OROMIA IRRIGATION DEVELOPMENT AUTHORITY

MADDAGURA ERBE SMALL SCALE IRRIGATION PROJECT

IRRIGATION & DRAINAGE SYSTEM DESIGN DRAFT FINAL REPORT

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ACRONYMS AND ABBREVIATIONS

a.s.l	Above Sea Level
Br	Birr
CROPWAT	Crop Water Requirement
d	irrigation depth
D	root depth
Ea	Application Efficiency
Ec	Conveyance Efficiency
Ed	Field canal Efficiency
ETcr	Crop Evapotranspiration
ETo	Reference Crop Evapotranspiration
Ha	hectare
H.H	House Holds
i	irrigation interval
IRn	Net Irrigation Requirement
IRg	Gross Irrigation Requirement
Kc	Crop coefficient
l	liter
LGP	Length of Growing Period
MD	Man Day
mm	millimeter
^oC	Degree centigrade
OD	Oxen day
P	allowable depletion
p	Total rainfall
p_{eff}	Effective rainfall
OWWDSE	Oromia Water Works Design and Supervision Enterprise
OIDA	Oromia Irrigation Development Authority
Qt	Quintal
s	Second
Sa	available water supply
UTM	Universal Traverse Meridian

1. INTRODUCTION

1.1 General

The agricultural practice of our country is characterized by rain fed subsistence farming that use outdate farming system which leads to low level of productivity and frequent drought & food insecurity problem in most part of the country. The region in particular is one of such areas is endowed with shortage amount of surface and sub-surface water resource, so there is no enough water for most farmers to produce more than one crop per year and also there are frequent yield reduction/ total crop failures due to uneven and erratic distribution of rainfall and the unusual climate changes which brings negative impact on the available natural resources. Thus, owing to rapidly increasing population (demand) of our country, which is exacerbated by backward agricultural activities and unusual weather changes, it's totally risks fully to rely only on rain fed agriculture.

One of the major alternatives to overcome/minimize such problem is to develop or improve the potential of agriculture through implementing small, medium and large-scale irrigation schemes for enhanced productivity by providing sustainable right/optimum amount of water that brings maximum yields throughout the year.

By Understanding these facts, our client, Oromia Irrigation Development Association, (OIDA), has developed a plan that alleviating the chronic problem of food shortage through efficient utilization of the enormous resource (land and water) so that social and political condition of the region will be improved by Increasing and diversifying the crop production. In meeting this broad objective, OIDA is currently involved in the design and construction of different irrigation projects and has signed an agreement with Oromia Water Works Design & Supervision Enterprise (OWWDSE) for requiring the consultancy services for Feasibility and Detail study and design of Maddagura Erbe small Scale Irrigation Project.

1.2 Objectives of Design

The main objective of the system design is to carry out Feasibility study and complete detailed engineering design of Irrigation & Drainage system which include identification of resources; fixing of design criteria, developing of infrastructure layout, designing of canals and drainage system, design of hydraulic structures, preparation of drawing album, preparation of BOQ, specification and tender document, etc. for the best selected scenario which is acceptable, easily manageable and economical without affecting achievement of the intended purposes.

1.3 Location & Accessibility

The command area of the project is located in woredas of Oda Bultum West Hararge Zone of the Oromia National Regional State. The capital of the woreda, ***Badessa***, is found some 380 kilometers east of Finfinne, and can be accessed using the 325-kilometer Finfinne-Ciro-Arbarakkate asphalt road to be followed by the Arbarakkate-Badessa all-weather gravel road which is about 55 km long, and is being upgraded into asphalt road. The selected headwork site is situated at 695340.54m Easting and 964869.3m Northing, which is accessed through 435Km weather road from the capital city of the region, Finfinne along the asphalt road leading from Ciro to Hirna and through gravel road of 35 km, Ciro town.

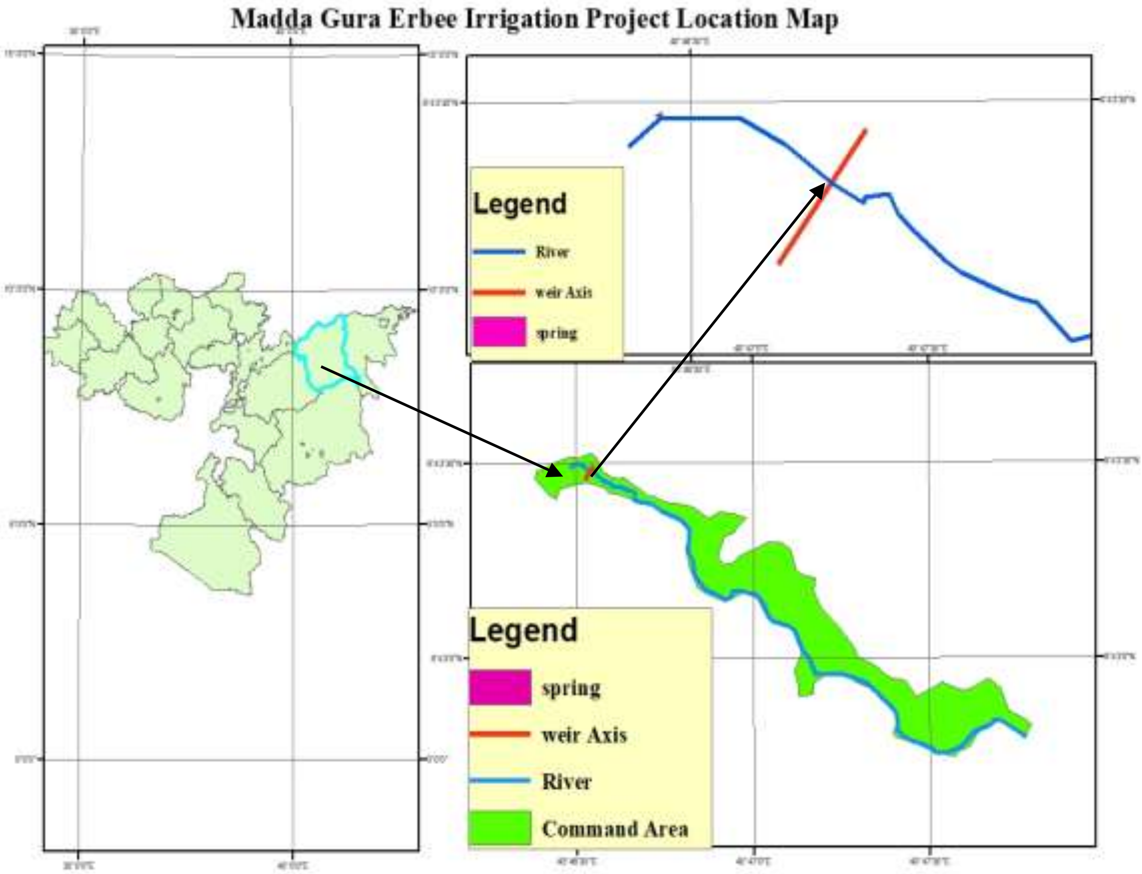

Figure 1-1: Location Map of Madda Gura Erbe Small Scale irrigation project

1.4 Report Structure

This report presents the system design of the project, which covers the Feasibility Study and detail design phase which focused on data collection, analysis and detail design of the system compromising design criteria, system layout, engineering design of canal and drain system, engineering design of hydraulic structures like cross drainage structures (Cross regulator, box off take, foot path, road crossing…etc. The report consisted of the following structures: Chapter one presents introductory part, chapter two describes the reference of other sectorial studies, design criteria is incorporated as chapter three; in the fourth chapter the irrigation system design are dealt in detail, the fifth chapter is about drainage design, chapter six present the design of hydraulic structures in the system, Road provided is described in chapter seven, Chapter eight is about project engineering estimate, implementation schedule is described in chapter 9; chapter 10 and the final chapter deals with conclusion and recommendations of the Design. Also Referenced & Appendix are incorporated in report.

2. REFERENCE OF OTHER SECTORAL STUDIES

As described in TOR and inception report, different professional experts have been recommended and participated in sectorial studies of Maddagura Erbe Project. Only summery of the more related sectorial reports to the system design are summarized in brief hereunder.

2.1 Summary of Hydrological Study

The project area is endowed with the spring source of water. The major water source for the area is this Saketa Spring. In addition to irrigation, this spring is also used for domestic and livestock drinking purposes in the rural area.

The Intake structure (Diversion weir) for the irrigation project is located just downstream of the Spring Eye. The catchment area at this location is estimated about 344.13km2. The hydrological data shows that mean monthly flow of the spring at weir site varies from 0.0387m3/sec to 1.26m3/sec and the mean annual discharge at headwork is 0.543m3/sec. The lowest mean flow usually occurs in March while the highest flow occurs in August. Currently, the existing irrigation projects in and around the project area from the Keto River is observed. 80% dependable flows have been derived at the diversion site which is summarized using the following table:

Table 2-1: 80% dependable mean river flows (m3/sec) of spring at selected diversion site

	Corrected Mean Monthly Stream Flow Time Series											
month	Jan	Feb	mar	Apr	may	Jun	July	Aug	Sep	oct	Nov	Dec
synthesized flow(m3/s)	0.0387	0.0703	0.1693	0.6083	0.9385	0.4325	0.7223	1.2621	0.9357	0.7293	0.4299	0.1606

2.2 Summary of Soil and Land Suitability

Targated Project has 75ha of Gross area, and Net Irrigable area is 48.1ha. River Diversion is the means to irrigate the area by canal using gravity. The proposed crops that can be cultivated by using surface irrigation are 4 (Low land Maize, Tomato, Onion, Pepper,) Crops. The results of the suitability evaluation of the project area for surface irrigation, indicates that total area of 6.56ha of land is found to be (S2), moderatly suitable for surface irrigation. An area amounting to 41.54ha is found to be (S3) marginally suitable for surface irrigation development. The areas identified as moderatly and marginally suitable for surface irrigation are constrained by slope. Depth, texture and chemical reaction (Ph) and nutrient availability (Avp and organic matter).

