Contents

6. HYDRO-METEOROLOGY

This project has come to be studied from the beneficiaries request for irrigation scheme introduction. It is found in *Fifota Washerbi Kebele* in *Dodola Woreda*. The area is one of the potential areas for agriculture in the District. However, the farmers have not used it effectively.

In the package of the study, Hydrology is one wherein we aim at analyzing the pattern and size of flow of the target river based on the watershed approach to arrive at beneficial recommendations. These help us to conclude whether the river flow could be used for irrigation or not.

6.1. Study Materials and Methods

The materials primarily used for the study of the project are *Oromia* Irrigation Development Authority and Ministry of Water Resources guidelines and manuals. Different irrigation books are used as secondary resources. The methods used/followed are:

- Preliminary preparation for the work (by checklist preparation, etc) at office level,
- Field observation,
- Discussion with the team members during field study,
- Taking appropriate field survey data,
- Taking required and related pieces of information from the selected aged project area dwellers,
- Water resource flow size measurement repeatedly during field study,
- Data compilation and analysis using recommended methods pointed out in the guide lines,
- Use of accessible helpful soft-wares,
- Careful interpretations of the analysis

6.2. Background and Literature Review

In the last six years we recognize the faster expansion rate of irrigated area in this Administrative Zone than the previous years. This is attributed originally to the irrigation Policy of the Country and Irrigation Proclamations of the Region. Practically, it is attributed to the implementation endeavors of the Regional Irrigation Development Authority. And *Dodola Woreda* which is one of the potential areas for agriculture in the Zone has taken its share of advantage of irrigation expansion.

With respect to the present project, the farmers in the area have a significant idea about irrigation though there are no practical experiences. They have obtained this from the farmers who practice mini irrigation on Wabe River - which *Gudayesso* River joins - with small pumps. Hence we can say that there is awareness in the minds of the farmers on the significance of irrigation on man's life. This helps further expansion of the system to newer areas with enough water resource.

6.3. Watershed Analysis

6.3.1. Watershed Location and Geometry

The watershed of the *Gudayesso* River with outlet at (495213.078m, 766527.837m, 2502.34m) UTM has been delineated by Global Mapper Version 17 and is found in *Wabe* River basin. It is bounded geographically in the limits of (506,235m, 754,705m) UTM by east, (476,416m, 761,529m) UTM by west, (494,872m, 766,918m) UTM by north and (484,791m, 754,317m) UTM by south. The area estimated is about 205.95 km^2. Its highest elevation is about 3,100m, its lowest is 2,502m at the proposed headwork site.

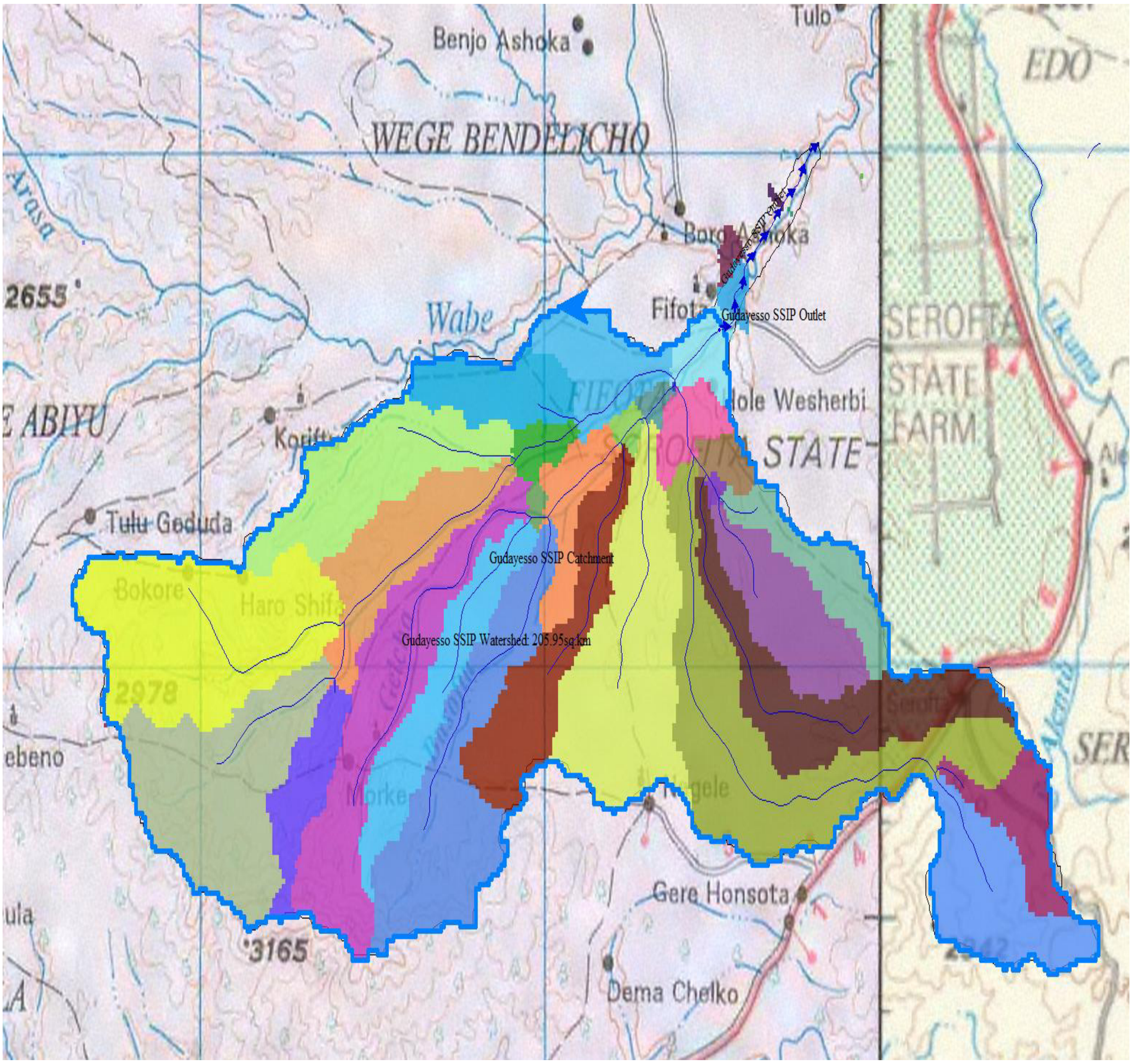
The watershed lies totally in *Dodola District* and near to Serofta State Farm. The watershed has a leaf shape with the longest runoff route length of about 20kms.

6.3.2. Land Use Cover Estimation

The reason why the term "estimation" is applied in the sub title is that the land use data either processed from satellite imageries, or from topographic maps are estimations. What is processed today may actually be changed tomorrow. The actual land situations are changing from time to time by manmade manipulations. Hence the use of the word is suitable.

Table 6.1: Watershed coverage and land use

Sr. No.	Cover type	Partial area (Ha)	Remarks
1	Agricultural land	11,925	
2	Trees (Scattered)	625	
3	Stream bank land	940	
4	Settlement area	1,550	
5	Pasturage	2,820	
6	Hilly and rolling lands	2,540	
7	Roads/Paths	195	
	Sum	20,595	



6.4. River Features

The major river in the watershed is *Gudayesso* River. This perennial River joins with *Wabe* River at about 3km downstream of the proposed outlet. There is another perennial river named *Ashalla* which joins Gudayesso River at about 0.7km downstream of the proposed outlet.

