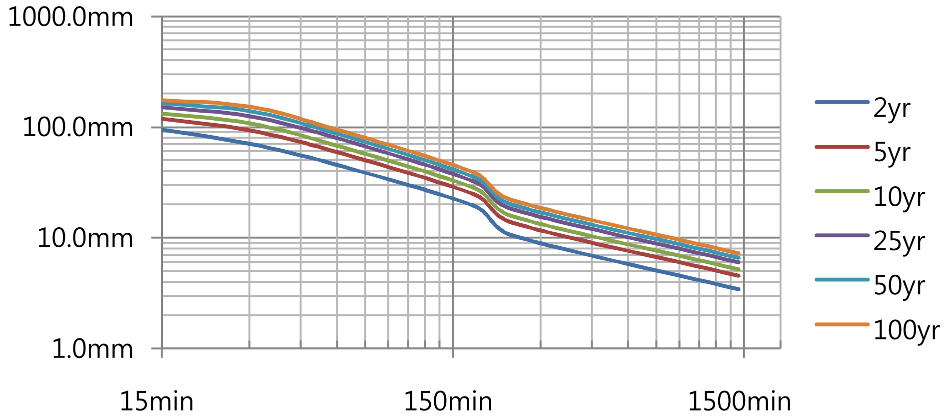
8.5.2. Probability Rainfall Analysis

In order to extract maximum rainfall values from corresponding duration curves, data collected from Mwanza, Chikwawa, Nchalo and Ngabu rainfall station 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 Figure 8.5-1.



[Figure 8.5-1] Probability Daily Rainfall - Frequency of SVIP Basin

Figure 8.5-2 is the rainfall intensity-duration data at lower Shire valley.



[Figure 8.5-2] Rainfall Intensity - Duration - Frequency Curves

The 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.

8.5.3. 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.

8.5.4. 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.

8.5.5. 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.

8.5.5.1. 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. The highest flood for Rivi Rivi River occurred in 1978 when 6,259m^3/s passed through gauging station 1R3.

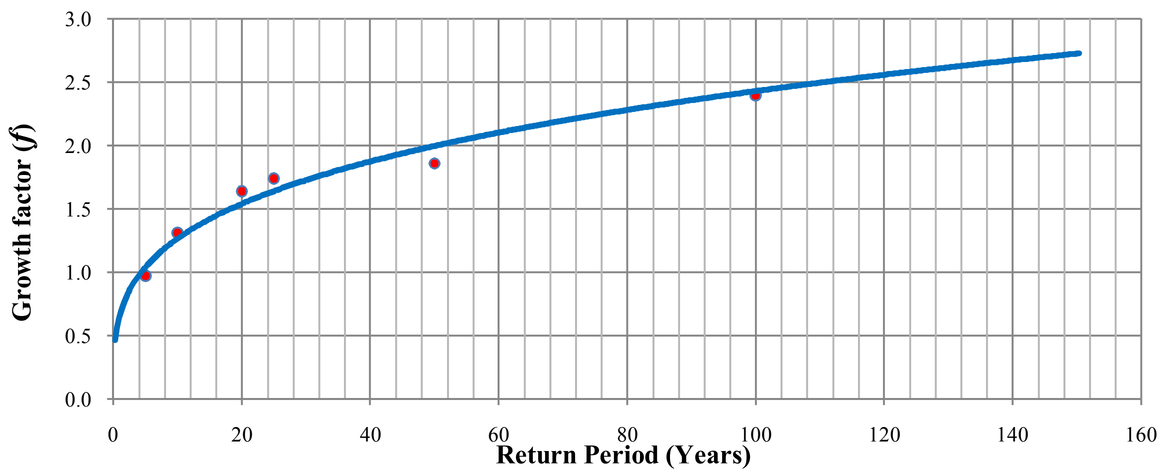
The relationship for the Rivi Rivi for instance was Q (Tr) = 1571.9 ln(Tr) – 200.33. This relationship had a correlation coefficient of 0.96. Calculations were carried out for 5, 10, 20, 25, 50 and 100 year return periods and the results are presented in Table 8.5-3.

[Table 8.5-3] Calculated Discharges in m^3/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

8.5.5.2. 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 8.5-3 below.



[Figure 8.5-3] 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.

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 8.5-4 shows the T-year flood magnitudes for the rivers under consideration.

[Table 8.5-4] 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

8.5.6. 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. 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.

8.5.7. 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 8.5-4 shows the extent of flooding in each zone by return period. These data were obtained from the flood zoning map of SVIP.

[Table 8.5-3] 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

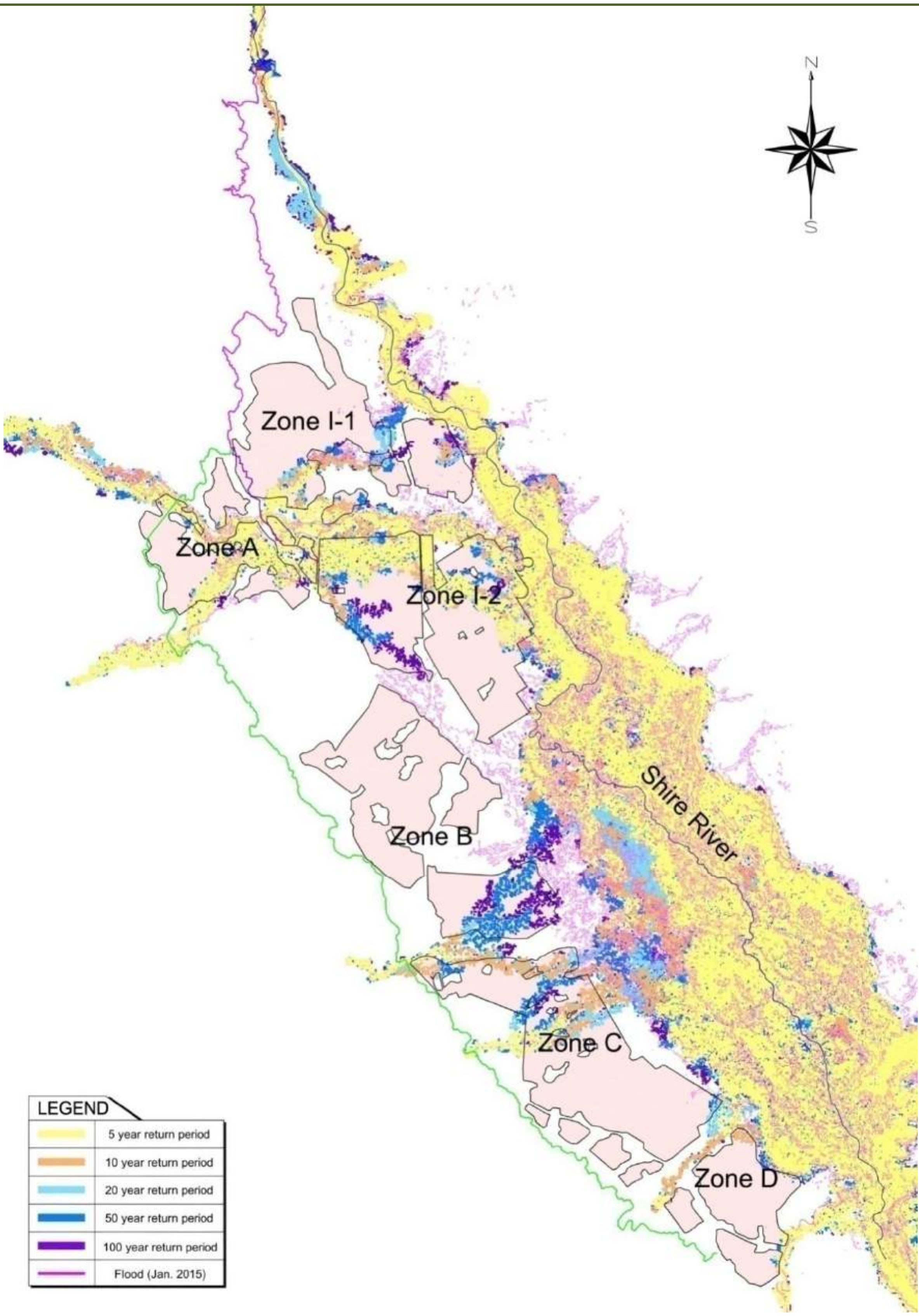
Areas likely to be effected by 10-year and 20-year frequency flood are similar to those that are affected by the 5-year flood, with some areas within Zone C.

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 8.5-4] Flood Map for the Project Area

8.6. Development of GIS

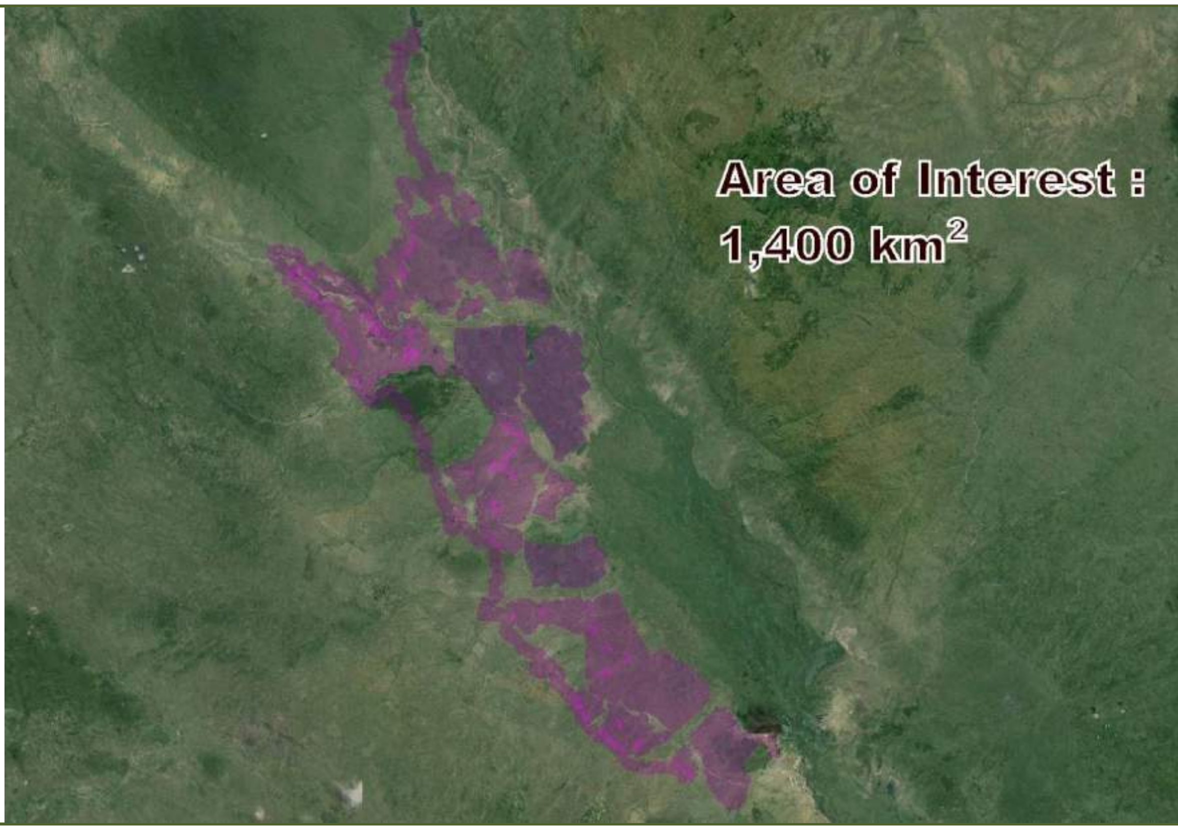
8.6.1. Work Scope

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

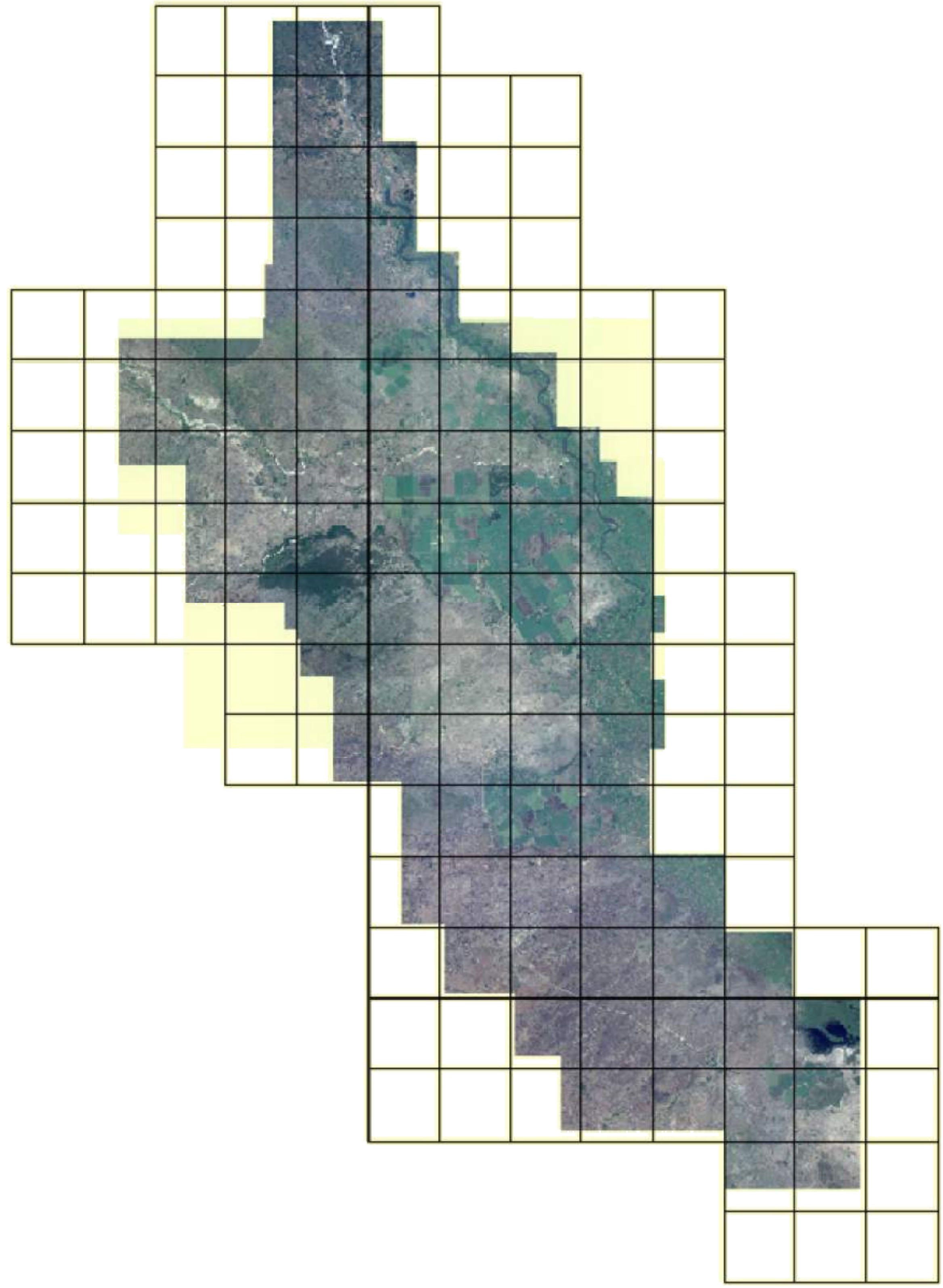
8.6.2. Area of Interest

Figure 8.6-1 shows the whole of Chikwawa area including the SVIP project area.



[Figure 8.6-1] Whole Chikwawa Area including the SVIP Project Area

Figure 8.6-2 shows the area of interest in the 1:5,000 scale map of Government of Malawi.

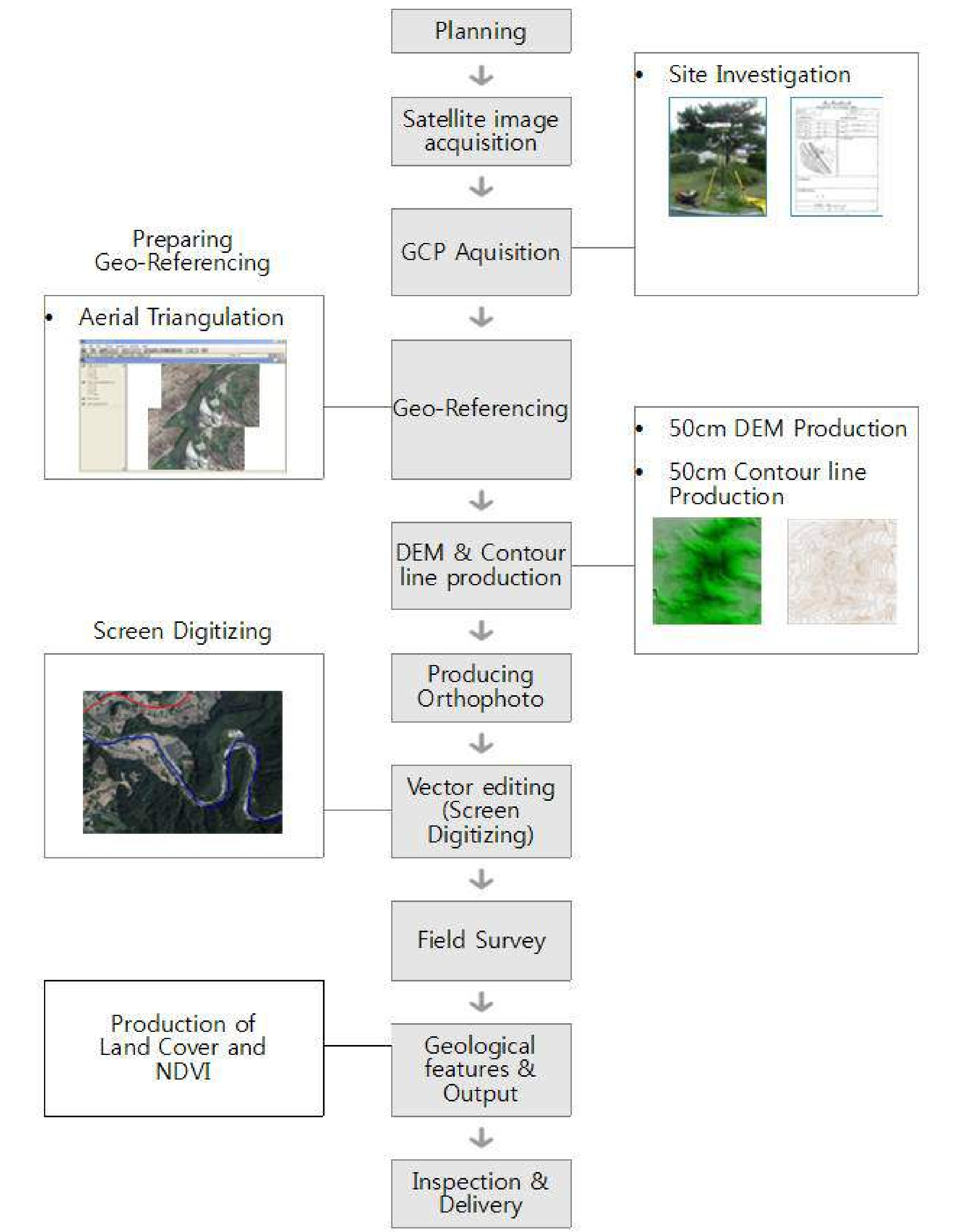


[Figure 8.6-2] Area of Interest in the 1:5,000 Scale Map of GoM

8.6.3. Methodology

Work Flow

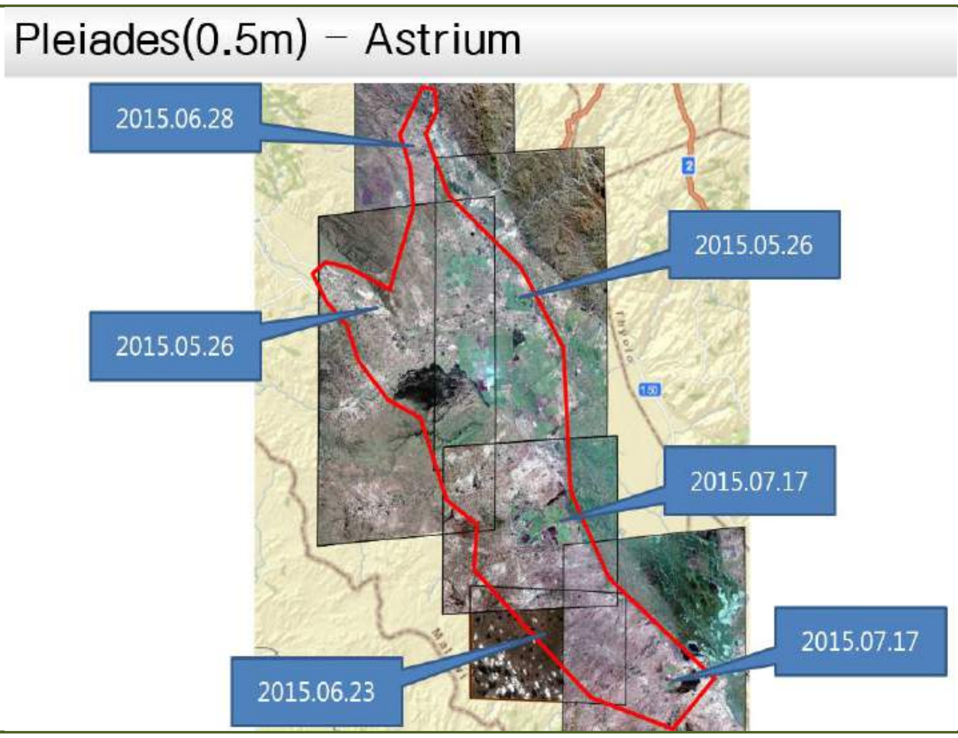
Figure 8.6-3 shows procedures adopted for GIS development.



[Figure 8.6-3] 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 8.6-4 shows the satellite images with the dates on which they were taken.



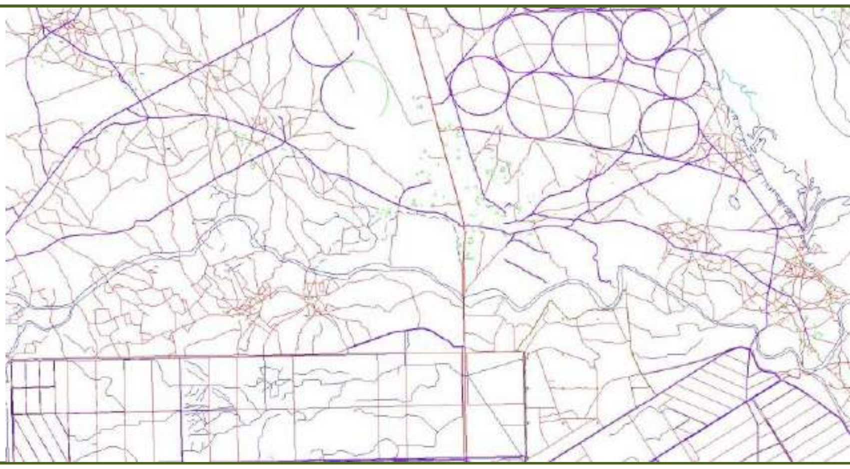
[Figure 8.6-4] Satellite Images with the Sates

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)

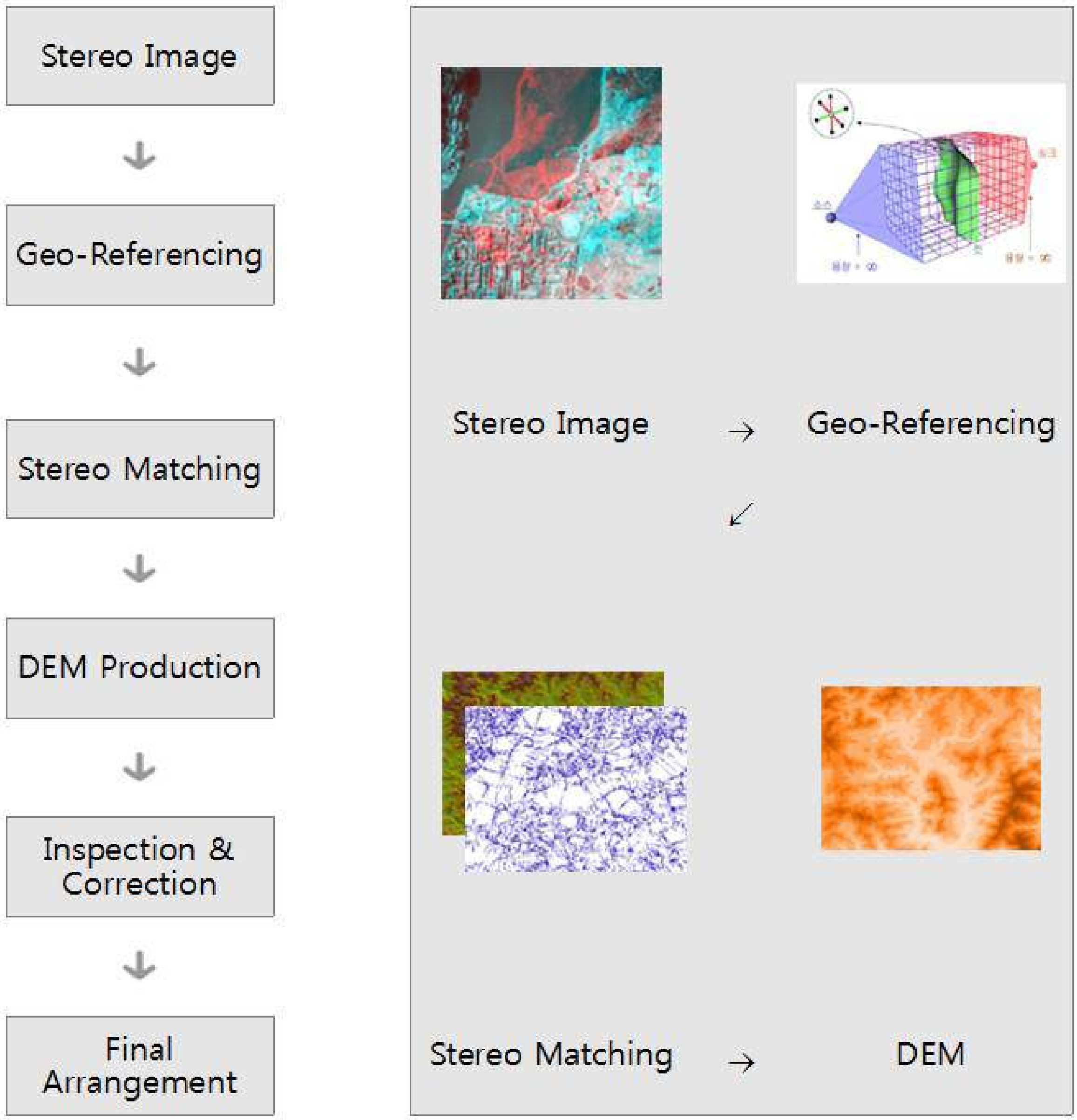
Projection is used ARC1950, and the purple line is the tracking data.



[Figure 8.6-5] Map Projection Evaluated by GPS

50cm Digital Elevation Model (DEM) Production

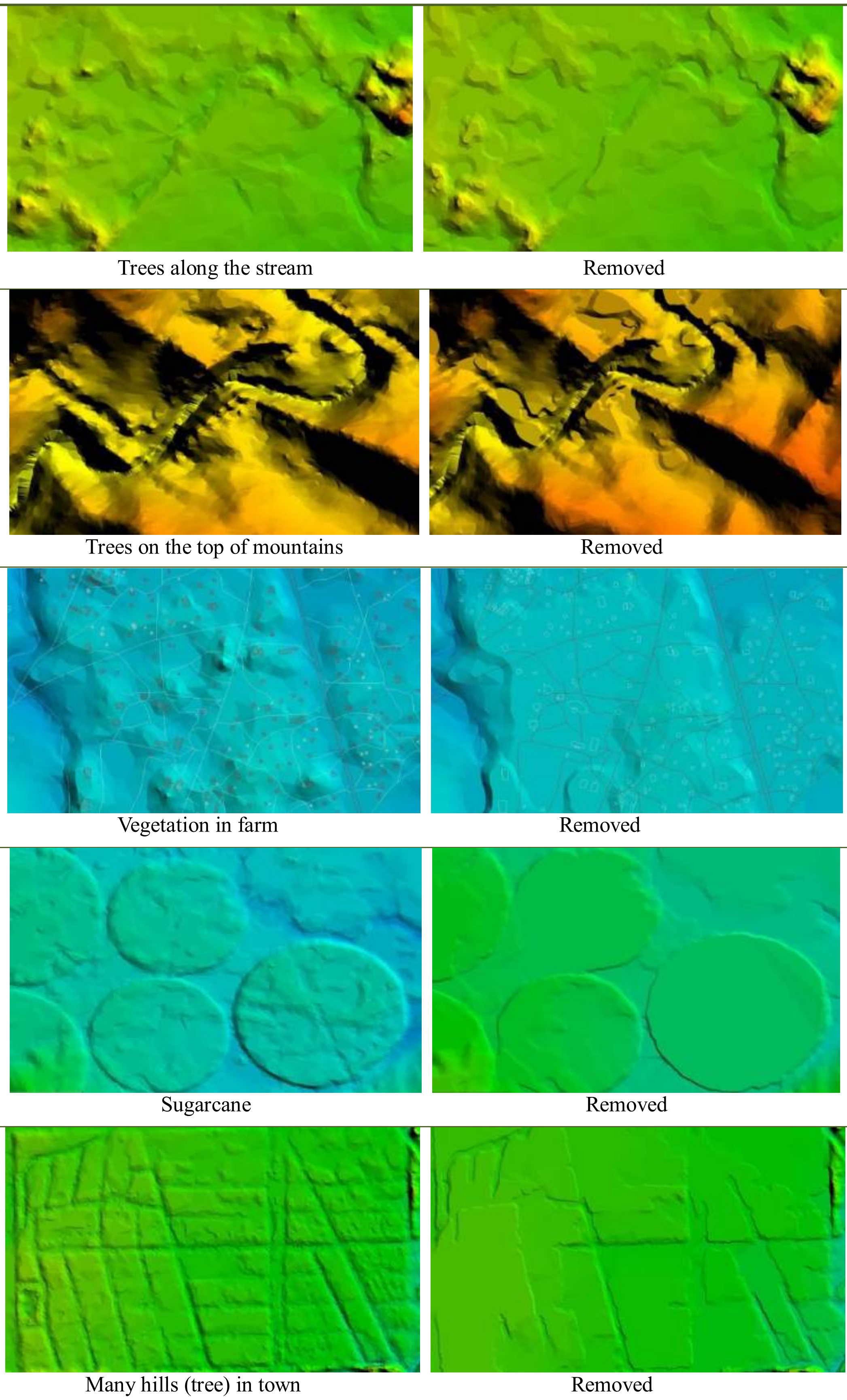
The DEM for the SVIP area was produced using existing elevation data and high resolution satellite images. Figure 8.6-6 shows the procedure adopted for the development of the DEM.



[Figure 8.6-6] 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.



[Figure 8.6-7] Contour (50cm interval) on the Bare Ground

0.5m Resolution Orthophoto Production

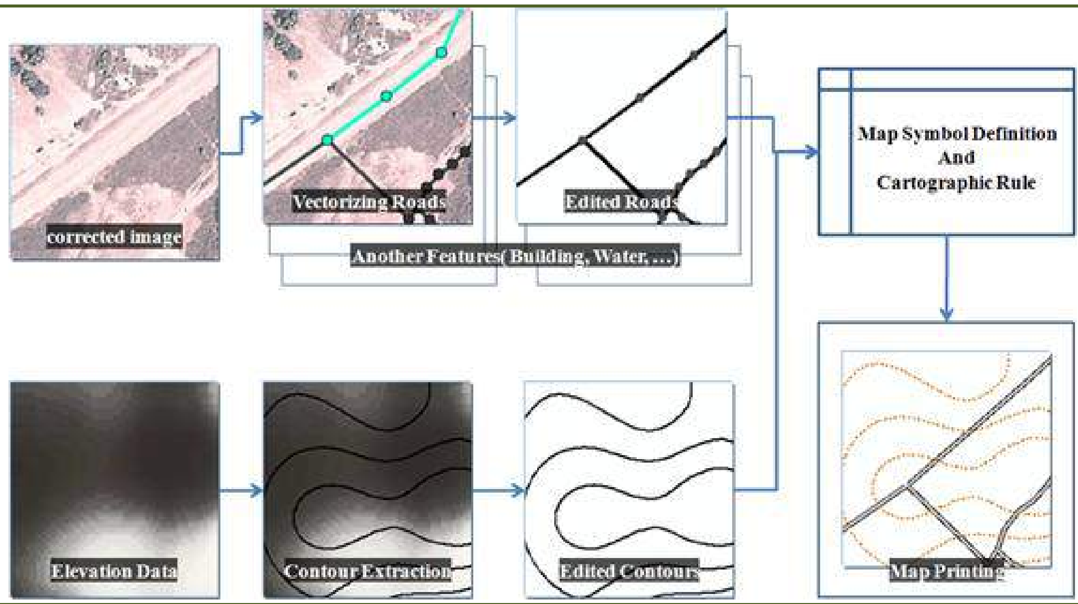
An orthophoto or orthoimage is an aerial photograph geometrically corrected ("orthorectified") such that the scale is uniform: the photo has the same characteristics as a map. Unlike an uncorrected aerial photograph, an orthophoto can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief lens distortion, and camera tilt. Table 8.6-1 shows the orthophoto production procedure.

[Table 8.6-1] Orthophoto Production Procedures

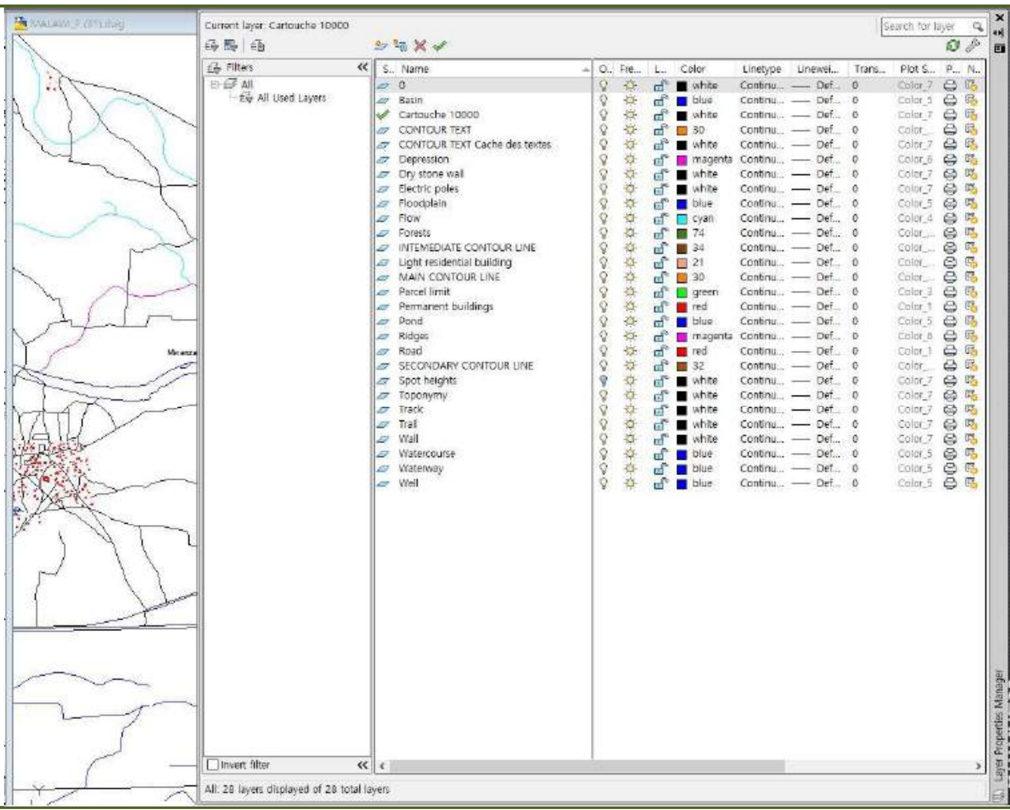
Process	Description
Planning and Preparation	- Collect aerial photograph and Aerial triangulation data - Use Direct Geo-referenced data interconnected with GPS/INS data
Input Images and Aerial Triangulation Data	- Set up coordinates - Input camera data - Input aerial photograph and Aerial triangulation 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

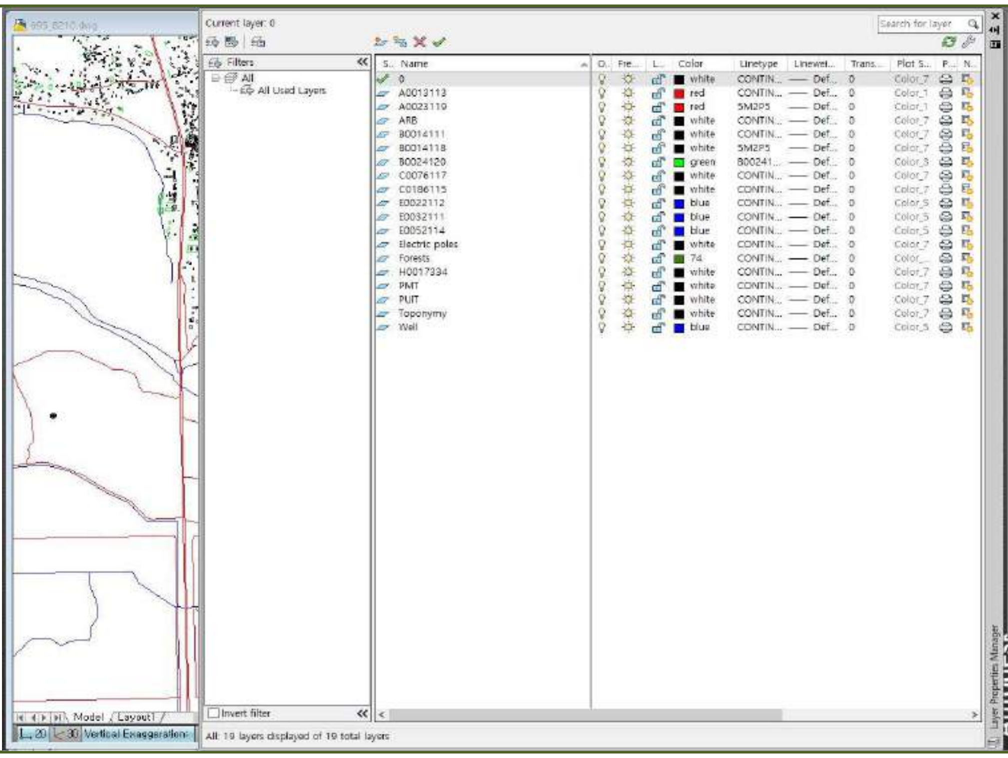
Screen digitizing is a critical process to identify features and information on images and determine extractable geographical features and to analyze correlations by using satellite images. Figure 8.6-8 shows the of vector editing procedure by screen digitizing. And the organized vector data (base map) for the GIS database is as following Figure 8.6-9 and Figure 8.6-10.



[Figure 8.6-8] Vector Editing Procedures by Screen Digitizing



[Figure 8.6-9] Digital Map Information without Layer



[Figure 8.6-10] Organized Base Map of Database (with 8 layer A~H)

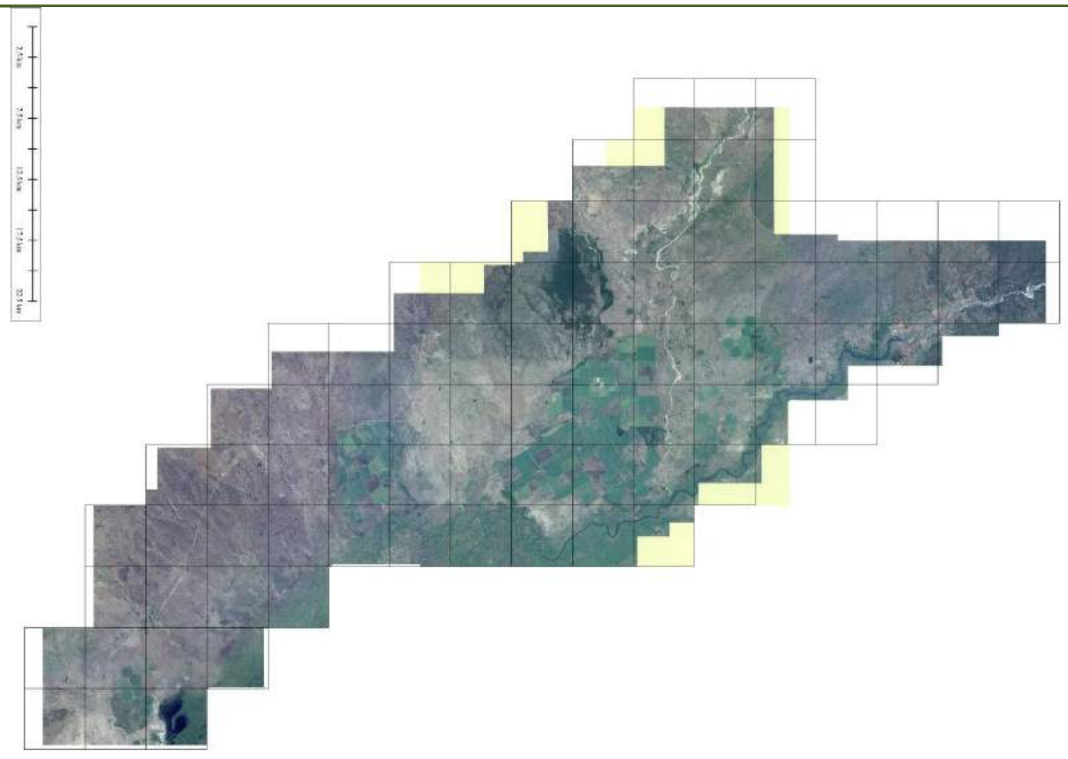
8.6.4. GIS Development

The final GIS product will contain topographic 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.

The GIS(Geographic Information System) is established using the digital base map. The base map is constructed by 'DWG' format first, because of CAD user. DWG file converted to shape file format(shp). The Shape file format is the most used geographic database format. The digital base map included 4 groups of data. This system have large 4 kinds of data group basically, 1st is Imagery, 2nd is Contour, 3rd is Vector map and last is DEM(Digital Elevation Model). It is difference with Layer but data group.

8.6.4.1. 1st Data Group: Imagery

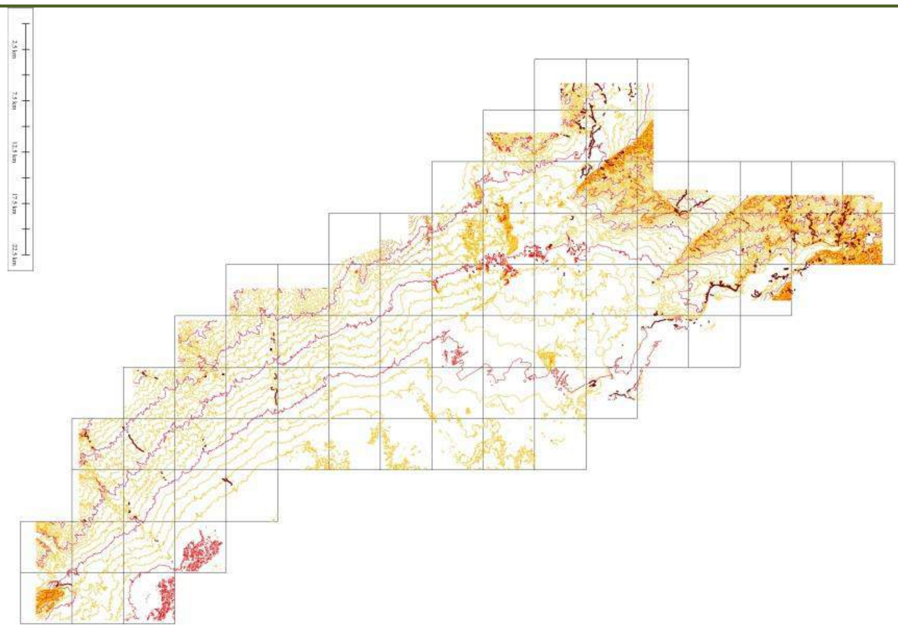
Imagery was purchased from Digital Glob company. The Image ground resolution is around 50cm. That Image was ortho-rectified with Ground Control Points. A total of 24 control points were used out of 28 ground survey result. (Attachment # GCP)



[Figure 8.6-11] Image Map

8.6.4.2. 2nd Data Group: Contour

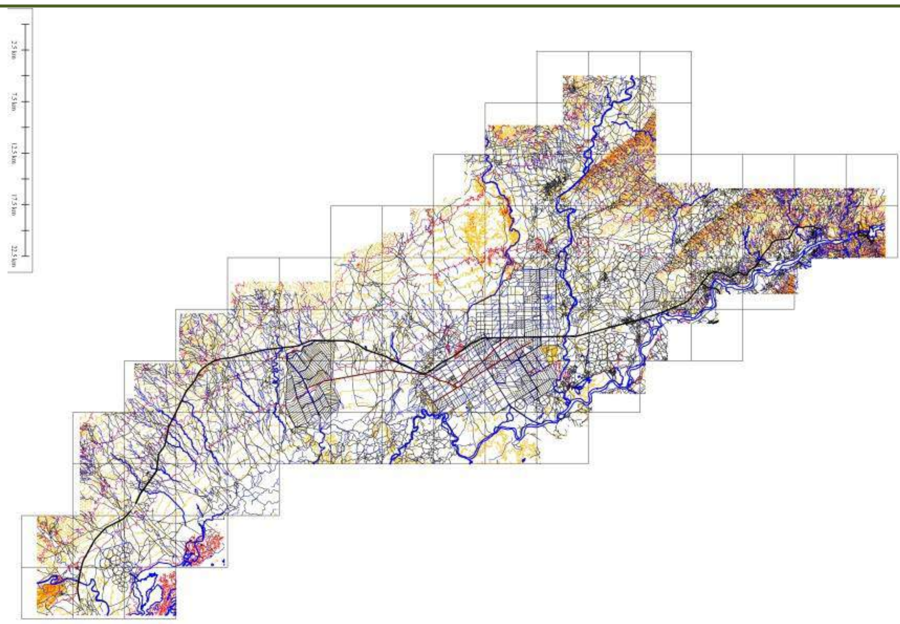
Contour was built by manually digitizing with image on the screen and spot heights were gathered by satellite. The contour interval is 50cm. when building the contours, careful precaution was taken to move the line from the top of trees to the ground within the farm lands. This was necessary to maintain accuracy of the results.



[Figure 8.6-12] Contour Map

8.6.4.3. 3rd Data Group: Vector Map

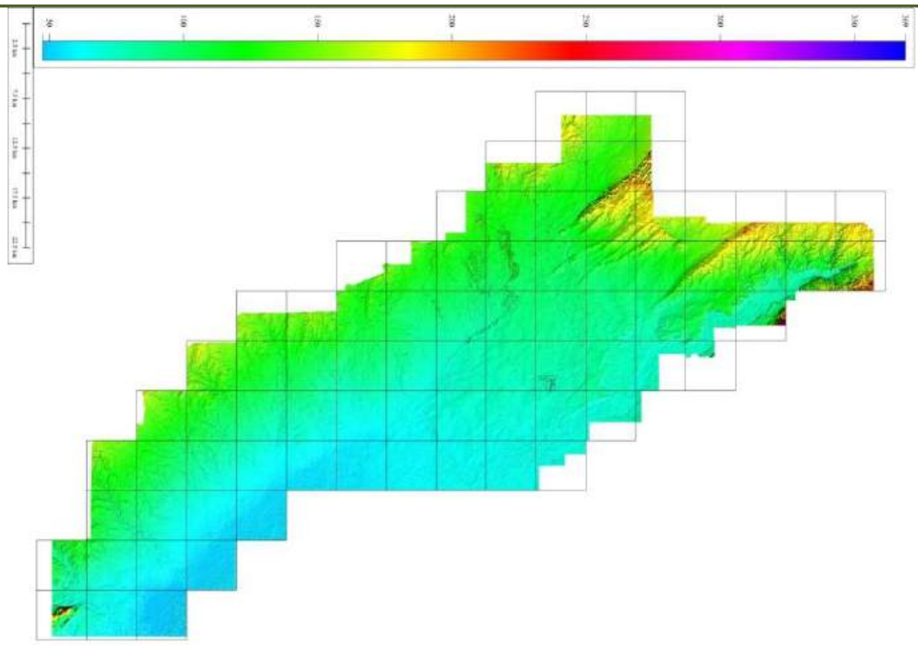
Vector map was also built by manually digitizing with image on the screen. All vector lines were defined by "National Standard of Geographic Feature Code (draft)". "National Standard of Geographic Feature Code (draft)" is flexible and built for future use. More than 200 code features are defined, and all kinds of features that might be identified in the future can be accommodated or added. All features have been grouped in 8 layers. (Attachment # National Standard of Geographic Feature Code)



[Figure 8.6-13] Digital Vector Map

8.6.4.4. 4th Data Group: DEM

Digital Elevation Model has been established with contours and spot heights. The contour lines were carefully moved from the top of trees to the ground in the middle of the farm lands, on bare ground. Therefore, the DEM is very closely showing the ground elevations. The DEM has a ground resolution of 50cm; there are spot heights at every 50cm interval.

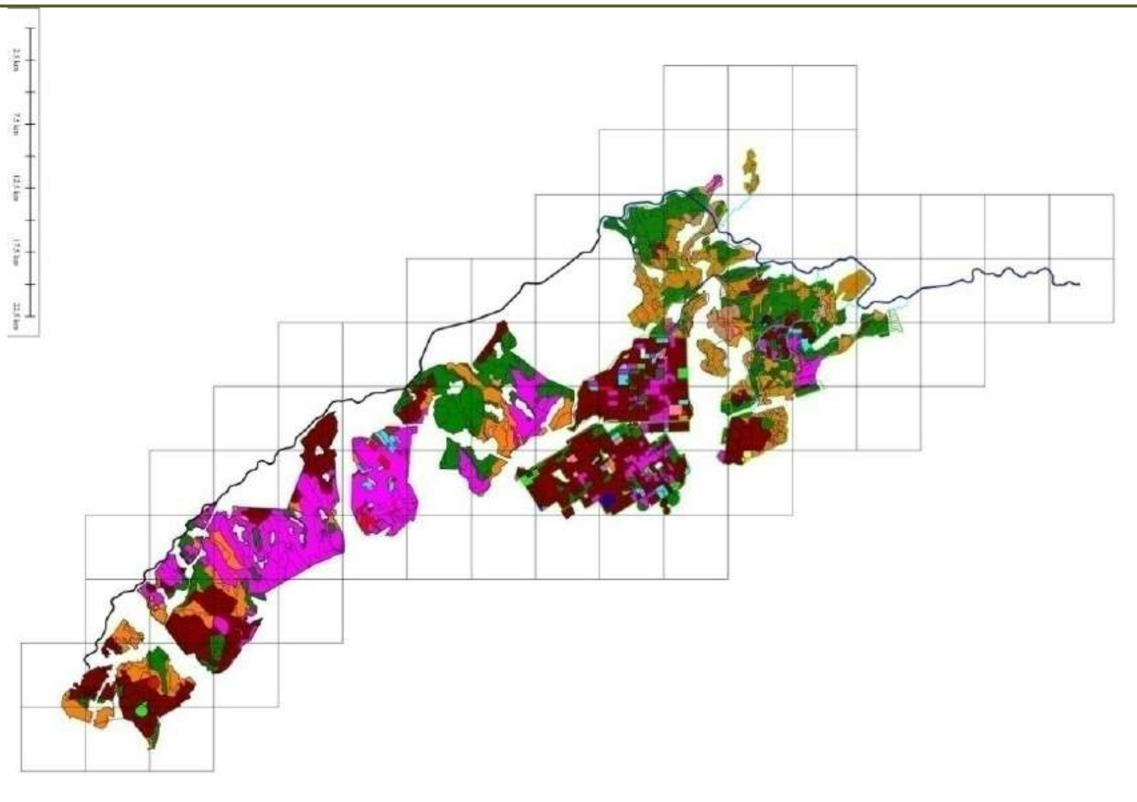


[Figure 8.6-14] Digital Elevation Model

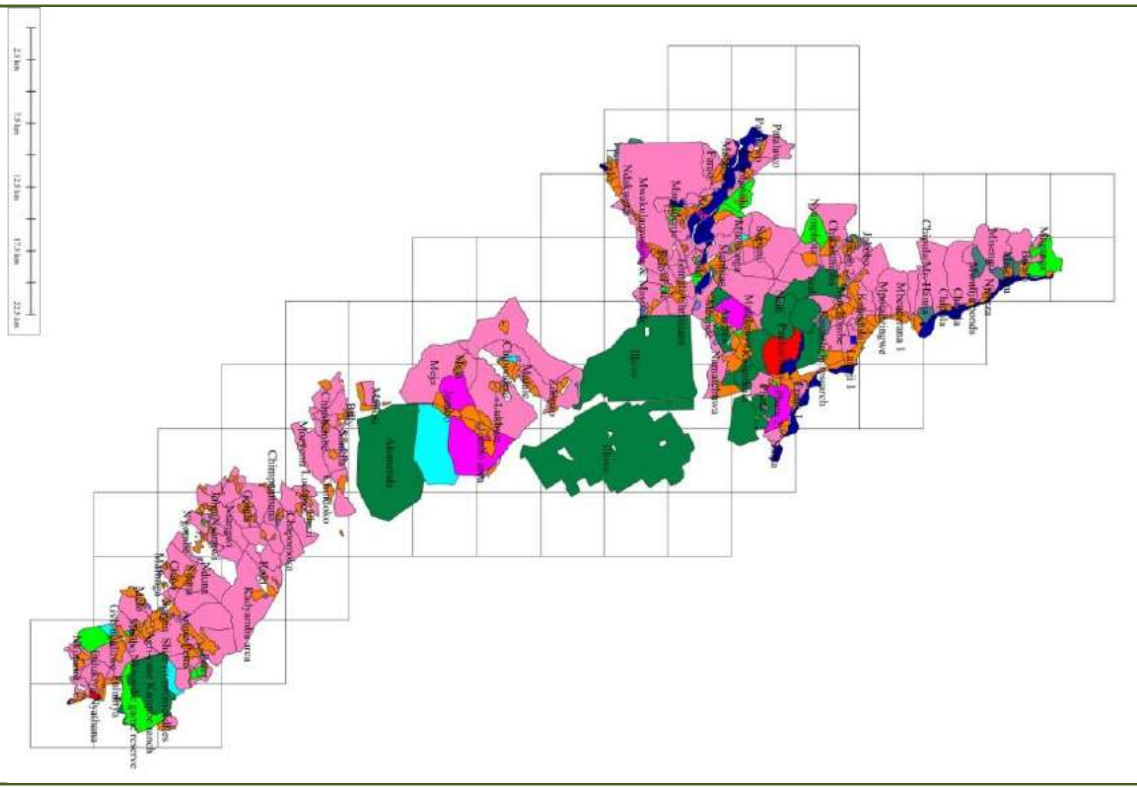
8.6.5. Additional Data Group

In addition to the four kinds of data sets: Image, Contour, Digital Vector Map, Digital Elevation Model, soil classification map and land use map have been prepared. Also included in the maps are data sets obtained from the Client, such as water points (water pump), health facilities, protected areas, primary and secondary schools.

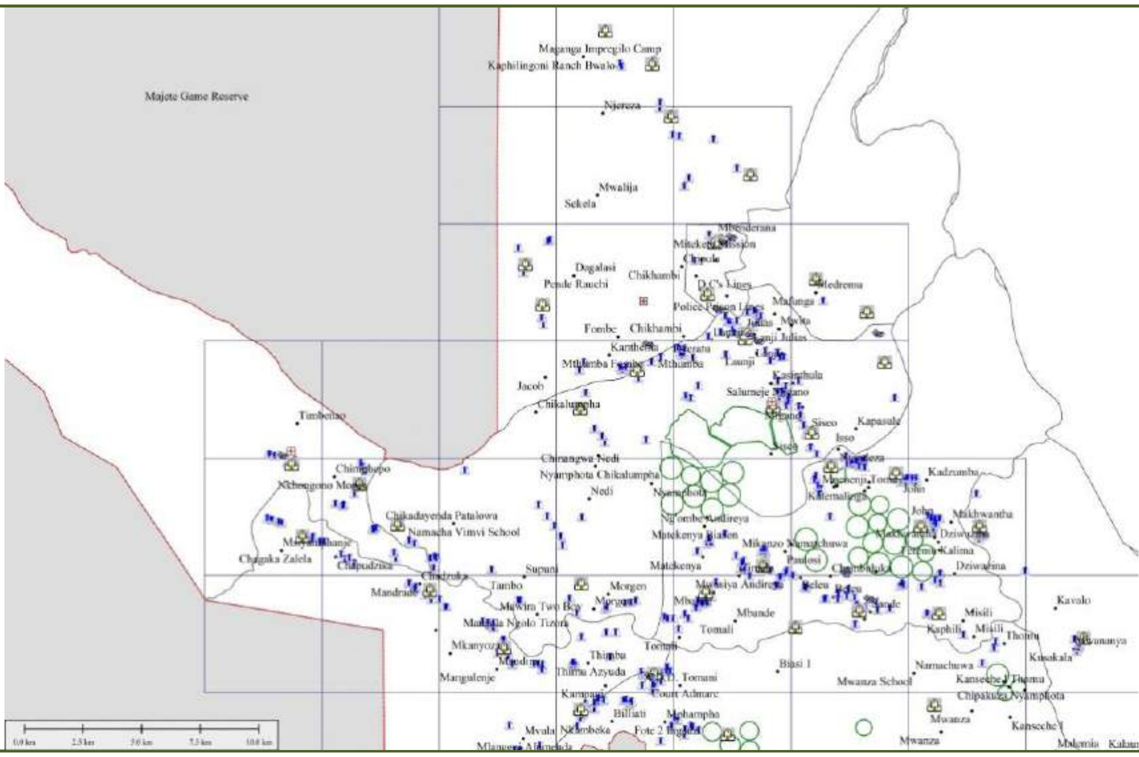
This is to demonstrate that any additional data of any type when it becomes available can be added onto the GIS overlay. The GIS base map that has been established in such a way that if somebody has data with location information, they can add on their data and analyze it with other data sets.



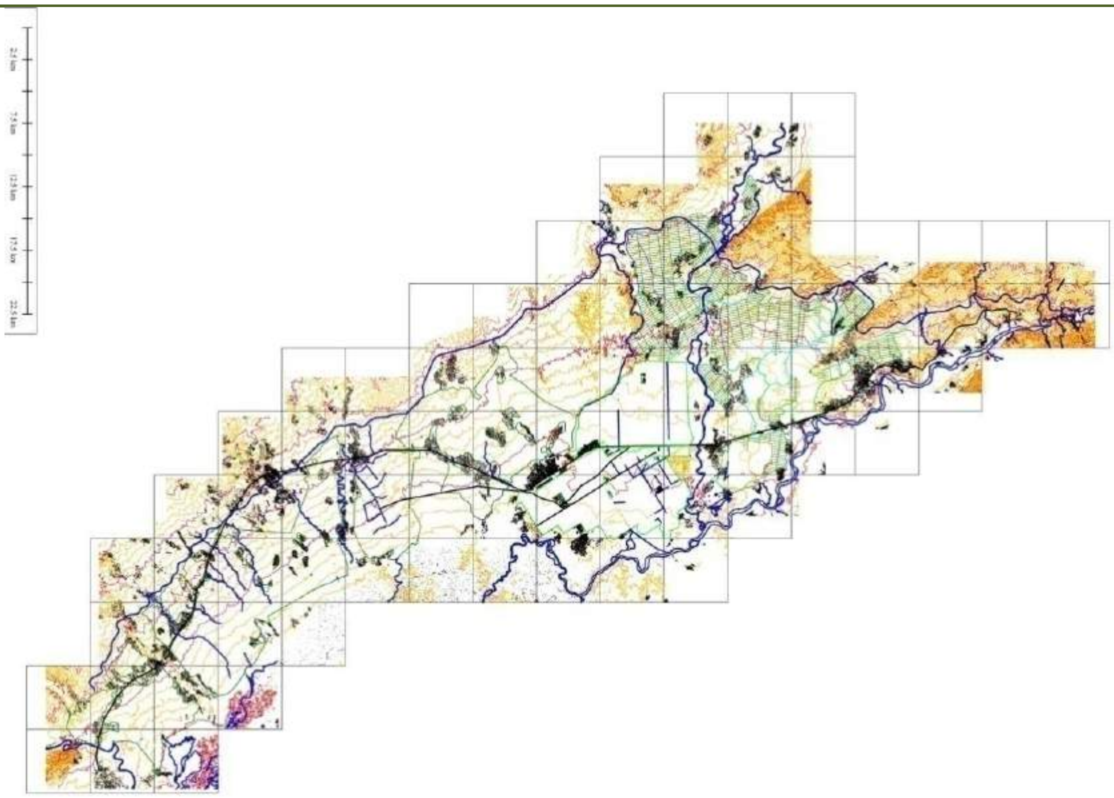
[Figure 8.6-15] Soil Class Map



[Figure 8.6-16] Land Use Map



[Figure 8.6-17] Hospital, Water Point Schools



[Figure 8.6-18] Design Lay Out of Irrigation System

8.6.6. GIS Training

In order to improve the GIS processing ability of Malawi government officials, they have been educated on how to use the delivered products.