The result indicated that some, 6.01ha moderatly Suitable(S2) ,41.74ha (S3) marginally situable for Maize cultivation by surface irrigation. For Tomato Some 2.48 (S1) Highly situable and 19.57 moderatly situable (S2) some 25.69 ha marginaly situable(S3)),For Pepper Some area of 2.48ha is(S1) Highly situable Some 3.52 ha moderatly situable(S2) and 41.74 ha marginaly Suitable (S3),for Onion,some 4.65 ha (S1) Highly situable ,Some11.03ha moderatly suitable (S2), and some 32.06 ha marginaly suitable(S3), The major limitations that downgraded the suitability level of the area to marginally subclass are Slope, Texture, Depth and Soil low nutrient availability like organic matter availabile phosphorus (Av.p) are correctable constrients

2.3 Agronomy

Among the bio-physical factors, temperature range, altitude range, moisture availability, slope range, soil conditions, are considered as the most important land quality and land characteristics influencing land suitability for crop production.

Cropping pattern is the yearly sequence of crops grown and the spatial arrangement of them and fallows in a given area. It is formulated with a view to obtain maximum crop production under a given situation. The crop water requirement for proposed cropping pattern has been calculated by using the climatic data available. This has been calculated in accordance with CROPWAT for Windows program that uses the FAO (1992) Penman-Monteith methods for calculating reference crop evapotranspiration. The crop characteristics like crop co-efficient (KC) have been adopted in accordance with the recommendations available in FAO Irrigation and Drainage paper No 24: Crop Water Requirement and No. 33. For the project cropping pattern, a calendar of sowing dates to harvesting dates is prepared for each type of crop.

Following this, the rainfall, soil and crop data inputs including effective rainfall, soil type, crop factor (Kc values) for the different growing stages, cropping pattern, and rooting depth for each crop type is provided to calculate the monthly crop evapotranspiration. From this, the net irrigation water requirement is deduced. Crop water requirement in mm is computed on monthly basis. The crop water computation result shows that the highest irrigation requirement for actual area is found in a month of February. The net irrigation requirement for actual area was found to be 0.44 l/s/ha for 24-hour irrigation without considering the project efficiency. The net irrigation requirement is divided by project efficiency (49%) to obtain the gross water requirement which is 0.98 l/s/ha for 24-hour irrigation. The proposed irrigation hour for the project is 12 hours.

Therefore, the scheme supply of the project is 2.0 l/s/ha for 12-hour irrigation time, for more information see annex 2 of this report & Agronomy report.

2.4 Engineering Geology

The river center is characterized by thick alluvial and residual soil deposit, while the left abutment is made up of vertical cliff forming limestone affected by open vertical cracks and thin bedding planes ranging from 7cm to 15 centimeters, that renders it extremely unstable. The right abutment is covered by about 0.7 meter thick soil followed by weathered bedrock up to 0.7 meter depth.

As mentioned earlier the site is underlain by the Hamanley limestone (Jh) of the Mesozoic sedimentary rocks Ethiopia. Outcrops of this rock were encountered making a vertical cliff on the left abutment while it was seen at 0.7 meter below the surface on the right abutment. At the river centre, as the existing canal-line and excavated pit indicate, bedrock was not encountered at shallow depth. The depth to bedrock at the river centre can be much deeper as the river flow line is believed to follow a weak zone formed by a fault line.

As it is universally known, limestone formations are prone to karstification which may result in the formation of subsurface or exposed caves, especially at crossing points of geologic structures. Such features may result in unexpected land subsidence as the caves migrate upward through time, and monitoring the site for such signs is essential after completion of construction.

A pit excavated at the right abutment revealed light brown silty clay of medium plasticity up to 0.3 meter, followed by light dark greyish clayey silt up to o.7 meter depth. Weathered bedrock was encountered from 0.7-1.2 meter depth.

Table 2: log of right abutment pit

No	Soil Interval (M)	Description
1.	0.0 -0.3	Light brown silty clay of medium plasticity
2.	0.3 – 0.7	Light dark greyish clayey silt
3.	0.7 -1.2	Weathered bedrock

Another pit excavated at the river centre revealed black silty clay of intermediate plasticity with plant roots up to 0.2 meter followed black silty clay of intermediate plasticity up to 0.5 meter, and mixed black and grey silty clay of intermediate plasticity with coarse gravel between 0.5 to 1.5 meter depth.

Table 3: Pit log of the river centre

No	Soil Interval (M)	Description
1.	0.0 -0.20	Black silty clay of intermediate plasticity with plant roots
2.	0.2 – 0.5	Black silty clay of intermediate plasticity, without roots.
3.	0.5 -1.5	mixed black and gray silty clay of intermediate plasticity with coarse gravel

Starting from the Diversion structure to the end the major canal line route cover is underlain by soil while the remaining is underlain by rock.

Natural construction materials for all purposes are found in very close range to all the structural sites. The **limestone** in the area is very suitable for masonry stone due to its horizontal bedding that made it of easy workability. The indurated limestone can also serve as aggregate source through manual or mechanical crushing.

The only material, that needs to be transported from Miesso that is about 150 kilometers from the site is sand for mortar preparation. Another option of sand source is the Diredawa sand which is of better quality since it derived from rocks of high quartzo-feldspatic composition.

3. DESIGN PARAMETERS

3.1 General

An envisaged irrigation scheme will have a network of irrigation canals, network of drains, network of roads, flood protection works, hydraulic structures; regulating structures (cross regulator, offtake), conveyance structures; etc. The canal system will be designed to convey irrigation water from head work to field, adequate in quantity and command, to all farms within the area served. While a network of surface drains is designed to drain out excess water (due to rainfall or irrigation) from fields and to convey it safely to natural drains. To ensure that the irrigation system installed will meet the need of the operator, fit the requirements of the soil and proposed crops, and provide efficient irrigation water management, the simple (so that users can understand and participate in the operation and maintenance); efficient (minimizing the losses in conveyance, distribution and application system) and the cost effective scenario have to be selected and designed from the different engineering alternatives available.

The sections hereinafter outline Planning and Design criteria for system design of Maddagura Erbe small scale irrigation project to ensure an optimum operational efficiency so that it is:

- Functionally capable to deliver estimated irrigation water requirement to farm field & drain out surplus water from the field;
- Economically viable by keeping overall cost of the system within the financial norms;
- Amenable for easy operation and maintenance at present, as well as in future;
- Socially acceptable to the mindset of the cultivator, who is going to utilize the irrigation water (as a primary input) to achieve higher productivity through irrigated agriculture;

The design criteria recommended and applied in this document are based on published guidelines as well as on the Consultants' and staff long-term experience and lessons learned from successes as well as the failures of irrigation projects.

3.2 Definitions

i. **Canal System:** defined as an open channel excavated & shaped to the required cross section in natural earth or compacted fill, with or without special treatment (lining) to the wetted surface. In the irrigation system, they are usually called canals and in the drainage system they are referred to as drain. Canal nomenclature is not standardized in the country and varies from project to project. In this project, the canal system consists of:

- **Main canal**: -It is the principal contour canals off taking from headwork and night storage. Main canal that offtake water from headwork intake is designed for 24 hrs continuous supplies, but the main canal that offtake from night storage and distributes water to distribution system is designed for 12 hrs continuous supply.
- **Field canals**: - is a channel which off takes from main/ branch/primary canal or secondary canal and runs across contour to distribute water among field furrows.

ii. **Drain system:** are provided to avoid excessive and prolonged submergence of crop during incessant wet spells of high intensity rainfall or to drain out excessive irrigation water during operation and surplus water due to mismanagement.

- **Field drains: -** open channels run across a contour to drain out surplus water from corresponding field block.

iii. **Road system:**

- **Foot path:** is a foot path with 1.7m width which is provided between tertiary canal and drain to connect the field block to inspecting road that run parallel to primary and secondary canal for accessibility of field block by farmers;
- **Inspecting road:** is a road path with 4.0m width that run parallel to primary and secondary canals for accessibility of the farm system;
- **Access road:** a main road path with 6.0m width that run parallel to main canals for accessibility of the project.

iv. **Area Definition**

- **Field Block:** is the smallest unit area considered in the design of the project, where the sizes of the irrigable command area are being determined by topography. The area irrigated from a single field canal/field offtake.
- **Command Area:** The area irrigated by a Main Canal or intake of headwork
- **Net irrigable total Area:** the total area that will be irrigable under the current consideration.
- **Gross irrigable total area:** the total area that will be irrigable in the future by considering additional consideration like bench terrace to irrigate more area that will not irrigable under current due to design criteria or the due to the future expansion.

v. **Canal Structures**

For satisfactory functioning of a canal system and to achieve the desired objectives, following types of structures are required to be provided in the canal network.

