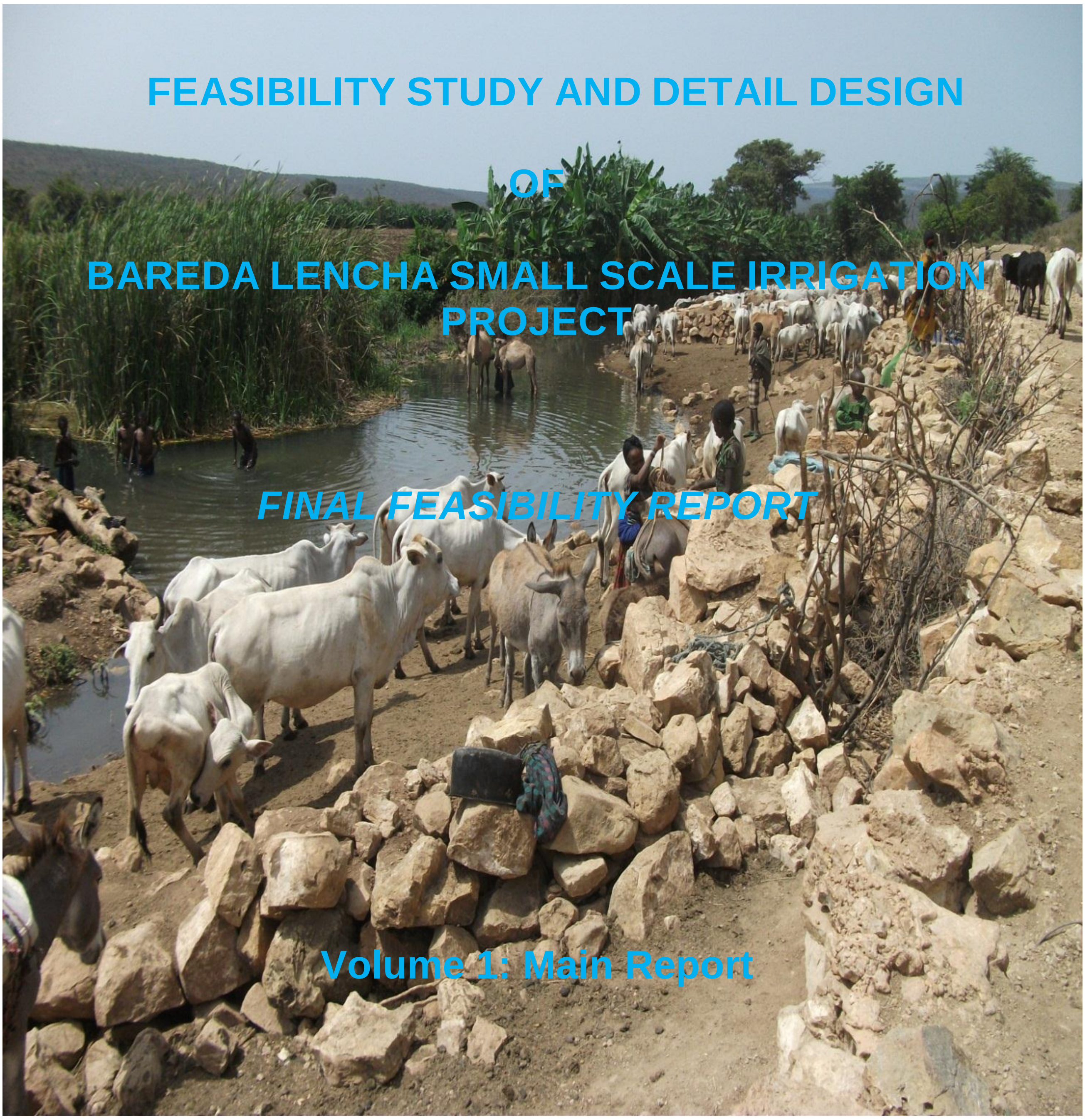
OROMIA WATER, MINERAL AND ENERGY BUREAU



FEASIBILITY STUDY AND DETAIL DESIGN

OF

BAREDA LENCHA SMALL SCALE IRRIGATION PROJECT

FINAL FEASIBILITY REPORT

Volume 1: Main Report

GENERATION INTEGRATED RURAL DEVELOPMENT CONSULTANT (GIRDC)

GIRDC
Commet Building (5th Floor)
H/Gebresilassie Road, Addis Ababa, Ethiopia
P.O.Box 322 Code 1250
Tel +251 (0) 116 63 15 90/91
girudco@ethionet.et

January 2013
Addis Ababa
Ethiopia

OROMIA WATER, MINERAL AND ENERGY BUREAU

FEASIBILITY STUDY AND DETAIL DESIGN OF BAREDA LENCHA SMALL SCALE IRRIGATION PROJECTS

FINAL FEASIBILITY REPORT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYM

A	Command Area
A_x	Canal Cross-sectional Area
a.s.l.	Above sea level
avg.	Average
B	Bank top width
b	Canal Bed Width
BC	Branch Canal
BL	Bareda Lencha
BOQ	Bill of Quantities
CBL	Canal Bed Level
CD	Collector Drain
CSA	Central Statistical Authority
CT	Cattle Trough
Ctd.	Continued
CWR	Crop Water Requirement
D	Canal depth including flow depth & FB
d	Flow depth
DBL	Design Bed Level
DEM	Digital Elevation Model
dev't	development
DS	Design Standard
ERA	Ethiopian Road Authority
ETB	Ethiopian Birr
ESRDF	Ethiopian Social Rehabilitation Development Fund
F	Furrow
FAO	Food and Agriculture Organization of the United Nations
FB	Free Board
FC	Field Canal
FD	Field Drain
FPE	Flood Protection Embankment
FSD	Feasibility Study and Detail design
FSL	Full Supply Level
GI	Galvanized Iron pipe
GIRDC	Generation Integrated Rural Development Consultant
GOV	Government
ha	hectare
hr	hour
IFAD	International Fund for Agriculture Development
LB	Left Bank
IRDMPSP	Integrated Resources Development Master Plan Study Project
l/c/d	Liter per capita per day
l/s	Liter per second
l/s/ha	Liter per second per hectare
IWR	Irrigation Water Requirement
LMR	Left side Main Road
LS	Livestock
LSIDP	Large Scale Irrigation and Drainage Project
LSR	Left side Service Road
LUT	Land Utilization Type
m^3/d	meter cube per day
m	Canal side slope
MC	Main Canal
MD	Main Drain
Min.	Minimum

Max.	Maximum
MFL	Maximum Flood Level
n	Manning's roughness coefficient
OWMEB	Oromia Water, Mineral and Energy Bureau
OGL	Original Ground Level
O&M	Operation and Maintenance
OP	Option
p	Wetted perimeter
PVC	Polyvinylchloride
Qd	Design Discharge
Qty.	Quantity
R	Hydraulic radius
RB	Right Bank
RBL	River Bed Level
RCC	Reinforced Concrete
RMR	Right side Main Road
RSR	Right side Service Road
RVLB	Rift Valley Lakes Basin
S	Canal bed slope
SC	Secondary Canal
SSIP	Small Scale Irrigation and Drainage Project
T	Canal top width
Tc	Time of Concentration
TC	Tertiary Canal
TD	Tertiary Drain
TOR	Terms of Reference
V	Flow velocity
Vs.	Versus
WUA	Water Users Association
WB	World Bank
WL	Water Level
WR	Water Requirement
WRB	World Reference Base
WS	Water Supply

1 BACKGROUND

1.1 INTRODUCTION

This is executive summary part of the final feasibility study and design report that presents Annex A: Main Report concentrating on ***only main study outputs*** for Bareda Lencha SSIP. Thus details of this summarized report are presented for each sector studies and can be referred in the separate annexed reports of relevant volumes.

The contract agreement for the study and design of this irrigation project is signed and entered on October 6th 2012 between the two parties: the client, OWMEB and the consultant, GIRDC. This project study is financed by International Fund for Agriculture Development (IFAD).

This modern irrigation project is studied and designed to feasibility level by GIRDC. The contract includes feasibility level to detail study and design level. This is the final feasibility study and design part thus detail study and design will be presented soon after approval of this final feasibility level study and design.

The nature of the project is small scale which is intended to be developed for smallholder farmers of the project area. There is intensive traditional irrigation experience in the project area for 24 hours of a day thus this project is not totally a new technology for the area, of-course it will introduce appropriate permanent regulating structures and other related infrastructures to improve efficiency of supply system and scale-up the project benefit.

This main report consisted of summarized study and design of:

- Socio economic study
- Soil Study
- Agronomy Study
- Watershed Study;
- Hydrology Study;
- Geology Study;
- Engineering Study and Design;
- Environmental Study;
- Financial and Economic Study
- In addition to this main report, there are ten separate annexed reports in three volumes.

In general, this report is summary of the separate annexed reports prepared and presented for this project. It encompasses a total of 13 separate sections each discussing specific ranges of matters and corresponding findings, the last section being incorporating details of supporting documents attached as appendix. Detailed contents of each of these sections are based on the assignments given in the terms of reference and acceptable standard guidelines of OBWME, MoWE and others known institutions like IFAD/FAO, WB.

Chapter-1: is the background section of the report where general information pertaining to this project such as objectives, accessibility, climate, vegetation, topography and soils, location, water and command resource potentials of the study area are briefly discussed.

Chapter-2: Summarizes findings of socio-economic study where existing basic socio-economic backgrounds of the beneficiary community have been studied, identified and made ready for other sectors study pertinent to this project.

Chapter-3: summarizes findings of a soil survey and land use and land cover assessment carried out in the project area in over a study area of 338 ha.

Chapter-4: describes assessments made in crop selection and designed cropping pattern on top of computation and analysis of crop water requirement and hence irrigation water requirement after combination of climate, soil data, crop data and the like from respective sector studies.

Chapter-5: addresses the degree of resource degradation in the catchment area and around the command area in order to investigate and introduce watershed rehabilitation interventions.

Chapter-6: describes assessments made and irrigation capacity of available water resource i.e. its potential.

Chapter-7: presents site investigation works carried out in the project area at the required sites like headwork, crossing sites and main canal routes.

Chapter-8: gives studies carried out for headwork of the project: namely, spring protection selection, design and stability analysis, and other structures for washing, bathing, and cattle trough. The main conveyance and on-farm structures of the project i.e. irrigation and drainage systems including on-farm structures layout and their hydraulic as well as structural design are well-thought-out. It also gives a framework of drainage systems in the project command area including external or natural and internal or designed drainage systems including protection works against floods coming from different potential sources either within or outside the command and their nature of overtopping banks during rainy seasons. This chapter also describes road network in and around the project area including access to the site and service road along secondary canals.

Chapter-9: highlights environmental Impacts and sustainability of the project which may be imposed owning to the interventions.

Chapter-10: gives summary of unit rate analysis, bill of quantities and engineering cost estimate for all Engineering items considered in the project activates.

Chapter-11: presents Financial Analysis and consequently viability of the project in-terms of financial feasibility.

Chapter-12: gives implementation schedule of the project by major activities.

Chapter-13: This section concludes the assessment and gives recommendations from the findings of the study and design of the whole aspects' of the project.

1.2 OBJECTIVES OF THE STUDY

This study has different objectives to realize fulfillment of feasibility and detail design of the project among which the followings can be mentioned:

i. To collect, process, analyze and depict baseline socio economic situation of the project area and reveal socio economic overview of existing situations, identify beneficiaries socio economic characteristic, identify basic economic and social problems/constraints and priority, development potentials and opportunities of proposed project impacts in alleviating many of the social and economic problems of the project area's agrarian communities and their attitude and contribution for implementation and sustainable operation of the irrigation system;

ii. Define, map, characterize (physically and chemically) and classify the soils of the site following the standard detailed soil survey methods using a survey intensity of one soil observation per 20 ha as a minimum and identify and map or delineate soil factors which restrict optimum production and recommend relevant ameliorative strategies and identify and map suitable area for irrigation development in the survey area;

iii. From existing socio-economic status of the project area, identify the limiting factors of the agricultural development; assess the suitability of the land resources for irrigation agriculture and identify promising types of crops potential to improve the livelihood of the beneficiaries as well as study the crop production that can increase quantity and quality to fulfill multiple demand of the direct and indire``````ct beneficiaries of the project beneficiaries;

iv. Assess the extent of resource degradation in order to launch watershed rehabilitation interventions using appropriate resource management techniques and conservation practices to conserve the upstream and protect the proposed downstream irrigation scheme;

v. Assess the hydro-meteorological conditions and water resource potential of the project area by estimating the rainfall amount in the project area, estimating evaporation and rainfall deficit, estimating the runoff at headwork sites, assessing upstream and downstream users for identifying water balance at the study area;

vi. Carryout site investigation for acquiring basic knowledge on geologic units and materials found and characterize the proposed site; identify materials covering and underlying the proposed headwork site and main canal route; outline foundation conditions at major structures; determine important geotechnical parameters so that it can be used for design of the intended structures and main canal route; and identify potential borrow and quarry sites that can be used as source for construction material;

vii. To study engineering aspects which is typically targeted to study, design and select optimum sizes and type of irrigation and drainage system layout including head work and on-farm structures so that it will be acceptable, easily manageable and economical without affecting achievement of the intended purposes;

viii. Undertake a comprehensive financial analysis of the project in terms of its viability so as to enable decision makers for its future implementation.

ix. Study environmental sustainability of the proposed project area to enable elimination and or minimization of possible negative impacts of the project through implementations of the recommended appropriate mitigation measures right from the project design to implementation and operation phases.

1.3 ACCESSIBILITY AND LOCATION

This irrigation project site is accessed from Addis Ababa through Adama (98km) – Chiro (326km) – Kulubi (466km) - Adele (510km which is a junction town) – Dawe (535km) – Kurfa (545km) - Bedeno (584km) – Burka (620km) towns. It is located at 32 km from Burka which means 652km from AA.

This access branches from the main AA-Harar asphalt road at Adele town (about 510km away from AA) to the right or south direction and is of gravel road. That is to say, the remaining 110 km road from Adele (or 127km from Harar) to Burka, i.e. Gola Oda Woreda capital is all weather road.

1.4 CLIMATE, VEGETATION, TOPOGRAPHY AND SOILS OF THE STUDY AREA

This project area is situated in a hot and arid climate with an average annual rainfall of just over 700 mm and average command elevation of 1115 m a.s.l. Long term mean minimum and maximum temperatures of the area however ranges from 13.2 ^{0}c in December to 33.6 ^{0}c in February. Its average temperature reaches 25 °C, which is therefore suitable for cash crop production. Average annual evapotranspiration estimated is 1836mm that varies almost uniformly with an average monthly value of 153 mm.
Valley banks along the study area is widely covered with bushes, interspersed mainly with patches of scrubland trees, of-course varying in density from thick bush by the river side to light bush elsewhere and occasionally open plains covered with widely spread acacia.

The soils in the study area are a mixture of stratified alluvium and colluvium and are not fully developed around riverine; there are extensive areas of outcrops and hard pans while moving away from the mother river, Mojo. There are also some heavy clay soils with vertic properties particularly in marginal drainage areas far downstream.

Topography and land slopes of the study area are also shown on Figure 1-1 and it clearly shows that plain (flat) land is centered towards the river banks and most part of the land is about 0-3% slope.

1.5 THE WATER RESOURCES

The major water resources potential in the study area are Mojo River and Mojo Gurati spring. This river was perennial in the past times but these days it is becoming intermittent and flashy. However, during rainy season, it overtops the banks and cause flooding problems in the command area. Source of water supply for the project is thus the spring which is perennial as informed by elders of the area. There are also seasonal streams bisecting the command area though not accountable as they are flashy and exist only in rainy seasons which of-course are used as source of spate irrigation whenever there is shortage of rainfall in the area.

1.6 THE COMMAND AREA

The command area is potentially immense. In view of that, the identified potential irrigable area for carrying out topographic survey was about 426 ha. The restrictive factor however is limited base flow of the source, Mojo Gurati Spring. And yet surveyed, this area as a result is carried down to 216 ha gross or 202 ha net for which infrastructure layout is done accordingly.

Figure 1-1: Location Map of the Project

2 SOCIO-ECONOMIC STUDY

2.1 RATIONALE

Government policy and development strategy gives due emphasis for agriculture sector development, water resource and irrigation development in particular as one the cutting edge to combat rainfall dependence of farmers and conceived as pillars for sustainable food security and alleviating food shortage and poverty. With this consent the regional states initiated study of several irrigation projects of which Bareda-Lencha irrigation project is one among those project identified for feasibility study.

2.2 OBJECTIVE

The overall objectives of the socio economic study is to collect, process, analyze and depict baseline socio economic situation of the project area.

2.3 METHODOLOGY

Different data collection approaches were applied to collect valuable and appropriate data. The approach includes review of secondary data and available report; discussion with relevant institutions, key informant interview, focus group discussion; community consultation, personal observation and site visiting. Community consultation through focus group discussion (Participatory rural appraisal (PRA) data collection techniques approach)used to obtain socioeconomic baseline information on existing agricultural practice and livelihood basis, socio-cultural, demographic issues, ethnic and religious composition of the people, land use pattern, major economic activities and social service provisions, anticipated positive and negative impacts of the proposed project.

2.4 SOCIO ECONOMIC FINDINGS

Bareda lencha irrigation project is located in Oromia Regional State, East Hrarghe Zone,Gola-Oda woreda, Bareda Lencha kebele about 34 km form Burka Woreda town.

2.5 POPULATION

East Haraghe zone has 19 woredas and the total population is projected to be 3,059,637 (CSA, statistical abstract, 2011). Gola-oda woreda constitutes 3.8% of the total East Hararghe population. The woreda is the largest with respect to land size (551.6km^2), but with the lowest population density (23.2 person/km2) compared to Haromaya woreda which is the highest population density 552.9 person/km2 in east Hararghe zone. Total number of household of Bereda-Lencha kebeleis 1474 which accounts 7.4% of woreda total population and female accounts about 49.7% of total population in the kebele.

With regards to population characteristics at project command area observed as homogeneous ethnic group of Oromo that has not made ethnic and socio-cultural diffusion of others. Similarly, homogeneous in religious and other cultural value and population in the project area belong to Muslim religion.

2.6 LAND HOLDING SIZE

The landhoding size of project area is ranging between 0.25- 2ha and the average farmland size is about 0.75ha.

2.7 COMMAND AREA AND BENEFICIARIES

Traditional irrigation use Guratti spring water source and traditional irrigation amounts over 100 hectares and the proposed irrigation project is expected to develop 202 ha with improved irrigation infrastructure. The estimated beneficiaries of the intended irrigation project are 270 households.

2.8 ECONOMIC ACTIVITIES

In general, agriculture (crop production and livestock husbandry) is the mainstay of the economy of the Gola-Oda woreda and Bareda lencha kebele. Crop production contributes contribute the major livelihood basis and food source. As estimated about 70% of the household economy depends on crop and farm activities and the remaining 30% derived from livestock as supplementary economic activities. Both rainfed and irrigated crop production practiced. Variety of crops adaptable to grow at the project area includes Maize, sorghum, Banana, ground nuts, Sugar cane and chat.

2.9 TRADITIONAL IRRIGATION EXPERIENCE

Traditional irrigation exists since long years of time immemorial and probably five to six generation as explained by the community group. Existing traditional irrigation schemes are managed by local leaders. Traditional irrigation use Guratti spring water source and traditional irrigation amounts about 170 hectares. Traditional weir site are constructed and made by local materials mainly wood, banana leafs and stone band. As indicated by farmers group, these traditional structures damage and taken away by flood each rainy season and exploiting their labor and time, causing loss of energy and labor productivity as well as misuse/ inefficient utilization of water and agricultural and community expressed high interest and desire and the positive attitude towards the project implementation is highly related to long years traditional irrigation experience and understanding of benefit and contribution from irrigation and expectation to achieve improved irrigation system.

2.10 INFRASTRUCTURE STATUS

As the project area is located long distance from woreda town and, basic social service needs concerted for improvement mainly access road / transportation, and there is no school and education service for girls and boys after 4th grade, health service mainly health center is located distance from the project area and hospital access is almost unthinkable at existing condition. The health access at project area is limited to health post, but the services have inadequate for various reasons.

Market roots and destination is very limited at current time, but good opportunity that road access is on construction that link the project area with woreda town. The area is currently in food shortage and high food demand and market problem in the short term is not expected. However, in the medium to long term period high production expected, but still low urban population and the woreda market and people purchasing power is low and needs to create market arrangement with traders for product marketing to Harer, Diredowa and other domestic market.

In addition, telephone service/ICT/Internet service, electricity is not accessible at project area and even some of these services are not accessible at woreda town. Thus, there is urgent need for the improvement and extension of basic infrastructures in the sphere of road, transport and communication.

Project social issue related to the project also assessed to minimize social impact, if any to arise. The settlement pattern of the study area is scattered at the hill edge mostly outside command area and people displacement is not expected due to the project and no social cost involved. Human and animal water demand, as well as upper and downstream users investigated and proposed to be taken into consideration in design of the project.

Proposed projects is planned in drought prone characterized erratic rainfall areas and demand driven, good traditional practice, strong local responsiveness, land and water resource available, etc. and socially feasible for implementation.

3 SOIL STUDY

3.1 GENERAL

This report presented the findings of a soil survey and land use and land cover assessment carried out at the project site in over a study area of 338 ha.

3.2 METHODOLOGY

This survey is intended to provide feasibility and detailed level information assessment about the land and soils of the area and then analyze and evaluate the suitability of the land for irrigated agricultural development. This helps to identify potentials and constraints of the area and assigning the lands for its best use through land evaluation. In view of this, the soil survey of this irrigation Project is undertaken at scale of 1:20,000.

The field survey for this assessment was carried out using the established transect of 500 m by 400 m for auger observation. Mapping of distribution of the soil type and soil mapping units of the study area through soil boundary delineations was made using the collected auger observation data, satellite imagery interpretation, and additional field visit within the study area. Representative sites for profile pits, infiltration and hydraulic conductivity test were selected and the necessary observations were taken for each soil mapping unit. The soil classification was then carried out using the revised world reference base for soil resources (WRB, 2006).

3.3 SOIL STUDY FINDINGS

3.3.1 Land use land cover

The major land use and land cover of the area is characterized by intensive perennial and annual crop production. Irrigated crop production is practiced by smallholders. Maize, Banana, Chat, sugar cane and sweet potato are the main cultivation both under rainfed and irrigated conditions where maize and chat takes the largest area coverage. The land along the river channels and periphery of Mojo River is mainly used for Banana and sugar cane production. (For details, refer Annex-B: Soil and Land Suitability).

3.3.2 Soil

Based on the procedures and methods of soil classification, two major soil types were identified in the study area having varying areal extent and distribution. These are Cambisols and Luvisols which are classified in two soil series as Haplic Cambisol (Chromic) and Cutanic Luvisols (Humic) having area coverage of 77 ha (23%) and 243 ha (72%) respectively. Soil of the study area were mapped in to four soil mapping units (SMU1, SMU2, SMU3 and SMU4) and one river bank based on those parameters of the soils important for use and management such as slope percent, effective depth and texture. SMU1 and SMU2 are Cutanic Luvisols developed on slope of 0-2% and 2-5% respectively and they are characterized by a very deep, darkish or over dark brown color and clay to loam textured soil. SMU3 and SMU4 are Haplic Cambisols on slope of 0-2% and 2-5% respectively. These soils are characterized by a very deep, dark reddish or brown over reddish brown or dark reddish brown color and clay to clay loam textured soil. Land associated with river and river courses of complex soil and cannot be mapped in each of the soil mapping unit was mapped as river bank.

3.3.3 Land suitability

Land suitability evaluation for surface irrigation was performed by matching and super imposing of the land use requirements and critical class limits with the soil and land characteristics and limiting factors of the SMU. As a result soils of the study area have remarkable potential for irrigated agriculture with surface irrigation. Accordingly, the intended project area is found to be moderately suitable for surface irrigation (Table 3.1). Similarly, land suitability evaluation for selected crops was also done and it is found that most soil of the study area is moderately suitable for Maize, Onion, Tomato, Haricot bean and Banana. The suitability result showed that most of the correctable limiting constraints of the land units are nutrient availability expressed as shortage of total nitrogen which could be amended through nitrogen rich fertilizer such as Urea.

Table 3-1: Results of surface irrigation suitability evaluation

SMU	Suitability under proposed irrigation	Area (ha)	Area (%)
SMU1	S2txp	147.65	43.84
SMU2	S2tp	93.95	27.89
SMU3	S2ip	49.48	14.69
SMU4	S2rip	28.31	8.41
River bank	N	18.61	5.17

Figure 3-1: Land Suitability Map of the Study Area

4 AGRONOMY STUDY

4.1 CROP SELECTION AND CROPPING PATTERN

Bereda Lencha small-scale irrigation project is one of the modern irrigation interventions designed to alleviate poverty and ensure sustainable development in Bereda lencha Kebele of Gola Oda Wereda. It's part of the five-year growth and transformation development plan to address the agro-pastoral communities have been affected by natural hazard mainly shortage of rainfall and drought. The project area is warm moist lowland area endowed with bi-modal rainfall pattern locally named Gena and Bona seasons. Maize based mixed farming system is the dominant farming has been supported by traditional irrigation scheme to cope the intermittent and inadequate rainfall distribution.