- Date: 9th November 2016
- Place: Office of DOI
- Participants: 4 persons
- Contents of Training:

  - File Download & Install. Manual& Start guide Memory Distribution
  - File Open and button menu
  - DEM Generate & Slop, Slop direction
  - 3Dimension Viewing with DEM - Canal Line changed
  - Read Attribute with Schools (students number)
  - Read Attribute with Water Point (How many points)
  - Example of Catography With Road & Stream
  - Cutting Data by Crop in DEM

[Figure 8.6-19] Training of GIS

CHAPTER 9. ASSESSMENT OF TECHNICAL OPTIONS

9.1. With / Without Illovo Estate

9.1.1. 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 12,759 ha of land planted with sugarcane. Illovo uses motorized 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.

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.

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 9.1-1 suggests the comparison of the whole scale of project including the design water requirement between with and without Illovo Estate.

[Table 9.1-1] 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.

9.1.2. Electricity Supply Aspect

These estates supply water to the cane fields by pumping water from Shire River. Table 9.1-2 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.

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 9.1-2] 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

9.1.3. Financial Analysis

9.1.3.1. With 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 Main canal 1 and Main canal 3 cost. Adding scale-up costs for Intake and Main canal 1 and the lining cost for Main canal 3 gives a total construction cost of 17,030,000 USD for the lined canal, and 45,730,000 USD for the pipe canal. 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 construction cost of hydro-power station producing equivalent amount of electricity, etc.

From the reference above, in the Africa region the hydropower cost varies from 1,000 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 9.1-3] 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

Annual O&M cost of pumping station of Illovo Estates (Nchalo + Alumenda + Sande + Kaombe) is estimated at 296,075USD a year 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.

Advantage in terms of Investment Recovery

As shown Chapter 4, 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.

For more details of assessment regarding including or not including Illovo refer to Option Assessment Report of KRC, July 2016.

9.2. Irrigable Areas to be Developed

9.2.1. 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.

Though there is no affirmative value on the reduction rate, 80~85% could be empirically acceptable. In this study the net irrigation areas was estimated at 85% of Gross areas except Illovo Estate zone.

[Table 9.2-1] 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**

9.2.2. Factors to be Considered

Topography

By using the digital topographic maps outlines were drawn of developable irrigation areas, a canal line connecting each irrigation area with the Main canal 1 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.

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

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

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.

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.

Because the irrigation system will provide more favorable conditions of water supplying and passages for cattle breeding.

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. Based on a 10-year flood, which is the standard for evaluating the vulnerability of farming land to flooding, most of the adjacent areas to the Mwanza River are prone to flooding, in particular the area around Illovo Sugar Estate at Nchalo. In areas that are vulnerable to floods, there may be need to implement structural measures for flood mitigation to curb flooding.

9.3. With / Without Lining the Main Canal 1

9.3.1. Factors to be Considered

The main canal 1 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 9.3-1 lists the details of each canal type.

[Table 9.3-1] 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

[Table 9.3-2] 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)

Hydraulic Conditions

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 Main canal 2. Thus, the altitude of the Main canal 2 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 Main canal 1 and Main canal 2 will have many structures such as drains, siphon and curved sections. This is so because the terrain that will be traversed by the Main canal 1 comprises complex mountainous environments. These structures have to be carefully designed because they cause a lot of energy losses in the conveyance system.

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 main canal 1.

[Table 9.3-3] 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	2,580	45	0.291
6	6.52	225	1,660	45	0.187
7	6.52	225	2,160	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 9.3-3, 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 main canal 1 with concrete.

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. This could be a major cause of high construction cost.

Conclusion

The geotechnical investigation carried along the main canal 1 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 recommended.

9.4. Main Canal Optimization

9.4.1. 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 Main canal 1 without Main canal 2. Zone A used to belong to Phase II in a feasibility assessment done before this TFS. If the irrigation plan of Phase I excludes Main canal 2 while including zone A, the feasibility of Phase I will greatly increase, but things will become unfavorable to Phase II.

Zone A is divided into the northern part and the southern part by Mwanza river. And the southern part cannot be irrigated by the Main canal 1. In order to supply water to this region, it is necessary to cross Mwanza river by connecting the Main canal 1 to the starting section of Main canal 2.

9.4.2. Methods of Crossing Mwanza River by Main Canal 2

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

[Table 9.4-1] Comparison of Two Options for the Main Canal 2 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.

Table 9.4-1 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. Both options have their own pros and cons. But Option 1 is more advantageous than Option 2, which would cause additional construction cost by extending the canal.

9.5. Phasing of the Project

9.5.1. Proposed Phasing of the Project

The implementation of SVIP will be divided into Phase I and Phase II. 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.

[Table 9.5-1] 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	508 ha
		A-b	3,919 ha	3,352 ha
		A-c	179 ha	157 ha
		A-d	246 ha	198 ha
		A-e	241 ha	204 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**

9.5.2. Alternatives for the Phasing of the Project

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.

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. This alternative makes it possible to supply water to new region along the canal and also in Nsanje District.

Third Alternative for the Phasing

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.

Fourth Alternative for the Phasing

This alternative involves excluding Illovo Sugar Estate and extending the Main canal 2 to Nsanje District. 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.

9.6. Type of Cropping Patterns

9.6.1. Chikwawa and Nsanje Districts

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.

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.

The main challenges to increased agricultural productivity are low rainfall, dry spells, high temperatures. 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.

9.6.2. Agro-Ecological Characteristics of the Shire Valley Region

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. 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 37^{o}C. High temperatures increase evapotranspiration.

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. 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.

9.6.3. Cropping Pattern for SVIP

Crop Selection

The crop recommendations are based on the following considerations:

- suitability to climate and soils;
- crop viability – gross margin analysis;
- 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.

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 9.6-1. 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 9.6-2). 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.

[Table 9.6-1] 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 + Suppleme ntary irrigation	Nov-April/May	Maize, cotton, sorghum, vegetables, pigeonpea	Drought tolerant, early maturity varieties adapted to low attitud e areas, grain quality	Early maturing varieties have lower yield potential compare d to long duration varieties
	Nov-May	Cotton	Preferred by market; quality o f 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 var ieties with good cooking quality e.g. Faya, Kilombero; high de mand (markets); sensitive to ph otoperiod	Low yield potential; producti on can be increased with mor e acreage and good agricultur al practices
Irrigation	April-July & July-October	Maize	Plant both early and medium du ration maize varieties	long duration variety may nee d 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 pote ntial	High demand for irrigation w ater when temperatures are ve ry high
	June –Oct	Rice		High water requirement; varie ties not sensitive to photoperi od

[Table 9.6-2] 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

9.6.4. 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 support with investment in processing plants for value addition, diversification of products and to reduce postharvest losses.

9.7. Type of Field Irrigation System

9.7.1. Current Situation

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 9.7-1 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.

[Table 9.7-1] 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

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.

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.

9.7.2. 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.

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.

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.

9.8. Use of Other Resources

9.8.1. 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 9.8-1 shows the name of river, location, basin area, and type and size of structure to be installed.

[Table 9.8-1] 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

9.8.2. Water Balance of Reservoirs

Runoff Estimation of SVIP Project Area

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". Water balance analysis shows that at all the 10 places the storage capacities of dams are unable to supply water.

Nthumba, Phwadz, and Thangadzi are the most favorably located. However, there is 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.

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.

Using the NWR Master Plan the sediment inflow into the dam was estimated (Table 9.8-2).

[Table 9.8-2] 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%

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. The Table 9.8-2 shows that most of dams will have very severe sediment problems.

9.9. With / Without Maintaining Current Pumping System

9.9.1. 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.

Kasinthula (1,429 ha) and Sande Ranch (750 ha) are located in Zone I-1 and pumps water for agriculture from Shire River. Nchalo estate (9,995 ha) of Illovo is located in Zone I-2 and pumps water for agriculture from Shire river. In zone B, Alumenda Estate (2,764 ha) pumps the irrigation water from Shire River. In zone D, Kaombe Estate (819 ha) pumps irrigation water from Shire river.

9.9.2. Technical Aspects

Table 9.9-1 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 9.9-1] 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)

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.

9.9.3. 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 10. WATER REQUIREMENTS AND WATER AVAILABILITY FOR SVIP

10.1. Irrigation Water Requirement

10.1.1. Assessment Factors for Water Requirement

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. SVIP area has 3 meteorological stations, one located at Chikwawa Boma, another at Nchalo Illovo and the third at Ngabu. For the Temperature, Wind, ETo and Rainfall data, Nchalo Illovo data were used. For Humidity, the data of Chikwawa Boma, Ngabu Meteorological Center were used.

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 will 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 project area and the results are presented in Table 10.1-1.

[Table 10.1-1] Areas of Crops for the Water Requirement

<table>
<tr><th rowspan="2">Total</th><th colspan="3">Sugarcane</th><th colspan="3">Cotton, Maize, Bean, Tropical Fruits</th></tr>
<tr><th>Total</th><th>Existing</th><th>New</th><th>Total</th><th>Existing</th><th>New</th></tr>
<tr><td>43,370 ha</td><td>19,083 ha</td><td>15,757 ha</td><td>3,326 ha</td><td>24,287 ha</td><td></td><td>24,287 ha</td></tr>
<tr><td>100%</td><td colspan="3">44%</td><td colspan="3">56%</td></tr>
</table>

<table>
<tr><th>Division</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th></tr>
<tr><td>Pattern Ⅰ</td><td colspan="12">Sugarcane(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 10.1-1] Cropping Pattern for the SVIP

Irrigation efficiency and crop water requirements vary depending on the type of irrigation system adopted. The TFS team has agreed with the client to estimate water requirement using furrow irrigation to the whole SVIP area. TFS has selected the following irrigation efficiency considering standards described above and many local conditions: Ea=64%, Ed=90% and Ec=90%, where Ea is application efficiency, Ec is conveyance efficiency, Ed is distribution efficiency. According to FAO standard, it is considered to be appropriate efficiency if the value obtained by multiplying Ea, Ed and Ec falls within a range of 50 to 60%. If Ea is multiplied with Ed and Ec of the irrigation efficiency that TFS selected, the result so obtained is 52%, which is within the FAO standard.

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.

10.1.2. Water Demand Estimation

TFS provided data for Crop Water Demand CROPWAT 8.0 to calculate monthly requirement for the period 1971 to 2014 by using yearly meteorological data from January to December. Table 10.1-2 shows the Monthly Maximum Water Demand in Various Frequencies. In general, a 5-year frequency was applied for the water demand estimation. The unit water requirement was estimated to be 0.001153m^3/s/ha (1.153L/s/ha). The total water requirement for the project is estimated to 50.0m^3/s.

[Table 10.1-2] 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

The design water requirement 50.0 m^3/s is for the total irrigable area of SVIP. The five year drought return period corresponds to 99.6 m^3/day/ha in September. The five year drought return period has been chosen compared to 10 years which would make the design of canals to be larger in size. It is the optimum return period when other factors such as cost and benefits are considered.

The design water requirements are based to satisfy the current crops, mostly sugarcane, in the already developed areas and the standard cropping pattern of dry beans, pigeon peas, cotton, soya bean, and maize for the new areas. It has also been assumed that the irrigation methods in the already developed areas remain the same and that new areas will be developed for surface irrigation. As such, the irrigation scheme has been designed for the most conservative scenario. In practice, a mix of irrigation methods, including surface and pressurized irrigation, is expected to be developed, based mostly on farmers' preferences, crop choice, land development cost considerations (with respect to soil and topography), and water productivity considerations. It is expected that a number of farm organizations will select sprinkler (central pivot) irrigation, which is more efficient. This will provide a buffer for possible climate change when higher crop water requirements can be expected and maybe reduced water availability. The total irrigation command area can also be adjusted during phase 2 when there is more clarity on the preferred on-farm irrigation methods

10.2. Water Availability

10.2.1. Introduction

The Shire River, with an annual mean flow of 395 m^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. This value is the peak requirement, which shall be required for the month of September. The value is obtained based on the cropping Pattern and assuming an overall irrigation efficiency of 52%.

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

The Shire River is the only outlet of Lake Malawi. Lake Malawi has a surface area of 28,769 km^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 395 m^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 Nsanje where the proposed project will be. 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.

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.

10.2.2. Review of Previous Studies

Recently several hydrological studies have been conducted to assess the amount of water flow in Shire River. Some of them are summarized below:

- The Norplan Study (2013) confirms that the irrigation and hydro power water demand (320 m^3/s) shall be fulfilled 96% of exceedance probability for Scenario 2 (1934-1953: Mean free water exceeding the required quantity), and 78% of exceedance probability for Scenario 3 (Recent days, mean free water exceeding the current average required quantity). The three different scenarios, which were considered representative for potential future hydrological periods, were:
  - Scenario 1 (1900-1919): Represents an extremely dry period with very low mean freewater.
  - Scenario 2 (1934-1953): Represents a period with mean free- water higher than average water demand over the 20 year.
  - Scenario 3 (1990-2009): Represents the most recent period with mean freewater more than current average demand, but with some dry years in the period.
- Water Resources Investment Strategy, Component 1 – Water Resources Assessment (WRIS, 2011) showed that 326.8 m^3/s is 80% exceedance probability runoff of Shire River at 1L12 point of Chikwawa. Table 10.2-1 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 to be 325.7 m^3/s.

[Table 10.2-1] Runoff Review of 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)

- National Water Resources Master Plan in the Republic of Malawi (JICA, 2014) showed that for the 1L12 location (Shire at Chikwawa) the average dry-season flows of Q75 = 464.894 m^3/s, and Q97 = 390.158 m^3/s.

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

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

As may be observed, the water availability at Chikwawa location is more than Liwonde location. Chikwawa location is near Kapichira Dam and that is the reason for using the Chikwawa location data. Liwonde location data is used to appreciate the impact of tributaries between Liwonde and Kapichira Dam to the flow of the water.

[Table 10.2-2] Water Dependability at Liwonde 1B1

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

[Table 10.2-3] Water Dependability at Chikwawa 1L12

Researcher	Flow Station	Flow Equaled or Exceeded				
		90%	80%	75%	60%	50%
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 the other months. It is interesting to see if the design water is available in September. Table 10.2-4 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, Liwonde and Chikwawa, 80% probable amount water is calculated to 170 m^3/s and 413 m^3/s respectively. The 80% probability at Chikwawa which is 413 m^3/s is is greater than 337 m^3/s.

[Table 10.2-4] Flowrates of Shire River in Sep. at 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			

In the same way the available water for the other critical months of August to December has been calculated (Table 10.2-5). The water balance shows that there is sufficient water for both ESCOM, environmental flow and SVIP.

[Table 10.2-5] Water Balance for the Months of August, September and October

Item		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

10.2.4. Conclusion

As we have seen from the studies of WRIS (2011), Norplan (2013) and TFS (2016), the flow of Shire River at Kapichira Dam is sufficient for demand by ESCOM, SVIP and Environment flow of 337 m^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 growing season in September, which enables the use of smaller amount of water;
- Adjust cropping pattern to plant the crops which use less water in September;
- Change the irrigation system from furrow irrigation to sprinkler/pivot irrigation system;
- The completion of Kamuzu Barrage is expected to improve the water availability in Shire River.
- Through proper design of the cropping pattern and improvement of the irrigation efficiency, the 50 m^3/sec flow is sufficient to irrigate the whole project area.

Comment of WB

Given the long term variability, since the 1960s the high level of regulation at Liwonde was radically changed the flow patterns. In terms of the data quality issues, we understand it isn't straightforward, but we just have to describe our best professional judgement. The lake levels are similar to the mid-1990s and still much above the lows of the early 20th century, which is after a series of dry years and particularly last year's drought. However with the upgrading of the barrage and most importantly the improved regulation regime, at least there will be less spillage and less intra-annual variation. In addition, a positive thing is, there is no climatic indication that points at long term drought conditions.

The cropping patterns were established to match water availability and avoid high demand in Oct-Dec. The KRCC and NORPLAN study are in general agreement on the availability of water and the impact on energy has been assessed.

CHAPTER 11. ADAPTATION OF THE SCHEME TO ENVIRONMENTAL AND SOCIO-ECONOMIC CONSTRAINTS

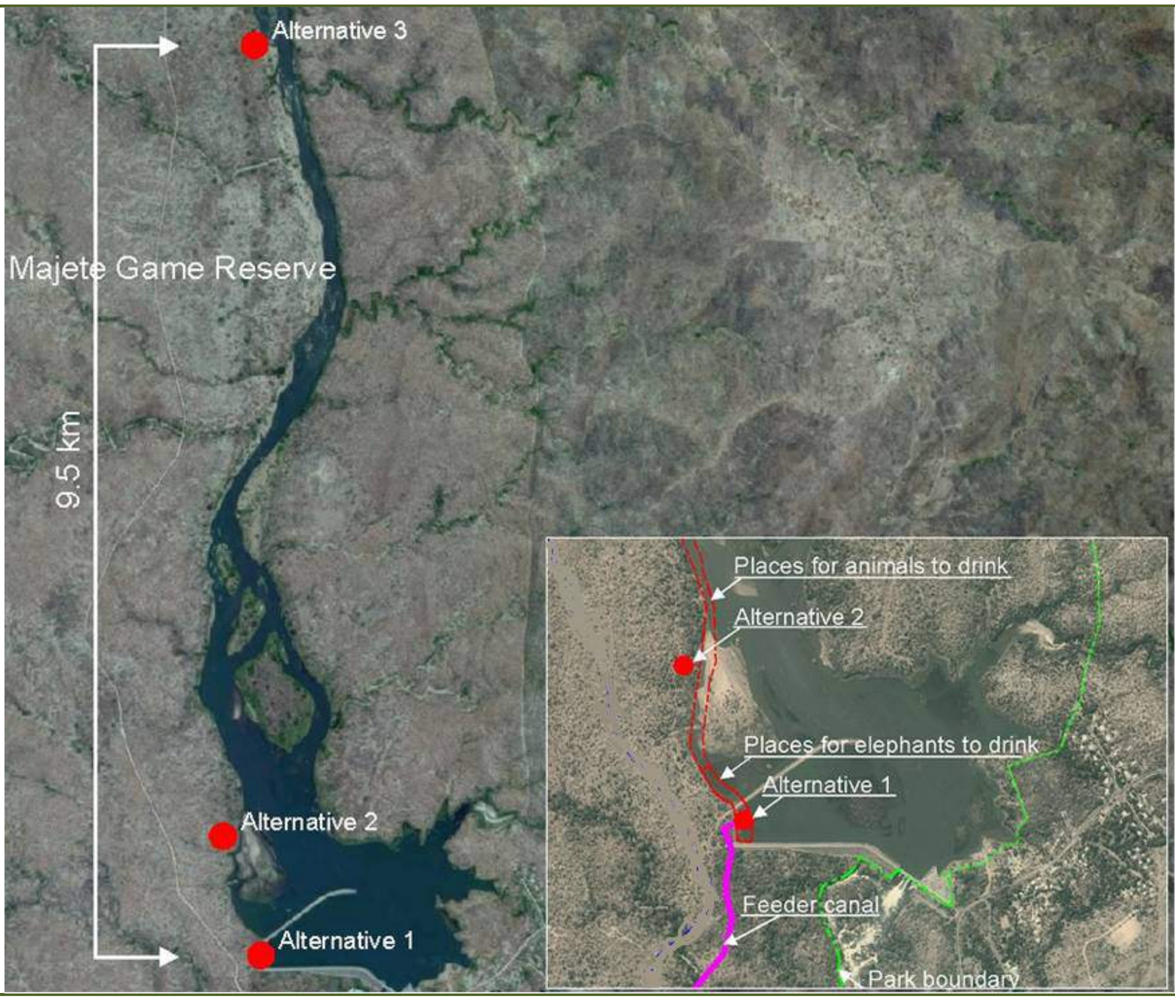
11.1. Majete Game Reserve, and Lengwe National Park

11.1.1. Majete Game Reserve

Since Kapichira dam, the water source of SVIP, is located within Majete Game Reserve, the first stretch of Main canal 1 including the intake structure shall be located in the Reserve area. Shire River, including Kapichira dam, provides water to many kinds of wild animals such as elephants, waterbucks, monkeys and impalas, therefore adverse impacts on these animals during and after the construction of the irrigation structures should be minimized

Location of the Intake Structure

Initially it was proposed to locate the intake at Hamilton Rapids upstream of Kapichira Dam as described in the CODA report(2008). The current proposal is to locate the intake on the western edge of the reservoir of Kapichira Dam as shown in Figure 11.1-1. The advantage of Alternative 1 (Fig 11.1-1) is that water can be abstracted easily and economically, has less environmental impact and is effective for O&M due to the short length of the required canal (See Table 11.1-1). To this regard, Alternative 1 was selected as the site for the intake structure.



[Figure 11.1-1] Alternative Locations of the Intake

[Table 11.1-1] Comparison of Alternative Locations of the Intake Structure

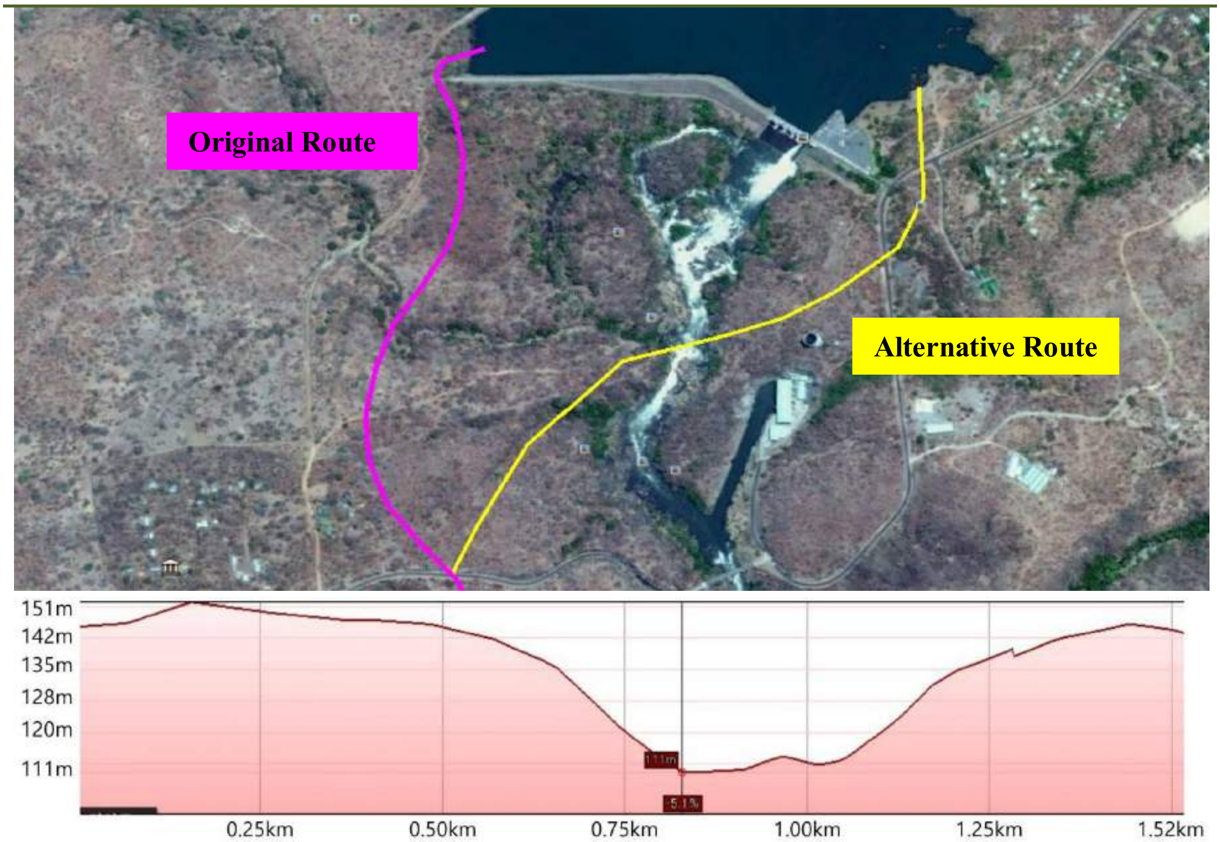
Items	Alternative 1(TFS) Current Location	Alternative 2(TFS)	Alternative 3(CODA)
Location (Figure 11.1-1)	15°53′38″ 34°44′49″	15°53′17″ 34°44′44″	15°51′10″ 34°44′49″ Hamilton rapids
Canal Length in the Reserve	About 2.2km	About 2.7km	More than 15km
Environmental Impact	Minimized impacts on animal movement 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 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 - Intake weir should be installed	- High sediment inflow - Intake weir should be installed - O&M condition is worse
Cost	Least	Medium	Highest
Feasibility	VG	G	NG

Another option for the location of intake structure is the site proposed by ESIA team on the other side of the selected location i.e. on the right hand side, where the ESCOM takes water for power generation. Regarding this, the TFS team discussed with an Engineer from ESCOM (Archibald KANDOJE, Senior engineer). He confirmed that there is no possibility for this as the site already contains many ESCOM facilities and create difficulty for having smooth ESCOM operational activities.

Apart from getting permission from ESCOM, the issue was assessed from technical point of view. In Figure 11.1-2 the yellow line is the alternative canal route which was suggested by ESIA Consultant. Table 11.1-2 shows the comparison of the two canal routes. The alternative canal route shall be longer by 230 m, and the cost will be 4.6 times higher than the original canal route. The high cost is induced from the aqueduct construction, which shall be built in the deep valley. Since the valley is covered with hard rock, the aqueduct construction will raise another severe environmental issues. Therefore, this alternative does not have any advantage as compared to the original canal route..

[Table 11.1-2] Condition of Construction for Two Canal Routes

	Original Route	Alternative Route
Length	1,280 m	1,510 m
Canal Type	Siphon: 760 m Lined open canal: 520 m	Concrete open canal: 500 m Water bridge: 1,010 m
Canal Section	B=20.2 m, b=12.7 m, H=3.3 m	B=12.7 m, H=3.2 m
Construction Cost	4,490,000 USD	20,995,999 USD



[Figure 11.1-2] Alternative Canal Route

Sound Barrier

There are also concerns by the ESIA study about noise, blasting and other disturbances during construction that may have impact on wildlife and the operation the Reserve. The geotechnical survey results indicate that no rock exist within 9 m depth of the intake structure site. Therefore no major blasting is expected during construction. However, considering these aspects the installation of a special absorptive sound wall was considered in the preliminary design and the required cost was reflected in the project cost estimate.

Main Canal 1 Route and Type

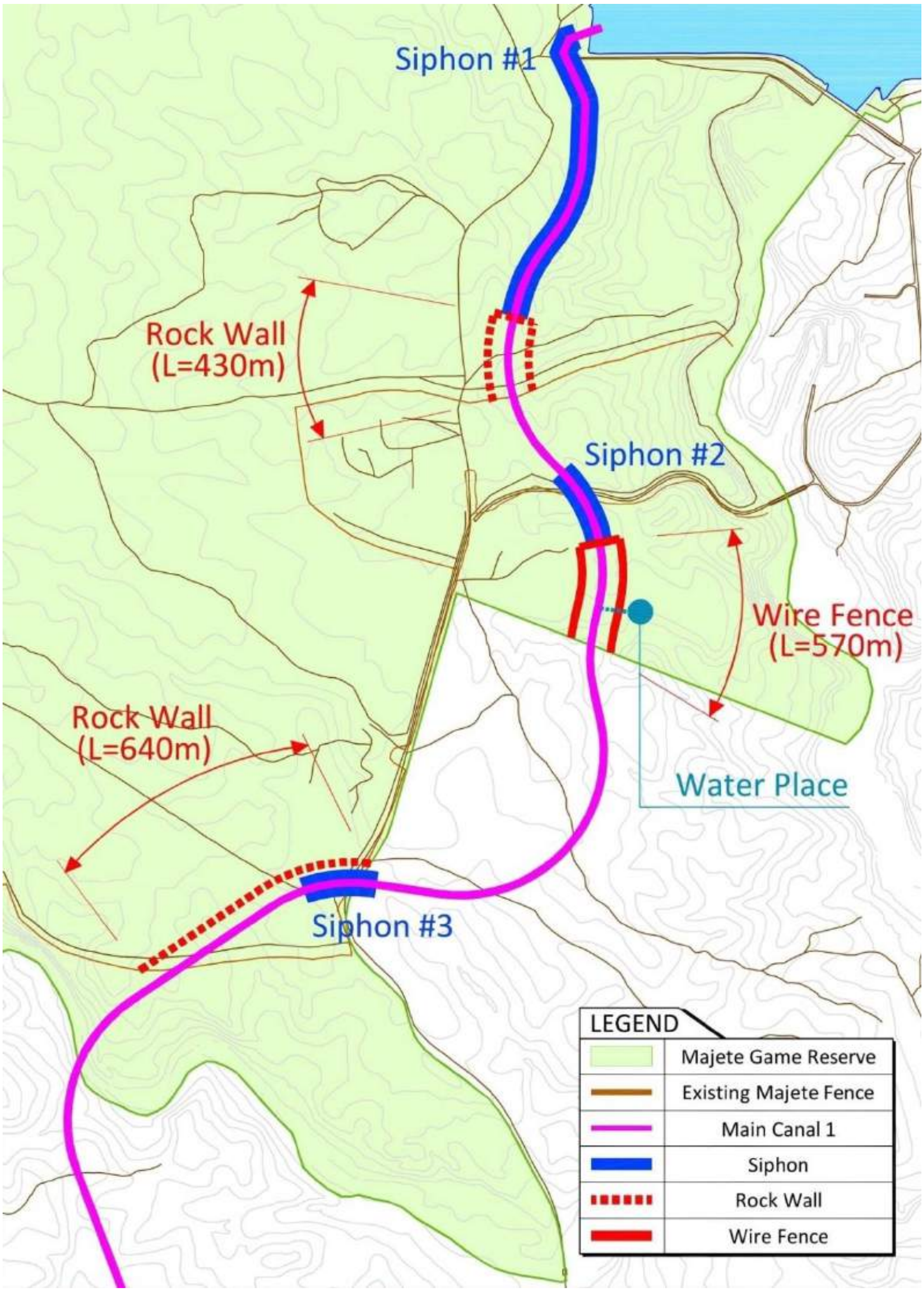
In order to minimize the environmental impact within the Reserve, the shortest route along the road was adopted (See Figure 11.1-2). The Majete section of Main canal 1 was planned as a long underground siphon structure, which shall be constructed in this manner to provide the free access of animals to their drinking places. This will also avoid degrading of the natural landscapes in this area.

If open canal is installed, a large area (30 m × 800 m) shall be occupied by the canal and it will divide the area into two parties, which will cause negative environmental impacts. Obviously, the construction cost for siphon (3.3 million USD) shall be higher than that for open canal (1.5 million USD). Though the cost is higher for the siphon structure, it is the best option in terms of environment preservation.

In terms of the measures of mitigation in the Reserve, the TFS Consultant discussed with the Park Manager (Craig Hay). The proposed measures of mitigation by the Park Manager are as below:

- Construction of masonry (or brick) walls (as proposed in the ESIA report) inside the fenced area of the Reserve: STA.0.8 ~ STA.1.2 and STA.2.7 ~ STA.3.3
- Installation of wire fence outside the fence protected area: STA.1.2 ~ STA.1.7
- Installation of cross roads: STA.0.8 ~ STA.1.0 and STA.1.4 ~ STA.1.7
- Watering point: STA.1.4 ~ STA.1.7

Figure 11.1-3 shows the description of the measures above.

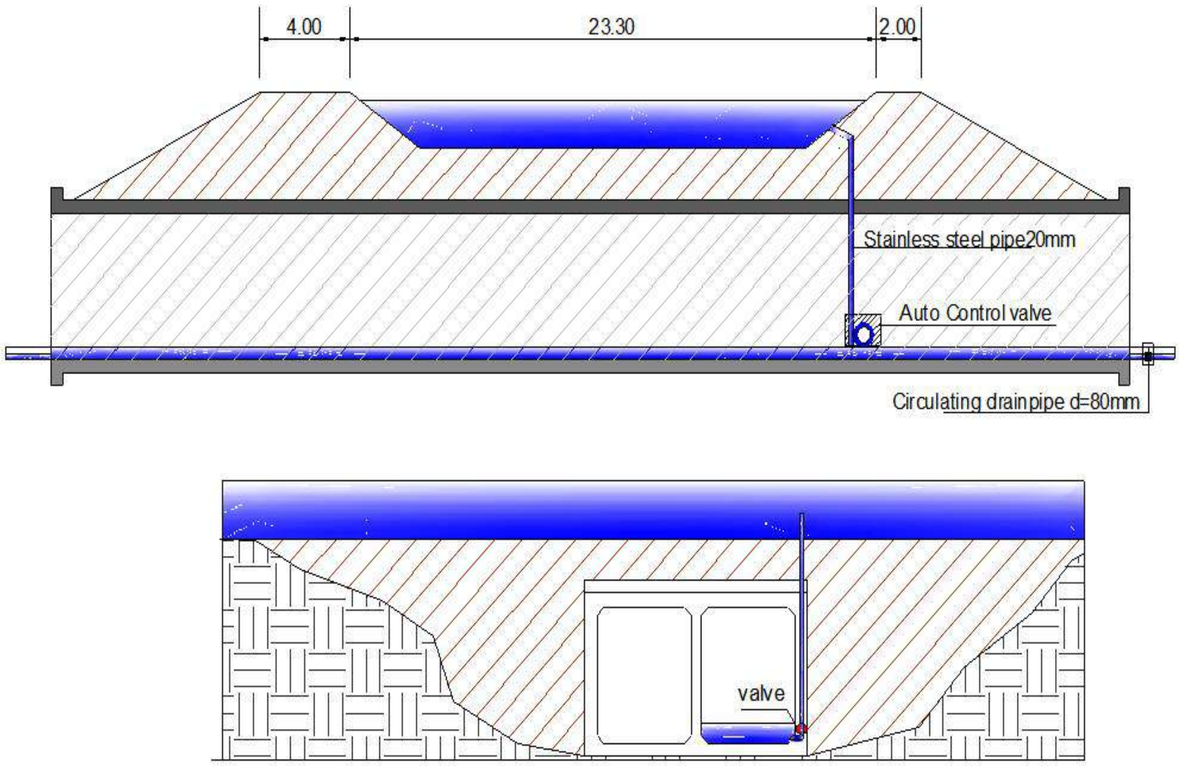


[Figure 11.1-3] Mitigation Measures in the Majete Reserve

The section STA.0.8 ~ STA.1.0 above, the section after the long siphon (755 m) inside Majete Reserve, is designed as an open canal section. If this section is designed as a culvert, it will be very expensive. In case of open canal the cost will be more or less 700 USD/m including the brick walls proposed above. On the other hand, in case of culvert the cost will be more less 8,000 USD/m (more than 10 times higher). Therefore the open canal will be much reasonable than the culvert type canal.

Water Supply Facilities for the Animals

The culverts shall be installed where the open canal crosses valley to facilitate flood evacuation. In Majete area, there is a small valley, where a culvert shall be installed. Normally this culvert is prepared through which flood could be evacuated. On top of this principal function this structure could be modified for a watering place for the animal in the area. A small pool shall be prepared at the bottom of the culvert, where water is supplied from the canal above through a simple water supplying pipe. This facility will improve the animals' survival conditions. Figure 11.1-4 shows a conceptual design of this facility.



[Figure 11.1-4] Conceptual Design of Pool under Culvert for Supplying Water to the Animals

Protection of Facilities and Animals

The facilities installed within the Majete Game Reserve should be protected from animals, and some measures have been proposed to prevent animals from damaging the facilities.

In this regard, the intake structure shall be surrounded by a 1.5 m high fence.

11.1.2. Lengwe National Park

Lengwe National Park area is located in the middle of the Main canal 2. The boundary of the Lengwe National Park has been delineated based on the digital map obtained by DoI. In this area many animals have free movement in different paths and directions. The Main canal 2 crosses this area through an 11 km long open canal section. The canal in this area should be designed not to aggravate the circumstances for the wild life. In this regard, the Consultants have discussed with the Park Managing Team on this issue. In conclusion, the Park Managing Team prefers an open earth canal with shallow water depth.

When the canal is designed in open earth canal the water loss through the ground will be important. If the canal has a shallow depth and large width, evaporation loss as well as infiltration loss will be increased.

However, while the lined canal aggravates the environment, the earth canal improves the environmental condition. When the earth canal is installed in this area, neither the separate watering places nor the fence along the canal are required. In this regard the Consultant recommends designing the earth canal in this area in the Phase II procedure.

The earth canal in this area should be a sort of regime canal which maintains the sediment balance between the settling and scouring amount. In this case, several bridges should be installed though which the animals and human could pass between two sides divided by the canal. In order to avoid interference between wild animals and farming operations at least 100 m wide buffer zone shall be provided in Zone A-b and B-a.

11.1.3. Protection of Canal Facilities

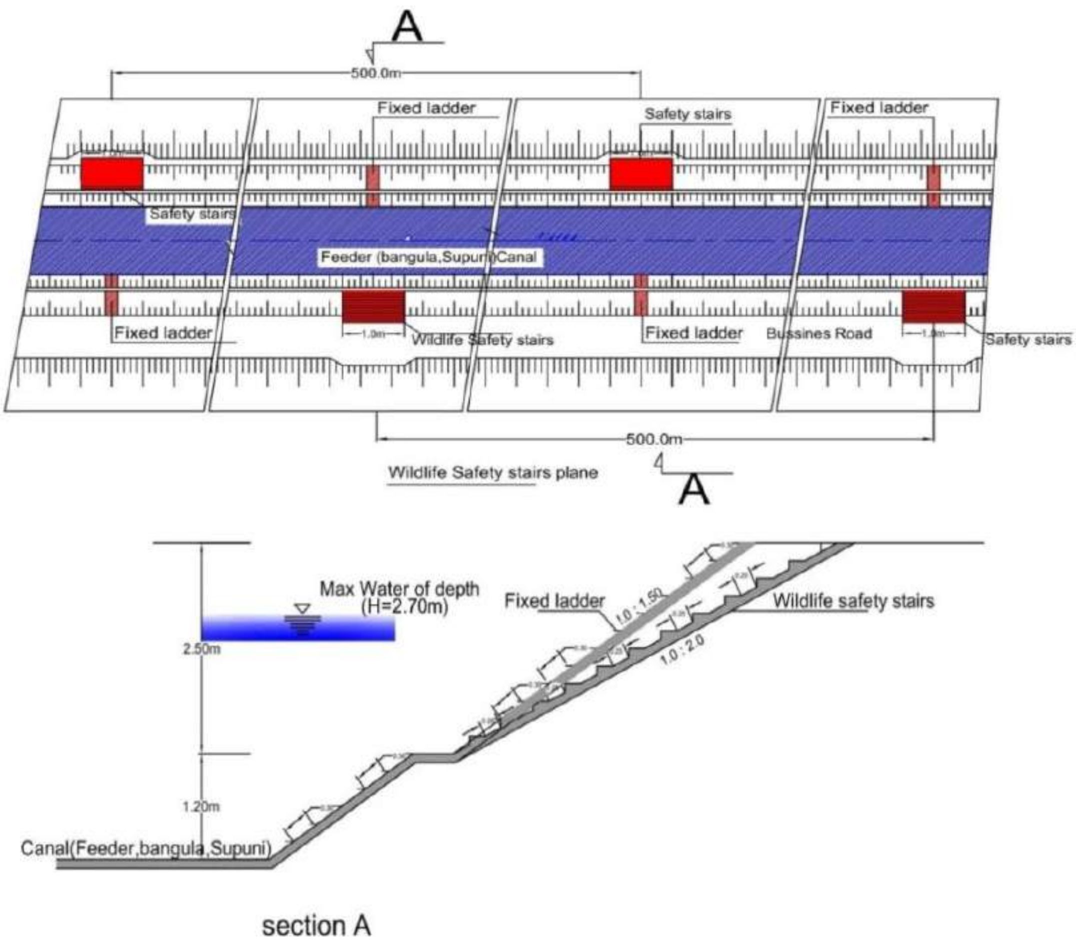
Intake Structure

Various aquatic animals such as hippos, crocodiles are living in the Kapichira Reservoir. These animals could enter into the intake structure. A sort of wire fence will be installed on the sill of the entrance concrete wall. This wire fence also could protect the invasive species entering into the reservoir from the downstream of canal.

Main Canals

The Main canals (Main canal 1, Main canal 2 and Main canal 3) outside of Majete Game Reserve and Lengwe National Park have a large width and a deep depth of water. These canals will pose a danger to humans and animals alike. Safety measures have been proposed to avert the danger.

A barbed-wire fence could be a surest way to prevent access to the canal. However, its cost shall be high and very prone to theft. Therefore the barbed-wire fence shall be installed only in some specific locations to protect structures. Also safety stairs 1 m wide and fixed ladders shall be installed every 500 m apart on both sides of the canals in order to facilitate escape in case they fall in the canal (See Figure 11.1-5). In addition, warning signposts indicating the risks shall be installed around the canal.



[Figure 11.1-5] Safety Stairs and Fixed Ladders in the Main Canals

<u>Secondary and Night Storages</u>

The secondary canals and the night storages shall be protected in the same manner as the main canals.

11.2. 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 flow in the Shire River. Table 11.2-2 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, and this is estimated to be 326 m^3/s, which is greater than 319.2 m^3/s, the water demand for both of electricity generation (269.2 m^3/s) and irrigation (50.0 m^3/s). This means that Shire River's outflows will potentiality satisfy the water demand for both.

During the dry season, inflow into Kapichira Dam mostly depends on the stream flow from Lake Malawi, the major source of water for the Shire River, through Liwonde Barrage. Flow discharge regulation at the barrage will determine the amount of water flowing through the Kapichira Dam into the Elephant Marsh and the shortage for the SVIP command area.

[Table 11.2-1] Analysis of Water Demand Compared with Q80 Discharge of the 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 Supply 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 11.2-2] Exceedance Probability Discharge (m^3/s) at Kapichira Dam

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						

11.3.Identification of Environmental, Grazing and Urbanization Reserves

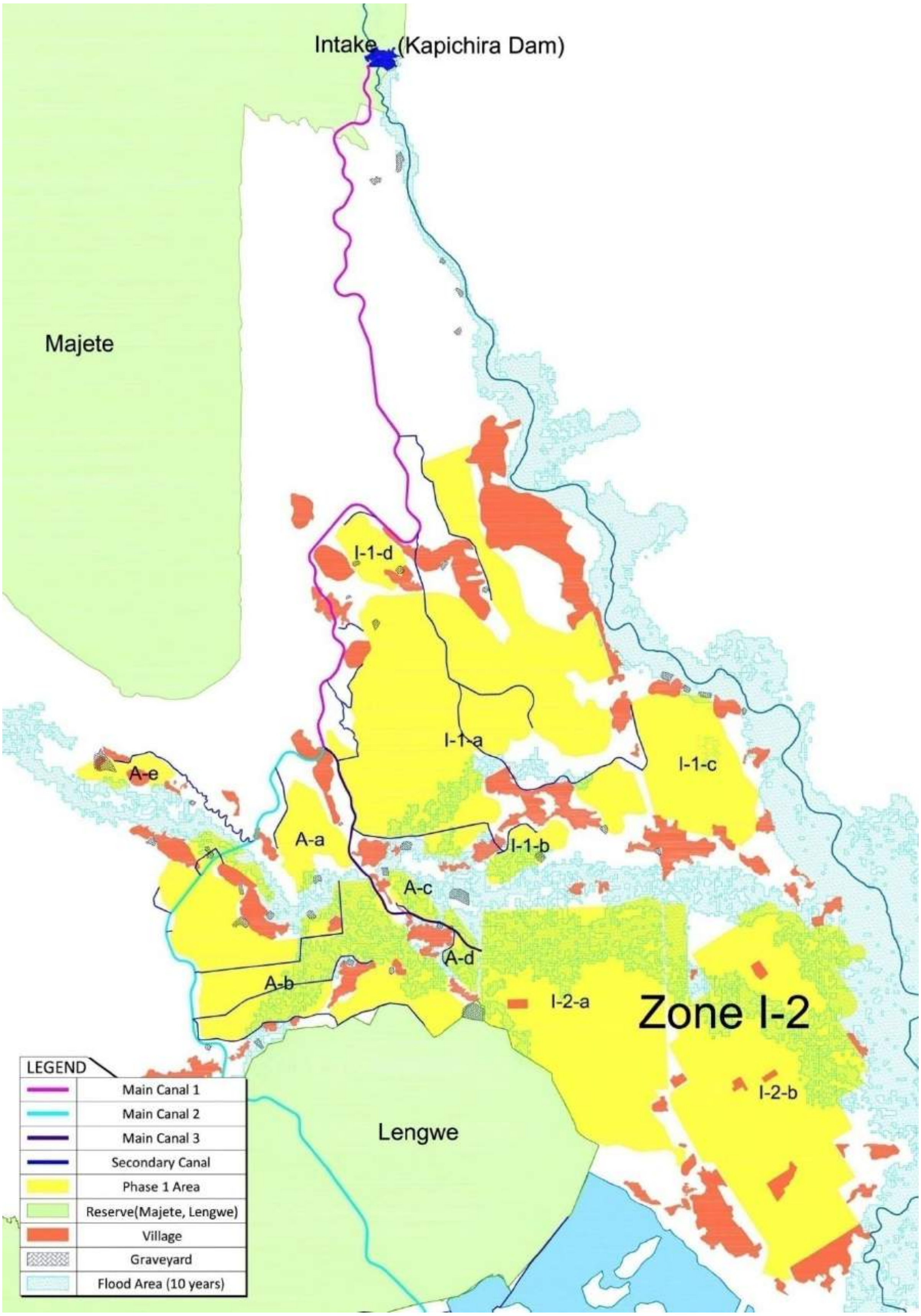
In terms of urban planning, there is an urbanization reserve area in Ngabu region, and this area was excluded from the project area.

There are many cattle that graze in the project area. Grazing places are communal but since cattle need not only grass but also water, they graze mainly along the river banks and roadside drainage channels.

In this regard, farm areas have been planned to avoid current grazing areas and therefore the actual grazing area will not be reduced significantly due to the SVIP. Many types of plants will grow along the drainage channels throughout the year after the project, thus creating rather favorable conditions for grazing.

Since many new roads will be constructed in the farm areas, in addition to the existing paths, much more grazing corridors shall be provided.

The environmentally sensitive areas such as village areas, reserves and parks, grazing areas, graveyard, and flood prone areas are isolated from the command areas and canal routes (Figure 11.3-1). If there are any minor areas remaining, they will be looked into during the detail design stage.



[Figure 11.3-1] Environmentally Sensitive Areas and Command Areas and Canal Routes

11.4. Invasive Fish Species

Lower Shire Fauna

There are a number of species of fish found in Lower Shire and it includes Tiger Fish. In the Middle Shire there are also a number of species, some of them similar to Lower Shire but there is no Tiger Fish in Middle Shire. Dr. Alfred O. Maluwa, in his part of the Baseline Study Report of May 2016 made a number of observations on fish fauna in the Lower Shire as follows:

Tiger Fish(Hydrocunusvittatus)

1) Habitat requirements

In Africa, tiger fish are found in many rivers and lakes on the continent and are fierce predators with distinctive, proportionally large teeth. The Tiger fish are found in Congo river system and Lake Tanganyika and is the largest member of the *Alestidae* family. The Tiger fish in Zambezi is another famous species which is called *Hydrocynusvittatus*. This species is found in Okavango Delta, Zambezi River (Including the Lower Shire), Lake Kariba, Cabora Bassa and Jozini dam in South Africa. Both the *goliath* and *alestidae* tiger fish are of African origin. Individual tiger fish have interlocking, razor-sharp teeth, along with streamlined, muscular bodies and are extremely aggressive and are aquatic predators who often hunt in groups to chase the prey. (http://bigfishesoftheworld.blogspot.com/2011/11/goliath-tigerfish-hydrocynus-goliath.html).

2) Water quality requirement throughout their life cycle

Tiger fish prefer water temperatures between 19 to 28^{o}C, with stable pH that is around 7.5. It prefers two types of habitats, i.e., deep water of more than 1,200 mm with fast flowing water and relatively deep (>700 mm) environments with no flow to fast flowing (0-1.35 m/s) habitat types. The species use water column and over hanging vegetation for taking cover from its predators such as crocodiles (Skelton, 2001).

3) Ability to pass obstacles such as dams, penstocks and water intakes

The Tiger fish migrate to rivers and tributaries to breed during the rainy season, but they are poor climbers of physical barriers unless the structure is completely submerged by the flooding waters.

Flow Velocities in the Main Canal

The design velocity of open canal section in the Main Canal is 1.2 m/s, and that in the siphon section is 2.1 m/s (See Annex 8). The highest flow velocity occurs at the intake gate, and it shall be 4.75 m/s with a 0.9 m head difference (See Annex 7). These flow velocities are much faster than 1.35 m/s, so that Tiger fish are not able to pass through it. Therefore, it is unlikely that Tiger fish will flow upward through the Main Canal and enter the main stream of the river.

Profile of the Middle Shire

The middle Shire river starts from Matope Bridge up to Kapichira Dam and is characterized by a series of rapids. Over a distance of approximately 80 km extending from Matope to the Kapichira falls, there are a total of 10 rapids and 5 major falls (steep rapids) of which Kapichira with two drops of 15 meters separated by 25 meters of steep rapids is the largest. (D. Teweddle, et. al, 1979).

The first rapids from Matope Bridge are the Kholombidzo Rapids which are about 26 m high over a distance of 3 km. After the Kholombidzo Rapids there are a series of small rapids (Toni, Chimbalame, Nachimbeya, Chilemba and Mbingewanda). Other major rapids are found at Nkula with a drop of about 50 m over a distance of about 5 km. These falls are followed by the Tedzani falls which drop about 39 m over a distance of about 2 km. The Tedzani falls are followed by Mpatamanga Gorge with a drop of about 20 m over a distance of about 1.5 km. After the Mpatamanga Gorge, there are the Kapichira Falls with a drop of about 75 m over a distance of about 2 km.

Barrages and Hydro Power Stations

Between Matope Bridge and Kapichira Dam, there are two barrages constructed on Nkula and Tedzani steep rapids for producing Hydro Power. Just like Kapichira dam, the barrages regulate Shire River flows and create head pond upstream of the intakes to the hydro power plants. They are provided with spillways for releasing excess flows. There is a head difference of 50 and 39 meters between the head ponds and the tail races at Nikula and Tedzani power stations respectively. There is also a clear fall of 5 to 7 meters between the upstream head pond and the downstream rapids at the spill ways. (See Figure 11.4-1)

In addition to these physical barriers, the rapids at Tedzani, Nkula and Kholombidzo form natural barriers for upstream migration of fish. The velocity of water from the barrages, when they are opened is more than 5 m/s which is greater than the maximum water velocity that Tiger Fish can swim against, 1.35 m/s. In view of these, the characteristics of the middle Shire River casts doubt that if the Lower Shire fish fauna negotiate their way into the Kapichira dam through the irrigation canals, they can enter upper Shire above Matope Bridge.

Conclusion for the Current Situation

The consultants and the TT visited Nkula and Tedzani to appreciate the natural and physical barriers to Tiger Fish. The rapids are distinct with very little vegetation as seen in the Figure 11.4-1.

According to ESIA Baseline study, "Tiger fish water flow requirement is either no flow at all (0 m/s) to fast flowing (0-1.35m/s). The Tiger fish migrates to rivers and tributaries to breed during the rainy season, but it is a poor climbers of physical barriers unless the structure is completely submerged by the flooding waters." As per these descriptions, if fish negotiates the Kapichira Falls through the irrigation canals, it is unlikely that they can enter the upper shire due to the long steep natural rapids and barrages at Tedzani and Nkula.

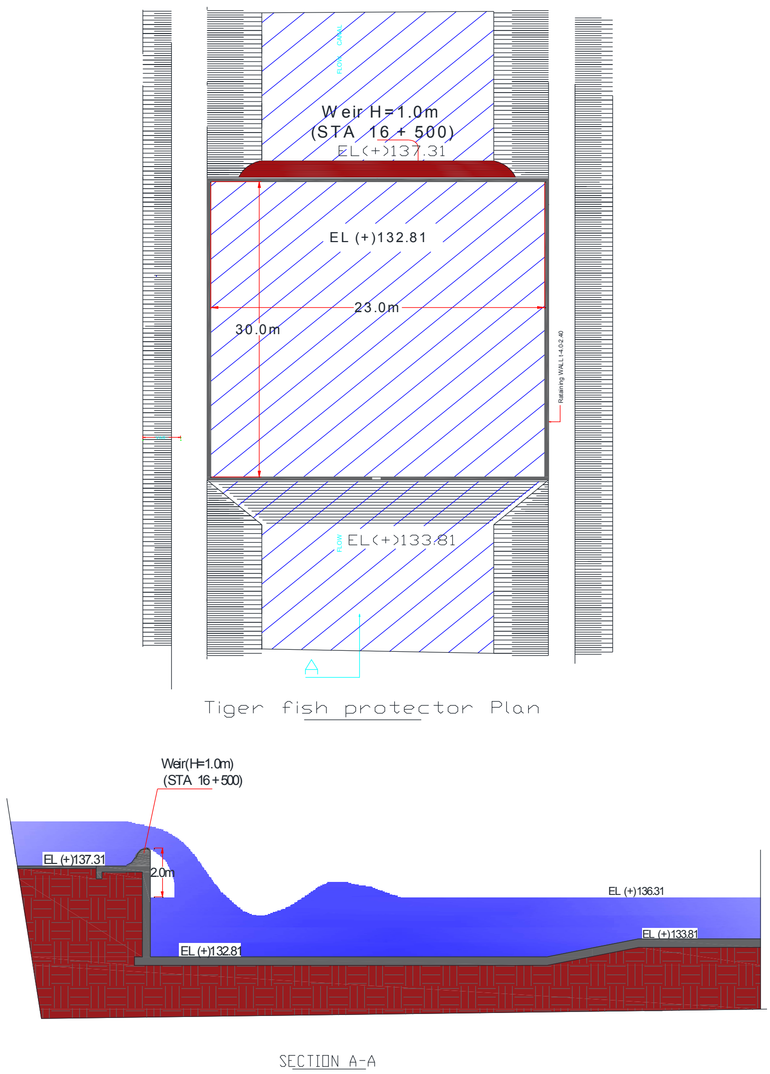
[Figure 11.4-1] Spillways of Nkula Dam (left) and Tedzani Dam (right)

Protection Measures of Fish Migration to Upstream

Even though the Consultant believe that Tiger fish cannot go upstream to Lake Malawi, the following mitigation measures are proposed as an extra precautions

1) Drop structure:

KRC is proposing a maintenance free mitigation measure, which requires the provision of a 1 meter high broad crested weir across the main canal combined with a 3.5 meters drop structure (see Figure 11.4-2). This is more or less similar to that of ESIA proposal and is maintenance free as no screens are required. Since the design depth of the Main Canal is 2.3 meter, the 1 meter high weir combined with the 3.5 meter drop will create a clear fall of 2.2 meters (4.5-2.3) which will create an efficient barrier for the Tiger Fish (as proposed by ESIA and ESMP studies).



[Figure 11.4-2] Drop Structure for Protection of Fish Migration

There are two options for the location of the drop structure: 1) inside Majete area, and 2) at the first secondary offtake (STA 16+600). Though it will increase the excavation cost, the first option is recommended by the ESIA study as it is a restricted area from human interventions.

On the other hand, if a drop structure for Tiger Fish protection is constructed in the Main Canal 1, some siphons could be removed. In this case the head loss will be reduced so that the canal slope could be made steeper than 1:8,000 or the height of the drop structure will be increased. In addition, it is possible to reduce the cross-section of the canal, which will reduce costs. On the other hand, Moses area (Block A-e) cannot be supplied with water through gravity irrigation, and a solar or diesel pumping station should be provided. All these issue together with other possible scenarios shall be addressed during the detail design process.

2) Barrier at the intake structure:

A barrier of stainless steel mesh shall be installed at the entrance of intake structure, which will protect migration of aquatic species such as crocodile and fishes from one side to the other side (See the Preliminary Design part).

3) Screen at the night storages:

Since the fish must pass through the night storages in this process, screens will be installed at the outlet of the night storages to prevent fish entering into the irrigation system.

In addition to the above ESIA consultant has also proposed 3 other possible options to be considered during detail design. (See details ESIA Impact Report; Section 8.7.2.2)

Option 1: High concrete wall

This is similar to KRC's proposal with following major technical features:

- A waterfall high enough to keep the fish from jumping over. This wall shall be vertical and made of concrete. The height shall at least 2 meters which exceeds the leaping abilities of the Tiger fish.
- A long area of shallow water of about 30 cm deep (called an apron) to keep fish from gaining speed and energy to jump. The length of the apron shall be a few meters. To convey 50 m^3/s, the apron will need to be several hundred meters wide which makes it impractical to construct it inside Majete.

Option 2: Fish screen

Fish screens are actual screens with small mesh size that retain fishes from moving along a canal or water intake. Fish screens should remain outside of the Shire flood risk zone. The mesh shall be small enough to exclude all Tiger fish life stages except for eggs. This option is not maintenance free as it requires reliable trash rack to clean the screen.

Option 3: A low concrete wall

This is similar to Option 1 with low wall combined with screen on top. This structure shall not be installed outside Majete otherwise people will use it as area to wash clothes to bring cattle to drink and to bath. This will lead to damages to the structure.

This option is economically advantageous while ensuring high efficiency. However, as the dam is low any damages to the structure would reduce its efficiency. The fence could simply be repaired in case of damages.

11.5. Health

Any irrigation scheme has the potential for inducing the development of water related diseases. In this regard measures should be taken to promote personal hygiene without contaminating the water and preventing people from drinking irrigation water. Signposts should be erected at strategic points to warn people about personal use of the irrigation water. Clean potable water should be provided separately to the community as a component of the implementation of this irrigation project.

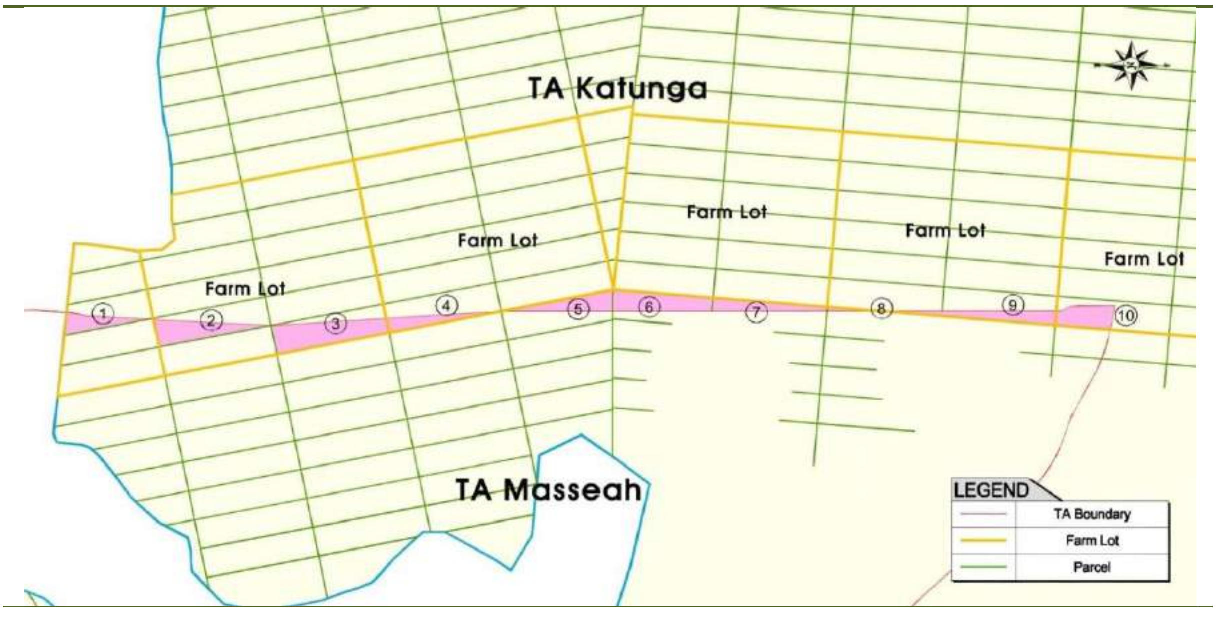
Water in the main canals, secondary canals and night storages shall be flowing all the time, and this could prevent breeding of some vectors that cause water related diseases. However, there will be many water pools in the small canals and drainages, which could harbor vectors of water related diseases. Protection measures against water related diseases should include an adequate control action to remove insects and other vectors, and specific guidelines should be included in the water management manual.