Regulating structures: Structures designed to regulate flow among canals to protect canal from damaging by the flow while dividing and to enhance efficiency of the system by maintaining unfair water distribution. These structures are providing in irrigation either of controlling amount of flow or for maintaining required flow depth/level in the canal/systems. The structures divided the flow in proportion to the areas commanded. This is usually achieved by provision of appropriate widths and heights (for rectangular & Trapezoidal section) and diameter size (if its pipe) of openings. To allow system operators' control, the openings are usually equipped/provide with moveable parts like gated or stop logs. Structures which can be classified in this category include:

- Cross regulatory
- Turnouts
- Division Box
- Check structure
- Escape/Waste ways

Conveyance structures: are provided whenever the available natural ground slope is steeper than the designed bed slope of the channel, the difference is adjusted by constructing vertical falls / drops or chute in the canal bed at suitable intervals. The functions of these structures are to convey water from a higher to a lower elevation and to dissipate excess energy resulting from this drop.

- **Protective structures:** Whenever a canal crosses a natural drainage on its passage it is necessary to construct cross drainage to dispose off drainage discharge so that canal water supply continues an interrupted and when a road crosses the canal culvert protection structure is provided so that the canal flow is not interrupted by the vehicles. Some of the example of protective structures include in this project are: aqueduct (flume), syphon, box culvert, pipe culvert, road crossing structure, foot path…etc.
- **Flow measuring structures** –In a typical irrigation system, water is usually measured at the storage reservoir outlet, the canal head works, and at lateral and farm turnouts. Water flow rate have to be measured for different reasons which includes:
    - When the water available from a particular source is limited and must be used very carefully.
    - Where farmers have to pay for the water used, discharges should be measured.
    - Flow measurements may also be useful for settling any disputes about the distribution of the water.
    - provide important information about the functioning of the irrigation system.

The type of measuring structure selected for these locations depends on availability of head, adaptability to site, economy of installation, and ease of operation. Flume type structure is selected for this project.

vi. Crop Water Requirements:

- **Consumptive use** – quantity of water transpired by plants, retained in plant tissues and evaporated from soil surface and vegetation (same as evapotranspiration for all practical purposes).
- **Non-consumptive use** – cultural water requirements for land preparation, presoaking of fields, puddling of rice fields, steady deep percolation losses from ponded rice field, leaching requirements etc.
- **Crop Water Requirements:** Crop water requirements (CWR) encompass the total amount of water used in evapotranspiration. The four procedural steps involved in the calculation of crop water and irrigation water requirements are:
  - Calculation of reference evapotranspiration (ETO) based on meteorological parameters collected from the near-by meteorological stations.
  - Fixing Crop coefficients for selected crops.
  - Determination of monthly crop water requirements (ETc) depending upon the cropping patterns and local conditions.
  - Determination of Irrigation water requirements/demand using calculated effective rainfall of the area
- **Effective Rainfall:** is the portion of rainfall that contributes to meet the ET requirement of crops. The CROPWAT Program uses the USDA Soil Conservation Service method for computing effective rainfall, which is a function of consumptive use of the crop under consideration and net depth of irrigation applied to the soil.
- **Cropping Pattern:** The extent of the command area that could be irrigated by the diverted water, other than the dependable yield, depends on the types of crops grown and the cropping calendar. As food security is the main objective of the project, the cropping pattern is planned to be dominated by food crops. However, for sustainability and profitability of the project, the crop mix is also considering high value crops.
- **Net Irrigation Water Requirement (IR):** refer to the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirements. The crop water requirement and Irrigation water demand for selected crops

have been estimated using dependable rainfall on a monthly basis and the FAO's CROPWAT computer model (FAO, 1996). The scheme water requirements are computed as aggregate of the crop water requirement. The irrigation schedules for each crop are computed based on the type of soils and the crop growth stage. Since the source of water has a good quality and the soils of the command area are of good permeability, well drained and clay texture with medium structure and no potential saline and sodic nature of the soils, no additional water is required for leaching requirement. Therefore, the net and gross irrigation water requirements are calculated using crop evapotranspiration, ETcrop, and effective rainfall as presented in the Agronomy report.

- **Irrigation Efficiency:** The amount of water stored in the root zone is estimated as the net irrigation dose. However, during the irrigation process, considerable water loss occurs through seepage, deep percolation, etc. The amount lost depends on the efficiency of the system. Irrigation efficiency is the efficiency of the total process of irrigation from the source of the water to the point where the water becomes available in the root zone of the plant. To account for losses of water incurred during conveyance, distribution and application to the field, an efficiency factor should be included when calculating the gross irrigation requirements. For this scheme, the overall efficiency can be divided into two; conveyance, distribution and application efficiency. The conveyance and application efficiency mainly depend on construction materials while the field application efficiency is very much dependent on the method of irrigation and characteristics of soil and land. Usual practice is to select a figure of overall efficiency of the system judiciously from the normally observed range of efficiencies as indicated below.

Table 3-1: Expected range of efficiency

S. No	Efficiency	**Expected range of efficiency**	
		Unlined	**Lined canal**
1	Water conveyance	0.65 - 0.70	0.75 - 0.85
2	Operational/Distribution	0.80 - 0.90	0.85 -0.90
3	Field Application	0.6 – 0.75	0.7 – 0.75
4	Overall	31 - 47 %	45 - 57%

- **Gross Irrigation Water Requirement:** Gross irrigation water demand is dependent on the overall efficiency of the irrigation system, which in turn is dependent on several factors such as method of irrigation, type of conveyance system, method of operation and the availability of structures for controlling water.

- **Irrigation scheduling:** Irrigation scheduling is one of the factors that influence the agronomic and economic viability of irrigated farms. It is important for both water savings and improved crop yields. The irrigation water is applied to the farm according to predetermined schedules based on soil water status and crop water requirements. Irrigation interval is a function of water holding capacity of the soil, the rooting depth of the crop under consideration, and the daily crop ET. The irrigation scheduling will depend on selection of crop and crop water requirement, time required for each irrigation and total time for irrigation. The type of soils and climatic conditions have a significant effect on the practical aspects of irrigation, which are the determination of how much water to apply and when to apply to a given crop.

vii. **System Capacity:** The system capacity will be determined taking into consideration the overall irrigation efficiency, the sum of the peak crop water requirement of each scheme and area size.

viii. **Drainage module:** the rate of drainage that demand on capability of the command area to be drained and excess water that can be resulted from either excess rainfall or excess irrigation or both from the command area. It's estimated by the hydrologist based the 24 hrs runoff flow.

3.3 Canal Network

Canal system is hydraulically designed to convey water from head regulator to the fields in the command area, by aligning the channels along the most economical route to serve entire command. Developing of detailing a canal system design comprises two distinct steps:

- Planning and developing alignment of canals and drains system
- Fixing of design canal and drain capacity
- Determination of canal cross section elements

3.3.1 Layout of Canals and Drain System

Both right and left main canals (two on right side and three on the left) will be aligned and designed as a contour canal. There would be one branch canal on the left, 5 primary canals (one on the right and four on the left side) that aligned along the contour and designed as a ridge canal which will runs more or less along the falling contour and crosses over few natural drains on its way. Steeper ridge slope is negotiated by providing drop/chute structures at suitable locations. A lot of small field canals that run across the contour are incorporated to irrigate small farm unit.

3.3.2 Fixing design canals and Drains capacity

The canal capacity is totally depending on the size of area to be irrigated by the canal; the consumptive & non-consumptive use of all crops to be cultivated and the overall efficiency of the system. It would, however, be a prudent practice to introduce some flexibility in the design canal capacity so that it may not fall short of the requirements in the future on account of unpredictability about future trends of development of new strains of high yielding crops (HYV) and cultivator’s preference to grow higher percentage of high value water intensive crops, with the development of irrigated agriculture in the command. To summarize the following three elements should be available to the design engineer to work out design canal capacity

- Area to be provided with irrigation facilities (Net Irrigable Area)
- cropping pattern and total crop water demand (consumptive & non-consumptive) for all crops
- Conveyance, operational and field application losses in the entire system i.e. expected overall efficiency of the system.

Rotation type of distribution has been adopted which can be varied according to demand.The demand varies according to the stage of crops over the growing period and size of the area.

3.3.3 Longitudinal gradient of Canal

Bed gradient of canals are fixed based on the following criteria:

Table 3-2: Standard criteria of longitudinal gradient of canal

Channel	**Capacity in cumecs**	**Bed gradient**
Main canal and Branch canal (Contour Canal)	30 to 100	1 in 5000 to 1 in 10,000
	10 to 30	1 in 3000 to 1 in 5000

	1 to 10	1 in 2000 to 1 in 3000
Secondary/primary canals (Ridge Canal)	1 to 3	1 in 1500 to 1 in 2000
	0.1 to 1	1 in 750 to 1 in 1500
Water courses	< 0.1	1 in 750 to 1 in 1000

3.3.4 Manning's Roughness Coefficient

Hydraulic design of canal cross section is done by Manning's formula, which has been carefully examined experimentally and the manning's coefficient of different materials are given in the following table.