The wereda data indicate that in project kebeles about 441 ha of land is cultivating under irrigated agriculture producing maize, sweet potato, banana and chat. The area has less than 120 length of growing period. The cropping pattern of the irrigation farming in the project area depict maize crop covers more than 85% total irrigated land and perennial crops occupy insignificant land area due to irrigation water and their importance in food basket of the community. The area has an average annual rainfall of 706 mm with average temperature of 25.2^{0}C and endowed with Luvisos soils characterized by clay and clay loam soil structure, which is suitable for most crops.

Agricultural activities in project area are entirely traditional using oxen power for ploughing and the communities have not experienced in modern input utilization. Artificial fertilizers are introduced this year to the raea and agro-chemicals are known by the beneficiaries despite high demand in the farming system because of low capacity of the cropping system to fulfill basic needs of the community. Farm labour is not scarce resource, in case of labor shortage they use labour to land (use right) exchange arrangements.

Despite low yield of staple crops the community involving in irrigation agriculture found in better condition to meet their needs as the result Bereda Lench kebele is found one of the least supported kebeles food aid and safety-net program. Based on community estimates maize yield ranges between 15 to 20 qt/ha, which is very low figure compare to the potential of improved maize seeds that can give up to 60 to 80 qt/ha under irrigation with smallholder management.

In order to revert the food insecurity situation in potential part of the Bereda Lencha kebele, Guriti perennial spring is proposed to develop modern irrigation scheme to support the rural communities ensuring sustainable agriculture and multifaceted rural development. Diverting part of the water flow from Gurati spring without affecting other benefits like human and livestock drink, sanitary and social services it will irrigate about 202 ha of irrigable land to address about 300 households.

The intended small-scale irrigation project proposes appropriate crop development interventions taking into account the existing agricultural resources and possible potentials to attain food security and sustainable development under irrigated farming. In reference to the project objectives and available resources suitable crops are selected and incorporated in suggested cropping pattern. The proposed cropping system has 200% cropping intensity all irrigable land will be cultivated twice a year under full irrigation and supplementary irrigation conditions. The cropping pattern encompasses six potential annual and perennial crops namely maize, haricot bean, onion, tomato, chat, and banana. The latter two crops are included to maintain the existing experience due to their social and economic importance. According to the proposed cropping pattern, maize will be major crop in both seasons because of multifaceted benefits for the community, the prior importance is securing food security using for home consumption and the surplus produce could be sold for income generation. Most importantly maize growing during dry season is mainly for market because of short supply of maize grain in off-season. The remaining crops onion and tomato area potential cash crops significantly enhance household income. Haricot bean is also planned to create opportunity to sustain the household income by supplying for domestic and export markets depend on the produce quality and care given to the production system.

Furrow irrigation application is recommended for the SSI project with peak duty of 0.67 lt/s/ha; January, February and March are most water demanding months of dry season cropping; similarly during wet cropping season the demand for irrigation water increased in August and September.

According to the proposed crop production development, the project will produce about 26,311 qt of different produce through modern irrigation agriculture and improved farm management with appropriate agricultural inputs. This study proposed appropriate inputs to secure the optimum yield from high yielding variety of proposed crops except chat plant.

4.2 CROP WATER REQUIREMENT

Crop water requirement is computed using CROPWAT8 and results are presented in detail in Annex-F: Irrigation Agronomy Report. However, summary of Crop water requirement is shown in table 4-1 below.

Table 4-1: Summary of Crop Water Requirement of BL Irrigation Project

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (mm)
A. Precipitation deficit													
1. Maize (Grain)	130.7	167.7	159.7	17.7	0	0	0	0	0	0	9.3	56.1	541.2
2. Chat	132.5	132.1	132.8	90.9	97.7	106.2	78.4	72	75.4	117.9	135.9	140.5	1,312.3
3. Banana	139.8	152.9	160.1	122.6	19	35.2	22.1	11.7	23.7	78.7	115.3	137.6	1,018.7
4. Onion	162.9	147.5	35.4	0	0	0	0	0	0	0	67.8	162.2	575.8
5. Tomato	162.6	144.6	15	0	0	0	0	0	0	0	49.8	129.7	501.7
6. Haricot bean R	0	0	0	0	0	18.4	68.1	111.7	55.5	0	0	0	253.7
7. Maize Rain	0	0	0	0	0	18.2	47.8	115.6	115.1	53.8	0	0	350.5
8. Haricot bean	142	157.2	37.6	0	0	0	0	0	0	0	0	48.8	385.6
B. Net scheme irr. req.													
-in mm/day	4.5	5.7	3.2	0.5	0.2	0.8	1.7	3.6	3.5	1.6	0.8	2.5	28.6
-in mm/month	140.1	158.6	97.7	15	5.3	23	51.5	110.8	103.5	50.5	24	76.3	856.3
													Average
-in l/s/h	0.52	0.66	0.36	0.06	0.02	0.09	0.19	0.41	0.4	0.19	0.09	0.28	0.27
C. Irrigated area (% of total area)	100	100	100	52	7	100	100	100	100	87	70	100	84.67
D. Irr. req. for actual area, (l/s/h)	0.52	**0.67**	0.36	0.11	0.28	0.09	0.19	0.41	0.4	0.22	0.13	0.28	0.31

Source: Agronomy Study Report of the same Project, 2012

4.3 IRRIGATION WATER REQUIREMENT

Irrigation water requirement of Bareda Lencha irrigation project is computed based on effective rainfall of Burka meteorological station as there is no data on the spot. This station is at 14km air distance from the project headwork site and both the project and station are located in the same zone of areal rainfall.

Mean monthly rainfall and effective rainfall distribution as compared to mean monthly evapotranspiration at the project site is shown graphically in Table 4-2 below.

Table 4-2: Monthly Mean and Effective rainfall distribution and NIR (mm) Vs. ETo at the project site

S/N	Description	Months												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	ETo (mm)	140.4	142.2	160.9	159.9	165.2	144.3	139.5	157.8	144.3	163.4	157.8	160.9	**1836.64**
2	Mean Monthly RF (mm)	23.3	10.3	79.7	119.9	114.2	77.6	158.6	196.3	150.9	76.4	28.7	24.6	**1060.46**
3	Effective RF (mm)	0	0	18.3	49.8	49.2	24	49.4	65.8	54.8	25.4	3.9	0	**340.60**
4	Nr. of Days in a Month	31	28	31	30	31	30	31	31	30	31	30	31	**365**
5	Overall NIR (mm)	152.4	161.5	84.3	6.8	5.3	25.3	81.2	113.7	58.6	10.7	27.0	86.9	**813**.7
6	Overall NIR (mm/Day)	4.9	5.8	2.7	0.2	0.2	0.8	2.6	3.7	2.0	0.3	0.9	2.8	Avg.= 2.24

Source: As analyzed from Climatic Data (Hydrology Report) of the Project Area

As it can be observed from this table and figure 4-1, evapotranspiration is distributed almost uniformly throughout the year with an average value of 153.05 mm per month exceeding effective RF thus irrigation will be required accordingly, though the demand varies from month to month depending on cropping pattern and intensity. Hence, this irrigation can be taken as a supplementary during rainy season and full irrigation during dry periods of the season.

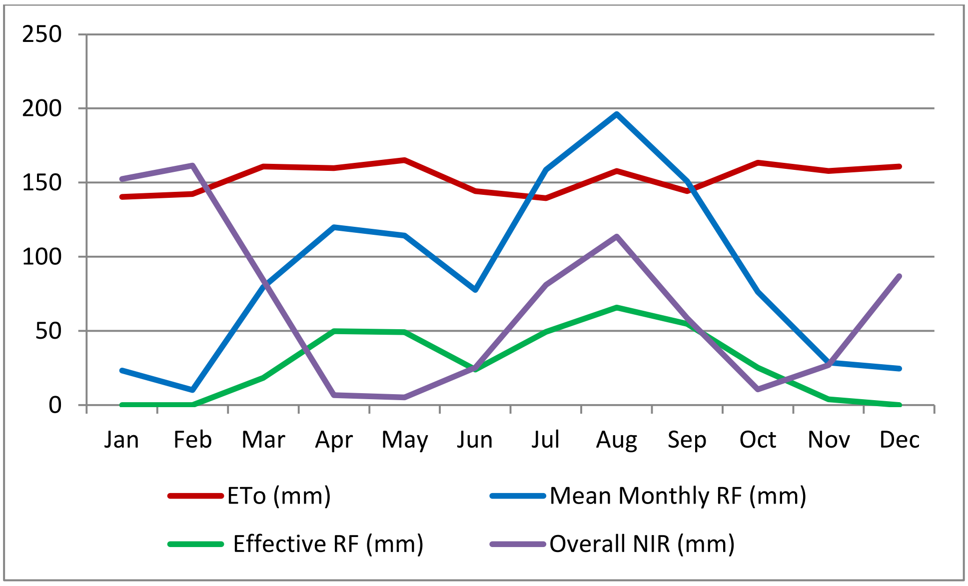


Figure 4-1: Monthly Mean and Effective rainfall distribution and NIR (mm) as Compared to ETo at the project site

4.4 COMPARISON OF IRRIGATION METHODS

There are many factors considered before selecting a particular irrigation method. These include availability of water resources, smoothness/roughness of topography, soils, climate, type of crops to be grown, availability and cost of capital and labour, type and appropriateness of a particular irrigation technology to the area and its associated energy requirements, water use efficiencies, as well as socio-economic, health and environmental aspects.

However, the TOR demands for designing main canals, to address potential command and beneficiaries and maintain equitable use of water in the water-shade (both in the right and left).

Moreover, this study area is located in a very flat land (where 0-3% slope accounts fort 47% of the area). Similarly, there is no any settlement in it; thus surface irrigation method by furrow irrigation application is considered as it is also proposed and agreed in the inception phase.

Table 4-3: Analysis of Gravity and Pressure Irrigation Methods Studied for the Project Area

S/N	Evaluation Factors	Application category		Remark
		Surface	Pressurized	
1	Technical			
	1.1 Water			
	1.1.1 quantity	high	low	Surface application in this area requires much more water than pressurized against limited source of water
	1.1.2 quality			
	Resistance to salinity,	low	high	Since there will be limited flow in pressurized system it can relatively resist as it is localized and rated as compared to surface application
	Developing potential of salinity,	high	low	Pressurized system especially drip can relatively resist since it is localized
	Resistance to sediment load	high	low	Pressurized system especially drip can easily be clogged thus surface application is more resistant
	1.1.3 Cost of delivery system	low	high	Surface system is cheaper than pressurized
	Sensitivity to soil type, depth etc.	high	low	Surface system leads to high runoff & hence drainage if soil is shallow. Infiltration rate of soil affects length of run & size of borders, furrows & basins as well as application rates from sprinkler. The more drainable soil the more is suitable for surface application.
	System Operation and maintenance	low	high	Pressurized system needs frequent replacement and service of on-farm equipment
	1.4 Topography/Land leveling	high	not necessarily	Land slopes limit selection of surface irrigation systems as it affects the length of run and the labor required for the operation of the system.
2	Social aspects			
	2.1 Acceptability	high	low	Until pressurized system is acquainted and beneficiaries understand their difference, it may take some time
	2.2 Affordability	high	low	Conventional experience of surface is there
	2.3 Manageability	low	high	Pressurized systems can be controlled easily than surface but require skilled operator
3	Climate and crop			
	Sensitivity to change of climate	high	low	Pressurized system requires relatively low volume of water thus able to compete with the physical constraints prevailing at the farm.
	3.2 Sensitivity to type of crop	high	low	Marketable & economic returns. Volume of water required is relatively high in surface system per crop type. Most vegetable crops have a shallow effective root zone depth & respond better to low moisture depletion levels. Consequently, irrigation systems that can provide small amounts of water at short intervals are preferred.
	3.3 Yield potential	low	high	Pressurized system yields 10 to 45% fold if handled as per design
4	Environmental			

S/N	Evaluation Factors	Application category		Remark
		Surface	Pressurized	
	4.1 Improve health,	low	high	bring socio-economic significant development
	4.2 Introduce health hazards	high	low	Ponding of water promotes diseases, such as malaria for surface application, introduce deterioration of biodiversity
	4.3 Drainage requirement	high	low	Surface application requires more drainage than pressurized.
5	Economic viability			
	5.1 Capital requirement	low	high	Costs of irrigation systems increase with the level of sophistication of water control means and the provision of components reducing the labor requirements. Man-hours needed in the piped systems range from one-tenth to one-quarter of those required for open canals.
	5.2 Labor requirement			
	5.2.1 Large number of labor	high	low	
	5.2.1 Skilled labor	basic	important	Any person can easily operate the piped systems since it is tape operated, while open canals can require skilled labor for it is operated by gates.
6	Energy requirement			Energy required for manufacturing, transport and installation of the various irrigation systems increases in the order of surface, drip, and sprinkler.

Source: Adopted from Feasibility Study and Design Report of Sego Irrigation and Drainage Project, 2010 (Unpublished)

5 WATERSHED STUDY

5.1 GENERAL

The OWMEB has launched a development plan through small scale irrigation development by assisting and irrigation management practices and the promotion of modern irrigation systems. In the study of irrigation project integrated watershed management should be also included for safe and sustainable management of the irrigation development as upstream activities affect downstream

Bereda lencha irrigation development is one of the projects where study of the integrated watershed management considers Mojo watershed which is the immediate catchments for the irrigation command area. The study comprises 74,707 ha of Mojo watershed.

5.2 IDENTIFIED WATERSHEDS

In addition to field assessment, existing data were collected from different offices that can be used for characterization of the watershed and setting strategic planning. Then the watershed was classified in to broader sub watershed and characterized by topography, soil type, erosion status and land use land cover and soil and water conservation was recommended in micro watershed level.

5.3 FEATURES OF IDENTIFIED WATERSHEDS

Generally topography of the watershed is dominated by undulating to very steep slopping land where moderately steep land takes the largest coverage (32.23%) and land cover is dominantly dense shrub cover. Cambisols, Luvisols and Vertiosls form the major soil of the watershed where more than 64% of the watershed is dominated with Cambisols. About 26% of the watershed is under cultivation including slopping lands on which soil erosion is accelerated. Broader sub watershed in the upper, central and lower edge of the watershed is highly to severely eroded especially in sub watersheds Upper Mojo1, Upper Mojo2, Chulul, Sede, Lower Deneba1, Lower Mojo2, Lower Mojo4 , Middle Denebe1, Middle Deneba2 and Middle Mojo5. Based on erosion status and slope of land structural and biological soil and water conservation measures were proposed for each micro watershed including cost of each measure suggested. Land capability classification for soil and water conservation requirement was also done for the whole watershed and it is found that currently most area of the watershed is miss-used where lands not suitable agriculture is being cultivated.

6 HYDROLOGY STUDY

6.1 HYDRO-METEOROLOGY

Meteorological and Hydrological data are essential elements in design of the storage dam, irrigation system, and flood protection works. The major parameters that derived from these data are minimum, mean and maximum flows of the river, water level of reservoirs, and the amount of water that can be diverted for the purpose of different uses. Based on this general concept, this report presented as the part of the feasibility and detail design study of Bereada Lench Small Scale Irrigation project, which is located in Oromia Region Easter Haragae Zone, Gola Oda Woreda. Geographical the spring site, which is the source of water for Irrigation purpose, is located at 41^{0}42'8.81" E longitude and 8^{0}44'12.16"N latitude

The catchment area prevailing to the spring site is computed as 210.11 sqkm, in Mojoargati River. Since the source of water is the spring we are not much on the computation of the catchment area as well as related flow parameters. Its altitude range is varying from 3320m a.s.l. at the high tip of the catchment to 1131m a.s.l. at the spring site. The catchment is also characterized with three soil type class and three land use classes. However it is dominated by Rendzic Leptosols and moderately cultivated area.

The climate of the country is mainly controlled by the seasonal migration of the Inter-tropical Convergence Zone (ITCZ), which is conditioned by the convergence of trade winds of the northern and southern hemisphere and the associated atmosphere circulation. Due to these factors the climatic variation of the country classified into four main seasons. Similarly the traditional climatic classification also implemented to describe the climatic condition of the project area and classified into classified into three climatic zones as Kola, Weyna Dega, and Dega, with 32.97%, 61.03%, and 6% area share respectively. Further the climatic area is summarized with the CROPWAT 8 environment and used to compute the potential evapotranspiration (ETo) in a monthly based and its mean montly ETo is 144.3mm at the command area.

Based on stations distribution map of NMA, Eight Meteorological stations are selected in rainfall analysis and their daily rainfall data is collected from Ethiopian Meteorological stations Agency. The normal ratio method and the double mass curve method are used for the gap filling and consistency test of the rainfall data in these stations. Based on monthly rainfall analysis the catchment is classified into bi-model rainfall regimes with two highest rainfalls at March/April and August. The point data that collected at stations are distributed as areal data using Thiessen Polygon method and the mean monthly areal rainfall for the catchment area and command area also computed and presented below in the table.

Table 6-1: Mean Monthly Areal Rainfall (mm) for Catchment and Command Areas

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Catchment	14.9	7.2	58.2	117.1	129.1	77.0	120.6	130.9	132.7	78.0	36.0	19.1	920.73
Command	13.4	7.7	47.2	92.2	91.5	56.6	91.8	112.3	98.5	59.0	23.1	13.4	706.6

6.2 LOW FLOW

Low flow analysis is an important element of hydrological analysis especially for the one who deals for the abstraction of water for different use without utilization of storage facility. In this project the amount of spring release is taking as dependable water for Irrigation purpose. Since there is no any measured data for the spring flow, the dependable flow is computed using Boussinesq equation and it is estimated as $0.198m^3$/sec.

6.3 CROSS DRAINAGE

In the project area, there are several cross drainage locations that the main canals need to cross however some these natural streams can be combined and allowed to cross together. One of them is the Mojo River, which has the biggest drainage catchment. Since all the cross drainage points have a catchment area more than 0.5sq km, we used SCS Method to compute the design flood. Based on the above method design flood for each cross drainage points for different return period are computed. (Refer Annex-A: Climate and Water Resource).

6.4 FIELD DRAINAGE

The amount of water in the field drain can be estimated in difference methods and set as drainage module. In this project use the maximum 24hr gap between the evapotranspiration and precipitation at the command area as drainage module. And it is 382mm in 24hr.

6.5 CONCLUSION

Using the eight meteorological stations and by filling the missing data in this stations using normal ratio method the rainfall data is computed and used for further analysis, which give reasonable information for the irrigation project going to design and implemented.

Even though there no sufficient hydrological gauging stations for spring flow the estimated flow using different hydrological techniques, which gives acceptable result for the design of the Irrigation project

Although the project area is characterized by the high bi-annual rainfall, it clearly shows that decreasing trend in the amount stream flow, which prevail the recharge of the spring. So it is good to consider the use of different storage structure for sustainable irrigation project in the area.

7 GEOLOGY STUDY

7.1 BACKGROUND

The present geotechnical site investigation work has been conducted as part of Bereda Lencha small scale irrigation development project. During the present study the site investigation works done includes engineering geological mapping of materials and geotechnical site investigation works. This is in order to asses, identify and outline site geology setting and determine important property of materials with respect to the intended project.

7.2 GEOLOGY

Based on the present investigation, the project area is found being characterised by different geologic materials. These are the unconsolidated soil overburden deposit and bed rock units. The unconsolidated soil overburden deposits are alluvium including River deposits, residual and colluvial deposit. The bed rock unit found in the area is exclusively the Mesozoic sedimentary Carbonate rock unit...

7.3 HYDROGEOLOGY

The project area is characterised by extensive aquifers with karistic permeability. There is no any ground water well developed in the area. However, based on the prevailing hydrogeologic setting, the area is found to be characterised by moderate to high ground water potential.

The expected high ground water potential is associated with the prevailing karstic carbonate rock unit. The proposed water supply source for irrigation is from the prevailing high discharge spring that is hosted by karstic carbonate rock unit. Such spring aquifer is the solution cavity/karst that appears on the surface due to the sinkhole that is connected to the surface resulting the spring water flow at the surface. A water sample has been collected from the prevailing spring in the area. The sample has been sent to the central water laboratory of WWDSE for the required physio – chemical analysis. The test has been conducted and analysed accordingly. Based on the test result, the TDS (Total Dissolved Solids) value recorded is 560mgg/l. This is of less concentration and within good range. The Ph value is 6.65 and overall result indicates that the water is within acceptable limit of WHO and Ethiopian Guidelines for drinking water.

7.4 GEOTECHNICAL INVESTIGATION

The present site investigation work has been conducted in compliance to the extent degree and complexity of the intended irrigation scheme and structure to be constructed.

Accordingly, during the present site investigation works the level of detail has been limited to surface and sub – surface mapping of materials using pits and auguring. Drilling of boreholes has not been accomplished. Depth of excavation and auguring was in the order of 3mts.

Field assessment and identification of materials has been conducted following the standard procedures for naming and classifying materials (BS 5930:1981). In addition, laboratory test and analysis has been conducted on selected and representative soil and surface water samples collected from the site of interest Furthermore, potential borrow and quarry sites have been assessed and identified in the project site and close vicinity. The sites have been delineated for use as source of rock for mason and aggregate, sand, embankment and fill materials during construction.

The main geotechnical units found at the headwork site and along the main irrigation cannel routes are loose unconsolidated Gravely SAND with silty clay soil mixes; stiff dark grey Clayey sandy SILT to Silty CLAY of intermediate to high plasticity; Stiff Reddish brown to dark brown sandy clayey silt to silty clay and boulder to gravel size rock fragments. Such geotechnical units are with varying geotechnical properties and hence with different parameters. Main interest regarding the headwork site and proposed irrigation command area is foundation bearing capacity, embankment stability and water tightness. Such properties have been properly assessed and determined based on in – situ tests, laboratory test and analysis.

7.5 IRRIGATION WATER QUALITY

During the present study, a surface water sample had been collected from the stream proposed for the irrigation water supply source. Accordingly, the required physio – chemical test and analysis has been conducted at the central water laboratory of Water Works Design and Supervision Enterprise. Based on the laboratory water quality test result, concentration of pertinent ions required for calculation has been extracted and calculated. Accordingly, the calculated and obtained for SAR becomes 1.53. Such a value classifies the water under Low Sodium water. Based on the norms specified, it can be used for irrigation in almost all soils and for almost all crops except those which are highly sensitive to sodium such as stone fruit trees and avocado, etc.

7.6 RECOMMENDATION

The headwork site east bank is characterised by dark grey silty clay soil of intermediate to high plasticity. It tends to be compressible. Hence it shall be properly compacted prior to construction. It is better if such soil material at foundation depth is replaced by sound rock fragments for thickness in the order of 0.5mts to increase foundation bearing capacity. Such rock fragment shall be properly compacted. To this foundation depth could be in the order of 1.5mts.

The proposed headwork site west side is characterised by rock fragments underlain by sound bed rock material. To this, the prevailing loose bouldery and coble rock fragments shall be well compacted. The foundation depth could be in the order of 0.5 to 1mts.

The material found along the main canal route is silty clay to clayey silt with occasional sandy material mixes. Such soil material is relatively impervious that would not cause excess leakage. Hence it is unlikely to use lining and no need for lining such cannel route. During construction of the canal line, the need for proper compaction and densification of the soil material is recommendable to increase water tightness and embankment shear strength.

Close follow - up and supervision works shall be conducted by assigning competent geologist at the site of interest

8 ENGINEERING STUDY AND DESIGN

8.1 THE HEADWORK

8.1.1 Headwork & Appurtenance Structures Arrangement

The source of irrigation water supply for this project is Mojo Gurati spring. This spring has been used for different purposes including source of water supply but not yet capped. Consequently, it is exposed for contamination and wastage and thus it needs a protection headwork which also supplies irrigation water both in left and right main canals. This headwork is located on spring eye and geographically it is situated at 797725m Easting, and 966783m Northing on the right side of Mojo River. It comprises other subsidiary structures among which protection work, outlet structure, cattle trough, and bath and washing basin can be mentioned. This headwork is intended not for storage but guiding flow to the designed intakes and hence the right and left main canals.

8.1.2 Site Works

General
Site work could be required before, during, and after construction of the spring protection work. Among these is fence work to be sited around the spring eye to prevent contamination from local animals. The site has also a slope along drainage channel sufficient to dispose of stored surface water from the spring eye. However elders of the area have told the study team that it is too deep below OGL to get eye of the spring.

Fence Work
The surrounding of the spring is designed to be fenced with a 30 m by 20 m wire meshed poles made of C-25 reinforced concrete to prevent animals and children from entrance. Thus, fence here is designed to be made of high and sturdy enough mass concrete to prevent the entrance of any animals commonly existent in and around the project headwork site.