11.6. High Ground Water Level Condition

Some low places in the project areas, such as those in the Zone D in the Phase II, have high groundwater levels. Although these areas have such high groundwater levels, it is possible to cultivate crops if proper and adequately monitored irrigation and drainage is applied. These areas could also be put to crops that consume a lot of water such as sugarcane or rice, etc. Alternatively, fish ponds could be constructed where the soils and drainage conditions are unsuitable for crop production, to promote fish farming in the area.

11.7. Socio-Economic Constraints

There are 5 TAs (Kasisi, Katunga, Chapananga, Masseah, Lundu) whose areas of jurisdiction are included in the SVIP. It would have been preferred to maintain all farming activities within the boundaries of each traditional authority but the farm block planning has been done according to the topographic conditions of the farm lands. These farm blocks cross the TA boundaries making the village boundaries and the farm block boundaries to be inconsistent. In this case TA boundaries shall be maintained as they now exist, and allocation of plots shall have to be compatible to the TA boundaries. Figure 11.7-1 shows the incompatibility of plot boundaries to TA boundaries in the areas of TAs Katunga and Masseah.



An arrangement between the TAs will have to be agreed upon how the plots crossing the boundaries shall be allocated, noting that there is no physical structure demarcating the areas of jurisdiction of the two TAs.

[Figure 11.7-1] Example of Plot Boundaries Crossing TA Boundaries of TAs Katunga and Masseah

CHAPTER 12. CARBON FINANCE POTENTIAL

12.1. Carbon Market

12.1.1. Background

Carbon finance is a new type of endeavor that helps corporations and governments to respond to the risk posed by climate change. The centerpiece of this new field is the trading of GHG emission reduction credits, known as the carbon market. Those companies whose GHG emissions are already regulated have begun making their emissions inventories, assessing their marginal abatement costs, and deciding whether to participate in the carbon market. The market is also being used by investors and speculative traders for whom carbon is fast becoming just another commodity.

At the political level, diverse countries of the world met in 1992 under the auspices of the United Nations at the ‘‘Earth Summit’’ in Rio de Janeiro, and agreed on the Framework Convention on Climate Change (UNFCCC). The Convention was signed in 1992 and entered into force in 1994. The key objectives of the Convention are to reduce emissions from economic activity and to lessen the impact of unavoidable climatic changes.

Two types of carbon market exist; the regulatory compliance and the voluntary markets. The compliance market is used by companies and governments that by law have to account for their GHG emissions. It is regulated by mandatory national, regional or international carbon reduction regimes. On the voluntary market the trade of carbon credits is on a voluntarily basis. The size of the two markets differs considerably. In 2008, on the regulated market USD119 billion were traded, and on the voluntary market USD704 million (Hamilton *et al.*, 2009).

The three Kyoto Protocol mechanisms are very important for the regulatory market: Clean Development Mechanism (CDM), Joint Implementation (JI) and the EU Trading System (ETS). Some countries have not legally accepted the Kyoto Protocol, but have other legally binding state and regional GHG reductions schemes. 2 Developing countries can only participate in the CDM.

In general for small-scale AFOLU projects in developing countries, the voluntary market is more interesting than the regulatory market because the CDM market has quite complex procedures and methodologies for project registration and the majority of agriculture and forestry.

12.1.2. Clean Development Mechanism (CDM)

Under the Kyoto Protocol developing countries are not obliged to reduce their GHG emissions, whereas industrialized countries (Annex I countries) have to fulfill specified targets. They can achieve these by reducing GHG emissions in their own country; implementing projects to reduce emissions in other countries; or trading. This means that countries that have satisfied their Kyoto obligations can sell their excess carbon credits to countries which find it more expensive to meet their targets. For developing countries the CDM is of most interest among the regulatory market mechanisms. An industrialized country implements an emission reduction project in a developing country. This can be an afforestation, an energy efficiency or a renewable energy project. Because of the uptake or savings of GHGs, carbon credits (CER) are generated. These belong to the industrialized country and will be used to compensate some of its domestic GHG emissions and reach their emission targets. The projects support sustainable development within the host country, as a new – additional – project is created which helps to slow down global warming. Through the project new technology is transferred to the host country, investments are made, additional jobs are created and the project reduces environmental impacts.

All projects must utilize rigorous baseline and monitoring methodologies that have been approved by the CDM Executive Board. Any project can submit a methodology for consideration or rely on methodologies that have already been approved. So far five methodologies have been approved for agriculture, 11 for afforestation/reforestation (A/R) and six for agricultural residues/biogas 3. At the moment the rules for AFOLU(Agriculture, Forestry, and Other Land Use) projects in CDM only allow for specific types of projects in developing countries (some examples of projects are given in Box 4):

Agriculture:

- Methane avoidance (manure management)
- Biogas projects
- Agricultural residues for biomass energy

Forestry:

- Reforestation
- Afforestation

12.1.3. Voluntary Market

The voluntary market has become very important for agriculture and forestry projects. Voluntary carbon credits (VER) are mainly purchased by the private sector. Corporate social responsibility (CSR) and public relations are the most common motivations for buying carbon credits. Other reasons are considerations such as certification, reputation and environmental and social benefits. Some companies offer clients to neutralize their carbon emissions (e.g. British Airways offers carbon neutral flights and Morgan Stanley provides the equivalent amount of carbon credits). The private sector can either purchase carbon credits directly from projects, companies (e.g. Eco-securities) or from carbon funds (e.g. The World Bank Bio Carbon Fund).

The story behind the credits plays a crucial role in these markets. AFOLU projects are usually valued highly for their social and environmental benefits, as they deal with people's livelihoods and the protection of important ecosystems.

12.2. Carbon Budget of SVIP

The SVIP affects carbon in the atmosphere in the following manners:

12.2.1. Reduction of Carbon in the Atmosphere

All crops absorb CO_2 from the atmosphere, yet this impact may be easily undone if the crops are harvested (and the organic matter is not permanently stored in the soil). Moreover disturbing the soil through tilling and weeding will remove extra CO_2 from the soil. Therefore only (semi-) permanent crops are considered to have a significant impact as Carbon sink. For the VISP the Fruit trees and Sugarcane are relevant.

Fruit Trees:

It is expected that in year 6, after the subsistence farmers have become accustomed to irrigated farmer for commercial purposes, more high value crops will be cultivated. Of the 43,000 ha that will be irrigated by the SVIP, 860ha will be planted with mangoes and 860ha with citrus, both of which may act as carbon sink[1]. In Zambia, citrus trees' carbon sequestration in biomass ranged from 24 tons CO_2 /ha for young trees to 109 tons CO_2/ha for mature trees (Mwamba Bwalya, 2012). However, the net effect of citrus cultivation also depends on the use of fertilizers, pesticides, water, electricity and fuel which may lead to CO_2 emissions between 0.22 tons CO_2/ha for low input orchards to 4.28 tons CO_2/ha for high input management."[2] Assuming that mangoes have the same sequestration as citrus and both will have a medium input of agro chemicals, it may be expected that the orchards under SVIP will reduce the CO_2 in the atmosphere by 172,000 tons.

Sugarcane:

Carbon sequestration of sugarcane may amount to 50 tons per ha, (Moundzeo et.al. (2011) in the Niari valley in Congo). The researchers conclude that "the sugarcane plantations contribute a great deal in the struggle against climate changes and their use in terms of bio fuel." This is in line what has been reported also by the sugar industries' research (see e.g. Parr, JF & Sullivan, 2007).[3] With 44 % of the project area eventually under sugarcane, SVIP would contribute to approximately 955,000 tons of CO_2 sequestration.

12.2.2. Reduced Emission

- Sugarcane only needs to be replanted about every six years, which reduces tilling of land that releases carbon dioxide. No-till techniques considerably lower the amount of fuel necessary to run agricultural machinery in the field.
- Sugar Cane molasses is used to produce ethanol, which according to the policy of GoM will be mixed with gasoline in a 1:4 ratio, thereby producing an effective fuel for vehicle that for 20 % comprises of ethanol, and will substantially reduce the use of fossil fuels in Malawi. Sugarcane.org claims that sugarcane " has the best carbon performance of all bio fuels".
- Bioelectricity. Sugar cane leftover stalks and leaves can be burned in boilers to produce bioelectricity to power the operations of sugarcane processing and often sell energy back to the grid. Producers can also obtain carbon credits from bioelectricity project.

12.3. Carbon Finance of SVIP

12.3.1. Sources of Fund

There are a few sources of funding available for Carbon Emission Reduction (CER):

Green Climate Fund (Kwan, 2015)

The Green Climate Fund (GCF) is a fund within the framework of the UNFCCC founded as a mechanism to assist developing countries in adaptation and mitigation practices to counter climate change. The GCF is based in the new Songdo district of Incheon, South Korea.

[1] An additional 860 ha is expected to be planted with Bananas, which does not have a considerable net sequestration.
[2] Mwamba Bwaly warned against intensive use of fertilizers beyond the optimum fruit bearing age.
[3] The Brazilian Organisation of Sugarcane (sugarcane.org) also promotes little use of mineral fertilizers and other agro-chemicals, to avoid a reduction of the net effect on the CO_2 levels.

These projects that are eligible for funding should have a considerable impact on climate change mitigation (in the sectors of (i) energy generation and access, (ii) forest and land use, (iii) buildings, cities, industries and appliances and (iv) transport) and/or adaptation (in the sectors of (i) food and water security, (ii) ecosystems and ecosystems services, (iii) infrastructure and built environment and (iv) livelihoods of people and communities.

Projects could be submitted for funding by country's accredited agencies, who could acquire accreditation through the Funds' fiduciary principles and standards, environmental and social safeguards and gender policy. Most of the accredited entities are multi-lateral organizations such as the Asia Development Bank, the World Bank, the German Development Bank (KfW) and UNDP. Yet Rwanda's Ministry of Natural Resources and the Caribbean Community Climate Change Centre are also accredited. To apply for these funds, the Malawi's Ministry of Irrigation would need to be accredited.

12.3.2. The Clean Development Mechanism (CDM) under the Kyoto Protocol

Under this mechanism, industrialized countries could invest in Malawi to help reduce Green House Gasses (GHG) emission. It aims to stabilize GHG concentrations in the atmosphere and assist developing countries to achieve sustainable development. A country X that funds a project in Malawi could receive Carbon Credits if (i) it can prove that the project would not take place without country X's support (principle of additionality) and (ii) it establishes a baseline to determine the future Carbon Emissions without the project. (Mitchell 2011)

The additionality criterion implies that projects need to be formulated and funded in the field of bio-fuels and/or co-generation in addition to the SVIP. Such projects would indirectly support SVIP as it would increase the demand for sugar cane.

12.4. Conclusion

The consultants did not find any carbon funding possibility for the SVIP. Additional projects of bio-fuels and co-generation could be supported by the CDM, but this would require that an industrialized country, such as Germany or the European Union, be found that is interested in assisting Malawi. Moreover, such a country should primarily be interested in receiving additional Carbon credits.

It is therefore recommended that the Ministry of Agriculture, Irrigation and Water contacts the EU delegation and German Embassy to explore their interest in funding ethanol production and co-generation based on sugar cane in Malawi.

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CHAPTER 13. PRELIMINARY DESIGN

13.1. Design Criteria

This chapter describes the important technical information about the layout and design of the canals and structures and on-farm works. In terms of the design criteria, the references of USBR, FAO and Indian Standard were applied. According to the USBR criteria, the canals which have the capacity of less than 100 ft^3/s (2.83 m^3/s) are regarded as the small canals, and those larger than 2.83 m^3/s are regarded as the large canals. Since the main canals (Main Canal 1, Main Canal 2 and Main Canal 3) have the capacities between (14 - 29m^3/s), the design criteria for the large canal was applied for these canals. On the other hand, the design criteria for the small canal were applied for most of the secondary canals.

The main design criteria applied to this design are as follows.

- Longitudinal Slop of main canals: 0.000125~0.001 (A typical design value is 0.000125 m/m, but in mountainous areas the slope may be as high as 0.001 m/m)
- Radius of curvature of main canals: 3~7 times of the top width of flow at maximum design discharge for large canals
- Ratio of flow depth (h) to bottom width (b): 1:2 ~1:4 for small canals; 1:4 ~1:8 for large canals
- Maximum flow velocity: 1.5 m/s
- Free board of canal: 0.45 m for canal capacity < 0.75 m^3/s; 0.6 m for canal capacity 0.75~1.5 m^3/s; 0.75 m for canal capacity 1.5~85 m^3/s
- Slope of tertiary and field canal: 0.005
- Slope of land leveling: 0.002~0.005

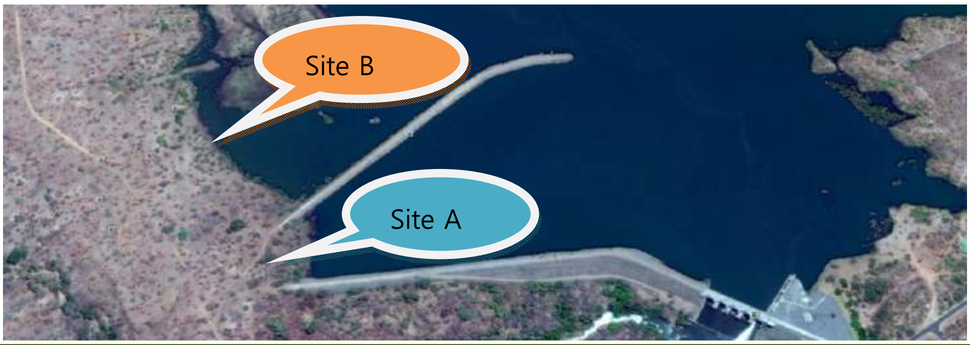
13.2. Intake Structure

13.2.1. Location

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 install the intake structure at the reservoir of Kapichira Dam. The location was determined considering the following points: foundation stability, economic feasibility, effectiveness for O&M, construction conditions, water intake condition, and administrative/impact aspects in Lengwe National Park, Majete Game Reserve, stakeholders, etc.

In addition, sedimentation issue was considered as the key criteria in the selection of the intake location. During the flood season, Shire River transports large volumes of sediments which could easily block the intake structure if it is not properly located. The Hydraulic Modeling results by Artelia also provided the theoretical basis for determining the location.

Figure 13.2-1 shows two alternative sites for the intake structure, and the advantages and disadvantages of each site. Figure 13.2-2 is close photos of Site A and Site B. KRC selected Site A as the most appropriate location. Later, the Hydraulic Modeling study verified the site to be the optimum location for the construction of the intake structure.

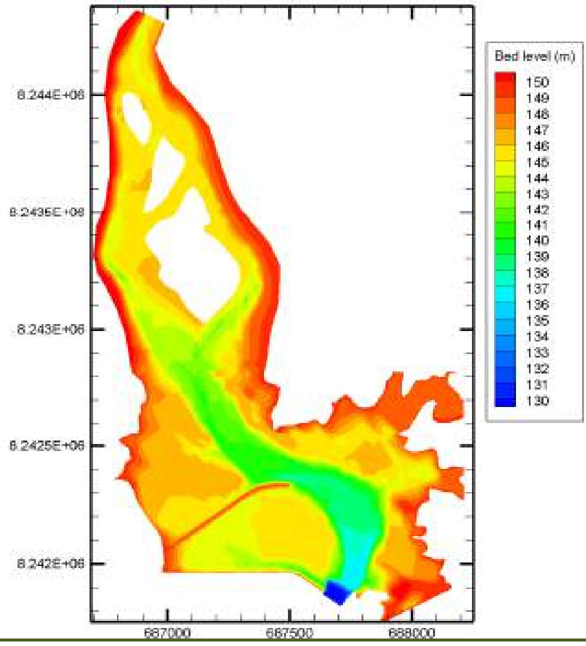
Items	Site A	Site B
Layout		
Advantages and Disadvantages	- Spur dike protects this area from sediment intrusion and provide stable hydrodynamics - Less rock blasting required - Less environmental impact - Length of Main Canal1 shall be shorter and more economical	- A lot of sediment will be deposited - Unstable hydrodynamics - A dike protection is required in the upstream of river - More rock blasting required - More environmental impact - Longer Main Canal 1 increases the construction cost

[Figure 13.2-1] Alternatives Sites for the SVIP Intake Structures at Kapichira Dam

[Figure 13.2-2] Location of Intake Structure at Kapichira Dam Site (Left: Site A, Right: Site B)

Sedimentation: Figure 13.2-3 shows lots of sediment piled up at Site B compared to Site A. In the coming year ESCOM has a plan to dredge the whole reservoir area including Site A.

[Figure 13.2-3] Image of Intake Structure Installed at the Site A



[Figure 13.2-4] Current Bathymetry of Kapichira Reservoir Area

The Hydraulic Modeling study undertook a bathymetric survey of the reservoir of Kapichira Dam and Figure 13.2-4 shows the resultant bathymetry map. Site A appears to have less sedimentation compared to Site B. Sedimentation has been occurring in the reservoir in various degrees since the construction of the dam, and at site A the elevation of the highest point is up to 146m a.m.s.l. However, ESCOM has a plan to dredge this area to 143m a.m.s.l., which is low enough for the normal operation of the intake structure. TFS team has discussed with ESCOM engineer (Archibald KANDOJE, Senior engineer) and confirmed that the dredging project is well underway and is expected to be implemented in the second half of next year.

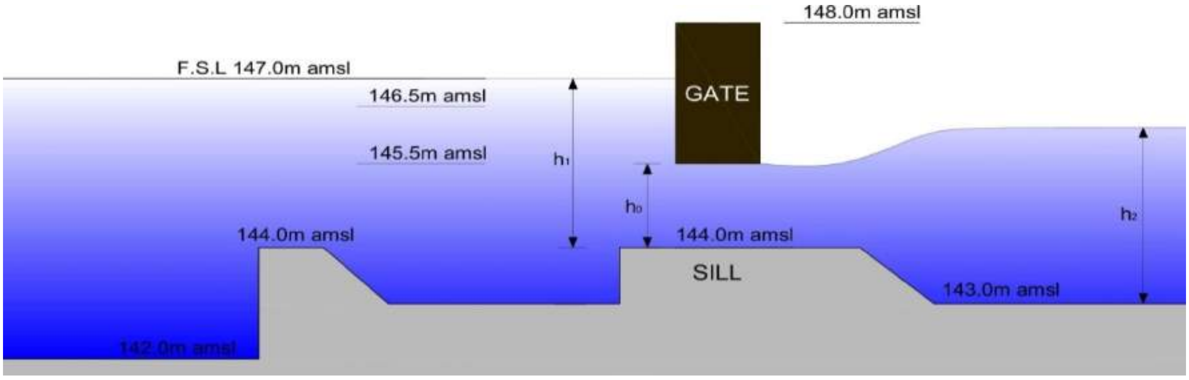
In case ESCOM will not undertake the dredging operations, the Hydraulic Modeling consultant has recommended to dredge a channel leading to the intake structure regularly. Width of the channel for Phase 1 shall be 40 meters dredged to elevation of 144 m. The initial dredging cost has been estimated and reflected in the project cost estimate.

The Engineer has also confirmed that currently ESCOM undertakes flushing operation 3~4 times during rainy season. The flushing duration will be about 8 hours. During these operations the water level goes down much below 144 m a.m.s.l., the sill elevation of SVIP intake structure (actually the sill elevation of spillway is 134 m a.m.s.l.). Hence irrigation has to be interrupted during the flushing operation.

However, since the flushing operations are carried out during the rainy season when the irrigation requirement is low, one day interruption of irrigation will not be a serious problem as such. Rather, this period can be used as an opportunity to inspect the canal condition.

13.2.2. Design Features

Kapichira Dam was constructed by ESCOM for electric power generation. The water level in the reservoir is strictly controlled following the reservoir operation regime. The Normal Maximum Pool Elevation was set at 147 m a.m.s.l. The allowable range of pool elevation for the power generation is set between 144 m ~ 147 m a.m.s.l. However, ESCOM operates the generators between 145.5 m a.m.s.l. ~ 146.5 m a.m.s.l. This is a strict regime which should be observed in the design of the SVIP intake and Main canal 1. Taking this into account, the sill elevation of the intake gates at the entrance into the Main canal 1 has been set at 144.0 m a.m.s.l, which will be the minimum water level of taking water for SVIP.

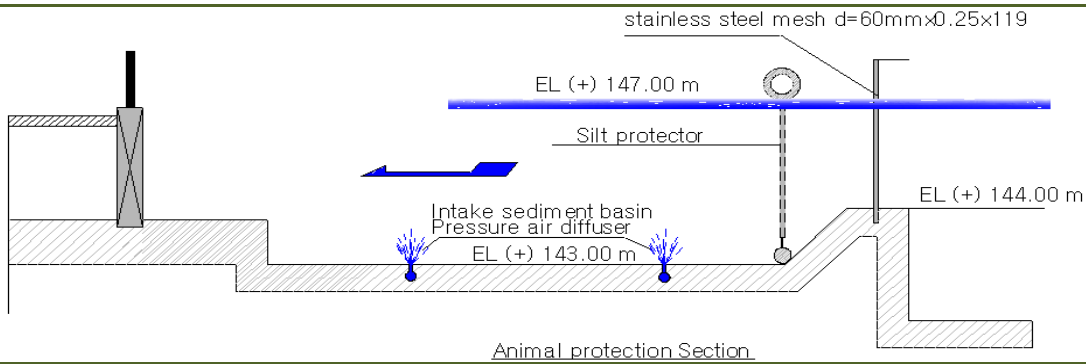


[Figure 13.2-5] Water Elevations at the Intake Gate

The SVIP intake structure shall comprise a 46.5 m long intake sill, with 12 sluice gates each 3 m wide. The gates shall be operated by an automatic control system. When the operator inputs the required amount of water into the system, the system shall automatically operates the gates based on the relation between the flowrate, gate opening and water level variation.

The 12 sluice gates shall be installed into two partitions, the first one comprising 8 gates and the second one 4 gates. The second partition shall allow abstraction of 18 m^3/s, and shall be operated when the water requirements of the scheme is less than 18 m^3/s. The first partition shall allow abstraction of up to 32m^3/s and shall be operated when the water requirements of the scheme are between 18 m^3/s and 32m^3/s. Both partitions shall be operated for scheme water requirements above 32m^3/s to the maximum requirement of 50m^3/s. This partitioning of the flow regime shall also be applied to the first siphon section of Main canal 1, and to all the other siphons shall be partitioned using the same ratio. This partitioning has been designed to prevent sedimentation within the siphon section during low flowrates, which may occur when the water requirement of the scheme is small or when the amount of river flow is limited.

Two siltation areas shall be provided at the front and behind the gates, where the pressurized diffusers shall be installed. The diffusers shall agitate and float the fine sediment in the siltation area, to enable the sediment particles to flow downstream with the irrigation water. A kind of floating curtain shall be provided in front of the intake structure for avoiding small floating debris including clay particles (Figure 13.2-6). With the floating curtain, a barrier of stainless steel mesh shall be installed at the entrance of intake structure, which will protect migration of aquatic species such as crocodile and fishes from one side to the other side. This barrier will also screen debris from entering the canal.



[Figure 13.2-6] Floating Curtain for Silt Protection

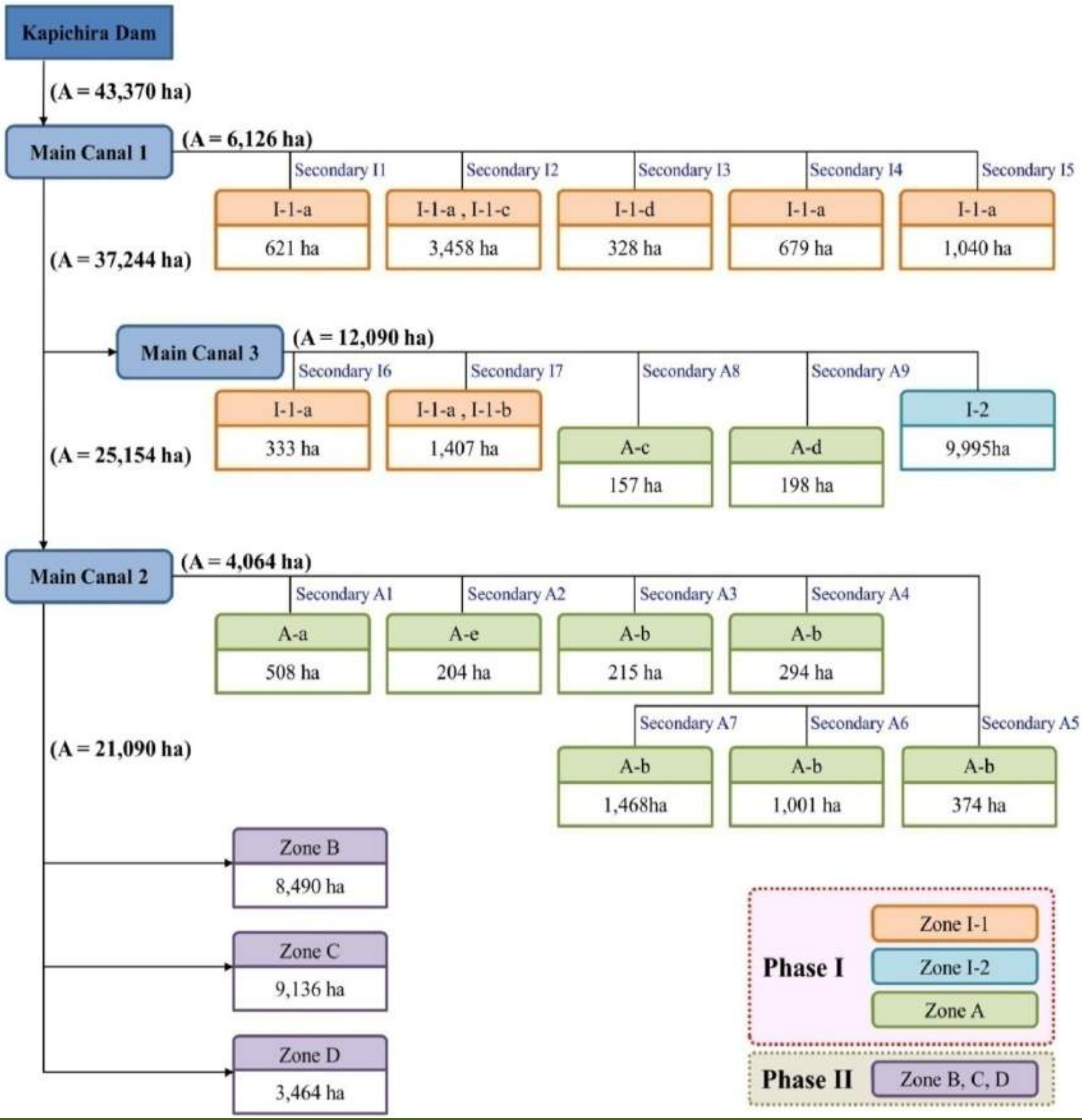
13.3. Main Canals

13.3.1. Canal Network Scheme

The total project area(Phase I + Phase II) of SVIP is 43,370 ha, which will be supplied with water from Kapichira Dam. The canal network is composed of the Main Canal 1, Main Canal 2 and Main Canal 3, and thereafter, secondary canals branch off the main canals. Figure 5.3-1 shows the canal network for the entire project area.

Main canal 1 is 33.7km long from the intake at Kapichira Dam to the point where it bifurcates into Main canal 2 and Main canal 3. From Main canal 1, five secondary canals supply water to Zone I-1 (6,126 ha).

Main canal 2 starts at the bifurcation structure (end of Main canal 1) and serves Zone A, B, C and D areas. The total length is 88.3 km, of which 18.4 km shall supply water to 4,064 ha of Zone A areas under Phase I. The rest of the canal (69.9 km long) shall supply water to 21,090 ha area of Phase II. Main canal 3 is 10.6 km long and shall supply water to 12,090 ha, including 9,995 ha of Illovo Nchalo Estate.



[Figure 13.3-1] Canal Network of the SVIP

13.3.2. Canal Route

The canal route was determined taking the following points into consideration:

i)To maximize the beneficial areas of gravity irrigation

ii) To minimize the length of canal

iii) To avoid settlement areas

iv) To minimize environmental and social impact

v) To Balance the quantities of cut and fill

vi) To maintain the design criteria

The water taken at the Kapichira dam shall be delivered down to the Bangula area. To maximize the gravity command areas, the canal route has to follow high ground sand all canals should have mild longitudinal slopes; Main Canal 1: 1/8,000, Main Canal 2: 1/5,000, Main Canal 3: 1/3,000.

The shorter the length of canal, the more economic and technical benefits are realized. To this regard, the crossing of Mwanza River was planned by constructing a siphon along the shortest route that will reduce the canal length by about 20 km.

The canal route has been selected to avoid settlement areas and sites of cultural heritage, such as graveyards. Also care has been taken to balance the cut and fill quantities as much as possible. Inside Majete Game Reserve area, care has been taken to minimize the adverse impacts during and after canal construction. To this effect the canal has been designed to pass through the Reserve area using a siphon structure. This will reduce the canal cross section and minimize the environmental impacts.

In compliance to the design criteria, the radius of curvature of the canal was set to be 3~7 times of the top width of flow at maximum design discharge (Reference: *Design of Small Canal* of USBR).

13.3.3. Canal Sections

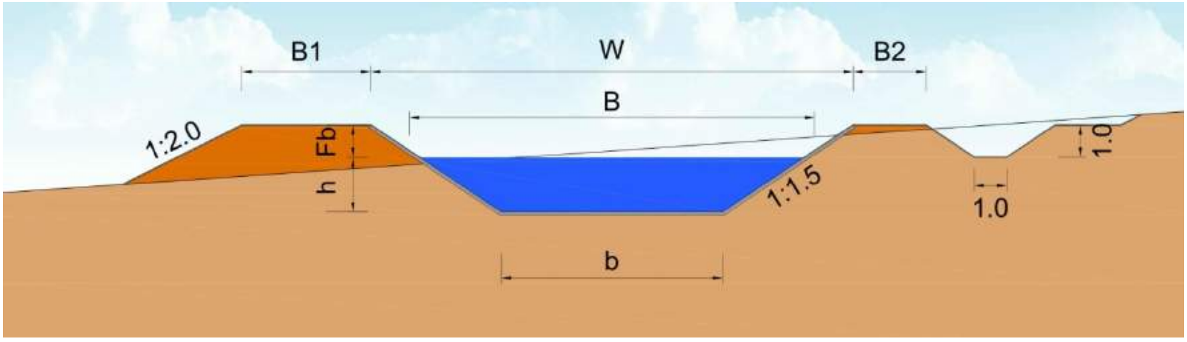
<u>Main Canal 1</u>

The Main canal 1has been designed to deliver the peak water requirement of 50 m^3/s for the entire project area of 43,370 ha (Phase I and Phase II). The implementation strategy is that Phase I (22,280 ha) shall be implemented first followed by Phase II at a later stage. Thus, for a substantial period of time, Main canal 1 shall supply water only to the Phase I area, which is about 51% of the whole project area.

Since there are 11 siphons in Main canal 1, the total head loss will be high (7.06 m). On the other hand the available head difference between the starting and the end points of Main canal 1 is 10.7 m (143.5 - 132.8 m a.m.s.l.). This means the available head for the canal slope is 3.64 m only. Therefore the canal should have a mild slope of 1:8,000.

If a drop structure for Tiger Fish protection is provided on Main Canal 1, some siphons could be removed and replaced by simple cross drainage structures. In this case the head loss will be reduced so that the canal slope could be made steeper than 1:8,000. In addition, it is possible to reduce the cross-section of the canal, which will reduce costs. On the other hand, Moses area cannot be supplied with water through gravity irrigation, and a solar or diesel pumping station should be provided. These issues together with other possible scenarios shall be addressed during the detail design process.

Dropping the canal by 3.5 meter will make some 275 ha (including the 205 ha Mosses area; block A-e) out of gravity command. To avoid impact on the adjacent villages, it is proposed to maintain the original canal route for the time being. This may increase the excavation cost. But on the other hand the filling cost will be reduced and somehow compensate the increased excavation cost. Accordingly the level of the bifurcation structure will also be dropped by 3.5 m. The location may shift horizontally but not significantly. On the other hand, the level drop of the bifurcation structure will result in reduction of the fill/embankment on Main Canal 2 significantly which is a major advantage for reducing the cost.

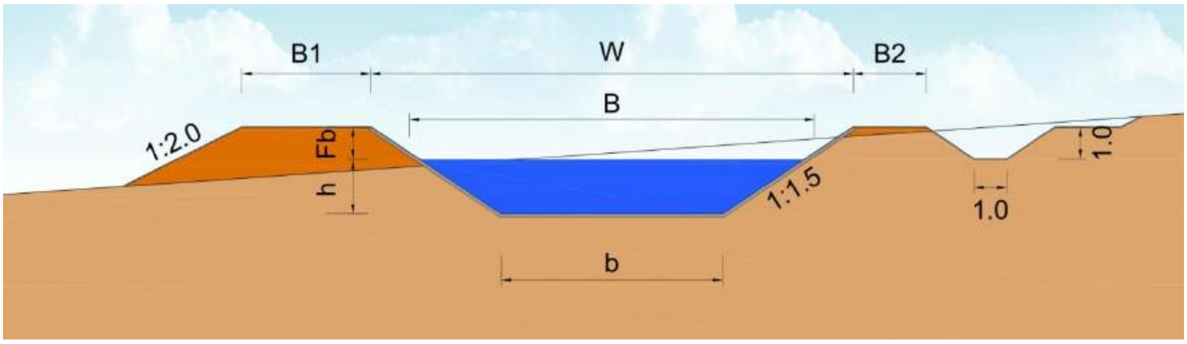


W	B	b	h	B1	B2	Fb
22.60m	20.20m	12.70m	2.50m	5.00m	2.00m	0.80m

[Figure 13.3-2] Cross Section of Main Canal 1

Main Canal 2

Main canal 2has been designed to deliver the peak water requirement of 29 m^3/s for 25,148 ha (4,058 ha of Phase I and 21,090 ha of Phase II). During Phase I, the maximum water delivery shall be only 4.68 m^3/s for 4,058 ha of Zone A.

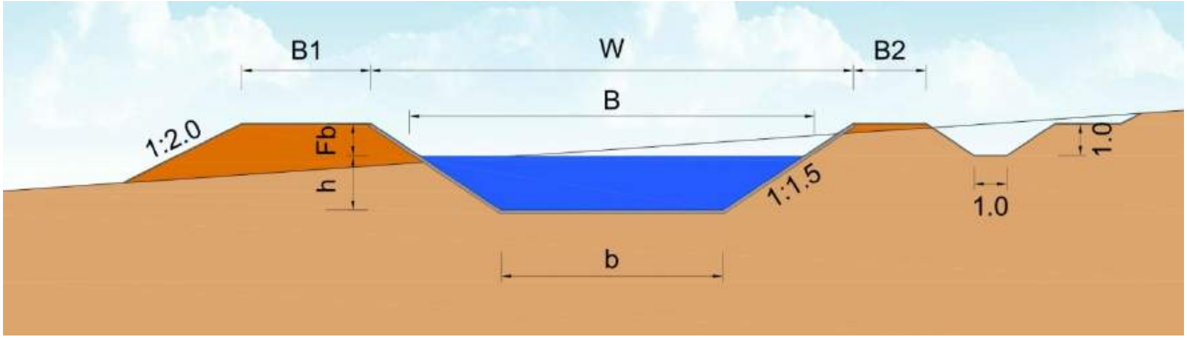


W	B	b	h	B1	B2	Fb
17.20m	14.80m	9.10m	1.90m	3.50m	2.00m	0.80m

[Figure 13.3-3] Cross Section of Main Canal 2

Main Canal 3

Main canal 3 has been designed to deliver the peak water requirement of 14 m^3/s for an area of 12,124 ha including 9,995 ha of Illovo Estate. Unlike the Main canal 1 and Main canal 2, this canal does not deliver water for the area of Phase II.

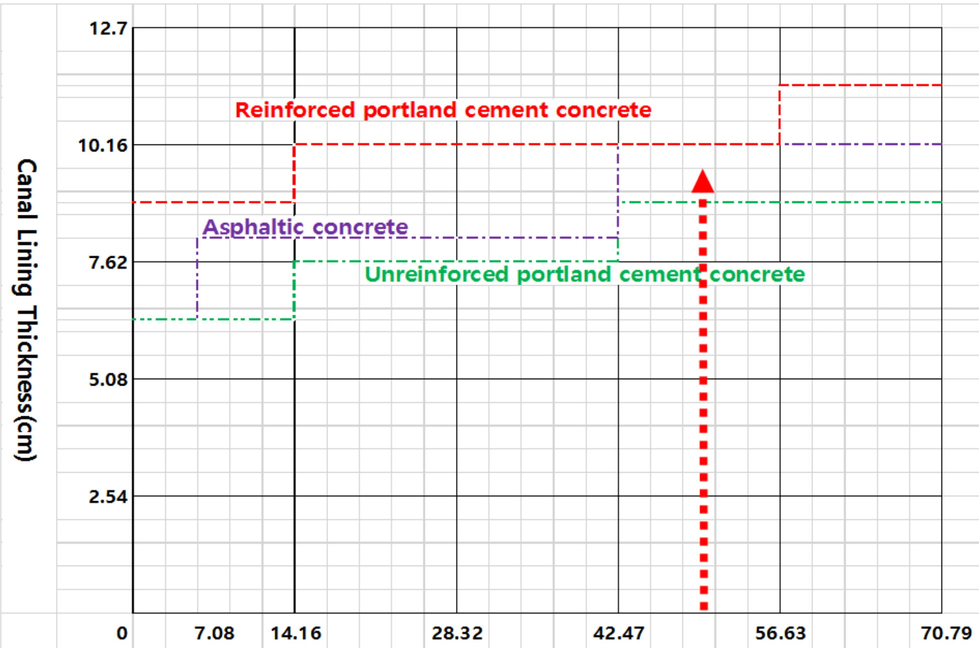


W	B	b	h	B1	B2	Fb
13.00m	10.60m	6.70m	1.30m	2.50m	2.00m	0.80m

[Figure 13.3-4] Cross Section of Main Canal 3

13.3.4. Thickness of Canal Lining

According to the recommendations of concrete canal lining thickness by USBR, (Figure 13.3-5), the thickness of concrete lining for 50 m^3/s is about 10 cm. Based on this recommendation, the thickness of concrete lining has been set at 10 cm.



[Figure 13.3-5] Canal Lining Thickness Criteria (USBR)

13.3.5. Freeboard of Canal Section

Freeboard is measured from the full supply level (FSL) to the top of lining. For lined canals having a discharge of less than 10 m^3/s, a freeboard of 0.6 m is recommended. For bigger lined canals a freeboard of not less than 0.75 m is generally provided. Since the maximum flowrate of Main canal 1 is 50 m^3/s, the freeboard has been set at 0.8 m.

13.4. Canal Structures

The main canal route crosses many obstacles such as valleys, rivers, gullies, and roads. Although the standard canal section has been designed as a lined earth canal with trapezoidal section, special type of structures such as siphon, culvert and bridge, etc. are required to cross these obstacles. Table 13.4-1 shows the important obstacles on the main canal routes. Other structures to be constructed on the canals include offtake structures, diversion structures, water level control structures, sedimentation basins, canal crossings, siphons, end canal structures, among others.

[Table 13.4-1] Important Obstacles on the Main Canal Routes

Main Canal Routes	Name of River & Road
Main Canal 1	Mwambezi, Masakale River, Manchombe River, Magwanyani River, Nthumba River, Kasinthula, Naphala River, S136 Road, etc.
Main Canal 2	Mwanzawakale River, Chingalumba River, Nthembe River, Nancholi River,Mwanza River, Nadzitimbe River, NkombeziRiver, Roads, etc.
Main Canal 3	Mwanza River, Nadzitimbe River, Roads, etc.

Siphons are planned for crossing locations where large valleys and rivers which have important flooding and large roads are passing. The culverts are planned where topographic change is severe but flooding is small. Culverts are also planned where small scale of rivers and roads.

13.4.1. Siphon

Table 13.4-2 ~ 13.4-4 show siphon structures of the Main canal 1, Main canal 2 and Main canal 3.

[Table 13.4-2] Siphon Structures on the Main Canal 1

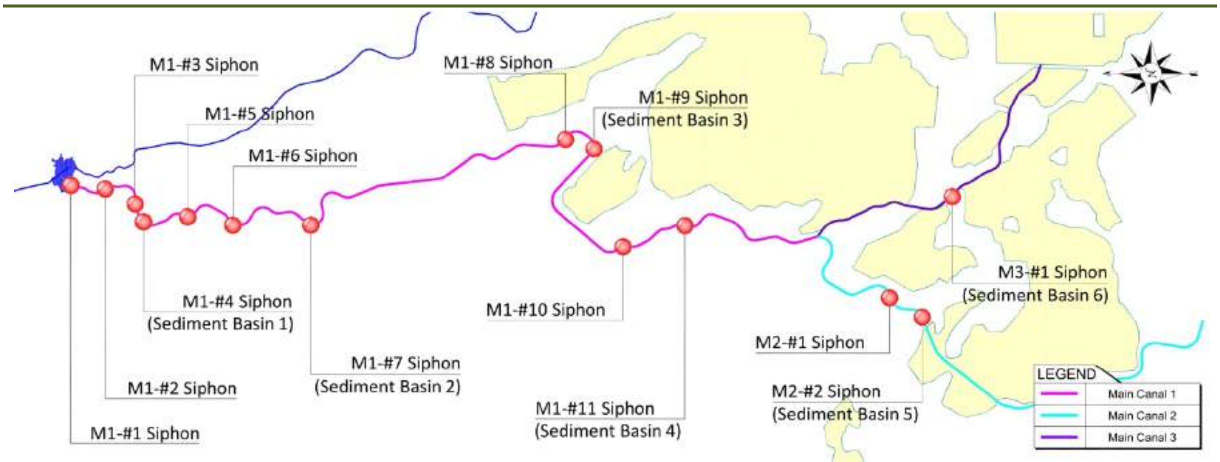
No.	Chainage	Length (m)	Size (m)	Remark
①	STA 0+64 ~ STA 0+817	755.40	8.0 x 3.0	Intake and #1 Siphon
②	STA 1+237 ~ STA 1+430	195.40	8.0 x 3.0	#2 Siphon
③	STA 2+710 ~ STA 2+890	181.70	8.0 x 3.0	#3 Siphon
④	STA 3+400 ~ STA 3+800	406.80	8.0 x 3.0	#4 Siphon
⑤	STA 5+025 ~ STA 5+290	267.30	8.0 x 3.0	#5 Siphon
⑥	STA 6+890 ~ STA 7+110	223.30	8.0 x 3.0	#6 Siphon
⑦	STA 9+890 ~ STA 10+220	335.00	8.0 x 3.0	#7 Siphon
⑧	STA 19+760 ~ STA 20+020	261.40	7.0 x 3.0	#8 Siphon
⑨	STA 21+110 ~ STA 21+580	475.00	7.0 x 3.0	#9 Siphon
⑩	STA 26+460 ~ STA 26+820	360.90	7.0 x 3.0	#10 Siphon
⑪	STA 28+760 ~ STA 29+320	571.30	7.0 x 3.0	#11 Siphon
Total		4,032.50		

[Table 13.4-3] Siphon Structures on the Main Canal2

No.	Chainage	Length (m)	Size (m)	Remark
①	STA 4+332 ~ STA 4+668	338.10	6.0 x 2.5	#1 Siphon
②	STA 5+732 ~ STA 7+608	1,900.00	6.0 x 2.5	#2 Siphon
Total		2,238.10		

[Table 13.4-4] Siphon Structures on the Main Canal 3

No.	Chainage	Length (m)	Size (m)	Remark
①	STA 4+943 ~ STA 5+307	366.00	4.0 x 1.5	#1 Siphon
Total		366.00		



[Figure 13.4-1] Location Map of Siphons and Sedimentation Basins on the Main Canal

#1 Siphon of Main Canal 1

The beginning section of Main canal 1(about 1 km) shall be constructed within Majete Game Reserve area. This section was designed as a siphon structure in order to minimize adverse environmental impact from this project. The siphon shall have a rectangular cross section (8 m (B) x 3 m (H)) and a length of 755.4 m.

The cross section shall have two partitions: (5 m x 3 m) and (3 m x 3 m), to correspond to the partitioning of the intake gates, (8 gates and 4 gates), considering the minimum water delivery. At the lowest point of siphon, a small duct will be installed for the purpose of evacuation of sediment or water leading it back to the river.

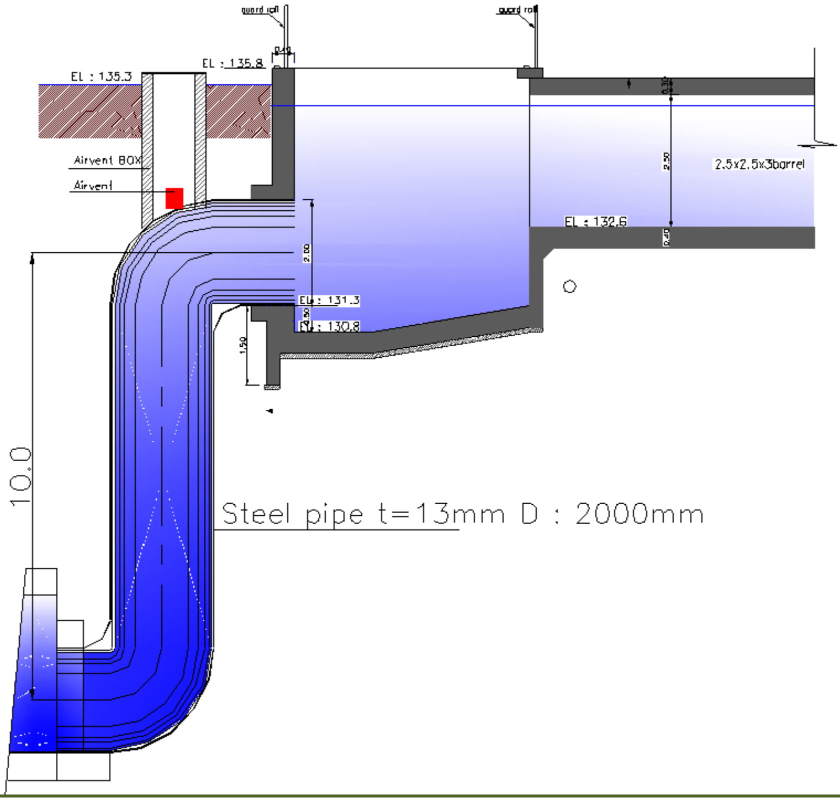
#2 Siphon of Main Canal 2

Another important structure is the siphon crossing the Mwanza River. It is 1.9 km long with a rectangular cross section (6 m (B) x 2.5 m (H)). This siphon also has two partitions: (4 m x 2.5 m) and (2 m x 2.5 m). At the lowest point of the siphon, a small duct will be installed for the purpose of evacuation of sediment or water leading it back into the river.

13.4.2. Other Structures

#1 & #2 Steep Sections of Main Canal 3

The beginning section of the Main canal 3 has a steep slope (1:27). Several design alternatives were examined such as open chute structure, drop structures, and steel pipe structure, etc. Considering their pros and cons, this section was designed as a composite structure of steel pipe and culvert. The steel pipe, 10 m long and 2 m in diameter, will form the vertical part of the chute, and a culvert of 240 m long shall form the horizontal part of the chute (5 m x 2 m in section). Another steep topographic condition exists at chainage No. STA. 1+140. At this section a similar structure shall be constructed. The vertical part shall comprise a steel pipe 9 m long and 2 m in diameter, and a culvert of 160 m long shall form the horizontal part in culvert (5 m x 2 m).



[Figure 13.4-2] Main Canal 3 Steel Pipe Chute Structure

Since these two structures have 10 m of height, establishing a mini scale hydropower generation plant could be considered. The flowrate varies between 6 m^3/s and 14 m^3/s depending on the crop water requirement. The system thus could generate between 0.4 MW and 0.9 MW of electric power. However, this has to be further investigated by a separate study.

Secondary Offtakes

A total of 16 secondary canal offtakes shall be constructed, 7 secondary offtakes to Zone I-1 and 9 secondary offtakes to Zone A. An Acoustic Doppler Current Profiler system shall be installed at the head of the secondary offtakes for accurate measurement of water discharges into each block. Each offtake structure has an orifice gate, and the operator manipulates the gate by observing the instrument to get the required flowrate. Table 13.4-5 shows details of secondary canals.

[Table 13.4-5] Detail Information of Secondary Canals

Secondary Canal	Main Canal	Chainage No.	Area (ha)	Q_{max} (m^3/s)	Length (m)	Ground (EL.m)	Canal (EL.m)
I1	Main 1	STA.16+600	621	0.72	7,742	138.98	137.42
I2	Main 1	STA.20+500	3,458	3.99	22,600	138.60	136.37
I3	Main 1	STA.22+500	328	0.38	1,351	135.10	135.35
I4	Main 1	STA.28+600	679	0.78	1,336	135.64	134.00
I5	Main 1	STA.31+100	1,040	1.20	5,708	135.40	133.13
I6	Main 3	STA.00+700	333	0.38	795	121.17	119.09
I7	Main 3	STA.02+400	1,407	1.62	9,418	105.24	104.04
A1	Main 2	STA.02+400	508	0.59	3,156	134.27	132.02
A2	Main 2	STA.05+600	204	0.24	7,302	132.38	131.11
A3	Main 2	STA.07+960	215	0.25	2,017	115.40	123.87
A4	Main 2	STA.09+700	294	0.34	1,366	125.79	123.52
A5	Main 2	STA.10+400	374	0.43	225	122.80	123.38
A6	Main 2	STA.12+400	1,001	1.15	8,071	124.58	122.98
A7	Main 2	STA.14+100	1,468	1.69	17,589	124.15	122.64
A8	Main 3	STA.07+700	157	0.18	766	95.12	92.98
A9	Main 3	STA.09+340	198	0.23	1,759	9242	92.43

Control Gate Structures of Main Canal 2 and Main Canal 3

Main canal 1 ends at the bifurcation point of Main canal 2 and Main canal 3. Control gates shall be installed at the head of both canals. The control gate for the Main canal 2 has three gates (3 m width x 2.5 m height x 3), and Main canal 3 has also three gates (1.8 m width x 2.5 m height x 3). An Acoustic Doppler Current Profiler system shall also be installed at the front side of the gates to measure the flows. At the end of the Main canal 2 a control gate shall be installed in order to prevent wastage of water and control the water depth in the canal.

At the end part of Main canal 3, an Acoustic Doppler Current Profiler system shall also be installed for accurate measurement of water supply to Illovo Estate.

Sediment Removal

During the rainy season a lot of sediment flows into the rivers and transported or deposited downstream. Sediment removal is one of the important issues of canal design. From the site exploration of Kapichira Reservoir the Hydraulic Modeling Consultant provided the mean diameter of bed load in the reservoir as 0.14 mm. This particle size will be the reference diameter for design of sediment removal at the intake structure.

The spur dike in the reservoir performs a great role to protect the intake structure from strong currents and sediment that flows down from upstream. The fore basin surrounded by the spur dike shall serve as a sedimentation basin. At the end of spur dike, distance to the intake structure is about 440 m.

The settling velocity of a particle of 0.14 mm was calculated using the Stokes formula, and it is about 0.017 m/s. When the water depth is 5m, the time required for a particle entering the entrance of fore basin to settle down on the bottom is about 300 seconds. When the maximum water requirement (50 m^3/s) is taken from the reservoir, the average flow velocity in this area is about 0.05 m/s. Therefore, the particle diameter of 0.14 mm shall be reached to the bottom after moving forward approximately 15 m from the entrance. In this regard the fore basin surrounded by the spur dike performs the role of sedimentation basin, so that an additional sedimentation basin is not required.

The particles smaller than 0.10 mm could enter the intake structure but do not seldom settle down in the canal flow. Nevertheless some particles could be settled in the intake structure. In preparation for the case, many diffusers will be installed at the intake gates, which will make the particles refloat with high air pressure (1 kg/cm^2) from the floor, and flowing down to the downstream.

Sediments entering into the canal will not emanate from the intake only, but also from outside of the canal due to various reasons (Sometimes during heavy rainfall the bank top could be severely scoured and the sediment enter into the canal.). These sediments could be coarser than those from the intake gates. To remove these sediments 5 sedimentation basins (3 basins for Main canal 1, 1 basin for Main canal 2, 1 for Main canal 3) are proposed to be constructed in front of the siphon structures, No. 4, 7, 9 and 11 on Main Canal 1 (refer to Figure 13.4-1 above) spaced every 10 km distance. All the sedimentation basin are located outside Majete. Since most of the sediment will be trapped in Main Canal 1 only one sedimentation basin is proposed on Main Canal in front of the siphon structure on Mwanza river. The sedimentation basins are designed based on the particle size of 0.3 mm, and they have rectangular shape with 35 m of length and 4~6 m of width. To avoid sedimentation in the siphons during low flows partitions have been provided to the siphons. In the open canal section the minimum velocity (0.5 m/s) shall be maintained to discourage sedimentation. This will be looked more during detail design.

Hydraulic modeling results (Artelia E&E) estimated that in average 162,000 ton of clay and 26,500 ton of silt per year shall enter the SVIP intake. Most of the silt particles will be trapped in the 5 sedimentation basins. However some fine silt and clay particles shall be moved to the Secondary Canals. Most of these particles shall be settled down in the night storage reservoirs. Consequently, the water coming out through the night storage reservoirs will contain few sediment particles.

The sediment piled in the sedimentation basins shall be evacuated through ejectors provided at one side of basins. The sediment in the canal could be flushed by high speed of water through the opening the gates in orifice condition. The top of these gates shall be set at the same height as the maximum flow level, so that the excess water shall overflows and get discharged into drains. Therefore the gates of 5 sedimentations basins could be used also as emergency spillway. The locations of sedimentation basins are shown in the Figure 13.4-1.

Drop structure for Tiger Fish Protection

In order to mitigate the Tiger Fish problem, it is proposed to provide a 1 meter high broad crested weir across the main canal combined with a 3.5 meters drop structure. This is more or less similar to that of ESIA proposal and is maintenance free as no screens are required. See the details in Chapter 11.4.

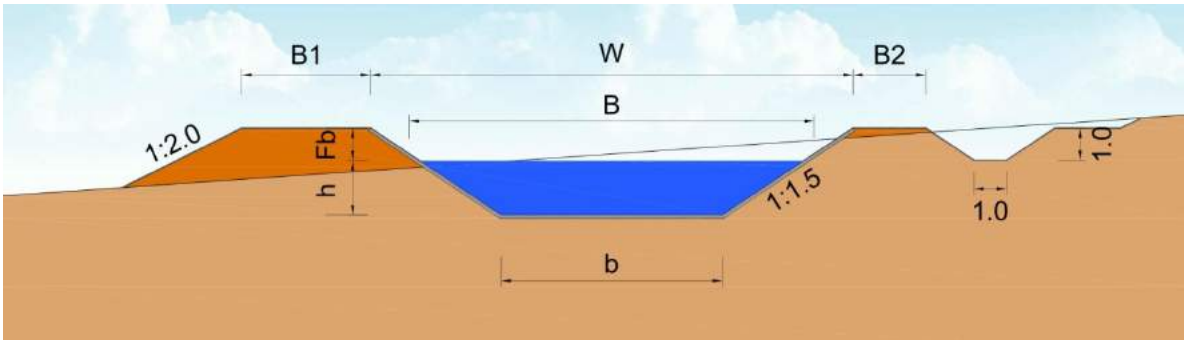
13.5. Secondary Canals

13.5.1. Secondary Canals for Zone I-1

The Secondary canals are connected to main canals (Main canal 1, Main canal 2 and Main canal 3), and supply water to each block of fields. Zone I-1 has 7 Secondary canals which will supply water to an area of 7,866 ha. 5 Secondary canals are directly connected to the Main canal 1, and 2 Secondary canals are connected to the Main canal 3. Table 13.5-1 shows the detail information of the Secondary canals for Zone I-1, and Figure 13.5-1 shows a standard section of secondary canals. All secondary canals are proposed to be lined to reduce seepage losses. ZoneI-1 and A areas are mostly dominated by light textured soils which will increase seepage losses. Similar canals at Illovo and Kathintula farmers are made to be lined for similar reason.

[Table 13.5-1] Secondary Canals for Zone I-1

Secondary Canals	Chainage No.	Net Area (ha)	Q_{max} (m^3/s)	Length (m)
SecondaryCanalI1	M1STA.16+600	621	1.384	7,742
SecondaryCanalI2	M1 STA.20+500	3,458	3.987	22,600
SecondaryCanalI3	M1 STA.22+500	328	0.756	1,351
SecondaryCanalI4	M1 STA.28+600	679	1.566	1,336
SecondaryCanalI5	M1 STA.31+100	1,040	2.398	5,708
SecondaryCanalI6	M3STA.00+700	333	0.768	795
SecondaryCanalI7	M3STA.02+400	1,407	1.939	9,418
Total		7,866	16.785	48,950



Secondary	W (m)	B (m)	b (m)	h (m)	Fb (m)	B1 (m)	B2 (m)
I 1	5.60	3.80	1.70	0.70	0.60	4.00	1.50
I2	9.10	6.70	4.30	0.80	0.80	4.00	1.50
I 3	5.00	3.20	1.70	0.50	0.60	4.00	1.50
I 4	6.40	4.00	1.90	0.70	0.80	4.00	1.50
I 5	7.10	4.70	2.30	0.80	0.80	4.00	1.50
I 6	5.00	3.20	1.70	0.50	0.60	4.00	1.50
I 7	6.60	4.20	1.80	0.80	0.80	4.00	1.50

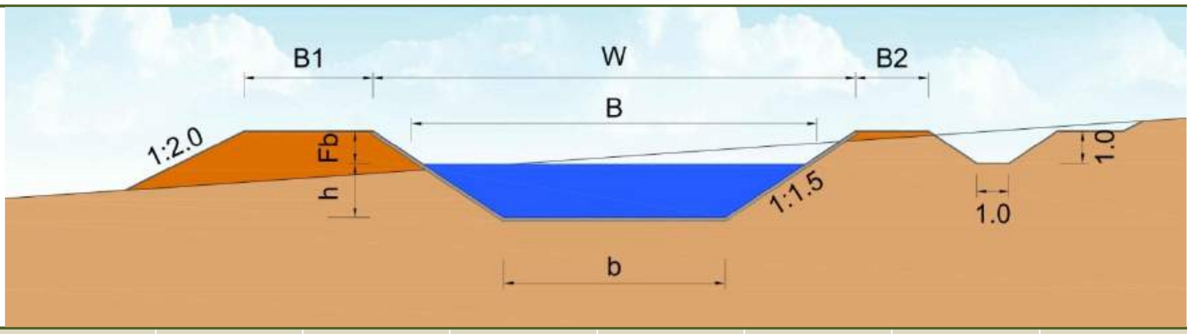
[Figure 13.5-1] Standard Section of Secondary Canals of Zone I-1

13.5.2. Secondary Canals for Zone A

Zone A has 9 secondary canals and they supply water to 4,419 ha. 7 Secondary canals are connected to the Main canal 2, and 2 Secondary canals are connected to the Main canal 3. Table 13.5-2 shows the detail information of the Secondary canals for Zone A, and Figure 13.5-2 shows a standard section of Secondary canals.

[Table 13.5-2] Secondary Canals for Zone A

Secondary Canals	Chainage No.	Net Area (ha)	Q_{max} (m^3/s)	Length (m)
SecondaryCanalA1	M2 STA.02+400	508	1.171	3,156
SecondaryCanalA2	M2 STA.05+600	204	0.235	7,302
SecondaryCanalA3	M2 STA.07+960	215	0.497	2,017
SecondaryCanalA4	M2 STA.09+700	294	0.678	1,366
SecondaryCanalA5	M2 STA.10+400	374	0.862	225
SecondaryCanalA6	M2 STA.12+400	1,001	2.308	8,071
SecondaryCanalA7	M2 STA.14+100	1,468	3.386	17,589
SecondaryCanalA8	M3 STA.07+700	157	0.359	766
SecondaryCanalA9	M3 STA.09+340	198	0.458	1,759
Total		4,419	10.188	42,251



Secondary	W (m)	B (m)	b (m)	h (m)	Fb (m)	B1 (m)	B2 (m)
A1	5.50	3.70	1.90	0.60	0.60	4.00	1.50
A2	3.60	1.80	0.60	0.40	0.60	4.00	1.50
A3	4.30	2.50	1.00	0.50	0.60	4.00	1.50
A4	4.80	3.00	1.50	0.50	0.60	4.00	1.50
A5	5.00	3.20	1.40	0.60	0.60	4.00	1.50
A6	7.00	4.60	2.20	0.80	0.80	4.00	1.50
A7	7.80	5.40	2.70	0.90	0.80	4.00	1.50
A8	4.30	2.50	1.00	0.50	0.60	4.00	1.50
A9	4.40	2.60	1.10	0.50	0.60	4.00	1.50

[Figure 13.5-2] Standard Section of Secondary Canals of Zone A

The Secondary Canal A2 is provided to serve Moses Area (block A-e; 205 ha). Due to the proposed drop structure for Tiger Fish protection on the main canal, this area can no longer be supplied water by gravity. Therefore, no night storage facility is required for this channel.