Table 3-3: Values of 'N' adopted for lined/unlined canals

Type of strata of channel		Rugosity coefficient
A. Unlined channel		
i)	Uniform section in soil	0.025
ii)	Sandy and gravelly or weathered rock	0.030
iii)	Less uneven and fairly uniform section in rock	0.03 to 0.04
iv)	Rough, irregular and uneven section in rock	0.04 to 0.05
v)	Water courses, field channels / field drains	0.03 to 0.04
B. Lined channels		
vi)	Cast in situ concrete lining	0.014
vii)	Precast concrete tile lining	0.0225 to 0.025

3.3.5 Velocity of flow

Higher velocities would reduce cross sectional area of canal and would reduce cost of construction. But there are some constraints on the upper permissible velocities in different types of strata. In case of canal through silty soils and silty clay soils and where canal water contains silt, it is advisable to design the section for non-silting and non-scouring velocity.

Table 3-4: Velocities normally permissible in different types of strata

Type of material	**Range of permissible velocity in m/second**
Rock	1.5 to 2
Decomposed, disintegrated rock	1.2 to 1.5
Gravel with silt, sand	0.9 to 1.2
Clay, clay loam	0.6 to 0.9
Sandy loam, silty loam	0.6 to 0.8
Fine sand, loose sandy soil	0.4 to 0.6
Masonry lining	1.5
Concrete lining	3.0
RCC Concrete Lined	>3.0m

3.3.6 b/d ratio (bottom width: depth of flow, ratio)

Once design capacity, rugosity coefficient, bed gradient and side slopes are fixed, what remains to be decided is canal bed width and depth of flow. General guidelines would be to provide higher b/d ratio for silty/sandy soils and loam, and lower b/d ratio for hard strata reaches and for lined canals. Secondly, higher b/d ratio at the head reach of canal facilitates reduction in width of canal (keeping depth of flow as same) in further reaches as the canal capacity reduces after major off taking channels.

Table 3-5: Range of recommended b/d ratios for unlined canal sections

Channel discharge in cumecs	Range of b/d ratio
0.1	1 – 2.5
0.5	1.25 – 3
1	1.5 – 3.5
2	2 – 4
5	
10	3 – 5.5
15	3.5 – 6
20	3.75 – 6.5
25	4 – 7
50	4.5 –9

3.3.7 Typical canal cross sections

Once canal section is finalized as explained above, next comes the layout of typical cross sections of canal in cutting, filling and partial cutting/filling reaches. Lower values of b/d ratio are preferable for lined section because, they give lesser wetted perimeter (for the same discharge) and hence economy in construction costs.

Table 3-6: Recommended b/d ratios for unlined canal sections

Q (m^3/sec)	**Range of b/d ratio**
0.1	1 – 2.5
0.1-0.5	1.25 – 3
0.5-1	1.5 – 3.5
1-2	2 – 4
2-5	2.5 – 4.5

3.3.8 Free Board (F.B.)

It is the difference between level of embankment top and full supply level (F.S.L.) of canal and is provided as a safety margin to prevent overtopping of canal banks in case of canal operation mismanagement, variation in actual rugosity coefficients, afflux due to additional actual losses at canal structures etc. It also permits temporary encroachment on it, to meet peak water demands in exceptional cases (total failure of rains etc.). It is provided as below

i. FB = 0.4d for depths of flow up to 2 m, with a minimum of 0.3 m (figures to be rounded to 0.1m)
ii. F.B. = 0.25d + 0.3 m for depths more than 2 m subject to a maximum of 1.5 m. (figures to be rounded to 0.1m)

Where 'd' is the depth of flow

Note: for this project some additional value is added to the free board to account the high probability of future expansion.

3.4 Design Criteria for Structures

3.4.1 Cross regulator

Main functions of cross regulators are: -

- To enable effective regulation of the canal system as a whole.
- When the WL in the parent channel is low, they help to raise water and feed the off-take channel to their full demand in rotation
- They help in closing of breaches in lower section of the channels
- They facilitate communication, since a road can be taken over them with a little extra cost.
- They absorb fluctuations in various sections of the canal system and thus prevent possibilities of the breaches in the tail reaches

Orifice free type flow equation is adopted for design of cross regulator that proposes in this project to divide the flow from parent trapezoidal canal having very large top width. The flow size is totally depending on:

- the area of the opening
- Shape of the opening
- Location of the opening: i.e. Head difference between u/s water level & D/s Water level of the structure govern the flow through the structure

And the following equation used to handle free orifice in the structure:

$$Q = Ce\ A\ (2gh_1)^{0.5}$$

- Ce is the effective discharge coefficient
- A is opening area.
- h1 is Head difference between u/s water level & D/s Water level of the structure

3.4.2 **Offtake/turnout**

Two types of offtake are proposed to be designed and used in this project either to divided tertiary canal to corresponding field canal proportionally or to offtake small quantity from larger canals (main/primary/secondary canal) directly to the field. To divide the flow in tertiary canals to corresponding field canals using box type offtake which is designed using weir formula like division box structure by assuming the same sill height and the same shape for all opening in the same structure. But to offtake small quantity of water from large quantity USBR pipe type offtake is selected which is designed using Orifice flow type formula like cross drainage structure. The equation used to handle free orifice in the structure:

$$Q = Ce\ A\ (2gh_1)^{0.5}$$, where

- Ce is the effective discharge coefficient
- A is opening area.

- h_1 is Head difference between u/s water level & D/s Water level of the structure

4 IRRIGATION SYSTEM DESIGN

4.1 GENERAL

The objective of this development is to make the farmers in respective of the command area beneficiaries of irrigation water to irrigate 75ha net irrigable area during minimum flow and by providing simple, strong and sustainable irrigation and drainage systems that are easy to understand and operate.

For this purpose, a network of canal system, related infrastructures layout system and irrigation farm structures, comprising various components starting from main conveyance to field canals have been designed which is totally based on layout, Crop water requirement and Efficiencies of different components of canal system. To develop the layout effort has made:

- to pass the canal route on the ridge so that it can easily irrigate the area;
- prefer canal route that minimize the earth work; and
- Lengths of alignments in hard rock are minimized as much as possible to avoid high cost of excavation in rock

Since the flow in River is critical during the dry time with respect to the available land resources and experience of the users to irrigate a land, night storage should be recommended and designed to maximize the area to be irrigated. Also, the project has been provided with simple water control and regulating structures that fulfill these requirements.

4.2 METHODOLOGY

The methodology followed to plan and designs the system design keto large scale project so summarized as follows:

- **Preparation *of* Map:** 41.8 ha was surveyed and the top map was produced using 1:1000 horizontal and 1:100 vertical scale and 0.5m contour interval to develop the layout of the system. 41.8ha gross area of land was evaluated by soil expert and finally the area suitable for surface irrigation and suitability map for the targeted project was prepared.

- **Preparation of Layout:** based on the top map and suitability map prepared, the layout in which the components of the irrigation system e aligned on the ridges and that of drainage in the valleys was prepared. Between two components of irrigation system, there should be one component of drainage system. The system should comprise from main canals to field canals, while the drainage system consists of from field drains to main drains. Also, the developed layout consists of a network of road which include foot path run parallel to tertiary canal & drains; inspecting road that run parallel to branch, primary and secondary canals, and access road that run parallel to the main canal.

- ***Discharge Capacity:*** The capacity of each canals were fixed based on crop water requirement estimated by agronomist (which governed by the climate, crop type, stage, management and environmental factor and proposed crop pattern); size of the land to be irrigated and efficiency of the system which mainly depend on the type of the canal and operational management. It is also required to fix the discharge capacities of different components such that they are able to carry adequate irrigation water to serve properly, the areas under their respective commands.
- **Fixation *of F.S.L*:** based on the standard design criteria fixed (described in chapter 3), the FSL of the canals were fixed and incorporated in this report and drawing album.
- **Hydraulic design of canals & drains:** parallel to fixation of F.S.L, the hydraulic design of the system network was performed based on the fixed engineering design criteria, available resources and requirement of crops.
- **Design of Structures:** Canal and drain structures on different components are essential parts of the system; they are required for regulating, monitoring, and controlling the irrigation supplies. It is, therefore, also required to decide about the type, location, size, and number etc of structures and prepare their detailed designs.
- Quantifying BOQ and estimation of project cost
- Developing implementation Schedule
- Conclusion & Recommendation
- Report Writing and preparation of drawing album

4.3 Topographic Survey

All the required benchmarks and stations have been established at the headwork site and important locations in the command area using stable features. Accordingly, all the benchmarks and other points in the project area have been properly connected to known national grid stations coordinates to provide adequate ground level topographic data for detail engineering design of the Irrigation scheme.

As described above, topographic survey and map preparation of 53 ha of the command area has been undertaken. The survey of the command area has been conducted with the help of Total station and the results have been fed into computer, from which topographical maps with required contour interval of 1m have been generated on appropriate scale 1: 1,000. In order to finalize the most economical alignment of main canal, strip contour survey on either side of the river, by taking levels along the envisaged alignment with bed slope of 1:2500 has been carried out. This has been marked & plotted with appropriate scale. Layouts for other supply and drainage canals have been established using the prepared topographic map of the irrigable area.