These poles will be of 1.8 m long on the surface and 0.6-0.7 m deep depending on soil nature underneath. It will also have grooves spaced at 30 cm interval to which wire mesh will be tied and spacing between poles of 1 m, giving a total of 102 poles.

For this purpose provide a wire meshed fence of 2m high for a 9m clearance around the Mojo Gurati Spring eye. Poles should be spaced at 1m interval and made of mass concrete reinforced with 10mm diameter bar. It should also be buried below OGL for a minimum of 0.5m depth on the road side and 1m on the downstream side.

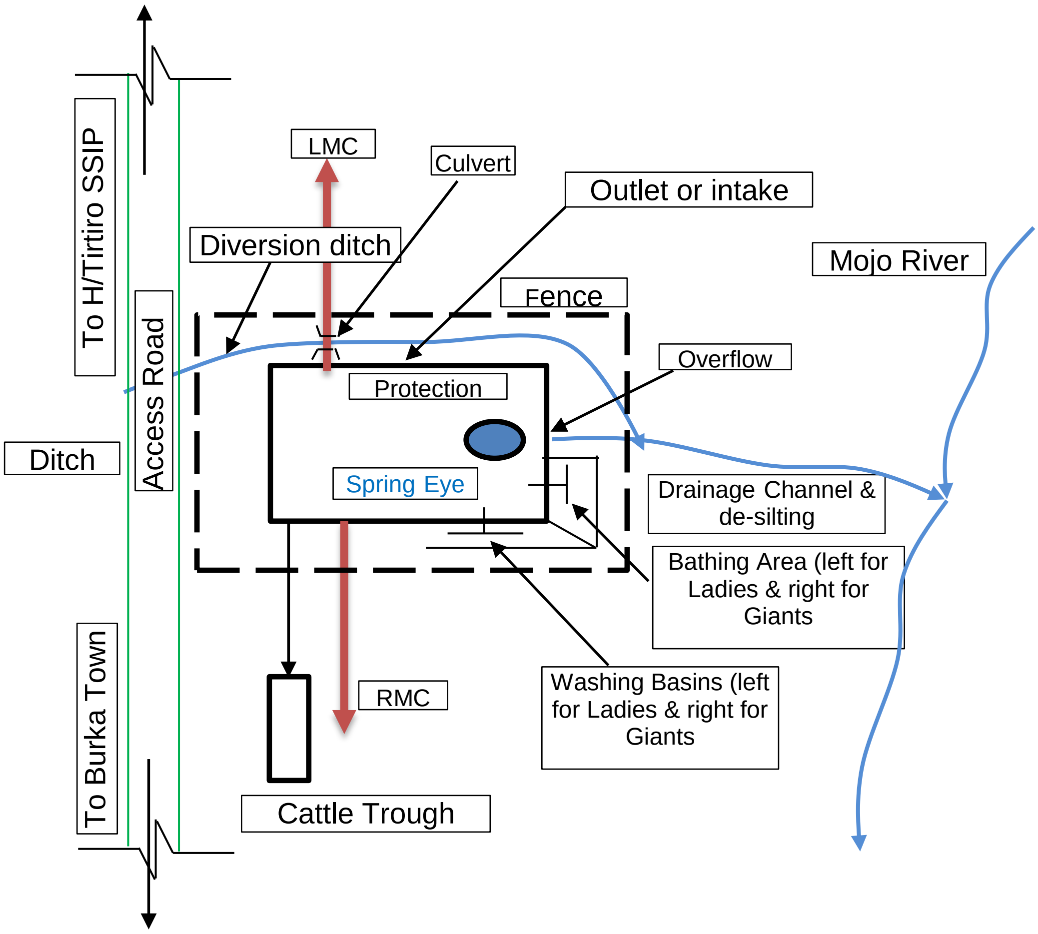


Figure 8-1Schematic Layout of Headwork of Mojo Gurati Spring

Figure 8-2: The Spring Eye & Traditional Protection work around the spring

1.1.1 Design of Spring Protection

General

Water from this spring is flowing in different directions. Thus water which previously flows out randomly in almost all directions needs to be collected and directed to the required ways/outlets by a protection structure.

The command area to be irrigated in this project is large enough and is situated at the mouth and bottom of Mojo River valley. However, available base flow of this spring is measured to be only about 198 lit/sec (refer Hydrology report) which even can drop below this figure during critical dry periods of the year, as informed by elders of the area. Thus, this flow is shared among different uses/demands as analyzed and shown in successive tables shown below.

Demand Analysis

As identified in the field, water from this spring is used for different purposes such as irrigation, washing, taking bath, drinking water for human beings and livestock and downstream releases. The following successive tables show demand analysis for all these identified consumptions.

Table 8-1: Daily Water Requirement for Livestock

Livestock type	Weight (kg)	Mean (litres)	Maximum (litres)	For planning purposes (litres)
Cattle	350	16.4	56.1	25
Sheep	35	1.9	5.2	5
Goats	30	2	5.4	5
Equines				12
			Avg.	11.8

Source: Design Criteria, RVLB IRDMPSP, Adami Tulu Water Supply Project, 2009

Table 8-2: Population Forecast and Water Demand Analysis

SN	Description	Unit	2012	2017	2022	2027	2032
1	**Population to be served**						
1.1	Rural Population	Nr	5,544	6,273	7,097	8,029	9,084
1.2	Livestock Population	Nr	5,030	5,520	6,095	6,729	7,430
	Sub Total		10,544	11,793	13,192	14,759	16,514
2	**Demand**						
2.1	Rural Domestic demand	m^3/d	111	125	163	185	227
2.2	Institutional water demand	m^3/d	17	19	24	28	34
2.3	Public Demand	m^3/d	3	4	5	6	7
2.4	Livestock Demand	m^3/d	60	66	73	81	89
	Sub Total of daily demand	m^3/d	191	214	266	299	357
2.5	Unexpected d/s release	m^3/d	19	21	27	30	36
2.6	***Total average daily demand***	m^3/d	210	236	292	329	393
		l/s	***2.4***	***2.7***	***3.4***	***3.8***	***4.5***
2.7	Average per capita demand	l/c/d	20	20	22	22	24
2.8	Maximum daily factor		1.25	1.25	1.2	1.2	1.2
2.9	Maximum daily demand	m^3/d	262	295	351	394	471
2.10	***Maximum daily flow***	***l/s***	***3.0***	***3.4***	***4.1***	***4.6***	***5.5***
2.11	Peak hour factor		1.9	1.9	1.7	1.7	1.7
2.12	***Overall Peak hour Demand***	***l/s***	***5.8***	***6.5***	***6.9***	***7.8***	***9.3***

Note: Institutional includes e.g. schools, clinic, etc.; Public includes taking bath & washing around the spring eye.

Figure 8-3: Livestock Demanding Water on Spring Eye

Assumptions considered in analyzing these demands are (some of which are adopted from RVLB IRDMPSP):

- Water demand is proportional to population growth;
- Population growth rate is 2.5% per annum for rural people;
- Design Period is 20 years;
- Institutional Demand is taken 15% of Domestic demand;
- Public Demand is taken 3% of Domestic demand;
- Unaccounted/unexpected demand for water is 10%;
- Domestic Demand is assumed to be 20 l/c/d for the 1st five years, 23 l/s/d for next ten years & 25l/s/d for last years;
- Unexpected d/s release is taken 10% of Domestic demand;
- 75% of measured discharge i.e. 198 l/s is assumed available for all the days of a year, and can be obtained every day (though it requires measured data on the spot every day);
- Number of livestock is taken lower as some of them may use other sources like Mojo River and other springs and all of them may not require at the same time (People in the eastern part of Ethiopia says, "We have feet and hence can walk and fetch water but our crops cannot do so. Thus…");
- Population Forecast is made using the following formula and CSA rural population growth rate of 2.5% per annum.

$$P_n = P_0\left(1+\frac{r}{100}\right)^n$$

Where, P_0 is number of initial population as collected from the project site,
P_n is future population after n years,
r is growth rate (%), adopted from CSA data.

Table 8-3: Water Balance and Irrigation Demand Analysis (Mm^3/Month)

SN	Demand & Supply	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.	Annual
1	Nr. of Days in a Month	31	28	31	30	31	30	31	31	30	31	30	31		
2	Domestic	9.3 l/s													
2.1	Institutional														
2.2	Public														
2.3	Livestock														
2.4	D/s Release														
Sub total		0.025	0.022	0.025	0.024	0.025	0.024	0.025	0.025	0.024	0.025	0.024	0.025	0.024	0.29
3	Spring Supply (expected base flow)	0.530	0.479	0.530	0.513	0.530	0.513	0.530	0.530	0.513	0.530	0.513	0.530	0.520	6.24
4	W/Balance (Mm^3/Month)	0.505	0.457	0.505	0.489	0.505	0.489	0.505	0.505	0.489	0.505	0.489	0.505	0.496	5.95
5	Irrigation demand	0.379	0.342	0.379	0.367	0.379	0.367	0.379	0.379	0.367	0.379	0.367	0.379	0.372	4.46
	or in (l/s)	141.5	127.8	141.5	137.0	141.5	137.0	141.5	141.5	137.0	141.5	137.0	141.5	138.9	

Note: Here irrigation demand is assumed 75% of computed water balance i.e. available water, because there was no measured monthly flow of the spring. Thus this percent is accounted since a one day measured flow cannot be taken as reliable flow data. It is only if 75% of available flow is allowed that monthly demand is satisfied, otherwise 60% allowance can attain if its total is considered.

From Agronomy report, the peak design duty (q) or crop water requirement in 24 hour as computed by CROPWAT8, is 0.67 l/s/ha. With this design duty, net area that can be irrigated, A=Q/q = 207 ha, where Q is average design discharge of the spring after water balance analysis and found to be 138.9 l/s (Refer table 8-3 above). This discharge is about 71% of computed low flow of the spring which is 198 l/s (refer Annex-A: Climate & Water Resource) and the measured flow on that specific day of the study indicates the same figure. The average value is adopted as the computed water supply demand of 9.3l/s is conservative value as well as it is demand expected at the end of project design period i.e. 20 years.

8.1.3 Design of spring protection/Headwork structure

This headwork structure is designed from a 12 m wide by 24 m long masonry wall lined in its inner wall and pointed on the outer side. The intention is that, spring water will circulate within this protection work then directed to different designed outlets proportionally such as outlet for irrigation, drinking water for human and livestock of-course in separate outlets. These sizes are fixed in search of joining main canals to the spring eye and hence flow, because the spring eye is situated a bit at lower location than start of existing main canals.

A proper design of such protective structure ensures not only an increased flow from this spring but also keep the spring water safe from easy contamination. Moreover, if the excavation for the headwall is too close to the spring eye, it may adversely affect the local water-flow pattern, and the spring might be lost.

The nature of the command area in this project is very flat even around the spring eye. Thus, intake at the headwork is designed to rise for 0.5 m height over the existing spring eye so that it can be diverted to the left and right main canals easily.

Existing water level on the spring eye = 1124.942 m a.s.l.

The outstanding issue in such spring supplied irrigation system is that intake level is fixed based on level of water on spring eye not from maximum elevation in the irrigable command and headloss along MC like that of diversion weirs.

Therefore, intake level for all supplies = 1124.942+0.5 = 1125.442 m a.s.l.

Since the command area is flat, shallow depth but wider canal is assumed. As a result, calculated water depths in the main canals are 0.38 m and 0.26 m for RMC & LMC respectively.

Moreover allowing a free board of 0.2 m to accommodate for unexpected discharge (during heavy rainfall) on the spring gives:

Protection structure top level = 1125.442+0.38+0.2 = 1126.022 m a.s.l.

OGL on the d/s side of spring eye =1124.745 m a.s.l. (survey data)

OGL on the u/s side of spring eye =1126.50 m a.s.l.

Thus height of this structure on d/s side = 1126.022-1124.745 = 1.277 take 1.3m. Thus adjusted top level of this structure = 1126.045 m a.s.l.

On the upstream side = 1126.045 - 1126.50 = -0.455 m i.e. it is below OGL by 45 cm.

Geology report shows that there is no problem of foundation bearing capacity with respect to the intended structure and depth of foundation is in the order of 1.5 m to 2 m. Thus, the total height of structure from its bottom is 1.3 +2.0 = 3.3m on the d/s and -0.455+1.5=1.045m, say 1.1 m on the u/s. However, surface drain from road should be protected by this u/s face. Thus it needs to be raised say by 0.2m above OGL for this purpose, i.e. it will be 1126.50+0.20= 1126.70m. But the depth is provided shallower as foundation is better on this side in-fact it protects contamination. Main u/s surface drain is tapped on the u/s road side catch drain or trench.

8.1.4 Stability Analysis of Protection Structure

This structure will always store water for short time for only 1.3m depth unless otherwise drained for clearance purpose, thus it is always under pressure being acting up on by water pressure for 1.3 m depth on the d/s side. Therefore, this stability analysis was dealt for such dynamic case and found safe (For details refer Annex E: Head Works, Irrigation and Drainage).

8.1.5 Diversion Ditch

As Mojo Gurati spring is intended to serve both irrigation and local water supply for human beings and livestock, a diversion ditch is required to protect against contamination from surface water on the upstream side. Thus the function of this ditch is simply to catch and divert runoff coming to the spring away from the spring eye.

In addition, the main access road to the project site passes just aside of this spring eye. Thus, the intended ditch is designed to be located along with this road at up gradient of the spring and then slope downhill and away from the spring eye at a distance of about 10m. It is connected to the upper drain side of access road passing along the spring then designed to join drainage channel emerging from the spring after crossing the road by pipe culvert and the LMC by culvert.

8.1.6 Overflow

Whenever there is no irrigation, flow in the canal should be diverted to somewhere else safely. For this purpose, an overflow is designed to discharge spring flow to the natural drainage channel which joins Mojo River just after some 100 meters downstream. Thus the size of this overflow must allow the maximum water flow to pass easily and safely away from the spring without causing erosion.

Accordingly, assume 1.5m wide by 0.51 m (i.e. 0.31m water depth plus 0.2m free board) deep open overflow which is arranged to discharge to the existing drainage channel.

Peak discharge = 198 l/s (currently measured flow) + 20% (to account for its max. flow) = 237.6, say 240 l/s. Then from, Q = A*V=b*d*V, velocity of spring flow over this opening, V = Q / (b*d) = 0.24/((1.5*(0.31+0.2)) = 0.31 m/s

There will be a projectile flow over the 1.3m high structure like that in drop structure or broad crested weir. Thus, energy dissipater structure with corresponding stilling basin is required. However this flow is small thus no u/s temporary storage, which as a result lead us to treat it in similar way to the case of drop as follow.

Table 8-4: Energy Dissipater Structure over Protection Work

SN	Description	unit	Given data	Remark	
1	Discharge(Q)	m^3/s	0.24		
2	u/s water depth(h1)	m	0.58		
3	u/s velocity(v1)	m/s	0.30		
4	D/s water depth(h2)	m	0.58		
5	D/s velocity(v2)	m/s	0.30		
6	Drop height(D)	m	1.3		
B	**Critical flow hydraulics**				
	Description	Symbol	Formula	Result	Adopt
1	Drop width	bc	0.734Q/(h1^1.5)	0.39	0.40
2	Unit discharge	q	Q/bc	0.59	
3	Critical depth	hc	(q^2/g)(1/3)	0.33	
C	**Type 1: Stilling basin**				
	Description	Symbol	Formula	Result	Adopt
	Basin width	B	18.46(Q)^0.5/(Q+9.91)	0.89	0.90
	Length	L_2	[2,5+1.1(hc/z)+0.7(hc/z)^3](x*hc)^0.5	1.83	1.90
	Lip height	h_c	hc/2	0.17	0.20

1.1.2 Drain Channel D/S of HW

Drain channel is a channel located after overflow of the protection work which is intended to drain water in excess of those identified demands to nearby Mojo River. Its section is assumed trapezoidal and shown along with overflow/drop.

Table 8-5: Design Parameters of Drain Channel (Headwork-to Mojo River)

Length, m	Q (m3/s)	n	S (m/m)	X= Q*n /√s	b (m)	m	d (m)	Y= $A^{5/3} / P^{2/3}$	X-Y	b/d	A (m2)	P (m)	R (m)	V (m/s)	Fb (m)	D (m)	T (m)	Remark
57	0.24	0.025	0.0015	0.153	0.40	1.5	0.411	0.153	0.000	0.97	0.42	1.88	0.22	0.57	0.3	0.71	1.63	Earthen trapezoidal

8.1.7 Outlets

Outlets are intakes at the starting point of main canals. The outlets should be operated as required but not again and again so as to maintain continuous flow in the main canals.

Outlet for Water supply and Cattle Trough

Since the spring is expected to serve for multipurpose uses, the consultant also considered water supply points at the headwork site both for drinking for human beings and cattle; because, this spring is the only perennial source of water supplying both for drinking water and irrigation in this area. Moreover, there are a number of livestock which are existing in and around the project area. Thus cattle troughs need to be designed at the headwork site such that it may not bring any pressure on the area.

Accordingly, a pipe for drinking water and cattle troughs of standard sizes on right direction, i.e. South of the spring eye has been considered so that it can accommodate maximum number of cattle population at a time (refer standard drawing number BL/FSD/10 for detailed dimensions of this structure and Figure 8-4).

GI pipeline is arranged such that it supplies the most peak demand, i.e. all 9.3 lit/sec along the same pipeline for domestic, and Livestock water supply but its arrangement is such that initially for human beings and then for livestock after it joins cattle trough (CT). For taking bath and washing clothes again it will be of the same pipe line but different areas both at separate compartments (left for Ladies and right for Giants). Thus we will have two outlets for domestic drinking water supply (WS), one for livestock (LS), two for taking bath and two for washing closes. Thus a total of seven outlets will exist on this pipe line. Its arrangement will be in the order mentioned above.

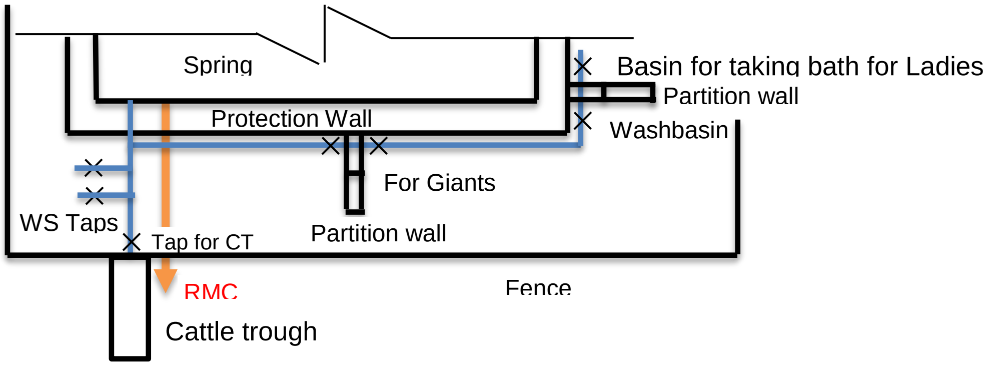


Figure 8-4: Schematic view of Pipe Network on HW

Intake level

Level of intake is taken same as RMC intake level = 1125.442 m a.s.l.

Design Discharge, Q is taken maximum value i.e. that of late times of the project life = 9.3 l/s

Assuming allowable velocity in PVC pipe = 1.0 m/s (as it is above headwall)

Thus Area of pipe, A (m^2) = Q/V = 0.0093 m^2

Thus, diameter d (m) = 0.104 m, provide one pipe of say 110 mm or 4” ϕ GI pipe.

The pipe will provide drinking water by two outlets laid in series for human beings first and then extend to cattle trough of 30m length. It will extend for 8.40m length horizontally thus headloss is not considered here as it is of short length (Refer Figure 8-5 or Drawing Nr. BL/FSD/10).

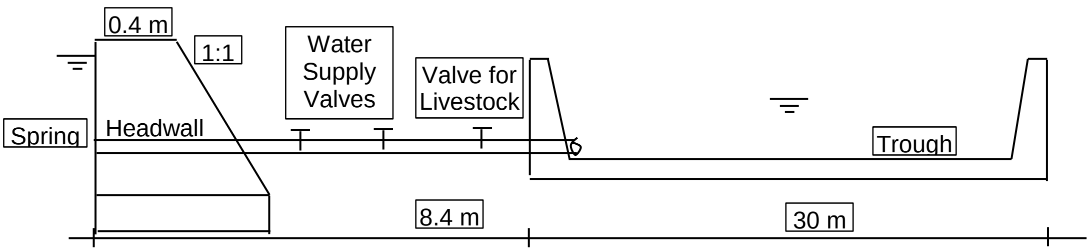


Figure 8-5: Schematic View of Headwork at Water supply Section

Washouts

Fixing its level

Washouts are PVC drainage pipes allowing the protection box to be drained so that the chamber can be cleaned after every irrigation seasons. They are designed to be set slightly into the bottom of the chamber (25cm from bottom i.e. OGL) and closed with an end cap or gate valve. Its' inner bottom level will be 1124.745 +0.25= 1124.995 m a.s.l.

Size of Drainage Outlet/Washouts
Available flow = 200 l/s + 20% (to account for its max. flow) = 240 l/s

Allowable Velocity in PVC pipe = 1.5 m/s (as it is under headwall)

Thus Area of pipe, A (m2) = Q/V = 0.16 m^2

Thus provide one pipe diameter d (m) = 0.451 m say 500 mm or

Two pipes of diameter d (m) = 0.319 m say 350 mm shall be provided. But cost and management wise, single pipe of 500 mm diameter pipe is preferred.

8.2 IRRIGATION SYSTEM

8.2.1 General

The source of irrigation water for the intended command area is Mojo Gurati Spring which emerges just near Mojo River. This river flows in a waterway meandering here and there and surrounded by flat floodplains on its both left/East and right/West banks.

Traditional irrigation has been practiced intensively in this project area though the command area is subject to flooding after every rainy season. This source also serves several purposes among which irrigation, washing, bathing, domestic use, cattle trough and downstream releases can be mentioned.

8.2.2 Irrigation Conveyance Options

As the geology report of this project indicates, soil along the existing canal route is of water tight in its nature which thus is not susceptible to seepage. Consequently, preferred conveyance system for this project is main canals of unlined i.e. earthen trapezoidal cross section along the same route as traditional once for the launching segment and follows contour for the remaining passageways. These canals are LMC which serve for areas on the left bank of Mojo River and RMC intended to serve the command area situated on the right bank of the same river.

8.2.3 The Command Area

The command area is irrigable land that is delineated and studied whereas the net irrigable command area as stated in the inception report is the area which is to be applied irrigation water and is obtained by deducting expected land to be taken for irrigation infrastructures from delineated gross command area and non-productive land. Non-productive land /unsuitable land/ category includes rocky, saline and very steeply sloping lands on other streams' banks other than source River but in the command, which is thus dependent on physical characteristics of the project area.

Indicative planning norms for land use of other projects' command area shows that a typical value of 3-6% of irrigation and drainage development is taken up by associated infrastructures from the productive or suitable command area. In addition, 2-3% is expected to be occupied by roads and other infrastructures from the same land. But this project is a small scale where such networked roads are not as such required along all but main and secondary canals. Thus, a total of only 3% is proposed and adopted for this project. Accordingly, summary of such design data are presented in subsequent tables in this chapter. Note: In this case no well networked road is expected to be required except along the main and secondary canals, as the project is of small scale in its nature thus no area is accounted for that.

Figure 8-6: Partial Views of Bareda Lencha Command Area

8.2.4 Hydraulic Units

Command hydraulic units are the basic building blocks for irrigation system operation and maintenance, which consequently defines irrigation and hence drainage boundaries and layouts. Accordingly, the gross irrigable area is subdivided into tertiary blocks/units with a target area between 1 and 8 ha depending on command area location (i.e. if it is marginal then it will be the actual size found, otherwise the designed size governs).

The tertiary unit is meant here the irrigation area supplied by one tertiary off-take. It consists of tertiary canals and field canals with their structures. Thus the average tertiary unit size will be about 100-200 m length by 100-400 m width for full-flagged block and half or less of this for partial blocks/units (Refer typical farm unit layout arrangement shown in Figure 8-7).

8.2.5 Layout Design

Command area delineation
Delineation of the command area is carried out based on: soil characteristics (suitability) of the area which includes depth and permeability; appropriate location of on-farm structures, topography including slope and micro relief; water availability; existing drainage pattern and accessibility of the command. These parameters provided basis for selecting the best field arrangement and for locating field ditches.

Systems Layout
As stated in the design criteria, farm unit in addition to slope and soil type is taken as the basic dividing block for designing the system layout of irrigation and hence drainage and other related infrastructures.

Thus, plan of a general layout for subdividing the gross command area in these units and as found suitable at marginal areas is the priority considered in designing this irrigation and related systems. Here alternate layout is exercised again and again before arriving at the final one.