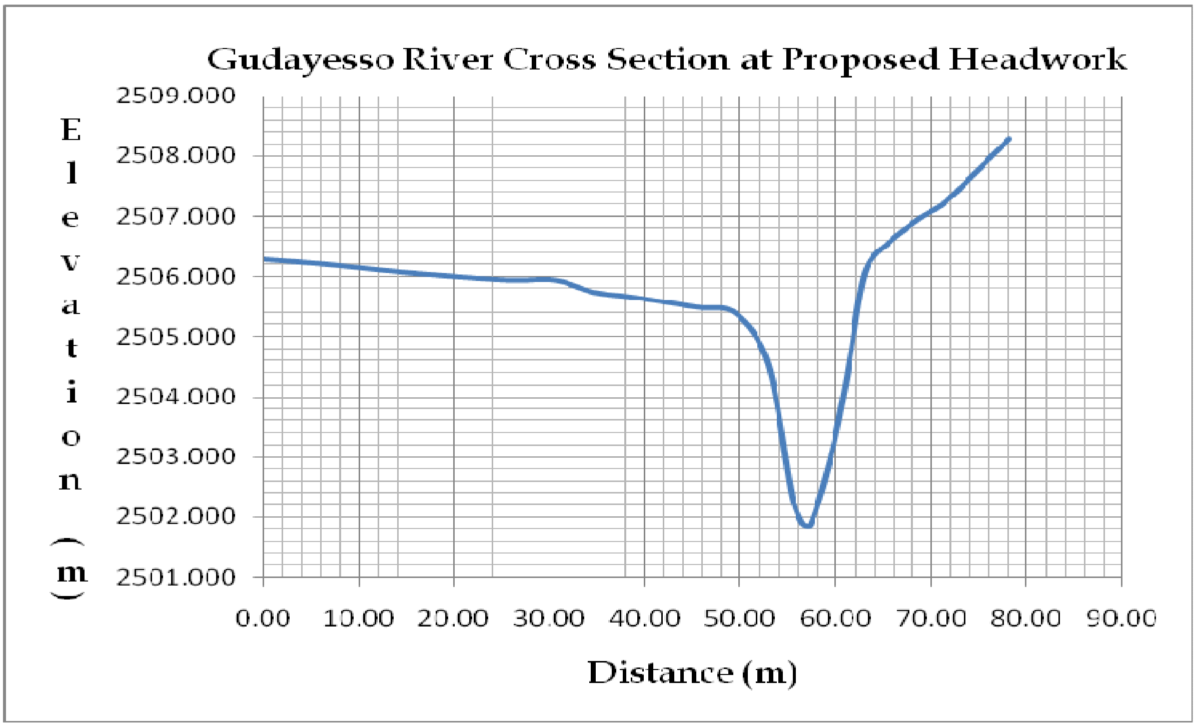
6.4.1. River Cross Section

This helps us to see the feature of the cross section, and to determine the flood level.

River cross section data

Easting	Northing	Elevation	Remarks	Partial Distance (m)	Cumulative Distance (m)
495207.788	766582.921	2506.283	Cross Section	0.00	0.00
495208.536	766576.332	2506.200	Cross Section	6.63	6.63
495209.239	766567.864	2506.062	Cross Section	8.50	15.13
495210.075	766557.632	2505.942	Cross Section	10.27	25.39
495210.640	766552.496	2505.940	Cross Section	5.17	30.56
495211.247	766548.550	2505.739	Cross Section	3.99	34.55
495211.745	766544.245	2505.651	Cross Section	4.33	38.89
495212.008	766537.781	2505.490	Cross Section	6.47	45.36
495212.386	766533.627	2505.382	Cross Section	4.17	49.53
495212.808	766530.273	2504.528	Cross Section	3.38	52.91
495213.078	766527.837	2502.348	Cross Section	2.45	55.36
495212.918	766526.723	2501.883	Cross Section-RC	1.13	56.48
495213.053	766525.918	2501.867	Cross Section	0.82	57.30
495212.761	766523.888	2502.936	Cross Section	2.05	59.35
495212.720	766522.110	2504.325	Cross Section	1.78	61.13
495213.180	766520.271	2506.065	Cross Section	1.90	63.03
495213.484	766517.770	2506.568	Cross Section	2.52	65.55
495213.837	766514.382	2506.987	1Cross Section	3.41	68.95
495213.565	766511.869	2507.241	Flood Mark	2.53	71.48
495214.405	766505.243	2508.292		6.68	78.16

Figure 6.2 River cross section



From the section we see that the left side of the river is generally lower than the right side in the head work area of the project. This feature of the land makes the river runoff flow over the flatter left side bank. Higher floods have no chance of flowing and rising to higher elevations on the right side where our pump facilities are to be installed.

6.4.2. Headwork Area River bed Profile

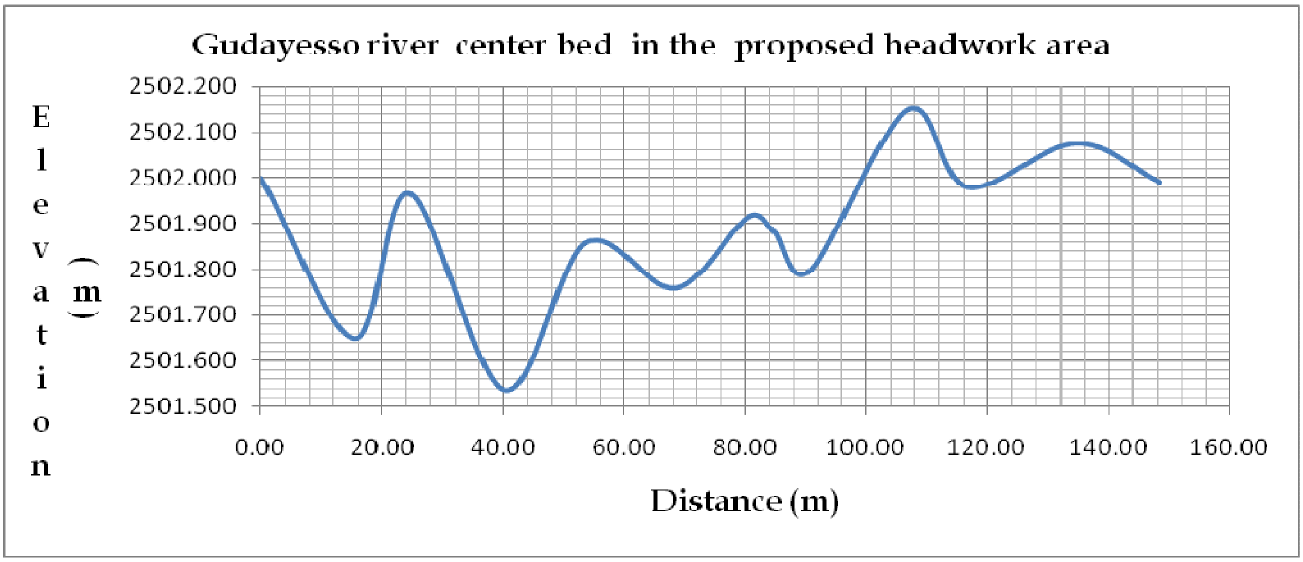
The bed of the river in the proposed headwork is shown below.

Table: River center survey data and analysis

Easting	Northing	Elevation	Remarks	Partial Distance (m)	Cumulative Distance (m)	Partial Slopes
495132.575	766503.596	2502.000	1RC	0.000	0.00	0.0000
495146.717	766509.775	2501.648	RC	15.433	15.43	0.0228
495154.849	766513.902	2501.966	RC	9.119	24.55	-0.0349
495168.986	766520.524	2501.536	RC	15.611	40.16	0.0275
495182.397	766521.631	2501.858	RC	13.457	53.62	-0.0239
495197.044	766523.839	2501.759	RC	14.812	68.43	0.0067
495208.705	766526.812	2501.915	RC	12.034	80.47	-0.0130
495212.918	766526.723	2501.883	RC at HW	4.214	84.68	0.0076
495218.512	766529.266	2501.797	RC	10.109	90.58	0.0117
495233.875	766534.513	2502.149	RC	16.234	106.81	-0.0217
495243.057	766537.911	2501.980	RC	9.791	116.60	0.0173
495257.889	766547.966	2502.076	RC	17.919	134.52	-0.0054
495268.349	766557.130	2501.991	RC	13.906	148.43	0.0061

The average slope of the whole segment is 0.0001. The majority of the segments under analysis have normal slope while others have backward negative slopes. They almost balance each other implying "flat" bed profile and slow flow of the natural river water flow in its natural state. It further implies silt deposition in the area.