4.4 Available Land Resources

The result of suitability evaluation of the project area for surface irrigation are indicates that a total of 41.8 ha of land is found to be moderately suitable for surface irrigation. The areas identified as not suitable for surface irrigation are constrained by slope and soil. The area identified as moderately suitable for surface irrigation is primarily constrained by slope, drainage and soil texture in the study area, as a result, the suitability level of the moderately suitable area can be improved by application of good quality of water and proper land preparation. The marginally suitable areas require careful land management, application of good quality of water and application of phosphorous fertilizer, this improve the suitability level to moderately suitable.

4.5 IRRIGATION SYSTEM LAYOUT

The layout of main canal is the most important and vital component of the entire planning work, that call for most careful consideration of all the factors governing the alignment: topography, suitability map, natural drainage pattern etc. The Irrigation System layout for the Command is being planned and designed keeping in view of; fitness to the existing topography; fulfill the requirement of proposed crops; irrigation water is able to reach every part of command area by gravity flow; minimum cost of construction and operation; operates efficiently/. free from trouble. The detail components of Keto irrigation system Layout developed described using schematic drawing and the following sub section:

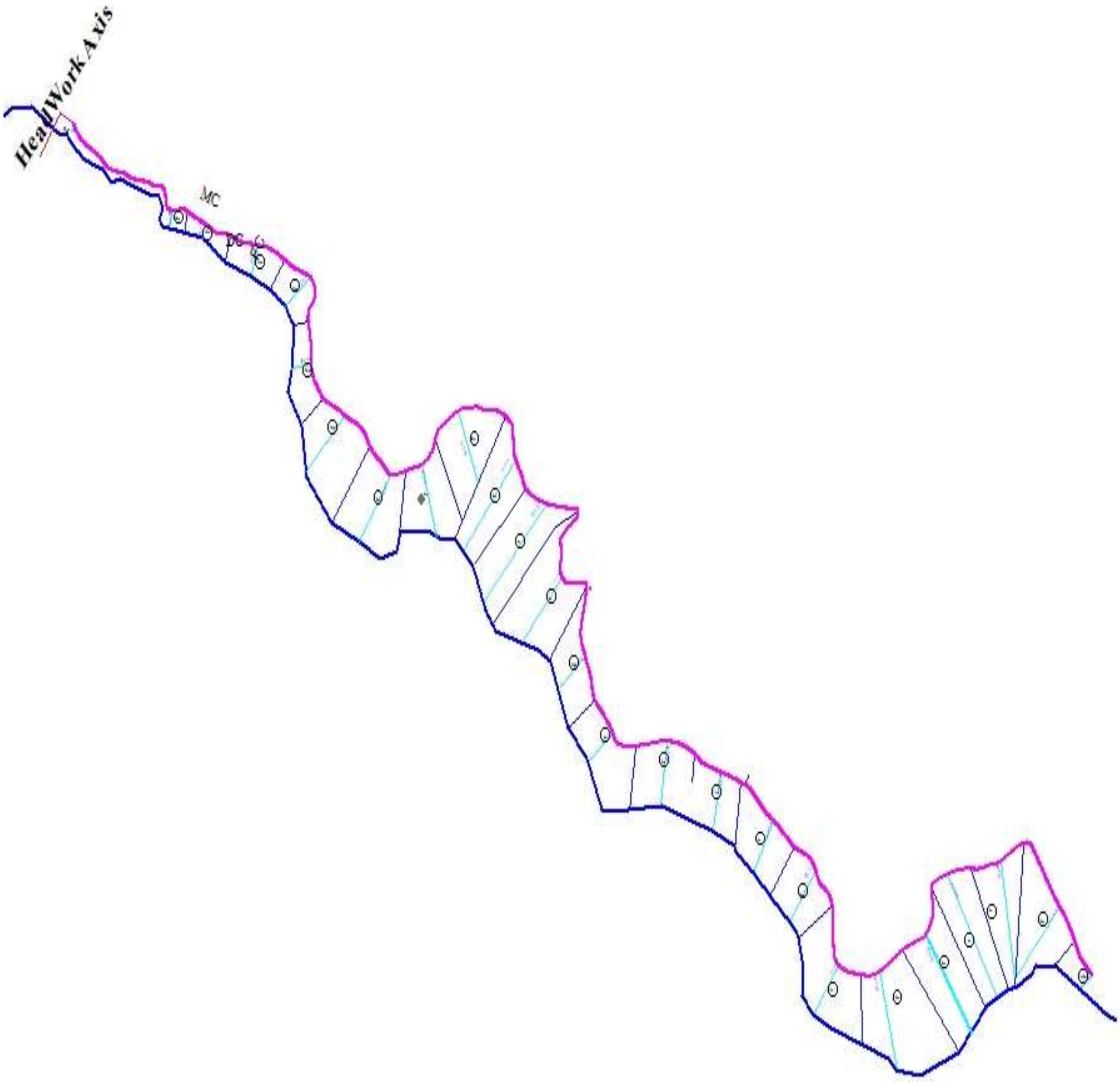

Figure 4-1: Schematic Drawing of Madagura Erbe Layout

4.5.1 **Main Canals**

The commands area is available on left side of the spring, 27ha net irrigable area is found on the left. The main canal run nearly parallel to contour to minimize the head loss. MC is canal that offtake water from intake of headwork, run parallel to contour for length of 3+239.64m to end to , and designed for 12 hrs. irrigation duty. Based on the geologist recommendation, the critical condition of water availability with respect to the land available and its length, the MC is designed as masonry rectangular canal based on the criteria fixed in chapter 3. MC is the biggest size contour canal that offtake water from the provided at the end of MC and the field canal directly offtake from this MC.

To summarize, main canals of 3.239Km length are designed as rectangular lined section. It is lined with masonry.

4.5.2 **Field Canals**

The command area of each tertiary canal is further sub-divided into several segments by field canals, which supply water to the furrows/ border strip. These canals are proposed to be open ditch based on the slope of the route/land. The construction of the field ditch for slope less than 6% is totally left for users,

4.6 Selected Method of Irrigation

These are the methods used to spread water as uniformly as possible in the soil to irrigate the crops. Surface irrigation, namely furrow border strip & hydro fume have been adopted for the project which described as follows:

- **Furrow irrigation** has been selected for land slope less than 4%. Furrows on ground slope less than 2% are aligned down the main slope. Whereas, for ground slope greater than 2% and less than 4% cross furrows alignments are set. Irrigation water is supplied from a head field canal.
- **Border strip irrigation** method is selected for land slope between 4%-6%. . Irrigation water is supplied from a head field canal.

The furrow/border strip sizes are designed based on the type of crop, topography and required flow rate. Also furrow spacing shall be decided depending on the crop types. The average length of furrow adopted for this project is 100m. Since the water head is no problems in keto project, for efficient applying of water to furrows a Plastic or aluminum siphon pipes are the best way. Assuming about 0.25 l/s per furrow is to be released in the furrows during irrigation, a 2 cm diameter siphon with minimum of 15 cm pressure head (command) will be sufficient for one furrow or a 3 cm diameter for two furrows. The length would be only 1m.

4.7 Irrigation Interval

Most common practice of irrigating fields is that, water would flow through the water conveyance network continuously and would be dispensed to the field, on which crop is standing, by rotation with a predetermined periodicity (i.e. interval between two successive watering) to match water requirement of the crop. Different types of crops are standing in the field at a time and are at different stages of crop growth. The amount of irrigation water applied for the crops varies depending on the growth stages of crops, climatic conditions and soil types. Irrigation interval is recommended based on maximum rooting depth, readily available moisture of the soil, peak water requirement of the crop and allowable depletion of the crop. In principle, the interval between two irrigations should normally be the time taken by the crops to reduce the soil water from field capacity to the lowest level of optimum soil regime. As described in irrigation report the irrigation interval is fixed using the following formula, for more information refer annex 2 of this report/agronomy report.

The interval between irrigations is given by:

i = d/ETc

d= p*D*Sa where i= irrigation interval (days)

d= irrigation depth (mm)

ETc= crop water use (mm/day)

p= allowable depletion (fraction)

D = root depth

Sa= available water capacity (mm/m)

4.8 Irrigation Efficiency

With a view to reduce canal loses, in light of high permeability of the formation along the entire canal routes, it is proposed to have suitable lining in the idle part of main canals (up to the night storage) and almost all secondary canal due to the steep rout of the canal which more reduce the conveyance and distribution loss. Accordingly, an overall irrigation efficiency of 45% has been adopted (70% of application efficiency, 85% of distribution efficiency and .85% of conveyance efficiency).

4.9 Command Area

Based on the topographic & suitable maps prepared and the developed layout, the net irrigable area is identified to field block level from where the tertiary blocks, secondary blocks and command area is calculated.