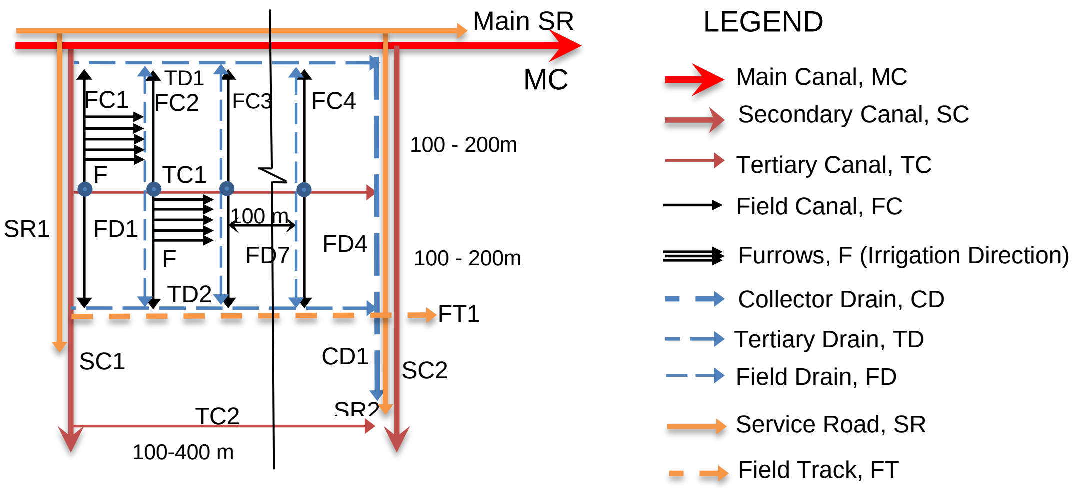


Figure 8-7: Typical Farm Unit Layout Arrangement

Some layouts are more expensive than others and some are more suitable than others. Some may be technically desirable but costly layouts may not be justified because of the farmer's limited financial resources during operation and maintenance.

In this layout, there are conveyances i.e. main canals which are designed such that they follow more or less the contour bordering the project command area. Secondary canals then branches from these canals and run down the slope perpendicularly or at an angle to the contour lines. However, if the ground slope is found steep in relation to the required canal gradient, then drop structures are incorporated into the design in order to reduce consequence of speedy water velocity i.e. erosivity of water.

Tertiary canals, which get their water from the secondary canals or main canals (depending on their length and location) run more or less parallel to the contour lines. On the other hand, the topography of this project area allows the secondary canals (SC) to effectively irrigate the fields located on both sides of the canal which is known as the herringbone layout where possible.

However, furrows are designed to run along contour lines but slightly running away from them to create some gradient (0.01 to 0.06%) for enabling flow of water (Refer Drawing Number BL/FSD/05: Infrastructure Layout). Although furrows can be longer when the land slope is steeper, the maximum recommended furrow slope is about 0.5% to avoid soil erosion. A minimum grade of 0.05% is recommended so that effective drainage can occur.

Tertiary Units' Data from Designed Layout

Tertiary Units are the smallest farm units within which irrigation water application will rotate in certain irrigation interval. There are a total of 50 such units corresponding to the tertiary canals mentioned under section 4.6. Farm units are normally based on secondary canals level thus a total of 4 farm units will exist which are accountable to WUA. Are of these TU varies from a minimum of 1.7 ha to a maximum of 10 ha.

Table 8-6: Summary of Tertiary Units Data as extracted from Layout

SN	Name of TU	Gross Area (Ha)	Location
1	TU1	2.05	RB
2	TU2	5.54	RB
3	TU3	7.14	RB
4	TU4	4.93	RB
5	TU5	4.01	RB
6	TU6	2.56	RB
7	TU7	4.31	RB
8	TU8	2.78	RB
9	TU9	2.81	RB
10	TU10	2.48	RB
11	TU11	2.09	RB
12	TU12	2.52	RB
13	TU13	2.12	RB
14	TU14	2.56	RB
15	TU15	1.82	RB
16	TU16	2.69	RB
17	TU17	2.31	RB
18	TU18	2.77	RB
19	TU19	2.53	RB
20	TU20	2.89	RB
21	TU21	2.47	RB
22	TU22	2.98	RB
23	TU23	1.98	RB
24	TU24	4.47	RB
25	TU25	4.60	RB
26	TU26	2.63	RB
27	TU27	2.66	RB
28	TU28	2.51	RB
Ctd.			
29	TU29	2.22	RB
30	TU30	2.46	RB
31	TU31	1.86	RB
32	TU32	2.55	RB
33	TU33	2.56	RB
34	TU34	3.45	RB
35	TU35	1.71	RB
36	TU36	6.29	RB
37	TU37	3.65	RB
38	TU38	7.26	RB
39	TU39	8.13	RB
40	TU40	9.31	RB
Sub Total		**138.66**	**RB**
41	TU41	6.61	LB
42	TU42	9.72	LB
43	TU43	10.00	LB
44	TU44	7.66	LB
45	TU45	3.57	LB
46	TU46	7.71	LB
47	TU47	8.33	LB
48	TU48	4.27	LB
49	TU49	5.65	LB
50	TU50	5.98	LB
Sub Total		**69.52**	**LB**
Total		208.18	
Riverine Area		8.42	
Gross Com. Area (ha)		**216.60**	

There are numerically 50 different tertiary blocks or units designed in total: 40 units or 80% of which are located on the right side and the remaining 10 units or 20% are situated on the left bank of the Mojo River. Yet, TU1 is supplied from LMC though it is located on the RB of Mojo River. In terms of area, 67% is located on the right side and the remaining 33% is on the left bank of the Mojo River. However, 66% of the area is supplied from RMC and the remaining 34% is supplied from LMC.

Potential command area surveyed in the project area is about 426.6 ha, however due to limited water resource of the spring; layout design is limited to only 216.6 ha gross, which includes 208.2 gross irrigable command area and 8.4 hectares of riverine areas.
These tertiary unit arrangements are presented in figure 8-8 below.

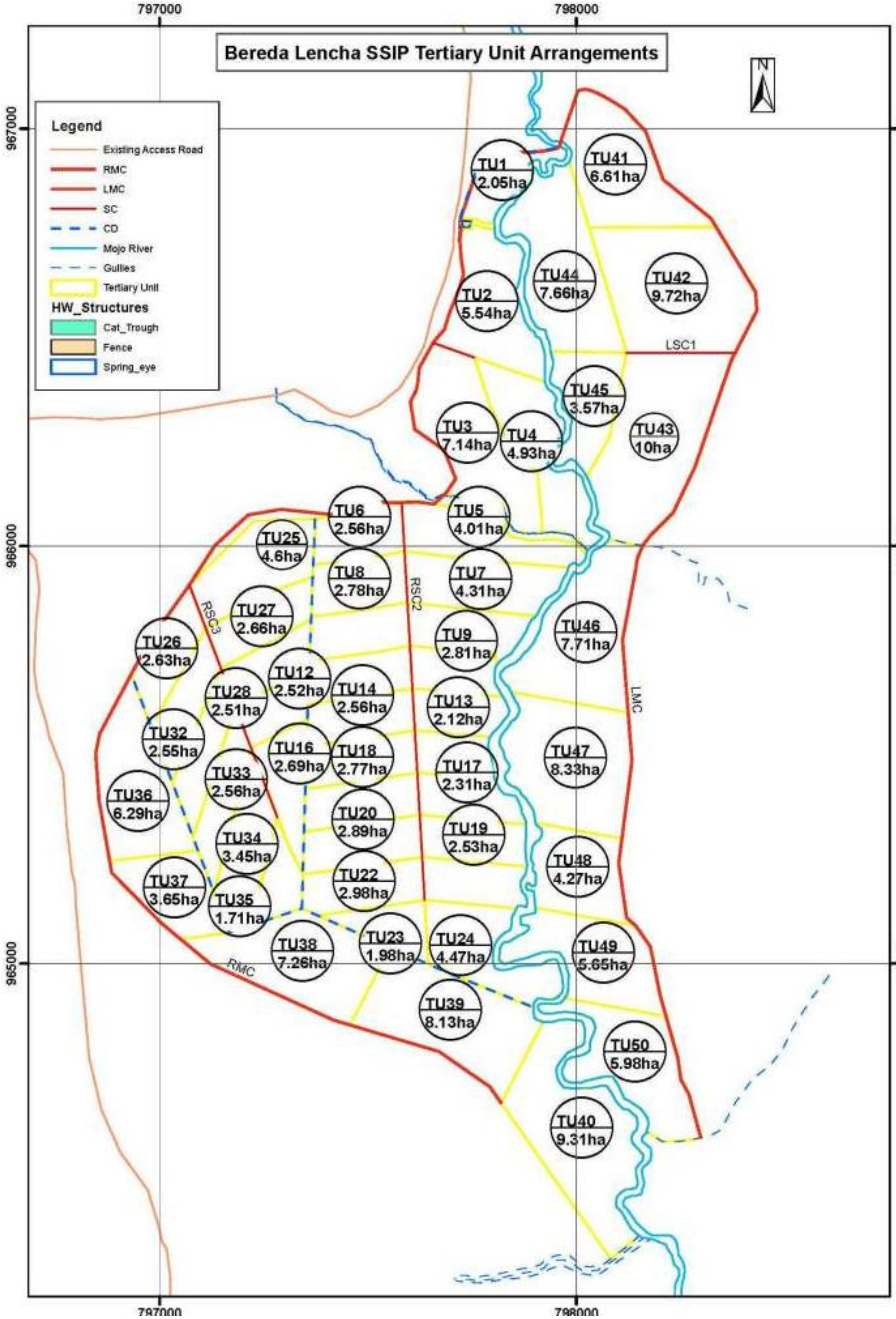


Figure 8-8: Tertiary Unit Arrangements in Bereda Lencha SSIP

8.2.6 Canal Categories & Adopted Terminology

Canals will be used for irrigation and drains for drainage systems and they all will be numbered and named starting from the headwork and working toward the end of the command area (i.e. from upstream to downstream consecutively). The left bank is the left side of Mojo River looking downstream i.e. looking in the flow direction. Irrigation canals and drains categories will be identified using the following codes:

Irrigation Canals

- Main Canal– MC (or Conveyance canal);
- Secondary Canal – SC;
- Tertiary Canal – TC;
- Field Canal/ Field Ditch – FC
- Furrows – F

Drainage Canals

- Collector Drain – CD;
- Tertiary Drain – TD;
- Field Drain – FD

If applicable, the suffix L or R, will be used to indicate off-taking side as either from Left or Right main canals respectively (For example, RSC1 is to mean the first secondary canal on the right side MC; similarly, RTC1-2 is to mean the second tertiary canal from right secondary canal-1; moreover, RFC3-1-2 is meant the second right side field canal on the first tertiary canal of third SC).

Drawing numbers are also named in the same way for example; Drawing No BL/FSD/01 is meant Bareda Lencha Feasibility Study and Design Project Drawing Number-01.

Field Canal
Field Canals or Field Ditches represented by FC is the smallest designed canal section which is intended to feed furrows in the field after receiving from tertiaries. They are designed to supply one way or both ways depending on topography of the command area.

There are 131 of such field canals varying in length from a minimum of 70 m to a maximum of 350 m depending on location of units. The total length of these canals is found to be 20.74 km. Lengths of each of these canals is attached in the appendix.

Table 8-7: Field Canals' Data as Summarized from Designed Layout

SN	Description	Length (km)	Gross Area (Ha)
1	Field Canals on LMC	7.47	71.57
2	Field Canals on RMC	13.27	136.61
Grand Total		**20.74**	**208.18**

Note: Even though these data are summarized here its cost has not been included in BOQ and cost estimate as per client's comment.

Tertiary Canals Data Summarized from Layout
There are a total of 50 tertiary canals designed in the project out of which 39 are located on the right side and 11 on the left side of Mojo River. These tertiary canals receive irrigation water

either from secondary canals or main canals (where secondary canals do not exist). They distribute this water to field canals or ditches as found appropriate.

Table 8-8: Tertiary Canals' Data as Summarized from Designed Layout

SN	Name	Length (km)	Gross Area (Ha)	SN	Name	Length (km)	Gross Area (Ha)
1	RTC0-1	0.21	6.29	30	RTC3-2	0.13	2.63
2	RTC0-2	0.126	3.65	31	RTC3-3	0.20	2.66
3	RTC0-3	0.46	7.26	32	RTC3-4	0.14	2.51
4	RTC0-4	0.31	8.13	33	RTC3-5	0.20	2.22
5	RTC0-5	0.35	9.31	34	RTC3-6	0.15	2.46
6	RTC1-1	0.21	5.54	35	RTC3-7	0.10	1.86
7	RTC1-2	0.21	7.14	36	RTC3-8	0.17	2.55
8	RTC1-3	0.30	4.93	37	RTC3-9	0.10	2.56
9	RTC2-1	0.35	4.01	38	RTC3-10	0.19	3.45
10	RTC2-2	0.11	2.56	39	RTC3-11	0.19	1.71
11	RTC2-3	0.21	4.31	**Sub Total under RMC**		**6.52**	**136.61**
12	RTC2-4	0.10	2.78	40	LTC0-1	0.13	2.05
13	RTC2-5	0.21	2.81	41	LTC0-2	0.27	6.61
14	RTC2-6	0.10	2.48	42	LTC0-3	0.31	7.71
15	RTC2-7	0.11	2.09	43	LTC0-4	0.20	8.33
16	RTC2-8	0.10	2.52	44	LTC0-5	0.12	4.27
17	RTC2-9	0.11	2.12	45	LTC0-6	0.11	5.65
18	RTC2-10	0.10	2.56	46	LTC0-7	0.12	5.98
19	RTC2-11	0.11	1.82	47	LTC1-1	0.22	9.72
20	RTC2-12	0.10	2.69	48	LTC1-2	0.44	10.00
21	RTC2-13	0.11	2.31	49	LTC1-3	0.42	7.66
22	RTC2-14	0.10	2.77	50	LTC1-4	0.21	3.57
23	RTC2-15	0.11	2.53	**Sub Total under LMC**		**2.54**	**71.57**
24	RTC2-16	0.10	2.89	**Total of TC (Gross)**		**9.06**	**216.9**
25	RTC2-17	0.11	2.47	**Riverine Area**			**8.42**
26	RTC2-18	0.10	2.98	**Total of Gross Com. Boundary**			**216.6**
27	RTC2-19	0.11	4.47	**Avg.**		**0.18**	**4.16**
28	RTC2-20	0.10	1.98	**Min.**		**0.10**	**1.71**
29	RTC3-1	0.22	4.60	**Max.**		**0.46**	**10.0**

Secondary Canals Extracted Data from Layout

Secondary Canals are designed to distribute water among tertiary canals. There are 4 such canals with a total length of 1.9 km out of which o.3km on the left and 1.6km on the right side of Mojo River. These canals discrete lengths and gross and net command areas (ha) are summarized in table 8-9 below.

Table 8-9: Summary of Secondary Canal Data from Layout

SN	Name	Length (km)	Area (Ha)		
			Gross	Infrastructures 3%	Net A(ha)
1	LSC1	0.260	30.95	0.93	30.03
Sub Total		**0.26**	**30.95**	**0.93**	30.03
2	RSC1	0.105	17.61	0.53	17.09
3	RSC2	0.95	55.15	1.65	53.50
4	RSC3	0.60	29.20	0.88	28.33
Sub Total		**1.65**	**101.97**	**3.06**	**98.91**
Grand Total		**1.92**	**132.93**	**3.99**	**128.94**

Note: Outstanding area (75.2ha) is that of TCs which are directly connected to the MC

Table 8-10: Summary of Main Canal Data as extracted from Layout

SN	Name	Length (km)	Gross Area (Ha) From		Sub Total
			SC	TC	
1	LMC	3.318	31.0	40.6	**71.6**
2	RMC	3.301	102.0	34.6	**136.6**
Grand Total		**6.619**	133.0	75.2	**208.2**

Source: Soil and Topographic Survey

Table 8-11: Net Command Area Analysis

Location	Studied Potential Area (ha)	Command Area (ha)					Percent Distribution	24 hr. design duty, l/s/ha	Required Q, l/s
		Delineated (Gross)	Riverine Area	sub total	Infrastructures 3%	Net			
Right Bank	212.91	136.6	1.1	137.7	4.1	132.5	66	0.67	88.8
Left Bank	249.71	71.6	7.32	78.9	2.1	69.4	34	"	46.5
Subtotal	462.6	208.2	8.42	216.6	6.2	201.9	100		135.3

Note: Net command area is assumed 3% deducted from delineated gross for infrastructure occupation.

8.2.7 Design of Canal Sections

Main Canal

The main canal layout is made so that the longitudinal slope of a canal is somewhere around 0.01% on flat topography and 0.15% on relatively steeper topography and tried to maximize the command area. As the geology report indicates it is unlikely to use lining for this canal as the soil material along this canal is relatively impervious that would not cause excess leakage but it is recommended that it need proper compaction and densification of the soil material to increase water tightness and embankment shear strength.

Figure 8-9: Existing RMC from Gurati Mojo Spring

Assumption:

- A minimum of canal bed width, b = 0.15 m is assumed to allow for smooth & practicable canal dimension for construction.
- As the soil is of good nature, side slope of the main canals is to be of the order of 1:1; and cross section of these canals is to be of trapezoidal type;
- These canals are unlined and are designed so that the velocity is low thus the bed and sides are not eroded by irrigation water. For this reason, these unlined canals tend to

be wide and shallow, spreading the flow over a large area to reduce the erosive influences of irrigation water.

- Though required discharge for some cases are small, capacity of canals is fixed not for this required amount but the design which is a bit greater than this value,
- Longitudinal slope of canals are set depending on profile of OGL such that it may not be buried and/or suspended.
- To avoid submergence of MC in the case of unforeseen flooding condition, the CBL is made shallower as much as possible.

As it can be observed from analysis made in the above tables, the required design discharges of right and left bank main canals are 88.8 l/s and 46.5 l/s respective

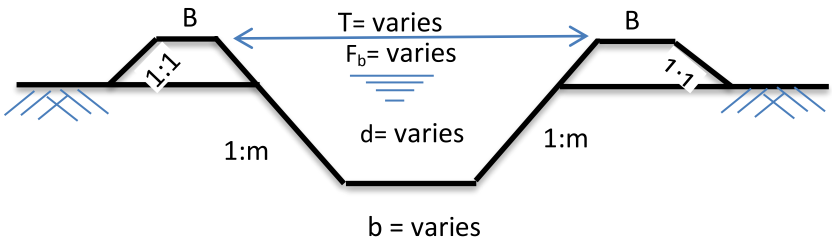


Figure 8-10: Typical Cross-section of Designed MC

Table 8-12: Left Main Canal Hydraulic Design Parameters

Chainage (m)	A_{net} (ha)	Duty (l/s/ha)	Q_{reqd} (m3/s)	n	s	b	m	d	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Q_{calc}	Q_{calc} - Q_{reqd}	Fb (m)	D (m)	T (m)	Remark
0+000-0+006.5	69.42	0.67	0.0465	0.025	0.0007	0.3	1	0.31	0.98	0.1864	1.17	0.16	0.31	0.058	0.011	0.2	0.51	1.31	Earthen trapezoidal
0+06.5-0+357.4	67.43	0.67	0.0452	0.025	0.0001	0.3	1	0.48	0.63	0.3710	1.65	0.22	0.15	0.055	0.010	0.2	0.68	1.65	"
0+357.4 – 0+358.9	67.43	0.67	0.0452	0.014	0.0001	0.2	1	0.40	0.50	0.2400	1.33	0.18	0.23	0.055	0.010	0.2	0.60	1.40	Transition
0+358.9 – 0+366.9	67.43	0.67	0.0452	0.014	0.0090	0.2	0	0.40	0.50	0.0800	1.00	0.08	1.26	0.101	0.055	0.2	0.60	0.20	Flume section
0+366.9 – 0+368.4	67.43	0.67	0.0452	0.014	0.0007	0.2	1	0.30	0.66	0.1511	1.05	0.14	0.52	0.078	0.033	0.2	0.50	1.20	Transition
0+368.4 -0+910	67.43	0.67	0.0452	0.025	0.0010	0.3	1	0.30	1.00	0.1813	1.15	0.16	0.37	0.067	0.022	0.2	0.50	1.30	Earthen trapezoidal
0+910 -0+988.89	67.43	0.67	0.0452	0.025	0.0002	0.3	1	0.41	0.74	0.2887	1.45	0.20	0.20	0.056	0.010	0.2	0.61	1.52	"
0+988.89 - 1+330.69	61.02	0.67	0.0409	0.025	0.0002	0.3	1	0.41	0.73	0.2922	1.46	0.20	0.20	0.056	0.016	0.2	0.61	1.52	"
1+330.68 -1+349.53	30.99	0.67	0.0208	0.025	0.0002	0.3	1	0.31	0.98	0.1850	1.16	0.16	0.17	0.031	0.010	0.2	0.51	1.31	"
1+349.53 - 2+2280	23.51	0.67	0.0158	0.025	0.0002	0.3	1	0.27	1.12	0.1527	1.06	0.14	0.16	0.024	0.008	0.2	0.47	1.24	"
2+280 - 2+560.3	23.51	0.67	0.0158	0.025	0.0005	0.3	1	0.22	1.35	0.1156	0.93	0.12	0.23	0.026	0.010	0.2	0.42	1.14	"
2+560.3 - 2+670	15.43	0.67	0.0103	0.025	0.0005	0.3	1	0.18	1.66	0.0868	0.81	0.11	0.21	0.017	0.007	0.2	0.38	1.06	"
2+670 - 2+780.1	15.43	0.67	0.0103	0.025	0.0001	0.3	1	0.26	1.15	0.1458	1.04	0.14	0.12	0.016	0.005	0.2	0.46	1.22	"
2+780.1 - 3+012.9	11.28	0.67	0.0076	0.025	0.0001	0.3	1	0.23	1.32	0.1199	0.94	0.13	0.12	0.012	0.005	0.2	0.43	1.15	"

Table 8-13: Right Main Canal Hydraulic Design Parameters

Chainage (m)	A_{net} (ha)	Duty (l/s/ha)	Q_{reqd} (m3/s)	n	s	b	m	d	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Q_{calc}	Q_{calc} - Q_{reqd}	Fb (m)	D (m)	T (m)	Remark
0+000 to 0+289.7	132.5	0.67	0.0888	0.025	0.0005	0.3	1	0.41	0.73	0.2924	1.46	0.20	0.31	0.089	0.001	0.3	0.71	1.72	Earthen trapezoidal
0+289.7 to 0+738.07	115.4	0.67	0.0773	0.025	0.0005	0.3	1	0.38	0.78	0.2624	1.39	0.19	0.29	0.077	0.000	0.3	0.68	1.67	"
0+738.07 to 0+743.08	115.4	0.67	0.0773	0.025	0.0005	0.3	1	0.38	0.78	0.2624	1.39	0.19	0.29	0.077	0.000	0.3	0.68	1.67	"
0+743.08 to 0+751.08	115.4	0.67	0.0773	0.014	tan(10)	Refer Syphon sizing													
0+751.08 to 0+756.08	115.4	0.67	0.0773	0.014	tan(10)														Pipe for syphon
0+756.08 to 0+816.57	115.4	0.67	0.0773	0.025	0.0005	0.3	1	0.38	0.78	0.2633	1.39	0.19	0.30	0.078	0.000	0.3	0.68	1.67	Earthen trapezoidal
0+816.57 to 1+055.2	61.9	0.67	0.0415	0.025	0.0005	0.3	1	0.32	0.94	0.1971	1.20	0.16	0.27	0.053	0.011	0.3	0.62	1.54	"
1+055.2 to 1+438.4	61.9	0.67	0.0415	0.025	0.0005	0.3	1	0.32	0.94	0.1971	1.20	0.16	0.27	0.053	0.011	0.3	0.62	1.54	"
1+438.4 to 1+693.8	33.6	0.67	0.0225	0.025	0.0005	0.3	1	0.24	1.25	0.1300	0.98	0.13	0.23	0.030	0.008	0.3	0.54	1.38	"
1+693.8 to 1+856.0	33.6	0.67	0.0225	0.025	0.0005	0.3	1	0.24	1.25	0.1300	0.98	0.13	0.23	0.030	0.008	0.3	0.54	1.38	"
1+856.0 to 2+163.7	27.5	0.67	0.0184	0.025	0.0005	0.3	1	0.24	1.28	0.1257	0.96	0.13	0.23	0.029	0.010	0.3	0.54	1.37	"
2+163.7 to 2+423.6	24.0	0.67	0.0161	0.025	0.0005	0.3	1	0.22	1.34	0.1170	0.93	0.13	0.22	0.026	0.010	0.3	0.52	1.35	"

Chainage (m)	A_{net} (ha)	Duty (l/s/ha)	Q_{reqd} (m3/s)	n	s	b	m	d	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Q_{calc}	Q_{calc} - Q_{reqd}	Fb (m)	D (m)	T (m)	Remark
2+423.6 to 2+670	16.9	0.67	0.0113	0.025	0.0005	0.3	1	0.19	1.59	0.0920	0.83	0.11	0.21	0.019	0.008	0.3	0.49	1.28	"
2+670 to 2+882.10	16.9	0.67	0.0113	0.025	0.0005	0.3	1	0.19	1.59	0.0920	0.83	0.11	0.21	0.019	0.008	0.3	0.49	1.28	"
2+882.9 to 3+277.6	9.0	0.67	0.0061	0.025	0.0005	0.3	1	0.13	2.29	0.0565	0.67	0.08	0.17	0.010	0.004	0.3	0.43	1.16	"

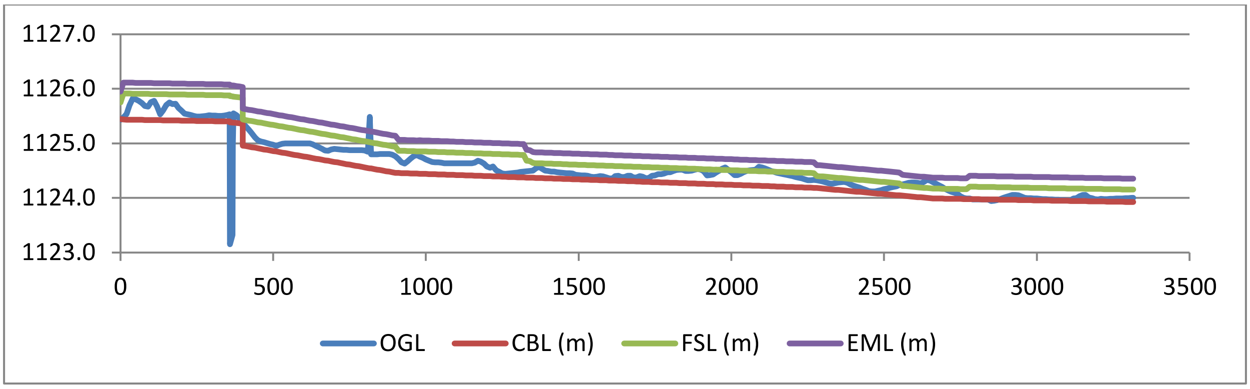


Figure 8-11: Left Main Canal and Flow Profile

Note: Details of this profile are attached as appendix-2 to the end of this document. Moreover, scaled drawing to the standard can be referred in drawing number BL/FSD/11.