Figure 6.3 River bed profile in the proposed headwork area



6.5. Meteorological Data Analysis

The center of the watershed is about 27kms from *Kofele* town where exists a meteorological station. The analysis of the rainfall data of *Kofele* Meteorological Station from 1991-2010 is presented below.

Table 6.2 Annual rainfall data of *Kofele* Meteorological station obtained from Ethiopian Meteorological Agency

	Jan	Feb	Mar	Apr	May	June	July	August	Sep	Oct	Nov	Dec	Total
1991	14.4	107	174.5	64.3	161.2	72.9	105.6	194.2	177.9	11.7	29.3	61	1174
1992	0	168	113.4	203.5	127.4	106	178.6	281.8	216.7	92.7	146.5	85.5	1720.6
1993	87.9	61.6	64.3	164.2	292.9	106	196	131.4	203.6	190.5	37.6	0.8	1537
1994	0	0.6	91.6	107.8	133	110	146	130.3	141.1	15.3	9.3	20.1	905.5
1995	0	18.7	79.8	300.7	75.2	84.5	169	142.3	104.6	58.8	7.8	87.8	1129.2
1996	137.8	34.4	204.9	244.6	133.9	83.4	182.1	142.9	177.4	78.5	45.4	31.7	1497
1997	60	8.2	160.9	188.5	104.4	190	83.4	190.4	0	288.5	0	18.4	1292.9
1998	80.4	68	0	0	0	131	75.3	96.6	167.4	127.8	46.1	6	798.6
1999	24.4	0	113.8	114.5	181.6	185	207.1	126	234.7	230	0	1.8	1418.5
2000	0	0	0	201.1	275.1	162	102.7	116.4	232.2	95.1	40.8	48.9	1274
2001	8.6	50.3	198.2	54.2	161.4	122	92.7	111.7	101.7	158.9	22.2	24.4	1106.3
2002	63.6	41.2	194	79.6	105.2	101	116.3	167.1	118.3	48.5	0	57.4	1092.2
2003	36.8	26.6	206.2	187.7	37.9	189	124.6	130.7	213	86.7	28.7	53.7	1321.6
2004	61.3	15	129.7	234.1	86.3	106	114.3	145.4	114.5	107.3	54.6	29.7	1198.1
2005	35.2	16.1	134.6	163.1	84.9	83	93.3	149.1	101.7	92.9	8.3	25.6	987.8
2006	12.2	75.6	213.3	120.1	152.9	104	158.3	121.6	129.3	89	10.9	28.2	1215.6
2007	48.2	87.6	179.7	165.5	142.1	79.6	95.4	144	138	48.3	12.5	1	1141.9
2008	5	14.2	40.7	45.8	238.2	153	91.3	131.1	143.1	129.9	77.4	0.7	1070.1
2009	79.2	28.7	76.5	62.8	47.04	97.5	93.3	173.5	127.2	108.9	11.3	196	1101.94
2010	53.4	87.4	98.8	144.3	132.4	95	94.7	97	0	0	0	0	803
Sum	808.4	909	2475	2846	2673	2361	2520	2924	2842	2059	588.7	778.7	23785.84

The total of the 20 years rainfall data is 23,785.85mm. The average = 23,785.85mm/20 = 1189.29mm.

Another data set of rainfall of the years 1955-2006 has been obtained from the Agency and the monthly average has been calculated. The total sum of these gives annual average for the years. The sum is 1199.65mm. Hence the average of the more number of years is more accurate than that of the 20 years.

Table 6.3 A 52-years monthly average rainfall of *Kofele* Meteorological station

Month	Average RF	Month	Rainfall
January	37.48	July	141.98
February	53.91	August	155.61
March	115.29	September	153.43
April	144.59	October	99.55
May	111.48	November	44.25
June	111.32	December	30.75
	574.07		625.57
Annual Average = Sum =1199.65			

From the above tables it can be seen that the monthly minimum are existing in the months from November to February. Irrigation is required in these months. The water requirement is calculated in *Agronomy* section of the Document.

6.6. River Flow Measurement and Surface Water Balance

Gudayesso River was measured two times for the purpose of the study in the same year. Dry time was prolonged this year and so we can say that it was good for our study. One was during site identification of the project area, the other during feasibility study.

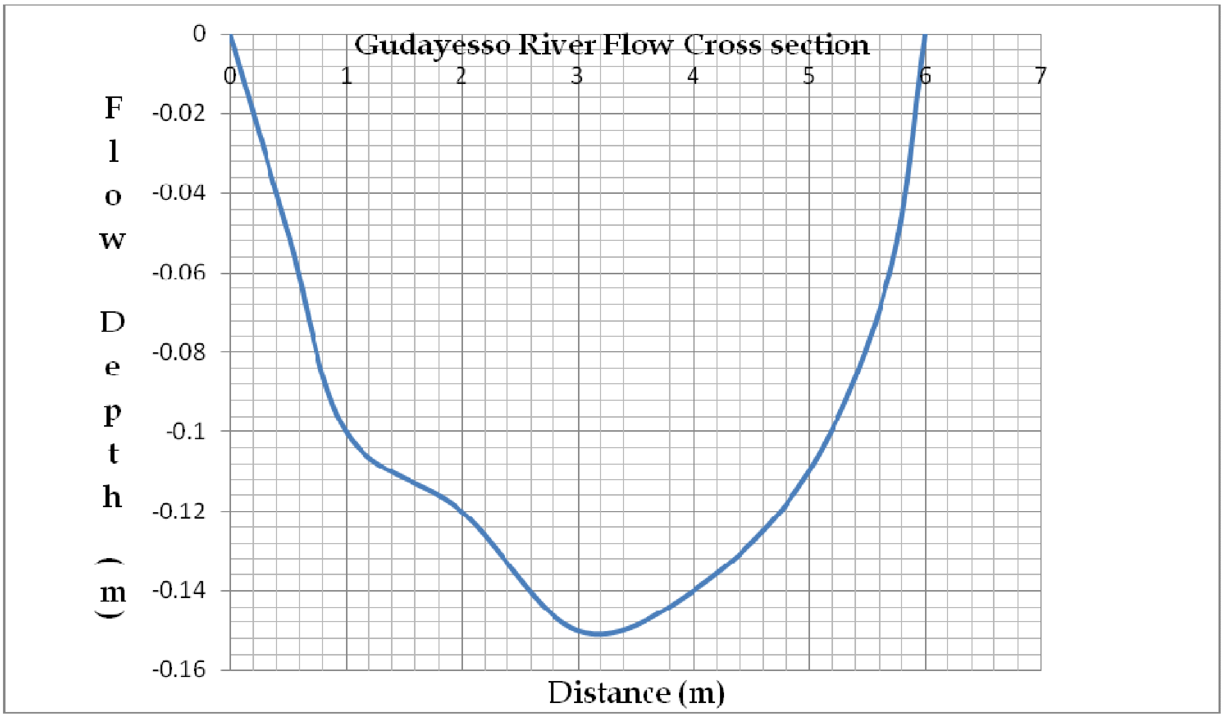
A. Measurement on 6/6/2007 E.C

The measurement data and its analysis is presented below

Table: Flow depth data

x	y
0	0
0.5	-0.05
1	-0.1
2	-0.12
3	-0.15
4	-0.14
5	-0.11
5.7	-0.06
6	0

Figure: The graph of the flow section is shown below



The sectional area is calculated and tabulated as:

Average Depth (m)	Span (m)	Flow Area
0.08	6	0.49

The flow velocity is as follows:

Trial	Distance (m)	Time (s)	Apparent Velocity (m/s)	Corrected Velocity by Factor (0.85)	Flow Area (m^2)	Discharge (m^3/s)
1	10	18	0.56	0.47		
2	10	28	0.36	0.30		
3	10	28	0.36	0.30		
4	10	26	0.38	0.33		
5	10	27	0.37	0.31		
6	10	32	0.31	0.27		
				0.33	0.49	0.16

B. Measurement on 17/06/2007 E.C

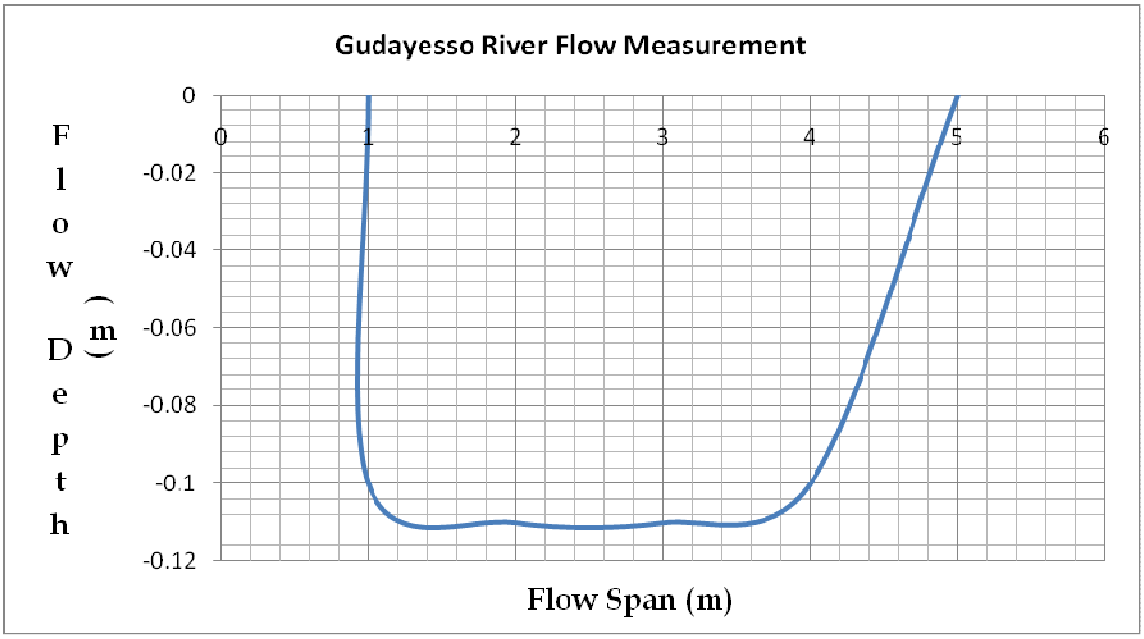
The results of ***Gudayesso*** River flow measurement during the feasibility study is presented below.

Table 6.4 ***Gudayesso*** river flow measurement data during second trip
The measurement data and its analysis is presented below

Table: Flow depth data

x	y
0	0
0.5	-0.05
1	-0.1
2	-0.12
3	-0.15
4	-0.14
5	-0.11
5.7	-0.06
6	0

Figure: The graph of the flow section is shown below



The sectional area is calculated and tabulated as:

Average Depth (m)	Span (m)	Flow Area
0.07	4	0.28

The flow velocity is as follows:

Trial	Distance (m)	Time (s)	Apparent Velocity (m/s)	Corrected Velocity by Factor (0.85)	Area (m^2)	Discharge (m^3/s)
1	11	22	0.50	0.43		
2	11	21	0.52	0.45		
3	11	19	0.58	0.49		
4	11	20	0.55	0.47		
5	11	22	0.50	0.43		
6	11	18	0.61	0.52		
				0.46	0.28	0.13

Conclusion: The values obtained during the two measurements are compared. The first result is 160 l/s while the second is 130 l/s.

The measurement was done on straight rocky bed of the river and at different times. In addition, many local elders told us that the usual dry-time flow size was almost the same as what we observed and measured. The season of dry time in the area was said in the year to be harsher and longer than the usual ones. Hence we can take the minimum Gudayesso River flow at the proposed headwork to be about 130 l/s.

Summary on Water Balance for Schemes on the River: The summary is presented in the following table.

Table 6.8 Water Balance Summary

Scheme	Measurement Location		Discharge (m^3/s)	Time of measurement (Month, Year)	Proposed for Irrigation (m^3/s)	Left for downstream
	Easting	Northing				
Gudayesso River	495213	766527	0.130	February, 2007 E.C		
Upstream				None	None	
Downstream				None	None	

6.7. Silt Load Estimation

The amount of silt load coming to the outlet should be estimated. Universal Soil Loss Equation could be adapted in Ethiopia to predict sheet erosion (Hurni, 1985). The various factors have been simplified for calculation. The actual situations of our study watershed are considered and evaluated.

The Equation is:

E = RKLSCP where E---------------------------------average annual soil loss, tons/km^2
R----------------------------------erosion index
K----------------------------------soil erodibility factor
L,S--------------------------------land gradient, slope length
C----------------------------------cropping management factor
P-----------------------------------conservation practice factor

- All eroded soil does not reach the catchment outlet, and hence the portion that could reach the outlet is worthy of estimation. For the delivery ratio, the following empirical formula could be used:

D = 34.4*A$^{-0.18}$ where A---------watershed area in km^2. It indicates the portion of the total eroded soil that reaches the outlet.

Table 6.9 Annual soil erosion estimation from the watershed

No	Factors	Parameter	Unit	Value
1	Rainfall Erosivity R	Annual Rainfall=1199.65mm	Annual Factor	665.80
2	Soil Erodibility K	Soil Color = Dark brown	Factor	0.2
3	Slope Length L	Length = 320m	Factor	3.8
4	Slope Gradient S	Slope = 10%	Factor	1
5	Land Cover C	Cover Type	Factor	0.23
6	Management Factor P	Ploughing on Contour	Factor	0.9
	Average Annual Soil Loss		tons/km^2	104.74
	Sediment Delivery Ratio		%	13.19
	Annual Sediment Yield at Outlet		tons/km^2	13.81
	Annual Sediment Yield at Outlet		tons	2,013.03

The last figure is the total annual estimated soil loss from the whole watershed that reaches the outlet. This hints at introduction of sediment management mechanisms in the headwork area on one hand and the watershed management plans on the other. The latter will be discussed in the *Watershed Management* section of the document in detail.

6.8. Maximum Flood Level Determination

The maximum flood level ever observed was shown by the elders of the project area at (495,213.565, 766,511.869, 2,507.24) based on the field survey data. The pump is to be installed on the right side of the river. This right side is higher than the left side. This nature of the ground makes any high flood inundate the lower left side of the river. For additional details see section 6.4 of the same document. In conclusion we have no fear of the right side inundation, but care must be taken in installing the pump at suitable location which is fairly higher above the indicated flood level.

Our interest here is to find the level of the anticipated flood which comes once in 50 years. The size of the flood is not our primary concern which is required for the design of weir or other structures. Since our project is of pump, we have to install it as near as possible to the river with its structures. The pump house should not be liable to any flood.

Accordingly, the local elders showed us the level of the maximum flood level observed ever in their life time.

6.9. Underground Water Situation

We have not done any detail drilling exploration to understand the underground water situation in the project area. But from information obtained in the area, we can say something. From the hand dug wells in the area, we understand that the water table is not at high depth. For more explanation see *Geology* report of the project Document.