13.6. Canal Regulation

The water level variation in the canals was calculated using HEC-RAS model (developed by US Army Corps), which is one-dimensional hydrodynamic model and widely used for the river and canal water simulation. For the Main canal 1, the calculations of model show that the water depth is maintained higher than 1 m throughout the whole stretch not only during high water demand but also during low flows. This is mainly due to its gentle slope of 1:8,000.

For regulating the water level in Main Canal 1, the gates of the 11 siphons on the Canal shall be used. These gates can enable water level regulation between the siphons without constructing cross regulators. Especially it could be very efficient for the small flowrate conditions. The two gates at the bifurcation structure located at the end of Main canal 1 could also serve as regulators. However, for the sake of easier management of water levels broad crested weirs are proposed to be provided at immediate downstream of all the offtakes of Main Canal 1, 2 and 3.

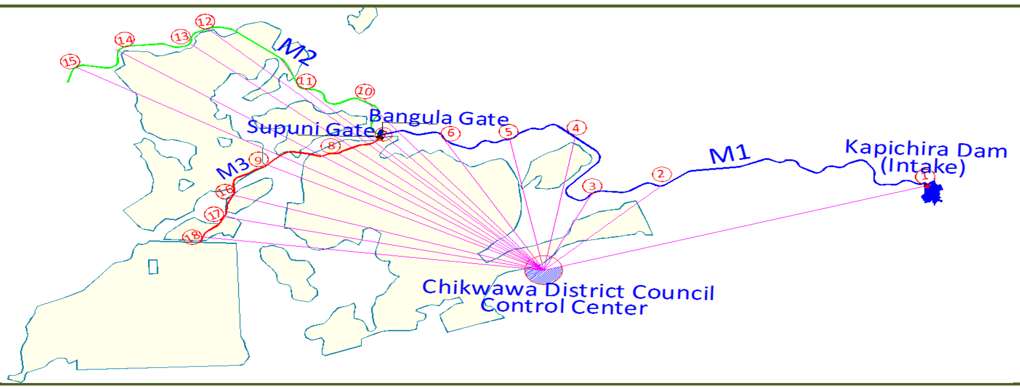
13.7. Canal Operation and SCADA System

The SCADA (Supervisory Control and Data Acquisition) system enables a scientific and efficient water management. A complete supervisory control system comprises a tele-monitoring system and a tele-control system. This system could be a very sophisticated system and requires high cost. This full system is not applicable in areas where electricity supply is not stable like in the project area.

From practical point of view, a rather simplified system is recommended for SVIP. The intake gates at Kapichira Dam shall be operated by an automatic system, which also could be operated by a tele-control system. Considering the O&M cost and easiness of operation, the gates of Main Canal 2 and 3 shall be directly operated at site (not tele-control system).

There are 16 offtakes on the three main canals (Main Canal 1, 2 and 3). An Acoustic Doppler Current Profiler system shall be installed at the head of the offtakes for accurate measurement of water discharges into each block. Each offtake structure has an orifice gate, and the operator adjust the gate opening observing the instrument to get the required flow. The flow measurement systems shall be installed at a total of 18 locations, including additional three locations (the bifurcation point of Main Canal 2 gate and Main Canal 3 gate and the entrance point of Illovo Estate).

The measured data shall be stored not only in the local devise at each site but also stored in the data logger system in the main office through a wireless tele-communication system. The tele-monitoring systems shall be installed at all these facilities including the intake structure, through which the real-time situation could be monitored in the main control centre. Figure 13.7-1 shows the conceptual diagram for SCADA system network proposed for the SVIP.



[Figure 13.7-1] SCADA System Network for the SVIP

13.8. Irrigation Method and Night Storages

The daily irrigation hours depends on the irrigation methods. For pivot irrigation system, irrigation is applied for 24 hours, i.e. the whole day. For furrow irrigation, water application is normally 12 hours, during the daytime. Therefore, the secondary canals shall be used only for 12 hours based for furrow irrigation methods.

The main canal was designed for 24-hour continuous supply, for the whole year. Therefore, there is an operating time gap between the main canal and the secondary canals. Night storages will therefore be provided in order to make up for the gap.

The canal size of the Secondary Canals shall be different between the upstream and downstream section of the night storage. The downstream canal section has a double size than that of upstream. In this regard, the more downstream the reservoir is installed, the lower the canal cost. However, since the water from the night storage should be supplied by gravity, it should be installed at a location higher enough to supply water by gravity. The elevation at the heads of the tertiary canals is low thus do not allow the construction of the night storage. However this could be looked in detail during detail design

Night storages shall be constructed at all the head of each secondary canal, 5 storages for Zone I-1 and 8 storages for Zone A. The Secondary canal I-2 supply water for Kasinthula and Phata& Sande Ranch Areas. These areas have pivot irrigation schemes which irrigate day and night. Therefore the night storages are not needed for this canal.

For field irrigation, supply of irrigation water depends upon types of crops cultivated, working time, irrigation method, and labor availability, among other conditions. For manual irrigation systems it is difficult to supply irrigation water around the clock. Therefore, night storages are incorporated into the design of the water reticulation system so that storage occurs during the night and irrigation can commence early during the day using the stored water.

Some parts of the project area are already being irrigated using sprinkler irrigation systems, but the major constraint is availability of uninterrupted electricity supply. With uninterrupted electricity supply, it is possible to irrigate crops around the clock. Where water has become a constraint, rotational irrigation is done.

The capacity of night storage is considered to be suitable for 1~1.3 times of 12-hour irrigation per day.

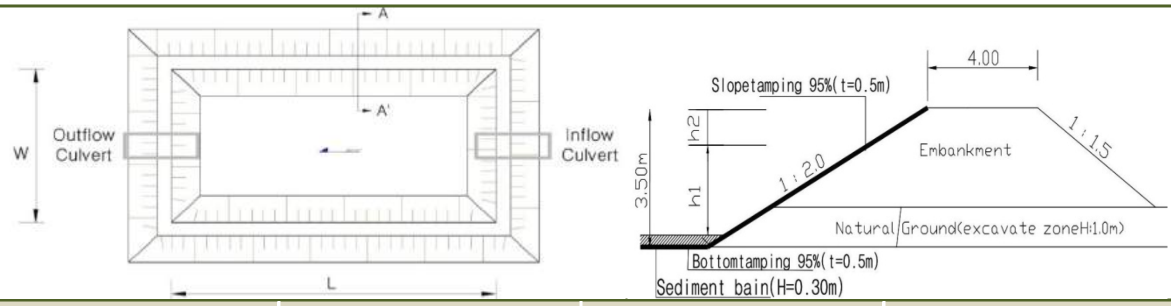
$$V = Q \times 12hr \times 3{,}600s$$

The capacity of the night storage is calculated based on the monthly average water requirement 0.0007841m^3/s/ha. The monthly water requirements are shown in the Table 13.8-1.

[Table 13.8-1] Water Requirement of 5 Year Return Period (m^3/day/ha)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
35.4	50.6	62.5	71.0	57.4	65.6	87.2	95.7	99.6	73.4	76.4	47.8

Night storages will have the same shape but 6 different dimensions. Figure 13.8-1 provides the 6 types of night storages. Table 13.8-2 and 13.8-3 show the specifications of night storages of Zone I-1 and Zone A respectively.



Type	W (m)	L (m)	H (m)
Type 1	220.0	100.0	3.50
Type 2	160.0	100.0	3.50
Type 3	140.0	80.0	3.50
Type 4	100.0	80.0	3.50
Type 5	90.0	40.0	3.50

[Figure 13.8-1] 6 Types of Night Storages

[Table 13.8-2] Night Storages for Zone I-1

Storage Name	Station	Volume(m^3)	Type	Remark
Night Storage I-1	M1 STA.16+600	21,000~27,000	Type 3	Secondary CanalsI1
Night Storage I-3	M1 STA.22+500	12,000~14,000	Type 4	Secondary CanalsI3
Night Storage I-4	M1 STA.28+600	26,000~33,000	Type 3	Secondary CanalsI4
Night Storage I-5	M1 STA.31+100	45,000~58,000	Type 1	Secondary CanalsI5
Night Storage I-7	M3 STA.02+400	44,000~56,000	Type 1	Secondary CanalsI7

[Table 13.8-3] Night Storages for Zone A

Storage Name	Station	Volume(m^3)	Type	Remark
Night Storage A-1	M2 STA.02+400	18,000~22,000	Type 4	Secondary CanalsA1
Night StorageA-2	M2 STA.05+600	7,000~9,000	Type 5	Secondary CanalsA2
Night Storage A-3	M2 STA.07+960	22,000~28,000	Type 3	Secondary Canals A3
Night Storage A-4	M2 STA.09+700	33,000~41,000	Type 2	Secondary Canals A4
Night Storage A-6	M2 STA.12+400	29,000~36,000	Type 2	Secondary Canals A5
Night Storage A-7	M2 STA.14+100	31,000~40,000	Type 2	Secondary Canals A6
Night Storage A-9	M3 STA.09+340	7,000~9,000	Type 5	Secondary Canals A8

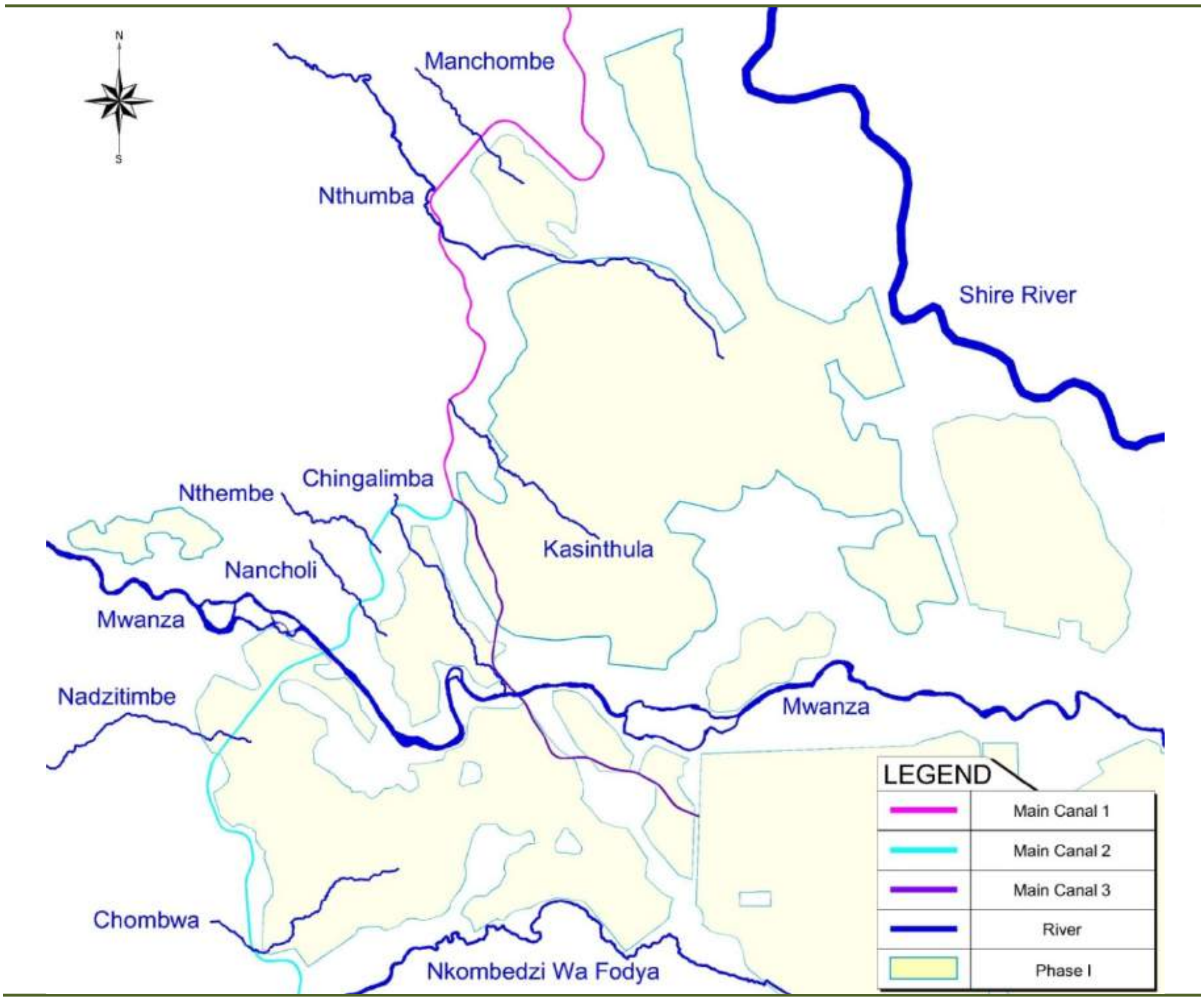
13.9. Drainage Canals

13.9.1. Natural River Condition

The project areas of the Phase I are located to the south of Majete Game Reserve and to the east and south of Lengwe National Park. Several rivers flow from the mountain range to the west of the project area, eventually discharging their waters into the Shire River. Most of these rivers flow only during the rainy seasons in indistinct river channels, their stream lines disappearing in the field. Figure 13.9-1 shows the natural river condition in the project area and Table 13.9-1 shows their properties.

[Table 13.9-1] River Properties in the Project Area

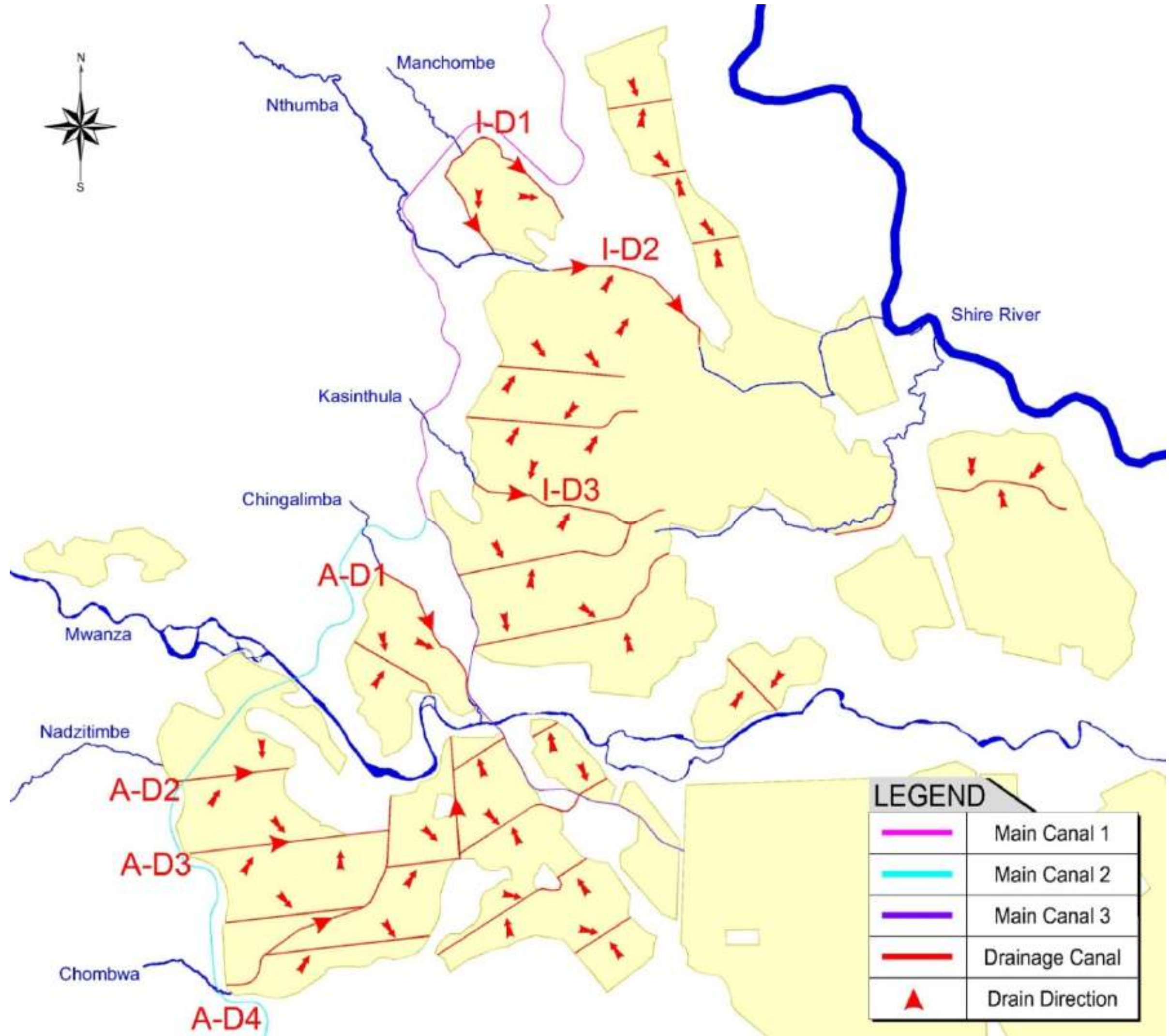
Rivers	Basin Area A(km^2)	Channel Length L(km)	Mean Width of Basin (A/L, km)	Basin Shape Factor (A/L^2)
Manchombe	42.85	18.56	2.31	0.12
Nthumba	69.04	33.26	2.08	0.06
Kasinthula	3.87	3.56	1.09	0.31
Chingalumba	15.83	1.52	10.42	6.86
Nthembe	2.71	2.84	0.96	0.34
Nancholi	2.13	2.44	0.87	0.36
Mwanza	1,618.39	127.06	12.74	0.10
Nadzitimbe	23.64	13.69	1.73	0.13
Chombwa	27.92	15.44	1.81	0.12
Nkombedzi	430.83	47.80	9.01	0.19



[Figure 13.9-1] Natural River Condition in the Project Areas

13.9.2. Drainage Canal Design

Planning of the drainage system considered the rivers and streams, topography and the existing natural drainage channels. The drainage system has been designed to evacuate excessive surface water as promptly as possible during the wet season, discharge excess irrigation water, and control the groundwater table. In the case of large drainage area, fields are provided with field and collector drains in order to evacuate excess rain or irrigation water. The main drainage canal is designed to evacuate the maximum flood coming through the natural rivers. Figure 13.9-2 shows the main drainage system.



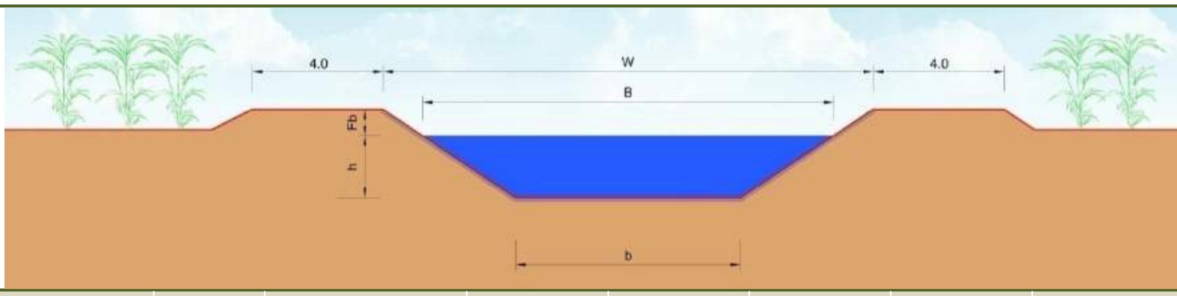
[Figure 13.9-2] Main Drainage Canal Planning

For the on-farm drainage canal design 5 year frequency of flood was considered. And for the natural river the NRCS Synthesis Unit Hydrograph Method and the Rational Method have been used for drainage design, based on 20-years of flood frequency. Table 13.6-2 shows the design flood for the rivers. The Rational Method gives good results when the upstream basin area is smaller than 8 km^2. From this reason the two cases in Table 13.9-2 used the results calculated by the Rational Method.

[Table 13.9-2] Design Flood for the Rivers

Zone	River	Basin(km^2)	Runoff(m^3/s)	Specific Yield	Remark
Zone I-1	Manchombe	42.85	174.53	4.07	NRCS
	Nthumba	69.04	219.25	3.18	NRCS
	Kasinthula	3.87	3.88	1.00	Rational Method
Zone A	Chingalumba	15.83	159.08	10.05	NRCS
	Nadzitimbe	23.64	169.75	7.18	NRCS
	Small streams Between Nadzitimbe& Chombwa	5.11	5.54	1.08	Rational Method
	Chombwa	27.92	121.82	4.36	NRCS

The drainage channels have been provided with a large bank on either or both sides as maintenance roads. Figure 13.9-3 shows the main drainage canal section. Improvements shall be done to the natural drainage channels, with minimum disturbance to the existing regime, to allow unimpeded continuous discharge.



Zone	No.	River	W(m)	B(m)	b(m)	h(m)	Fb(m)
Zone I-1	I-D1	Manchombe	23.7	21.3	14.4	2.3	0.8
	I-D2	Nthumba	30.9	28.5	21.0	2.5	0.8
	I-D3	Kasinthula	5.5	3.7	0.7	1.0	0.6
Zone A	A-D1	Chingalumba	21.0	18.6	12.3	2.1	0.8
	A-D2	Nadzitimbe	33.1	30.7	23.8	2.3	0.8
	A-D3	Small Streams	7.9	6.1	3.7	0.8	0.6
	A-D4	Chombwa	25.6	23.2	16.3	2.3	0.8

[Figure 13.9-3] Standard Cross Section of Main Drainage Canal

13.10. On Farm Works

13.10.1. Approaches to Land Consolidation

Comprehensive land consolidation includes the re-allocation of parcels together with a broad range of other measures to promote rural development. Such activities include village renewal, support to community based agro-processing, construction of rural roads, construction and rehabilitation of irrigation and drainage systems, domestic water supply, erosion control measures, environmental protection and improvements including the designation of nature reserves, and the creation of social infrastructure including sports grounds and other public facilities.

Comprehensive land consolidation projects introduce major changes throughout the project site, and generally require the participation of all beneficiaries or stakeholders in the project area. The success of a project thus depends to a great extent on the initial steps taken to obtain the support and cooperation of farmers and other stakeholders who would be affected by the project. Information and communication is essential. People must understand how they will benefit from the project and how the changes will impact on them.

Which type of irrigation to be selected depends on the cropping pattern, crops to be grown, topographic condition, farming scale, and labor availability. Flood irrigation is most suitable for rice cultivation because of its demand or more water than other crops. However current research in irrigated rice cultivation is introducing irrigation practice that utilizes less water. Sugarcane can be grown using either furrow irrigation or sprinkler irrigation. Land for growing rice and sugarcane need to be properly leveled. On the other hand, sprinkler irrigation and pivot irrigation are suitable for upland crops such as maize (corn), and cotton, which require less water. These upland crops do not need to have land leveling as long as the topographic undulation is not severe.

Regardless of the crop water usage, land consolidation is required for efficient farming. In large scale farms like SVIP, land consolidation is essential. Land consolidation through land leveling for flood and furrow irrigation should be designed precisely to make the most of an effective open canal and drainage system, minimizing earth works as much as possible.

13.10.2. Decision of Parcel/Field Size

In the land consolidation design, the size of each parcel/field of farmland should be designed considering the topographic condition, farm size, size of agricultural machinery, household size, and crops. Planning of service and access roads should be a component of land consolidation. Large sugarcane farms, Illovo and Kasinthula, have well developed irrigation systems of pivot, sprinkler, and furrow irrigation. Table 13.10-1 shows the sizes of land parcels of the existing estates within the project area.

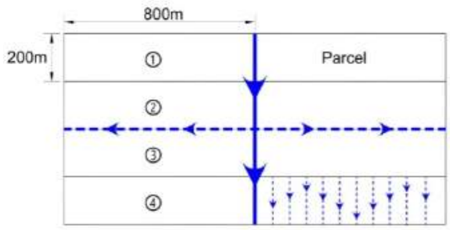
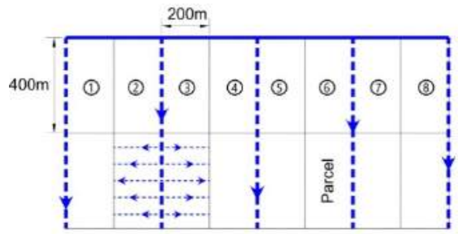
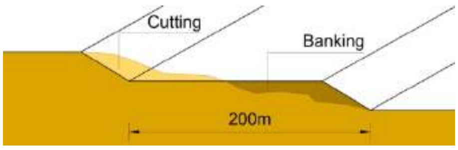
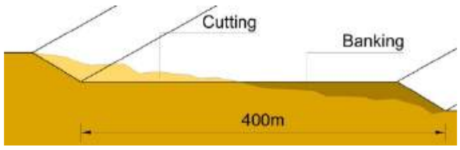
[Table 13.10-1] Land Parcel/Field Size of Existing Estates in SVIP

Estate	Max/ Min	Rectangle			Circle	
		Long Side(m)	Short Side(m)	Area(m^2)	Diameter(m)	Area(m^2)
Illovo (Nchalo)	Max	750	400	300,000	950	700,000
	Min	240	175	42,000	630	300,000
Kasinthula	Max	980	220	215,600	950	700,000
	Min	190	160	30,400	820	520,000
Alumenda	Max	1,280	230	294,400		
	Min	140	85	12,000		
Phata& Sande Ranch	Max				950	700,000
	Min				710	400,000
Kaombe	Max				950	700,000
	Min				810	510,000

The longer the long side length of a land parcel, the more economical the project becomes. However, there will be some limitations such as available space, variation of topographic change, installation of roads and so on. Considering these factors, the length of long side of a standard parcel for the project is decided to be 800 m.

The length of short side depends on the irrigation method, furrow slope, and soil type, etc. For the furrow irrigation FAO recommends the maximum length of short side as 200 m for the clay soil, and 170 m for the loam soil when 0.3 % of furrow slope is applied. Since the representative soil type in the project area is Loamy Clay type, the length of short side of a standard parcel is decided to be 200 m. This way a standard parcel has the size of 800 m x 200 m (16 ha). The other advantage of this parcel size is that four parcels could be easily transformed to pivot has area of 50 ha without involving much modification to the civil works.

[Table 13.10-2] Review of the Unit Parcel Size

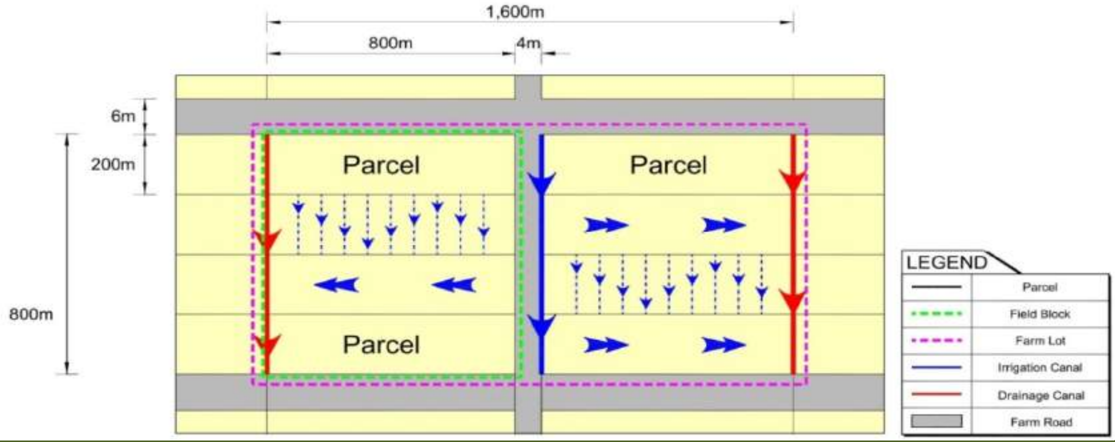
Item	Parcel (200m x 800m)	Parcel (400m x 200m)
Farm Lot	⬩A = 800m x 1,600m = 128ha  	⬩A = 800m x 1,600m = 128ha 
Earth Movement	⬩a few earth movement  	⬩a lot of earth movement 
Field Canal	⬩Cross Section: flow capacity can supply the irrigation water to the parcel of 15ha ⬩Length: 800m x 8ea = 6,400m	⬩Cross Section: flow capacity can supply the irrigation water to field block of 51ha ⬩Length: 800m x 4ea = 3,200m
Tertiary Canal	⬩Cross Section: flow capacity can supply the irrigation water to the farm lot ⬩Length: 800m x 1ea = 800m	⬩Cross Section: flow capacity can supply the irrigation water to the farm lot ⬩Length: 1,600m x 1ea = 1,600m
Drainage Canal	⬩Cross Section: drainage capacity can drain the irrigation water to the farm lot of 128ha ⬩Length: 800m x 1ea = 800m	⬩Cross Section: drainage capacity can drain the irrigation water to the field block of 128ha ⬩Length: 800m x 4ea = 3,200m
Parcel	⬩A=16ha (200m x 800m) ⬩Advantageous for the mechanical farming	⬩A=8ha (400m x 200m) ⬩Advantageous size for smallholders
O&M Road	⬩Length: 800m x 2ea = 1,600m	⬩Length: 800m x 4ea = 3,200m
Change of Irrigation Method	⬩Favourable size to change the irrigation method from furrow to pivot due to a few earth movement	⬩Difficulty of the irrigation method change from furrow to pivot
Select	O	

13.10.3. Farmland Layout

The irrigation and drainage system and roads in a unit parcel of land shall be based on its size. The roads inside the farmland have been planned to be spaced at every 1.6 km distance. In this regard, several parcels comprise a single block around which the roads shall be installed. A field block shall comprise 6 parcels, and a farm plot shall comprise 2 field blocks. Table 13.10-3 shows a standard farmland composition, and Figure 13.10-1 shows the standard farmland layout with irrigation and drainage channels.

[Table 13.10-3] Standard of the Farmland Layout

Item	Long Side	Short Side	Remark
Parcel	800 m	200 m	
Field Block	800 m	800 m	Add up 4 parcels
Farm Lot	1,600 m	800 m	Add up 2 field blocks

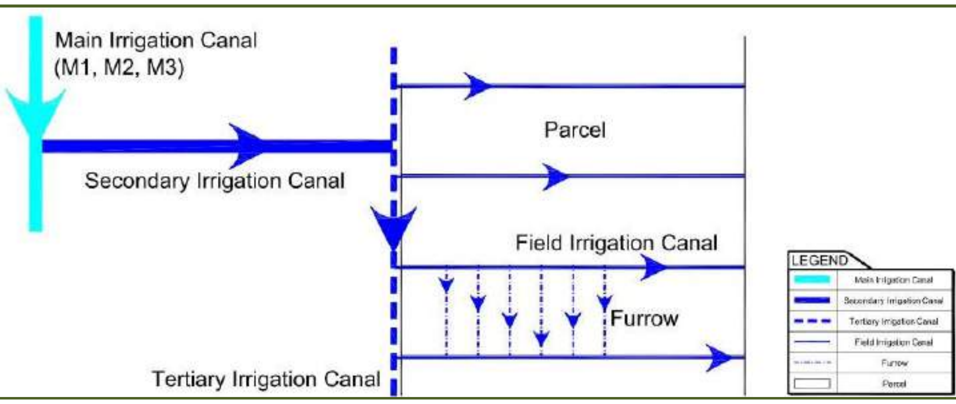


[Figure 13.10-1] Farmland Layout and Irrigation and Drainage Canals

13.10.4. Irrigation and Drainage System

Irrigation Canal Design

The irrigation canal in the farmland is composed of 2 types: (i) Tertiary irrigation canal, and (ii) Field irrigation canal (Figure 13.10-2).



[Figure 13.10-2] Schematic Diagram of Irrigation Canal in a Block

1) Tertiary Irrigation Canal

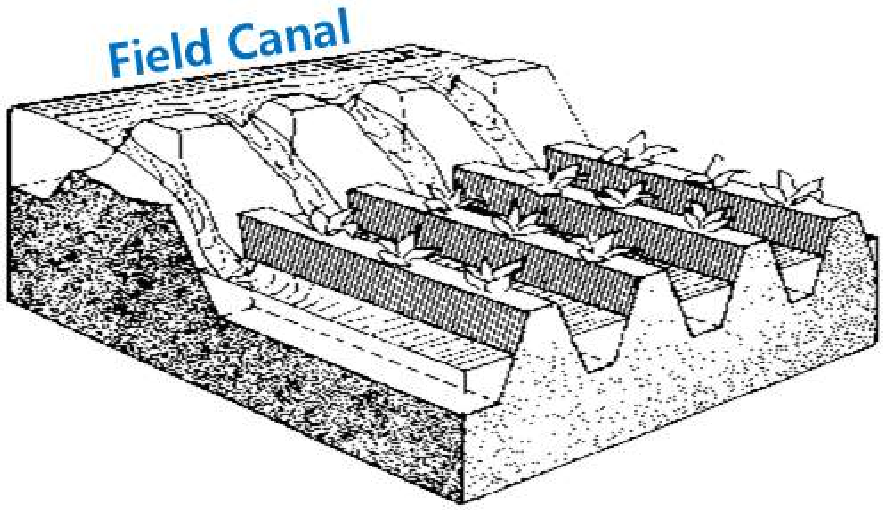
Since the secondary irrigation canal covers both sides of blocks (total 8 parcels), the canal section was designed to supply enough water for parcels on both side of the canal. Also, since irrigation is carried out during the daytime, the canal has to be designed to carry 2 times the design water amount. The unit discharge of secondary irrigation canal is as below.

$$Q = 4 \text{ parcel } (4 \text{ x } 800\text{m x } 200\text{m}) \times 2\text{ea} \times 0.001153\text{m}^3/\text{s/ha} \times 2 = 0.295\text{m}^3/\text{s}$$

2) Field Irrigation Canal

The field canal will supply irrigation water directly to the parcel through furrows (Figure 13.10-3) on both sides of the canal. Therefore, the field canal has been designed to carry 2 times of design water amount, similar design to the secondary canals. And the irrigation schedule is assumed once every 5 days. The unit discharge of secondary irrigation canal is as below.

$$Q = 1 \text{ parcel } (800\text{m x } 200\text{m}) \times 0.001153\text{m}^3/\text{s/ha} \times 2 \times 5 = 0.184\text{m}^3/\text{s}$$



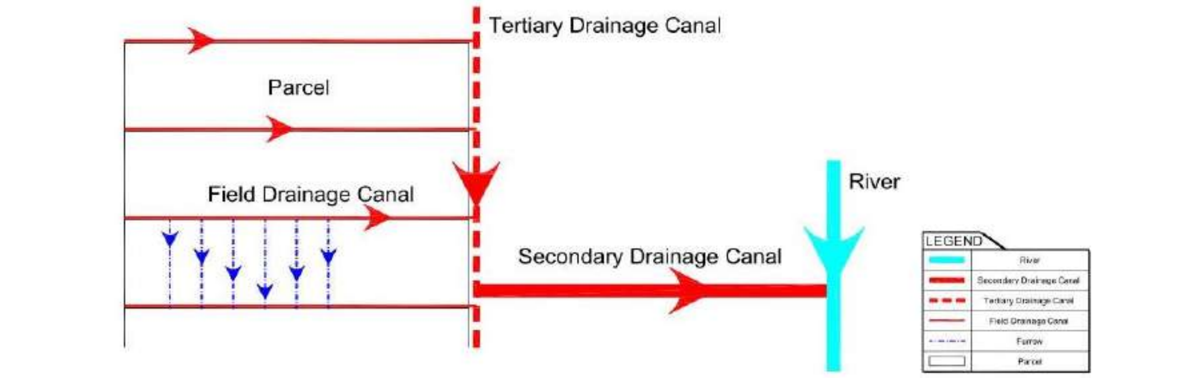
[Figure 13.10-3] Irrigation Water Supply through the Field Canal (Furrow Irrigation)

3) Water Supply Control Gates

On the tertiary canals, each block has a check gate which enables supplying water only for the scheduled block. Each field canal has a diversion gate which is connected to the tertiary canal. These gates enable to supply water to each field uniformly following the schedule.

<u>Drainage Channel Design</u>

Like irrigation canal, the drainage canal in the farmland is composed of 2 types: (i) Tertiary drainage canal, and (ii) Field drainage canal (Figure 13.10-4). The secondary drainage canal drains outflow from the tertiary drainage canal or field drainage canal, and it is drained outflow to river.



[Figure 13.10-4] Schematic Diagram of Drainage Canal in a Block

The size of drainage channels within a parcel of land has been determined using the Rational Method in consideration of the unit drainage block, rainfall, ground coverage condition and so on. Estimation of runoff has taken into consideration a design return period of 5 years, and a drainage block comprising 8 parcels, to come up with a drainage capacity of 0.65 m^3/s.

$$Q = 0.2778 \times C \times I \times A = 0.2778 \times 0.4 \times 4.6 \times 1.28 = 0.65 m^3/s$$

where, C is runoff coefficient: 0.4 (in case of field crop, 0.2~0.4)

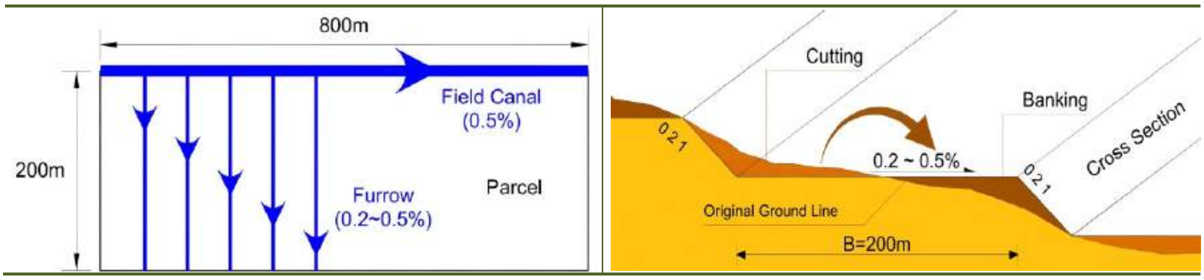
I is rainfall intensity (mm/hr): 4.6mm/hr (in case of 5 year return period)

A is basin area (km^2): 1.28km^2 (16ha × 8 parcels)

13.10.5. Land Leveling and Earth Work

Land leveling is required for land consolidation suitable for furrow irrigation system. Since the land leveling cost depends on the amount of earth movement, it should be reflected in the design process.

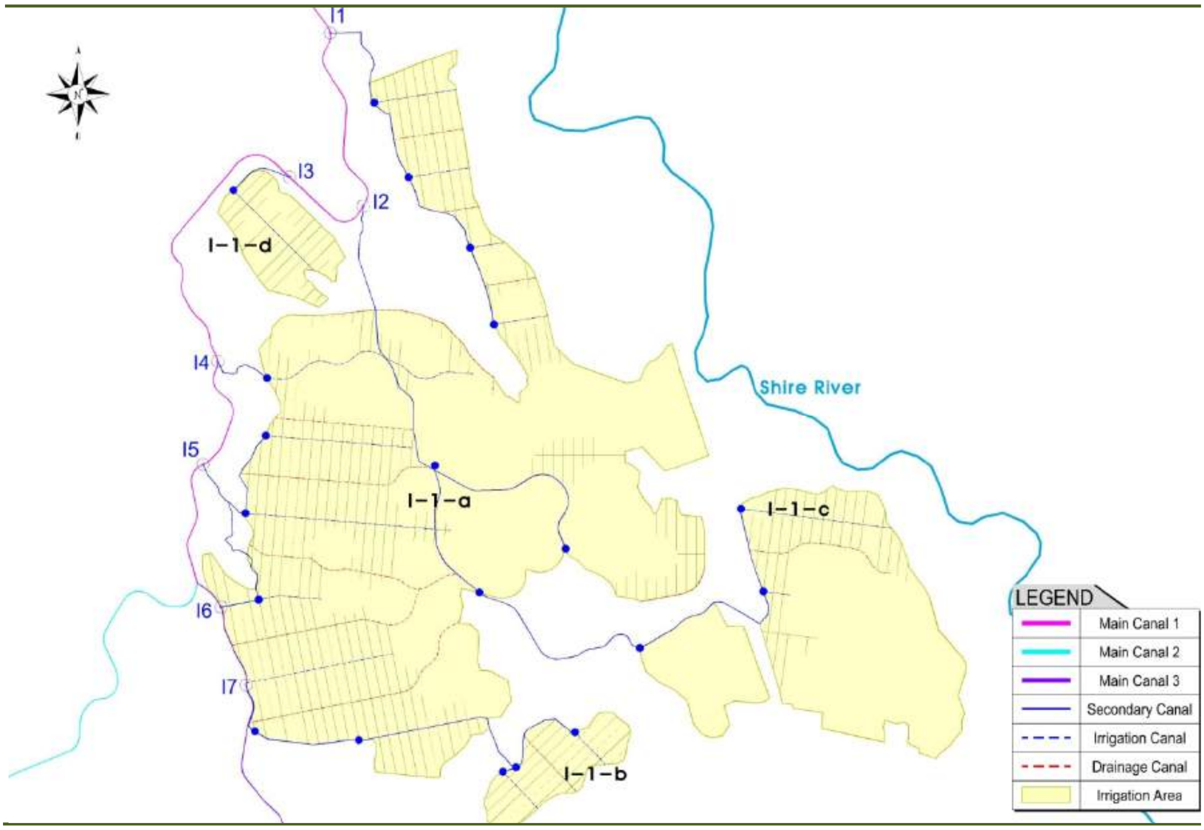
The furrow direction shall have a slope of 0.2~0.5% considering the required slope of furrows, soil erosion, amount of earth movement, etc. The field canal, 800 m length, which delivers water to furrows in a parcel, shall have a slope of 0.5%.



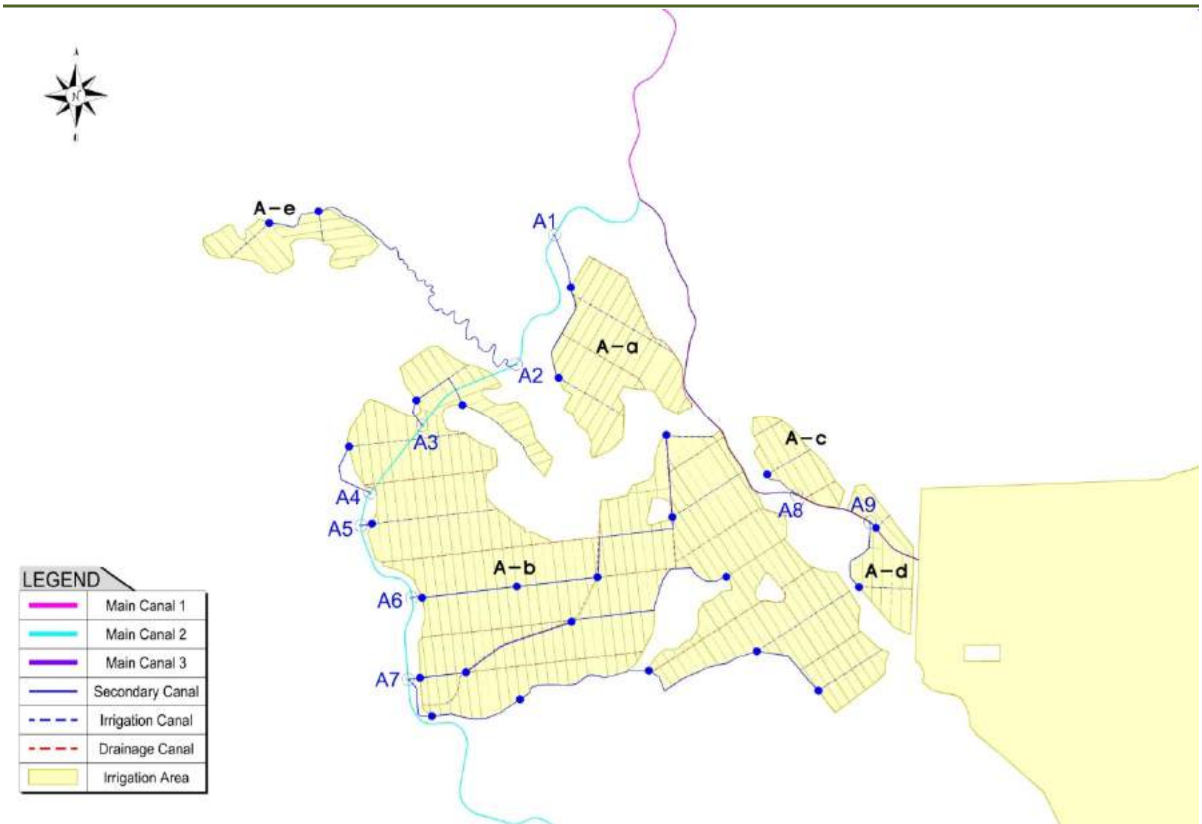
[Figure 13.10-5] Slope of Parcel (left) and Earth Movement in a Parcel (right)

13.10.6. Land Consolidation Plan

Farmland planning took into consideration the topography and natural geographic conditions. Secondary canals have direction from the west to the east, and the field canals have direction from the north to the south. In this regard, each zone has been divided into blocks comprising parcel size fields. Figure 13.10-6 and 13.10-7 show the field arrangement for the land consolidation for Zone I-1 and Zone A respectively.



[Figure 13.10-6] Land Consolidation Layout of Zone I-1



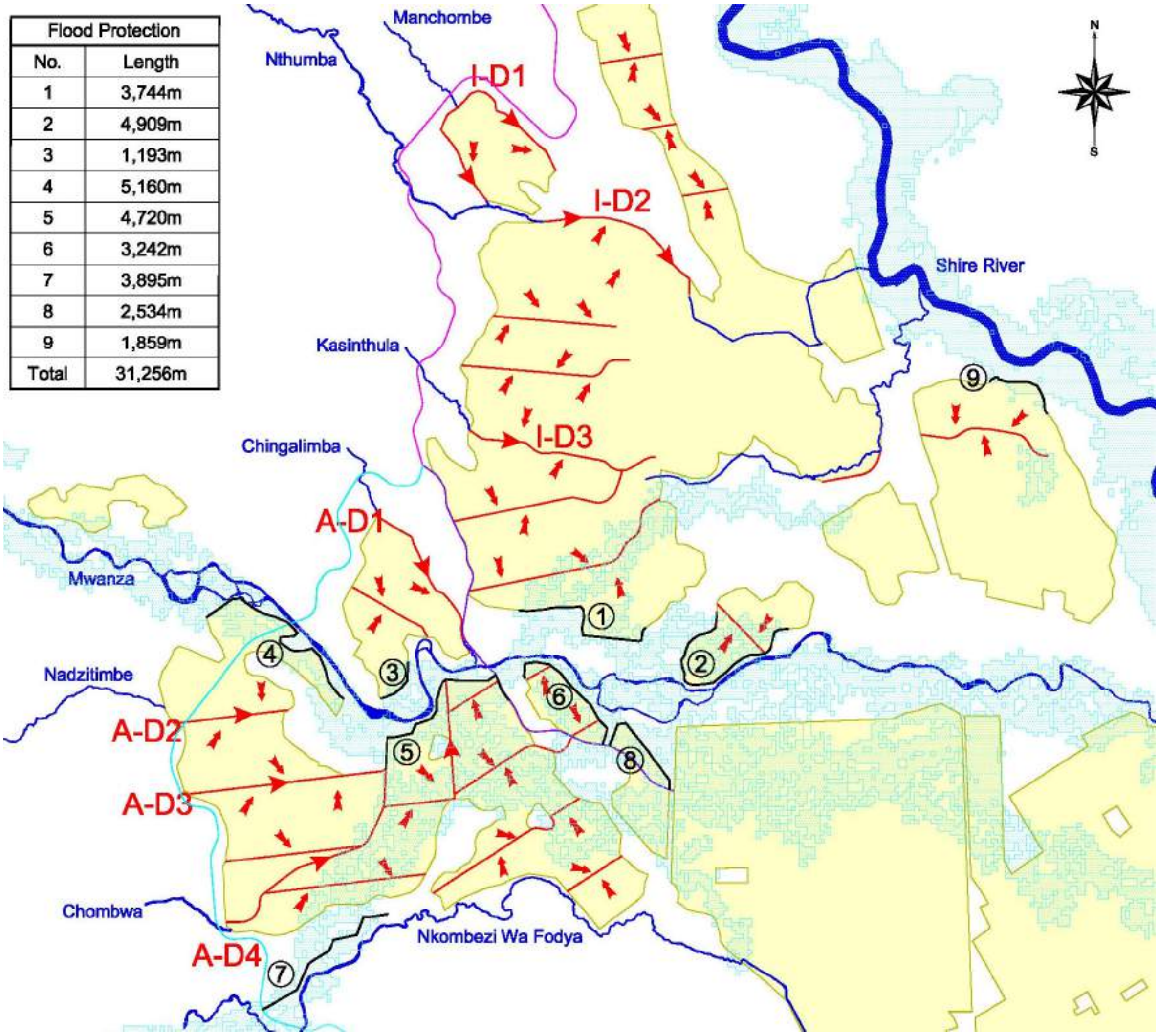
[Figure 13.10-7] Land Consolidation Layout of Zone A

13.11. Flood Protection

Zone I-1 and Zone A are separated by Mwanza River, and the NkombeziWaFodya River flows between Zone A and Lengwe National Park. Nearby areas are often subject to flood damage because of these rivers. In the process of determining the boundaries of Zone I-1 and Zone A most of the 5 year frequency flood affected areas were excluded. Exceptional disaster flood protection measures have also been taken into consideration.

Mwanza River originates in Mwanza District and joins the Shire River in Chikwawa District, and has a catchment area of about 1,100 km^2. Zone I-1 and Zone A are located in the downstream area of Mwanza River. Most of the flood affected areas from 5 year frequency flooding were excluded during the delineation of Zone I-1 and Zone A. The northern part of Zone A-b is prone to have 5 year frequency flooding because of a temporary river. This issue was tackled by providing of large drainage canal along the route of the temporary river.

The areas which could be affected by 10 year frequency flood shall be protected by dikes, which are shown in the Figure 13.11-1. The dike was planned in limited areas to avoid heavy damages to the nearby villages. The total length of dikes shall be more or less 30 km. However this shall be further investigated together with cost benefit analysis during the detail design phase.



[Figure 13.11-1] Flood Protection Plan for 10 Year Frequency

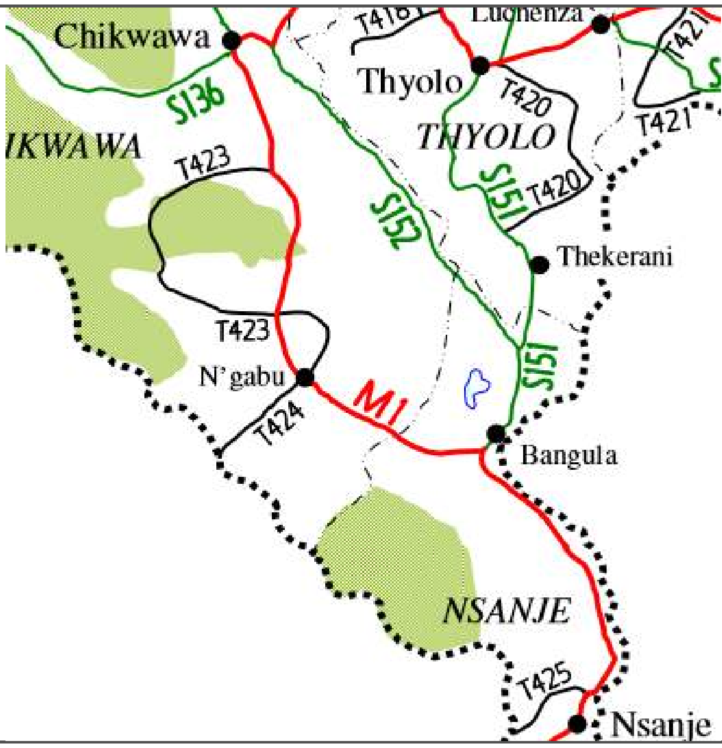
The total area which takes benefit from the both of flood protection measures, drainage canal and dikes, will be around 1,069 ha. (Actually it is difficult to separate the flooded areas between the areas affected by river and the areas affected by poor natural drainage conditions which the fields already have.)

The flooding study report of SRBMP, "Implementation Service Provider (ISP) for Flood Risk Management (Area Intervention Plan TA LUNDU)", suggested to use the dambo area in the Lengwe National Park for storing flood water. This could be helpful to reduce flooding in the area of Zone A-b Road Network

13.11.1. Existing Road Network

The existing roads in the project area are Main Road M1, Secondary Roads S136 and S152, Tertiary Road T416, T423, and many small district and traditional roads, by which the villages are connected to each other. The M1 road is the principal road through which Chikwawa connects to Nsanje to the south and Blantyre City to the north. The Secondary Road S136 connects Chikwawa to Mwanza to the west, and the Tertiary Roads T416 and T423 connect villages to the M1 Road and thereafter throughout the Southern Region. Figure 13.12-1 shows the road network in Chikwawa and Nsanje districts.

After the project implementation, many new roads will be constructed within the project area connecting to the existing road network. These new roads will provide much improved access conditions. Along the secondary canals (direction from the west to the east) several roads, which are called as O&M Roads, 4 m wide, will be constructed at 1,600 m distance apart. Also along the farm block boundaries (direction from the north to the south) several roads, which are called Farm roads, 6 m wide, will be constructed at 800 m distance apart. These roads will be connected to the main paved roads, and will provide much improved traffic conditions among the villages and Chikwawa DC.



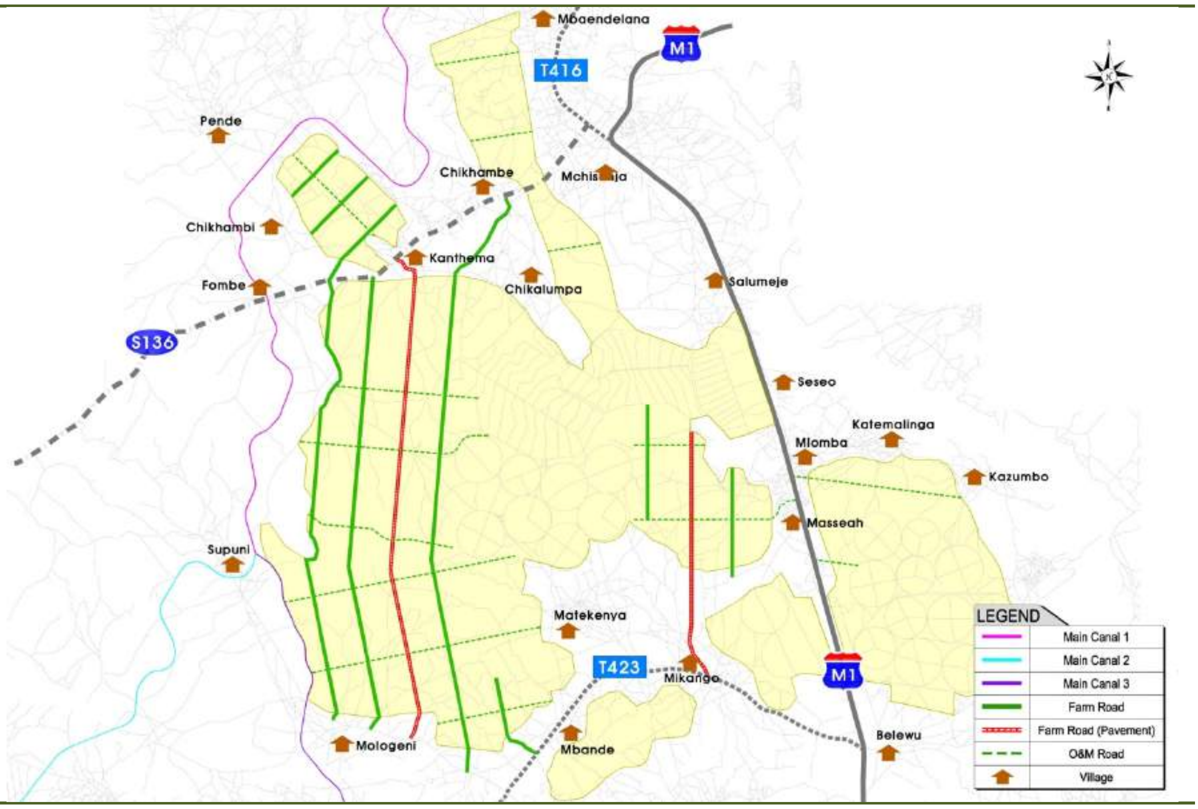
[Figure 13.11-2] Layout of Road Network of Project Area

13.11.2. Farm Road Plan of Zone I-1

Zone I-1 is enclosed within the Main road M1 on the east boundary, S136 road on the north, and T423 road on the south. Mbandelana, Chikhambi, Fombe villages are located around the S136 road, and Mbande, Mologeni, and Supuni villages are located around the T423 road.10 farm roads (6 m wide) connect from the northern area to the southern area, and 15 O&M roads (4 m wide) connect villages to farms.

[Table 13.11-1] Farm Road Plan of Zone I-1

No	Location	Length(m)	Width(m)	Remark
1	Chikhambe ~ Chikambi	1,321	6	Earth
2	Chikhambe ~ Chikambi	1,630	6	Earth
3	Chikhambe ~ S136 ~ Mologeni	11,426	6	Earth
4	S136 ~ Mologeni	9,270	6	Earth
5	S136 ~ Mologeni	9,989	6	Murram
6	Chikhambe ~ S136 ~ Mologeni	12,117	6	Earth
7	Matekenya ~ T423	1,900	6	Earth
8	Kasinthula ~ Inside farm	2,318	6	Earth
9	Kasinthula ~ T423	5,014	6	Murram
10	Inside farm ~ Mikango	2,205	6	Earth
	Total	57,190		



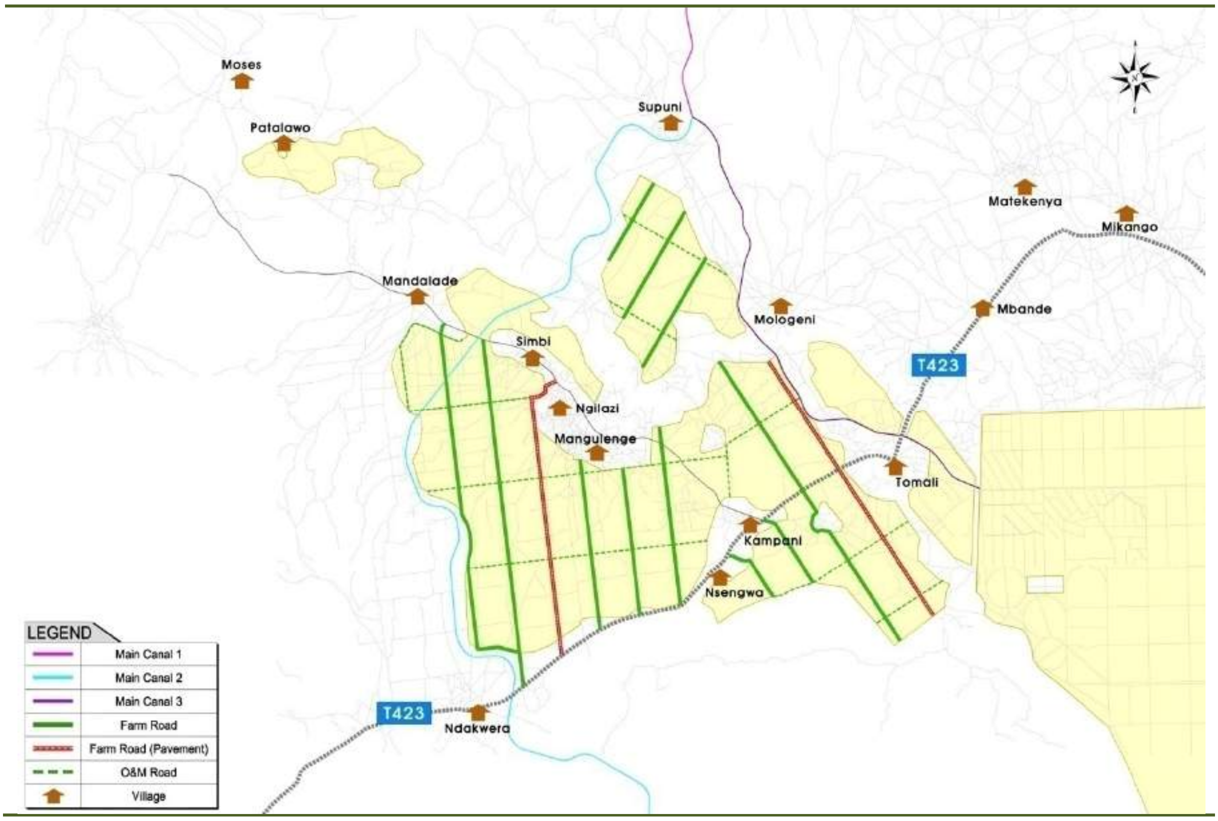
[Figure 13.11-3] Layout Road Plan of Zone I-1

13.11.3. Farm Road Plan of Zone A

Farm roads in Zone A have been planned to connect villages to farmlands, villages to towns, and villages to the existing road network. 13 farm roads (6 m wide) connect from the northern area to the southern area, and 8 O&M roads (4 m wide) connect villages to farms.