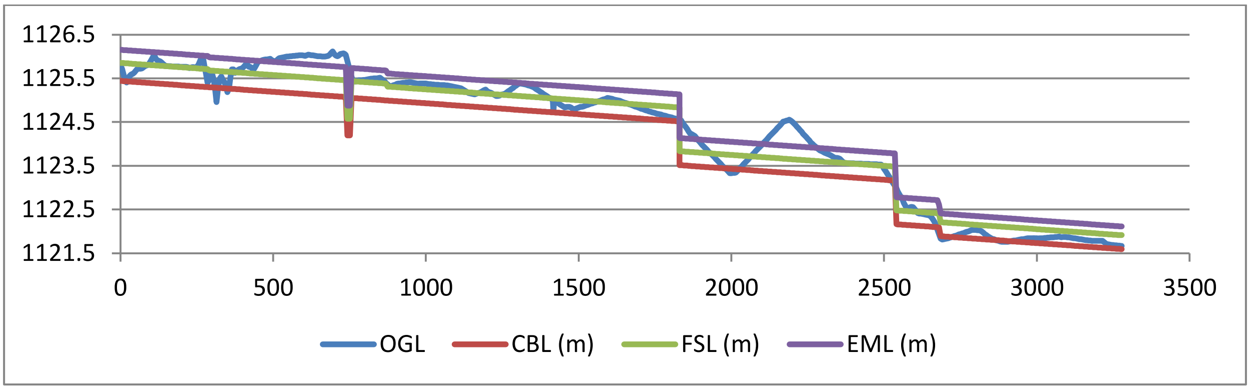


Figure 8-12: Right Main Canal and Flow Profile

Secondary Canal

Design hydraulic parameters and corresponding profiles of all the four secondary canals of this project are shown consecutively as under. Longitudinal slope of these canals were fixed such that they can feed tertiary canals and more or less parallel (if possible) to OGL. Thus this slope was the governing input for fixing cross sections of these canals in addition to command size and irrigation duty.

Table 8-14: Chainage and Corresponding Irrigation Areas of Secondary Canals

SN	Name	Chainage	Remark	Area (Ha) Gross	Infra. 3%	Net
1	LSC1	0+000	LTC1-1 & 2 Off-take	30.95	0.93	30.03
		0+000 to 0+260	LTC1-3 & 4 Off-take	11.23	0.34	10.89
2	RSC1	0+000	RTC1-1 & 2 Off-take	17.61	0.53	17.09
		0+000 to 0+105	RTC1-3 Off-take	4.93	0.15	4.78
3	RSC2	0+000 to 0+002	RTC2-1&2 Off-take	55.15	1.65	53.50
		0+002 to 0+117	RTC2-3&4 Off-take	48.04	1.44	46.60
		0+117 to 0+239	RTC2-5&6 Off-take	41.49	1.24	40.24
		0+239 to 0+344	RTC2-7&8 Off-take	36.20	1.09	35.11
		0+344 to 0+446	RTC2-9&10 Off-take	31.59	0.95	30.64
		0+446 to 0+547	RTC2-11&12 Off-take	26.91	0.81	26.10
		0+547 to 0+648	RTC2-13&14Off-take	22.40	0.67	21.73
		0+648 to 0+749	RTC2-15&16 Off-take	17.32	0.52	16.80
		0+749 to 0+850	RTC2-17&18 Off-take	11.90	0.36	11.54
		0+850 to 0+953.8	RTC2-19&20 Off-take	6.45	0.19	6.26
4	RSC3	0+000 to 0+002	RTC3-1&2 Off-take	29.20	0.88	28.33
		0+002 to 0+110	RTC3-3&4 Off-take	21.98	0.66	21.32
		0+110 to 0+214	RTC3-5&6 Off-take	16.81	0.50	16.30
		0+214 to 0+312	RTC3-7&8 Off-take	12.13	0.36	11.77
		0+312 to 0+418	RTC3-9&10 Off-take	7.72	0.23	7.49
		0+418 to 0+596	RTC3-11 Off-take	1.71	0.05	1.66

Table 8-15: Hydraulic Design Parameters of LSC1

Length (m)	A_{net} (ha)	Duty (l/s/ha)	Q (m3/s)	n	s	b	m	d	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Q_{calc}	Q_{calc} - Q_{reqd}	Fb (m)	D (m)	T (m)	Remark
0+000 to 0+002	30.03	0.67	0.0201	0.025	0.005	0.3	1	0.13	2.30	0.056	0.67	0.08	0.54	0.030	0.010	0.2	0.33	0.96	Earthen trapezoidal
0+002 to 0+260	10.89	0.67	0.0073	0.025	0.005	0.3	1	0.10	3.12	0.038	0.57	0.07	0.46	0.018	0.010	0.2	0.30	0.89	"

Figure 8-13: LSC1 Profile

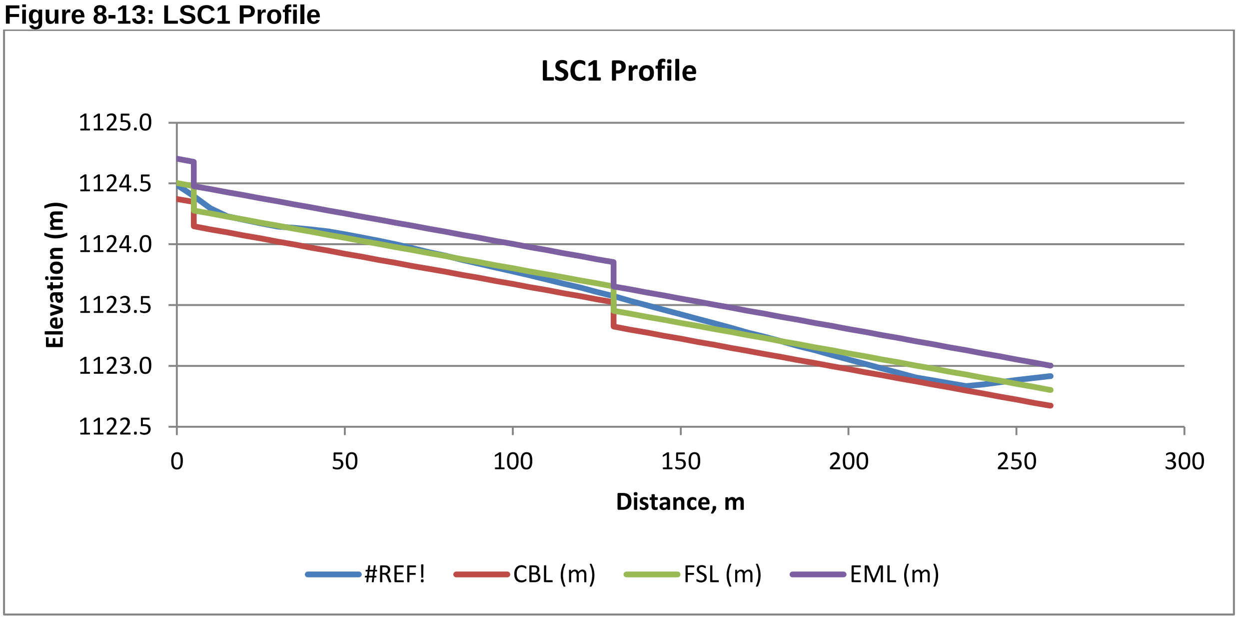


Table 8-16: RSC1 Designed Hydraulic Parameters

Length (m)	A_{net} (ha)	Duty (l/s/ha)	Q (m3/s)	n	s	b	m	d	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Q_{calc}	Q_{calc} -Q_{reqd}	Fb (m)	D (m)	T (m)	Remark
0+000 to 0+002	17.09	0.67	0.0114	0.025	0.0040	0.3	1	0.10	3.14	0.0378	0.57	0.07	0.41	0.016	0.004	0.2	0.30	0.89	Earthen trapezoidal
0+002 to 0+105	4.78	0.67	0.0032	0.025	0.0040	0.2	1	0.07	3.02	0.0177	0.39	0.05	0.32	0.006	0.002	0.2	0.27	0.73	"

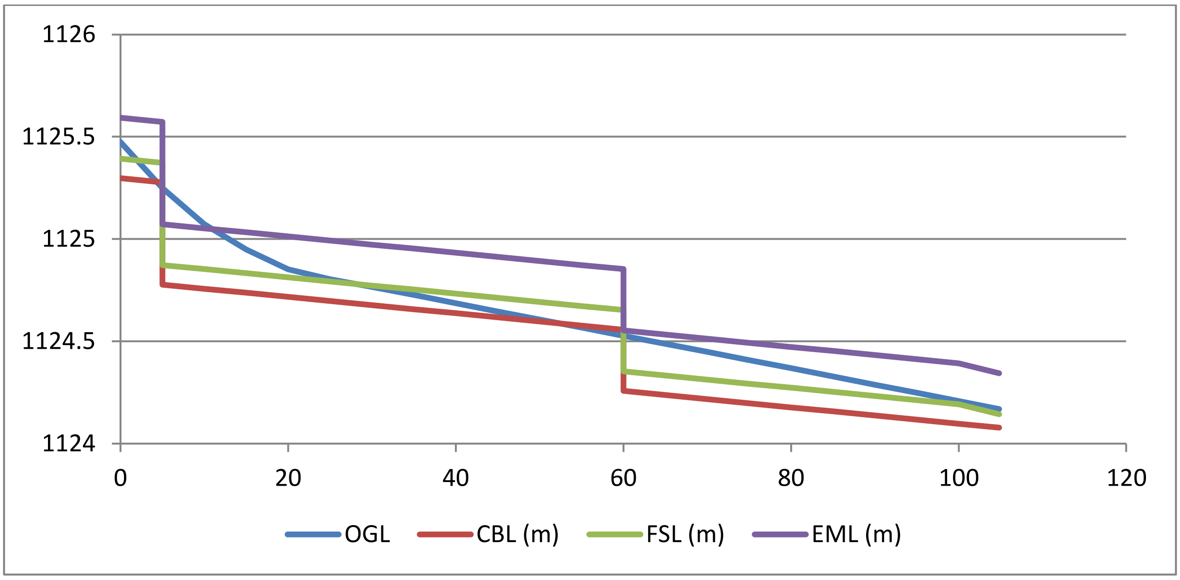


Figure 8-14: RSC1 Profile

Table 8-17: Designed Hydraulic Parameters of RSC2

Chainage (m)	A_{net} (ha)	Duty (l/s/ha)	Q (m3/s)	n	s	b	m	d	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Q_{calc}	Qcalc -Q_{reqd}	Fb (m)	D(m)	T(m)	Remark
0+000 to 0+002	53.50	0.67	0.0358	0.025	0.0050	0.3	1	0.16	1.84	0.0757	0.76	0.10	0.61	0.046	0.010	0.2	0.36	1.03	Earthen trapezoidal
0+002 to 0+117	46.60	0.67	0.0312	0.025	0.0050	0.3	1	0.16	1.84	0.0757	0.76	0.10	0.61	0.046	0.015	0.2	0.36	1.03	
0+117 to 0+239	40.24	0.67	0.0270	0.025	0.0050	0.3	1	0.15	2.05	0.0655	0.71	0.09	0.57	0.038	0.011	0.2	0.35	0.99	
0+239 to 0+344	35.11	0.67	0.0235	0.025	0.0050	0.3	1	0.14	2.20	0.0596	0.69	0.09	0.55	0.033	0.010	0.2	0.34	0.97	
0+344 to 0+446	30.64	0.67	0.0205	0.025	0.0050	0.3	1	0.13	2.33	0.0551	0.66	0.08	0.54	0.030	0.009	0.2	0.33	0.96	
0+446 to 0+510	26.10	0.67	0.0175	0.025	0.0050	0.3	1	0.13	2.28	0.0568	0.67	0.08	0.54	0.031	0.013	0.2	0.33	0.96	
0+510 to 0+547	26.10	0.67	0.0175	0.025	0.0015	0.3	1	0.17	1.74	0.0815	0.79	0.10	0.34	0.028	0.010	0.2	0.37	1.04	
0+547 to 0+648	21.73	0.67	0.0146	0.025	0.0015	0.3	1	0.16	1.87	0.0739	0.75	0.10	0.33	0.024	0.010	0.2	0.36	1.02	
0+648 to 0+749	16.80	0.67	0.0113	0.025	0.0015	0.3	1	0.14	2.10	0.0632	0.70	0.09	0.31	0.020	0.008	0.2	0.34	0.99	
0+749 to 0+850	11.54	0.67	0.0077	0.025	0.0015	0.3	1	0.12	2.54	0.0494	0.63	0.08	0.28	0.014	0.006	0.2	0.32	0.94	
0+850 to 0+953.8	6.26	0.67	0.0042	0.025	0.0015	0.2	1	0.08	2.56	0.0218	0.42	0.05	0.21	0.005	0.000	0.2	0.28	0.76	

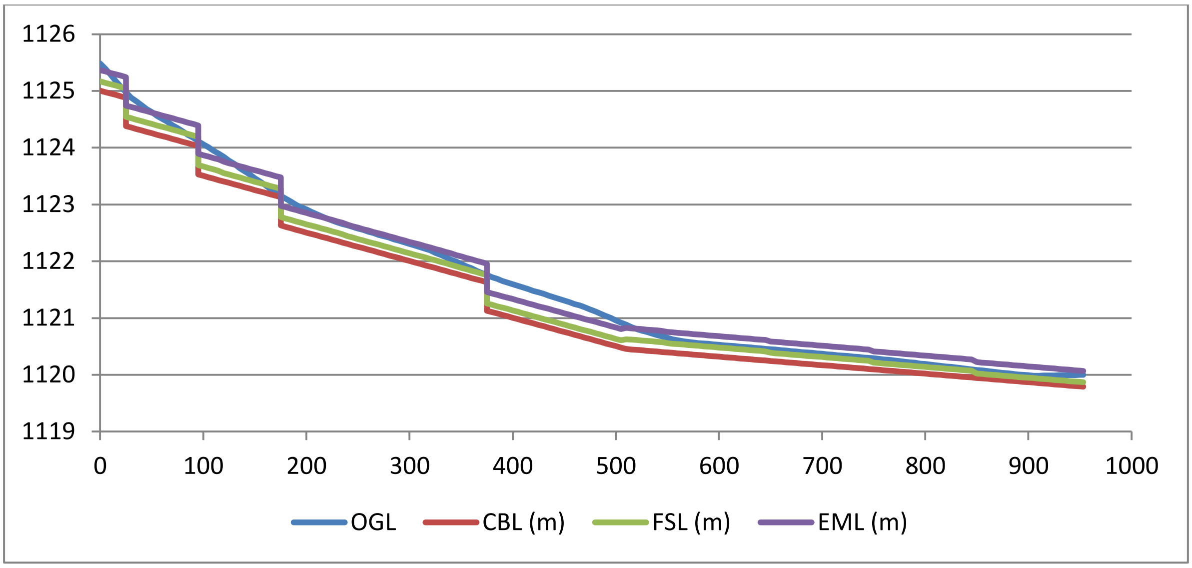


Figure 8-15: RSC2 Profile

Table 8-18: Designed Hydraulic Parameters of RSC3

Chainage (m)	A_{net} (ha)	Duty (l/s/ha)	Q (m3/s)	n	s	b	m	d	b/d	AX (m2)	P(m)	R (m)	V (m/s)	Qcalc	Qcalc - Qreqd	Fb (m)	D (m)	T (m)	Remark
0+000 to 0+002	28.33	0.67	0.0190	0.025	0.0050	0.3	1	0.12	2.41	0.0528	0.65	0.08	0.53	0.028	0.009	0.2	0.32	0.95	Earthen trapezoidal
0+002 to 0+110	21.32	0.67	0.0143	0.025	0.0050	0.3	1	0.11	2.66	0.0465	0.62	0.08	0.50	0.023	0.009	0.2	0.31	0.93	
0+110 to 0+214	16.30	0.67	0.0109	0.025	0.0050	0.3	1	0.09	3.17	0.0373	0.57	0.07	0.46	0.017	0.006	0.2	0.29	0.89	
0+214 to 0+312	11.77	0.67	0.0079	0.025	0.0050	0.3	1	0.09	3.25	0.0362	0.56	0.06	0.45	0.016	0.009	0.2	0.29	0.88	
0+312 to 0+418	7.49	0.67	0.0050	0.025	0.0050	0.3	1	0.08	3.69	0.0310	0.53	0.06	0.43	0.013	0.008	0.2	0.28	0.86	
0+418 to 0+596	1.66	0.67	0.0011	0.025	0.0050	0.2	1	0.05	4.43	0.0111	0.33	0.03	0.30	0.003	0.002	0.2	0.25	0.69	

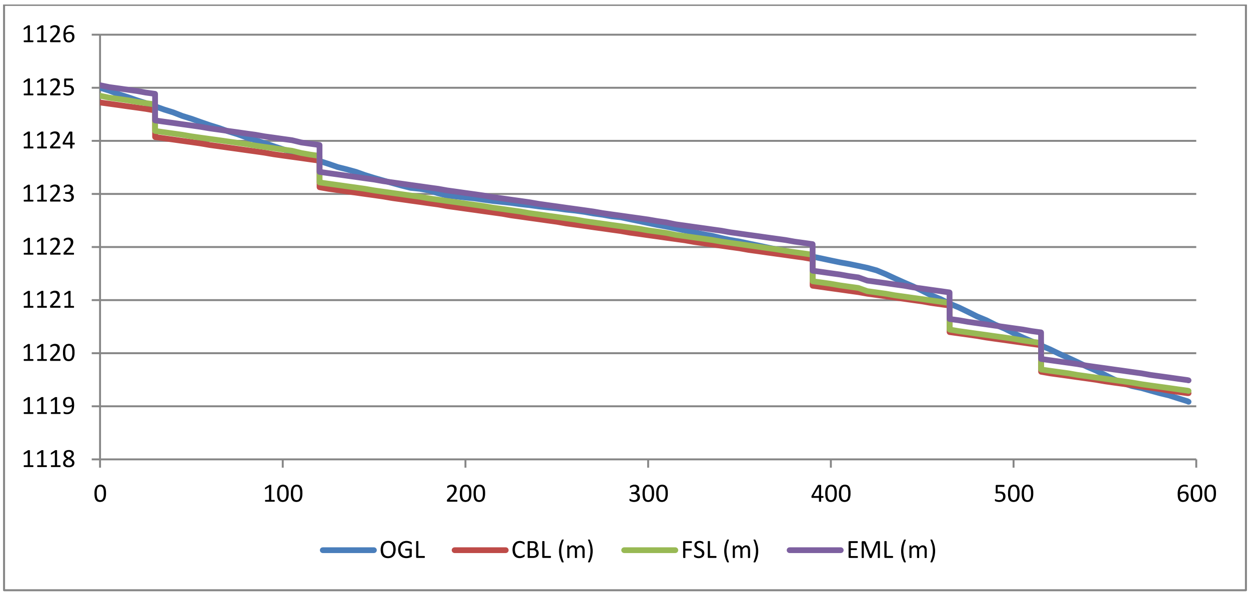


Figure 8-16: RSC3 Profile

Detail Design of Sample Tertiary Unit

A typical tertiary unit has been shown in Figure 8-7. However, a physical designed tertiary canal and corresponding tertiary unit selected for detail design is RTC-1-1 which is located in TU2. This unit consists of three field canals which are supposed to operate at a time. Thus rotation will be expected at the tertiary unit level. These details are shown in table 8-19 below.

It involves detail design of tertiary canal and corresponding field canals situated within this unit as shown here under.

Table 8-19: Detail Design for Typical Tertiary Unit

SN	Parameter	Unit	Value	Remark
1	Net area of RTC1-1	ha	5.38	
2	Duty at head of TC	l/s/ha	0.67	50% efficiency has been accounted for all losses
3	Furrow Length, FL	m	100	
4	Field Canal Length, RFC1-1-1	m	281	
5	Field Canal Length, RFC1-1-2	m	207	
6	Field Canal Length, RFC1-1-3	m	142	
7	Area of RFC1-1-1	ha	2.81	
8	Area of RFC1-1-2	ha	2.07	
9	Area of RFC1-1-3	ha	1.42	
10	Discharge, $Q_{TC} = Q_{FC1\text{-}1\text{-}1} = Q_{FC1\text{-}1\text{-}2} = Q_{FC1\text{-}1\text{-}3}$	l/s	3.6	Rotation within TC is assumed
11	Furrow spacing, Fs	m	0.9	Assumed same for all FC
12	Area of each Furrow	ha	0.009	
13	Calculated stream discharge, Qs of each Furrow	l/s	0.006	i.e. If all 24hrs/day is to be spent in this field
14	Assumed stream discharge of furrow through single outlet of furrow	l/s	2.5	If intended to speed up irrigation at a time. This will be flow through each furrow outlet.
15	Thus Nr. of furrows that can served at a time from availed discharge at off-take	Nr	1.4	i.e. If 2.5 l/s rate is used 2 furrows can be served at a time with incoming flow at off-take
16	Nr of furrows that can be supplied in 24 hr by 2.5l/s rate	Nr	415	i.e. instead of supplying 1Furrow by 0.006l/s in 24hrs, supplying 2.5l/s per furrow can increase this Nr to 415 in 24hr
17	Irrigation duration per day	hr/day	24	
18	Thus, area that can be irrigated in 24hrs by applying 2.5 l/s rate to these furrows	ha	3.73	
19	Or total time required to finish irrigating in RFC1-1-1	hr	18.1	i.e. 40 hours and 30 minutes will be required to rotate within these three field canals. If 1 l/s stream discharge is used 101 hrs or 2 days and 5 hours will be required, and so on
20	And total time required to finish irrigating in RFC1-1-2	hr	13.3	
21	And total time required to finish irrigating in RFC1-1-3	hr	9.1	

Detail Design of Selected Tertiary Unit & Associated Canals

The selected tertiary unit for detail design is TU2 that consists of one tertiary canal, RTC1-1. This canal feeds three field canals that are laid one after the other: namely, RFC1-1-1, RFC1-1-2 and RFC1-1-3. This unit and hence tertiary canal irrigates an entire net command area of 5.38 ha. Properties of field canals under this unit are indicated in table 8-20 below.