6.10. Water Quality

The dwellers have noticed no flaw on the water quality of the Gudayesso River which may be observed on plant life in the (proximity of the) river and its banks. Nor have they heard of anything since long.

6.11. Summary and Conclusion

The physical characteristics, land use cover, river features and water resource of the watershed of the project area have been identified and analyzed. From the analysis, the minimum dry-times river flow and the sediment load estimation have been determined. The level of the ever observed river flow discharge is also shown.

We can conclude that the river has reliable flow and the flood level mark helps us to locate the pump house with caution against flood risk.

7. DESIGN OF PUMP IRRIGATION SYSTEM

7.1. Introduction

This project area has high potential for crop production though not consumed to its best. This discipline is important as it ultimately identifies the reliability of the proposed pump system for irrigation in the project area. This brings together the amount of water, the topographical suitability of land and the way of abstracting the water and distributing it to the land. In the process of identification, accessible materials and approaches have been used. Finally based on the prudent observations and analyses, a clear cut recommendation is made.

7.2. Objectives and Materials Used

The general objective of engineering applied here to irrigation pump system design aims at increasing production through irrigation, as the area is of high potential. Specifically it aims at bringing out easy and cost effective design for this project and to benefit this project area community.

Materials Used and Procedures Followed
-GPS and Total station in surveying
-Topographic map (1:50,000) and Global Mapper v17
-Guidelines and manuals of Irrigation Projects Study and Design of Oromia Irrigation Development Authority,
-References from known International Irrigation Books
The ways followed are:-
-Project site investigation,
-Discussions with community representatives,
-Systematic data collection, analysis and interpretation,
-Using different data from other study disciplines.

7.3. Irrigation Water Resource

The water resource for the project is *Gudayesso* River from which the name of the project is derived. The elders of the area state that the river is without doubt perennial. The *Hydrology* report shows reliability of the minimum flow of the river. And the minimum dry time flow was determined to be 130 l/s. From this flow, 80 l/s (which is 61% of the minimum flow) has been determined to be taken for irrigation by pump.

7.4. The Land Resource

The total surveyed area is about 100 Hectares. The center of the project area is at about (495,360, 765,925, 2554) m UTM. Of the total surveyed area, about 83 hectares is under agriculture, the rest is of miscellaneous use. The following table summarizes the surveyed area land use type.

Table 7.2 Surveyed Area Topography analysis

No	Category of the Surveyed area	Area (Ha)
1	Agricultural area	83.00
2	Stony area	4.60
3	Riverbank area	10.80
4	Grave area	0.15
5	Road patches	1.40
		99.95

The extent of the agricultural land having slope 0- 3% is about 34 hectares, and with 3-7.8% is 30 hectares, and with 7.9-12% is 19 hectares. Limiting the maximum slope of the irrigable area to 8%, we can have the irrigable area of 64 hectares. But the amount of water to be abstracted by the pump for the project has been limited to 80 l/s (*Section 7.3*). The irrigation duty is 1.28 l/s for 12 hours (see *Agronomy*). With this duty we can irrigate = (80 l/s)/(1.28l/s/Ha) = 60ha of land for 12-hours.

7.5. Water Abstraction

The river flow has only one way of abstraction: by pump. At upstream or downstream, there is no site on the river suitable for gravity diversion.

7.6. Pump Irrigation System Layout

In the river course, a small diversion weir helps water enter the approach channel which conveys it to a suction pool from which the pump is to create means of suction. The pump(s) then deliver(s) the water to the temporary storage pond through delivery pipe. The main canal which is about 310m runs taking water from pond almost on the ridge dividing the water among secondary canals on both sides. The main canal then branches into two sub-main canals each of which has division boxes at known locations to give the water to secondary canals. The secondary canals distribute the water amongst tertiary canals which run almost along contours. Field ditches which run across contours then take water to supply to fields through furrows contours-wise. Lengths of the canals are designed considering:

- Suitability for irrigating the farm plots;
- The location of any other canal or structure related with it;
- The location and topography of the command it is found in;

- Introduction of extra structure (e.g. transgressing a road necessitates a road crossing structure);
- Interference with living houses and other man made features;
- Easiness for management.

The lengths of the canals are presented with their design aspects attached in the annex.
The water distribution is facilitated by the existence of the field structures: division boxes, road crossings, drops and outlets. Field operation suitability has also an attention: farmers should easily operate and maintain the system: for this purpose on-canal bridges, foot paths by canals side are necessary.

The detail is shown on the *Gudayesso SSIP Topo and Layout* file. The arrows on the canals indicate the flow directions in the canals.

7.7. Irrigation Efficiencies

The touch on the pump irrigation system layout gives us a hint to determine the irrigation efficiencies. Besides, we are taking water from the river is by pump and hence is very precious: not to be deemed as the water to be taken by gravity. Geology report shows that the upper top soil of 30 cm thickness is dominantly sandy. Consequently the main canal should be lined to avoid the precious water loss.

From the above, we can see the system to have:

- Conveyance efficiency = 95%

- Distribution efficiency = 80% and the rest efficiency issues have been dealt with in *Agronomy* section.

7.8. Design of Diversion Structure

As bringing the pump to the river is risky, water should be led to the pump location nearby. Hence a river water diversion structure is required. This helps to divert the river water and also helps to form a sort of pool to store water temporarily when the flow becomes lean. This structure requires no sophisticated design.

Accordingly fix its maximum height to 1.20m and its shape trapezoidal. A total closure by the wall may create silt deposition that may otherwise lead to the approach channel. Hence a silt sluice gate is required.

The stability analysis of the structure is calculated on excel sheet and presented in the tables of 22 columns.

i) Water upto crest level-

Weir Height, H	U/s slope, H:V	Upstream horizontal diversion from vertical x	Weir crest width b_1	Downstream horizontal diversion from verticaly	Weir base b_2	Stone unit weight (kg/m³)	Water unit weight (kg/m³)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1.2	0.83	1.00	0.60	1.05	2.65	2000	1000
Silt unit weight-horizontal (Kg/m³)	Silt unit weight-vertical (Kg/m³)	Coefficient of friction	Seismic horizontal acc	Coefficient of uplift pressure	Coefficient of earth pressure	Concrete allowable unit shear stress (kg/m²)	D/s slope, H:V
360	920	0.75	0.15	0.4	0.45	140000	0.875

The next columns table follows:

Force type	Forces (kg)		Lever arm (m)	Moment at toe (kg-m)	
	Vertical	Horizontal		+	-
9	**10**	**11**	**12**	**13**	**14**
U/s column water weight	600.00		2.32	1390.00	
Horizontal water pressure		720	0.40		288.00
Weir self weight	1200.00		1.98	2380.00	
	1440		1.35	1944	
	1260		0.70	882	
Uplift pressure	-636.00		1.77		1123.60
Silt Pressure	248.4		2.32	575.46	
		116.64	0.40		46.656
Weir body seismic load		180	0.40		72.00
		216	0.60		129.60
		189	0.40		75.60
Sum	4112.40	1421.64		7171.46	1735.46

The last table showing analysis result,

FS against overturning > 2	FS against sliding > 1	Shear friction factor > 4	Resultant distance from toe (m)	Eccentricity e (m)	Buoyancy > 1	Normal stress at toe (kg/m^2)	Normal stress at heel (kg/m^2)
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**
4.13	2.17	263.1	1.32	0.00	7.47	1562.89	1540.81
Safe	Safe	Safe		No tension	Safe		

ii) Weir submerged

Weir Height, H_w	U/s slope, H:V	Upstream horizontal diversion from vertical x	Weir crest width b_1	Downstream horizontal diversion from vertical y	Weir base b_2	Stone unit weight (kg/m^3)	Water unit weight (kg/m^3)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1.2	0.83	1.00	0.6	1.05	2.65	2000	1000
Silt unit weight-horizontal (Kg/m^3)	Silt unit weight-vertical (Kg/m^3)	Coefficient of friction	Seismic horizontal acceleration coefficient	Coefficient of uplift pressure	Coefficient of earth pressure	Concrete allowable unit shear stress (kg/m^2)	D/s slope, H:V
360	920	0.75	0.15	0.4	0.45	140000	0.88
Discharge head over crest H_u (m)	Approach velocity (m/s)	Velocit head (m)	Total head over crest H_e(m)	Tail water depth H_d (m)			
3.37	1.65	0.14	3.51	1.27			