The results of the suitability evaluation of the project area for surface irrigation are shown in Tables 4.1. The areas identified as moderately and marginally suitable for surface irrigation are constrained by slope. The total area not included Rock surface, Canal Area and town. Thus, we can incorporate the area which its slope > 8%. The following tables describe the gross area, the net area under each main, branch, primary and secondary canals with their corresponding length and design:

Table 4-1: Net Irrigable Command Area, canals length & Capacity of Main Canal

No	Name of Canal	Total Length	Net irrigable area	Required Capacity of Canal	Remark
		m	ha	l/s	
1	Main Canals				
1.1	MC	3,239.64	23	44	

Table 4-2: Field canal with net Irrigable Command Area

	Canal Name	Area	uty for 24h	Q-Planned	Aval.Q	Duty for 12hr)
		ha	l/s/ha	l/s	L/s	
1	MC	23	0.98	44.22	44.3	2
Field Canal offtake from MC						
	FC1-0-0-1	0.14				
	FC1-0-0-2	0.2				
	FC1-0-0-3	0.5				
	FC1-0-0-4	0.5				
	FC1-0-0-5	0.6				
	FC1-0-0-6	0.8				
	FC1-0-0-7	1.4				
	FC1-0-0-8	1.1				
	FC1-0-0-9	1.2				
	FC1-0-0-10	1.1				
	FC1-0-0-11	1				
	FC1-0-0-12	1				
	FC1-0-0-13	0.8				
	FC1-0-0-14	1				
	FC1-0-0-15	1.1				
	FC1-0-0-16	0.9				
	FC1-0-0-17	1				
	FC1-0-0-18	0.9				
	FC1-0-0-19	1				
	FC1-0-0-20	1.5				
	FC1-0-0-21	1.2				
	FC1-0-0-22	1				
	FC1-0-0-23	1				
	FC1-0-0-24	1.2				
	FC1-0-0-25	0.42				

4.10 Irrigation Water Demand & Balance Analysis

The maximum water duty calculated for the project is 0.98 L/sec/ha for 24 hours and 2.0 l/sec/ha for 12-hour irrigation. The total net irrigable area identified is 23ha with total area of 48.1ha. The summary of the monthly-based water demand/balance analysis of the target project is presented in the following table:

Table 4-3: Water Demand & water balance Analysis

Months	Monthly 80% dependable flow		Madda gura ErbeMonthly Irrigation demand 24hrs based			Downstream Monthly release 24hrs based		Total demand		Flow balance		Remark
	(m^3/sec)	(Mm3)	(l/s/ha)	(m3/sec)	(Mm3)	(m3/sec)	(Mm3)	(m3/sec)	(Mm3)	(m3/sec)	(Mm3)	
Jan	0.0387	0.1036541	0.978	0.0225	0.060	0	0	0.0225	0.0602342	0.0162	0.04341984	
Feb	0.0703	0.1700698	0.800	0.0184	0.045	0	0	0.0184	0.0445133	0.0519	0.12555648	
Mar	0.1693	0.4534531	0.289	0.0066	0.018	0	0	0.0066	0.0177965	0.1627	0.43565664	
Apr	0.6083	1.5767136	0.000	0.0000	0.000	0	0	0.0000	0	0.6083	1.5767136	
May	0.9385	2.5136784	0.000	0.0000	0.000	0	0	0.0000	0	0.9385	2.5136784	
Jun	0.4325	1.12104	0.000	0.0000	0.000	0	0	0.0000	0	0.4325	1.12104	
Jul	0.7223	1.9346083	0.000	0.0000	0.000	0	0	0.0000	0	0.7223	1.93460832	
Aug	1.2621	3.3804086	0.000	0.0000	0.000	0	0	0.0000	0	0.9357	2.50617888	
Sep	0.9357	2.4253344	0.000	0.0000	0.000	0	0	0.0000	0	0.7293	1.8903456	
Oct	0.7293	1.9533571	0.000	0.0000	0.000	0	0	0.0000	0	0.4299	1.15144416	
Nov	0.4299	1.1143008	0.400	0.0092	0.024	0	0	0.0092	0.0238464	0.1514	0.3924288	
Dec	0.1606	0.430151	0.733	0.0169	0.045	0	0	0.0169	0.0451757	-0.0169	-0.04517568	Stress

4.11 HYDRAULIC DESIGN OF CANALS

4.11.1 Full Supply Level of Main Canal

The project command area encompasses different landform with changing morphology and abrupt variation of slopes, which is scattered and surrounded by different outcrops and undulating landforms with irregular ground elevation. After studying in detail, the topographic features and the variation in elevations of the command areas situated at different locations, the full supply level (FSL) of the Main Canal has been fixed as 1436.08m at the downstream end of the irrigation headwork intake outlet, i.e. at 0+000 chainage of main canal for MC. This is sufficient to provide gravity flow irrigation in the entire planed command.

4.11.2 Selected Design Parameters

i. Roughness co-efficient- 'N'

Coefficient of rugosity largely depends on the type of surface. Different values are taken for different surface types. Based on the recommended N for 'Criteria for design of lined canals and guidance for selection of Type of Lining' the following values of 'N' have been adopted:

Table 4-4: Adopted Roughness co-efficient

Type of Surface	Canal component	Value of 'N'
Masonry lining	Lined Part	0.017
Concrete lining	Lined Part	0.014
Earthen Canal	Earthen Part	0.025

ii. Canal side Slopes

As per geologist recommendation, (see engineering geology and geotechnical report) main canals is lined. The canal is adopted as rectangular.

iii. Free Board

For main and branch canals, in addition to the value of free board required to prevent overtopping of canal banks in case of canal operation mismanagement, variation in actual rugosity coefficients, afflux due to additional actual losses at canal structures etc., and appreciable free board is adopted to account peak water demands in exceptional cases and future expansion probability. But for other small canals the criteria fixed in chapter 3 is holds. The minimum total depth (flow depth + freeboard) for earthen canals is 0.6m, which is one criterion in fixing the freeboard especially for small earthen canals.

iv. Longitudinal gradient of Canal

Bed gradient of canals are fixed based on the criteria fixed in chapter 3 with a little modification to account the project situation that minimize the earth work and enhance stability.

v. Velocity of flow

In case of canal through silty soils and silty clay soils and where canal water contains silt, it is advisable to design the section for non-silting and non-scouring velocity. For this design, the criteria fixed in chapter 3 were adopted.

vi. b/d ratio (bottom width: depth of flow, ratio)

Higher b/d ratio for silty/sandy soils and loam, and lower b/d ratio for hard strata reaches and for lined canals. Higher b/d ratio at the head reach of canal facilitates reduction in width of canal (keeping depth of flow as same) in further reaches as the canal capacity reduces after major off taking channels. The criteria fixed in chapter 3 were adopted.

4.11.3 **Designed of Lined Canals**

As per geologist recommendation & critical conditions on the availability of the resources, main canals route that pass-through rock exposure made lining, specifically the main canals route between the intake of headwork and the night storage on both sides were designed as masonry rectangular section using the above fixed criteria. Also due to the steepest existing slope of primary and secondary canals, most of their reaches were designed as concrete lined rectangular section by using conveyance structures like chute and drop.

Sample Design: MC

The whole length is designed as masonry rectangular canal using the Manning formula and continuity equation with the design criteria fixed as input. For stability purpose the following shape of the section with coping of 5mm thickness were adopted. Also, for the same reason, stability of canals, plastering with 2 coats are strongly recommended. Since the canal is ended to night storage, the capacity of the canal was fixed using 24 hrs. irrigation duty.

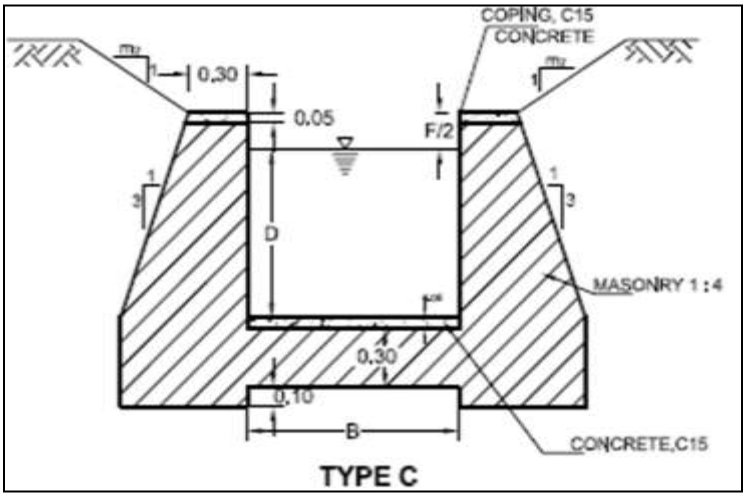

Figure 4-2: Masonry Lining Thickness for Rectangular Canal Section

$$Q = A*V;$$

$$V = \frac{1}{n} R^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

A = bh

p =b + 2h

R = A/p

Where:

Q	is	Design Discharge (m^3/sec)
A	is	cross-sectional area in (m^2)
V	is	mean velocity (m/sec)
p	is	Wetted Perimeter(m)
R	is	Hydraulic mean depth (m)
S	is	Slope of canal, and

Using the above formula, the hydraulic parameters of the Left main canal are fixed as follows;