Table 8-20: The Three Field Canals Designed to be feed by Selected Tertiary Canal

Name	Length (km)	Chainage	Gross Area (Ha)	Net Area (Ha)	Q (l/s)
RFC1-1-1	0.28	0+000 – 0+280	2.56	2.48	1.66
RFC1-1-2	0.21	0+280 – 0+490	1.40	1.36	0.91
RFC1-1-3	0.14	0+490 – 0+630	1.58	1.54	1.03
Total			**5.54**	**5.38**	**3.6**

Table 8-21: Designed Hydraulic Parameters of RTC1-1

Chainage (m)	Anet (ha)	Duty (l/s/ha)	Q (m3/s)	n	s	b	m	d	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Q_{calc}	Q_{calc} - Q_{reqd}	Fb (m)	D (m)	T (m)	Remark
0+000 to 0+002	5.38	0.67	0.0036	0.025	0.0005	0.3	0.5	0.11	2.71	0.0394	0.55	0.07	0.15	0.006	0.002	0.2	0.31	0.61	Earthen trapezoidal
0+002 to 0+105	2.89	0.67	0.0019	0.025	0.0005	0.2	0.5	0.09	2.33	0.0209	0.39	0.05	0.13	0.003	0.001	0.2	0.29	0.49	
0+105 to 0+208	1.54	0.67	0.0010	0.025	0.0005	0.2	0.5	0.06	3.60	0.0127	0.32	0.04	0.10	0.001	0.000	0.2	0.26	0.46	

Note: Though this hydraulic design parameter is for the intended 24hr supply system one should not stay longer time in one plot thus this table is updated for a 3hr irrigation periods as shown in table 8-29.

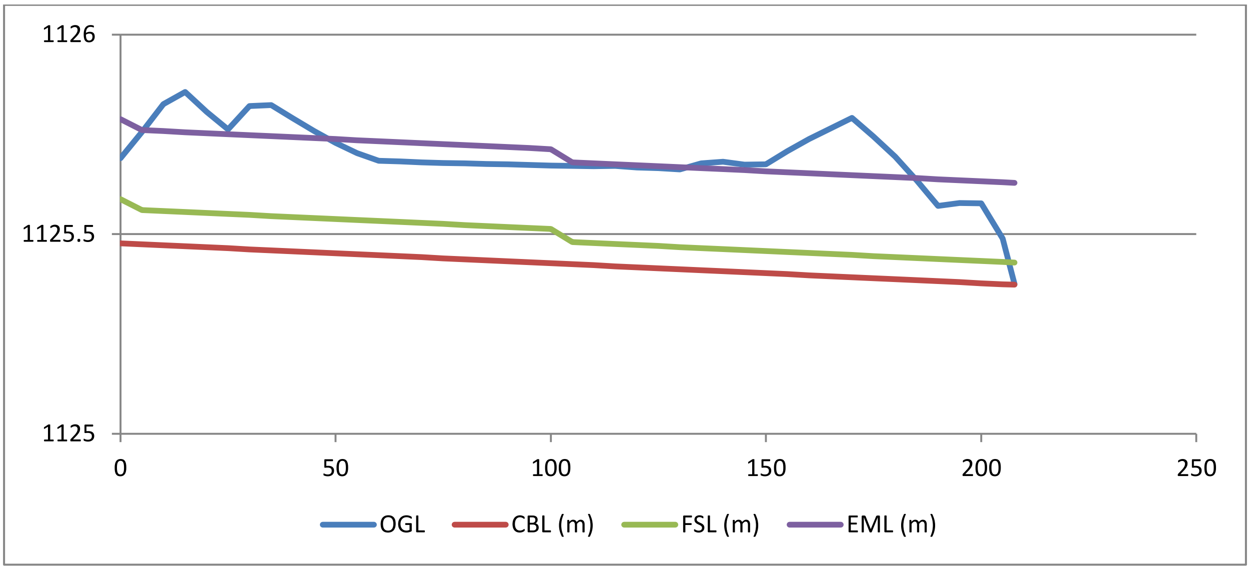


Figure 8-17: RTC1-1 Profile

Furrows

As stated under layout section, furrows are designed to run along contour lines; in addition furrow irrigation system is expected to consist of furrows and ridges, of which the shape, spacing and length depend mainly on the crops to be grown and the types of soils. Distribution of irrigation water to these furrows could be either by siphons which are intended to take water from the field ditch or by jet of water to be released to the furrows from Lay-Flat-Tube (perforated at off-take of each furrow), or traditional diversion system from field ditch.

However, the intension here is that, flow in this case is small enough thus the beneficiaries are expected to manage it easily as they have long experience since years back. Thus no cost has been accounted for furrows within this irrigation system.

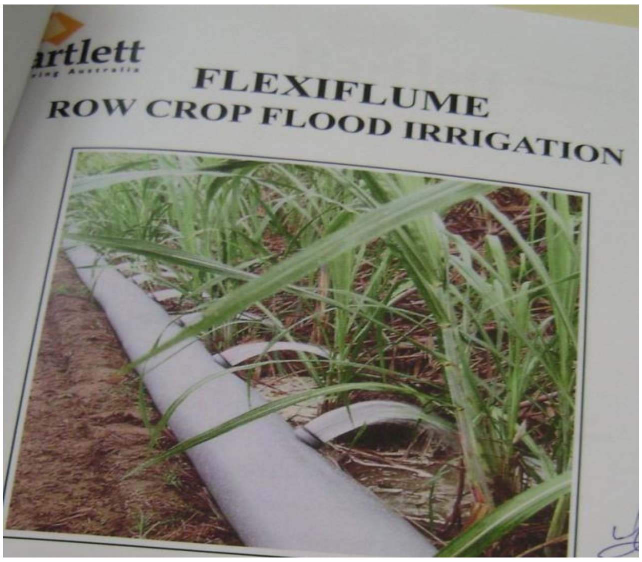


Figure 8-18: Typical Flexi flume/Lay-flat-tube in Operation

Figure 8-19: Typical Siphon tube systems in Operation

Figure 8-20: Existing Flooding Irrigation Experience at the Project Area

8.2.8 On-Farm Structures

General

These are structures designed to facilitate non-destructive and easily manageable irrigation works on the field and along conveyance system. They are referred to all activities related to each secondary and tertiary unit of the project. This unit involves works such as land development; furrows; field and tertiary canals and related structures works such as off-takes/turnouts, division boxes and gate works; tertiary and field drains and related structures works such as drops, culverts, fords etc. if any. Such on-farm works are designed and presented under the following successive sections.

Flume

A flume is here is representing a structure with a change in canal cross-sectional profile of main canal from trapezoidal to rectangular in order to traverse River. It is an aqueduct designed from masonry abutments and concrete crossing channel. There is one such structure supposed to cross or convey irrigation water over the main drainage i.e. Mojo River channel as shown below.

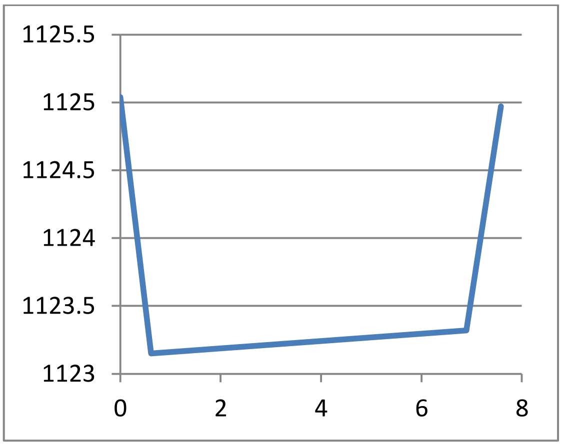


Figure 8-21: Traditional Canal Crossing Structure over Mojo River & its Section

The picture shown above (left) is a traditional crossing structure taken on Mojo River, whereas, the right side is its surveyed cross section. This structure is submerged and flooded after every rainy season. Thus it needs to be elevated over a dyke which is intended to be built for flood protection work (Refer Drawing Number BL/FSD/22: Flume Structure Across Mojo River).

Table 8-22: Hydraulic Design Parameters of Mojo River at Fluming site

Q (m3/s)	n	s	X=Q*n /√s	B (m)	m	d (m)	Y= $A^{5/3}$/ $P^{2/3}$	X-Y	b/d	A_X (m^2)	P (m)	R (m)	V (m/s)	F_b (m)	D (m)	T (m)	Remark
74.04	0.025	0.0065	22.96	8	1	1.87	22.96	0.0	4.3	18.4	18.4	1.4	4.01	0.5	2.4	12.7	Earthen trapezoidal

Table 8-23: Flume Hydraulic Design Parameters

Q (m^3/s)	n	s	X=Q*n /√s	b (m)	m	d (m)	Y= $A^{5/3}$ / $P^{2/3}$	X-Y	b/d	Ax (m2)	P (m)	R (m)	V (m/s)	Fb (m)	D (m)	T (m)	Remark
0.0465	0.014	0.009	0.01	0.2	0	0.30	0.011	0.00	0.7	0.06	0.8	0.08	1.21	0.2	0.5	0.6	Rectangular RCC

Table 8-24: Summary of Hydraulic Design of Flume structure

Item Description	Value	Remark
Width of River at crossing site (i.e. Top width of River Bank-to-Bank), m	8.00	Survey data
Thus flume length will be (i.e. top width of end support), m	8.60	0.5m wide (top) end footings assumed
CBL at entrance to crossing site, m	1125.407	LMC Design data
OGL on right bank, m a.s.l.	1125.04	Survey data
OGL on left bank, m a.s.l.	1124.97	"
River Bed Level, RBL, m a.s.l.	1123.15	"
OGL - RBL, m	1.89	Bank Level - RBL
50 years designed flood, m3/s at crossing site	74.04	From Hydrology Report
Estimated flood depth against Q_d at this site, m	1.87	d, computed against Q_d=$Q_{50\ yrs}$
MFL at this site, m	1,125.02	MFL = RBL + d
Assumed FB, m	0.35	
Designed dyke level, m with existing cross-section	1,125.37	
Effective head	0.04	marginal
Proposed scour depth	2.0	Geology Report
Canal Design Q, m3/s	0.047	
Material selected		RCC
Maximum pillar height h	2.22	h = MFL+FB
Flume Bed Level/Soffit Level	1,125.37	
Roughness, n	0.014	
Flume Shape		Rectangular
Canal flow depth d, m	0.40	
Canal bed width b, m	0.2	
Incoming canal Free board Fb, m	0.2	
Total canal depth D, m	0.60	
Fluming canal bed slope, m/m	0.009	
Velocity of incoming flow, V1 m/s	0.23	
Water Area, m2	0.08	
Froude No, Fr	0.01	Flow is subcritical
Wetted perimeter, p	1.00	p = b+2d
Hydraulic radius, R (m)	0.08	R = A/p
S*L or (canal long. Slope * length of Flume)	0.08	
Head loss, h_L = 1.2 x (v22 - v21)/2g + hf should be < SL	0.09	0.09 > 0.08, thus flow is possible

Since the river is narrow at this section, provision of footing in the middle is not required as it reduces carrying capacity of the river. Thus, only left and right end supports constructed from masonry walls are provided.

Syphon

Canal inverted syphon structure is a concrete pipe barrel designed to cross the right main canal under Deneba River bed as the high flood level of this drain is higher than the canal bed level at this crossing. Such structure is selected because the river has no defined channel other than the proposed flood protection embankment/dyke of 1.16m height. The designed protection embankment is 8m wide with side slope of 1:3. Thus the syphon crossing will have an 8m middle almost horizontal reach and a 5m bends on both inlet and outlet sides to cross under the left and right banks of the stream.

A 30cm reinforces concrete pipe has been chosen to cross under the stream. Design capacity of this barrel is taken the same amount as that of incoming canal discharge. Other design parameters including diameter and head losses are presented in table 8-25 below.

Table 8-25: Design Parameters of Syphon at 0+724 on RMC

Input				Output		
SN	Description	Quantity	Unit	Description	Quantity	Unit
1	Design capacity	0.08	m^3/s	Hydraulic radius (R)	0.15	m
2	Barrel (pipe or square) size:			Chezy coefficient (C)	56	$m^{1/2}/s$
	- Diameter (D)	0.60	m	Total siphon wet section	0.28	m^2
	- Height (h) if square barrel	0.0	m	Siphon velocity (V_2)	0.27	m/s
	- Number of barrels	1.0	No.			
3	Manning coeff. (n)	0.014	$m^{1/2}/s$	Head losses in m:		
4	Barrel bend radius (R_b)	10.0	m	- inlet (dh_i)	0.000	m
5	Barrel slope angle	10.0	degrees	- outlet (dh_o)	-0.001	m
6	Inlet coeff. (k_i)	0.5	-	- barrel bends (dh_b)	0.000	m
7	Outlet coeff. (k_o)	1.0	-	- on length (dh_l)	0.003	m
8	Canal u/s velocity (V_1)	0.31	m/s	Sub-total head losses	0.002	m
9	Canal d/s velocity (V_3)	0.29	m/s	Trash rack loss 10%	0.000	
10	Siphon length	18.0	m	Additional losses 10%	0.000	m
11	Siphon bends (B_s)	2.0	No.	Total head losses	0.002	m

Notes: * for pipe barrel h=0,

Adopted formulas:

- Bend losses $dh_b = [0.124+0.274(h/R_b)*3.5]*d/90*B_s*V_2^2/2g$
- Inlet loss $dh_i=ki\ (V_2^2/2g-V_1^2/2g)$
- Outlet loss $dh_o=ko\ (V_2^2/2g-V_3^2/2g)$
- Loss on length of $dh_l= (2g*L/C2*D/4)*V_2^2/2g$ for pipe barrel
- Chezy's coefficient $1/n*R^{1/6}$

Scour depth at the crossing site has been checked for the selected bed material of stiff sandy silty clay soil. It is accordingly found out to be 1.7m for 50 years return period design discharge of 32.5m^3/s. However, the river has no defined channel (as mentioned above) except the trained section and as the bed will be covered by 0.5m thick gabion mattresses on top extending 2m u/s and 2m d/s (i.e. a total of 4.6m including pipe diameter) & collars are also provided on pipe joints at 2m interval along syphon length. Bed level of the syphon structure is thus set to 0.8m below this river bed level.

Details of this can be referred in Annex-E: Headworks, Irrigation and Drainage, section 4-8.

Division Box

Division Boxes are approached using broad crested weir formula, $Q= CLh^{3/2}$ assuming that flow will be proportionally distributed among all outlets.

Where Q= discharge through rectangular opening, m^3/s

c = coefficient of discharge, C= 1.7
L = effective length of crest form, in m
h = flow depth over the weir, m

Assuming equal c & sill height, S for two or three divided canals, the proportion is: $Q_1/Q_2 = Q_2/Q_3 = L_1/L_2 = L_2/L_3$

Where Q_1= flow in the first canal
Q_2= flow in the 2nd canal and
Q_3= flow in the 3rd canal
L_1= crest length of opening a cross the first canal
L_2= crest length of opening a cross the 2nd canal
L_3= crest length of opening a cross the 3rd canal

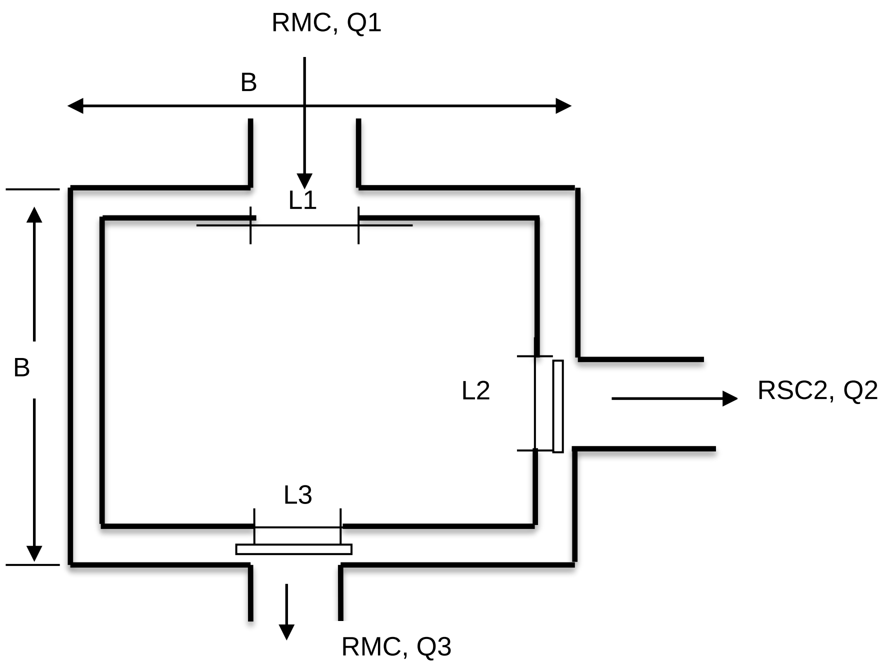


Figure 8-22: Schematic View of Division Box at RSC1 off-take

Table 8-26: Design Parameters of Division Boxes on MCs

DB	Canal	Q1	Q2	Q3	h	$h^{3/2}$	L1	L2	L3	d	f_b	D	b	B	OGL	CBL
RDB1	RMC to RSC1	0.09	0.01	0.08	0.15	0.06	0.9	0.1	0.8	0.38	0.3	0.7	0.30	1.5	1125.47	1125.297
RDB2	RMC to RSC2	0.08	0.04	0.04	0.15	0.06	0.8	0.4	0.4	0.32	0.3	0.6	0.20	1.2	1125.48	1125.004
RDB3	RMC to RSC3	0.04	0.02	0.02	0.15	0.06	0.4	0.2	0.2	0.24	0.3	0.5	0.20	0.9	1125.00	1124.72
LDB4	LMC to LSC1	0.05	0.02	0.03	0.15	0.06	0.5	0.2	0.3	0.31	0.2	0.5	0.15	1.1	1124.49	1124.373

Drop Structures

These are canal structures used to control the velocity of canal water by limiting the canal longitudinal slope to one that generates an acceptable velocity for dissipating the energy of falling water.

Table 8-27: Design Parameters of two Drops: one on LMC & the other on RMC

SN	Description	unit	Results				Remark
			RMC		LMC		
			1st Drop	Adopt	1st Drop	Adopt	
A	**Given Data**		1m ht.		0.2m ht.		Others to be presented in detail report
1	Discharge(Q)	m^3/s	0.023		0.045		
2	U/s water depth(h1)	m	0.24		0.30		
3	U/s velocity(v1)	m/s	0.22		0. 33		
4	D/s water depth(h2)	m	0.24		0. 30		
5	D/s velocity(v2)	m/s	0.22		0. 33		
6	Drop height(D)	m	1.0 0		0.20		
B	**Critical Flow Hydraulics**						
	Description	**Sym.**	**Result**		**Result**	**Adopt**	
1	Drop width	bc	0. 14	0.20	0.20	0.30	
2	Unit discharge	q	0.11		0.15		
3	Critical depth	hc	0.11		0.13		
C	**Stilling Basin**						
	Description	**Sym.**	**Result**	**Adopt**	**Result**	**Adopt**	
1	Basin width	B	0.28	0.30	0. 39	0.40	
2	Length	L_2	0.86	0.90	0. 56	0.60	
3	Lip height	h_c	0.05	0.10	0.07	0.10	
D	**Protection works**						
1	U/S Protection work	L	1.43	1.50	1. 52	1.60	Same for D/S

Culverts

Culverts are canal crossing structures used to facilitate easy access within the scheme. They are arranged along with other on-farm structures and provided at division boxes on main canals to secondary canals. For the rest locations since all canals are of small sizes, traditional crossings can be provided by beneficiaries as need be.

The selected culvert is of box type as it will bridge the command to the main access road. It will have similar slope & total depth equal to the parent canal. Thus, the canal should converge on arriving such site and diverge while crossing it. The bridge is also expected for providing bearing capacity to heavy trucks that will freight products from the corresponding farm plots.

There are four of such road-crossing culverts on main canals (Drawing Number BL/FSD/25).

Table 8-28: Hydraulic Design Parameters of Culverts

d(m)	Q(m3/s)	S	b*d	b+2d	$[n*Q/b*d]^{3/2}$	Left	Right	f_b	V	Dculv (m)
0.30	0.0773	0.0005	0.09	0.90	0.00132	0.10	0.39	0.18	0.86	0.48
0.32	0.0415	0.0005	0.06	0.84	0.00087	0.08	0.26	0.18	0.65	0.50
0.24	0.0225	0.0005	0.05	0.68	0.00053	0.07	0.16	0.20	0.47	0.44
0.31	0.0208	0.0002	0.05	0.76	0.000502	0.06	0.30	0.16	0.45	0.47

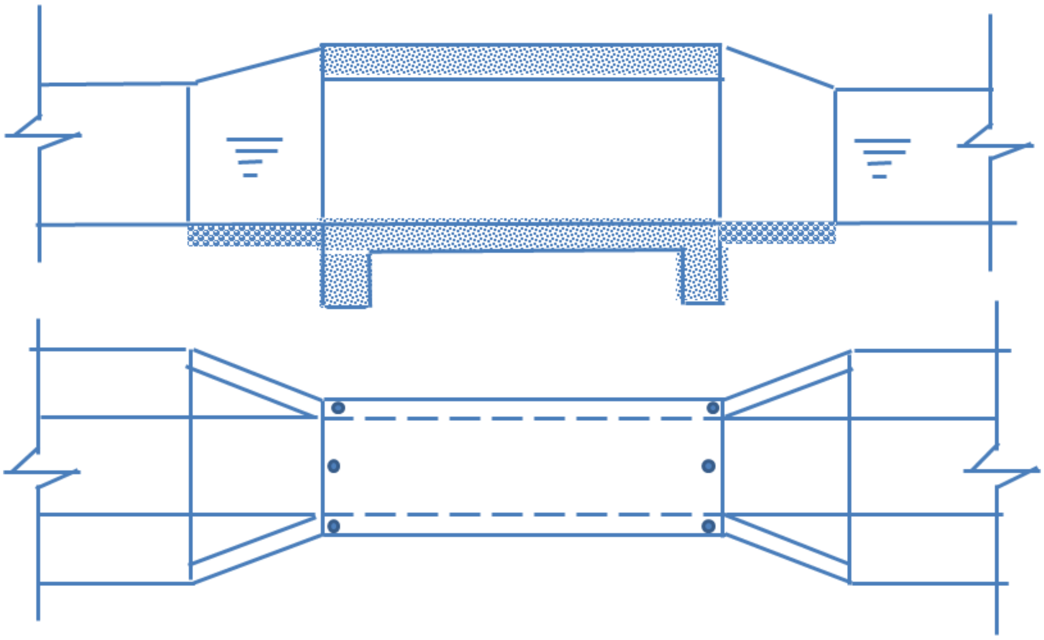


Figure 8-23: Schematic representation of Box Culvert

Turnouts

Turnouts are on-farm structures fixed in the banks of secondary canals to divert water to tertiary canals. There are two cases for off-taking of tertiary canals: those tertiary canals which take-off directly from MC and those which take from SC. Those which take-off from MC are arranged on one side only thus provided with one gate but those which takes-off from SC are arranged such that they supply on both sides of SC thus provided with two gates per two TCs.

There are 32 of such structures in total out of which 14 of them supply on both sides. The remaining turnouts are thus one sided only.

They are considered separately unlike off-takes which are estimated in detailed analysis of a single tertiary unit along with other similar structures within that unit.

$Q = CA\sqrt{2gh}$,

$A = \Pi D^2/4$

$h = y - \frac{D}{2}$

$(\frac{4Q}{\Pi C})^2 \div 2g = D^4(y - \frac{D}{2})$

Where, D is pipe diameter, m

C is a coefficient and = 0.81 assuming it is submerged out flow

A is pipe diameter, m^2

h is water head in a pipe, m

With the assumed stream discharge in single outlet of a furrow of 2.5 l/s total time required to finish irrigating 3.73 ha of RFC1-1-3 is 9 hours and 06 minutes. Thus total discharge required in tertiary canal under consideration i.e. RTC1 feeding three field canals within the unit to irrigate 5.38 ha net through a turnout is 3.6 l/s if in 24 hours using 0.67 l/s/ha or 29 l/s if intended to complete in 3 hours (i.e. 0.67*24/3). Thus design of turnouts is let for the maximum condition 3 hours.

Accordingly, a graph shown below is produced to optimize size of turnout which in this case is a pipe diameter. However assessment for optimization has shown that the graph is of curved nature rather than parabolic so that it enables us to select the least but optimum size of pipe. Thus select a pipe diameter of 200 mm (where change is noticeable) for each turn out to tertiary canals and details can be referred in drawing number BL/FSD/26.

Table 8-29: RTC1-1 Design Parameters for 3 hour's irrigation in RTU2

Chainage (m)	A_{net} (ha)	Duty (l/s/ha)	Q (m3/s)	n	s	b	m	d	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Q_{calc}	Q_{calc} - Q_{reqd}	Fb (m)	D (m)	T (m)	Remark
0+000 to 0+002	5.38	5.36	0.0288	0.025	0.0005	0.3	0.5	0.31	0.96	0.1425	1.00	0.14	0.24	0.035	0.006	0.2	0.51	0.81	Earthen trapezoidal
0+002 to 0+105	2.89	5.36	0.0155	0.025	0.0005	0.3	0.5	0.28	1.09	0.1210	0.92	0.13	0.23	0.028	0.013	0.2	0.48	0.78	
0+105 to 0+208	1.54	5.36	0.0082	0.025	0.0005	0.2	0.5	0.19	1.05	0.0561	0.63	0.09	0.18	0.010	0.002	0.2	0.39	0.59	

Note: This design of RTC1-1 is done for shortening irrigation periods to3hrs in one plot so that irrigation can be attained in a specific plot rapidly. Thus outlets are designed for this capacity than those mentioned in table 8-21.