[Table 13.11-2] Farm Road Plan of Zone A

No	Location	Length(m)	Width(m)	Remark
1	Mandalade ~ T234	7,400	6	Earth
2	Mandalade ~ T234	6,950	6	Earth
3	Ngilazi ~ T423	5,848	6	Murram
4	Mangulenge ~ T423	3,046	6	Earth
5	Mangulenge ~ T423	2,937	6	Earth
6	Mangulenge ~ T423	3,585	6	Earth
7	T423 ~ Nsengwa	1,299	6	Earth
8	T423 ~ Kampani	1,647	6	Earth
9	Mologeni ~ T423	6,887	6	Earth
10	Mologeni ~ Tomali	6,042	6	Murram
11	Supuni ~ Simbi	1,783	6	Earth
12	Supuni ~ Ngilazi	2,541	6	Earth
13	Supuni ~ Mangulenge	2,528	6	Earth
	Total	52,493		

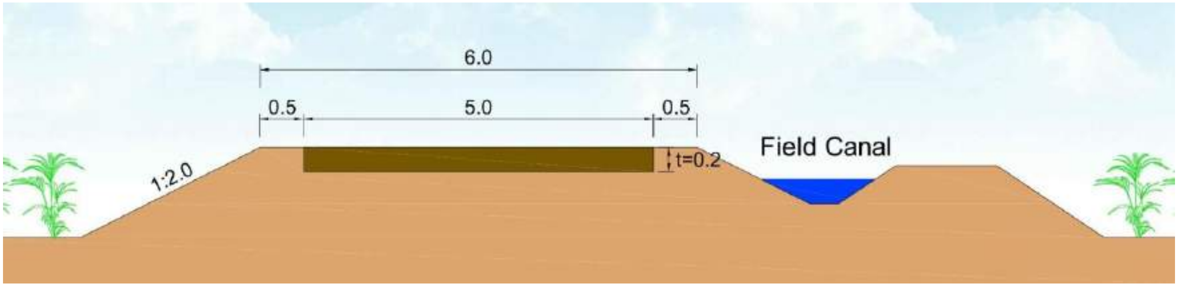


[Figure 13.11-4] Layout Road Plan of Zone A

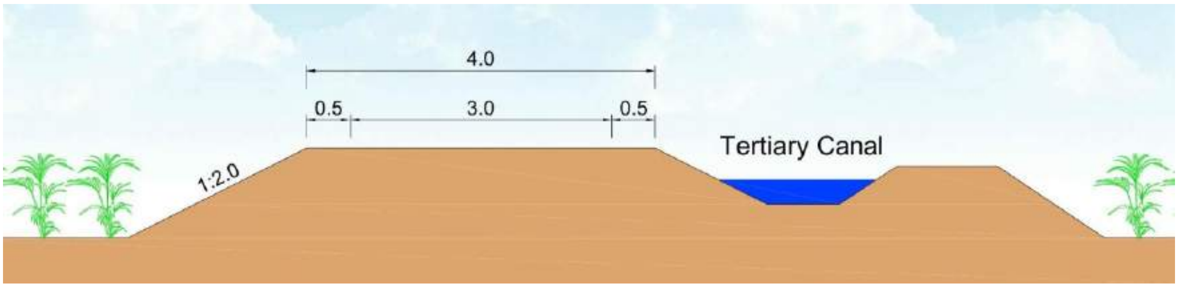
13.11.4. Standard Section of Farm Road & O&M Road

As mentioned above there are two types of roads in the project area; Farm roads and O&M roads. The farm roads are parallel to the contour lines and field canals. These roads largely connect the southern areas and the northern areas, which improve the traffic conditions of the communities. The O&M roads are perpendicular to the contour lines and field canals. These roads connect the eastern areas and the western areas. Figure 13.12-4 and 13.12-5 show the standard sections of farm road and O&M roads.

The roads will be covered with a special soil (murram) with compaction for maintaining a good condition of road. This type of covering will be applied to the side roads of the Main Canals also.



[Figure 13.11-5] Standard Sections of Farm Road



[Figure 13.11-6] Standard Sections of O&M Road

CHAPTER 14. WATER SUPPLY AND SANITATION

14.1. Drinking Water Demand

14.1.1. Drinking Water Demand

The domestic water supply system was planned for the customers currently being serviced by the Southern Region Water Board at Chikwawa and possibly planned extensions. The domestic water demand was decided based on the estimated future population using the population of 2008 obtained from "2008 Population and Housing Census (National Statistical Office, Malawi)".

14.1.2. Estimation of Population

Table 14.1-1 shows the populations in Malawi from 1966 to 2008, and Table 14.1-2 shows the yearly increasing ratio in Chikwawa.

[Table 14.1-1] Population in Malawi, 1966-2008

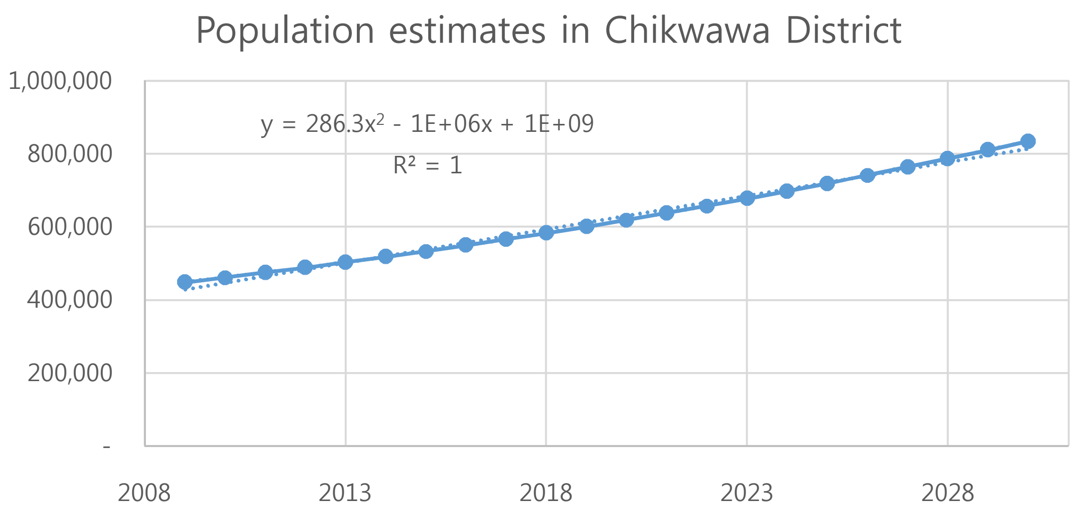
Years	Malawi	Southern Region	Chikwawa District	Remark
1966	4,040,000	2,067,000		
1977	5,547,500	2,754,900	194,400	
1987	7,988,500	3,965,700	316,700	
1998	11,244,915	4,633,968	356,682	
2008	13,077,160	5,858,035	434,648	
Growth Ratio	185%	150%	167%	Reference year: 1966

※The census is excuted every 10 years, and the most recent census was conducted in 2008.

[Table 14.1-2] Population in Chikwawa District, 1977-2008

Years	Population	Yearly Growth Number	Yearly Growth Ratio
1977	194,400		
1987	316,700	12,230	6.29%
1998	356,682	3,635	1.15%
2008	434,648	7,797	2.19%
Average(32years)		11,086	3.11%

The water supply plan was to benefit residents within and around the Chikwawa Boma area, parts of TA Kasisi and TA Katunga. Applying the growth rate to the population estimated in 2008 gives the extrapolated population of 30,619 for 2016, and 41,335 for 2026, the target year (See Figure 14.1-1).



Years	2014	2016	2021	2026	Remark
Chikwawa District	518,287	549,706	638,633	742,098	
Chikwawa Boma	5.57%	5.57%	5.57%	5.57%	
	28,869	30,619	35,572	41,335	

[Figure 14.1-1] Population Estimation of Chikwawa Boma

14.1.3. Drinking Water Demand

The total water demand for the target years was estimated based on the unit water requirement per capita as 50~70 liters. Many boreholes have already been installed in this target area, but the water quality is poor in most of them. There has been a lot of deposition of scale within the galvanized iron pipes making it difficult to supply water to the houses.The design unit water requirement per capita was decided as 30 litres, considering the existing water systems and Table 14.1-3 shows the results. If the target year is set to 2026, the water demand shall be 1,240 m^3.

[Table 14.1-3] Water Demand for the Target Years for Chikwawa Boma

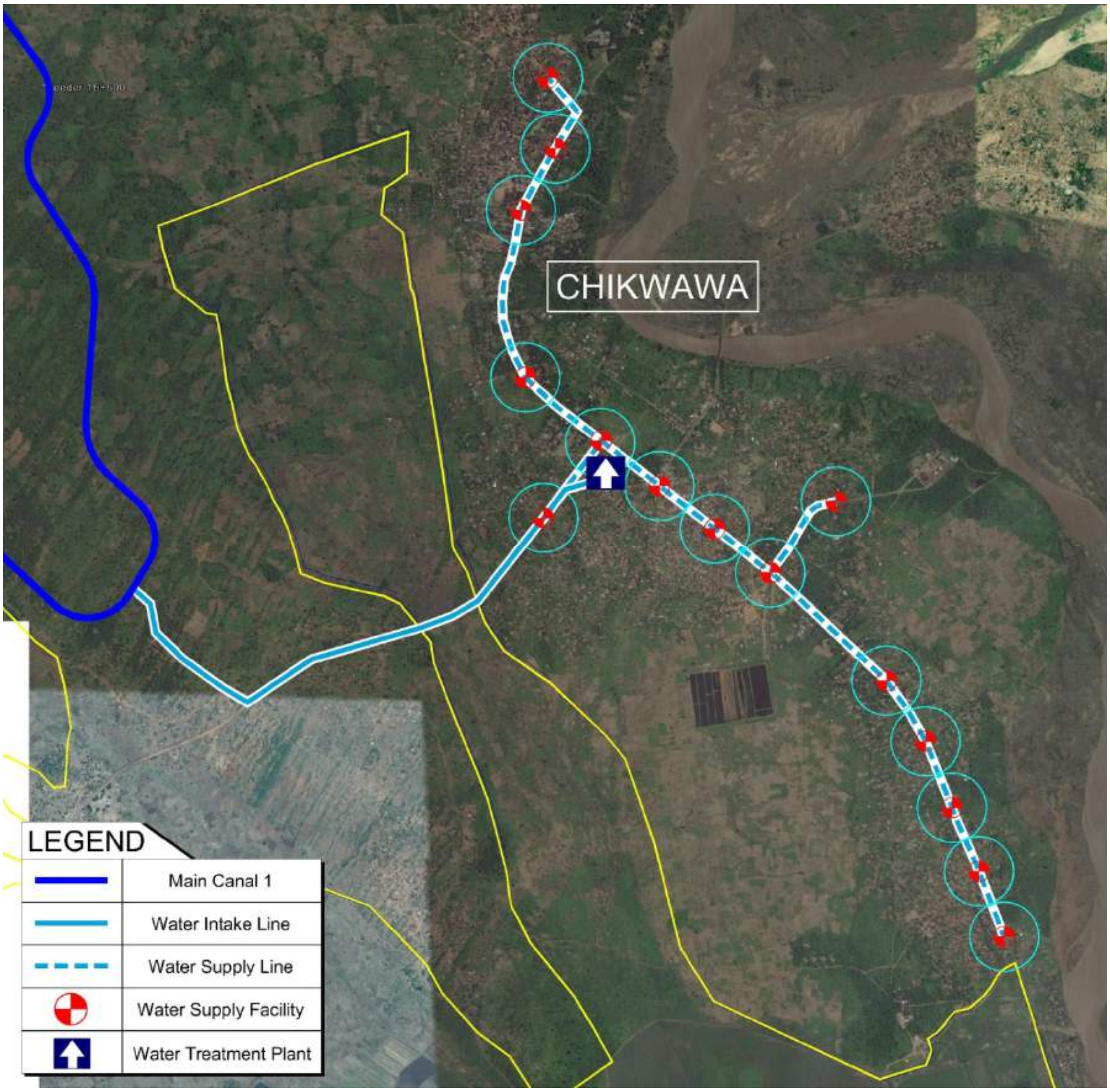
Years	2014	2016	2021	2026	Remark
Population	28,869	30,619	35,572	41,335	
Unit Water Demand	10 ℓ	15 ℓ	25 ℓ	30 ℓ	
Water Demand	290 m^3	460 m^3	890 m^3	1,240 m^3	

14.2. Water Treatment System

The water treatment method proposed is either a compact sand filter system or membrane filter system, since the water demand is small scale. The proposed water treatment systems will treat water very efficiently and rapidly compared to the conventional WTP process. The water treatment system shall be installed near the cross point of the road T416 and S136. From where the treated water shall be delivered through the pipeline using overhead water tanks. The proposed system has also been discussed with the chief manager of Chikwawa station of Southern Region Water board.

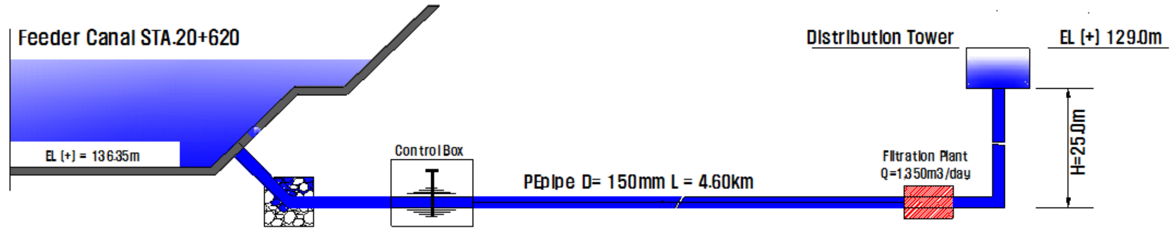
14.3. Design Layout

The water shall be taken from the Main Canal 1. A PCF filter system shall be installed at this location. The water taps shall be installed at every 250 m distance along the pipeline. Figure 14.3-1 shows the Drinking Water Supply Plan.

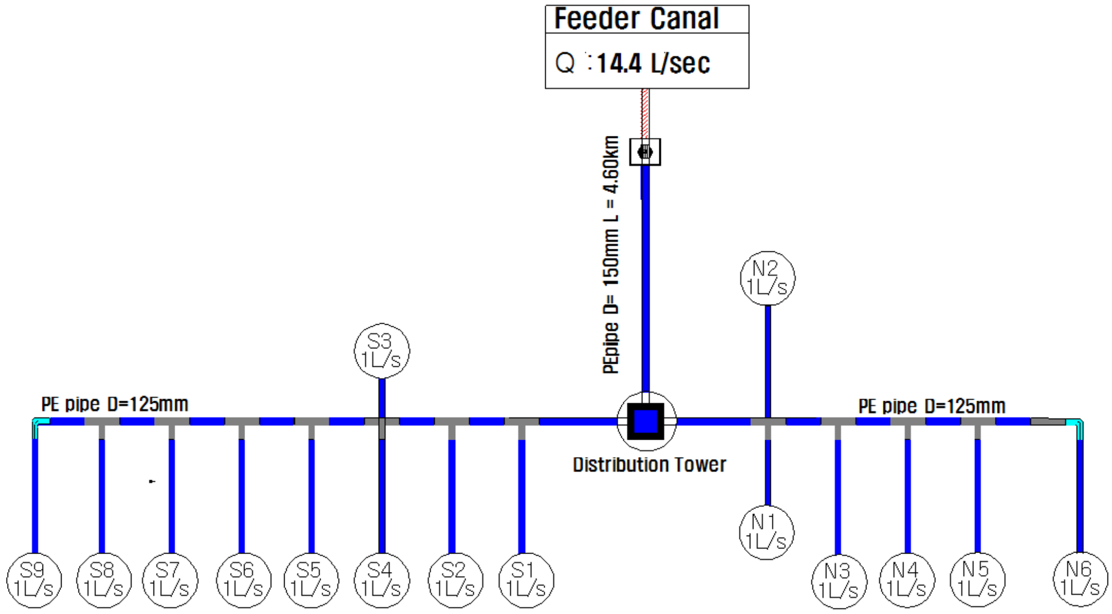


[Figure 14.3-1] Drinking Water Supply Plan

A 150 mm diameter pipeline will convey water from the Main canal 1 to the water treatment system over a distance of 4.6 km. Overhead tanks shall be installed near the water treatment works at a height of 25 m. A distribution pipeline of 125 mm diameter and 7.8 km long shall deliver treated water to a total of 15 well points installed at 500 m distance to each other. The water supplying capacity shall be 14.4 l/s. Figure 14.3-2 and Figure 14.3-3 show the main transmission pipeline and distribution pipeline. The direct costs of pipeline, taps, tanks, water treatment, etc. have been included in the project cost.



[Figure 14.3-2] Main Transmission Pipe Line



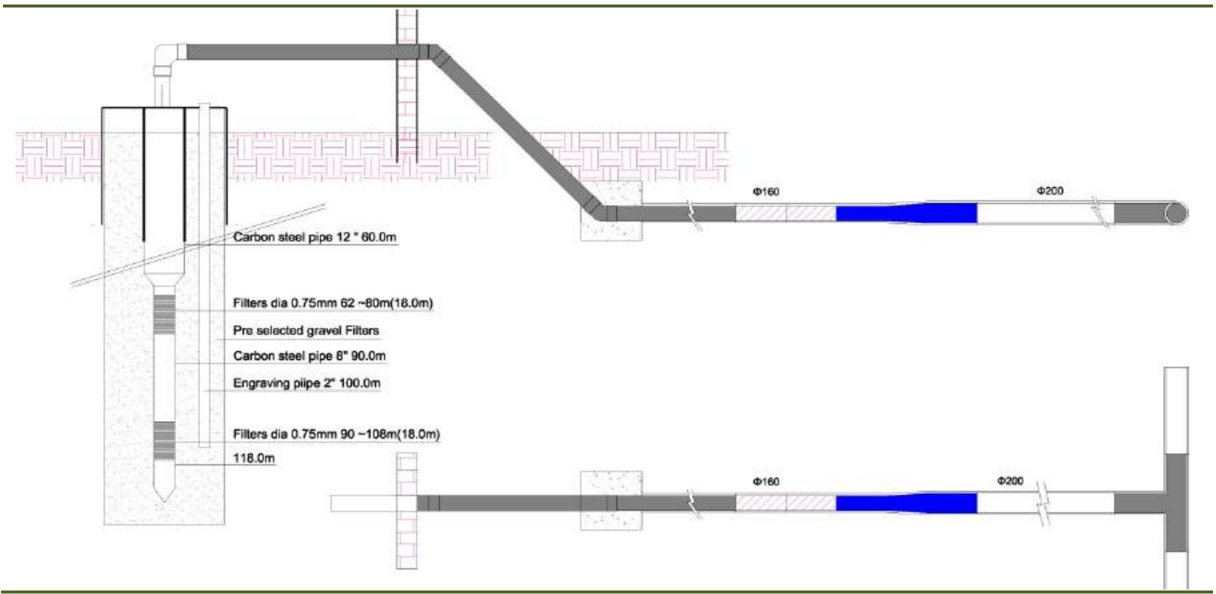
[Figure 14.3-3] Distribution Pipe Line

14.4. Ground Water Supply System

Since the SVIP Phase I area is very large, it is very costly to set it up as a single water supply zone. Following the hydrogeology study this area has a good potential of ground water resource. Therefore TFS proposed to develop several local water supply systems using ground water resource.

There are 12~14 villages in the Phase I area. It is desirable to organize four or five water supply zones by bundling two or three of these villages within a range of 3 km and to construct a separate supply network for each zone.

We planned to drill a bore hole each zone and supply water to the villages within 3 km. The depth of the bore hole is 60 m or more, and when a submerged pump of 75 HP performance is installed, the discharge amount of 30 l/s can be secured. Assuming 30 liters of water consumption per person per day, it is possible to supply about 40,000 people, considering 50% of the operation time. The installation cost per unit is estimated to be approximately USD 200,000. Figure 14.4-1 shows a standard water supply system using ground water.



[Figure 14.4-1] Ground Water Supply System

CHAPTER 15. PROJECT COSTING

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.

15.1. Project Cost Estimation

15.1.1. 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 2016 when the exchange rate was 741MK to 1 USD.

[Table 15.1-1] Exchange Rate 1 USD

Descriptions	Sub Explain	Unit	Malawi(MK)	
			2015	2016
Exchange Rate	1	USD	650	741

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 15.1-2] Labor Costs in Malawi (2015~2016)

Descriptions	Unit	2015	2016	
		MK	MK	USD
Unskilled worker	m.d	1,000	1,100	1.484
Skilled worker	m.d	2,500	5,700	7.692
Concrete work	m.d	3,000	3,000	4.048
Steel worker	m.d	2,500	2,500	3.373
Carpenter	m.d	2,000	2,000	2.699
Scaffolding man	m.d	2,000	2,500	3.373
Stonemason	m.d	1,700	2,000	2.699
Plumber	m.d	2,000	2,000	2.699
Supervisor	m.d	3,500	3,800	5.128
Machine main operator	m.d	4,000	5,500	7.422
Machine Supervisor	m.d	8,000	8,500	11.470
Truck driver	m.d	4,000	5,000	6.747
Machine driver	m.d	4,000	5,500	7.422
Painter	m.d	2,000	2,200	2.968
Welder(general)	m.d	2,000	2,200	2.968

*Date Offer: GoM, GK WORKS, WILLY& PARTNER ENGINEERING SERVICES

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 15.1-3] Materials Cost in Malawi (2015~2016) (Excluding VAT)

Descriptions	Sub Explain	Unit	2015	2016	
			MK	MK	USD
Cement	50kg	NO	6,500	6,500	8.771
Rebar	All size	ton	800,000	800,000	1079.622
Sand	Include transportation	m^3	20,000	18,000~20,000	24.291~26.990.
Gravel	Include transportation	m^3	25,000	15,000~25,000	20.242~33.738
Plywood	12mm *121* 242cm	m^2	8,000	13,500	18.218
Wire	#20 D=0.9mm	kg	1,500	890~1,500	1.201~2.2024
Nail	N50	kg	1,500	1,500	2.024
Farm oil		ℓ	3,000	1,500	2.024
Super		ℓ	800	750	1.012
Diesel		ℓ	800	750	1.012
Wire Mesh	#6 150*150	m^2	13,000	31,500	42.510
Hume Pipe	D=1000mm	m			
Steel Pipe	T=12 D=2000mm	m		3,500	4.723
Winch		NO		10.500	0.014
Spindle		m		2,500	3.373
Geo-membrane	0.7m/m	m^2		1,800	2.429
Concrete class 35		m^3		171,600	231.578
Concrete class 25		m^3		153,725	207.456
Murram		m^3		30,000	40.485
Shore		NO		13,500	18.218

*Date Offer: GoM, GK WORKS, WILLY& PARTNER ENGINEERING SERVICES

Construction Machinery Cost

Construction machinery costs presented in Table 15.1-4 were prepared following the price investigation carried out in 2015~2016.

[Table 15.1-4] Construction Machinery Cost (Excluding VAT)

Descriptions	Sub Explain	Unit	2015	2016	
			MK	MK	USD
Bulldozer	19ton	day	260,000	261,000	352.226
Bulldozer	32ton	day	300,000	270,000	364.372
Wetland Bulldozer	13ton	day	200,000	261,000	352.226
Excavator(Caterpillar)	1.0 m^3	day	179,000	225,000	303.643
Excavator(Caterpillar)	0.7m^3	day	180,000	180,000	242.914
Loader(tire)	1.72 m^3	day	200,000	200,000	269.905
Motor grader	3.6m	day	200,000	270,000	364.372
Dump truck	10ton	day	60,000	60,000	80.971
Dump truck	15ton	day	75,000	75,000	101.214
Tire roller	8~15ton	day	75,000	99,000	133.603
Vibration roller	10ton	day	95,000	108,000	145.748
Water tank(water-cart)	16,000 ℓ	day	50,000	50,000	67.464
Concrete mixer	0.10 m^3	day	15,000	108,000	145.748
Concrete mixer	0.45 m^3	day	35,000	108,000	145.748
Concrete mixer	1.0 m^3	day	70,000	108,000	145.748
Caterpillar crane	15ton	day	20,000	144,000	194.331
Motor generate	50kw	day	20,000	155,000	209.176
Concrete vibrator	Ø45, 2.6kw	day	12,000	12,000	16.194
Air Compress		day			
Tire Roller (self-propelled type)	15~25TON	day			
Vibration Roller (self-propelled type)	10TON	day		108,000	145.748

*Date Offer: GoM,GK WORKS, WILLY& PARTNER ENGINEERING SERVICES

15.1.2. 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 15% 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 the total project cost shall be reasonable in the range 6~6.5% considering the scale of SVIP.

15.1.3. Calculation of Project Cost

The total cost of SVIP taking into account direct and indirect construction costs is estimated at 623,362 thousand USD excluding VAT. 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, Main canal 1and all the canal system up to crossing Mwanza River are based on a total hectarge of 43,370 ha of the project area.

[Table 15.1-5] SVIP Investment Cost (thousand USD, Excluding VAT)

Descriptions	Total		Phase I		Phase II	
	Quantities	Cost	Quantities	Cost	Quantities	Cost
I. Direct Total Cost		419,016		171,576		247,440
1) Intake	1 LS	4,564	1 LS	4,564		
2) Main Canal 1	L=33.80km	49,892	L=33.80km	49,892		
3) Main Canal 2	L=77.90km	67,200	L=18.40km	21,830	L=59.50km	45,370
4) Main Canal 3	L=10.64km	7,240	L=10.64km	7,240		
5) Secondary Canal	L=246.00km	49,480	L=92.40km	17,020	L=153.60km	32,460
6) Drainage Canal	L=84.00km	25,520	L=32.40km	9,840	L=51.60km	15,680
7) Night Storage	36unit	4,690	12 unit	1,610	24 unit	3,080
8) On Farm Works	33,434ha	206,380	12,266ha	57,440	21,168ha	148,940
9) SCADA	2 LS	3,020	1 LS	1,110	1 LS	1,910
10) Water Supply	1 LS	1,030	1 LS	1,030		
II. The Cost of Compensation		19,850		7,300		12,550
III. Contingency(15% of I+II)		65,821		26,831		38,990
IV. Consultant(6% of direct cost)		25,135		10,295		14,840
V. Additional Costs		93,540	1 LS	34,400		59,140
1) Farm organization development and farm investment		52,480		19,300		33,180
2) Farm operations development (RAP)		5,440		2,000		3,440
3) Farm institutional support		3,540		1,300		2,240
4) Project management		27,190		10,000		17,190
5) Costmary land law implementation		4,890		1,800		3,090
VI. Total Project Cost		623,362		250,402		372,960

15.1.4. Financial Plan for Project of Phase I

The implementation of PhaseI 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.

[Table 15.1-6] Financing of AfDB-WB/FAO(WB-P158805) (thousand USD)

Total	WB	AfDB	Remark
210,000	160,000	50,000	

[Table 15.1-7] SVIP Investment Cost of Phase I (Excluding VAT)

Descriptions	Quantities	Cost(USD)	Remark
I. Direct Total Cost		171,576,000	
1) Intake	1 LS	4,564,000	
2) Main Canal 1	L=33.80km	49,892,000	
3) Main Canal 2	L=18.40km	21,830,000	
4) Main Canal 3	L=10.64km	7,240,000	
5) Secondary Canal	L=92.40km	17,020,000	
6) Drainage Canal	L=32.40km	9,840,000	Flood Protection : 936,000
7) Night Storage	12unit	1,610,000	
8) On Farm Works	12,266ha	57,440,000	
9) SCADA	1 LS	1,110,000	
10) Water Supply	1 LS	1,030,000	
II. The Cost of Compensation		7,300,000	
III. Contingency(15% of I+II)		26,831,000	
IV. Consultant(6% of Direct Cost)		10,295,000	
V. Additional Costs		34,400,000	
1) Farm organization development and farm investment		19,300,000	
2) Farm operations development (RAP)		2,000,000	
3) Farm institutional support		1,300,000	
4) Project management		10,000,000	
5) Costmary land law implementation		1,800,000	
VI. Total Project Cost		250,402,000	

15.2. Annual O&M Cost Estimation

The maintenance of the irrigation system amounts to 0.6 % of the construction cost for Phase 1 and 0.5 % for Phase 2. These are the weighted average of the maintenance cost for all separate components as calculated in table 16.3-8.

Operation cost of the system depends on the Water Service Provider in charge of operating (and maintaining) the system up to water meters and Cooperatives that are responsible for operations (and maintenance) of the on-field systems between the water meters and the crops. These costs are discussed in detail in section 16.3.5.

15.3. Review on the Costs of On Farm Works

Generally, the furrow irrigation type requires higher cost compared to pivot or sprinkler irrigation. In the project area there are some out-growers schemes such as Phata and Presscane. Phata has 306 ha of area and Presscane is planning 2,216 ha area. Phata has pivot and sprinkler irrigation system, and Presscane is planning a pivot system. The direct costs per hectareof these farms were compared to SVIP furrow irrigation system, and the Table 15.3-1 shows the results.

[Table 15.3-1] Comparison the Direct Costs per Hectare (USD, Excluding VAT)

Items	SVIP	Phata		Presscane (Pivot)
		Pivot	Sprinkler	
On Farm Works	4,682	2,800	2,800	3,400

The cost of On-Farm Works is higher in SVIP because of the selected furrow irrigation system, which requires intensive land leveling works and the construction of many tertiary and field canals and drains, access roads and associated structures. The bulk of the construction cost goes for the land leveling works. If there is a possibility of minimizing the land leveling works (through proper design of the farm layout and field gradients), the cost of the on farm works could be reduced substantially.

The furrow irrigation costs is the most expensive compared to sprinkler or pivot irrigation systems. However its operational cost is minimum and is easy to use by common farmers.The furrow system will also needs more water than the other methods.

In spite of these, the furrow irrigation system was agreed to be used for conservative estimation of water demand and project cost.

CHAPTER 16. FINANCIAL AND ECONOMIC ANALYSIS

16.1. Introduction

This chapter presents the findings of the financial and economic analysis of the proposed infrastructure, together with the additional investments in institutions and extension services that need to be undertaken to make this irrigation project a success.

Apart from the usual Cost- Benefit Analysis of the project (from the point of view of the project as well as the country as a whole), it will also cover a financial analysis of the cooperatives and the enterprise managing the Shire Valley Irrigation Scheme (hereafter, called the Water Service Provider, WSP).

Additionally, it will present the main mitigating measure to reduce environmental impact, the 800 m long siphon in the Majete Game Reserve, and the drop structures in Main Canal 1 to prevent migration of harmful fish species in to Lake Malawi. In the section on Externalities, some positive effects on the environment will also be discussed in qualitative terms.

Most of the data were compiled in October 2016, but some were updated with the latest FAO estimates wherever available. Where the latter is the case, it is explicitly mentioned.

16.2. Financial and Economic Analysis

Financial analyses of projects are made from the point of view of an investor while economic analyzes regard projects from the country's (or the Government's) point of view. This difference means that market prices which an investor has to consider, have to be converted to economic or efficiency prices. For this purpose conversion factors are used, which will be presented below.

16.2.1. Economic Prices of Agricultural Produce

The markets for agricultural produce have been liberalized since the beginning of this century (FAO, 2014, p.15). GoM (2016 – 3) does not mention any serious distortions in the markets for agricultural products either when it briefly discusses the related value chains. As a result, we may assume that for most of the agricultural products, the market prices reflect the efficiency price.

However, the GoM decided to keep control on the trade in maize. Its measures varied from outright bans on export of maize, to bans on private domestic trade, export licensing, and export contracts with the Governments of neighboring contracts signed by GoM (FAO, 2014, p.16). Additionally, since 2006, the Government sets minimum prices for the producers and maximum prices at which the retailers can sell maize. Nevertheless, in 2008 it set a maximum farm gate price at which the Agricultural Development and Marketing Cooperation(ADMARC) that is to enforce GOM's pricing policy could buy from the farmers (ibid p.40). In spite of these restrictions private trade is happening with disregard of this price band. Only 8 % of the maize sold by farmers was marketed (in 2008) through ADMARC and farmers are still selling directly to households and traders (ibid, p.10). Moreover, GoM has also been supporting the maize growers through its Farm Inputs Subsidy Program that targeted some 50 % of the small farmers to receive fertilizers and seeds for maize production (and well as seeds for tobacco).

Without the exchange rate distortions and inefficiencies along the value change, Malawian farmers would have received 10,000 MWK per ton of maize (or 29 %) more than they actually did (ibid. p.41; percentage calculated from fig 22 on p.42). Of these disincentives for the farmers, 12 % is caused by the exchange rate policy (ibid, p.41). In 2012 the GoM introduced an officially freely floating Kwacha, yet there still appears to be a slight difference between the market rate and the official bank's exchange rate. Nevertheless, one may assume that the economic farm gate price for Maize is – on the average- 17 % higher than the price received by the farmers.

Economic price of Maize = 1.17 * market price of maize;
(or US$279 /ton compared to US$239/ton

Other crops:
Economic price = financial price

16.2.2. Conversion Factors

16.2.2.1. Non-traded Goods

Certain commodities cannot be exported or imported, because their domestic price is below the import price (cost insurance freight included, C.I.F) but higher than the export price (free on board, F.O.B), due to local conditions of demand and supply, or market distortions. These goods are called "non-traded goods". Ideally the economic prices for these goods are computed for different types of goods taking into account the many factors that are involved. However, it is common practice to apply a Standard Conversion Factor that is equivalent to the ratio of official exchange to the parallel USD-Malawian Kwacha rate, which amounts to 0.96.

Standard Conversion Factor: 0.96

16.2.2.2. Traded Goods

Fertilizers

Some of the inputs are directly imported from abroad and their real cost to the Malawian economy would be the Import Cost (with Insurance and Freight included). These have been calculated for the fertilizers (see section 16.2.1.2).

The cost of fertilizers is currently subsidized by the Government of Malawi in a scheme that is being revised. However, these subsidies that are limited to Urea and "NPK 23: 21: 0 +4S", do not seem to reach all farmers. Moreover the subsistence farmers in the Shire Valley are not using much fertilizer on their rain fed crops. Additionally, it is Government's policy to abandon these subsidies.

It has been assumed in this feasibility study that the farmers in the Shire Valley Irrigation (SVI) scheme will not be benefitting from any government subsidy on fertilizers, which gives a further justification for using computed efficiency prices.

These and other possible distortions in the fertilizer market are usually corrected by replacing the market price of these traded good (i.e. imported or exported commodities) with the computed Import Cost (CIF), as presented in the following Table 16.2-1.

[Table 16.2-1] Derivation of Economic Prices for Fertilizers (USD)

Fertilizer	Unit	Urea (b)	DAP (d)	Potassium Chloride (c)	TSP
World Market Rice Price FOB (a)					
2016 prices	$/t	200.00	355.00	270.00	300.00
Freight	$/t	50,00	42.00	132.00	132.00
CIF Beira	$/t	250.00	397.00	402.00	432.00
Beira Handling	$/t	4.42	4.42	4.42	4.42
Transport to Blantyre*	$/t	100.00	100.00	100.00	100.00
Transport, handling & margin to farm gate **	$/t	10.00	10.00	10.00	10.00
Farm gate price	$/t	360.00	507.00	512.00	542.00

Notes/ Sources: (a) from World Bank Commodity Price Projections, July 2016
(b) originating from the Middle East'
(c) from Casablanca, Morocco
* Road Fees: Peak season (Aug-Dec): USD95 -125/tonne
Slack season (Jan - Jul): USD95 -60/tonne
According to dr. Andy Kalinda, CEO SFFRFM
**Blantyre - project area: 50 Km at USD 0.20 per ton.km

Economic prices of other fertilizers that are not mentioned in the Commodity price projections were determined by using the 0.96 Standard conversion rate. This includes the often used 23:21:0 + 4S, which seems to be blended in the Middle East for the Malawi market only.

Other Traded Goods

For other goods the market prices in Blantyre are known and already include the transportation and the Value Added Tax (VAT). However these goods are imported against the official exchange rate that differs from the real scarcity rate that people are prepared to pay for the USD in the parallel market.

Consequently the prices of the imported goods have to be corrected for the VAT (prices multiplied with 1/(1 + 0.165)) and subsequently corrected for the shadow exchange rate by multiplying with 0.96 (the ratio of the official rate to the parallel market rate of the kwacha. See Squire and Van der Tak, 1975, p.33).

It should be noted that another possible market distortion, import duties, are not relevant for this project in Malawi, since imported construction materials are exempted from import duties, as appears from GoM, 2016 – 3, which was confirmed by the National Revenue Authority, Blantyre on 4 November 2016).

For these reasons, the estimates of the financial cost in this chapter only include the 16.5 % VAT. When converting these costs into economic cost, the VAT has been removed by multiplying with1/(1+ 0.165), before the conversion factors mentioned above were applied.

Fuel

According Centre for Social Concern(p.45), Petroleum and Diesel are subjected to 30 % excise duty.

Therefore, the cost of fuels need to be corrected by 1/1.3 = 0.77 in addition to the standard conversion factor of 0.96, which results in a Fuel Conversion Factor of 0.74.

It has furthermore been assumed that 33% of the cost of Transport and Equipment has to be incurred for fuels (see section 16.3.4).

Fuel Conversion Factor: 0.74

16.2.2.3. Labor

Financial analysis

In the current situation, the households cultivate approx. 0.5 ha of land in Phase 1 area and 1.2 ha in Phase 2 area on the average. In order to do so they avail of 1.76 and 1.90 household members on the average (GoM, 2016-3, p.40)

Information available from the Agricultural Development Planning Strategy (AgDPS, MoW, 2016-1) and the Agronomist's survey (based on focus group discussions) allowed for the compilation of cropping calendars for four crops, which together account for 74 % of the area cultivated in Phase 1(see section 16.4.2.1). Figure 16.2-1 also shows the estimated labor demand per month for one hectare estimated as a weighted demand (with the relative area per crop as the weights) and per half (0.5) ha. It appears that labor demand per month is lower than the average available labor per household. One may thus safely assume that family labor is sufficient to satisfy labor demand on the average.

Consequently, labor does not need to appear as a separate cost in the financial analysis.

Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total labour demand (person.days)	Area in Phase 1 in ha	%
Cotton	44	17	24	24	24	7	19	4		163	509	16%
Maize	30	28	3	10		20	6	0.6		97	1,220	37%
Pigeon peas	43	10		20		16		37	4	130	214	7%
Sorghum	35	12		2		10		3		62	1,321	40%
Weighted total/ ha	35.1	18.4	4.9	9.7	3.8	13.6	5.0	4.6	0.3		3,264	100%
Total per 0.5 ha	17.5	7.7	2.1	4.1	1.6	5.7	2.1	1.9	0.1			
Available labour/ h.h.	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7			

Legend
- land preparation
- planting + fertiliser application
- thinning, weeding, pesticide application and scouting
- banking
- pesticides application
- harvesting etc

[Figure 16.2-1] Cropping Calendar for Cotton, Maize, Pigeon Peas & Sorghum with Labor Demand (in person days)

Economic analysis

According to the 2013 Labor Force Survey (Govt. of Malawi, 2014), 64 percent of the employed people (aged 15–64) are working in the agricultural sector (58.5 for male and 69.9 for females) and only 2.6 (2.8 for males and 1.6 for females) in the construction sector. For the Southern region alone, 58 percent are in agriculture and 2.9 in construction (ibid, p.25). The percentage of employed persons who are active in the informal sector amounts to 88.7 percent (93.6 for women, ibid , p.30).

In the Southern region, 8.7 percent of the labor force is unemployed (10.4 percent for women), i.e. without but available for work.

Yet 46.2 percent (46.0 for women) of the population in the rural areas of the southern region are economically inactive (ibid, p.17), which includes the group of subsistence (foodstuff) farmers. Thistallies well with the finding of the same report (p.24) that in the southern region, only 66 percent of the population between 15 - 64 years of age are employed. For those with no or only primary education this percentage amounts to 73.0 percent (78.8 and 68.9 percent for man and women respectively).

The percentage of the employed persons who classify as managers and professionals amount to 0.6 and 3.2 percent respectively (and 0.2 and 2.4 for women), which shows how scarce certain qualifications are in Malawi.

These observations are supported by UNESCO that shows that In Malawi there is a clear shortage of skilled labor in the agro-processing and construction industries with high vacancy rates “among those holding intermediate certificate which is two steps below technicians for agro processing and 50 percent of the jobs in the construction sector are vacant (UNESCO, 2014, p.11).

From this information, one may conclude that there is a relatively large pool of people with little education who could be relatively easily recruited as unskilled labor without causing a significant loss in production. As a result, the opportunity cost of unskilled labor is quite small. Nevertheless, these costs have been included in the economic analysis, also of the “without project” situation in which a day of family labor has been valued at their efficiency price.

However, it would be a challenge to find skilled labor with relevant experience, such as managers and construction workers with a matching education. For this reason, the Ministry of Labor regards the SVIP as a training ground for Malawian workers. It hopes that the project will reduce the push factor that young people are experiencing these days which leads them to work in the Middle East (Commissioner of Labor, personal communication, Lilongwe, 20 October 2016).

In case foreign managers (for instance for the cooperatives growing sugar cane) are attracted, the economic cost would be equal to the financial cost.

A special case arises for the cost of the design and supervision of the infrastructure of SVIP. The scheme will to a great extent be designed by international consultants whose opportunity cost for Malawi are not much higher than their financial cost and a conversion factor of 1 (one)would be appropriate. The supervision of construction will be undertaken by a mixture of national and international experts. The national staff needs to be rather skilled and conversion factor for skilled labor should best be applied to computer the economic cost. Therefore it is assumed that a conversion factor for consultancy services of 1.15 would produce the best available estimate for their economic cost.

Consequently, the following Shadow Wage Conversion Factors were used.

Conversion factor
- Unskilled labor: 0.5
- Skilled labor: 1.25
- Consultancy services: 1.15

16.3. Cost

16.3.1. SVIP's Cost

For the SVIP the following cost will be discussed.

- Establishment and operations of the Water Service provider (WSP);
- Establishment and operations of cooperatives, incl. equipment required for mechanization(separate for KAMA and 2 non-cane cooperatives);
- Agricultural Extension;
- Transformation Strategy;
- Compensation for loss of lands and produce;
- Dredging cost;
- Construction cost;
- Maintenance cost

16.3.2. Institutional

16.3.2.1. Water Service Provider (WSP)

During the three and a half years construction period, an organization will be established that will operate and maintain the common parts of the infrastructure, and issue bills for the consumers (the sugar cane companies, the cooperatives and the Southern Water Board for the drinking water supply in Chikwawa Boma). The cost of operating this organization is the operation cost of the Shire Valley Irrigation (SVI) scheme.

Apart from an office and the usual office equipment, it will also avail of heavy equipment to maintain (and repair) the common part of the SVI scheme.

It is assumed that the WSP will comprise of the following departments under leadership of a Managing Director: Operations, Maintenance, Human Resources and Finance, Communication and complaints. Additionally it will have secretaries, drivers, guards and office cleaners. Details are presented in Appendix.

The cost estimate related to this organization presented in Appendix amounts to USD 2.25 million establishment cost in Y-1 (in financial prices) and USD 853 thousand annual operation cost (from GoM, 2016 -2 with some amendments, see Table 16.3-1).

[Table 16.3-1] Summary of WSP's Investment and Operational Cost* (In USD)

Description		Finc.	Econ.
Investment			
	Equipment*	270,667	259,840.00
	Machinery / heavy equipment**	1,976,471	1,897,412
Total Investment		2,247,137	2,157,252
Annually recurrent cost			
	Salaries	700,160	875,200
	Office cost	25,600	24,576
	Operational cost	71,040	68,198
	Maintenance (incl. for machinery)***	56,880	54,605
Total	Recurrent	853,680	1,022,579

Note: * half of this equipment is assumed to be replaced every 4 years.
** half of the heavy equipment is assumed to be replaced every 10 years.
*** excluding the maintenance of the common part of the SVI scheme's infrastructure.

Investment in the WSP is assumed to be done in the year before Phase 1 will be completed, and an expansion of the same size will take place before Phase 2 will be completed.

16.3.2.2. Cooperatives

The cooperatives that will be in charge of part of the command area of the scheme will be formed by the farmers in that area. Following the model for the Phata Out-Growers Sugarcane Cooperative, the farmers will contribute the land they have in possession as shares in the cooperatives. As shareholders, they will receive part of the profit made by the cooperative. The cooperatives will also put aside land for cultivation of other crops that they can either consume or sell to the market. The farms of the cooperatives will be managed by professional staff. It is assumed that farming will be mechanized in order facilitate large-scale farming.

Initially the thinking was to have cooperatives that would cover an area of 500 - 1,000 ha. However, currently the Government of Malawi intends to establish a maximum of 5 new cooperatives (GoM, 2017) in Phase 1 area, including Phata and Kasinthula, that are currently growing sugarcane and KAMA that has plans (but no funding yet) to grow sugarcane. Together these 5 cooperatives will cover the entire area of Phase 1 whose total area is 11,829 ha; excluding Illovo (Nchalo and Sande Ranch) which amounts to 10,449 ha. The grand total area for Phase 1 (including Illovo and smallholder farms) is 22,278 ha. This would give the area distribution as in Table 16.3-2.

[Table 16.3-2]Cooperatives' Area for Phase 1 and Phase 2

Phase 1		Existing (ha)	New (ha)	Total (ha)
Coop 1	Kasinthula	1,429	0	1,429
Coop 2	Phata	296 + 400	0	696
Coop 3	KAMA (sugarcane)	0	2,925	2,925
Coop 4	New (non-cane)	-	3,390	3,390

Coop 5	New (non-cane)	-	3,390	3,390
Total		2,125	9,704	11,829
Phase 2		**Existing (ha)**	**New (ha)**	**Total (ha)**
1	Alumenda	2,764	-	2,764
2	Kaombes	819	-	819
Coop 3	3		3,501*	3,501
Coop 4	4		3,501	3,501
Coop 5	5		3,501	3,501
Coop 6	6		3,501	3,501
Coop 7	7		z3,501	3,501
Total			17,507	21,090

Note: * in the analysis it has been assumed that there will be 5.16 cooperatives of 3,390 ha in Phase 2 area.

This table shows that there will be 2,925 ha newly irrigated land for sugarcane and 6,780 ha irrigated land for other crops in Phase 1 area and 17,507 ha of irrigated land for non-sugarcane in Phase 2.

Cooperatives without sugarcane

For cooperatives growing non – sugar cane crops the required investment is presented in Table 16.3-3. The latter have been computed from PWC's estimates for a 500 ha cooperative, assuming that economies of scale may be realized as a result of which the cooperatives in Phase 1 and 2 areas respectively require 6 (six) times as much investment in buildings, machinery and motor vehicles as a 500 ha cooperative. This assumption was applied to all cost components except for those related to the managers of which there will be only one (1) per cooperative instead of 6 or 7.

Moreover, the training of the cooperative staff is covered under the Transformation strategy discussed in Section 16.3.2.4.

[Table 16.3-3] Investment3,390 ha Cooperative(non-sugarcane crops), in 2016 USD

Description	Finc. Cost	Econ. Cost	Remarks
Farm buildings	975,000	936,000	Only one Manager's house
Farm machinery	822,000	789,120	
Motor vehicles	300,000	288,000	Only one manager's vehicle
Training (budgeted in Transformation Strategy)			
Total Investment	2,097,000	2,013,00	

The annually recurrent cost has been computed from those for a 500 ha cooperative (computed by PWG in the GoM, 2016-1) as in Table 16.3-4. This table shows that the reduction of recurrent cost amounts to 14 % (USD 607,100 instead of 6.78 *103,000).

[Table 16.3-4] Computation of O&M Cost of 3,390 ha Cooperatives, in USD

Average Size of coop		500 ha	3,390 ha	Comments
General transport		$5,000	$30,000	
Permanent staff costs		$50,000	$300,0000	Only one manager needed
Maintenance costs:				
Vehicles	10 %	$7,500	30,000	
Machinery and equipment	5 %	$6,850	$41,100	
Buildings and immovable property	2 %	$3,500	$19,500	Only one managers house needed
Administration costs:				
Insurance		$5,000	$24,600	
Communication (telephone, internet, etc.)		$5,000	$20,000	
Subscriptions (to unions and professional organisations)		$500	$500	
Electricity (overhead)		$4,000	$24,000	
Local authority permits/taxes		$2,000	$12,000	
Accounting/audit fees		$5,000	$10,000	
Bank charges		$5,000	$5,000	
Board/management committee expenses		$4,000	$12,000	Three tiers
Training Budget		Covered by Transformation Strategy*		
TOTAL OVERHEADS		**$103,350**	**$607,100**	

Note: * the cost of the transformation strategy remains the same for the entire project area, irrespective of it being divided into cooperatives of 500 or 3,390 ha each

Additionally, it was assumed that every 4 years 50 % of the vehicles have and every 10 years 50 % of the farm machinery needs to be replaced.

The total cost of the cooperatives in the entire areas of Phase 1 and 2 areas have been computed by multiplying these standard cost with the number of 3,390 ha cooperatives that fit in to the total command areas (2 and 5.16 for Phase 1 and 2 respectively).

Part of the operation cost of the Cooperative is to manage the On-Farm irrigation system, while another part is for agricultural production. It has been assumed that all equipment mentioned in Appendix A2 is for agricultural purposes, except for 50 % the miscellaneous equipment that is used for operating the scheme. Of the recurrent cost the following items are assumed to be needed for irrigation, assuming a total of 25 % of the total cost for Insurances Communication, Transportation and salaries will be needed to operate and maintain the irrigation system. Altogether they amount to 16 % of the total overhead cost.

[Table 16.3-5] Financial and Economic Cost of Operating the Farm Irrigation System per Cooperative(of 3,390 ha) in 2016 USD

Cost Item	Financial (USD)	Economic (USD)
Maintenance Farm buildings	750	720
Insurance	7,500	7,500
Salaries	75,000	93,570
Transportation	7,500	7,500
Communication	7,500	7,500
Total	98,250	116,970

For Cropping Pattern 1, each of Coops will be using 75,800 Ml of water per year during the first 5 years and 76,700Ml from Crop Year 6 onwards, for which they will have to Irrigation Service Charges to the Water Service Provider (see section 16.4.5).

The cost of investment and O&M of the on field irrigation system are incurred to serve the agricultural practices of the Cooperatives as well as the individual households who grow their own food crops on the smaller plots (of which we assumed an area of 0.2 ha). It has been assumed that these cost are borne for the full 100 % by the cooperative and the households who are shareholders do not have to make additional financial contributions.

Sugarcane growers

The only available cost estimates for establishing sugarcane plantations are from AfDB and ADF (1999) for a smallholder out-grower project of 2,140 ha in Dwangwa area of Nkhota District, (Salima ADD, Central Region), that pumps water from Lake Malawi and River Mkoma via lined canals and a center pivot irrigation project. The cost estimates made in that appraisal report are based on quotations, net of taxes (p.14). In table 16.3-6 the 1999 cost of capital goods have been converted in 2016 prices using a US Import Price Index for Capital Goods from Federal Reserve Bank of St. Louis (2017), which show that such goods have become 31 % more expensive over the period 1999 – 2016. The resulting estimates indicate investment cost of US$2,289 per ha in 2016 prices. The Operation and Maintenance cost are included in the crop budget for Sugarcane, which was prepared in consultation with the manager of Phata (see Appendix B-13 and Section 16.4.4).

Annual overheads were related to those of the estimates for non-cane cooperatives, with the basic assumption that Sugar cane requires one third of the management staff (and thus the salaries) of non-cane cooperatives. General transport and communications are thus also 66 % lower than for Cooperative 4 and 5. Electricity however is related to the pumping of water and is thus related to the ratio between the crop water requirements of sugar cane to the average water requirement of the non-cane crops. The resulting overheads amount to USD 234,066 in financial and 259,066 in economic prices.

The part needed to operate and maintain the on farm irrigation system of KAMA is assumed to be the same as in the cooperatives without sugarcane: 16 % of the total overhead, or USD37,450 and USD1,450 per ha in financial and economic prices respectively.

[Table 16.3-6] Investment Cost in Sugarcane Plantation in thousands of US$

	AfDB scheme (2,140 ha)					Kama New (2,925 ha)	
	Foreign Exchange		Local Cost	Total (Finc. cost)		Finc. Cost	Econ. Cost
	1999 UA million	1999US$ t housand*		1999 US$	2016 US$	2016 US$	2016 US$
Civil Works						In VSIP	
On-field irrigation equipment							
Equipment	1.76	2,351	0	2,351	2,883	3,940	3,7838
Lifting Plant	0.43	574	0	574	704	963	924
Steel Pipeline	0.51	681	0	681	835	1,142	1,096
Meteorological gadgets	0.01	13	0	13	16	22	21
Vehicles	0.11	147	0	147	180	246	236
Farm Machinery and Equipment	0.15	200	0	200	246	336	322
Office Equipment and supplies	0.02	27	0	27	33	45	43
Total (excl VAT)	2.99	3,994	0	3,994	4,898	6,694	6,426
VAT						1,105	-
Total						7,799	7,487
Cost per ha				1.866	2.229	2.267	2.197

Note: *1UA = US$ 1.33587, (AfDB and ADF, 1999)

The investments are assumed to have the following maintenance cost and replacement:

[Table 16.3-7] Maintenance Cost and Replacement Period of Cooperative's Assets

	Annual Maintenance (% of capital cost)	Replacement
On field irrigation system	5	Only annual Maintenance
farm machinery	5	Half every 8 years
motor vehicles	10	Every 10 years
Office Equipment and supplies	5	Half every 5 years

16.3.2.3. Agricultural Extension

In order for the SVI scheme to be successful in sustainably raising agricultural outputs and farmers' income, an effective system of agricultural extension should be in place. In many irrigation project this is simply assumed to be the case, which has often led to disappointing performance of the irrigation scheme that soon started to fall apart for lack of maintenance due to lack of benefits. Asian Development Bank (2012) for instance shows that, in Cambodia, irrigation schemes that had been constructed would not have met the feasibility criteria if lack of maintenance would have been realistically taken into account during the feasibility studies. Moreover it also demonstrates the outflow of funds from the country in repayment of loans that are not justified by incremental agricultural production due to the de facto destruction of capital invested.

The Chikwawa's District Agricultural Development Office has not been able to fill 50 % of the 124 positions of extension workers, due to a combination of poor facilities (offices and accommodation with erratic electricity supply and related inconveniences and challenges to implementing the tasks), lack of incentives to do field work (actual disincentives by lack of transport apart from bicycles to cover at least 20 km within the area) as well as competition from NGOs with better working conditions and benefits. The Ministry of Agriculture, Irrigation and Water therefore prefers to make use of private sector extension workers who will be recruited by the Cooperatives and included in the Transformation Strategy (or "Agriculture Investment and Transformation Strategy" as it may be called elsewhere) that will be implemented during the three years of construction.

16.3.2.4. Transformation Strategy

Well-functioning commercial cooperatives with farmers who are currently producing for their own subsistence are key to the success of the SVI scheme. Farmers need to be first sensitized and organized, and thereafter trained; district officials need to be engaged in the process as facilitators as well as mediators in case of conflict. The SVIP intends to implement a Transition Strategy that comprises of different components:

a) Farm organization development and farm investment;
b) Farm operations and development;
c) Farm institutional support;
d) Project management;
e) Customary land law implementation.

The estimates used in this report were provided by the FAO team that was working at the World Bank's Project Appraisal Document. However, a word of caution is warranted: with the number of experts proposed in this strategy there is a risk of lack of farmers' ownership of the processes and consequently a flat learning curve on the side of the cooperative's members. This might imperil the capacity development that the transformation strategy intends to deliver.

The financial cost of this strategy amounts to:US$34.4 million for Phase 1 and US$59.1 for Phase 2 (see table 16.3-8).

[Table 16.3-8] Components of Transformation Strategy with Their Cost (in 2016 USD)

Description	Phase I	Phase II
Farm organization development and farm investment	19,300,000	33,180,000
Farm operations development (RAP)	2,000,000	3,440,000
Farm institutional support	1,300,000	2,240,000
Project management	10,000,000	17,190,000
Costmary land law implementation	1,800,000	3,090,000
Total	34,400,000	59,140,000

These cost have been converted into Economic cost by applying a rate of 1.19, which was the average of the conversion rates for the different components in the draft version of this chapter. Unfortunately for this final World Bank – FAO estimates no details of cost of vehicles and their O&M, experts and workshops are available.

16.3.3. Compensation

Two different types of compensation have to be distinguished: (i) for loss of land due to construction of the canals and (ii) loss of production at the land during construction and land leveling.The amount per hectare that households will receive as compensation depends on the income lost.

These cost have been provided by the World Bank

Compensation for resettlement and loss of land: Phase 1: USD7,300,000 Phase2: USD12,555,000

It is assumed that the disbursement of the compensation is proportional to the assumed construction progress: 26 % in Year 1, 33 % in Year 2, 32 % in Year 3 and 9 % in Year 4.

16.3.4. Dredging

During the period between 2001 and 2016, 46 million tons of sediments (consisting of sand, silt and clay) has been deposited in the reservoir of the Kapachira Dam (Artelia, 2016, p.18). Arteria's hydraulic study determined that an intake of the SVIP canal just downstream of the spur dyke in the reservoir is "more beneficial than the upstream location as it enables to have significantly less sediments entering the intake" (Artelia, p.30). Nevertheless it recommends that regular dredging of the downstream RHS deposits to ensure that the 50 m^3/hr. discharge can reach the intake (Ibid, p.43).

In the conclusion of the study, Artelia distinguished two alternatives. In the first one, ESCOM does not perform a large scale dredging of the reservoir and continues to operate at a high water level (minimum 146.0/146.5 m). This alternative would still require dredging a channel (40 m wide at the bottom) to secure sufficient water reaching the intake. The flow in this channel would reduce the sedimentation rate and maintenance dredging would not be necessary. The estimated cost isUS$ 503,688 that has been included in the cost of the intake.

In the second alternative, ESCOM would undertake a large scale dredging of the reservoir to be able to operate at a lower water level. In order to counterbalance difficulties of the water flow to reach the intake priority should be given to the area downstream of the spur dyke. Moreover, it would also require maintenance dredging of approximately 100,000 m^3 of sediments per year. The estimated cost of this alternative is not available, most likely because they obviously are much higher than of the first option.

16.3.5. Construction

Tables 16.3-9 and Table 16.3-10 present the financial cost of the infrastructures of Phase 1 and Phase 2, which were the basis of the financial and economic analysis in this chapter. It should be noted that this chapter only considers the physical contingencies and not the price contingencies that are also included in other chapters of this report. (7.5 % instead of the 15 % mentioned in the other chapters of the feasibility study report). Another difference with the other parts of this report is that the resettlement cost is mentioned under the "Other cost" (see Tables 16.3-3 and 16.3-4) and not under construction cost.

Financial and Economic Analysis of projects conducted in constant prices only consider physical contingencies; price contingencies are not taken into account. As a result, the contingencies in this chapter are 7.5 %, while in the other chapters 15 % is used. On the other hand, the contingencies are computed over the cost including VAT.

[Table 16.3-9] Financial Cost of Phase 1 (VAT included)

Description		Quantities	Total (USD)
I. Direct Total Cost (incl. VAT)			**199,886,040**
a) Intake*			4,564,000
b) Main Canal 1		L=33.80km	49,892,000
c) Main Canal 2		L=18.40km	21,830,000
d) Main Canal 3		L=10.64km	7,240,000
e) Secondary Canal		L= 92.4km	17,020,000
f) Drainage Canal		L=32.40km	9,840,000
g) Night Storages		14	1,610,000
h) On Farm Works **		12,266	57,440,000
i) SCADA		1	1,110,000
j) Water Supply System			1,030,000
Total (a – j)			171,576,000
VAT (over a – j)	16.5%		28,301,040
II. Contingency (% of direct cost)	7.5%		14,991,453
III. Consultant (% of direct cost)	6.0%		11,993,162
IV. Total Project Cost Phase 1			**226,870,655**

Note: * includes US$503,688 for dredging

** includes land levelling, tertiary canals, drains and roads

Phase 1 Construction Cost
(excl. Resettlement and required institutional cost)
Total cost: USD 226.9 Million
Donor funding: USD 198.6 Million
GoM taxes: USD 28.3 Million

[Table 16.3-10]Financial Construction Cost of Phase 2 (VAT included)

Descriptions		Quantities	Total(USD)
I. Direct Total Cost (incl. VAT)			**288,267,600**
a) Intake			0
b) Main Canal 1			0
c) Main Canal 2		L=59.5 km	45,370,000
d) Main Canal 3			0

e) Secondary Canal		L=153.6 km	32,460 000
f) Drainage Canal		L=51.6 km	15,680 000
g) Night storages		24 units	3,080 000
h) On Farm Works *		21,168 ha	148,940 000
i) SCADA		1 LS	1 910 000
Total a – i			247,440,000
VAT (over a – i)	16.5%		40,827,600
II. Contingency (% of direct cost)	7.5%		**21,620,070**
III Consultant (% of direct cost)	6.0%		**17,296,056**
IV. Total Project Cost Phase 2			**327,183,726**

Note: * includes land levelling, tertiary canals, drains and roads

Table 16.3-11 and 16.3-12 show the conversion of financial cost to economic cost of Phase 1 and Phase 2 infrastructure. It also shows the other investments that are required to make the SVIP a successful undertaking. The economic cost of the Transformation strategy is higher than its financial cost due to it requiring many experts (skilled labor).