Bed width, b (m)	0.3
Full Supply Depth, h (m)	0.25
N	0.013
Slope, S	0.001
M (H: V)	0:1
Cross Sectional flow Area, A (m^2)	0.07
Wetted perimeter, P (m)	0.79
Mean Hydraulic Radius, R(m)	0.09
Velocity, V (m/sec)	0.6
Required Discharge, Q (m3/sec)	0.044
Design Discharge, Q) m3/sec)	0.044
A free board, F(m)	0.350
Total Depth, D(m)	0.6

The hydraulic parameters for others lined main, primary, & secondary canals were fixed in similar way and tabulated in the following tables, table 4.6 to table 4-10:

Table 4-5: Hydraulic Design of Main & Branch Canals

No	Canal Name	Chainage(m)		Q-Planned	Types Of Canal	b	y	Fb	D	S	m1	b/y	TW	A	P	R	n	V	Q - Design
		From	To	l/s		(m)	(m)	(m)	m		(H:V)	m	m	m2	m	m		m/s	l/s
1	MC	0.00	140	44.22	Lined	0.3	0.25	0.35	0.6	0.001	0	1.22	0.3	0.07	0.79	0.09	0.013	0.60	44
2	MC	140	1300	44.22	Lined	0.3	0.23	0.37	0.6	0.002	0	1.29	0.3	0.07	0.76	0.09	0.013	0.64	44
3	MC	1300	2160	44.22	Lined	0.3	0.12	0.48	0.6	0.004	1	2.50	1.5	0.05	0.64	0.08	0.013	0.88	44
4	MC	2160	2240	44.22	Lined	0.3	0.05	0.55	0.6	0.125	0	6.13	0.3	0.01	0.40	0.04	0.013	3.01	44
5	MC	2240	3020	44.22	Lined	0.3	0.22	0.38	0.6	0.002	0	1.39	0.3	0.06	0.73	0.09	0.013	0.68	44
6	MC	3020	3100	44.22	Lined	0.3	0.06	0.54	0.6	0.063	0	4.86	0.3	0.02	0.42	0.04	0.013	2.39	44
7	MC	3100	3239.64	44.22	Lined	0.3	0.28	0.32	0.6	0.001	0	1.05	0.3	0.09	0.87	0.10	0.013	0.52	44

4.12 Design of Field Canal

The whole constructions of fields channels are left for the farmers to be prepared every season during land preparation, as a result their cost is not included in project. But the field canal capacity is determined using the area of the farm unit and assumed stream discharge of furrow. Also, the typical off take location and size at the inlet of each field canals are designed and included in this report.

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5 DESIGN OF HYDRAULIC STRUCTURES IN THE SYSTEM

5.1 General

Type and number of different structures required for the scheme have been determined based on the scheme layout. The structures to be designed should be designed as per standard criteria and local situation so that it's hydraulically and structurally safe. To achieve this, we focus on many parameters like foundation condition, topographic situation, type & availability of construction materials, purpose/function of structures, selection type of structures, construction materials selection, fixing design criteria, selection of construction method being adopted….etc. so that economical and structurally safe structures that will perform efficiently and competently with minimum head/amount loss, easy operation, less maintenance cost, easily accessible…etc. will be implemented. There are different hydraulic structures proposed and designed for Maddagura Erbe system including:

i. Regulating Structures: Cross Regulator and Offtake
ii. Conveyance structures: Canal

The design of typical structures was done using standard procedures and presented in the following sections and using drawing in drawing album.

5.2 Regulating Structures

5.2.1 Design of Offtake Structures

Types off take structures is provided: Box off take structures where the fields are directly irrigating from main canal. The detail design box offtake structures were presented in final report; the sample design is presented using drawing album.

6 ROAD WORKS

To carryout operation and maintenance activities effectively and efficiently, and to carry out any development activities within the project area, 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 proposed.

i. **Foot path:** 1.75m width foot path are provided parallel to the tertiary canal, in between tertiary canal and corresponding tertiary drain for effective accessible of field block and offtake on tertiary canal by users. The construction is totally left for users.

ii. **Inspecting road;** 4m width road are provided parallel to primary and secondary canals for accessibility of secondary and tertiary blocks. The costs of these roads are included in project. Main design parameters are presented in table below:

iii. **Access road:** parallel to the main canals, 6.0m width of road are provided for accessibility of the whole system. The costs of these roads are included in project. Main design parameters are presented in table below:

Table 6-1: The Proposed Road Dimensions

Design Parameter	Unit	Inspection Road	Access Road
Carriageway width	m	4	6
Minimum shoulder width on each side	m	0.5	1
Minimum horizontal radius at curves	m	15	50
Cross fall (from center line)	%	4%	3%
Screening Crusher dust	mm	5	5
Aggregate Sub base	mm	150	200
Earthen Embankment (selected material)	mm	300	400

Note: The typical cross section is shown in drawing album.

7 ENGINEERING WORKS & COST ESTIMATE

7.1 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 attached as appendix to this report in Appendix 1.

7.2 Bill of Quantities & 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. The estimated bill of quantities, rate and cost of each item are summarized in the following table and annex 1:

Table 7-1: Summary of Estimated Engineering Cost of Project

Description	Total cost	Comm.Share
Preparatory Work	561,869.02	
Access Road Construction	500,000.00	-
Head Work Construction	2,870,888.52	62,452.51
Canals System	306,835.80	35,027.82
Structures on Canals	429,500.53	-
Sub Total	**4,669,093.86**	**97,480.33**
Community Share (%)	100%	2.1%
Management & Construction Supervision (5%)	233,455	4,874
Total	**4,902,548.55**	**102,354.34**
Physical Contingency (10%)	490,255	10,235

S.Total	**5,392,803.41**	**112,589.78**
VAT (15%)	808,921	16,888
Grand Total	**6,201,723.92**	**129,478.24**
Community Share (%)	100%	2.1%

8. IMPLEMENTATION SCHEDULE

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 year provided that the required predicted supply conditions of material, financial availability and manpower arrangement are available /fulfilled.

9.CONCLUSION AND RECOMMENDATION

The suitability level of the land enhanced by using other technology type like border strip with hydro flume…etc. Surface irrigation, namely furrow border strip & hydro fume, which enhanced the suitability area irrigated. After deducting non-suitable area like rock exposures, gully and stream/river, area of unsuitable soil and residential areas, 41.8ha of land is identified as net irrigable area that will be irrigated by furrow using field ditch; border strip using field ditch and using border strip with hydro flume. However due to water scarcity, during dry time only 23 ha is targeted to irrigated.

The analysis made on water availability indicate that mean monthly flow of this spring at diversion site is 44 m3/sec and the peak annual discharge at diversion site is 105.71m3/sec. The lowest mean flow usually occurs in March while the highest flow occurs in August.

The crop water computation result shows that the highest irrigation requirement for actual area is found in a month of January. The net irrigation requirement for actual area was found to be 0.98 l/s/ha for 24-hour irrigation without considering the project efficiency. Therefore, the scheme supply of the project is 2.0 l/s/ha for 12-hour irrigation time.

The water balance analysis done for dry time irrigation indicates that for February and March months, water stress will happen. To minimize these problems, we strongly recommend performing maintenance and operational activities that enhance efficiency of the overall project. As described in agronomy report, the overall project efficiency used in for this project is 45%,

Though our finding of analysis and design shows that the project is technically feasible in all engineering aspect, environmentally friendship and socially acceptable we strongly recommend improving the existing agricultural practice. Also, we recommend to strictly and precisely constructing the canals with lining to save water and increasing service quality.

REFERENCES

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Annex 1: Madagura Erbe Small Scale Irrigation project-Engineering Cost Breakdown

BILL OF QUANTITIES AND COST							
Item No	**Description**	**Unit**	**Total Qty**	**Qty of community Share**	**Unit cost(Br)**	Total cost	**Comm.Share**
1	**Preparatory Work**						
1.1	Mobilization	LS	1.00	-	25,000.00	25,000.00	
1.2	Demobilization	LS	1.00	-	35,000.00	35,000.00	
	Sub total 1-1					**60,000.00**	**-**
1.2	Engineering surveying and Preparation of as-built drawings and site plan including operation and maintenance manual	LS	1.00		60,000.00	60,000.00	
	Sub total 1-2				.	**60,000.00**	**-**
1.3	**Camping amd Office Facilities**						
1.8	Camping (3m x 13.85m office & bed room, 4m x 6m kitchen & Cafeteria, 5m x 5m store, 4mx2m Toilet & Shower, 2m x 2m guard house					-	
1.8.1	Site clearing	m^2	175.00		2.92	511.00	
1.8.2	Excavation	m^3	63.34		57.2	3,622.82	