The next table follows…

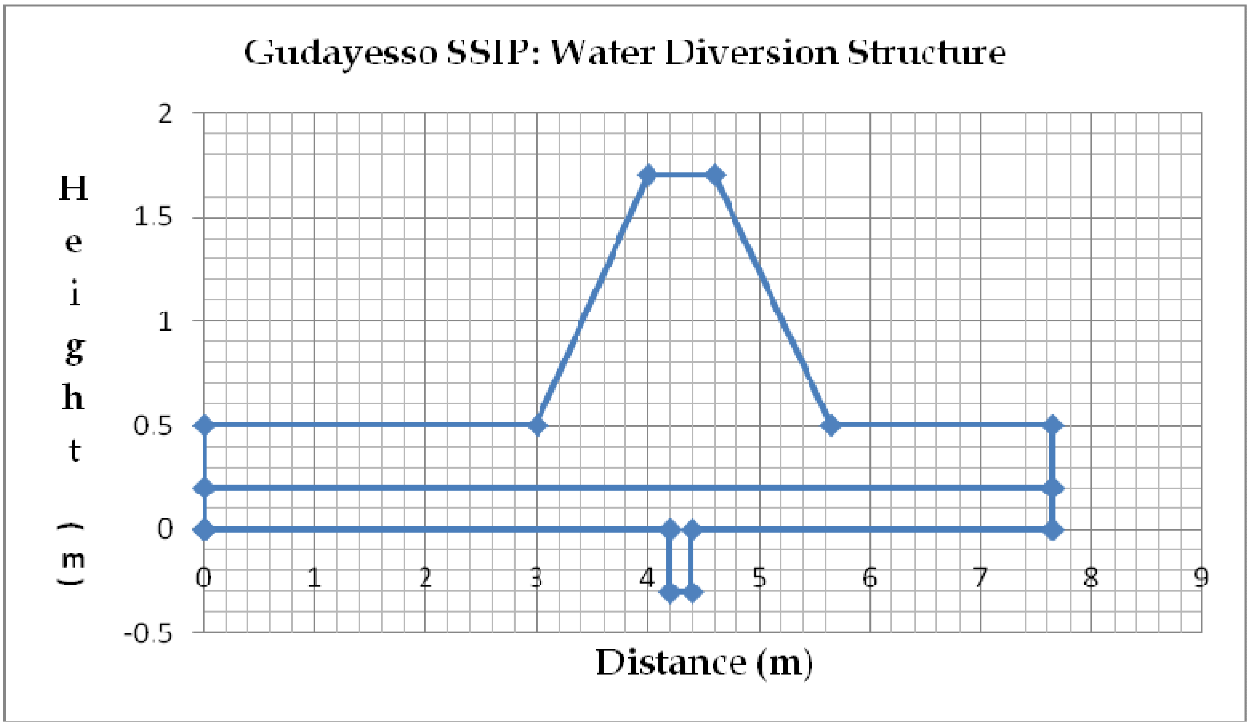
Force type	Forces (kg)		Lever arm (m)	Moment at toe (kg-m)	
	Vertical	Horizontal		+	-
9	**10**	**11**	**12**	**13**	**14**
U/s column water weight over sloping side C_1	600.00		2.32	1390.00	
Horizontal water pressure P1		720	0.40		288.00
Horizontal water pressure P2		4210.5	0.60		2526.31
Vertical water pressure over crest P3	1011		1.45	1465.95	
U/s column water weight over sloping side but above crest C_2	3370.00		2.15	7245.50	
Downstream water pressure P4	630.00		0.35	220.50	
Downstream water pressure P5		-720	0.40		
Weir self weight	1200.00		1.98	2380.00	
	1440		1.35	1944	
	1260		0.70	882	
Uplift pressure U_1	-2422.10		1.77		4279.04
Uplift pressure U_2	-673.10		0.88		594.57
Silt Pressure	248.40		2.32	575.46	
		116.64	0.40		46.66
Weir body seismic load		180	0.40		72.00
		216	0.60		129.60
		189	0.40		75.60
Sum	6664.20	4912.15		16103.41	8011.78

The last table showing result analysis follows….

FS against overturning > 2	FS against sliding > 1	Shear friction factor > 4	Resultant distance from toe (m)	Eccentricity e (m)	Buoyancy > 1	Normal stress at toe (kg/m²)	Normal stress at heel (kg/m²)
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**
2.01	1.02	76.54	1.21	0.11	2.96	3145.71	1883.88
Safe	Safe	Safe		No tension	Safe		

Summary: The vertical trapezoidal weir with height 1.2m, top base 0.60m, bottom base 2.65m, upstream face slope (H:V) 0.83 and downstream face slope 1.04 is stable under all conditions.

Figure 7.2 Section of the diversion structure



The sectional dimensions have resulted from the fulfillment of the stability analysis for the structure. Under all conditions the analysis has showed us stability of the structure against sliding, overturning, shear, tension and buyouancy.

7.9. Design of Retaining Wall

This structure is important to protect the weir from risk as the river bank is dominantly of soil nature in the area and to keep the water in its course.

The design criteria is structural stability against hydraulic, silt and earth pressure all of which is calculated on excel sheet and presented below in columns.

Weir Height, H_w (m)	Wall Height, H (m)	Top base b_1 (m)	Wall lower base b_2(m)	Base of outer sloping part b_2-b_1	Outer vertical wall height part y (m)		Masonry unit weight (kg/m³)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1.2	2.25	0.6	0.68	0.08	0		2400
Coefficient of earth pressure	Masonry allowable unit shear stress (kg/m²)	Masonry unit weight (kg/m³)	Soil specific weight (Kg/m³)	Coefficient of friction	Coefficient of uplift pressure	Water unit weight (kg/m³)	Concrete allowable unit shear stress (kg/m²)
0.45	140000	2000	1800	0.75	0.4	1000	140000