Phase 2 Construction Cost (excl. resettlement)
Total cost: USD 327.2 Million
Donor funding: USD 286.4 Million
GoM taxes: USD 40.8 Million

When computing the Economic cost of the infrastructure, it was assumed that 33 % of the cost of Transport and Equipment comprises of fuels, based on the following:

- Average cost of equipment: US$50,000, with 3 years lifetime
- Average maintenance cost: US$3,333/year
- Average fuel consumption: US$10,000/year
- Total cost (3 years) : 50,000 + 10,000 + 30,000 = 90,000
- Fuel as % of cost of Transport and Equip.: 33 %

[Table 16.3-11] Phase 1 Investment Cost, Financial and Economic Cost by Component

Phase 1			Financial Cost ($)	CF	Economic Cost ($)
Bill n°1 - Labour					
	Skilled		5,676,388	1.25	7,095,485
	Unskilled		7,961,102	0.50	3,980,551
Bill n° 2 - Materials					
	Foreign		60,196,952	0.96	57,789,074
	Local		31,622,729	1.00	31,622,729
Bill n° 3 - Transportation & Equipment			66,118,829		58,673,849

Of which Fuel		21,819,214	0.74	16,146,218
Others		44,299,615	0.96	42,527,631
Subtotal Bill N° 1 & to 3		171,576,000		159,161,688
Bill n° 4 - VAT		28,310,040		-
Bill n° 5 - Contingencies	7.5%	14,991,453		11,937,127
Bill n° 6 - Consultants	6.0%	11,993,162		13,792,137
TOTAL Construction Costs		226,870,655		184,890,951
Other Costs				
Compensation		7,3000,000	1.0	7,3000,000
Water Service Provider (Appendix A1)*		2,247,137		2,157,252
Cooperatives (Appendix A2)*				
- 2 new Non- sugarcane coops		4,194,000		4,026,240
- KAMA		7,798,809		6,426,486
Transformation strategy*				
Farm organization development and farm investment		19,300,000	1.193	23,024,900
Farm operations development (RAP)		2,000,000	1.193	2,386,000
Farm institutional support		1,300,000	1.193	1,550,000
Project Management		10,000,000	1.193	11,930,000
Customary land law implementation		1,800,000	1.193	2,147,000
Total Investment Cost		282,810,602		245,840,129

Note * for the details of the conversion from financial to economic values, see Appendix 5. A-1, and A2

Sources: Construction and resettlement cost from other parts of this report; Cost of the Transformation Strategy, WSP, and Cooperatives from Appendices A.

[Table 16.3-12]Phase 2 Investment Cost, Financial and Economic Cost by Component

Phase2			Financial Cost ($)	CF	Economic Cost ($)
Bill n°1 - Labour					
	Skilled		8,226,132	1.25	10,282,665
	Unskilled		11,145,454	0.50	5,707,727
Bill n° 2 - Materials					
	Foreign		86,717,851	0.96	83,249,137
	Domestic		45,889,236	1.00	45,889,236
Bill n° 3 - Transportation & Equipment			95,191,325	0.96	91,383,672
Of which Fuel			31,413,137	0.74	23,245,722
Others			63,191,325	0.96	61,227,060
Subtotal Bill N° 1 & to 3			247,429,998		229,601,547
Bill n° 4 - VAT			40,827,000		
Bill n° 5 - Contingencies		7.5%	21,620,070		17,220,116

Phase2		Financial Cost ($)	CF	Economic Cost ($)
Bill n° 6 - Consultants	6.0%	17,296,056		19,890,464
TOTAL Construction Costs		327,183,723		266,712,127
Other Costs				
a. Compensation		12,555,000	1.0	12,555,000
b. Water Service Provider (Appendix A1)		2,215,294		2,157,252
c. Cooperatives (Appendix A2)		10,820,520		10,387,699
d. Transformation strategy				
Farm organization development and farm investment	33,180,000		1.193	39,583,740
Farm operations development (RAP)	3,440,000		1.193	4,103,920
Farm institutional support		2,240,000	1.193	2,672,320
Project Management		17,190,000	1.193	20,507,670
Customary land law implementation	3,090,000		1.193	3,686,370
Total Investment Cost		411,946,381		362,366,098

[Table 16.3-13]Construction Cost* at Financial and Economic 2016 Prices (USD) (Excl. resettlement)

Description	Financial (USD)	Economic (USD)
Phase 1*	226,870,655	184,890,951
Of Which		
- 800 m long Majete Siphon (mitigating measure)**	3,300,000	2,706,914
- Drop structures in Canal 1 (mitigating measure)**	2,320,000	1,890,712
- Chikwawa Boma water supply	1,030,000	969,194
- Dyke for protection against 1:10 floods	936,000	767,779
Phase 2*	327,183,723	266,712,127
Total Phase 1 and 2	554,054,379	451,603,078

Note: * Including SCADA, (7.5 %) contingencies, (6 %) consultancy cost and VAT

** Economic cost computed by assuming the same ratio between economic and financial cost of the entire construction (0.8205)

<u>Construction Cost Reapportioned</u>

Since the scheme's Intake, the Main Canal 1 and Main Canal 3 provide water to both Phase 1 and Phase 2 and the latter covers 48.6 % of the project area, a second version of the analysis allocates 51.3 % of the cost of these components to Phase 1 and the remainder to Phase 2.

[Table 16.3-14]Construction Cost of Phase 1 with Cost of Infrastructure that Serves Phase 2 Reapportioned

Description		Financial ($)		Economic ($)
Direct Total Cost (incl. VAT)		156,666,718		123,020,272
a) Intake		2,344,512		2,201,117
b) Main Canal 1		25,629,357		23,155,669
c) Main Canal 2		11,214,000		10,607,421
d) Main Canal 3		7,240,000		6,873,951
e) Secondary Canal		17,020,000		16,174,333
f) Drainage Canal		9,840,000		8,970,778
g) Night storages		1,610,000		1,480,926
h) On Farm Works		57,440,000		51,553,177
i) SCADA		1,110,000		1,054,986
j) Water Supply System		1,030,000		947,913
Total a - j		**134,477,869**		**123,020,272**
VAT (% of a-j)	16.5%	22,188,848		
Contingency (% of direct cost)	7.5%	11,750,004		9,226,520
Consultants cost (% of direct cost)	6.0%	9,400,003	1.15	10,810,004
TOTAL CONSTRUCTION		177,816,724		143,056,796
Other Cost				
a. Compensation for resettlement		7,300,000		7,300,000
b. Water Service Provider (see Appendix A1)		2,247,137		2,157,252
c. Cooperatives(see AppendixA2)				
d. 2 new Non-sugarcane coops		4,194,000		4,026,240
e. KAMA		7,798,809		6,426,486
f. Transformation strategy		34,400,000		41,032,100
Total Investment Cost		233,756,671		204,005,774

16.3.6. Maintenance

Maintenance is usually grouped together with the Operating cost of an irrigation scheme to form the three characters of “O&M” for “Operating & Maintenance”. Projects’ financial and economic analyses usually elaborate these costs beyond the gross ‘x %’ approach.

Maintenance of the irrigation schemes comprises of two sets of activities:

- Annual maintenance (and minor repair)

  The Maintenance cost of the common parts of the infrastructure will be managed by the Water Service Provider (WSP) and recovered from the users through the fees charged(See Section 16.5.3).

  The cost of maintaining the On Farm Works (item 8 in Table 16.3-15) will be managed by the cooperatives and funded by the profits they will make, before payment of dividend to its members.

- Regular replacement of the mechanical parts and the SCADA

  It has been assumed that every 10 years the mechanical parts and the SCADA will have to be replaced, at a cost of 3 % of the direct construction cost.

The economic cost of maintenance were computed from the financial cost under the assumption that the maintenance requires approximately the same ratio of skilled and unskilled labor, foreign and local materials and transportation & equipment as the construction of the schemes. Subsequently the same ratio of economic to financial cost (including VAT) may be applied (0.831 for both Phase 1 and Phase 2).

[Table 16.3-15]Annual Maintenance Cost (USD) of Phase 1 + Phase 2

Description	Phase 1	Phase 2	Total
Maintenance Cost	1,127,134	1,622,450	2,749,584

VAT included in the cost of individual structures

O&M Cost of Phase1

Annual (Thousand USD)

Description		%	Direct Cost	Maintenance
I)	Direct Total Cost		**199,886,040**	**1,066,309**
1	Intake	0.75%	5,317,060	39,877
2	Main Canal 1	0.50%	58,124,180	290,620
3	Main Canal 2	0.50%	25,431,950	127,159
4	Main Canal 3	0.50%	8,434,600	42,173
5	Secondary Canal	0.50%	19,828,300	99,141
6	Drainage Canal	0.75%	11,463,600	85,977
7	Night Storages	0.50%	1,875,650	9,378
8	On Farm Works	0.50%	66,917,600	334,588
9	SCADA	1.50%	1,293,150	19,397
10	Water Supply	1.50%	1,199,950	17,999
II)	Contingency	7.50%	14,991,453	79,973
III)	Total Project Cost (without Consultants' cost)		214,877,493	1,146,282

average 0.6%

O&M Cost of Phase2

Description		%	Direct Cost	Maintenance
I)	Direct Total Cost		288,267,600	1,509,256
1	Intake	0.75%	-	-
2	Main Canal 1	0.50%	-	-
3	Main Canal 2	0.50%	52,856,050	264,280
4	Main Canal 3	0.50%	-	-
5	Secondary Canal	0.50%	37,815,900	189,079
6	Drainage Canal	0.75%	18,267,200	137,004
7	Night Storages	0.50%	3,588,200	17,941
8	On Farm Works	0.50%	173,515,100	867,575
9	SCADA	1.50%	2,225,150	33,377
10	Water Supply	1.50%	-	-
II)	Contingency	7.50%	21,620,070	113,194
III)	Total Project Cost (without Consultants' cost)		309,887,670	1,622,450

average annual maintenance 0.5%
replacement of SCADA and mechanical parts 3.0%

Note: * total construction cost except for contingencies and consultant’s cost (but VAT included).

It has been assumed that there are no consultancy fees for Maintenance. Also in the case that the part of the cost of the Intake, Canal 1 and Canal 3 are allocated to Phase 2, the annual maintenance of these three components was computed with the percentages in Table 16.3-15, and the reduced investment cost for Phase 1. The cost of the regular replacement of the mechanical works and SCADA was computed as 3 % of the reduced cost of the scheme in Phase 1. In this manner the Maintenance cost of Phase 1 is also partially reapportioned to Phase 2.

To analyze the feasibility of the cooperatives, the maintenance cost of the on-farm irrigation system has been apportioned to KAMA and the two cooperatives in Phase 1 proportional to their area, which resulted in USD100,852 for KAMA and USD116,668 per annum for each of the 2 cooperatives of Phase 1 area (in financial terms).

16.3.7. Mitigation Measures

Majete Game Reserve

The most obvious environmental impact is related to Main Canal 1 traversing the Majete Game Reserve over a distance of approximately 1 km, which may (i) split the Reserve into two sections and (ii) may lead to considerable sound pollution during construction which may impact wildlife and affect tourism. To mitigate the potential splitting of the park, the following options were considered:

a) An underground inverted siphon for 750m distance, with the remaining 260m within the reserve boundary with fenced open trapezoidal canal. This option would give safe crossing by the animals over most of the intersection. However, there are concerns that the animals may break the fence protecting the open canal with potential risk for their life.

b) The same inverted siphon, but for the remaining 260m there will be a rectangular box canal covered by slabs to avoid the risk mentioned under a).

Another alternative for the siphon could be an open canal with bridges at specific intervals. Nevertheless, it would still separate a part of this 70,000 ha park from the rest, which is not the case with the siphon that will be covered by grass so the animals hardly notice it. This option is therefore not further considered.

[Table 16.3-16] Cost of Majete Siphon and Alternative Open Canal (2016 USD)

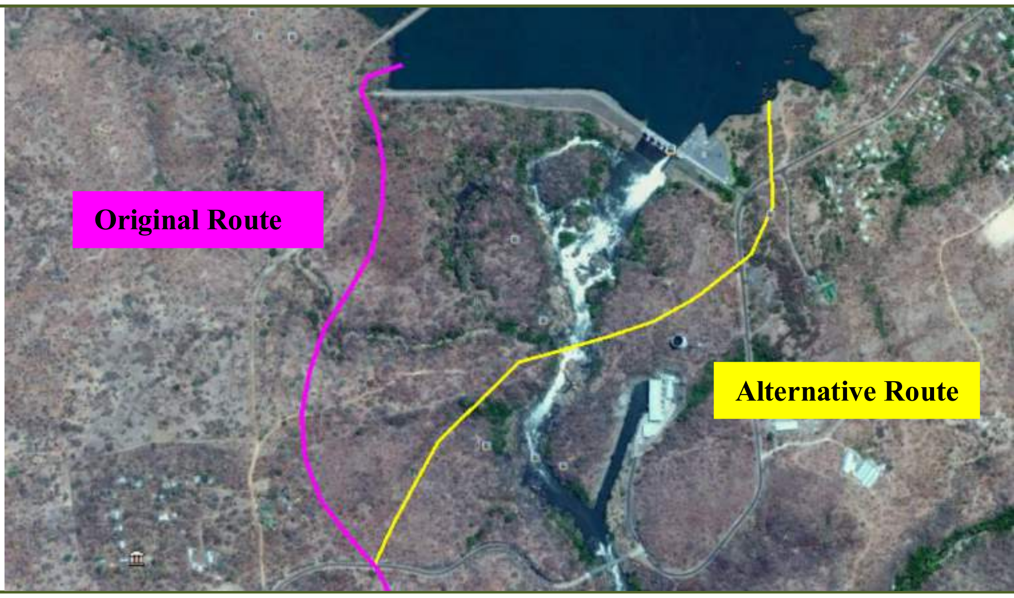
	Financial Prices	Economic Prices
1. Fully open Canal	1,745,170	1,431,845
2. Majete Siphon*	3,300,000	2,706,914
Additional cost (2-1)	1,554,830	1,25,391
a. 240 m open trapezoidal canal*	120,780	99,073
b. 240 m rectangular box canal covered by slabs	1,672,000	1,371,503
Additional cost (b - a)	1,551,220	1,272,430

Note:* included in the design already

As no data are available on number of tourists visiting, or how it would ecologically affect the reserve, the benefits of this mitigation measures could not be determined. Yet the objective is to mitigate the impact of splitting the reserve in to two, which is already prevented in the area with the siphon. One may, therefore, assume that the benefit of the rectangular box canal covered with slabs is equivalent to one third of the cost of the siphon, or USD 1,100,000. One could then argue about the frequency of these benefits materializing: every year or less frequent. Yet the selection problem boils down to a choice between alternative (a), the open trapezoidal canal at a cost of USD120,780 and zero (0.0) benefits and (b) the box canal covered by slabs at a cost of 1,672,000 with 1,100,000 benefits occurring at debatable intervals, but indisputably starting in the year after construction of the canal. Intuitively, one may conclude that alternative (b) is superior.

The second negative impact on Majete Reserve concerns the noise, blasting, and other disturbances during construction that may have adverse impact on wildlife and the operation of the reserve.

An alternative course of Main Canal 1 (the yellow line in Figure 16.3-1) with the intake on the right bank and crossing the Shire River by aqueduct to supply the canal on the right side (where the irrigable area is located) beyond Majete Reserve boundary. Figure 16.3-1 shows the profile of the alternative route. Table 11.1-2 (that is repeated and expanded below as 16.3-13) presents details of the two alternative routes.



[Figure 16.3-1] Location of Main Canal 1 (Planned and Alternative Route)

[Table 16.3-17] Conditions of Construction for Two Canal Routes

	Original Route	Alternative Route
Length	1,280 m	1,510 m
Canal Type	Siphon: 760 m Lined open canal: 520 m	Concrete open canal: 500 m Water bridge: 1,010 m
Canal Section	B=20.2 m, b=12.7 m, H=3.3 m	B=12.7 m, H=3.2 m
Construction Cost		
Financial Prices (USD)	4,490,000	21,000,000
Economic Prices (USD)	3,683,044	17,225,816
Cost correction (financial prices- USD)		
Additional cost for section in Majete after the siphon	1,551,220	0
Sound absorbing walls	586,000	0
Total Financial Cost	6,627,200	21,000,000

The construction cost of the original route needs to be corrected for the cost of the measures to mitigate the potential splitting of the reserve and the noise pollution. The former are known from Table 16.3-16, with the "rectangular box canal covered by slabs" as the preferred measure in addition to the siphon. The cost of the sound absorbing walls was estimated by the KRC engineers. If a Least Cost analysis were possible, the original route with the mitigating measures would be the preferred alternative. However, the alternative route does not affect Majete at all, while the impact could only be minimized or reduced with the original route.

The most relevant question in this context is how the alternative route would affect the project's feasibility. With an additional cost of USD14,372,780, the alternative route would increase the total construction cost with 6.3 %, which – according to the sensitivity analysis in section 16.6.4 and Appendix E would reduce the FIRR with 0.6 per cent points, and the EIRR with 0.8 per cent points. For this reason, the route through the Majete Reserve is preferred, also from an economic point of view.

Disturbances elsewhere

The disturbances during construction do not only affect Majete Reserve. In other areas, the usual procedures limiting noise, dust and chemical pollution (grease, oil and fuels) should be respected and made binding through the contracts with the contractors. Green procurement procedures, which allow for accepting a higher price for construction companies that- in their bid-extendenvironmental protection are recommended.

Invasive fishes

The risk of invasive fishes migrating upstream through the canal system and into Lake Malawi is considered a major risk.

Since they have no natural enemies, the Tiger Fish (*Hydrocenusvittatus*, that can grow upto 105 cm long) may pose a risk to the fish catch in the lake that amounted to 40,000 tons in 2003 (computed from FAO), and that already has been suffering from overfishing (IRIN, 2014) and dropping water levels (The Guardian, 2013). Unfortunately no data are available on the monetary value of the fish catch, but it seems likely that the USD2,320,000 for the drop structures that have been included in the design of canal 1toprevent the Tiger Fish from migrating upstream, is a small amount compared to the potential damage this fish might cause.

Elephant Marsh

There is concern about the reduced availability of water in the Elephant Marsh resulting from diversion of $50m^3/s$ of water. The preferred strategy to mitigate this risk is to release more water from the dam into the Shire River. Yet unfortunately, no study on the ecological and economic impact of reducing the water flow to these marshes is available. In any case, contrary to what its name suggest, there are currently no elephants in the marsh.

In sum, the measures in green in table 16.3-18 are recommended. However, apart from the measures already included in the design (indicated with an asterisk) they have not been included in this analysis since no decision has been taken about them.

[Table 16.3-18] Mitigating Measures Recommended, with Related Additional Cost

Measure	Financial Cost	Economic Cost
2.1 Majete Siphon*	3,300,000	2,706,914
2.2 Cost open canal	1,745,170	1,431,845
Additional Cost of Mitigation (2.2-2.1)	1,554,830	1,275,391
2.3 240 m open trapezoidal canal *	120,780	99,073
2.4 240 m rectangular box canal covered by slabs*	1,672,000	1,371,503
Additional cost (2.4 - 2.3)	1,551,220	1,272,430
Sound absorbing walls Φ	586,000	477,568
Drop structures in canal 1 *	2,320,000	1,890,712
Total Cost of mitigation (3 + 6 + 7+8)	6,012,050	4,916,101

Note: * already included in the standard design

Φ Financialcost converted into economic cost with an weighted average conversion factor for all components in Phase 1 construction cost (0.815)

16.3.8. Investment and Operation and Maintenance (O&M) Cost per Hectare

Total investment and construction cost per ha is higher for Phase 2 than for Phase 1, due to the length of Canal 2 and higher cost of On Farm works, which is due to the sugar cane plantations, that cover almost half of Phase 1 area already being developed.

Total investment cost of Phase 1 (including resettlement and institutional development) amounts to USD10,971/ha in financial cost andUSD9,217/ha in economic cost.

The O&M cost are approximately the same in financial as in economic prices (see Tables 16.3-19and Table 16.3-20) due to the higher economic cost of skilled labor in the WSP that forms the bulk of the operational cost.

[Table 16.3-19]Investment and O&M Cost per Household and Hectare, Phase 1

Cost per ha and Household	Financial Cost ($)	Economic Cost ($)
Total investment	282,810,602	254,736,929
Total construction cost	226,870,655	184,890,951
Investment cost per ha	12,694	11,035
Construction cost per ha	10,184	8,299
Average Annual Maintenance cost	1,429,157	1,164,709
Annual Operation Cost		
- Water Service Provider	853,680	1,022,579
- Cooperatives	196,500	223,940
Average Annual O&M cost	37,451	41,451
Annual O&M cost per ha per year	2,516,788	2,462,678
Annual O&M cost per household per year	113	111

[Table 16.3-20]Investment and O&M Cost per Household and Hectare, Phase 2

Cost per ha and Household	Financial Cost ($)	Economic Cost ($)
Total investment	411,946,381	362,188,678
Total construction cost	327,183,723	266,712,127
Investment cost per ha	19,533	17,182
Construction cost per ha	15,514	12,646
Average Annual Maintenance cost	1,914,085	1,559,906
Annual Operation Cost		
Water Service Provider	853,680	1,022,579
Cooperatives	506,970	603,565
Average Annual O&M cost	3,274,735	3,186,051
Annual O&M cost per ha	155	151
Annual O&M cost per household	120	116

[Table 16.3-21]Investment and O&M Cost per ha, Phase 1 and Phase 2 together

	Financial Cost ($)	Economic Cost ($)
Total construction cost Phase 1 and 2	554,054,379	451,603,078
Total investment cost Phase 1 and 2	694,756,982	608,206,227
per ha		
Total construction Phase 1 and 2 per ha	12,776	10,413
Total investment cost Phase 1 and 2 per ha	16,020	14,024
Average total O&M cost per year	5,791,552	5,648,729
Average Annual O&M per ha	134	130
Average Annual O&M per household	120	117

16.4. Benefits

16.4.1. SVIP's Benefits

Table 16.4-1 presents an overview of the different benefits that are included in this financial and economic analysis. Details are discussed in this section.

[Table 16.4-1] SVIP's Benefits Identified (In USD)

Description	Phase 1		Phase 2	
	Financial	Economic	Financial	Economic
1. Incremental Crops - Food Crops and Cotton	X	X	X	X
2. Incremental Sugar cane	X	X	X	X

Description	Phase 1		Phase 2	
	Financial	Economic	Financial	Economic
3. Water charges paid by Sugar Cane companies	X			
4. Water charges paid by Cooperatives(non-sugar growing)	X		X	
5. Reduced electricity consumption		X		
6. Drinking water Chikwawa Boma	X	X		
7. Livestock	X	X	X	X
8. Aqua culture	X	X	X	X
9. Flood Protection	X	X		
10.Illovo's saving in cost of O&M of its pumps	X	X		
11.Paid employment opportunities		X		X
12.Multiplier		X		X
13.Positive externalities		X		X

16.4.2. Incremental Crop Production

The more secure availability of water that comes with irrigation is expected to increase the yield per ha of the crops planted. However, these higher yields and new crops often require increased agricultural inputs, such as fertilizers, pesticides and additional labor inputs per hectare. Therefore, the relevant variable to consider is the, so called, Gross Margin, which is defined as

Gross Margin = Production Value per ha – Production Cost per ha

With: Production Value = Yields/ ha * farm gate price of the crop.

16.4.2.1. Without Project Situation

Area currently planted with crops

The main data on area planted in Phase 1 and Phase 2 originate from the District Agricultural Development Offices. These offices provided data for each of the Extension Planning Areas (EPA), of which the command areas of the SVI scheme covers a part (see Figure 16.4-1). It was assumed that the area planted with each of the crops was homogeneously distributed over the each of the EPAs. As a result, the area planted with each of the crops was assumed to be a share of the total planted area that was proportional to the share of the project area in the entire area of the EPA (see Table 16.4-2). The resulting estimates are presented in Table 16.4-3.

This table shows that the Phase 1 project area currently has a cropping intensity below 0.5 for the areas where currently no sugarcane is grown. Crop(ping) intensity is defined as total area cultivated divided by total crop land (Price Gittinger, 1985; Ruthenberg, 1971).A farm of 100 ha of crop land with 100 ha of perennial fruit trees has a cropping intensity of 1 (or 100 in Ruthenberg's numbers). The same if it is cultivated with 50 ha of maize and 50 ha of cotton. However if there is 50 ha of summer maize; 25 ha of winter maize and 50 ha of cotton, the cropping intensity is 1.25. A double crop of rice on all of the 100 ha implies a cropping intensity of 2.0. The crop intensity below indicates that, in 2015 – 2016, more than half of the land is left fallow also during the summer season.

[Figure 16.4-1] Extension Planning Area Related to SVIP

[Table 16.4-2] Percentage of Area of EPA in SVIP Command Area

EPA	% in SVIP Command Area
Chikwawa District	
Kalambo	1 %
Mitole	12 %
Mbewe (except for Illovo)	10%
Mikalango	25 %
Dolo	33 %
Livunzu	0 %
Nsanje District	
Mogoti	10%

Source: estimated from Figure - 1

[Table 16.4-3] Area Currently Planted in the Project Area by Crop in ha

Crop	Phase 1	Phase 2	SVIP area
Maize	1,220	2,424	3,644
Cotton	509	3,618	4,127
Sorghum	1,321	3,806	5,127
Millet	413	3,044	3,457
Pigeon Peas	214	137	351
Cow peas	232	1,072	1,304
Sesame	147	483	630
Cassava	10	14	24
Sweet potato	96	105	201
Total	4,162	14,702	19,043
Current Total Non Sugarcane Area	9,704	17,507	27,211
Cropping Intensity	41%	84%	70%

Source: computed from ADD, 2015 – 16 crop estimates, 1st round (summer crop only)

The production value was estimated by multiplying the area planted of the crops in Table 16.4-3 with the Gross Margins compiled by PWC. However for Millet, and sweet potatoes no Gross Margins were available. These two crops together account for 12 and 21 % of the area planted in Phase 1 and 2 respectively. It has been assumed that the production value per ha on these lands is the average of the land for which gross margins are known.

Additionally, there are bananas, mangoes and citrus trees in the project area. However, most are the result of random disposal of seeds that are led to grow as nature pleases, and therefore have a very low productivity (an estimated MK5,000 per year for mangoes). Consequently they have not been included in the computation of the production value without project.

Moreover, the project area has recently been suffering from a number of droughts that seriously affected crop production. Food has been provided to the area in 2015 and NGOs are providing seeds to mitigate the loss of good quality planting materials, since farmers traditionally use their own seeds. The impact of deteriorating quality and availability of seeds could have a rather devastating and longer lasting impact on agricultural production, even though rains may bring some relief on lands that are said to “grow everything as soon as water is available”. Yet, given increasing frequency and intensity of severe weather events that accompanies climate change, it is not unlikely that, without the project there will be a reduction in agricultural production in the project area. Yet due to lack of reliable models to forecast the impact of climate change on agricultural production in Malawi, this likely development cannot be quantified.

16.4.2.2. With Project Situation

The introduction of irrigation will lead to an increase of yields and gross margins of the crops currently grown in the area. It may also lead to an extension of area planted with a given crop and/or new crops in an irrigated area.

The project currently already comprises of 12,175 ha grown with sugarcane in Phase 1. Phata is currently expanding on another 400 ha. There is3,575 ha in Phase 2 where sugar companies are irrigating the land, and will continue to do so. For these areas the incremental benefits are limited to a relatively small increase in yield (see section 16.4.3). On the other hand, the plans of KHAMA association to expand their sugar cane plantation (with support of PressCane) are not yet funded. These 2,925 ha will be included in the SVI scheme and is therefore part of the incremental benefits.

Given this situation with sugar cane growers, there is only 6,779 ha of land left for cooperatives to grow other crops than sugarcane, which would imply 2cooperatives of 3,390ha each, given GoM plans to limit the number of cooperatives in Phase 1 area to 5 (see Section 16.3.2.2).

Yet, these plans also imply a potential risk that the sugar cane producers will expand beyond the 44 % of the total of Phase 1 and 2. At that point, they may start consuming additional water at the expense of the other farmers who are growing food crops, since the SVI scheme has been designed to a serve a maximum of 44 % of the area with sugarcane (see chapter 5 on the design of the scheme). Since the expansion of the sugarcane area in Phase 1 is nearing this 44 % point, it is likely that there won't be any room for sugarcane in Phase 2.

[Table 16.4-4] Newly Irrigated Area by VSIP by Phase in ha

	Existing Sugarcane*	Newly Irrigated Areas			Total*
		New Sugarcane	Other crops	Total New*	
Sande Ranch	454	-	-	-	
Others	2,125	-	6,779	-	
Of which:		-	-	-	
Kasinthula	1,429	-	-	-	
Phata existing	296	-	-	-	
Phata under Construction (2017)	400	-	-	-	
Kama		2,925		-	
Phase 2	3,583	-	17,507	17,507	21,090
Alumenda	2,764				
Kaombe mcp	484				
Kaombe Trust	335				
Total Phase 1 and 2	16,157	2,925	24,286	27,211	43,368

In this analysis, the newly irrigated areas without sugar cane have been divided in to areas of 3,390 ha each. Consequently, this report distinguishes 2 cooperatives in the Phase 1 (in addition to KAMA) and 5.16 cooperatives in the Phase 2 area.

In the SVIP, the change from subsistence to commercial farming is expected to be accompanied by far-reaching mechanization and the use of pesticides and herbicides to avoid the increase in labor requirements that usually comes with the introduction of irrigation. Given the very low proportion of the population owing and thus having experience with draft animals (GOM, 2016 -2, p.72) this seems a rational endeavor. The mechanization may also provide a relief of self-exploitation that the farmer's drudgery often entails.

16.4.3. Non-cane Crops

For the non-cane crops two different cropping patterns have been studied. Based on the Agricultural Development Planning Strategy (AgDPS, GoM, 2016 –1, p.148) during the first 5 years after completion of the infrastructure, the cooperatives of farmers will focus on the cultivation of the usual food crops supplemented by cotton as a cash crop[1] (see Table 16.4-5), in order to gain experience with irrigated farming aimed at commercial production, before planting more perishable crops. In year 6, higher value fruit crops will be planted.

Years (Y 1-5 and ≥Y6) related to the cropping pattern refer to the years of the planting cycle and not the project years. For Phase 1, the planting of crops will start in year 4 of the project (so cropping Y1-5 is Y 4–8 in the project years). In case of the analysis of Phase 1 and 2 together, Phase 2 will start in project year 4 and will be completed in Year 7. For these areas planting will commence in project year 8. So for Phase 2, Crop Year 1 = Project Year 8.

[Table 16.4-5] Area Planted with Field Crops in Standard Cooperative of 500ha, Cropping Pattern 1

Crop	Y 1- 5	≥Y6
Cotton	1,129	1,061
Soya beans	1,129	1,061
pigeon beans	1,129	1,061
Maize	1,695	1,593
Dry beans	1,695	1,593
Bananas	0	68
Mangoes	0	68
Citrus	0	68
Total	6,676	6,572
Cropping intensity	2.0	1.94

[Table 16.4-6]Areas Newly Irrigated by Crop and Phase(in ha), Cropping Pattern 1, after Crop Year 5

Crop	Phase 1	Phase 2
Sugar cane	2,925	0
Cotton	2,122	5,478
Soya beans	2,122	5,478
Pigeon peas	2,122	5,478
Maize	3,186	8,225
Beans	3,186	8.225
Bananas	136	350
Mangoes	136	350
Citrus	136	350
Total	16,070	33,947
Cropping Intensity (excl. Illovo and Phata)	1.66	1.94

[1]Please note that there will not be enough water for the cooperatives to embark upon sugar cultivation, given the design being based on 44 % of the land planted with sugarcane. Moreover, Illovo has indicated that it has reached full capacity utilisation for cane processing and does not intend to invest in additional capacity, given the world market price for sugar. As a result only PressCane's ethanol plant may be possible demand for additional sugar cane.

[Table 16.4-7] Area Planted on 3,390ha Cooperative, Cropping Pattern 2

Crop	ha
Cotton	993
Soya beans	993
Pigeon beans	993
Maize	1,491
Dry beans	1,491
Bananas	136
Mangoes	136
Citrus	136
Total	5,960
Cropping intensity	1.76

In the first scenario's, high value bananas, mangoes and citrus will be introduced on 6 % of the area as stand-alone crops in year 6 after the farmers are sufficiently skilled in commercial irrigated farming (approx. 2 % each, according to table 6.5, p.148 of the AgDPS).

The alternative, second cropping pattern depends more on the technical expertise and experience of the professional manager and agricultural extension expert. The cooperatives will commence fruit crops right from the beginning and on a bigger area than in Cropping Pattern 1 (136 ha per cooperative instead of 68 ha).

[Table 16.4-8] Areas Irrigated by Crop and Phase, Cropping Pattern 2 (In ha)

Crop	Phase 1	Phase 2	Both
Nr of cooperatives	2.0	5.16	7.16
Cotton	1,986	5,128	7,114
Soya beans	1,986	5,128	7,114
Pigeon beans	1,986	5,128	7,114
Maize	2,982	7,700	10,681
Dry beans	2,982	7,700	10,681
Bananas	272	700	974
Mangoes	272	700	924
Citrus	272	700	974
Total by coops	12,736	32,891	45,627
Sugar cane growers	2,925	0	2,925
Total	15,661	32, 891	48,552
Cropping intensity	1.61	1.88	1.78

16.4.3.1. Gross margins per hectare

Without project

Unfortunately, no data were available on the current (i.e. without project) gross margins in the Shire Valley. Attempts to collect data from the Chikwawa Agricultural Development Division (ADD) were not successful.

Data on the relevant cropping budgets that were collected from MoA's statistics by PWC pertain to the country as a whole obviously overestimate the gross margins (see table 16.4-9).

[Table 16.4-9] Average yields in Shire Valley and the country as a whole

	(2010 to 2015) in Shire Valley	National average
Beans	1.0	0.5
Cassava	14.7	2.0
Cotton	0.9	1.1
Cowpeas	0.4	2.2
Groundnuts	0.5	4.17
Maize	0.72	3.5
Pigeon pea	0.9	0.9
Rice	2.9	3.5
Sesame	0.3	2.0
Sorghum	0.8	4.0

Source: Column 2 Shire Valley ADD annual crop yield estimates (quoted in AgDPS, Oct 2016)
Column 3: PWC, Oct 2016)

In order to arrive at the GM for the project area, the national averages yields were replaced with those in the second column of table 16.4-9. Fertilizer and pesticide application (wherever used) and the input for labor for those activities that obviously related to the volume of produce (harvesting, grading, bagging etc.) were reduced proportionately. Labor input for land preparation and other activities not related to the yields were not amended. Moreover, the PWC estimates were also adjusted to exclude transportation cost to the markets, as this analysis is done in farm gate prices. Details of the Gross Margins of the different crops are presented in Appendices B.

With project

The introduction of irrigation will lead to an increase of yields and gross margins of the crops currently grown in the area. The transition from subsistence to commercial irrigated farming will take a few years. Especially new techniques for the preparation of seedbeds, choice of planting material, calibration of equipment; application of chemicals, and, harvesting may require a few years before they will effectively be adopted. In addition, the new farmers are likely to suffer higher post-harvest losses before they learn the various techniques of preserving the produce.

Consequently, after the introduction of irrigation, the yields of the crops planted will start at a lower level and will reach the potential only after a few years, due to the farmers' learning curve. In the case of SVIP, there will also be mechanized harvesting (with a combine), which will be rented from an enterprise rather than owned by each cooperative individually. However, it may take a while before such enterprises are sufficiently in place and their temporary absence may contribute to a lower level of yields in the initial years. As a result, it has been assumed that the yields of the main crops will develop as presented in Table 16.4-10. The agricultural inputs, on the other hand, are assumed to remain at the recommended levels from Year 1 to Year 5, except for Mangoes and Citrus where the learning period coincides with the growing stages of the trees that only start to bear fruit in year 3 and gradually increases until the tree reaches maturity in Y8 for mangoes and Y15 for Citrus.

The data required for the finc and econ analysis were compiled by PWC while preparing the AgDPS (Govt. of Malawi, 2016-1). Data on inputs, yields and prices originated from official Government of Malawi publications as far as the potential for the different crops that are grown in Malawi are concerned. PWC collected the prices of the different agricultural inputs from the suppliers, including some fertilizer companies in Blantyre. The PWC estimates have been amended as follows:

- prices have been corrected to exclude transportation cost from the farm gate to the markets
- PWC's estimates for Crop Water Use have been replaced with those used by KCC during the design of the scheme. This applies for fruits, pig peas, maize, dry beans and soybeans. For the other crops no KCC estimate was available and the PWC's have been retained.

[Table 16.4-10] Assumed Development of Yields of the Main Field Crops (in tons/ha)

Year	1	2	3	4	5
Cotton	4	5	6	7	7
Soya beans	2	2.33	2.66	3	3
Pigeon beans	1.8	2	2.2	2.4	2.4
Maize	3	3.66	4.32	5	5
Dry beans	1,5	1.83	2.16	2.5	2.5

Table 16.4-11 presents a comparison of the Gross Margins without and with irrigation. The Irrigation Service Charge (ISC) according to the recommendations of PPP Feasibility study (GoM, 2016 – 3) that aim at full recovery of the O&M cost and part of the investment cost ofthe system up to the water meters through a fixed part of USD100/ha (in addition to a variable part dependent on the crop water requirements) have been deducted. Also the cost of maintaining the on-farm canals that are the responsibility of the cooperatives have been deducted at USD34/ha in financial and US28/ha at economic prices.

Table 16.4-11 shows that in spite of these costs, the gross margins still have the potential to improve of farmers' income and maintain the cooperatives objective (see also section 16.5).For some crops in the without project situation the financial GM are higher than the economic value due to the inclusion of family labor in the latter and their omission in the financial cost (see section 16.2.23).

[Table 16.4-11] Gross Margins for Major Crops, with and without Project, Financial and Economic Prices, in USD/ha

Crop	Financial		Economic	
	Without project	With Project	Without project	With Project
Beans (dry)*	492	1,172	399	1,757
Cassava (dry)	199		164	
Cotton*	312	2,394	207	2,572
Cow peas	53		11	
Maize *	43	210	- 41	464
Pigeon peas*	646	1,349	560	1,399
Sesame	18		-34	
Sorghum	63		24	
Soya beans*	-42	149	-172	205
Sugar cane**		2,812		2,897
Bananas**		2,125		2,447
Mangoes**		5,124		5,275
Citrus**		10,992		11,278

Notes: * in Crop Year 4 or 5, when the farmers have gone through their learning curve and the potential yield is reached:

** average over the 40 years period, assuming that the productivity is maintained until year 30 after these crops reach maturity (after 2 years for bananas, 10 years for mangoes and 14 years for citrus).

These estimates have been applied to both the individual households producing for home consumption (also in KAMA; see section 16.5.1) and the cooperatives without sugarcane in Phase 1 and 2 areas.

Yet, for the analysis of the Cooperatives (section 16.5.1) the total sum of ISC and cost of maintain the on-farm canals have been separated from the other cost.

16.4.4. Sugarcane

Three different type of sugar cane areas have been distinguished:

a) New areas: it is assumed that the incremental benefits on KAMA's2,925 ha, will commence with USD2,152/ ha in Y1 and increase until USD2,977/ha in Y2 and Y4 to decline to USD2,707 in Year 7. (See Appendix B – 13 in financial prices). In Year 8, the fields need to be cleared, land preparation has to be redone and the entire crop needs to be replanted, to start another 7 years cycle.

[Table 16.4-12] Changes Made to PWC's Crop Budgets for Sugarcane

	PWC	Adjusted Value*	Remarks
Yields per ha	110 – 135 t/ha.year	105 – 110t/ha.year	
Labor input for planting	20 d/ha	50 d/ha	PWC's estimates seem to ignore chopping, loading and offloading
Lifetime of standing crop	10 years	7 years	After 5-6 years the cane loses its productivity, and under good practice needs to be replanted

* Based on comments from Phata's Manager and consistency with ILLOVO's Annual Report 2016

b) Illovo's sugarcane yields. It is very likely that, compared to 2015 –2016 the yields in these plantations will also increase due to more reliable and controllable water supply. At the time of preparing this report, Illovo had difficulty pumping water from the Shire River due to the low water level. Even though the term "drought" was not mentioned in Illovo's annual report, it is likely that the 2016 reduction in yields (see Table 16.4-13) is the consequence of Illovo having trouble with water supply. It is therefore assumed that the benefits of the VSIP also entails 10 % of the gross margin per hectare.It is not unlikely that these benefit will increase in time due to climate change.

[Table 16.4-13] Illovo's Sugarcane Yields (tons per ha)

2016	2015	2014	2013	2012
94	103	101	104	105

Source: Illovo, Annual Report 2016, p. 15

c) Outgrowers: the farmers who have contributed their land voluntarily to a cooperative to jointly grow sugar cane as well as other crops with a professional manager. This pertains to Phata Outgrowers (the area planted in 2016 – 17 and the area that will be cultivated in 2017 -18) in Phase 1 and Alumenda, Kaombe mcp and Kaombe Trust in Phase 2. Phata outgrowers are currently suffering from limited and unreliable electricity supply, which occasionally leads to reduced water application. It is assumed that their yield of sugar cane will increase by 10 % as a result of being connected to the SVI scheme.

It is assumed that the economic benefits described in this section are equivalent to the financial benefits.Table 16.4-14 presents the average incremental production over a period of 40 years. The value for the non-sugar crops is high due to high productivity of the tree crops, after 10-15 years.Illovo's relatively low incremental benefits per ha are due to the fixed part of the Irrigation Service Charge that is US$100/ha higher than of the out-growers' (and KAMA's see Section 16.4.5).Nevertheless, this sugar company will still benefit around USD 1.0 million per year from participating in the SVIP2.

[Table 16.4-14] Incremental Crop Income per Hectare (In USD)

Phase 1 Crops	Financial Net Crop Income ($)			Economic Net Crop Income (S)		
	Without Project	With Project	Increment	Without Project	With Project	Increment
Existing Sugar Cane*						
Illovo*	2,544	2,599	54	2,750	2,825	75
Others*	2,544	2,699	154	2,750	2,925	175
New Sugar cane area (KAMA)	123	2,699	2,576	81	2,925	2,844
Average of non - sugar cane crops**	123	2,266	2,143	81	2,507	2,426

Note: * The cost of maintening the On Farm Irrigation System has been included.

Phase 2 Crops	Financial Net Crop Income ($)			Economic Net Crop Income (S)		
	Without Project	With Project	Increment	Without Project	With Project	Increment
Existing Sugar Cane	2,544	2,669	54	2,750	2,925	175
Average of non - sugar cane crops	141	2,266	2,125	89	2,507	2,418

16.4.5. Irrigation Service Charges (ISC)

In order to compute the ISCto be paid by the different consumers, the crop water requirements used during the design of the scheme were converted into Ml per ha for the main crops (see Table 16.4-15).

[Table 16.4-15]Crop Water Requirements of Selected Crops, Cropping Pattern 1 (>Y6)

Crop	Water Requirement (Ml/ ha, or thousands of m^3 per ha) per Season	Area Phase 1*	Area Phase 2*
Sugar Cane	20,770	15,499	3,583
Cotton	10,356	2,122	5,478
Maize	12,402	3,186	8,225
Dry Beans	14,678	3,186	8,225

[2]These benefits may be lower than estimated in other parts in the report, due to a different Irrigation Service Charge. Yet they are in addition to Illovo's benefits of reduced electricity consumption.

Soy Beans	8,064	2,122	5,478
Pigeon Peas	8,064	2,122	5,478
Bananas **	18,000	136	350
Mangoes	12,400	136	350
Citrus	12,400	136	350

Note: * for Y6 and onwards (for Y1-5 there won't be any fruit crops yet.

** Between 900 and 1,800 mm per year (Ekanayake et.al 1995). This table presents the highest of this bracket since especially Chikwawa District is known for it high temperatures.

Source: KCC's estimates of Crop Water Requirements used in the design. Mangoes and Citrus PWC's estimates; Bananas: Ekanayake et al (1995)

These Crops' Water Requirements were multiplied with the number of hectares (for both Y1-5 and >6Y) to compute the total amount of water that cooperatives and sugar cane companies have to pay for. It should be noted that KAMA will include not only sugarcane but also food crops cultivated by the share holders (see Section 16.5.1).

In line with the PPP Feasibility Study (GoM, 2016-3, p.15), it was assumed that the following service charges will be paid for the water, which will allow for the recovery of the cost of O&M and part of the investment cost and sufficient incentives for a private company to participate in a Private – Public Partnership (see section 16.5.2.).

[Table 16.4-16] Irrigation Service Charge (US$/ha) according to PPM Study

	Variable (US$/Ml)	Fixed (US$/ha)
1. Illovo	8.6	200
2. Phata, Kasinthula and Sande Ranch	8.6	100
3. Newly irrigated areas (KAMA + non-sugar cane coops)	8.6	100

Source: GoM (2016 – 3), p. 15

For reasons of presentation, these charges have been excluded from the inputs in the crop budgets in Appendix B.1. They have been presented as a separate entry in the analysis of the cooperatives (see Appendix A3).In GM table 16.4-11 on the other hand, they have been included in the total of cost of inputs.

16.4.6. Reduced Electricity Consumption

According to the information provided by Illovo, the Sugar Estate is currently using 22 MWh of electricity to pump up the water from the Shire River in order to irrigate the entire 9,995 ha of plantation. This electricity consumption requires a production capacity of 10,000,000Kwh, or a daily use of about 333,333 Kwh/day (see Section 3.1.5 of the Draft First Stage report) for which a production capacity of the maximum amount of electricity used reaches as much as 22.2MW/yr. ILLOVO alone utilizes 8 % of the country's entire production capacity of 288 MW[3], (including the standby thermal power plants).

[3] ESCOM avails of 285.85 MW hydropower in 4 different stations and 1.05 MW diesel plant in two stations (ESCOM, 2016).

The total power consumption that could be reduced when the sugar cane growers in the project area get their irrigation water from the gravity-fed SVI scheme, amounts to 17.42 MW (see table16.4-17).

The expected savings from the SVI scheme would thus be a one-time investment in a power plant with such a capacity, which would cost USD34,800,000, according to the cost per MW capacity in First Stage report, p 3-18. Additionally, there will be annual savings of the O&M cost of such a power plant, which is assumed to be 2 %, or USD 697,000. Since these savings don't accrue to the SVIP but only to the republic of Malawi, they are only economic benefits.

[Table 16.4-17] Reduction in Electricity Consumption thanks to SVIP

Company / Cooperative	Total Area (in ha)	Cane Area (ha)	Potential Capacity (in MW)	Source of Information
Illovo		9,995		
Current consumption			18,00	PTT team
Required for booster pumps			5,00	PTT team
Potential Reduction			13,00	
Phata	330	296	0,60	Phata's manager
Khasentula	NA	1,429	2.9	
Sande Ranch	674	454	0.92	Prop. to area according to table 3.3-1, p.3-4 cane area only
Total			17,42	
Total Saving in Investment	$2,000	per kW capacity	34,833,784	First stage report p.3- 18

	Financial	Economic
One time Benefits (Y4)		USD34,833,784
Annual Benefits		USD 696,676

16.4.7. Illovo's Reduced Maintenance Cost

Apart from the reduced electricity consumption, Illovo will also reduce the cost of maintaining the 6 pumps. We may assume that the cost of switching the pumps on and off is negligible.

The reduction of maintenance (and repair) cost could be estimated if the type of pumps (with their capacity), their age and annual repair cost is known. The reduction in maintenance could be computed by the following formula:

Hr up / (Hr up + Hr boost + Hr non) x M

With: H up = Nr of hours to pump water to higher fields (Western part of the plantation)

Hr boost = Nr of hours as booster pump

Hr non = Nr of hours the pumps are used for non-irrigation purposes

M = Annual Maintenance cost

At the time of writing this report, no data were provided by Illovo about its finances or cost structure (apart from its Annual Reports), so the reduction in these cost could not be estimated. Nevertheless, a spreadsheet has been included in the file that was used to prepare this report for future computations.

16.4.8. Drinking Water Supply Chikwawa Boma

For drinking water, the people in Chikwawa Boma, the main semi urban area of Chikhwawa District, depend on a malfunctioning system managed by the Southern Water Board that comprises of 3 tube wells/ boreholes of approx. 65 m depth. At least one of these wells is currently out of operations due to a pump that has fallen into to the well and can't be retrieved. Additionally, there is insufficient electricity to fill the 10 meters high water tower to provide a continuous water supply to a relatively small area. Some of the villages around the road between Mbenderama and Migano don't receive any water due to their elevation.

Additionally there are 28 different water points installed by NGOs and development projects, of which 13 are located in the premises of an institution such as schools, prison and a mosque and are therefore accessible for the population to a limited extent only. Of the 15 public water supply points, at least 7 were officially known to be salty[4].

Field visits to Chikambi -3 and Mbendera 2 and 3 and discussions with inhabitants of Nuaji 1 and 2 yielded reports of (mostly) women having to walk to the specific spots in the Shire River that are safe from crocodiles for 20 min – 1 hour (one way) to fetch water. Others get water from one of the public taps of the Southern Water Board, where waiting times were reported up to 6 hours, since the pressure of the tap is very low and people fetch water in large quantities at a time.

Table 16.4-18 provides an incomplete picture that shows that at least 15,000 people in 2,776 households will benefit from the SVIP water supply scheme.

[Table 16.4-18] Number of People and Households that will Benefit from SVIP Water Supply Scheme

Name of Village	Nr of People	Nr of HH
Mbenderana 1 +2	4,482	566
Drima (Diwa)**	788	131
Chikhwama**		
Dyeratu**		
Lauji 1	1,152	289
Lauji 2	2,107	353
Salumeji1 +2	1,319	249
Kasinthula**		
Migano	612	189
Lingawa*	1,309	294
Nyukatu**		
Chikhambi 3	732	153
Kabudel(a 1)	1,198	274
Kantefa**		
Julius Village *	729	139
William**	644	139
Total	15,072	2,776

Note: * only the village with this name in the Chikwawa Catchment Area

** population data not available (at the time of the feasibility study)

Source: SK WASH Data Base, 2015, provided by WASH Coordinator

4 I.e. according to a data base of 2010 of the District's Water and Sanitation Coordination Unit, in which 5 of the wells on the list provided by the Southern Water Board could not be traced.

A conservative estimate is that the households in the area benefiting from the SVIP scheme together lose 2,700 hours per day. Per year this amounts to 123,000 working days of 8 hours. Under the assumption that this could be reduced by 50 percent, the SVIP scheme would imply a gain of 61,500 days per year. Some girls who said they had been waiting at the SWB point for more than 5 hours stated that such time savings would allow them to attend school regularly[5].

In monetary terms these benefits would amount to some USD30,000 per annum. Compared to the without project situation, these incremental benefits will increase by the population growth of 2.55 % per annum. The economic benefits are considered to be the same as the financial, since are they already based on the assumption that only 50 percent of the time saved will be used productively.

The regular visits to the river do not remain without health risks, as appears from the incidence of bilharzia that appears to be a rather common disease. Moreover, lack of cash and the poverty of the population in general lead some households to consume the river water without any treatment. Respondents reported that the MK500 for 250 ml of sterilizing Liquid that is commonly used for 200 gallons of river water is regularly not available. Boiling of water is too expensive given the price of char coal.

In the catchment area of Chikwawa Hospital (with 48,000 people), there were 56 confirmed cases of cholera in 2015 (and one death). For service area of the SVIP water supply scheme this would amount to some 19 cases (assuming an equal distribution among the area).

[Table 16.4-19] Incidence of Main Water Borne Diseases, Chikwawa District Hospital

Chikwawa Hospital (45,890 people)				Of which in SVIP's water supply service area (estimated nr of cases with 15,000 people)*
Data Element	2014	2015	2016 (Jan to Sep)	
Schistosomiasis - new	79	81	109	102
Diarrhoea non-bloody under 5 years - new	1,076	894	2,458	1,746
Eye infection - new	2,845	4,487	3,472	3,983
Dysentery - new	587	1,187	731	915

Note: * the average of the column for 2204, 2015 and 1,333 Times the column for 2016

Source: Chikwawa Health Management Information System, received 2 November 2016

Patients treated at the hospital receive medications free of charge (when available), so the reduced medical cost is only an economic benefit. Yet, these benefits are quite small compared to the investment of the SVIP and have therefore not been included. Nevertheless, there is no doubt that a new water supply system with sufficient pressure providing water of a quality that meets WHO standards for drinking water, would have a significant contribution to the population of Boma.

Thus the quantifiable benefits amount to only US$30,000 per year. At this level and with the annual maintenance cost assumed at 1.5 % of the capital, the investment in this water supply system has a

[5] It may be expected that because of sufficient pressure coming from a 25 m high water tower, the waiting time at the water points would be reduced much more than by 50 % (assuming that there will be sufficient electricity to keep the tank filled).

negative NPV of US$589,000. However, the social benefits and second order benefits (long-term of increased time available for girls' education) however would be much bigger in quantitative terms.

UNICEF Malawi's web site states (http://www.unicef.org/malawi/wes_3975.html, accessed 13 October 2016): *"Ensuring that children and women have access to safe water and appropriate sanitation and that they learn healthy hygiene practices is a big determinant of children survival and development. With water -borne diseases being among the major causes of death in young children in Malawi, providing safe water and improved sanitation takes on urgent dimensions." (.....) "The water and sanitation sector has been prioritized in the Malawi Growth and Development Strategy."*

	Financial	Economic
Annual Benefit		
(increases with population) :	USD30,000	USD30,000

16.4.9. Livestock

Without project

In the project area, 22 % of the household are holding at least 1 goat, 18% at least 1 chicken, 10 % at least 1 cow, 7 % at least 1 pig, 4 % ox/bulls and 8 % poultry (GOM, 2016-3,p.70).Meat is the main livestock product in two-third of the households. About three quarters of the households consume all the meat, mutton and eggs. Only about one third of the households sell livestock regularly, mainly when in need of cash. Only 2% of the households sell animals regularly for investment reasons (GoM, 2016-3, p.15).

[Table 16.4-20] Assumed Revenues from Livestock, without the Project

Livestock	Assumed weight (kg)*	Gross revenue (US$/ animal) – producer prices	Assumed average nr of animal sold or consumed per household per year	Revenue by all households (US$)	
				Phase 1	Phase 2
Goats	17.5	47	0.33	325,7	424,974
Cattle	315	693**	0.07***	1,018,710	1,329,174
Total				1,344,420	1,754,148

Notes: * Assumed 70 % of the weight in well managed farms)

** The weight valued at a price of US$ 2.2/kg

*** 10 % of hh (with an assumed average of 2 animals / hh) and 33 % selling

Source: Goats: AssaM.Magang et al (2015); Cattle: PWC's spreadsheets; nr per hh: assumed from GoM 2016 – 3, p

The organization of the irrigation system requires that the households will have to forego the benefit of these free roaming livestock practices, the total of which is considerable as a result of the large number of households in the project area. Since chicken usually roam around the homestead, it is assumed that the related benefits will continue with the project and they are therefore not included in this analysis.

Loss of benefits of free roaming livestock
Phase 1: US$1,344,420 per year
Phase 2: US$1,754,148 per year

The effects of extreme climate conditions are multi-dimensional and generally tend to adversely impact on the livestock sector. Droughts result in a reduction in the availability of water and grass in the grazing areas as well as in crop residues from the cropping areas(p.34).

With project

This agricultural sub-sector could benefit well from the introduction of irrigation in the project area.

The expansion of the irrigated crops will limit the free roaming of the cattle. This could be counterbalanced by developing irrigated pastures to boost the carrying capacity of the remaining grazing areas (para 6.2, p.150).

Smallholder livestock farmers in Chikwawa and Nsanje are already organized and have established Livestock Associations. Nevertheless, they reported lack of training for both the association as well as its members. It is recommended therefore that these livestock farmers should also be trained, by the improved agricultural extension services that are part of the Transformation Strategy.

Cost of pastures are assumed to be covered by the SVIP that will hand over to the cooperatives and/or individual farmers the required irrigation canals and leveled land that could be ready for grass sowing.

The grass cultivation can be supplemented by cattle pen-fattening is an intensive system of producing quality beef and can be operated as a stand-alone lucrative business (GoM, 2016 -1). Cattle pen-fattening involves the feeding of beef cattle with a protein balanced, high-energy diet for a period of 90 days under confinement to increase live weights and improve the degree of finish and thus (p.155).

PWC, as part of the preparation of the AgDPS (GoM, 2016-2), provided a spreadsheet model on a farm that starts with 100 adult cows and 80 calves and that grows to a total herd of 521 cattle in 10 years, in which year it would sell 85 cattle.

The following amendments were made to this model:

[Table 16.4-21] Amendments made to PWC's Model of Cattle Farm

	PWC	This analysis	Explanation
Cost of adult cows	Not mentioned	US$ 990	Equivalent to the returns of a cow culled (according to PWC)
Cost of calves	Not mentioned	US$ 330	1/3 of the cost of an adult cow
Labor input	7 days per year for Y1 - 10	Starting with 5 * 365 days in year 1 to 10 * 365 days in year 10	Y1: 180 cattle Y10: 521 cattle
Cost of stables and troughs etc.	Not mentioned	US$100,000	
Development after 10 years	PWC' spreadsheet stops with Year 10	Y11 – Y30 assumed to have the same cost and returns as Year 10	

With these amendments, investment in such a cattle farm has an FIRR of 15% and an EIRR of 16 % (Financial and Economic Benefit Cost ratios of 1.98 and 2.17). Increasing the culling rate from 15 to 20 % of the adult cows every year would have the benefit that it stabilizes the size of the herd around

455, but would not increase the economic feasibility, since it would reduce the sales of excess heifers and (3 years old) steers. Details are presented in Appendix B2.

Given the size of the herds (521 cattle in Year 10, of which 83 are sold), it has been assumed that each of the cooperatives will invest in one (1) of such a cattle farm.

Annual Net Benefits from Livestock (cattle)		
	Financial	Economic
Phase 1 (5 cattle farms):	US$315,701	US$327,958
Phase 2 (7 farms):	US$441,981	US$459,141

Apparently, under these assumptions, these cattle farms do not entirely compensate the loss of benefits that the inhabitants of the project area are currently having from the free – roaming livestock.

16.4.10.Aquaculture

GoM, 2016 – 1 reports on the substantial investment in aquaculture that have taken place since independence (p. 37). Currently about 10,000 fish ponds exist in the country as a whole and the ponds are owned by a total of 6,000 smallholder farmers.

The AgDPS recommends to revitalize the Kasinthula Fish Farm, to supply fingerlings and have a marketing role. Yet, the experience with Phata Outgrowers Association shows that such a revitalized institution is not a necessary requirement for successful fish farming.

For an individual cooperative, a fish farm would provide additional protein rich food for its members in addition to a steady source of cash income, that would contribute to a positive balance that translate to increased dividend paid to the members. According to GoM (2016-1, p 172 – 173) a gross margin of USD 1,356 per hectare would be quite feasible, while deep pond technology with sex reversed male, the gross margin could increase up to USD4,500 per hectare.

On the other hand, the data presented in the AgDPS (p.174) would indicate a gross margin of some USD 13,000 per hectare year (given two harvest with 7,000 kg each time per ha). Yet, one hectare of fish ponds is likely to comprise of ten ponds of 1,000 m^2, each of which is surrounded by the same amount of land for access path, net drying areas and greens. It is assumed that each of the 5 cooperatives will allocate 6 ha of land to aquaculture, with a net area of 3 ha of water surface.

However, the AgDPS data do not include any cost for maintenance of the ponds. This report assumes that this amounts to 10% of investment cost per year.

It is therefore assumed that the investment amounts $20,000, and during the first year (the year of establishing the fish pond) one production cycle will be implemented. In subsequent years two cycles will be implemented every year (see Appendix B3).

Annual Net Benefits from aquaculture in Phase 1 (5 coops):	
Financial prices:	US$161,470
Economic prices:	US$195,737

16.4.11.Enhanced Flood Protection

The initially envisaged drainage canals of SVIP prevent the 1:5 years flooding in an area of 867 ha. Thus without the irrigations scheme, the farmers would lose an amount of USD158/ha or USD460/ha every five years at financial and economic prices respectively. The total amount of USD146,324 and USD426,054 are considered the financial and economic benefits of the irrigation project.

Additionally, the project envisages additional works to protect from 1:10 years floods through a dyke (see p. 89). In the area protected, 110 ha are planted with sugar cane and 93 ha with miscellaneous crops. In these areas, the dyke prevents loss of irrigated land with a much higher income per ha than the land where the 1: 5 floods are prevented (see table 16.4-22).

The cost of the additional 30 km long dyke amounts to USD936,000 in financial terms and USD767,779 in economic prices.

The financial IRR of investing in this additional dyke is 4 % while in economic prices it is 7 % (see Appendix D.1). Consequently one may conclude that it makes economically sense to construct a dyke to protect the area that is prone to 1:10 years flooding, as a result of which it could be included in the SVI scheme.

The total benefits of the additional flood protection works amount to USD505,142 and USD569,238 in financial and economic prices respectively, based on loss marginal benefits (i.e. benefits from crops without the overhead and maintenance considered). Given the occurrence of a major flood in 2015, it is assumed that the next one would occur in 2025, or in Year 8 of the project, and thereafter every 10 years.