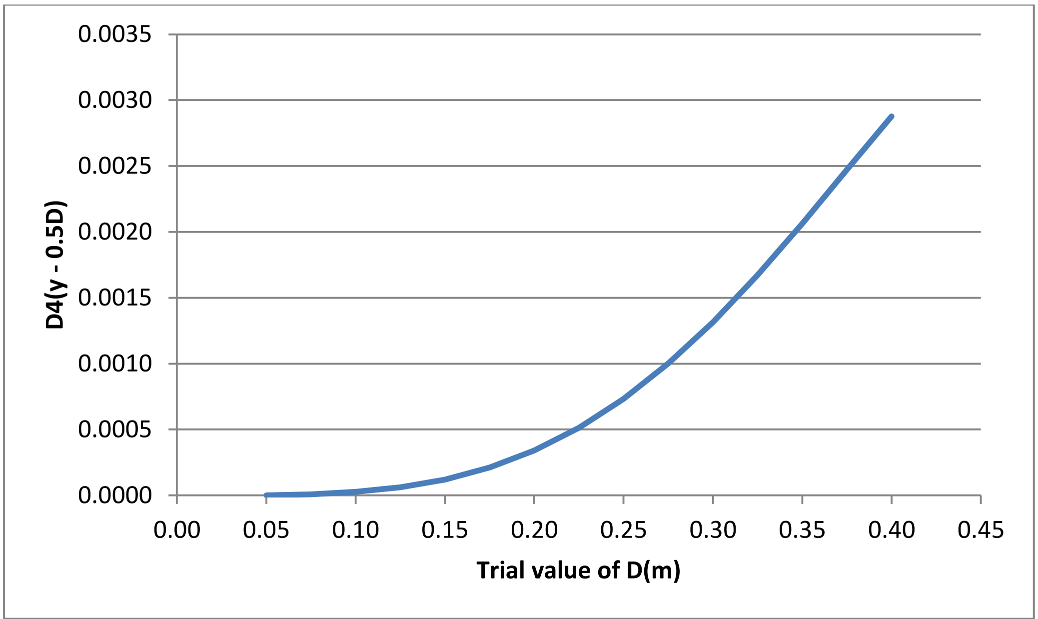


Figure 8-24: Optimization of Turnout Pipe Diameter

Table 8-30: Hydraulic Design Parameters of Turnouts

Turn out	On canal	Q (m^3/s)	Y(m)	$(4Q/\Pi C)^2/19.62$	Trial value of D(m)	$D^4(y - 0.5D)$	D (mm)	Adopted Diameter (m)	Remark
TO-1	FTC1-1-1	0.0288	0.31	0.000104	0.40	0.0029	400.00		2-way
		0.0288	0.31	0.000104	0.38	0.0025	375.00		2-way
		0.0288	0.31	0.000104	0.35	0.0021	350.00		2-way
		0.0288	0.31	0.000104	0.33	0.0017	325.00		2-way
		0.0288	0.31	0.000104	0.30	0.0013	300.00		2-way
		0.0288	0.31	0.000104	0.28	0.0010	275.00		2-way
		0.0288	0.31	0.000104	0.25	0.0007	250.00		2-way
		0.0288	0.31	0.000104	0.23	0.0005	225.00		2-way
		0.0288	0.31	0.000104	0.20	0.0003	200.00	200	2-way
		0.0288	0.31	0.000104	0.18	0.0002	175.00		2-way
		0.0288	0.31	0.000104	0.15	0.0001	150.00		2-way
		0.0288	0.31	0.000104	0.13	0.0001	125.00		2-way
		0.0288	0.31	0.000104	0.10	0.0000	100.00		2-way
		0.0288	0.31	0.000104	0.08	0.0000	75.00		2-way
		0.0288	0.31	0.000104	0.05	0.0000	50.00		2-way

Off-takes
Off-takes are other on-farm structures built on tertiary canals to divert water to field canals. Thus they are opening to field canals but supply one way.

Thus there are 131 of such structures arranged on tertiary canals i.e. at head of each field canal. Each of them is to be controlled with simple shutters on which chain is attached to lift to the required level.

Hydraulic Design Parameters of Off-takes
Flow in off-takes is governed by the orifice formula like that of turnouts.
Since flow in each field canal is expected to be same as that of corresponding tertiary canal, size of turnout designed for head regulators of tertiary canal is taken same size as that of field canal. Thus same pipe diameter of 200mm is proposed here too.

8.3 DRAINAGE SYSTEM

8.3.1 General

When irrigation or rainfall water cannot fully infiltrate into the soil or ground water rises over a certain period of time or cannot move freely over the soil surface to an outlet, then ponding or waterlogging occurs. Smoothening the land surface or establishing series of drainage network so as to remove low-lying areas in which water can settle and partly solve this problem. In this project area the main drain outlet is in the nearby location, thus excess water can be discharged through an open surface drain system.

Poor drainage and waterlogging can cause several adverse effects among which the following can be mentioned: lack of aeration of roots, reduction in soil temperature, delays in timely cultivation operations, inhibited activities of soil bacteria, creation of salinization, and damp climate. Thus, provision of adequate surface drainage in such flat land of this irrigation project is inevitable.

There are accordingly two drainage scenarios considered in this study: external drainage and internal drainage. External drains convey runoff from floods arising from areas upstream of the command area, as well as runoff from within the command area. They are usually well defined water courses which usually require channeling, stabilization measures and/or bank protection. The external drains can be associated with soil and water conservation measures for sloping land; whereas internal drains excavate within a scheme's command area to drain excess rainfall falling onto land within the command area, excess irrigation water and possibly control groundwater levels.

Thus, drains will be required primarily to remove excess water resulted during the rainy season from these two sources which can indirectly control maximum groundwater levels and the risk of salinization.

8.3.2 Identified Existing Natural Drainage System

The project command area is seen not well served by an extensive natural drainage network that can be left undisturbed as drainage (environment biodiversity) corridors due to its flatness, i.e. drainage density is very low. However, the following identified existing natural drains are considered as sources of potential flooding of command area in addition to overtopping from Mojo River. There are main and secondary canals crossing drains which need to be bypassed carefully either by aqueduct or siphons depending on availability of driving head at the inlet.

Most of this existing streams and rivers do not have well defined channels with adequate capacity, thus there is the risk that some floods may spill out of these natural drainage corridors. Analyses were therefore undertaken to determine the potential flood water levels in the main streams and rivers passing through the project command area and where it would be necessary to provide embankments to protect irrigated land from flooding.

On the other hand, drainage from the command area has to be removed by additional drainage networks introduced along with irrigation infrastructures be irrigation canals, or roads or both. In this project area, the command area is very flat and is thus prone to drainage and flooding.

There are nine cross drains identified along the main canal routes of the irrigated land. But none of them has defined channel except Mojo River and spreads while approaching the command. Thus some of them are combined so as to minimize land take and number of structures and hence cost of them. Some of them especially smaller ones are expected to join drains of access road running along main canals. These are shown in the table below and infrastructure layout. Design flood magnitudes of all of these cross drainages are obtained from Hydrology study report of the same project and presented in flood protection design part of this document. Major streams (#2) are designed for 50 years and minor ones are for 25 years return periods.

Table 8-31: Potential Cross Drain Sites for which Design Floods are estimated

SN	Name	X	Y	Expected Design Floods (m^3/s)				Description
				10	25	50	100	
1	Spring Site	797725	966783		√			Spring Eye
2	LCD-1	797998	967738			√		Flume on Mojo R.
3	LCD-2	798428	967552		√			Cross Drain
4	LCD-3	798517	966921		√			"
5	LCD-4	798408	966186		√			"
6	LCD-5	798205	965586		√			"
7	RCD-1	797277	966105		√	√		Flume/syphon on Deneba R.
8	RCD-2	796933	965429		√			Cross Drain
9	RCD-3	797064	965021		√			"

Source: Collected from Infrastructure Layout Map

8.3.3 Layout of Drains

Drainage channels are aligned so as to follow two routes: primarily, natural drainage lines for main drains connecting low lying areas or fields, and secondly, irrigation canals for the others (on opposite sides but same direction). As for drains along irrigation channels, curves are maintained to be as gentle as possible to avoid scour damage where applicable.

Tertiary drains are designed to run parallel to the corresponding tertiary canals and more or less contour lines, but on extreme ends of tertiary units. Tertiary and field drains normally feed directly into collector drains or the minor streams and rivers that bisect the command area if available although collector drains are required in some areas where the natural drainage network is less well defined.

There are also other potential gullies and main drains which need to be guided or protected so that they bypass the command area safely i.e. without affecting irrigation schedules and eroding or flooding of the command area. These gullies and main drains are organized in table 8-32 below and their design and costs are presented in flood protection section.

Table 8-32: Gullies and Main Drains crossing the command

SN	Name	Length, km	Location
1	Mojo River	4.86	Bisect the command in to two; out of this length 386 m is on the d/s & 955 is on the u/s of command area
2	Deneba Stream	0.94	located on the RB of command
3	Gullly_1 Center	0.48	On the LB of command
4	Gullly_2 Center	0.65	On the left end of command
5	Gullly_3 Center	0.50	On the right end of command

8.3.4 Design Water Levels

The water level in the drains at design capacity should ideally allow free drainage of water from the fields. Design of these drain dimensions are considered to be based on a peak discharge (i.e. for the worst case).

The non-vertisols soils have sufficient depth, infiltration and permeability to allow drainage, and leaching if necessary. Thus the priority here would be to remove surface water following rainfall and from excessive irrigation. For non-vertisols on the flat plain (as in this project area) some degree of groundwater table control to maintain water levels below the root zone would be advantageous and a design water level in the tertiary / field drains of 0.5 m below natural ground level is considered. For the non-vertisols found on the well-drained (terraced) slopes, the design (flood) water level in tertiary / field drains need only be 0.2-0.3 m below natural ground level. This “freeboard” is considered to guard against drainage channel over-topping rather than to draw down the water table.

8.3.5 Drain Sections and Design Parameters

Sections of drainage system are designed from trapezoidal as it can collect more excess flow than other sections. For smaller drains such as tertiary and field drains, a uniform section / design discharge is adopted. However for larger i.e. collector and main drains the design discharge is considered to increase along flow direction of the drain channel.

For internal drains, a representative drainage module of 44.2 l/s/ha has been modeled in Hydrology study report. This design discharge of in internal drains is estimated depending on a 24 hour field drainage module of 382 mm. These results are shown in table 8-33 below and 8-34. In addition to this, 10% of irrigation supply in corresponding tertiary canals is anticipated to be drained as excessive or mal-operation may result.

Table 8-33: Collector Drain Data

SN	Name	Leng, km	Catch. Area, km2	Qd_{25} (m^3/s)				Remark
				External	Internal	Excess irrigation	Total	
1	RCD1	0.35	2.08	0.20	0.0	0.0	0.2	External, along LMC
2	RCD2	1.55	3.21	0.27	3.73	0.004	4.0	Across RMC at 1+055
3	RCD3	0.84	1.31	0.15	1.29	0.002	1.4	Across RMC at 1+693

Source: Extracted from Layout Map

The channels capacities are designed for a Manning’s n value of 0.30 assuming the channel is established with some weed growth and not freshly dug. Thus, a Manning’s roughness coefficient of 0.03 is adopted.

As regard to average flow velocities in earthen canals is concerned, to prevent weed growth and dislodge snails and control schistosomiasis would need to be about 0.6-0.8 m/s. Of-course, V.T. Chow (page 158) suggested 0.75 m/s is appropriate to minimize weed growth.

Field Drains

These drains are the smallest designed drains which are intended to collect excess water from on-farm/ fields and deliver it to tertiary drains or main drains/e.g. Mojo River/ depending on their location.

There are 55 of such drains having a total length of 14.17km. They run along field canals and their length ranges from 57 m to 373m.

Tertiary Drains

Tertiary drains are larger than field drains as they collect excess water from those field drains which feed them. They are designed to feed collector drains or main drains /e.g. Mojo River/ depending on their location.

They are 30 in number and 8.24km of total length. Their length varies from 150m to 475m. Summary of these data are presents in table below.

Table 8-34: Summary of Properties of Tertiary Drains

SN	Name	Length km	Drain Area, ha	Drainage module, l/s/ha	Qd, m3/s		SN	Name	Length km	Drain Area, ha	Drainage module, l/s/ha	Qd, m3/s
1	LTD0-1	0.48	16.33	44.21	0.72		Ctd…					
2	RTDM-2	0.43	4.56	44.21	0.20		17	RTDM-8	0.26	2.31	44.21	0.10
3	RTDM-3	0.31	3.77	44.21	0.17		18	RTDM-9	0.25	2.53	44.21	0.11
4	RTDM-1	0.47	7.14	44.21	0.32		19	RTD2-2	0.20	4.60	44.21	0.20
5	RTDM-4	0.23	2.81	44.21	0.12		20	RTD3-1	0.27	2.63	44.21	0.12
6	RTD2-1	0.22	2.56	44.21	0.11		21	RTD3-2	0.29	2.51	44.21	0.11
7	RTD2-3	0.23	2.78	44.21	0.12		22	RTD2-4	0.24	2.66	44.21	0.12
8	RTD2-5	0.24	2.48	44.21	0.11		23	RTD2-6	0.20	2.22	44.21	0.10
9	RTD2-7	0.25	2.52	44.21	0.11		24	RTD3-4	0.36	2.55	44.21	0.11
10	RTD2-8	0.26	2.56	44.21	0.11		25	LTD0-2	0.32	10.00	44.21	0.44
11	RTD2-10	0.27	2.69	44.21	0.12		26	RTD3-3	0.33	2.46	44.21	0.11
12	RTD2-11	0.28	2.77	44.21	0.12		27	RTD2-9	0.22	1.86	44.21	0.08
13	RTD2-12	0.29	2.89	44.21	0.13		28	RTD3-5	0.27	3.45	44.21	0.15
14	RTDM-5	0.22	2.09	44.21	0.09		29	RTDM-10	0.22	2.47	44.21	0.11
15	RTDM-6	0.18	2.12	44.21	0.09		30	RTD2-13	0.26	2.98	44.21	0.13
16	RTDM-7	0.19	1.82	44.21	0.08		**Total**		**8.23**	**107.1**	**44.21**	**4.74**

Collector Drains

There are three collector drains in addition to existing natural gullies which are intended for serving as collector of drainage water and convey it to the main drainage or outfall which in this case is Mojo River. Out of these drains, collector drain RDC3 has been selected for detail design and the results are presented as follows.

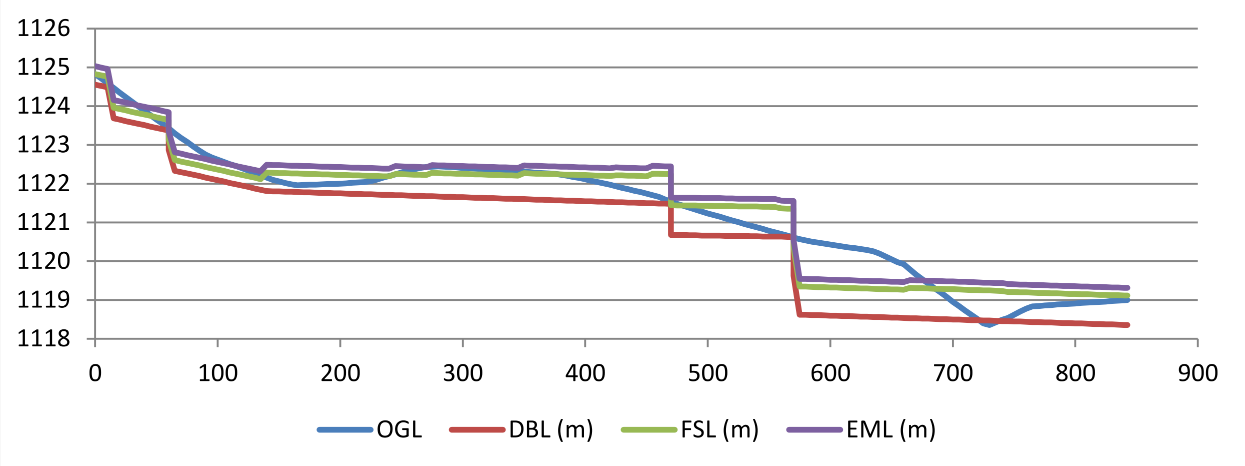
Table 8-35: Hydraulic Design Parameters of Collector Drain, RDC3

Length (m)	A_{drain} (ha)	Duty (l/s/ha)	Q (m3/s)	n	s	X= Q*n/√s	b	m	d	Y= $A^{5/3}$ /$P^{2/3}$	X-Y	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Fb (m)	D (m)	T (m)	Remark
0+000 to 0+137.2	3.47	44.21	0.15	0.03	0.007	0.055	0.3	1.5	0.27	0.0552	0.0002	1.10	0.1945	1.29	0.15	0.79	0.2	0.47	1.72	Earthen trapezoidal
0+137.2 to 0+243	5.02	44.21	0.22	0.03	0.001	0.210	0.4	1.5	0.48	0.2112	0.0007	0.84	0.5311	2.12	0.25	0.42	0.2	0.68	2.43	"
0+243 to 0+275	7.53	44.21	0.33	0.03	0.001	0.315	0.5	1.5	0.55	0.3166	0.0008	0.92	0.7198	2.47	0.29	0.46	0.2	0.75	2.74	"
0+275 to 0+348	9.39	44.21	0.42	0.03	0.001	0.394	0.5	1.5	0.60	0.3931	0.0009	0.83	0.8463	2.67	0.32	0.49	0.2	0.80	2.91	"
0+348 to 0+422	11.85	44.21	0.52	0.03	0.001	0.4972	0.5	1.5	0.67	0.4972	0.0000	0.75	1.0090	2.92	0.35	0.52	0.2	0.87	3.11	"
0+422 to 0+453	13.89	44.21	0.61	0.03	0.001	0.5826	0.6	1.5	0.69	0.5826	0.0000	0.87	1.1370	3.10	0.37	0.54	0.2	0.89	3.28	"

Length (m)	A_{drain} (ha)	Duty (l/s/ha)	Q (m3/s)	n	s	X= Q*n/√s	b	m	d	Y= $A^{5/3}$ $/P^{2/3}$	X-Y	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Fb (m)	D (m)	T (m)	Remark
0+453 to 0+560	18.56	44.21	0.82	0.03	0.001	0.7785	0.7	1.5	0.77	0.7793	0.0008	0.91	1.4147	3.46	0.41	0.58	0.2	0.97	3.60	"
0+560 to 0+663	20.08	44.21	0.89	0.03	0.001	0.8424	0.7	2	0.73	0.8424	0.0001	0.96	1.5626	3.95	0.40	0.57	0.2	0.93	4.40	"
0+663 to 0+715	23.54	44.21	1.04	0.03	0.001	0.9873	0.7	2	0.78	0.9874	0.0001	0.90	1.7593	4.18	0.42	0.59	0.2	0.98	4.62	"
0+715 to 0+742	24.67	44.21	1.09	0.03	0.001	1.0346	0.8	2	0.78	1.0346	0.0000	1.03	1.8238	4.27	0.43	0.60	0.2	0.98	4.70	"
0+742 to 0+842.5	24.67	44.21	1.09	0.03	0.001	1.0346	0.9	2	0.76	1.0354	0.0008	1.19	1.8275	4.29	0.43	0.60	0.2	0.96	4.73	"

This drain collects drainage water from nine tertiary units and conveys it to collector drain two, RCD2 which finally joins the main drainage, Mojo River.

Figure 8-25: Profile of Designed Collector Drain, RDC3



As design discharge, Qd of drains varies along its reach. Thus representative drop located in the middle of the reach is taken for analysis. Accordingly, a drop of 0.8 m depth situated at Chainage of 0+470 is considered as follow.

Table 8-36: Hydraulic Characteristics of Drop on RMD3

SN	Description	unit	Results	
			Computed Value	Adopt
A	Given Data			
1	Discharge(Q)	m3/s	0.82	
2	u/s water depth(h1)	m	0.77	
3	u/s velocity(v1)	m/s	0.58	
4	D/s water depth(h2)	m	0.77	
5	D/s velocity(v2)	m/s	0.58	
6	Drop height(D)	m	0.80	
B	Critical Flow Hydraulics			
	Description	Symbol		
1	Drop width	bc	0.90	0.9
2	Unit discharge	q	0.91	
3	Critical depth	hc	0.44	
C	Stilling Basin			
	Description	Symbol	Result	Adopt
1	Basin width	B	1.56	1.6
2	Length	L2	1.99	2.0
3	Lip height	hc	0.22	0.3
D	Protection works			
1	U/S Protection work	l	1.56	2.0

8.4 FLOOD PROTECTION WORKS

8.4.1 General

The command areas of this project area especially along Mojo and Deneba River banks are susceptible to flooding all around their meandering sections. Especially, Deneba River losses its defined channel while approaching the main river thus needs to confine and direct it to Mojo River by training.

The requirement for this flood protection system was expected to be decided by the client as requested in the inception report in view of its high cost of dyke all along the mentioned river banks or irrigate only in the dry season. However, nothing has been said thus the consultant decided to design it and include in the bill of quantities of this project.

8.4.2 Potential Sources of Command Area Flooding

Such potential sources of command area flooding are stated in the drainage design section and their lengths are also presented in table 8-37. These potential sources are briefly described as under.

Mojo River: This River is one of the potential sources of flooding of the command area on both of its right and left banks. It drains the upstream of its catchment starting from Gara Muleta Mountain and runs in deep valley but gets flattened on approaching the intended command area. Moreover, it overtops both the right and left banks and submerges the command area for short periods of time. Thus, it needs to be protected and bypassed the command so that area under consideration can be used for the intended purpose.

Deneba Stream: This stream drains the upstream of its catchment starting from Bedeno town well but loses its defined channel on arriving the right side of the command area. It damps eroded and transported soils well distributed on this area but submerges irrigable land for certain periods of times.

Gullly-1 and 2 are located on the left side of Mojo River: the first gully being in the middle of the command and the second gulley at the most downstream end of the command. Regardless of their location they are potential sources of flooding of the command area on left bank of Mojo River. They drain left escarpments of the valley and get spread over the proposed command area. Thus, they need to be collected and channeled artificially and let connected to Mojo River. Gullly-3 is the most end gulley situated on the right bank of the command. Its nature is similar to those gullies on the left bank but drains the right bank escarpments which is noticeable while moving to the command area. It needs to be guided on its left bank so that it will not overtop and flood the right side command area.

Table 8-37: Potential Gullies and Main Drains crossing the command

SN	Name	Leng, km	Catch. Area, km2	Qd_{50} (m3/s)	Location
1	Mojo River	4.86	470.786	74.0	Bisect the command in to two; out of this length 386 m is on the d/s & 955 is on the u/s of command area, the remaining being situated within the command area.
2	Deneba Stream	0.94	210.213	32.5	located on the RB of command
3	Gullly_1 Center	0.48	14.169	5.55	On the LB of command
4	Gullly_2 Center	0.65	0.488	0.13	On the left end of command
5	Gullly_3 Center	0.50	33.595	2.59	On the right end of command
		7.43			

Though the total length shows 7.43km only half of the total length of Mojo River protection works is assumed as it has already defined channel unlike other potential sources of flooding. Thus total length of protection works against overtopping is 4.99km.

8.4.3 Hydraulic Design Parameters of Crossing Drains

Hydraulics of Deneba River

This river crosses access road as well as the right side command area. As it loses its natural waterway on arriving this command area, training this river is unquestionable. Consequently, longitudinal slope the designed channel section is adopted from profile of its OGL and found uniform slope of to be 0.0065 all along it way downstream till it joins Mojo River. The width of this stream is also digitized from imagery and found varying from 8 to 10 m within this reach. However, 8 m wide channel is designed so as to minimize land take and there is no more additional tributaries within the reach of considered channel.

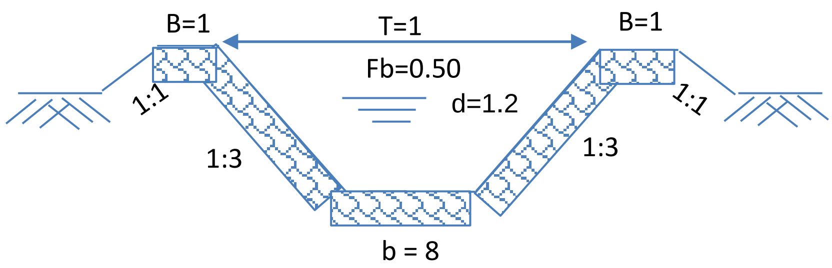


Figure 8-26: Cross section of Designed Deneba River Section

Training this stream and protecting its segment which is situated within the command area (for about 411m out of 937.3 m total length under consideration) using gabion on both of its banks is technically the best option. However, it is seen costly (about 6.6 million) and thus only embankment fill and compaction is considered for 937.3 m total length under consideration and accordingly determined the following hydraulic characteristics.