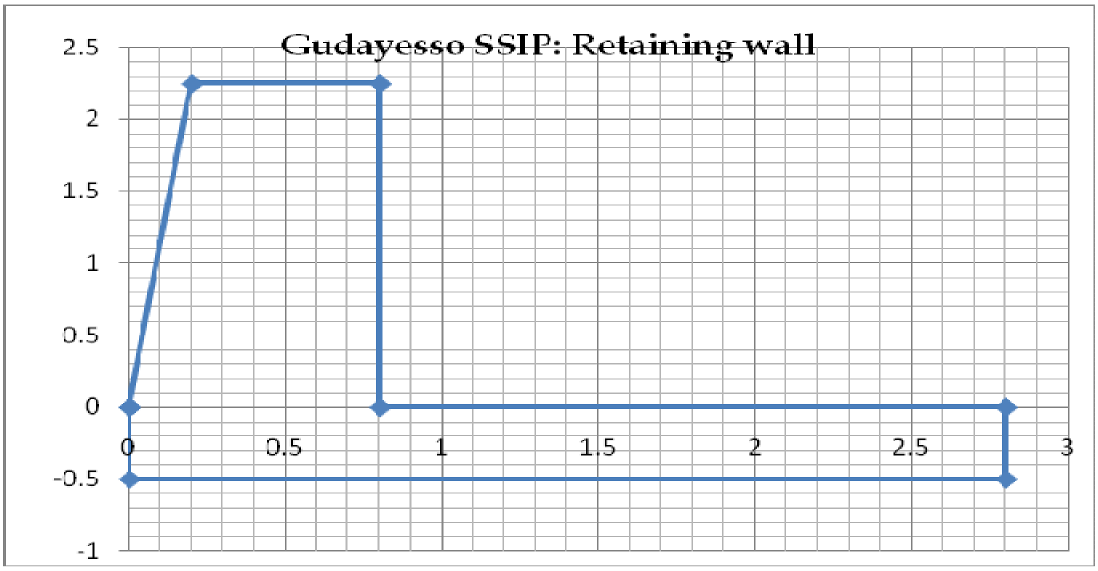
The next table follows…

Force type	Forces (kg)		Lever arm (m)	Moment at toe (kg-m)	
	Vertical	Horizontal		+	-
9	**10**	**11**	**12**	**13**	**14**
Wall self weight W_1	2700.00		0.30		810.00
Wall self weight W_2	180.00		0.63		112.80
Wall self weight W_3	0.00		0.72		0.00
Outer Earth Pressure P_o		2050.31	0.75	1537.73	
Outer Earth Weight W_4	72.90		0.65		47.63
Inner Earth Pressure P_i		-583.20	0.00		0.00
Uplift pressure U	-306		0.23	69.36	
Inner water pressure P_{iw}		-253.13	0.00		0.00
Sum	2646.9	1213.99		1607.09	970.43

The last table showing the result,

FS against overturning >1.5	FS against sliding<=0.75	Shear friction factor > 4	Resultant distance from toe (m)	Eccentricity e (m)	Buoyancy
15	**16**	**17**	**18**	**19**	**20**
1.66	0.46	2063.59	0.24	0.10	9.65
Safe	Safe	Safe		No tension	Safe

Hence a wall river-side vertical face of 2.25m, top base 0.6m and 0.8m bottom base fits the purpose. The following figure shows its section.



7.10. Design of Approach Channel

The pump could not be taken directly over the water source due to fear of flood inundation. Hence the river water should be taken as near to the pump as possible. For this purpose approach channel is a structure which conveys water from the river to the suction pool. It should deliver the amount of water required. Rectangular section is easier for construction than the possible options. The following table shows its design. Manning's and Continuity equations are used.

- Floor bed/River bed level at diversion structure = 2502.30m
- Intake sill level = 2502.30m + 0.50m = 2502.80m

Table 7.3 Approach channel design calculations

Gudayesso	Length (m)	Discharge Q (m^3/s)	Total area it irrigates (Ha)	Manning's Roughness Coefficient	Bed slope	Calculated flow depth (m)
1	**2**	**3**	**4**	**5**	**6**	**7**
Approach Channel	8.00	0.08	60	0.013	0.010	0.17
Inner bed width (m)	Free board (m)	Flow sectional area A (m^2)	Total depth D (m)	Wetted Perimeter P_w (m)	Hydraulic radius R (m)	Flow velocity (m/s)
8	**9**	**10**	**11**	**12**	**13**	**14**
0.33	0.35	0.055	0.52	0.66	0.08	1.46

Note: Columns 1, 2, 3,4,5, 6, and 9 are input data; the others are calculated. In summary the rectangular canal of 0.45m inner bed width and 0.55m depth serves the purpose.

As the velocity of the water in the channel is high care should be taken. Hence a concrete thickness of 15cm with a mix ratio of 1:2:3 for the bed will be safe. It starts at the location 495,212.89m, 766,523.59m.

7.11. Design of Suction Pool

The water which comes into the approach channel should get a temporary depository. The suction pool is a structure which serves the purpose as the temporary water storage near the pump.

The following are worthy of consideration:

- The maximum flood level in the area = 2507.241m (see *Hydrology* report)
- Suction pool proposed location (495,215.30, 766,514.30, 2507.05m)
- The minimum natural river side elevation on the suction pool ground = 2506.80m
- Approach channel end bed level = 2502.74m

The minimum ground elevation on the ground of the pool location is lower than the flood level indicating the necessity of protective structure against flood inundation risk. Hence a highly compacted soil dyke could serve the purpose.

- The dyke height = 2507.241m + free board – 2506.80 = 2507.50m – 2506.80m = 70cm

And the pool's part which temporarily stores water should be below this level. Allowing the pool's depth to be 1.5m:

- The finish bottom of the pool = 2502.74m – 1.5m = 2501.24m
- Reinforced concrete layer over hard core = 20cm
- Hard coring thickness = 20cm
- Excavation bottom level = 2501.24m – 0.40m = 2500.84m
- Excavation depth for the pool = 2507.25m - 2501.24m + 0.40m = 6.41m
- Allow the inner finished plan for the pool bed of 3m X 3m
- Masonry thickness = 0.40m

The pool will be covered by a steel plate of 10mm thickness, for suitability panel by panel. The pump takes the water through the suction pipe from the pool.

7.12. Pump House Site Selection and its Design

Location:-This is one of the most important issues in pump irrigation system design. Hence the center of the proposed and fixed site is (495,217.10, 766,510.760, 2507.50). Generally the geology of the headwork site is good and so is that of the pump house. The maximum flood level indicated was is given 2507.241mm.

- Pump house center ground elevation > Maximum flood level elevation:

  2507.50m > 2507.241m

- Elevation difference between pump house center ground elevation and approach channel pipe end bed elevation = 2507.50m – 2502.74mm = 4.76m

Number of pumps:-The description under section 7.4 of the same document justifies the use of two pumps. Operating with only one pump results in the quick wear of the pump and halt of irrigation when the pump fails. Hence installing two pumps leads to more results: irrigation will not be stopped and hence crop failure resulting from this will be avoided and the pump wear will be decreased.

Pump house size:-As two pumps are going to be installed, the house should have enough air circulating in it and spaces should be available within the house for ease of operation and management. Hence the house with inner size 5m X 4m suits the purpose. There should be enough openings for ventilation.

Pump house foundation:-The foundation finish level is determined by the difference of elevation between the pump seat and the water surface in the suction pool. To be on safe condition, the pump is expected to be brought as near to the water as possible.

- The house ground level = 2507.50m
- Bringing the pump seat down by 1.0m to decrease the elevation difference, 4.76m, discussed above in the previous paragraph, we can make the floor bed finish level to be at 2506.50m
- The approach channel's end bed level = 2502.74m
- Difference = 2506.50m - 2502.74m = 3.76m
- Selected material fill = 10cm thick,
- Hard core = 25cm,
- Reinforced concrete = 25cm
- Pump house bottom excavation level = 2506.50 - 0.60m = 2505.90m
- Pump center line above floor finish level = 0.30m
- Elevation difference between minimum water flow level in the approach channel and pump center line = 2506.50m + 0.30m – 2502.74m = 4.06m

7.13. Pump Details and Design

7.13.1. Pump Operation Hours

The operation hours of the pump is calculated based on the following agronomic data (See Agronomy section of the Document):

- The irrigation area of the project, 60 hectares
- Weighted one time (gross) irrigation depth, 43.2mm
- Weighted irrigation interval of the project, 6.00 days
- The size of the discharge which the pump actually draws from the source, 80 l/s

Hence, the Pump Operation Hours = (60*43.2)/(0.08*6.00)*1/360 = 15.00 hrs. For safety, we use two pumps each of which operates 7.50 hrs daily.

- If the irrigation working hours of the area is 12 hours, the excess time flow is stored. Hence a storage pond is required.

7.13.2. Pump and Pipeline Design

The steps involved are described as follows.

- The water amount to be pumped is first to be determined, it is 80 l/s.
- Using the fixed elevations of the of minimum water surface, pump level, delivery pool level, suction and discharge pipes, and pump accessories, friction head losses are calculated in suction and discharge sides. Pipes, fittings, etc are all considered. The calculation is done Excel sheet and presented here.