Annual Net Benefits from flood protection in Phase 1:

1: 5 years (by irrigation scheme): USD114,082 and 52,377in finc. and econ. prices respectively

1: 10 years (additional dyke): USD505,142 and USD569,238 in finc. and econ. prices respectively

[Table 16.4-22] Benefits from SVIP's Flood Protection

	Total Area (ha)	Area Flooded (ha)			Rainfed Returns (USD/ha)		Loss prevented by irrigation scheme (USD)		Main Crop	Irrigated Returns (USD/ha)		Loss prevented by 1:10 years protection* (USD)	
		1:5	1:10	Increment	Finc	Econ	Finc	Econ		Finc	Econ	Finc	Econ
I-1	2,062	59	196	137	123	57	7,269	3,337					
Of which I-1-b	382	59	86	27	123	57	7,269	3,337	Misc.	2,283	2,752	54,947	59,498
I010c	1680	0	110**	110					Sugar cane	2,747	3,025	302,157	321,798
A-c + A-c	5,199	808	873	65	123	57	99,545	45,703	Misc.	2,283	2,752	132,279	143,235
Total	7,261	867	1,069	202			114,082	52,377				489,384	524,530

Notes: * assumed to start in Year 8 of the project (5 years after completion of Phase 1)

** it is expected that the entire area will be planted by Sugarcane

16.4.12.Paid Employment Generated

The farmers will be working on the plot of 0.2 ha allocated to them for their home consumption, using their family labor. On the remainder the cooperatives will be growing cash crops, be it only sugarcane (in the case of KAMA), or a combination of cotton and the food crops that the farmers are growing as well. For these activities the cooperatives will be recruiting laborers for the daily farm activities, for which the worker will receive a normal salary of USD1.34 per day (approximately MK1,000). These workers will be the farmers who are a member of the cooperative.

Over the total of 5,827 ha of newly irrigated land that the cooperatives in Phase 1 will be working on (see table 16.5-1), between 3,100 and 3,400 permanent full time equivalent jobs will be created, and for Phase 2 there will be 9,400 and 10,200 permanent full time equivalents jobs available during the first year and starting Year 6 respectively (see table 16.4.-23A.).

For KAMA the annual amount of wages earned by the farmers will be US$300,477. For Phase 2, where no new land will be planted with sugar cane, salaries up to the amount and will be generated for the first five years and staring from year 6 onwards respectively.

It has been assumed that the farmers who are currently growing crops in the project area are subsistence farmers, who do not receive a salary. As a result the income generated by working for the cooperatives will all be considered incremental.

A second activity that generates employment and income is the construction of the infrastructure, the total cost of which is known from the Feasibilities Studies cost estimate. Assuming that the cost without VAT will be divided by the workers and the contractors on a 60 : 40 basis (after deduction of VAT paid; 60 % for wages and 40 % for the contractors' overhead and profits). The resulting sum of wages for unskilled and skilled labor were converted into full time equivalents with an average wage rate of USD 4.5 per day for skilled and USD1.48 per day for unskilled construction workers and 220 working days per year.

Thirdly, staff will be recruited for the Water Service Providers and Cooperatives. The cost is known from the Appendices on the WSP and the Coops. FTE's generated by cooperatives were calculated under the assumption of an average salary of US$750/month.person (against US$900 per month on the average for the SWP. Estimates are presented in Table 16.4-23.

[Table 16.4-23] Paid Employment Generated by SVIP (In days, full time job equivalents* and USD)

Part A: Agriculture

	Phase 1		Phase 2	
	Y1 - 5	Y6 and Onwards	Y1 - 5	Y6 and Onwards
Non sugar cane crops (days)	682,909	753,484	2,059,921	2,242,006
Full time job equivalents*	3,104	3,425	9,363	10,191
KAMA (days)	223,689	233,689	-	-
Full time job equivalents*	1,017	1,017	-	-
Total employment created (days)			2,059,921	2,242,006
Full time job equivalents*	4,121	4,442	9,363	10,191
Daily wage	USD 1.34	USD 1.34	USD 1.34	USD 1.34
Total cash income(USD/year)	1,217,817	1,312,620	2,767,058	3,011,649

Part B: Salaries Generated in Construction

Cost of Labour	Unskilled	Skilled	Total	per Year
Phase 1				
Full time job equivalents*	4,198	984	5,182	Of 3.5 years duration on the average
Salaries	4,100,138	2,923,462	7,023,600	
Phase 2				

Full time job equivalents*	4,337	1,980	6,317	Of 3.5 years duration on the average
Salaries	4,236,6355	5,879,204	10,115,838	
Total				
Full time job equivalents*	8,535	,2964	11,499	Of 3.5 years duration on the average
Salaries	8,336,773	8,802,665	17,139,438	

Part C: Staff of the Water Service Provider and Coops

Phase 1			
Service Water Provide	Full time job equivalents*	71	
	Salaries	700,160	per year
Cooperatives	Full time job equivalents (FTEs)*	67	per year
	Salaries	600,000	per year
Phase 2			
Service Water Provider	Full time job equivalents*	71	per year
	Salaries	700,160	per year
Cooperatives	Full time job equivalents*	172	per year
	Salaries	1,548,000	per year
TOTAL	Full time job equivalents*	243	per year
	Salaries	2,248,160	per year

Note: * Only the new cooperatives whose lands are not irrigated without the SVIP (2 in Phase 1 and 5 in Phase 2 areas)

Total benefits from paid employment:
Agricultural : Phase 1 :1.3 million /year (Year 6 and onwards))
Phase 2 : 3.0 million /year (Year 6 and onwards
Construction Phase 1: 2.0 million /year (3.5 years)
Phase 2: 2.9 million /year (3.5 years)
WSP and Coops (40 years)
Phase 1: 1.3 million /year
Phase 2: 2.2 million/year

16.4.13.Multiplier

Investment in Agriculture is known to have a positive impact on the economy as a whole. Farmers' spending induce further economic growth. The strength of this multiplier effect varies by country and circumstances, including the extent to which food is being traded and the proportion of income spend on food and on imported commodities. The PAD project in Tanzania reports that *"for each shilling earned in the sugar sub-sector, an additional 3.2 shills are generated by other businesses"*(World Bank, Appendix 10, p.12).

USAID (2014) compared 15 different studies on the multiplier in Sub-Sahara Africa and concludes that most of them estimate the value of the agricultural multiplier around 1.5. "*That is, a $1 increase in agricultural income brought on, say, by an investment or technological change can raise national (or in some studies, non-farm rural) income by $1.50*" (USAID, 2014, p.1). In other words, income generated by the VSIP will result in an additional income of 50 % of the initial amount for other people.

The entire impact of the multiplier is however difficult to predict. It is obvious that the cash income generated and discussed in the previous section will have a secondary impact resulting from onward expenditure. The agricultural income generated by the cooperative may also have a similar impact, but the extent to which this occurs depends very much on how much money is transferred to the cooperative in dividends (the salaries paid by the cooperatives is already covered “paid employment”). Moreover, without detailed expenditure studies it will be difficult to tell how big such a multiplier effect will be.

16.4.14.Externalities

In addition to the benefits quantified in the previous sections, there are a number of other developments that will be positive for the project. The increase in quantity and reliability of water in the area is expected to create an environment that is conducive to additional investments. Firstly this pertains to the processing industries (other than sugar cane processing which is already in place). Malawi Mangoes has already shown interest in contract farming to acquire good quality fruits for its processing.

It is also expected that the canals in the Shire Valley will have a positive impact on wild life. The scheme’s technical design includes some drinking troughs for animals of the Lengwe National Park. Currently the streams are dry after the rains stop, and the inclusion of PVC outlets from the canal will provide a small but almost constant flow of water from which many animals are expected to benefit. The cost of these PVC piles are below USD1,000.

Additionally, as suggested by the PTT, it is recommended to make tree planting (and maintaining) at construction camps a compulsory activity, which may lead to additional vegetation after completion of the canals. Together with the drinking troughs that are part of the designs of the SVI scheme, such vegetation is likely to attract more animals and may thus contribute to increased tourism.

Moreover, as was observed by some villagers during the consultation meetings, improved employment opportunities and additional income generated by the irrigation scheme is likely to reduce the poor people’s incentive to poach.

16.5. Main Stakeholders

16.5.1. Cooperatives

The Cooperatives are at the core of this analysis as they provide the key to the transition from fragmented and often manual subsistence farming to mechanized commercial farming. It provides the economies of scale that is necessary for this transition.

This analysis assumed a standard size of 3,190ha land that will be cultivated with cropping pattern 1 or 2 (see section 16.5.2.2).As discussed in section 16.3.6.2 the investment cost that each cooperative will have to make amounts to USD2,097,00 and the annual operating and maintenance cost to USD544,100 (excl. replacement cost of the equipment and maintenance of its irrigation system).

All of the land that the households contribute to the cooperatives as share holders (both KAMA and the Non-cane Cooperatives) will benefit from the irrigation system of the SVIP. Most of it will be cultivated commercially in a mechanized manner, by the cooperative under professional management.

It has been assumed that these households will each receive 0.2 ha that they will cultivate with the four food crops: soya beans, pigeon peas, maize and beans. This area is 2/3 of what they are had planted in the 2015 – 2016 season in the Phase 1 area, and will be cultivated with the same cropping techniques as the cooperative applies on the remainder of the plots, which will allow for a cropping intensity on the farmers' grown plot of 200 % The cooperatives will be growing fruit and commercial crops: cotton and the food crops for the Non- Cane cooperatives and the sugarcane for KAMA.

[Table 16.5-1]Distribution of Area between Cooperatives and Households for Phase 1 and Phase 2

	Nr of households	Total area	Used for food production by individual households (ha)	For agricultural production by cooperative (ha)
Phase 1				
KAMA*	5,834	2,925	1,169	1,756
Coop 4	6,771	3,390	1,354	2,035
Coop 5	6,771	3,390	1,354	2,035
Total Phase 1	19,384	9,705	3,877	5,827
Phase 2				
Each of the 5.16 non-cane coops	4,750	3390	950	2440
Total Phase 2	24,509	17,507	4,902	12,605

Note: * computed from COWI's information under the assumption that the population density in the KAMA area is the same as in Cooperative 4 and 5.

The benefits of the cooperatives will thus be based on the acreage in the fifth column in Table 16.5-1 while the cost pertain to the entire area (see section 16.3.6.2). It is furthermore assumed that the households will only grow the food crops Soya, Pigeons Peas and Maize. The tree crops and cotton are grown with considerable economies of scale by the cooperative, so the households will not grow these crops on any significant level (apart from a few fruit trees near the homestead).

In line with the AgDPS (section 6.1.2.1), it is assumed that the individual households will grow soya beans and pigeon peas in the summer and maize and beans in the winter season. Consequently the acreage grown with the field crops by each of the cooperatives is as follows:

[Table 16.5-2]Area Cultivated by Cooperatives and Households and by Crop for Phase 1

Crop	Total area per coop		Grown by Cooperative		Individual household
	Y1-5	>Y6	Y1-5	>Y6	
Cotton	1,129	1,061	1,129	1,061	0
Soya beans	1,129	1,061	452	384	677
Pigeon Peas	1,129	1,061	452	384	677
Maize	1,695	1,593	1,018	916	677
Beans	1,695	1,593	1,018	916	677
Bananas		68		68	0
Mangoes		68		68	0
Citrus		68		68	0
Total		6,573	4,067	3,862	2,708
Crop Intensity*			200%	190%	200%

KAMA has been established with the purpose of growing sugarcane. The total area available will be 2,925, which will be utilized as follows by the cooperative and the 5,843 households in the area.

[Table 16.5-3]KAMA Area Cultivated by Cooperatives and Households and by Crop

	Area Grown by households	Area grown by Cooperatives
Total	1,169	1,756
Sugarcane	0	1,756
Soya	584	0
Pigeon peas	584	0
Maize	584	0
Beans	584	0

The cost of the inputs for crops is included in the GM calculations and, even though they will be managed by the cooperatives, and do not need to appear in a cash flow analysis as separate items.

In addition to these crops, the Cooperatives are also engaged in livestock (see section16.4.9) and aquaculture (see section 16.4.10).

Since the land that is the main resource of the cooperative as a legal entity is acquired free of charge, the financial and economic feasibility of these organization is beyond any doubt even if (i) the benefits of the households farming are not included in the cooperative's and (ii) the cooperative will be financially responsible for the maintenance cost of the entire on-farm irrigation system, including the canals that provide water to the households' plots. This conclusion applies to both the cooperatives without sugar-cane and KAMA.

It has further been assumed that each cooperative will receive a credit for 100% of the initial investment cost and 50 % for its overhead for their first year of operations. This loan will be repaid in 5 years with a one year grace period (during which the interest of 12.22 % per annum has to be paid).

The cooperative will have to pay 20.2 % tax on its profit (the net benefits minus interest payments). Moreover, every year it will retain 20% of its "profit after taxes" as a reservation for unexpected circumstances. The remainder will be paid to the member households as dividends.

Table 16.5-4 indicates that the both the Cooperatives that won't grow sugarcane as well as KAMA are very profitable, also when the production of the households are excluded from the coops' benefits and even when financing cost and profit taxes are deducted.

[Table 16.5-4] Benefit – Cost Ratios of Standard Cooperative of 3,190 ha and KAMA

A. Non-sugarcane cooperatives (cropping pattern 1)

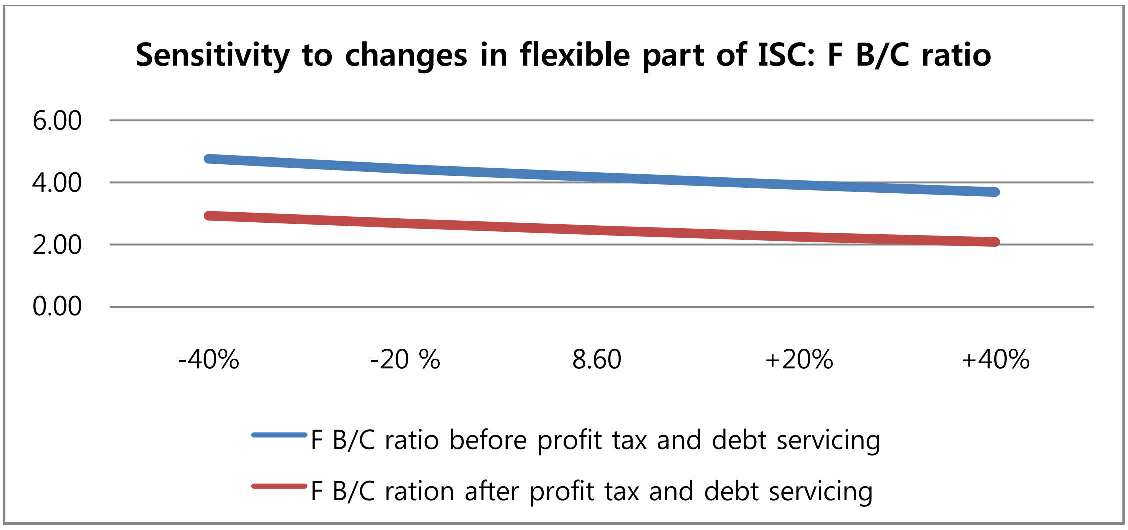
	Financial		Economic	
	B/C ratio	IRR	B/C ratio	IRR
Entire cooperative Without financing and taxes considered	4.16	127%	4.78	183 %
With financing cost and profit taxes deducted	2.45	99%		
Cooperative's farming only* Without financing cost and taxes	3.6	88%	3.82	121 %
With financing cost and profit taxes deducted	1.9	66%		

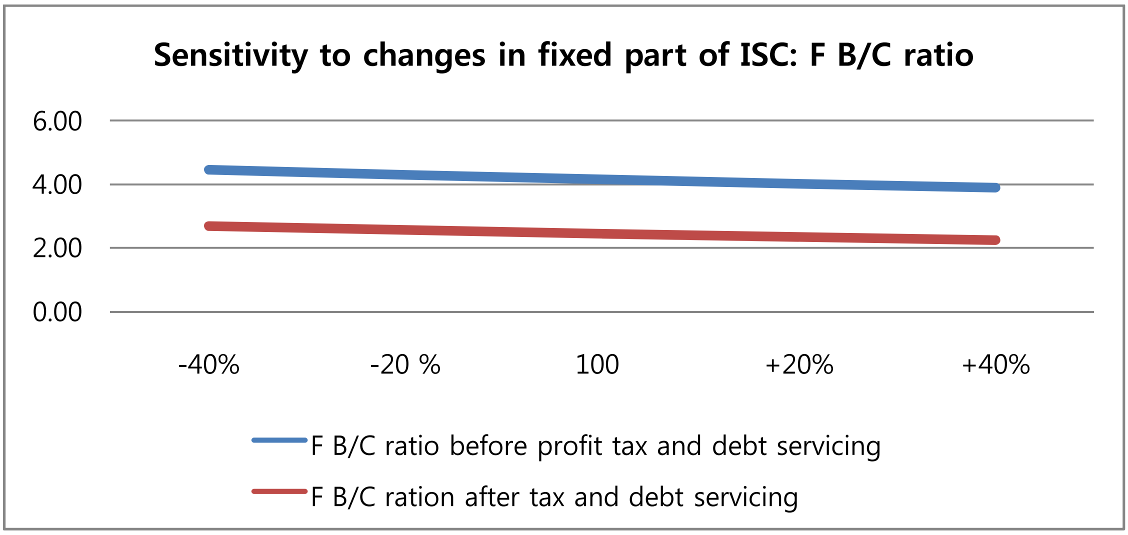
B. KAMA

	Financial		Economic	
	B/C ratio	IRR	B/C ratio	IRR
Entire cooperative Without financing and taxes considered	3.11	45%	4.20	80 %
With financing cost and profit taxes deducted	2.10	29%		
Cooperative's farming only* Without financing and taxes considered	2.34	32%	3.17	58%
With financing cost and Profit taxes deducted	1.36	18%		

Note: * Computed with the area cultivated by the households set to zero (0) and the water consumption reduced accordingly. The B/C ratios were computed as PV (Net profit)/PV(investment + maintenance + overhead cost); the IRRs were computed over the net cash flow (after deduction of all cost, incl. financing cost and taxes)..

The following figures show that this profitability is little sensitive to changes in the flexible and fixed parts of the Irrigation Service Fee.





16.5.2. Individual Households

The average landholding per household for the current non- cane area amounts to 0.5 ha for Phase 1 and 0.71 ha for Phase 2 (see Table 16.5-5). The average for Phase 1 includes the area planned for KAMA, which will not be under irrigation before the SVIP starts but excludes the area planned for Phata 2, which will be under irrigation before construction of the SVIP will commence.

[Table 16.5-5] Nr of Households in Phase 1 and Phase 2

Phase			Irrigated area (in ha)			Nr of hh	Nr of ha /hh
			Existing	New	Total		
Phase 1	Coop 1	Kasinthula	1,429	0	1,429	838	1.71
	Coop 2	Phata 1	296		696	378	1.84
		Phata 2	400			400	1.00
	Coop 3	Kama	0	2,925	2,925	19,384	0.50
	Coop 4	New		3,390	3,390		
	Coop 5	New		3,390	3,390		
	Total		2,125	9,705	11,829	21,000	0.56
Phase 2	Coop 1	Alumenda	2,764		2,764	654	4.23
	Coop 2	Kaombes	819		819	550	1.49
	Coop 3	3		3,501	3,501	24,509	0.71
	Coop 4	4		3,501	3,501		
	Coop 5	5		3,501	3,501		
	Coop 6	6		3,501	3,501		
	Coop 7	7		3,501	3,501		
	Total			17,507	21,090	25,713	0.82

Source: areas from other parts of this KRC report; Nr of households from COWI, February 2017

Areas cultivated with the main summer crops amount to 0.21 and 0.60 ha per household on the average for Phase 1 and Phase 2 respectively. In addition to the income from crops, the farmers have income from livestock that is mostly free range

The individual farmer outside the sugar estates has the choice between continuing to grow his rain fed crops(in one the summer season only)supplemented with some livestock or contributing his land to a cooperative that will manage the combined area to grow cash crops and food crops. Those who will join the cooperative will also benefit from the irrigation system on the plot that they will receive for their own food production, which is assumed to be 0.2 ha per hh in this analysis.

During the time that these households will not be working on their own small plots, they will provide labor to the cooperative for which they will be paid the usual wage rate for agricultural labor of US$1.34 per day. In the financial analysis of the "with project situation" this wage rate has also been included as an opportunity cost of cultivating their own plot. In the economic analysis, these market wages were replaced by the Shadow Wage Rate (see Section 16.2.23).

Table 16.5-6 shows that the individual households benefit considerably from joining the cooperatives, being the two coops that will not get engaged in sugarcane cultivation or KAMA.

[Table 16.5-6] Incremental Net Financial Benefits per Household

A. Phase 1area, Non- sugarcane crops

		Without Project (0.3 ha/hh cultivated)	With Project (40 years average) (0.2 ha/hh)	Increment
Crop Income		33	210	177
Livestock	Cattle	49	0	-49
	Goats	16		- 16
Wages from Coop.			35	35
Dividends from Coop*		-	472	472
Total		97	697	595

Note: * After deduction of financing cost, taxes and 20% reservation.

B. Phase 1 area, KAMA

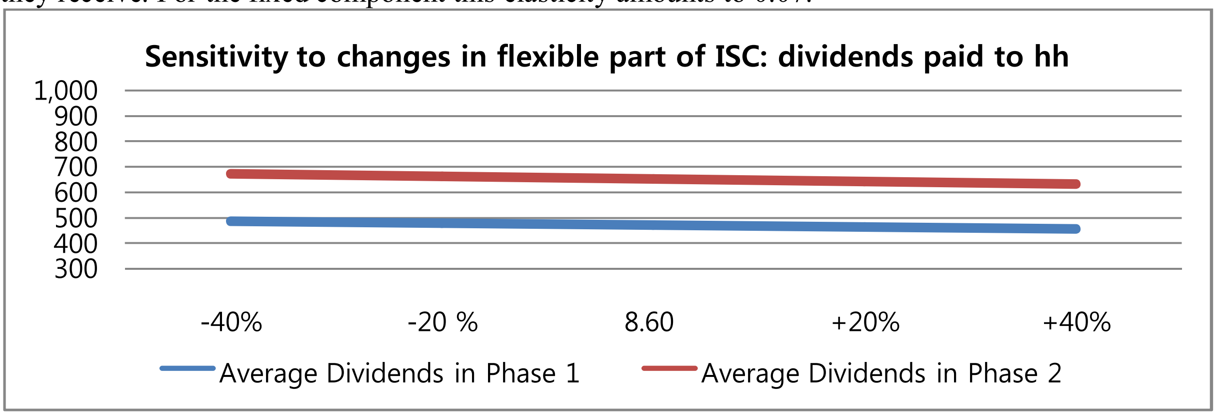
		Without Project (0.3 ha/hh)	With Project (40 years average) (0.2 ha/hh)	Increment
Crop Income		33	210	177
Livestock	Cattle	49	-	-49
	Goats	16		-16
Wages from Coop.		-	51	51
Dividends from Coop			351	351
Total		97	612	515

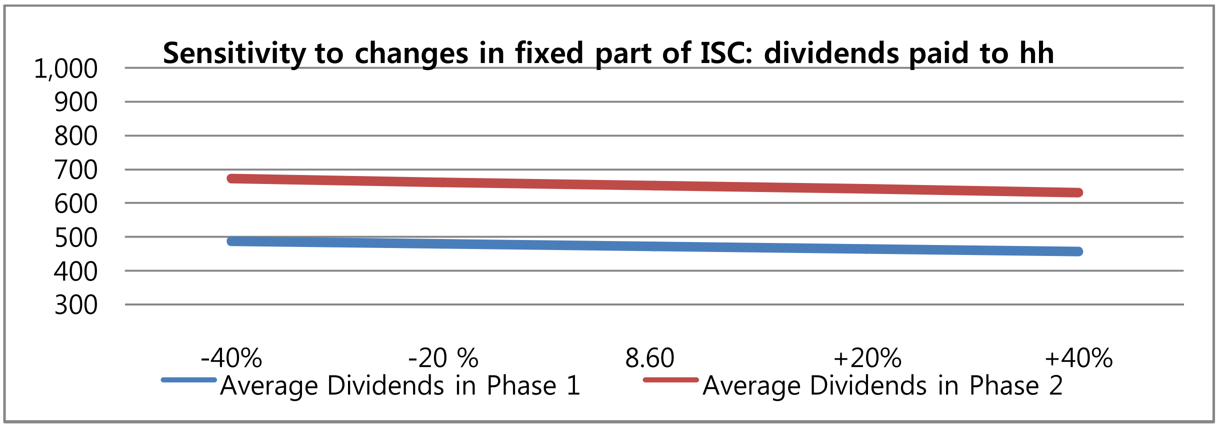
C. Phase 2 area, Non - sugarcane

		Without Project (0.6 ha /hh)	With Project (40 years average) (0.2 ha/hh)	Increment
Crop Income		80	210	127
Livestock	Cattle	49	-	-155
	Goats	16		
Wages from Coop.		-	51	51
Dividends from Coop		-	652	652
Total		144	908	760

From Table 16.5-6 one may conclude that the individual households are better off joining a cooperative with irrigated farming than staying outside an irrigated farm.

The following figures show that the households will be affected by changes in the Irrigation Service Charge. A 10 % change in the flexible component leads to approx. 1.5 % changes in the dividends they receive. For the fixed component this elasticity amounts to 0.07.





16.5.3. Water Service Provider

The Water Service Provider (WSP) is the organization that will be responsible for operating the infrastructure once it is completed. On the basis of an analysis of the risk of water infrastructure development and water distribution, the PPP Feasibility Study (see GoM, 2016-3) recommends a Private – Public Partnership either through a concession (Build- Operate and Transfer) or a Design – Build and Operate modality. However it also identifies a management contract between Government and a private company as a "fallback option" "in case none of these two options would be implemented" (GoM, 2016-3, p.1). In all cases the Service Provider6 would deliver bulk water to big commercial farms: the main sugarcane estates and the cooperatives in the project area.

Its tasks entail the operating and maintaining the common structures from the intake up to and including the meters. After the meters, the maintenance will be the responsibility of the co-operatives who will comprise of the relevant water user associations with competent staff.

Based on the cost estimates in this (KRC) Feasibility Study, the PPP study calculated the so-called 'true cost" apportioned to the different parts of the irrigation scheme, and used these to compute water charges comprising of a fixed and a variable part for three groups of consumer: (i) Illovo, (ii) Phata, Kasinthula and Sande and (iii) New land area (i.e. not previously irrigated). The fixed cost is to cover at least the financial cost of the private partner and the variable cost is to recover (at least) the O&M cost (annually recurring and replacement) as well as the fees to be paid to the National Water Authority. These true costs would point to uniform variable cost and fixed cost that are twice as high for the newly irrigated land than for Illovo (ibid. p.14).

However, in order to comply with the social approach of the SVIP and the include considerations of capacity to pay, it proposed the following system of Irrigation Service Charges (ISC):

[Table 16.5-7] Irrigation Service Charges Proposed by PPP, Study

	Variable (US$/Ml)	Fixed (US/ha)
Illovo	8.6	200
Phata, Kasinthula and Sande Ranch	8.6	100
Newly irrigated areas	8.6	100

Source: GoM (2016 – 2), p. 15

[6]The final version of the PPP study calls it "Scheme Management Entity". This report prefers the term used in draft version of the PPP studies: Water Service Provider.

With these ISC, the SVI scheme would comply with the criteria for a feasible private sector partnership of 20 %. From discussions with companies that have experience in similar partnerships in France, Spain and Morocco the study concludes that there is indeed an interest in a concession for the development of the infrastructure and the delivery of bulk water (ibid p.28).

Additionally, the PPP study also distinguishes charging water to the Southern Region Water Board according to a progressive tariff[7].

16.5.4. Government of Malawi (GoM)

The main impact on the Government will be the Value Added Tax it will receive over construction services and materials and the additional goods produced as a result of the improved water management. Additionally, the GoM is likely to benefit from profit taxes levied over the profit of the Cooperatives.

The total value of taxation on construction materials and services amount to:

[Table 16.5-8] Revenues from Construction Services and Materials (during Construction Periods)

	VAT over local materials
Phase 1	28,301,040
Phase 2	40,827,600
Total	69,128,640

Source: Table 16.3-9 and 16.3-10

Given Malawi's policy of tax exempted construction materials that are imported for development purposes, no import duties may be expected from these materials.

Sugar cane

As for the VAT on incremental sugar production, the following computations have been made:

[Table 16.5-9] VAT Received from Increased Sugar Production in US$ per Year

		Phase 1	Phase 2
New Sugarcane areas (Kama; tons of cane)		315,482	-
Existing plantations (tons of cane)*		135,620	38,645
Total incremental cane production		451,102	38,645
Incremental sugar production (tons)**		56,704	4,858
Sugar retail price	650		
of which VAT (Mk/kg)	92.1		
Total incremental VAT million MK		5,220.19	447.21

7 Unfortunately GoM, 2016-3, p.15 does not show the correct rates.

	Phase 1	Phase 2
in million US$	6.96	0.60

Notes: * Assumed 10% increase resulting more reliable water supply (see Section 16.4.4)

Source: ** From 2012 – 2016, Illovo produced 126 kg of sugar out of every ton of cane it processed (computed from Illovo, 2016, p.15)

*** Business Malawi, 4 December 2015

Assuming that all production for the domestic and export market will be sold through the formal sector, for fruit crops the VAT may be expected is computed as follows:

[Table 16.5-10] VAT Received from Increased Trade of Fruit Trees in US$ per Year

	Area (in ha)		Annual Prod Value per year US$/ha)	VAT	
	Phase 1	Phase 2		Phase 1	Phase 2
Bananas	136	350	4,948	110,685	285,848
Mangoes	136	350	7,140	259,719	412,479
Citrus	136	350	12,675	283,548	732,273
Total				553,952	1,430,600

Note: * average over 20 years period, based on farm gate prices

<u>Other field crops:</u>

It is likely that some 20 % of the other field crops will be used for home consumption and 10 % of the remainder will be sold through the informal market. As a result 72 % of the total production value will be subject to VAT.

[Table 16.5-11] VAT Received from Increased Trade of Other Agricultural Produce in US$ per Year

	Area		Annual Prod Value (US$/ha)*	VAT revenue (US$)	
	Phase 1	Phase 2		Phase 1	Phase 2
Other field crops				72%	of prod value
Cotton	2,122	5,480	3,134	790,130	2,040,538
Soya beans	2,122	5,480	823	207,415	535,656
Pigeon beans	2,122	5,480	1,866	470,316	1,214,606
Maize	3,186	8,228	1,194	451,955	1,167,189
Dry beans	3,186	8,228	2,612	988,651	2,553,226
Total field crops				2,908,467	7,511,216

Note: * after 4 – 5 years when the farmers have grown accustomed to irrigated farmer for the markets

It should be noted that the actual basis of VAT levying will be higher than these tables indicate, since the production values are based on farm gate prices, while the VAT will be levied on the basis on wholesale and retail prices.

[Table 16.5-12] Additional Profit Taxes Received from Cooperatives

	Annual Profit tax receipts (20.2 % on Gross returns minus interest payments)
Phase 1 – Non sugar coops (2 additional coops)	2,127,324
Phase 1 – KAMA	658,463
Phase 2 Non sugar coops (5.16 additional coops)	5,318,311
Total	8,104,098

[Table 16.5-13] Project Financing from VAT and Profit Taxes

	Phase 1	Phase 2	Phase 1 + Phase 2
VAT receipts (during construction, on construction materials and services) One time	28.31	40.83	69.14
Total annual VAT receipts from increased and traded agri. production	10.42	9.54	19.96
Total annual profit tax from Cooperatives	2.79	5.32	8.10
Total Annual revenue from taxes	13.21	14.86	28.06
Initial loan required (for total investment)	282.8	411.9	694.8
Accumulated interest during 10 years grace period	17.7	25.7	43.4
Total debt at end of grace period	300.5	437.7	738.2
Annual Debt Repayment*	9.6	14.0	23.6
Scheme's Operation cost (million US$ per year)	1.03	1.23	2.26
WSP	0.85	1.02	1.88
Cooperatives	0.17	0.21	0.38

Note: * Assumed a 40 years maturity and 1.25 % interest per year and a 5 years' grace period (during which interest will be added to the debt)

Table 16.5-13 shows that the incremental Government's revenue in the project area would be sufficient to repay a soft loan with a maturity of 40 years for Phase 1 area. This remains true as long as the interest is below 1.6 % per annum. Combined with the profit tax paid by the cooperatives, the additional Government revenues resulting from the project's output would be sufficient to repay the soft loan in both Phase 1 and Phase 2 areas.

A grace period of 5 years would be sufficient to cover the period of the learning curve related to the transition from subsistence rain-fed farming and would also reduce the country's total debt, even to the extent that the annual repayment for both Phase 1 and Phase 2 would be covered for some 97% by the incremental VAT receipts.

On the other hand the VAT revenues are not sufficient to pay for the scheme's O&M cost too. Yet, as has been shown in section16.5.2, the Irrigation Service Charge proposed by the PPP study would be sufficient to recover these O&M cost (and also make a contribution to recovery of the capital cost).

Moreover, this report did not quantify multiplier effects that are likely to materialize in Malawi's Southern region and possibly also in other parts of the country. Obviously more trade will lead to additional VAT revenues and additional income in the formal sector and thus revenues in income tax (which have not been quantified in this report either).

16.6. Economic Analyzes

This section first presents the results of the economic analysis of the Phase 1 and 2 together, assuming that construction of Phase 2 will commence after completion of Phase 1 in year 4. Both Phases are expected to take 3.5 years. In Phase 1, 6 contractors will be employed and in Phase 27 contractors. These results are summarized in Table 16.6-1.

Thereafter, Phase 1 will be presented, but with reduced cost for part of the intake, Main Canal 1 and Main Canal 2 that are also serving Phase 2.

16.6.1. Phase 1 and 2 together

[Table 16.6-1] Economic Analysis- Phase 1 and 2 Combined, Cropping Pattern 1 (In USD)

At water charge for cooperatives = USD6 and USD9 for sugar cane growers

Net command area		ha	43,000	
	Of which: - currently irrigated – sugarcane - new irrigation being constructed(Phata: 2017) - new irrigation area		15,749 400 27,251	
Cropped area with project (6 years after completion of the schemes)		ha		
	Sugar Cane (incl. KAMA)		18,674	
	In 7cooperatives for newly irrigated area			
	- Cotton		7,602	
	- Maize		11,414	
	- Dry Beans		11,414	
	- Soy Beans		7,602	
	- Pigeon Peas		7,602	
	- Fruits		1,458	
	Total cropped area/year	ha	68,691	
	Cropping intensity		1.58	
			Finc	Econ
Project Construction Costs		$	554,054,379	451,603,078
Total Project Investment			694,756,982	608,206,227
Construction cost / ha		$/ha	12,776	10,413
Investment cost / ha			16,020	14,024
	Internal Rate of Return (IRR)		7.3	8.9
	Net Present Value (NPV, at d = 6 %)		107,062,375	214,853,167
	Benefit Cost Ration (B/C ratio a d = 6 %)		1.15	1.34

O&M Costs Estimates:				
	Total annual O&M costs	USD	5,791,552	5,648,729
	O&M costs / ha	USD/ha	134	130
	Average incremental income /ha	USD/ha	1,343*	1,493*
	O&M costs as a % of the incremental income at farm level		9.9%	8.7%

Note: * with Phase 2 starting upon completion of Phase 1

The relatively high average incremental income/ha for Phase 1 and Phase 2 combined is due to the bigger newly irrigated area as a percentage of the total command area in Phase 2 than in Phase 1.

16.6.2. Phase 1 with Cost Reduction for Components Serving also Phase 2, Cropping Pattern 1

Since part of the Intake, Canal 1 and Canal 3 also serve Phase 2, the cost of these structures have been re-apportioned to Phase 2, proportional to the area served. This applies to the construction cost as well as the maintenance cost. The operation cost, on the other hand do not need to be shared since the WSP has been designed in such a way that it initially serves only Phase 1 and is more or less duplicated when phase 2 is completed. The operation cost of thee cooperatives is proportional to the number of coops in each of the two phases.

The results of the analysis presented in Table 16.6-2.It should be noted that the irrigation scheme is not only producing high benefits compared to its cost, but the O&M cost, even though quite high, are still affordable since it is less than 10 % of the incremental crop production benefits (including Illovo where the benefits in terms of agricultural production are modest).

[Table 16.6-2] Financial and Economic Analysis of Phase 1 with Reapportioned Cost for Components also Serving Phase 2, Cropping Pattern 1

At water charge for cooperatives = USD6 and USD9 for sugar cane growers

Net command area		ha	21,300	
	Of which: - currently irrigated – sugarcane - new irrigation being constructed(Phata: 2017) - new irrigation area		 12,174 400 9,704	
Cropped area with project (starting 6th year after completion of the scheme)		ha		
	Sugar Cane (incl. KAMA)		14,330	
	In 2 cooperatives + KAMA's households			
	- Cotton		2,122	
	- Maize		3,770	
	- Dry Beans		3,770	
	- Soy Beans		2,706	
	- Pigeon Peas		2,706	
	- Fruits		407	
	Total cropped area/year	ha	29,881	
	Cropping intensity		1.34	
			Finc.	Econ.

Project Construction Costs	$	177,816,724	143,056,796
Total Project Investment		233,756,671	204,005,974
Construction cost / ha	$/ha	7,982	6,421
Investment cost / ha		10,493	9,157
Internal Rate of Return (IRR)		9.3	10.8%
Net Present Value (NPV, at d = 6 %)		111,174,348	131,997,384
Benefit Cost Ration (B/C ratio a d = 6 %)		1.41	1.53
O&M Costs Estimates:			
Total annual O&M costs	USD	2,363,620	2,416,812
O&M costs / ha	USD/ha	106	108
Average incremental income /ha	USD/ha	1,081	1,195
O&M costs as a % of the incremental income at farm level		10%	9%

16.6.3. Phase 1 with Cost Reduction for Components Serving also Phase 2, Cropping Pattern 2

The second cropping pattern with fruit trees being planted upon completion of the irrigation scheme seems to be most beneficial, with an EIRR of 11.3 % (compared to an EIRR of 10.8 % for cropping pattern 1). The affordability of the scheme in terms of O&M cost has also slightly improved the good score for Cropping Pattern 1.

[Table 16.6-3] Financial and Economic Analysis of Phase 1 with Reduced Cost for Components also Serving Phase 2, Cropping Pattern 2

Net command area	ha	21,300	
Of which: - currently irrigated – sugarcane - new irrigation being constructed(Phata: 2016) - new irrigation area		12,174 400 9,704	
Cropped area with project (starting 1st year after completion of the scheme)	ha		
Sugar Cane (incl. KAMA)		14,330	
In 2 cooperatives + KAMA's households			
- Cotton		1,986	
- Maize		3,566	
- Dry Beans		3,566	
- Soy Beans		2,570	
- Pigeon Peas		2,570	
- Fruits		816	
Total cropped area/year	ha	29,403	
Cropping intensity		1.32	
		Finc	Econ.
Project Construction Costs	$	177,816,724	143,056,796
Total Project Investment		233,756,671	204,005,974
Construction cost / ha	$/ha	7,982	6,421

Investment cost / ha			10,493	9,157
	Internal Rate of Return (IRR)		9.8	11.3
	Net Present Value (NPV, at d = 6 %)		134,142,617	157,186,641
	Benefit Cost Ration (B/C ratio a d = 6 %)		1.49	1.63
O&M Costs Estimates:				
	Total annual O&M costs	USD	2,363,620	2,416,812
	O&M costs / ha	USD/ha	106	108
	Average incremental income /ha	USD/ha	1,127	1,326
	Share of O&M costs in the incremental income at farm level		9.4%	8.1

The small difference between Cropping Pattern 1 and 2 is due to the relatively high investments that need to be made during the first year of the fruit tree cultivation. In Cropping Pattern 1 those cost are discounted since the investment is made only six years after completion of the irrigation scheme, while in Cropping Pattern 2 they are to be made in the first year after completion of the construction.

16.6.4. Sensitivity Analysis

A cash flow analysis with part of the construction cost of Phase 1 reapportioned to Phase 2 is most justified as it prevents that Phase 1's cost would be incorrectly high. The second cropping pattern seems to be as realistic as the first one, especially since professional managers will be recruited by the cooperatives. Yet it presents a more profitable solution. For these reasons, the sensitivity analysis was conducted for the combination of the part of Phase 1 cost reapportioned and Cropping Pattern 2.

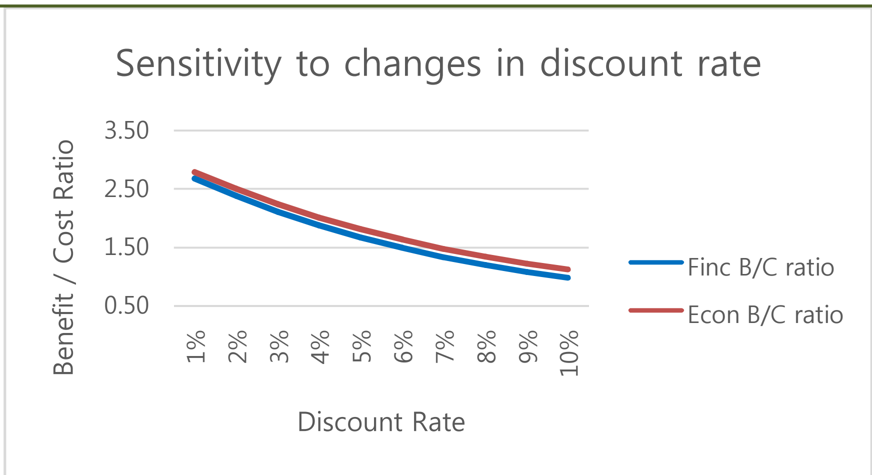
The following figures show that the IRRs and Benefit/ Cost ratios are most sensitive to changes in the construction cost. The robustness of the system may be explained by the large number of different benefits that VISP is expected to produce with none of them having a predominant impact on the outcome.

This report observed that the cost of the Transformation Strategy may be rather high. This observation was made in relation to the chances that most of the activities will be undertaken by experts instead of farmers. Lowering these costs by 25 % would increase the EIRR by 0.6 per cent (see Figure 16.6-7).

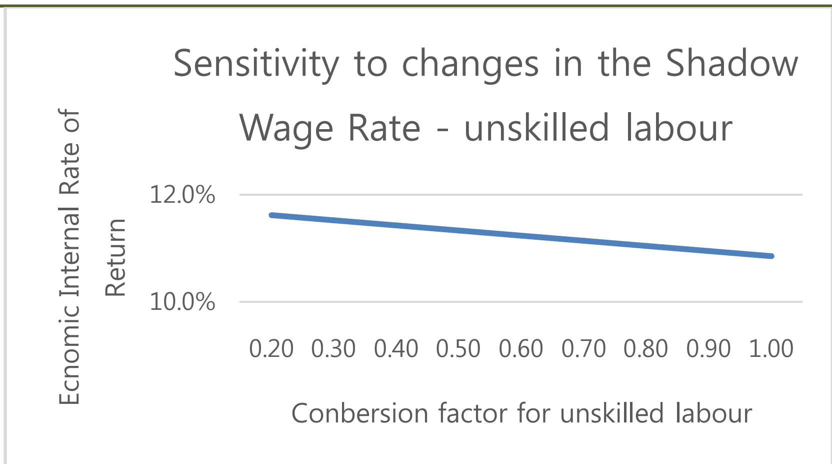
The financial and economic feasibility of the project is even less sensitive to a change in the cost of the compensation for resettlement and (temporary) loss of harvest. (see Figures 16.6-9 and 16.6-10)

This report mentioned that the estimates of the current production in the project area are rather uncertain. The best available data indicate that the farmers in Phase 1 area are currently producing US$123/ha in financial and US$81 in economic prices (with labor cost included in the latter). The available data also showed that only 41 % of the Phase 1 area was cultivated in 2015 -16. Apart from the observation that the low cropping intensity is plausible given the recent droughts, the sensitivity analysis in Figures 16.6-14 and 16.6-15indicate that even if the production value (thus the combined effect of land productivity (US$/ha) and area cultivated) would be 5 times as high as estimated in this report, the EIRR would only be reduced by 0.4 percent (from 12.1 to 11.7 %) and the E B/C ratio on from 1.51 to 1.42.

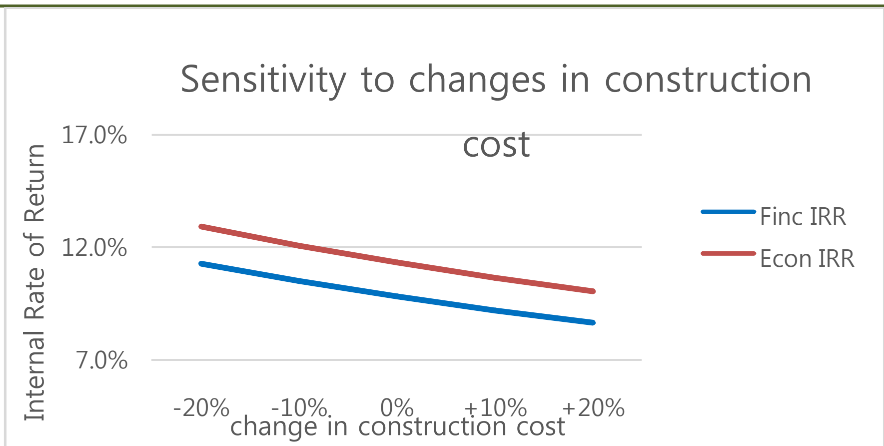
However, a word of cautions is warranted: the sensitivity analyses in this section consider different variables in isolation. A comparison of the draft version of this report with the current shows that a combination of higher transformation cost, higher compensation cost, the introduction of dual system of ISC (fixed and variable parts) may have a considerable impact on the EIRR, especially if it would be combined with a lower net production values.



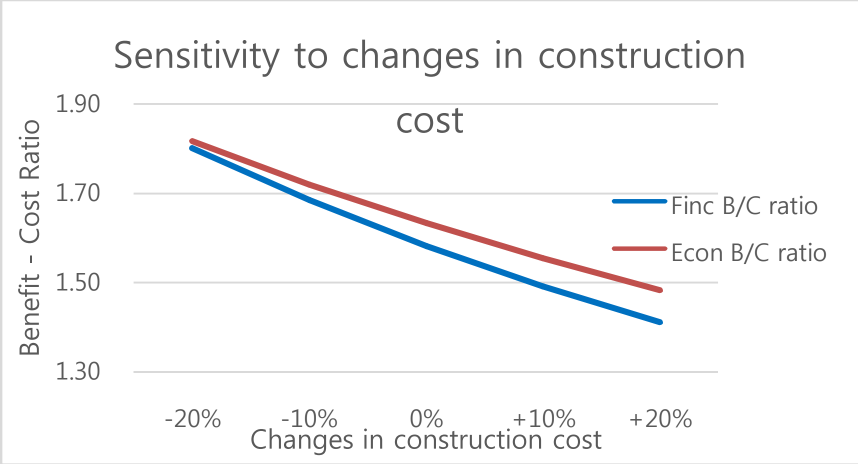
[Figure 16.6-1] Sensitivity to Changes in Discount Rate



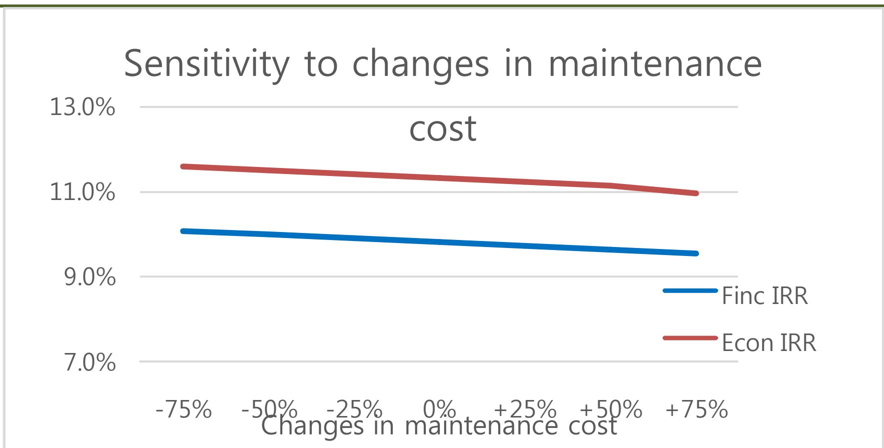
[Figure 16.6-2]Sensitivity to Changes in the Shadow Wage Rate - Unskilled Labour



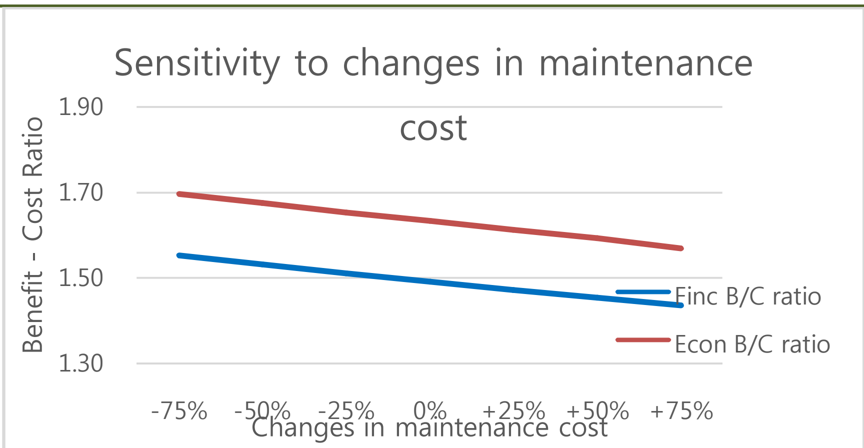
[Figure 16.6-3]Sensitivity to Changes in Construction Cost



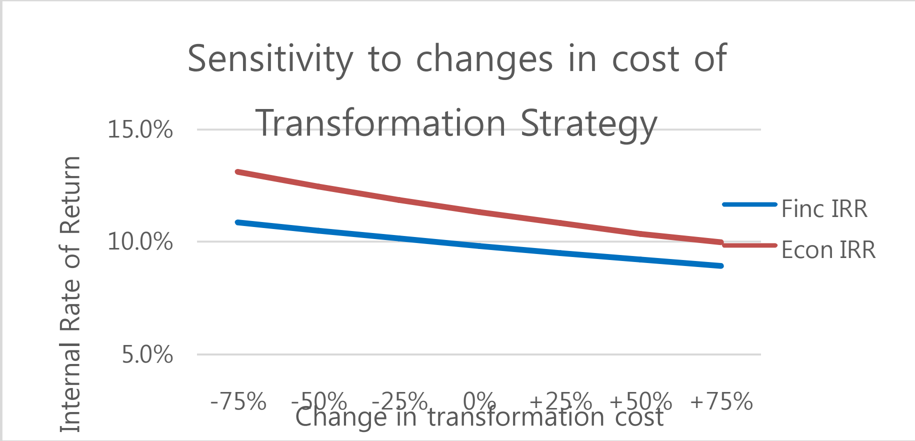
[Figure 16.6-4] Sensitivity to Changes in Construction Cost



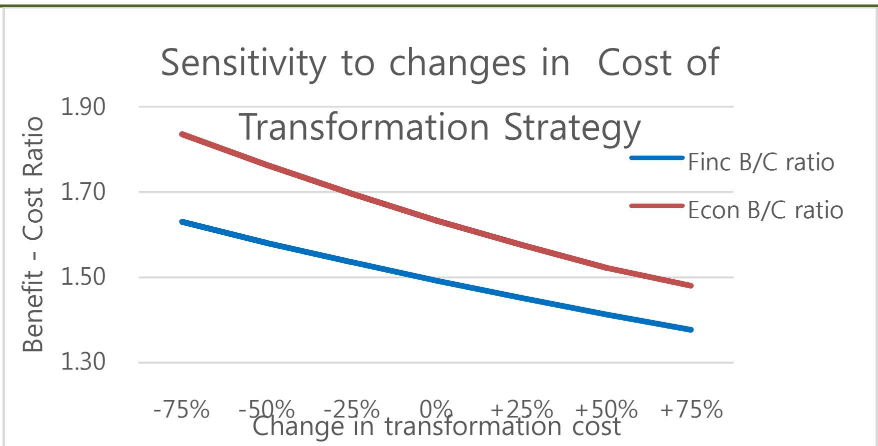
[Figure 16.6-5]Sensitivity to Changes in Maintenance Cost



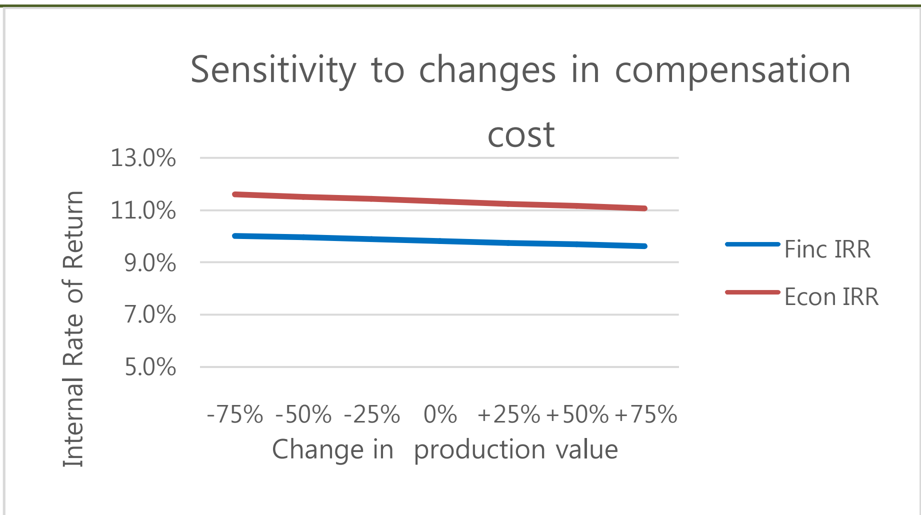
[Figure 16.6-6]Sensitivity to Changes in Maintenance Cost



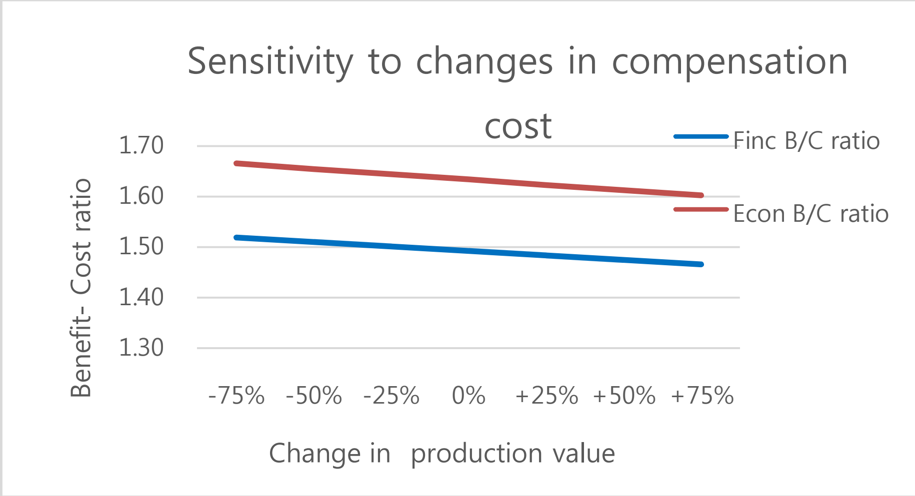
[Figure 16.6-7] Sensitivity to Changes in Cost of Transformation Strategy



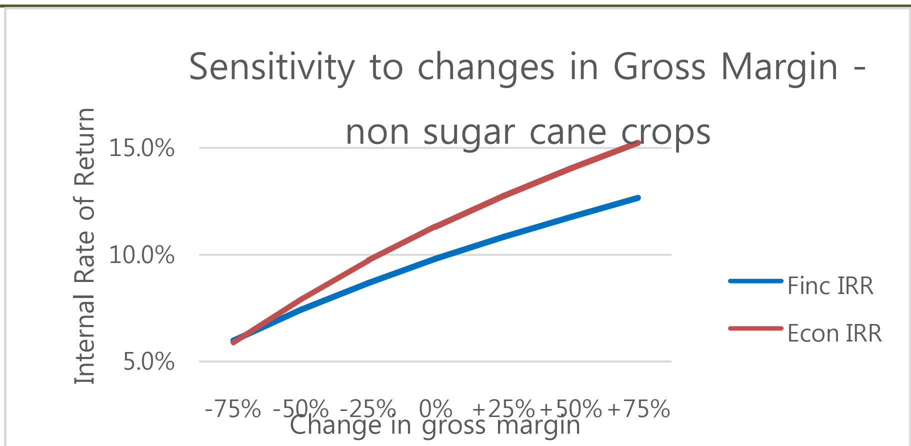
[Figure 16.6-8] Sensitivity to Changes in Cost of Transformation Strategy



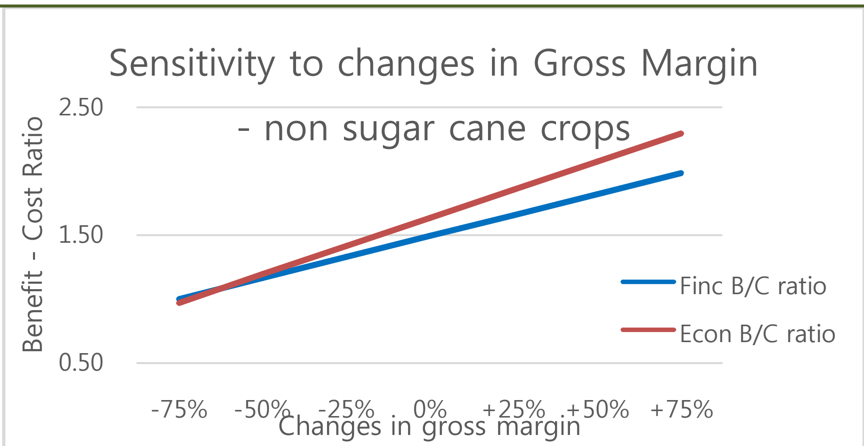
[Figure 16.6-9] Sensitivity to Changes in Compensation Cost



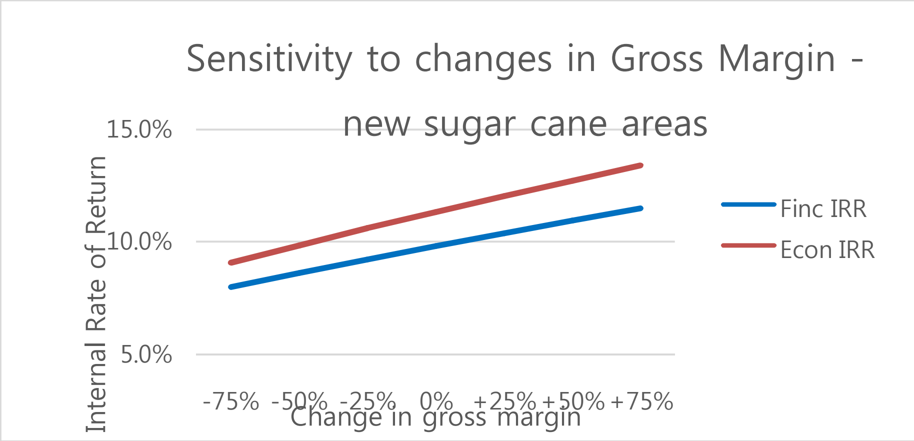
[Figure 16.6-10] Sensitivity to Changes in Compensation Cost



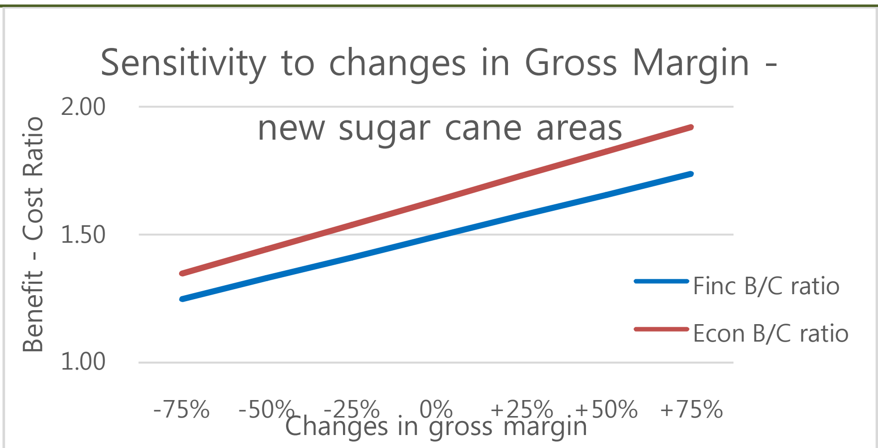
[Figure 16.6-11] Sensitivity to Changes in Gross Margin - Non Surgacane Crops



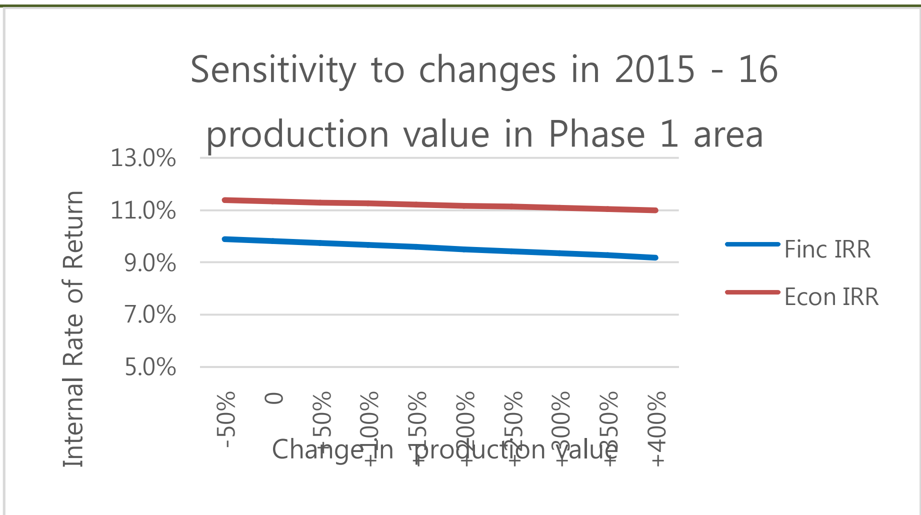
[Figure 16.6-12] Sensitivity to Changes in Gross Margin - Non Surgacane Crops



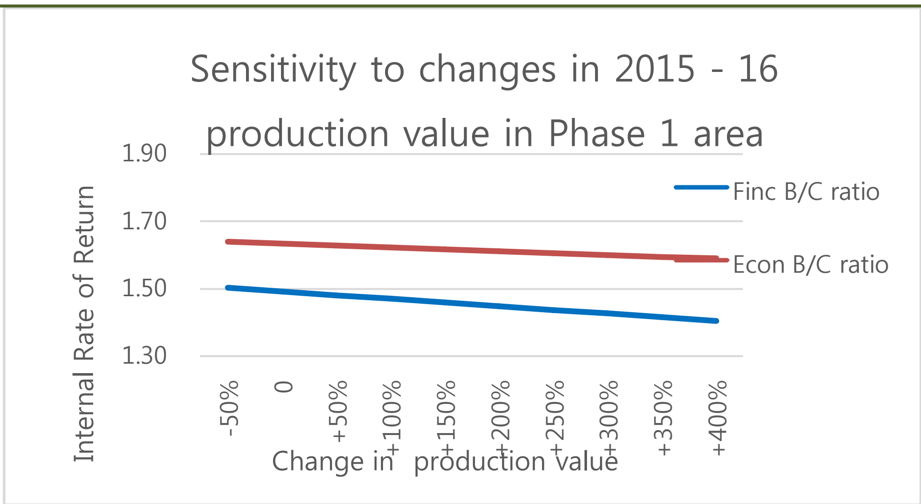
[Figure 16.6-13] Sensitivity to Changes in Gross Margin - New Surgacane Areas



[Figure 16.6-14] Sensitivity to Changes in Gross Margin - New Surgacane Areas



[Figure 16.6-15] Sensitivity to Changes in “without Project” Production Value



[Figure 16.6-16] Sensitivity to Changes in "without Project" Production Value

16.7. Conclusion

This chapter assessed the cost and benefits from the irrigation system of Phase 1 and 2 of the SVIP, together with its related institutions. Economic prices have been determined for Maize on the basis of an FAO study from which one may conclude that the economic price is 17 % higher than the market price. For non-traded goods a standard conversion factor has been used based on the ratio of the parallel market and official exchange rate of the Malawian Kwacha. For fertilizers, economic prices were estimated on the international market rates. The economic price of fuel was derived by correcting for excise duty and the parallel exchange rate. Moreover, it was calculated that 33 % of the cost of Transportation and Equipment as determined by the design engineers comprise of fuel.