Table 8-38: Hydraulic Characteristics of Designed Deneba River Segment

Q (m^3/s)	n	s	X=Q*n /Ös	b	m	d	Y= $A^{5/3}/P^{2/3}$	X-Y	b/d	Ax (m2)	P (m)	R (m)	V (m/s)	fb (m)	D (m)	T (m)	Remark
32.477	0.030	0.0065	12.085	8	3	1.16	12.065	0.0191	6.91	13.2747	15.32	0.87	2.44	0.5	1.66	17.94	Earthen trapezoidal

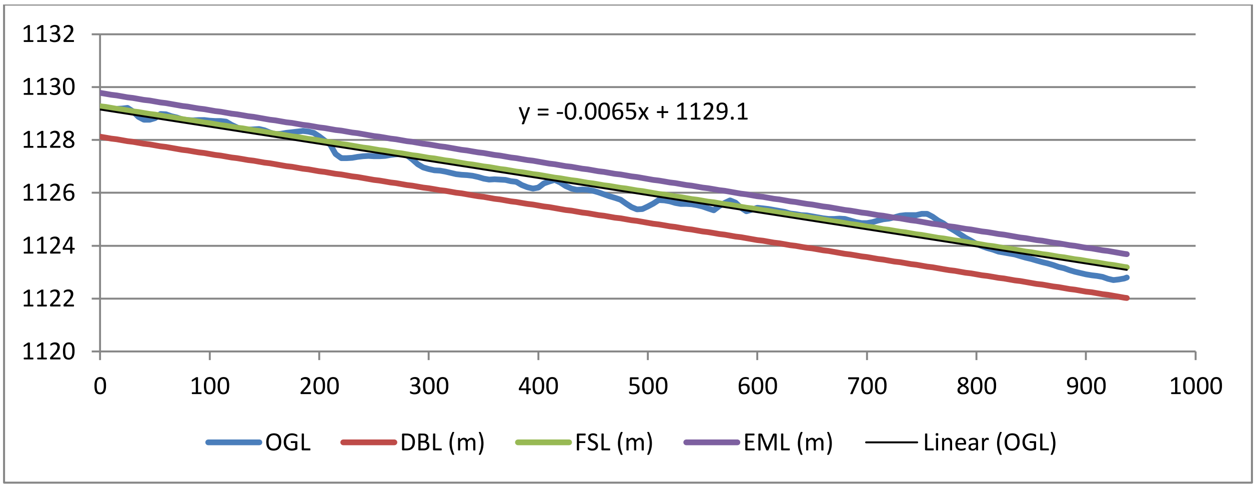


Figure 8-27: Profile of Designed Deneba River Reach

Hydraulics of Gully-1

Table 8-39: Hydraulic Parameters of Designed Segment of Gully-1

Drain	Length (m)	Q (m3/s)	n	s	X=Q*n /√s	b	m	d	Y= $A^{5/3}$ /$P^{2/3}$	X-Y	b/d	AX (m2)	P (m)	R (m)	V (m/s)	Fb (m)	D (m)	T (m)	Remark
Gully-1	0+000 to 0+474.7	5.546	0.030	0.0010	5.2617	5	3	0.91	5.2617	0.000	5.52	7.00	10.7	0.65	0.79	0.3	1.21	12.24	Earthen trapezoidal

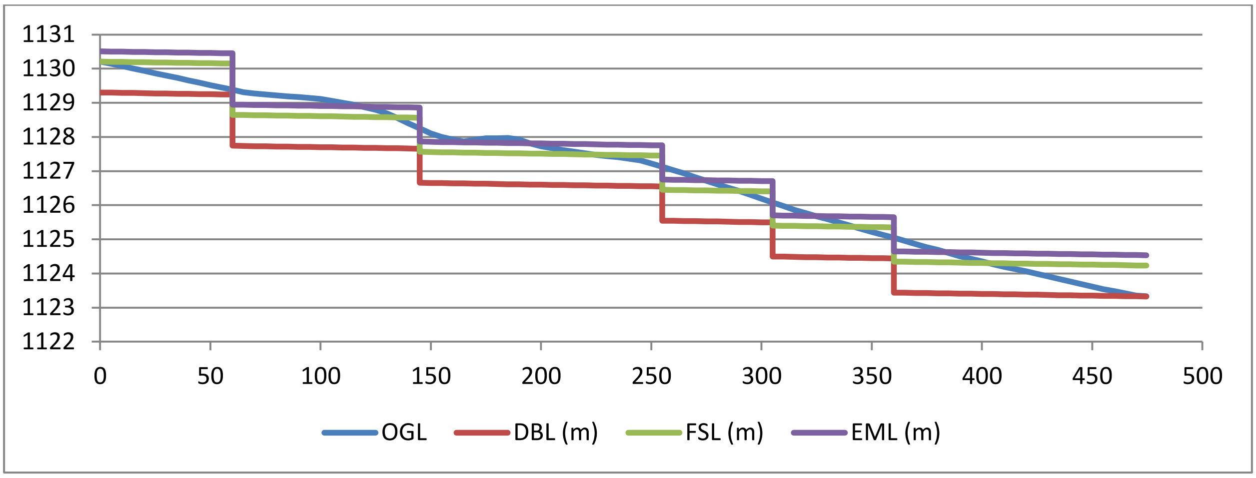


Figure 8-28: Profile of Gully-1 (Crossing on LMC)

Cost of other gullies and flood protection embankment works along Mojo River are estimated depending on cost per meter length of the above potential sources.

Table 8-40: Hydraulic Design Parameters of Drop on Gully-1 (Crossing on LMC)

SN	Description	Unit	Results	
			Drop Value	Adopt
A	Given Data			
1	Discharge(Q)	m3/s	5.55	
2	u/s water depth(h1)	m	0.91	
3	u/s velocity(v1)	m/s	0.79	
4	D/s water depth(h2)	m	0.91	
5	D/s velocity(v2)	m/s	0.79	
6	Drop height(D)	m	1.00	
B	Critical Flow Hydraulics			
	Description	Symbol		
1	Drop width	bc	4.72	4.8
2	Unit discharge	q	1.16	
3	Critical depth	hc	0.51	
C	Stilling Basin			
	Description	Symbol	Result	Adopt
1	Basin width	B	2.81	2.9
2	Length	L2	2.27	2.3
3	Lip height	hc	0.26	0.3
D	Protection works			
1	U/S Protection work	l	2.73	2.0

Hydraulics of Mojo River

This river is a mother outlet for the whole drainage of the catchment. It bisects the command in to two. As there are no as such large tributaries in the middle, same design discharge is considered as that at flume crossing all along its reach running within the command boundary plus some distance upstream and downstream of this boundary.

For the selected 50 years return period design flood of 74 m^3/s, corresponding design head for the existing cross section is computed out to be 1.87 m (refer table 7-22). Whereas, the difference between river bed level and river bank level is 1.89 m. However if we allow a free board of 0.5 m, then dyke depth required is =1.87+0.5-1.89 m = 0.48 m.

Thus a 0.48 m high 1 in 3 side slope embankment work is assumed on both sides of this river for about 4.8 km to protect overtopping of this design flood.

8.5 ROAD WORKS

8.5.1 General

To carryout operation and maintenance activities effectively and efficiently, and for any development activities within the scheme, basic infrastructures especially access road in to the scheme and within the scheme are critically required. The size and type of access and service/farm roads which are supposed appropriate for the project are selected and designed. Accordingly, as this project is of small scale in its nature running along Mojo River on its left and right banks and land is badly required by beneficiaries', there will not be as such networked farm roads along tertiary and field canals. Hence, only main roads along both left and right main canals and four service roads along secondary canals are designed to connect to the main dry weather access road running from Burka town to Tirtiro village.

8.5.2 Road Network

Road networks in this project are considered and laid along main and secondary canals so that production can be transported to the main access road and hence market areas and/or beneficiaries' residents. Main access roads design parameters are presented in table 8-41 below.

Table 8-41: The Proposed Road Dimensions

Design Parameter	Unit	Service/ Inspection Road	Scheme Access Road
Carriageway width	m	4	7
Minimum shoulder width on each side	m	0.5	1
Minimum height above ground level	mm	-	700
Minimum horizontal radius at curves	m	15	50
Cross fall (from center line)	%	4%	3%
Minimum thickness of earthen embankment	mm	-	400
Sub-base thickness (graded crushed rock)	mm	150	200
Base course thickness (graded crushed rock)	mm	50	150
Total (graded crushed rock) thickness	mm	200	350

Table 8-42: Designed all road types together with their lengths and locations

SN	Name	Length (km)	Remark
1	RMR1	2.95	Laid along RMC but joins main road prior
Sub Total RMR		**2.95**	
2	RSR1	0.12	
3	RSR2	0.95	
4	RSR3	0.60	
Sub Total SR		**1.67**	
Grand Total Right side		**4.62**	
5	LMR1	3.25	Laid along LMC
Sub Total LMR		**3.25**	
6	LSR1	0.26	
Grand Total Left side		**3.51**	
Grand Total		**8.13**	

Standard cross sections for these roads are presented in Volume 4: Engineering Drawings, Drawing Nr. BL/FSD/31.

9 ENVIRONMENTAL IMPACT ASSESSMENT

9.1 METHODOLOGIES USE FOR EIA STUDY

A feasibility study, of an Environmental Impact Assessment (EIA) is carried out for this project. The study helps in ensuring environmental sustainability of an area. Its main objective is to harmonize possible environmental problems expected during project implementations with its surrounding and downstream project areas. The overall approach used to carry out the EIA study of Bareda Lencha Small Scale Irrigation Project was based on the Terms of Reference provided and EIA guideline.

The EIA study data was collected through field observation, stakeholders' consultations, review of relevant documents and reports. Secondary data was collected from zone and wereda sectors and administration. Essential data was collected from East Hararghe Zone Agriculture, Water, Mines and Energy and Rural Land and Environmental Protection departments. Similarly, secondary data was collected from almost all wereda sectors. Consultations were conducted with the zone and wereda sectors and local community representatives.

9.2 FINDINGS AND MITIGATION

The EIA study showed no major adverse impact by the project implementation as it is small scale irrigation project. But minor adverse impacts associated with the project implementation can be controlled through environmental monitoring and management measures. The project implementation will result in various major socio economic benefits to the people of the intended project area. The identified main benefits include employment opportunities, promoting food security and community livelihood enhancement, improving community living standard, infrastructure improvement, minimize or eliminate flooding, promoting agricultural sector development and helps in enhancing environmental sustainability of the area. Above all, the project helps in ensuring food security of the people of the irrigation command area and its surrounding.

Conversely, construction and operation of the project can result in several adverse environmental and social impacts. The impacts are indicated by project phases, project design or planning, construction and operation phases. The major adverse impacts on the physical, biological and social environments are related to impacts on water balance and downstream environmental release, soil erosion and siltation, Deneba and Majo Rivers flooding, water logging and salination, impacts on water quality, aquatic ecology, public health, resource uses and movements access disruption.

Stakeholders' views on the project were identified through consultative meetings. Four stakeholders' consultations were conducted with zone and wereda sectors and project area community representatives. Participants of the consultative meetings were recommended possible measures to minimize and/or eliminate project adverse impacts and optimize benefits for the development of the project area, the country and sustainable use of the environmental resources of the area. All consulted stakes were expressed positive attitudes towards the project.

The identified impacts were evaluated based on the impacts type, duration, nature, magnitude, reversibility and significance to determine effectiveness to minimize or eliminate expected adverse impacts through the project development periods. Among all, the major identified adverse impacts of the project are related to Gurati Spring water abstraction and downstream release and movement access disruption by canals.

Based on the project size and the project area real conditions, though those impacts are expected, they can be managed and mitigated using the recommended measures. To minimize or eliminate possible adverse impacts of the project; promoting efficient irrigation water use, conducting permanent water quality monitoring, promoting conservation activities, conducting permanent de-silting activities, optimize agrochemicals application and use, strengthen on-farm management, etc are among the recommended major measures. The impacts on the socio-economic environmental components can be managed by promoting community domestic safe water supply, creating awareness on waterborne and water related diseases prevention, draining marshy areas, borrows pits and any stagnant water points to control mosquito and other disease causing vectors breeding, harmonize land use conflicts, ensure coordination and collaboration of sectors in public health control and promote health services coverage are among major measures.

The study also investigated environmental monitoring plans based on the project area environmental conditions. The major environmental monitoring plan are monitoring water balance and downstream release, soil and water conservation, construction activities, soil fertility, salinity and sodicity change trends, groundwater levels and salinity for wells and springs within the command area, Gurati Spring water quality, ground water discharges and underground water quality change trends, livestock and grazing land carrying capacity trends, agrochemicals application and use, public and environmental health, benefits or household income level trends and conducting environmental audit. Implementations schedule of the monitoring plan were also proposed by project phases; design, construction and operation phases with frequency and institutional responsibilities.

Environmental cost was estimated for the environmental management, monitoring and training to effectively implement the recommended measures. The overall environmental cost is estimated at Birr 1,432,335.00 (one million four hundred thirty two thousands, three hundred thirty five birr only) for the first year and Birr 4,297,005.00 (four million two hundred ninety seven thousands and five birr only) for the first three years of the project period.

Finally, the environmental assessment study result came up with conclusions that there is no condition obtained that lead to “no-go” option of the planned project expansion if the identified mitigation measures are properly implemented and managed. Therefore, Bareda Lencha Small Scale Irrigation Project is found technically and economically feasible, socially and environmentally acceptable with best opportunity to achieve the development goal of the wereda, region and the country as a whole in attaining food security of the project area.

10 BILL OF QUANTITIES AND COST ESTIMATE

10.1 UNIT RATE ANALYSIS

Before estimating bill of quantities of each item, rate build up is made for all bill items of the project in consideration of cost of current construction materials and approximating future inflation of input construction items (as contingencies). Based on these costs, the estimated investment cost and annual operation and maintenance costs are derived for budgetary purposes and financial viability evaluation.

Summary of analyses of these rates are indicated in appendix part of Appendix 1: Summary of Unit Rate Analysis.

10.2 SUMMARY OF BILL OF QUANTITIES AND COST ESTIMATE

Estimated costs of the project construction, which are considered as the engineers estimate, are prepared based on three particulars: namely, the established design criteria of this project and bill of quantities and estimated current rate for construction and procurements of items as shown in detail under Annex-E: Head Works, Irrigation and Drainage, chapter-8. In arriving at this estimate of this bill of quantities of each item, take-of-sheet was scrutinized in excel program and summarized here is only BOQ, rate and cost.

11 FINANCIAL AND ECONOMIC ANALYSIS

11.1 GENERAL

Both financial and economic analysis are computed based on comprehensive and standard analysis approach that considered all outflow and inflow to the project and relevant guiding principles indicated including requirement of the TOR of the client.

11.2 OBJECTIVE

The specific objective is to test whether the project meets the basic financial and economic viability and justify whether the project is worth full for investment of scarce capital resources. With this in mind, it tried to show the rate of return on capital investment in implementing the project, and indicated the degree of financial Viability of the project. The analysis also indicates the net returns, which will accrue due to the farmers and the project in general.

11.3 METHODOLOGY

The analysis considered scenarios under **"with" and "without"** project situations. Under both scenarios identified cost outflow and income inflow, developed crop and farm budgets per hectare, crop net return per hectare, net incremental return and computed the analysis.

In making the analysis, the required procedure and methodological approach adopted to arrive at reliable financial Viability indicators.

- Investment cost estimated based on the engineering estimate and derived from BOQ and included supervision cost (5%), contingency (10%) and VAT tax (15%)
- Maintenance cost included assuming 2% of investment cost
- Farm implements identified and included
- Replacement cost identified and considered every five years that expected to be incurred by farmers
- Constant market price used for both cost and benefit to absorb inflation effect
- In the economic analysis appropriate conversion factors used
- Other operational cost identified and quantified as appropriate

The standard and commonly used financial and economic feasibility analysis tools used that includes Net present value (NPV), internal rate of return (IRR), and B/C ratio to determine viability of the proposed project.

11.4 THE PROJECT AND BENEFICIARIES

The Bareda lencha irrigation project is located in East Hararghe zone, Gola oda woreda, Bareda lencha peasant association. The proposed irrigation use diversion irrigation system from Gurratti spring water source. The net irrigable area of 202ha expected to be effective under proposed irrigation system. The average land holding size at the project area is 0.75ha and the project expected to support 270 household beneficiaries.

11.5 PROJECT COST

11.5.1 Investment Cost

The irrigation infrastructure and system development cost estimated to birr 7,082,601.89. The total investment cost including management/supervision (5%), contingency (10%) and VAT tax (15%) estimated to birr 9,407,465.96.

Table 11-1: Summary of Total Investment cost- Irrigation infrastructure & system dev't

No	Item	Estimated cost	Community	
			Share (ETB)	Share (%)
I	**Irrigation system**			
1	Preparatory Work	656,711	0.0	
2	HW/Spring Protection works	547,985	37,115	
3	Main Canals and related structures	580,970	313,057	
4	Secondary Canals and related structures	259,802	38,571	
5	All Tertiary Units	1,006,326	111,156	
6	Collector Drains	685,844	145,737	
7	Flood Protection	3,344,963	401,924	
	Total	**7,082,601.89**	**1,047,559**	
II	**Management & Supervision cost (5%)**	**354,130.09**		
III	Total Investment cost	7,436,731.98		
	Total Investment with Contingency (10%)	8,180,405.18		
	Grand total Investment with VAT (15%)	**9,407,465.96**		

11.5.2 Other Investment cost

With development of the irrigation system, improved farm tools and implements required. Farm tools are estimated based on the area planned for development (sprayers -1/ha and others tools 3/ha and 2 motor cycle for management and supervision of the project and the total cost estimated to birr **1,485,748**. Except the motor cycle cost, this cost are assumed to be covered and financed by household beneficiaries and the motor cycle assumed to be covered from Woreda agriculture office budget.

11.5.3 Operation and Maintenance cost

Operation and maintenance cost assumed the annual cost for running the schemes that includes maintenance cost, motor cycle and other running cost, training and other capacity building cost. Farmers training and capacity building assumed in the first year and the total cost of operation and maintenance cost estimated to birr 317,374.9 in the first two years and decrease to 183,002.2 then after.

11.6 PROJECT FINANCING AND COMMUNITY PARTICIPATION

Farm tools and other replacement cost as well as operation and maintenance cost is to be covered from beneficiaries' communities. In addition to this, the project investment is expected to be financed with participation of communities that willing to contribute labor and other local materials and the total estimated to about 14.8% of the total irrigation system investment cost, and the remaining project and investment costs expected to be covered and financed either from government source or other external sources.

11.7 CROPPING PATTERN

Without project wet season production and cropping pattern includes mainly maize and Banana and dry season includes maize, banana and sweet potato and few production of chat. With project condition also considered local cropping and farmers preference and enables to produce two season production of diversified crops that includes wet season (maize, chat, banana and Haircoat bean) and dry season (maize, chat, banana, Haircoat bean, onion and tomato).

11.8 WITHOUT PROJECT RETURN AND COST

Without project wet and dry season production estimated and the total annual farm cost estimated to be birr1,795,307, and Gross total farm income of birr 5,044,950 and the annual net return amounts to birr 3,249,643.

11.9 WITH PROJECT RETURN AND COST

11.9.1 Total Annual Net Return

Farm budget was prepared for each crop by years for both wet and dry season. The total annual net return in the first year of operation is birr 1,619,477 and expected to increase to birr 9,525,329 at full optimization stage of year 3 and after.

11.9.2 Net incremental return

Net incremental return estimated by deducted without project net return from the with project total net return of the project. Accordingly, net incremental return is birr 6, 275,686that shows about 193.1% additional net incremental return to the without project.

11.10 FINANCIAL ANALYSIS RESULT

The financial analysis was carried out after developing all the project cost and benefit flow and gross and net returns accruing to the farmers and/or project owners. The Net Present Value is Birr 37,717,924.49 which is highly positive and based on the IRR criteria, the IRR results indicate 46.8% which is more than the opportunity cost of capital (11%), indicating the viability of the project. Based on the B/C ratio criterion, it result 1.84 which is much above one and meet the viability criteria in all yardstick indicators.

11.11 ECONOMIC ANALYSIS RESULT

The computed economic analysis result indicates viability of the project under all the viability indicators with positive economic net present value of birr 40,176,756.61, Internal rate of return 47.6% which is much above the cut point rate and economic benefit-cost ratio 1.78.

11.12 SENSITIVITY TEST

Sensitivity test was also computed under different scenario and assumption with change in some variables, mainly with change in cost outflow and return inflow. The sensitivity test result justifies and meet viability requirement under all the scenarios and assumptions.

In general, the irrigation project return outweighs the cost and tested worth full from both financial and economic point of view. As discussed in different sectorial reports of feasibility study, the project is technically feasible, socially acceptable by the beneficiaries and stakeholders, and financially attractive, and institutionally possible to organize and manage at small holder household level, and the national policy favors the establishment of such projects as a strategy to alleviate food supply in the country and recommended for implementation as it proves efficient allocation of capital resource.

12 IMPLEMENTATION SCHEDULE BY MAJOR ACTIVITIES

As any project is time limited task, its implementation should have timetable so that necessary inputs be arranged accordingly. In view of that, this project is expected to be completed in one fiscal year under predicted supply conditions of material, financial availability and manpower arrangement.

The following table shows such schedule designed and presented for major activities of this project.

Table 12-1: Indicative Implementation Schedule of the Project by Major Activities

Bill No	Activity	One Fiscal Year											
		Quarter-1			Quarter-2			Quarter-3			Quarter-4		
		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	Mobilization, Demobilization & Access Road Construction,												
2	Engineering surveys and preparation of as built drawings												
3	Camp (Warehouse, Construction staff residence & Toilet) construction												
4	Headwork/protection works												
5	Main Canal (RMC & LMC) Works												
6	Secondary Canal (RSC1, RSC2, RSC3& LSC1) Works												
7	Tertiary and Field Canal Works												
8	On-Farm Structure Works including Cross Drain Structures												
9	Drainage Works												
10	Service Road and Flood Protection Works												
11	Supply and installation of pipe and gate works												

Note: Indicated schedules do not show scope of works but timetable at which each activity should be considered be in parallel or separate.

13 CONCLUSIONS AND RECOMMENDATIONS

The proposed Bareda Lencha small scale irrigation project is intended to irrigate about 300 hectares of land as stated in the TOR, however the study has revealed that yield of this spring is limited and serve for multipurpose uses such as irrigation, water point for domestic water supply and livestock consumption, cloth washing, taking bath for all groups of the community and downstream releases/uses for environmental purposes. Consequently, computed water balance including irrigation water requirement has shown that flow of this spring cannot accommodate nothing more than 202 net hectares of land.

This study has also shown that, there are a number of uses from this spring all being at the same spot. Thus it is found necessary to design separate supply systems for all these uses in contrast to the existing experience. Accordingly, necessary infrastructures are included along with headwork design.

This study has also shown that Mojo Gurati spring water is of low turbidity, and no night storage structure is needed as the beneficiaries use it for all the 24 hours of a day, unless otherwise deficit irrigation is used which of-course is not recommended. The consultant thus maintained existing traditional irrigation experiences of 24 hours of a day with respect to irrigation durations in a day. This has been raised for discussion in the inception report of the consultant and accepted by the client.

One of the most important findings from this study is that source of supply is almost fully under full utilization. Yet, major benefit of this project will be introduction of appropriate permanent structures and related infrastructures to improve efficiency of supply system. However, the major problem of the area is overtopping of and hence flooding of the command area from the main river Mojo and other streams bisecting the command by Deneba and the like. Thus drainage network as a solution and flood protection dyke or embankment as protection mechanisms are designed to overcome such consequences including river training of those streams.

The project is also expected to contribute other direct and indirect social and economic development effect and benefit to the society at large than direct irrigation benefits and hence implementing this irrigation development project is tested worth full from financial and economic point of view.

Engineering cost per hectare of this project is found out to be 35,073 ETB/ha net, thus the project is within the normal range of engineers estimate.

The results of financial and economic analyses carried for the base condition show viability of the project from financially viable option for investment. The financial viability test result indicated Net Present Value/NPV of birr 37,717,924.49, Financial Internal rate of return/IRR of **46.8%** which is much above the opportunity cost of capital, B/C ratio of 1.84 which is above one to bring added value for investment capital and under the financial viability indicators worth for implementation. The project is still viable with increase in investment cost by 10% and decrease in benefit by 10% and even assuming simultaneous adverse change in both variables and advisable to implement in line with proposed development plan.

Economic viability also tested and the result is much greater than the financial return. The project is also anticipated to contribute to other social and economic development for the area and implementing the proposed irrigation development project is tested worth full from financial and economic point of view.