1.8.3	Cart away all excess excavated material for safe place with a radius of more than 500m	m^3	88.52		31.2	2,761.82	
1.8.4	25cm thick hard core	m^3	89.70		36.4	3,265.08	
1.8.5	Masonry work with 1:3 mortar mix	m^3	38.40		858.54	32,971.37	
1.8.6	5cm thick mass concrete (1:2:4 mix ratio)	m^3	12.71		1698.84	21,592.26	
1.8.7	2cm cement screed	m^2	91.00		90.64	8,248.24	-
1.8.8	CIS walling G-32	m^2	337.00		142.91	48,160.67	
1.8.9	CIS roofing G-32	m^2	194.50		211.94	41,222.33	
1.8.10	Chip wood wall ceiling	m^2	256.00		129.33	33,108.48	
1.8.11	Supply, assemble and fix in position eucalyptus wall post of length 3 m with span length of 1.2m	No	161.00		225	36,225.00	
1.8.12	Supply and fix purlin in Eucalyptus wood size 50 x 70 mm nailed into eucalyptus truss	m	586.00		69.375	40,653.75	
1.8.13	Supply, assemble and fix in position eucalyptus roof truss	No	36.00		225	8,100.00	
1.8.14	Supply and fix purlin in zigba wood size 50 x 70 mm nailed into eucalyptus truss including three coats of anti - termite external treatment	m	190.00		69.375	13,181.25	
1.8.15	Supply and fix CIS doors size 1.0x2.10m	No	14.00		3139.25	43,949.50	
1.8.16	Supply and fix CIS windows size 1x1.2m	No	9.00		2150.25	19,352.25	

1.8.1 7	Fence 2.0m height & 15cm φ eucalyptus poles placed every 2m with barbed wire at 20cm vertical interval & erected in 0.6m depth embedded with concrete	LS	1		84943.2	84,943.20	
	Sub total 1-3					**441,869. 02**	
	Sub total					**561,869. 02**	
2	**Access Road Construction**						
2.1	Access Road Maintenance cutting to an average depth of 0.3 m, with 6m width	km	5		100,000. 00	500,000.0 0	
	Total for 2					**500,000. 00**	**-**
3	**Head Work Construction**						
3.1	**Earth Works**						
3.1.1	Site clearing to an average depth of 20 cm	m^2	248		7.00	1,732.50	1,732.50
3.1.2	Ordinary soil Excavation for bed	m^3	803		48.00	38,556.00	38,556.00
3.1.3	Soft rock excavation	m^3	203		160.00	32,400.00	
3.1.4	Hard Rock excavation	m^3	176		420.00	73,710.00	
3.1.5	Fill and Compaction of Normal Soil	m3	369		60.00	22,140.00	22,140.00
	Subtotal 3-1					**168,538. 50**	**62,428.5 0**

3.2	**Stone(Masonry & Concrete) Works**		**0**				
3.2.1	**Weir Body**						
	Cyclopean Concrete (40% concrete and 60% Stone)	m^3	662.3		1260	834,435	
	25cm thick C25 Concrete(1:2:3) for Coping	m^2	82.0		2700	221,400	
	Lean concrete, C-10(1:3:6) 10cm thick for bedding	m^3	2.5		1700	4,250	
	Dia. 10mm	Kg	4422.656	60	265359.36	265359.36	
	Plastering	m2	718.08	149.7858755	107558.2414	107558.2414	
	Sub total					**1,433,002.60**	**-**
3.2.2	**Apron**						
3.2.2.1	**U/s Apron**						
	Stone masonry work with mortar mix 1:3	m^3	12.4		1200.0	14850.0	18.5625
	Lean concrete, C-10(1:3:6) 10cm thick for bedding	m^3	3.6		1700.0	6171.0	5.445
	Sub Total					**21,021**	**24**
3.2.2.2	**D/s Apron**						
	Stone masonry work with mortar mix 1:3	m^3	53.0		1200.0	63,558	
	15cm thick C25 Concrete(1:2:3) for Coping	m^4	18.2		2700.0	49,005	
	Lean concrete, C-10(1:3:6) 10cm thick for bedding	m^3	5.9		1700.0	10,005	

	Sub Total					**122,568**	**-**
3.2.3	**Cut off**						
3.2.3 .1	**U/s Cut Off**						
	Stone masonry work below OGL with mortar mix 1:3 cost includes metal formwork	m^3	1.5		1200.0	1,782	
	Lean concrete, C-10(1:3:6) 10cm thick for bedding	m^3	0.3		1700	561	
	Sub Total					**2,343**	**-**
3.2.3 .2	**D/s Cut Off**						
	Stone masonry work below OGL with mortar mix 1:3	m^3	53.0		1200.0	63,558	
	15cm thick C25 Concrete(1:2:3) for Coping	m^2	18.2		2700	49,005	
	Lean concrete, C-10(1:3:6) 10cm thick for bedding	m^3	0.3		1700	561	
	Sub Total					**113,124**	**-**
3.2.4	**Under sluice**						
3.2.4 .2	**Under sluice**						
	Stone masonry work below OGL with mortar mix 1:3	m^3	17.5		1200.0	21,000	
	15cm thick C25 Concrete(1:2:3) for Coping	m^2	5.4		2700	14,458	
	Lean concrete, C-10(1:3:6) 10cm thick for bedding	m^3	3.6		1700	6,069	
	Sub Total					**41,526**	**-**

3.2.5	**Retaining Wall**						
3.2.5 .1	**U/s Retaining Wall**						
	Stone masonry work above OGL with mortar mix 1:3	m^3	137.6		1260.0	173,376	
	Stone masonry work below OGL with mortar mix 1:3	m^3	34.4		1200.0	41,280	
	Plastering all the exposed surfaces 2cm thick first coat with mortar of 1:3 mixing ratio and the second coat with 2cm thick 1:2 mixing ratio	m^2	109.4		2700	295,354	
	Lean concrete, C-10(1:3:6) 10cm thick for bedding	m^3	3.4		1700	5,848	
	Sub Total					**515,858**	**-**
3.2.5 .2	**D/s Retaining Wall**						
	Stone masonry work above OGL with mortar mix 1:3	m^3	205.9		1260	259,371	
	Stone masonry work below OGL with mortar mix 1:3	m^3	71.6		1200	85,920	
	Plastering all the exposed surfaces 2cm thick first coat with mortar of 1:3 mixing ratio and the second coat with 2cm thick 1:2 mixing ratio	m^2	204.6		80	16,371	
	Lean concrete, C-10(1:3:6) 10cm thick for bedding	m^3	7.2		1700	12,172	
	Sub Total					**373,834**	**-**
3.2.6	**Intake**						
3.2.6 .2	**Left Intake**						

	Concrete, C20 (1:2:4) cost includes metal formwork	m^3	4.0		2700	10,800	
	Sub Total					**10,800**	**-**
3.3	**Gates Implementation**						
3.3.1	**Under sluice gate installation for left, as per drawing**						
	12mm thick sheet metal,1.3m x1.3m;14mm dia of stiffening bar; 12mm dia bar for anchorage & Dia.20mm for handling	No	1		15000.0	15000.0	
3.3.4	**Offtake gate installation, as per drawing**						
	5mm thick sheet metal,0.6m x0.6m; 12mm dia of stiffening bar; 16mm dia bar for anchorage	No	1		10000.0	10000.0	
	Sub total					**25,000**	**-**
3.5	**Protection Works**						
	Stone Pitching	m^3	86.0		450	38,688	
	Filter Material under benth of apron	m^3	57.3		80	4,585	
	Sub Total					**43,273.01**	**-**
	Total of Headwork					**2,870,888.52**	**62,452.51**
4	**Canals System**						
4.1	**Main canals , Length=3239.64m)**						
4.1.1	clearing up to 20m cm depth soil	m^2	4,378.48	4,378.48	8.00	35,027.82	35,027.82

4.1.2	Excavation of ordinary soil depth	m^3	889.19		54.00	48,016.48	
4.1.3	Excavation of Soft Rock	m^3	200		119.00	23,800.00	
4.1.4	Excavation of Hard Rock	m^3	63		365.00	22,948.36	
4.1.5	Masonry work with 1:3 mortar work	m^3	85.27		1689.0	144,019.38	
4.1.7	Plastering with 1:3 mix ,3 coats	m^3	220		150.00	33,023.75	
	5mm thick coping of C 15		8		2,358.00		
	Fill and Compaction of Normal Soil		124		138.00		
	Sub Total 4-1					**306,835.80**	**35,027.82**
5	**Structures on Canals**						
5.1	**Offtakes(25 in No)**						
5.1.1	clearing up to 15m cm depth soil	m2	88.53		8.00	708.28	
5.1.2	Excavation of Normal Soil	m3	51.73		54.00	2,793.17	
5.1.3	Masonry work with 1:3 mortar	m3	46.20		1689	78,033.31	
5.1.4	Plastering with 1:3 mix ,3 coats	m2	194.86		150.00	29,228.92	
5.1.6	Cemented Stone Pitching (1:3 ratio)	m3	8.85		550.00	4,869.41	
5.1.7	C10(1:3:6), Lean Concrete	m3					

			19.88		2,118.00	42,108.52	
5.1.8	5mm thick double framed with angle iron Gate works supply & Installation, as per drawing	No	25.01		800.00	20,004.32	
5.1.9	Back fill and compaction	m3	43.04		64.00	2,754.60	
	Sub Total 5-2					**180,500.53**	**-**
5.9	**Social Service Structures**						
5.9.1	Foot Bridge structures(it's location decided by the community) as per drawing	LS	12.00		14,000	168,000.00	
	Washing Basin (it's location decided by the community) as per the drawing	LS	3.00		21,000	63,000.00	
	Cattle Trough/Water Point for Animal(it's location decided by the community) as per the drawing	LS	3.00		6,000	18,000.00	**-**
						249,000.00	**-**
	Total 5					**429,500.53**	**-**
	Total Cost					**4,669,094**	**97,480**