A review of the cropping calendar and available labor according to the Baseline Survey conducted by COWI, showed that family labor is sufficient under the current rain-fed conditions. No labor cost was thus entered in the financial cropping budget analysis of the "without project" situation. In the "with project situation", the households have clearer choice between working on their own land and working for the cooperative and in this situation labor has been valued at the labor market rate in the financial analysis. A shadow wage rate has been determined at 50 % for unskilled labor and 125 % for skilled labor on the basis of the information of the Labor Force Surveys, among others.

The analysis in this chapter has shown that the Shire Valley Irrigation project is financially and economically viable. The combination of Phase 1 and 2 under cropping Pattern 1 produces a positive NPV and a financial and economic Benefit- Cost ratio of 1.15 and 1.34 respectively. The EIRR amounts to 8.9 %. The rather small difference between the financial and economic Benefit-Cost ratio is by and large due to the fixed part of Irrigation Service Charges (US200/ha for Illovo and US$100/ha for the Outgrowers and the Non-cane cooperatives), which is considered a financial, but not an economic benefit.

When considered in isolation, Phase 1 is burdened by part of its infrastructure that also serves Phase 2. The cost of the intake, Canal 1 and Canal 3 could be 51 % lower if it were not intended to serve Phase 2 area too. To counterbalance this effect and comply with standard practice of cost assignment, the investment and maintenance cost of these three parts of Phase 1 infrastructure have been reapportioned to Phase 2 pro rata to the area served by the two phases.

The Phase 1 infrastructure also entails two components that are not related to irrigation. The extra dyke to protect an additional 202 ha from 1:10 year's floods has a financial IRR of 4 % yet an economic IRR of 7.0%.The improvement of the water supply system in Chikwawa Boma at a cost of US$1.03 million has a negative NPV, but will have significant benefits that cannot easily be quantified.

The main quantifiable mitigation measures were also analyzed. The 800 m long siphon in the Majete Game Reserve is obviously better than an open canal over the entire kilometer that Canal 1 crosses the park as it avoids the park to be separated into two separate sections. The comparison between the two options for the remaining 250 meters is inconclusive for lack of data on the actual impact. Yet intuitively, the analysis shows a preference for the rectangular box canal covered with concrete slabs.

Avoiding the Majete Reserve entirely would have the least impacts. In additional of the (partly) separation of a section of the park, it would also entirely avoid noise pollution during construction. Yet, after correcting for some mitigation measures, such as sound walls that would need to be installed during construction in the reserve, the additional cost of an alternative route of the canal would increase the EIRR by 0.8 per cent points. This adds to the technical preference for the initial idea of a siphon through which the water will traverse the Reserve.

The benefits of drop structures in the secondary canals to prevent invasion of fish species to Lake Malawi could not be quantified, but its low cost (USD2,320,000) would be no reason for not avoiding the risk of seriously affecting a freshwater fisheries that is already under stress.

Two cropping patterns were examined, with the main difference being the timing at which fruit crops are planted. The second alternative, with bananas, mangoes and citrus being planted upon completion of the Phase 1 infrastructure is slightly more beneficial with an EIRR of 11.3 % compared to 10.8 % for cropping pattern 1. The small difference in EIRR is due to the high initial investment cost of the fruit trees, which start in Crop Year 6 for cropping pattern 1 and in Year 1 for cropping pattern 2.

Under Cropping Pattern 2, the O&M cost of Phase 1 (with part of the cost reapportioned to Phase 2) amounts to 9% and 8% of the incremental gross income per ha, when measured in financial and economic prices respectively. One could thus conclude that the maintenance of the system is quite affordable.

The cooperatives will be making substantial profits, even after deduction of repayment of loans, and related interest for the investment and half of the first year's overhead. When computed over only the plots cultivated by the cooperatives, the FIIR amounts to 74 % and the EIRR to 121%. In this computation the benefits from the households' food production are excluded while the cooperative still pays for the O&M of the entire on-farm irrigation system, including for the field canals providing water to the households' plots.

Consequently, the households that decide to join a cooperative will gain significantly from the dividends that the cooperatives will be paying their members. The total benefits that are expected to accrue to these households imply a six-fold increase of their annual agricultural income for Phase 1 area and 6.5 times increase in Phase 2 area, in spite of a loss of income from the free roaming livestock. Even if the without project income would be under-estimated, there is still considerable gains to be made for the households in joining the cooperatives. This conclusion holds true for both the cooperatives that will not grow sugarcane and KAMA (where the households will also have access to a plot of land to grow their own food crops).

Government of Malawi's tax base will also increase. It could forego the receipts of VAT on the construction materials and services amounting to US$ 69 million as a contribution to the construction of Phase 1 and 2 infrastructures. Once the schemes have been completed, an expected average annual revenue of US$13.2 and US$14.9 million from VAT on increased trade in agricultural goods and profit tax paid by the cooperatives is expected to materialize in Phase 1 and Phase 2 respectively. These incremental revenues would be sufficient to repay a very soft credit to the Government for the construction of the schemes.

Sensitivity analysis shows that these parameters are rather robust, which is related to the large number of different benefits that the scheme will have. These analyses also show that SVIP will not loose its feasibility if the current production in the project area were seriously underestimated.

Additionally, there are also a number of benefits that have not been quantified. More water may benefit wildlife in, and lead to more natural vegetation outside the parks, thereby also further contributing to climate change mitigation. With a large number of people living at the fringes of the scheme's command area, the economic multiplier is likely to have a wider impact. As mentioned above, also the relatively small drinking water component in Chikawa Boma (serving some 15,000 people) will have multiple impacts through reducing the time that villagers (especially young girls and women) need to fetch water every day. For some, this may remove an obstacle to attend primary and secondary school.

The Operation and Maintenance cost were computed separately. Also from the perspective of the Operations and Maintenance cost that were computed separately in this study, the SVIP is considered feasible. With the O&M cost amounting to approximately 8 % of the incremental income per hectare, affordability should not be a problem, especially as the O&M cost will be paid the cooperatives. Nevertheless, this low percentage does not release government and the farmers to ensure that adequate and timely maintenance does indeed take place. The sensitivity analysis showed robust results, but did not include an analysis of what happens if the system is not or badly maintained. Studies in other countries show how serious those impacts are.

The PPP study argued in favor of a 20 % (of the investment cost) private partnership in the project, for which possible international investors may be interested. This financial and economic study showed that cost recovery of the private participation as well as the O&M cost of running the irrigation scheme is feasible as well, without negatively affecting the feasibility of the cooperatives.

With a Private Partnership of 20 %, it might be possible to recover the private investment and O&M cost, as argued by the PPP feasibility study and it will still be affordable for the cooperatives.

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CHAPTER 17. INSTITUTIONAL FRAMEWORK

A proper institutional framework capable of adapting evolving environment is a must in irrigation projects. In most cases, an absence of a proper institutional framework, as the project is designed, does not guarantee sustainable irrigation production. The institutional framework will usually consider factors that will help operations in the future, as well as connect the national irrigation policies and water management policies to ensure food security in the area. Thus, the funding arrangements for construction, rehabilitation and operation are dependent of a good institutional framework. For example, an irrigation project will have better chance of long term sustainability if the water users can afford to pay for the operation and rehabilitation; and their ability to pay, too, depends on the price they receive for their products, which is greatly influenced by government policies on food prices and international prices.

The focus on the organization(s) or institution(s) framework in the SVIP is on what the project can take for effective and sustainable delivery (farmer organizations, cooperatives and farmer clubs and organizations in the value chains). The framework also looks at the overall institutional set-up for the project, addressing water management in links with agricultural development and detailing for each organization, thus, it looks at (i) responsibilities, (ii) governance principles, (iii) financial resources and flows, (iv) modalities of representation in “upstream” organisation. Consequently, in liaison with the socio-economic team, the framework will determine a detailed price setting for each organization level, considering operation and maintenance costs, financial flows between levels as well as farmers’ ability to pay.

This report, looks at the institutional framework while the major technical feasibility studies are making headway. This work is based on trips to the area, reports by other consultants that did primary data collection, meetings with other consultants working on similar issues (Communication, Community Participation, Land Tenure and Resettlement Framework (CCPLTRF) consultancy team and Agricultural Development Plan Strategy Team), update meetings coordinated by Project Technical Team (PTT), and continuous discussions with technical members of the feasibility study. The following are covered: the legal framework, key players in the project and activities involved, Relating the Key players, Organisations formed including Operation and Maintenance, Optimising Canals, and pricing.

17.1. Legal Framework

17.1.1. Land Bills

First and foremost, the changes in the area by having the canals developed will involve a lot of changes in land and partly ownership of land. This means that there is need to understand the land legal consequences of such changes before looking at different players and their roles.

Recently, land bills (land bill, physical planning Bill, Land Survey Bill and Customary Land Bill) were passed in the recent parliament seating (July-August 2016) and are likely to replace the 1965 land act. In September (2016), the President assented to the bills[1]. There are some changes from the Land Act (1965). The Land Act (1965) defines three categories of land – private, public and customary – the rights, restrictions and responsibilities attached to these. Private land means land

[1]When the Bill has been passed and the President assents to the bill, what remains is the gazetting to make it an Act.

owned, held or occupied under a freehold title, or a leasehold title, or a Certificate of Claim or which is registered as private land under the Registered Land Act. Public land, not being customary land or private land, which is occupied, used or acquired by the Government. Customary land is land held, occupied or used under customary law.

The Land Bills have retained large parts of the Land Act. However, instead of having the in three categories, Land Bill divides land into two categories namely public land and private land. The bill further sub-divides public land into 'government land' and 'unallocated customary land used for the benefit of the community as a whole'.

Customary land in the (in the Land Act (1965) was held, used or occupied by the people communally, meaning that the land was not individually or privately owned and as such could not be used as security to obtain a loan from the bank. Currently, in the Customary Land Bill, individuals in the local community will now have an opportunity to seek permission from the Traditional Authority of the area to register this land. This means that they can now be recognized as the private owners of the land.

This will mean that individuals will then be able to use this land as security for obtaining a loan from the bank. The owner will also be able to lease or sublease their land or transfer ownership through their will or transmission.

17.1.2. Irrigation Act

The Irrigation Act is the amongst the most important legislative framework governing irrigation activities in Malawi. A draft Irrigation Act was prepared by the Ministry of Irrigation and Water Development through the Department of Irrigation in 1998. This Act has now been gazetted in Parliament. And became a law in 2001.

In relation to the farmer organization, the Water Resources Act (2005) provides for the creation of Catchment Management Authorities, association of water users and stakeholders in water resources, environmental conservation and management as it relates to water; and establishment of a water tribunal. Under the Water Resources Act of Malawi, ownership of all public water in Malawi is vested in the President, and the control of public water is vested in the Minister responsible for water affairs. It is mandatory by law that anyone or any institution intending to divert, dam or store public water to obtain a water right. Water Rights can be conferred on water user if provided with an application backed up by full details of land ownership.

Implication in the Irrigation Area

During the implementation of the project, all the above factors should be taken into consideration. In resettlement, when the government is acquiring such land for public use, compensation is not paid for the land itself because it is considered as having no value (Land Act, 1965). With the Customary Bill passed and assented, there will be need to compensate for the land where the land has been registered. It is however expected that it will take quite a while before people decide to change their land into private land[2], partly, because of the cost implication, and because, they may feel they will still not get the land easily used as collateral[3].

[2]The survey fees are prohibitive and cannot easily be afforded by the people in the rural areas
[3]The Banks in Malawi do not have a good record in terms of giving loans and have hardly accepted loans using

17.2. Land Tenure

According to the baseline undertaken by COWI (2015), there is 81% customary land and the remainder is private land. This is the same for adult men, adult women, young men and young men. The proportion of customary land in Phase 2 is 91%, much higher than the 75% in Phase 1, probably because of the already existing irrigation projects in Phase 1, such as Illovo and Kasinthula that have private leases for at least part of their land.

17.3. Key Players

At national level there is the Ministry of Agriculture, Irrigation and Water Development and related coordinating unit for the project, the PTT (directly under the Ministry), Ministry of Trade and Industry, Ministry of Gender, Children, Disability and Social Welfare, and Ministry of Youth and Sports Development. At district level, apart from the district council, there are development committees (district, area and village), NGOs and other development initiatives in the area. All these have responsible undertaking in the value chains that will be created by the project. Among the private sector organisations, there is Illovo and other newer players eg Press Cane, Kaombe. Traditional leaders and organisations that will be created at a later stage within their geographical areas will also be key and form the main linkages with the rest of the population in the areas.

17.3.1. Roles and Relating the Key Players

There have been several discussions among the different teams of consultants in ensuring a common understanding in relating the key players. Below are the detailed members, as well as a model presentation of their relationship. The responsibilities have been determined within the current factors and situation, however, as the project gets to implementation stage, these may change slightly or having additional roles.

Players Providing Policy Direction

Ministry of Agriculture, Irrigation and Water Development

- The Ministry generally provides policy direction in all issues related to irrigation, food security and implementation of the project.
- The Ministry is also responsible for leadership in general coordination of the project, and the related agricultural activities.
- The Ministry is the main body that liaises with the donor organisations regarding the overall performance (outputs).

Government Ministries that are important for the SVIP, but not part of the SVIP Management, are:

- Ministry of Trade and Industry
- Ministry of Gender, Children, Disability and Social Welfare responsible for promoting gender equity and implementation of the National Gender Policy.
- Ministry of Youth and Sports Development responsible for implementing the National Youth Policy.

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even leased land.

These ministries have been taken as part of key ministries because their mandates and activities that has a direct bearing on the SVIP. The Ministry of Gender, Disability and Welfare deals with gender and youth groups as well as people living with a handicap in the project area and its current undertakings. The Ministry of Youth and Sports Development also deal with the youth and their activities in the project area. The ministries are therefore important in ensuring the involvement of the vulnerable groups.

Political representatives such as Members of Parliament and Ward Councilors are part of the national and local government system through membership of District Executive Council Meeting, the Area Development Committee, Area Executive Committee, and the Village Development Committee. They are listed as a separate target audience since they play an important role in key in involving different groups of people in their constituencies.

The Ministry of Trade and Industry constitute the headquarters and district trade offices. Chikwawa district has a Trade officer based at the district headquarters. The ministry has the mandate for cooperative development in Malawi which includes provision of initial training, registration of cooperatives as well as conducting annual performance assessment of the cooperatives. Currently the Ministry of Trade and Industry has challenges that affect delivery of services – inadequate human and financial resources to effectively deliver their services; the ministry has centralized provision of initial training and registration of cooperatives at the headquarters level which makes it difficult for them to reach out to the cooperatives. This affects cooperative development in the country.

Other Government departments that provide technical and extension services which cover the whole range of technical and extension services required for development of the all potential crops are equally important though they have not been fully listed. Such crops include: cereals, legumes, fruits, vegetables, oil seeds, fibre crops; livestock and aquaculture. Most of the farmers are already familiar with such government technical and extension service providing institutions and the approaches that they use.

District Council Offices

The District Council (DC) performs the following functions:

- make policy and decisions on local governance and the Council's development for the local government area;
- consolidate and promote local democratic institutions and democratic participation;
- promote infrastructural and economic development through the formulation, approval and execution of district development plans;
- mobilize resources within the local government area for governance and development;
- maintain peace and security in the local government area in conjunction with the Malawi Police Service;
- make by-laws for the good governance of the local government area;
- appoint, develop, promote and discipline its staff;
- cooperate with other Councils in order to learn from their experiences and exchange ideas;
- perform other functions including the registration of births and deaths and participate in the delivery of essential local services[4].

[4] Local Government Act 1998, Part II Article 6.

Within the DC, there is the Area Development Committee (ADC) and Area Executive Committee (AEC), whose roles are "linking between the District Council and the Villages". The members of the ADC overlap with the meetings held by the Traditional Authority but are not the same.

The ADC is a representative body of all the Village Development Committees (VDCs). It is composed of Ward Councillors, youth and women groups, representatives of religious groups and the business community, and chaired by an elected person among the members. The T/A plays an advisory role and the secretary is the AEC Chairperson.

Main functions of the ADC are to:

- Prioritise, identify and prepare project proposals addressing community needs covering more VDCs,
- Organise monthly meetings together with VDCs,
- Supervise, monitor and evaluate implementation of projects at T/A level,
- Bring together community members and resources for self-help projects, and
- Improve and prioritise project proposal for VDCs for submission to the DEC5.

The AEC is a technical and advisory committee to the ADCs. It comprises of extension workers of Government Ministries, NGOs and corporations.

Main functions are to;

- Assist and advise the ADC on identifying and preparing proposals,
- Carry out field appraisals of proposed projects,
- Review project proposals before submitting them to DEC,
- Conduct data collection and analysis at community level,
- Take a lead in the organization of VDCs, and
- Train and assist VDCs in setting their own guidelines and coming up with development projects.

Since there are many extension workers from different sectors and NGOs in a T/A area, AEC membership is limited to these core sectors: Health, education, community development, agriculture, forestry, water and NGOs. Each sector has one representative.

The VDC is a representative body of a village or a group of villages, and it is the entity closest to the people at grassroots level. Therefore, the Committee is important in the planning system of the District Council.

The Committee comprises one elected member from each village within the VDC, a Ward Councillor, four female representatives and an elected extension worker. It is chaired by an elected member and its main functions are to;

- Identify and prioritise community needs as well as preparing project proposals and submitting them to the ADCs,
- Supervise, monitor and evaluate the implementation of development activities in the villages,
- Initiate community self-help activities, and
- Encourage and bring together community resources for people's participation in self-help activities.

[5] The functions of the ADC, AEC and VDC are based on the information on the website www.malgamw.org/Lilongwe%20District%20Assembly.html, 26 January 2016.

17.4. Current Institutional Set-Up

17.4.1. Coordination

The coordination of SVIP is made up of three Committees, a Project Technical Team and an Inter-ministerial Task Force which share management roles in the general coordination of the SVIP. The committees are The Project Steering Committee, Project Technical Committee and a District Task Force Committee (based in Chikwawa).

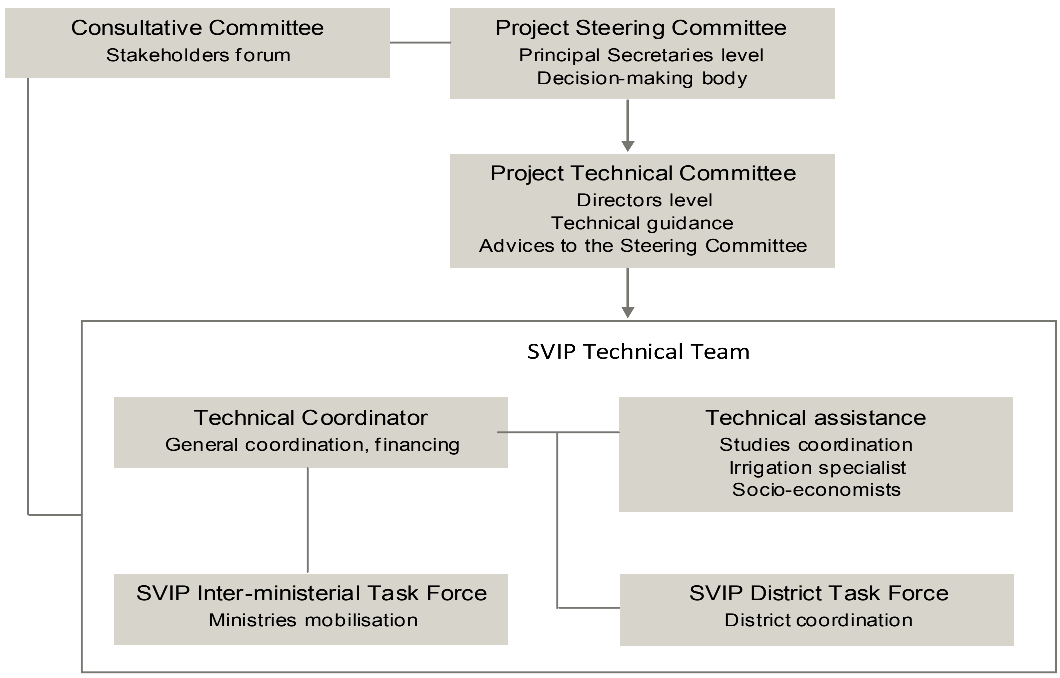
The Project Steering Committee is the decision-making body of the SVIP. It is composed of the Principal Secretaries of the Ministries composing the SVIP Inter-ministerial Task Force and chaired by the Principal Secretary of MoAIWD.

The Project Technical Committee advises the Project Steering Committee and provides guidance to the PTT. It also makes all technical decisions that do not require the PSC's endorsement. The PTC is composed of the Directors of the Departments represented in the SVIP Inter-ministerial Task Force and chaired by the Director of Irrigation Service.

The Project Technical Team is responsible for coordinating the Feasibility Study and monitoring the consultant teams' work. It is chaired by the MoAIWD and with a full time Project Technical Team Coordinator (PTTC).

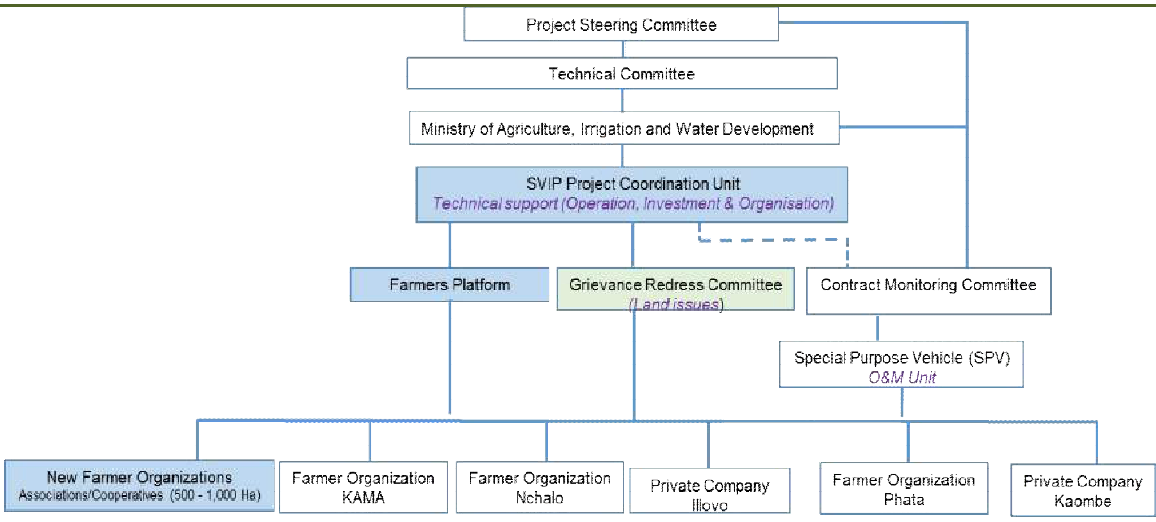
The Task Force is chaired by the PTTC and gathers officials from ministerial departments. Its purpose is to ensure a smooth information flow between the project and the ministries, mobilise the ministries when required, and provide outputs on need basis. Each of the departments participates in the project preparation. The SVIP Inter-Ministerial Task Force meets on a monthly basis and as need arises whereas PTC and PSC meet at critical stages of the project preparation.

At district level, a consultative committee, chaired by the Chairperson of the SVIP District Task Force, gathers the main stakeholders and is the arena where the various interests are discussed. The consultative committee informs the PTC and PTT on the position of and trade-off between stakeholders.



[Figure 17.4-1] Current Coordination

17.5. Proposed Institutional Set-Up during Implementation



[Figure 17.5-1] Institutional Set-Up

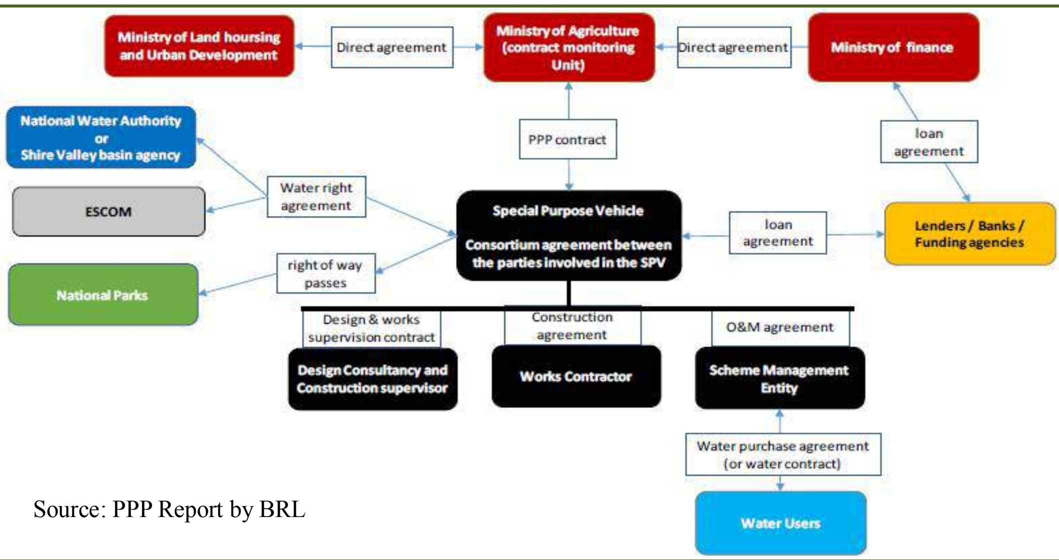
17.5.1. Coordination

The coordination of the Project will not change. The current situation will continue, to ensure that government has some control on the project. Thus the Steering Committee, a Technical Committee and Project Coordinating Unit will continue, with both the Ministry and district level involvement.

A Contract Monitoring Committee will be formed whose main purpose will ensure quality control and proper procedures are followed all times. This will report directly Ministry and Project Steering Committee with some work relationship with the Coordinating Unit.

17.5.2. Operation and Maintenance (SPV)

This will be operated by private operator also termed as Special Purpose Vehicle (SPV), under PPP. However, for proper operations and control, there will be good interrelated relations between the SPV and other actors to help in the success SVIP operations.



Source: PPP Report by BRL

[Figure 17.5-2] SVP Relations with Other Stakeholders

According to the PPP report, a Scheme Management Entity (SME) will be the main institutions that will be formed through PPP, under SPV. The SME will be the organization of the SPV in charge of scheme operation and maintenance as well as the billing and collection of the ISC from private clients and farmers groups. The SME will sell and grow water for agricultural purpose and Water supply.

Contract Monitoring Unit

A Contract Monitoring Unit will need to be established in the Ministry to ensure smooth operations of the SPV and eventually SME. It is recommended that the Monitoring unit be composed by representatives of the ministry of agriculture, Irrigation and water development, representatives of ministry of finance and representatives of the PPP commission. It duties will include:

- Gathering and verifying data on the technical performance of a PPP, as specified by the key performance indicators and “out-puts” required by the PPP contract
- Gathering and verifying financial and cost performance data of contract
- Monitoring and ensuring compliance with and enforcement of the legal terms and conditions of the contract
- Coordinating with other relevant compliance bodies and regulators or outside monitoring specialists, such as specialized outside lawyers, engineers, environmental specialists, or other experts retained to advise on specific PPP performance issues

Since the unit will be in charge of the day to day supervision of the private operator, the composition of the unit in terms of human resources might require the following positions:

- 1 Unit chef
- 1 legal expert
- 1 S&E specialist
- 1 irrigation engineer
- 1 Accounting specialist

The above positions could be virtual positions, using expertise from the different Ministries directly involved in the SVIP.

Scheme Management Entity (SME)

The SME will be the organization of the SPV in charge of scheme operation and maintenance as well as the billing and collection of the ISC from private clients and farmers groups. The SME will sell grow water for agricultural purpose and Water supply.

The agreement between the private sector (SPV) and the Public authority will be either a concession (recommended option or a management contract (complete operation and maintenance contract)/ DBO contract, performance based. The supervising authority (regulator) of the PPP contract will be the Contract Monitoring Unit as already discussed.

Table 5-7: Staff for operation and Maintenance (phase 1 only: 21,000 ha) per year

Position	Number	Net Annual Cost (USD)	Gross Total (USD)	Gross Total (M.MK)
General Manager	1	21 600	30 857	22
Chief of Operation Dept	1	16 800	24 000	17
Chief of Maintenance Dept	1	16 800	24 000	17
Chief of Irrigation Sector	1	12 000	17 143	12
Engineer	1	14 400	20 571	15
Human ressources Dept Chief	1	16 800	24 000	17
Security Chief Unit	1	12 000	17 143	12
Administrative staff	0	9 600	-	-
Customers Unit Chief	0	12 000	-	-
Chief Accountant	1	16 800	24 000	17
Specialized workers	4	7 200	41 143	29
Drivers	3	4 800	20 571	15
Waterman	4	4 800	27 429	19
Collection fee agents	0	6 000	-	-
Assistant accountant	1	6 000	8 571	6
Secretary	4	3 600	20 571	15
Workshop chief	1	9 600	13 714	10
Guards	4	1 800	10 286	7
Total	29		324 000	230

Source: BRLi financial model for SVIP

[Figure 17.5-3] Staff for Operation and Maintenance (Phase 1) per Year

And with the following annual operation cost:

Table 5-8: The operating costs per year

	Number	Annual Cost (USD)	Total	Total (M.MK)
Renting for offices	1	18 000	18 000	13
Renting for machinery	12	2 000	24 000	17
Insurances	3	1 500	4 500	3
Electricity, water, etc	12	500	6 000	4
Fuel, maintenance of vehicles	3	3 600	10 800	8
Stationary (including for customer invoicing)	0	12 000	-	-
Small equipment	12	1 000	12 000	9
Contingencies (25%)			18 825	13
Total			94 125	67

Source: BRLi financial model for SVIP

[Figure 17.5-4] Operating Costs per Year

17.5.3. Farmer Organisation

According to the household survey conducted by COWI (2015), only 14% of farmers have implemented irrigation, indicating low levels of irrigation experience. For farmers to effectively participate in large scale irrigation commercial farming, it is important that they are organized and do not operate as individuals. Organization of smallholder farmers will facilitate aggregation of small pieces of land currently cultivated or owned by households/families under customary land tenure into large chunks of land for purposes of developing irrigation systems. It will also facilitate joint ventures that will enable smallholder farmers to effectively participate in the commercial production of crops and livestock (PWC, 2016)[6].

General Structure

It is proposed that Farm Cooperatives with between 500 and 1000 hectares will be the main organisations operating in the area. It is recommended that they do not exceed 1,200 because the bigger they are, the more difficult they will be in managing and thus perform the value chain role. So far, the area has the following organisations/associations: Kama, Nchalo, Kasinthula and Phata.

The proposed cooperative structure has been depended on Phata Model, which seems successful and in their presentations to other communities, most communities have appreciated that model. The cooperative follows Ministry of Trade's basic guidelines regarding training and how they can operate. However, the members still come up with their own rules on the operations, either in form of by-laws or constitution (agreed by members).

The suggested Phata Model has adopted and generally meets the criteria and principles in Box 1 below:

Box 1: Principles of the proposed model

i. Ability to mobilize and empower farmers economically and socially.
ii. It improves the crop productivity
iii. Enhance productivity of land secure, land tenure system.
iv. Should have adequate and appropriate technical, managerial and financial management capacity.
v. Should be efficiently and sustainably managed
vi. Should be flexible to changes in the market to enable switching of crops grown.
vii. Should integrate both food security and commercial objectives.
viii. Is transparent and accountable to the farmers.
ix. Should have farmers as owners of the institution and land.

Kama Irrigation Scheme[7], also one of the established organizations, also intends to follow the above model.

Private Sector Operator

In both cases (Phata and Kama), a private sector company is used by the farmers' cooperative to provide professional management services. The strategy is that the private sector company will provide capacity to farmers in a such way that in future they can manage the corporate professionally on their own.

6 PWC, 2016, Formulation of the Agricultural Development Planning Strategy, Final Interim Report, Shire Valley Irrigation Project, (SVIP)

7 Press Cane Limited, a subsidiary company of Press Corporations, initiated a private company model approach. It supported the establishment of the Katunga-Maseya Sugar Cane Cooperative Society (KAMA) to carry out agricultural activities to produce sugar cane to supply its ethanol plant. The Company is planning to develop 2,270 ha of land under irrigation of both sugar cane (2,000 ha) and food crops (270 ha) in the Shire Valley, under Traditional Authorities (TA) Katunga and Maseya areas

Governance Structure

Board of Directors

Under the Cooperative Structure, the farmer organization will have a board to look at the strategic direction of the organization. It will be responsible for approving integrate plans and multiplies all budget for the irrigation scheme. This will receive periodic reports from the Executive Team and overseer the private sector. It will also have powers to recommend the cancellation of the Contract of the private sector company, based agreed committee terms.

The Executive

This is usually composed of 8 to 12 members who are elected by the members on annual basis or whatever period they may agree in the by-laws of the organization. The Executive will have the following positions:

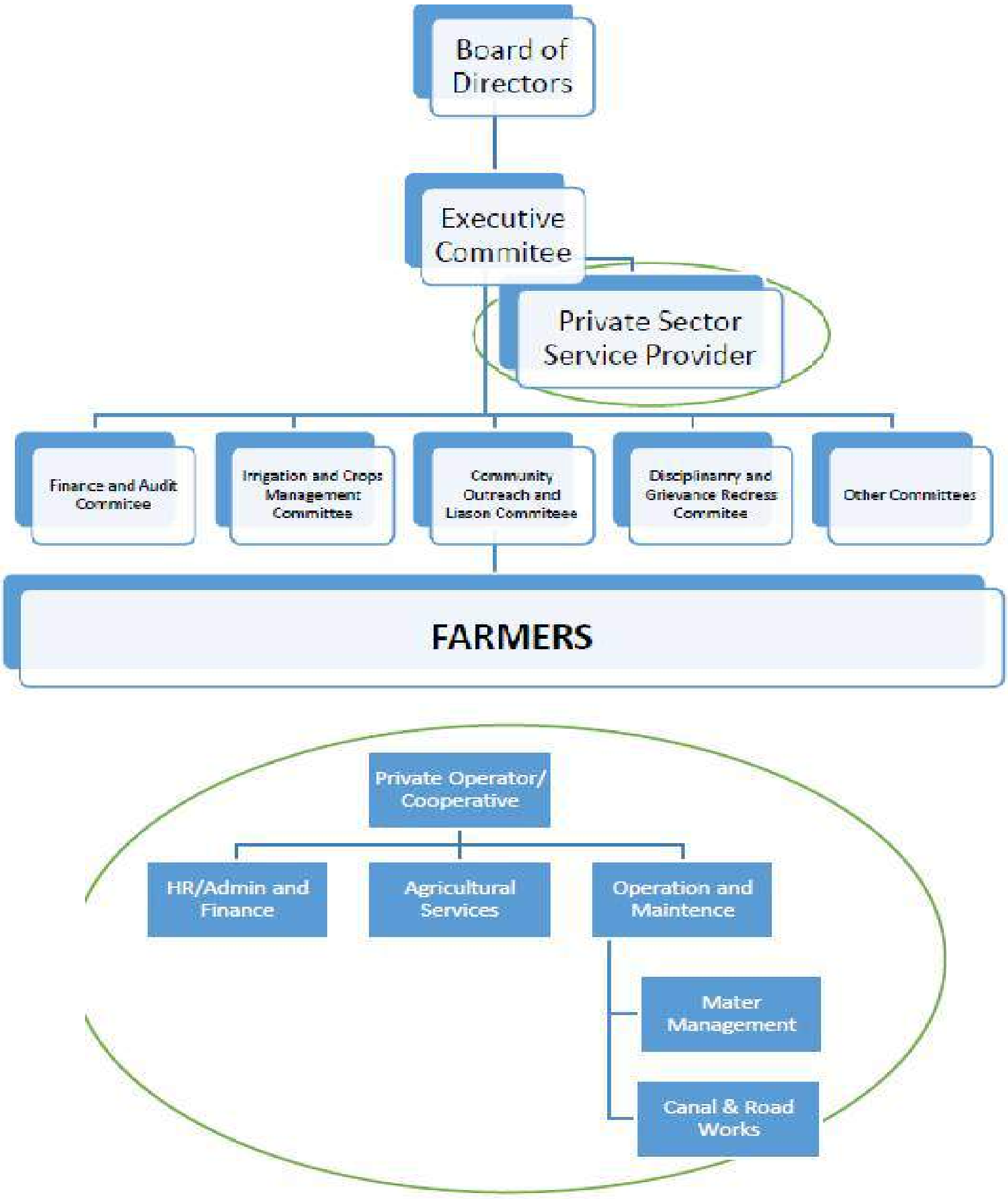
- The Chairperson
- The Vice Chairperson
- The Secretary
- The Vice Secretary
- The Treasurer
- Executive Committee Members

The Committee members may be assigned responsibilities per type of work the cooperative is dealing with. In this case the members may responsible for dealing with smaller committees (Irrigation and Crop Management Committee; Community Outreach Committee; etc).

Technical Operations of the Cooperative

This is where the private operator comes in. The Board and Executive are all figure heads with little technical knowhow. The private operator will ensure that the cooperative is operating at a profit; able to negotiate contracts with buyers; support farmers in understanding shareholding; Ability to deal with Financial Institutions when more resources are involved.

Currently, Agricane does this role for Phata irrigation scheme. It was contracted by the cooperative, with agreed terms and conditions. Some of the roles include providing all technical, financial and management services to cooperative at cost. It is responsible for production, processing as well as marketing of crops grown at a cost to cooperative.



[Figure 17.5-5] Basic Organogram

The private operator will have a general structure of an organization, and more important, a department that deals with Operation and maintenance (working together with members of the Cooperative) at the downstream level. It will the responsibility of the Cooperative that the downstream branches of the canal are well maintained. One private operator can give support to a number of cooperatives depending on location of those cooperatives.

Investment in Cooperative Formation

For 6 Farm Organisations, about US$1.5m would be required in the setting-up. This covers about $180,000 for each cooperative, covering most of the investment costs including some operational costs for the first 12-24 months.

There shall be additional costs which will be for items that can be communally used, including tractors, harrows, trucks etc. These will be managed by one of the private operators and come up to about $400,000.

The general initial investment for the cooperative includes some basic offices and a warehouse. The cooperative will also require a pick up / utility vehicle and motorcycles as well as few members of staff (driver and some watchmen).

The tables below give summary of breakdowns:

Training

Included in the costs are two levels of training proposed. The first is the basic one for the formation of a Cooperative, usually provided by the Ministry of Industry and Trade. Each Cooperative will need to go through such a Training, of which at the end they will be given a certificate of incorporation.

The second training will cover operation and maintenance, and will target Executive members of the Cooperative, especially the committee dealing with operation and maintenance. Thus about 3 people per cooperative will go through this training, which has a full curriculum like the one for Water User Association. Below are the details of the training, and the costing has been included in the common assets for all cooperatives.

- General water management
- Understanding by-laws in the water sector
- Finance
- Record keeping
- Contract management
- Improved crop production
- Irrigation scheduling
- System O&M
- Water charges fee
- Conflict management

[Table 17.5-1] Costs for Formation of Cooperatives

Details	Unit	Quantity	USD/Unit	Total Cost (USD)
(1) Capital Expenditure Items(year 1)				
Farm Buildings				
Offices	Blocks	1	52,239	52,239
Warehouse	no.	1	45,522	45,522
Subtotal				**97,761**
Motor Vehicles				
Pick-up trucks / Utility Vehicle	no.	1	22,388	22,388
Motor Cycles	no.	2	2,239	4,478
Subtotal				**26,866**
(2) Recurrent Expenditures Items/year				
Electricity	Year	2	4,478	8,956
Insurance	Year	1	2,015	2,015

Salaries and Wages	Months	24	693	16,632
Telephone and other communication	Year	1	1,493	1,493
Subscriptions	Year	1	746	746
Transport - sugarcane	USD/t	108	63	6,804
Subtotal				**36,646**
Cooperative Training				
Professional fees – Coop Expert		6	250	1,500
– Co-facilitator		6	250	1,500
Materials and services		1	6,000	6,000
Farmer field tour		1	1,600	1,600
Transport for consultants		6	100	600
Transport for farmers to Training Facilities		1	1,500	1,500
Follow-up leadership training		1	6,000	6,000
Subtotal				**18,700**
Total Investment required				**179,973**
Workshop	no	1	29,815	**29,815**
Farm Machinery				
Tractors	no	4	29,851	119,404
Trailers	no	3	6,716	20,148
Ploughs	no	4	8,507	34,028
Discs (heavy duty)	no	4	8,881	35,524
Ripper	no	1	5,970	5,970
Harrows	no	1	2,985	2,985
Ridger	no	1	1,493	1,493
Subtotal				**219,552**
Motor Vehicles				
Lorries	no	2	59,701	119,402
Passenger vehicles	no	1	8,955	8,955
Motor Cycles	no	2	2,239	4,478
Subtotal				**132,835**
Training				
Professional fees (WUA Expert)		27	250	6,750
Professional fees (Co-facilitator)		8	250	2,000
Professional fees (Legal Expert)		11	250	2,750
Materials and services		1	6,000	6,000
Farmer field tour		1	1,600	1,600
Transport for consultants		27	100	2,700
Tpt for farmers to Training Facilities		1	1,500	1,500
Subtotal				**23,300**
Total				**405,538**

17.5.4. Farmers' Union

A farmers' Union will be a virtual institution with representations from all the parties benefiting from SVIP. This will even include representation from big firms such as Illovo. The main purpose is to periodically discuss the issues that are common to all of them. Any issue that requires redressing will be taken to the coordinating Unit.

Membership

This will be composed of 2 members from each organization's Board or Executive Committee. The Chairperson for this group will be elected annually.

Meetings

The Farmers' Union will have meetings every quarter hosted by each organization on a rolling basis. Occasionally, they will invite representative from the Coordinating Unit to such meetings, especially when there are issues that require addressing or clarification.

Cost of Meetings

Each organization will bear the cost to attend the meeting.

17.5.5. Grievance Redress Committee

This is a Committee that will be formed to deal with grievances due to land issues, as well as problems in the membership within the Farmer Organisations. The committee has been proposed considering the number of households that will be affected in the construction of the Canals and the relocations within the Farmer Organisations to have effective Cooperatives. The Committee will meet as and when required.

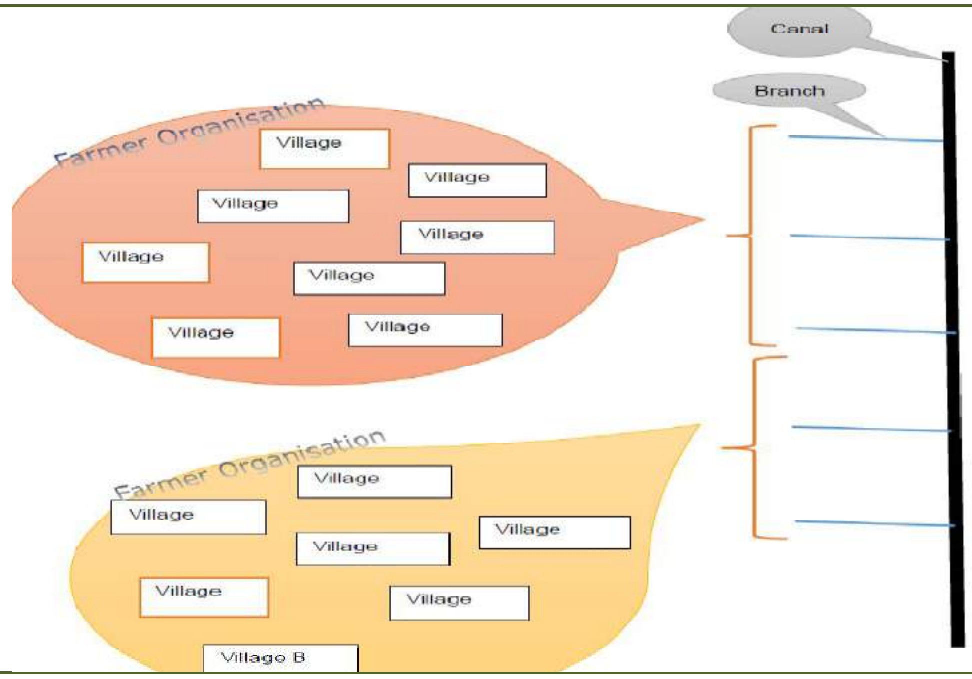
Cost

The major cost for this will depend the calculated compensations.

17.6. Optimization of the Canals

The canals designed in the project will need to be fully optimized. This may require good top-bottom approach in terms of management of farmer organisations. A more appropriate approach is to have a branch (or several branches) serve a specific farmer organization. The sizes of branches vary so much so it would not be automatic to say every two (or three) branches serve one organization. The longest branch goes up to about 3,000 km while the shortest is about 500 km. Obviously, the farmer organisations will comprise several villages. With the organization being responsible for a number of canals/branches, it will be easy to calculate water usage for that particular Farmer organization.

The sketch below shows how this may work.



[Figure 17.6-1] Optimization of the Canals

17.7. Water Service Provider

The Water Service Provider (WSP) is the organization that will be responsible for operating the infrastructure once it is completed. On the basis of an analysis of the risk of water infrastructure development and water distribution, the PPP Feasibility Study (see GoM, 2016-3) recommends a Private – Public Partnership either through a concession (Build- Operate and Transfer) or a Design – Build and Operate modality. However it also identifies a management contract between Government and a private company as a "fall-back option" "in case none of these two options would be implemented" (GoM, 2016-3, p. 1). In all cases the Service Provider8 would deliver bulk water to big commercial farms: the main sugarcane estates and the cooperatives in the project area.

Its tasks entail the operating and maintaining the common structures from the intake up to and including the meters. After the meters, the maintenance will be the responsibility of the co-operatives who will comprise of the relevant water user associations with competent staff.

Based on the cost estimates in this (KRC) Feasibility Study, the PPP study calculated the so-called 'true cost" apportioned to the different parts of the irrigation scheme, and used these to compute water charges comprising of a fixed and a variable part for three groups of consumer: (i) Illovo, (ii) Phata, Kasinthula and Sande and (iii) New land area (i.e. not previously irrigated). The fixed cost is to cover at least the financial cost of the private partner and the variable cost is to recover (at least) the O&M cost (annually recurring and replacement) as well as the fees to be paid to the National Water Authority. These true costs would point to uniform variable cost and fixed cost that are twice as high for the newly irrigated land than for Illovo (ibid. p. 14).

However, in order to comply with the social approach of the SVIP and the include considerations of capacity to pay, it proposed the following system of Irrigation Service Charges (ISC):

[8] The final version of the PPP study calls it "Scheme Management Entity". This report prefers the term used in draft version of the PPP study's: Water Service Provider.

[Table 17.7-1] Irrigation Service Charges proposed by PPP, study

	Variable (US$/Ml)	Fixed (US/ha)
Illovo	8.6	200
Phata, Kasinthula and Sande Ranch	8.6	100
Newly irrigated areas	8.6	100

Source: GoM (2016 – 2), p. 15

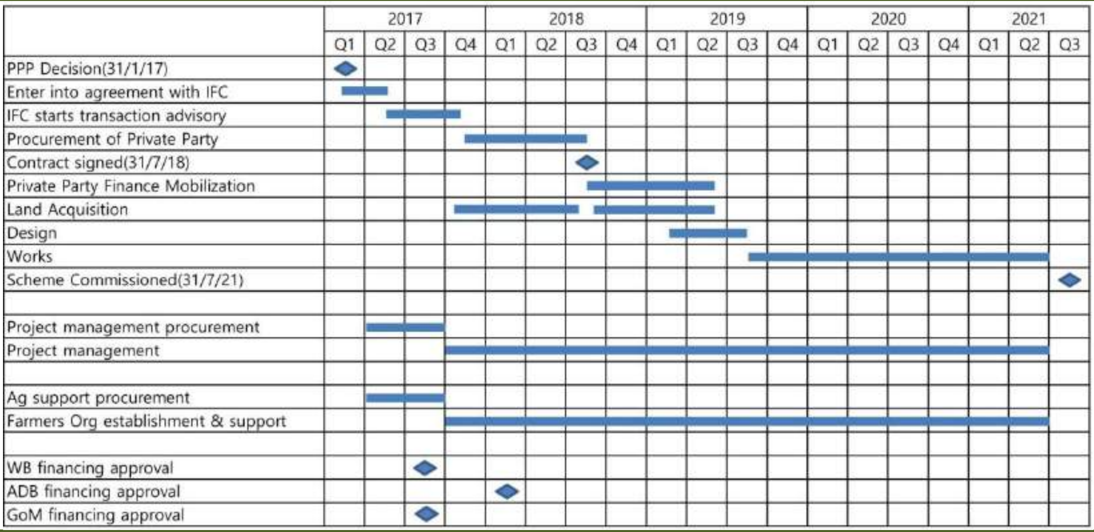
With these ISC, the SVI scheme would comply with the criteria for a feasible private sector partnership of 20 %. From discussions with companies that have experience in similar partnerships in France, Spain and Marocco the study concludes that there is indeed an interest in a concession for the development of the infrastructure and the delivery of bulk water (ibid p. 28).

CHAPTER 18. PROJECT IMPLEMENTATION TIME FRAME

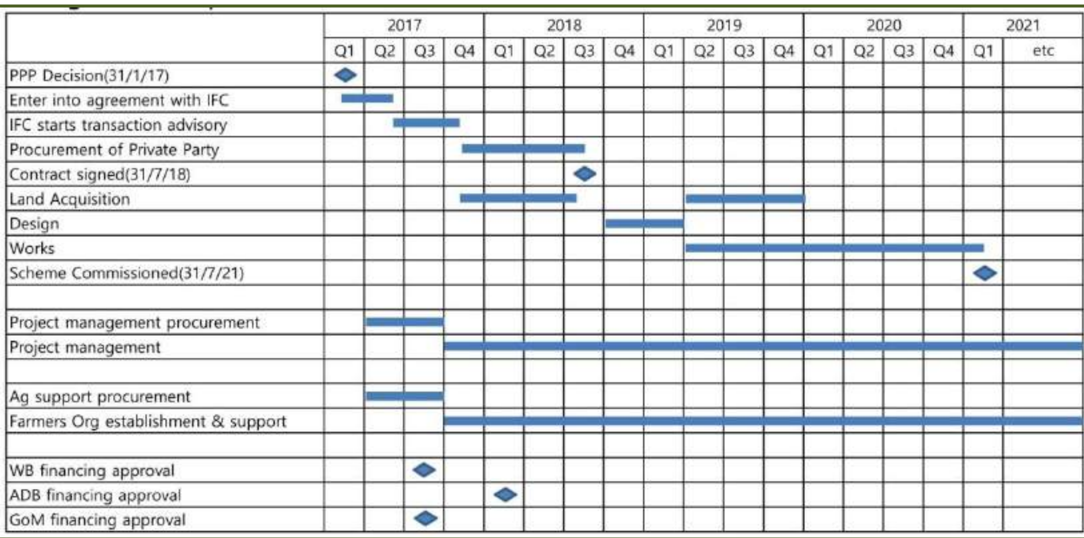
The people in Chikwawa have been made aware of a number of studies for the Shire Valley Irrigation Project (SVIP) for many years. Under the current SVIP, awareness campaigns have been conducted and the people were assured that the project will take off. During the awareness campaigns the people have said they are tired of the studies and they want to see the actual implementation. They are also aware of the milestones set by all previous World Bank and African Development bank Missions that indicate the critical dates for preparation and commissioning of the project activities. The government of Malawi has also huge interest to expedite project activities and start implementation as soon as possible. The Honorable Minister of Agriculture, Irrigation and Water Development has visited the project on two occasions. The impression he has shared with the public is that the works for the project will start early 2018 and was pushing for earlier start than early 2018. It is essential to keep the existing project momentum and positive spirit of starting the project early as expected by all stakeholders and beneficiaries. During the 7th to 18th November Joint World Bank, African Development Bank and FAO Mission, the following scenarios for implementation were reviewed:

1. Using PPP Procurement Arrangement
   a. Concession arrangement: A long term (20 year) agreement where the private operator designs, builds, operates, maintains and partially finances the bulk water infrastructure.
   b. Design, Built and Operate (DBO) arrangement: A medium to long term (10 - 20 year) agreement where the private operator designs, builds, operates and maintains, but does not finance part of the bulk water infrastructure.
2. Using Normal Public Procurement with management Contract Arrangement: Where the public authority designs and builds the infrastructure under traditional public procurement. A medium term (10-20 years) agreement is then put in place for the private sector to operate and maintain the assets through performance based payments
3. Using Normal Public Procurement Arrangement; As in item 2, but with the continuation of the TFS Consultant for undertaking the detail design.

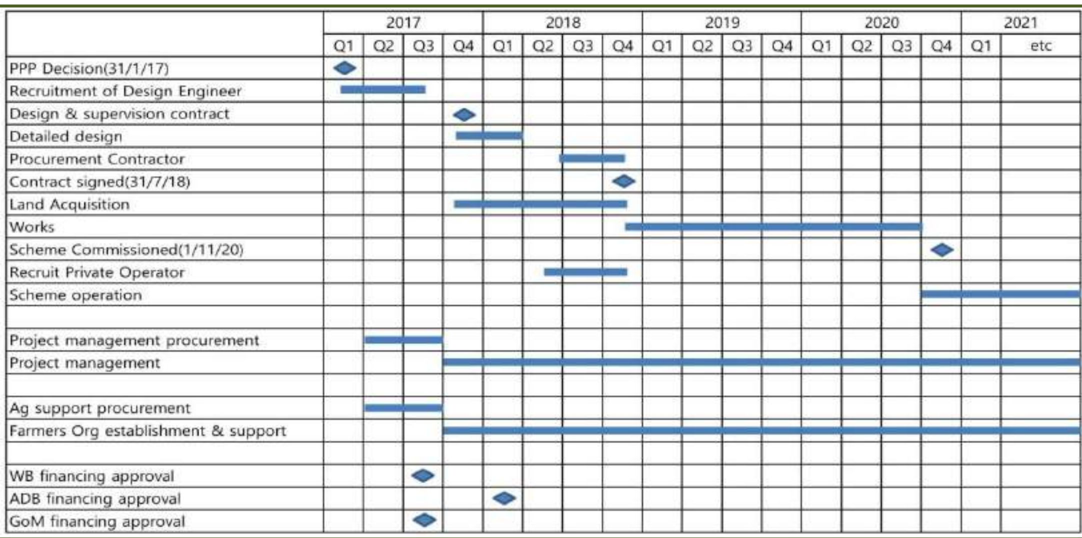
The first and second scenario were prepared by the mission and the third scenario was prepared by the Project Technical Team. All the scenarios have their advantages and disadvantages and there is need to review the scenarios carefully to appreciate the impact on timing for implementation. Figures 18.1-1 to 18.1-4 show the expected time lines under the different scenarios. The decision to start work soon lies with Government direction following review of the upper mentioned three scenarios.



[Figure 18.1-1] Concession



[Figure 18.1-2] Design Build Operate



[Figure 18.1-3] Traditional with Management Contract

[Figure 18.1-4] Traditional with Management Contract, but with TFS Consultant Continuing with the Detailed Design

[Table 18.1-1] Pros and Cons of the Different Scenarios

Scenario	Advantage	Disadvantage
PPP - Concession	• Possible to fill financing gap, • benefits to the project of whole life management	• Delay in start of implementation, • Risk of not finding a partner
PPP - DBO	• lower risk option for the private sector, • benefits to the project of whole life management	• Not possible to fill financing gap, • Delay in start of implementation, • Risk of not finding a partner
Public Procurement with Management Contract	• Less delay in project implementation, • Possible to have professional management	• Not possible to fill financing gap,
DITTO - Detail Design TFS Consultant	• The fastest scenario to start implementation, • Possible to have professional management	• Not possible to fill financing gap,

As seen from the above figures and table, the PPP option can help to get a partner that could contribute to the CAPEX and assist in filling the financing gap. Though the second scenario does not contribute to the CAPEX, the PPP-DBO option can offer a professional/reliable operation of the project. However, the procurement process is long for both PPP options. Moreover, due to the risk involved for the private sector there is high chance of not getting a partner. The main experience of PPP in Africa for irrigation is in Morocco. The lack of experience within the country for irrigation PPP means that the processes will take long because people will be very cautious with the new procedures. Countries that have undertaken implementation using PPP for irrigation in the World are few and this means competition will be limited. This will substantially delay the project implementation.

On the other hand, the process for going through the traditional public procurement arrangement is short but any financing gap for the project has to be filled by the government or by another source. Particularly, if the option of the Technical Feasibility Study Consultant, who has undertaken this Feasibility study is made to continue with the detail design, it would avoid the need to procure a design consultant which will take a minimum of 7 to 9 months. This would make the commencement date of project implementation to be even shorter (by almost one year than the PPP option).

In general, selection of the best option for the implementation of the project should be decided taking the following points into consideration:

1. Availability of a reliable private partner, through market sounding and having wide choice of selection for good competition,
2. Availability of funding to fill financing gap,
3. Adequate knowledge and experience by the borrower to be able to effectively supervise the whole process and acting without hesitation.
4. The recurrent draught and urgent needs of the farmers at Chikiwawa to address the need and pressure from the beneficiaries and politicians to quickly implement the project should be taken on board.

<u>Conclusion</u>

When all the factors are taken on board, it is noted that the fourth scenario has more advantages to the government in terms of addressing the pressing need for implementing the project expeditiously and that the government has adequate experience in handling public procurement.