The following table of 45 columns shows the detail calculations.

- The friction losses in pipes are calculated by *Darcy's-Wesbach* Formula.
- Losses in all fittings are calculated as portions of velocity heads of respective pipes.
- The atmospheric pressure at the site has been calculated considering its decrease of 0.36m for every 300m as one goes higher than sea level.
- Net positive suction head available has been calculated with 0.3m head as factor of safety.

Pump	Water minimum surface elevation (m)	Pump center location level (m)	Discharge level (m)	Water access by	Water to be pumped (m^3/s)	Pressure head at suction (m)	Pressure head at discharge (m)	Atmospheric pressure at water surface(m)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Gudayesso	2502.74	2506.80	2555.56	Suction lift	0.080	0	0	7.33
Delivery line length (m)	Assume velocity of water in suction pipe (m/s)	Assume velocity of water in discharge pipe (m/s)	Area of suction pipe (m^2)	Diameter of suction pipe (m)	Area of discharge pipe (m^2)	Diameter of discharge pipe (m)	Suction static lift (m)	Suction pipe length (m)
10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
579	1.25	1.75	0.064	0.29	0.046	0.24	4.06	10
Friction coefficient for suction pipe	Friction coefficient for discharge pipe	Friction Head Loss for suction pipe (m)	Friction Head Loss for discharge pipe (m)	Velocity head in suction pipe (m)	Head loss in strainer (suction side) (m)	Head loss in foot valve (suction side) (m)	Velocity head in discharge pipe (m)	Discharge side head loss in elbow (m)
19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
0.0087	0.0094	0.10	14.06	0.08	0.08	0.06	0.16	0.15
Discharge side head loss in reflex valve (m)	Discharge side head loss in sluice valve (m)	Discharge side head loss in adapter (m)	Discharge side head loss in 2 couplings (m)	Discharge side head loss in all gaskets (m)	Discharge static head (m)	Total Suction Lift (m)	Total Discharge Head (m)	Total Head (m)
28	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
0.12	0.12	0.15	0.28	1.51	48.76	4.38	65.29	69.67

Water vapor pressure (From Standard Tables) (m)	Net positive suction head available (m)	Pump operation (Hours/Day)	Daily Discharged Water Volume (m^3)	Energy to lift water (kWh)	Power required to lift water (kW)	Water Horse Power (hp)	Pump efficiency	Motor's mechanical power (kW)
37	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
0.25	2.40	8.00	2304	437.37	54.67	74.35	0.60	91.12

Note: Columns 2-6, 10-12, 18, 37, 39 and 44 are for the required inputs based on which other parameters area calculated by standard formulae.

7.13.3. Pump Fuel and Lubricant Cost Estimation

It is important to estimate the annual operation cost of the pump. Under this enter the fuel, oil and spare parts cost are estimated.

- Fuel cost = pump hourly fuel consumption*Daily operation hours*Total number of irrigation days*Unit fuel cost (Birr)

  = 3 l/hr*8hr*130days*22Birr/l = 68,640Birr

- Lubricant Cost = 20,000Birr
- Spare parts cost = 15,000Birr
- Annual Operation Cost = 103,640Birrs

7.13.4. Assistant Storage Pond

The pond is designed to assist the pumps by storing water. The pond storage does not irrigate extra land, but it makes the pumps “take rest”.

Table 7.5 Storage pond size

The pond design is done from the considerations of volume required, its cost, pump operation hours, discharge entering the pond, and the seepage effects. Accordingly:-

- The volume is = 80 l/s x 4 hours = 1,152m^3;
- The dead storage size, here 5%, = 57. 6m^3;
- To minimize seepage hard core mixed well with mortar can be recommended;
- The volume of materials of the pond will be minimum when its dimensions are equal both ways. Hence a stoarge pond of inner sides 31m x 31m with a depth of 1.25m is suitable for the purpose.

7.13.5. Pump Set and Accessories

General: The instrument set to be installed in the pump house is pump, suction pipe, silt excluders, delivery pipes, sluice valve, check valve, and fittings.

Suction Side: The end of suction pipe should have a trash and silt excluder to avoid pump damage. On the suction side, joints should be avoided to minimize loss. It is better to use steel pipe for the suction side.

Discharge Side: We use UPVC (PN 16) pipes on this side, for they do not rust easily. The PN number indicates normal pressure which hints at the pipes pressure resistivity. On the discharge side the pump flange is joined to a steel pipe by a suitable fitting. Next to this a sluice valve is installed to serve the purpose of total disconnection of the pump set and the discharge pipe line when needed. The detail of the pump set and accessories is found in the *Bill of Quantities and Cost Estimates (below)*.

Pumps energy source: in the area electricity is not easily accessible; the energy source for the pumps is diesel.

7.13.6. Pumps Daily Operation Schedule

The following table shows the schedule.

Table 7.4: Schedule of pumps operation

Operation and non-operation hour	Pump		Pumps operations (Hrs/Day)		
	Pump 1	Pump 2	Pump 1	Pump 2	Both pumps
Day 1					
6:00 am to 11:00am	✓	X	5	0	5
11:00 am to 5:00 pm	X	✓	0	6	6
5:00 pm to 10:00 pm	✓	X	5	0	5
Sub Total	2 times/day	1 time/ day	10 hrs/day	6hrs/day	16hrs/day
Day 2					
6:00 am to 11:00am	X	✓	0	5	5
11:00 am to 5:00 pm	✓	X	6	0	5
5:00 pm to 10:00 pm	X	✓	0	5	6
Sub Total	1 time/ day	2 times/day	5hrs/day	10 hrs/day	16hrs/day

Summary:

No	Item	Type	Size	Recommendation
1	2 alternate diesel pumps	Surface, centrifugal	Discharge = 80l/s; Water lifting power = 55kW = 74hp; Total head = 70m; Efficiency = 60%, Motor mechanical power = 91kW.	Durability required, spare parts be easily within reach,
2	Suction side pipe	Steel	10m, 300mm ID	
3	Discharge side pipe	UPVC	580m, 250mm ID	With 16PN

7.14. Design of Main Canal- Lined

The design of this canal is based on the continuity and Manning's equations. Bed width and velocity are assumed within allowable value, average field slope is taken as input, the capacity is input, and other values are calculated by the formulae. The values should be such that the velocity assumed should be equal to the calculated one. If the calculated velocity does not equal the assumed one, and the calculated bed slope is not practical, the process is repeated. The calculated slope should be equal to the average land slope. Great variation between design calculated canal bed slope and the average land slope will definitely result in either deeper cut depths, or in unnecessary fills.

It has been reasoned out that the main canal be lined.

Table 7.5:- Main canal design

(Manning's n = 0.013; Free board F = 0.25m; Duty = 1.28 l/s/Ha; Irrigation interval = 6 Days; Canal bed slope = 0.0012)

Gudayesso	Canal length (m)	Total Area it irrigates (Ha)	Discharge Q (m^3/s)	Daily Irrigable Area (Ha)	Daily Canals Capacity (m^3/s)	Assume Flow Velocity v (m/s)	Flow sectional area A (m^2)	Assume bed width b (m)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
MC-1	310	39.4	0.050	6.6	0.008	0.30	0.028	0.50
MC-1-1	580	12.2	0.016	2.0	0.003	0.21	0.012	0.40
MC-1-2	265	8.4	0.011	1.4	0.002	0.19	0.009	0.40

The next table follows…

Calculated flow depth d (m)	Total depth D (m)	Wetted Perimeter P_w (m)	Hydraulic Radius R (m)	Design drop height (m)	Number of drops required	Design canal bed slope	b/D
10	**11**	**12**	**13**	**14**	**15**	**16**	**17**
0.12	0.37	0.74	0.04	0	0	0.0012	1.36
0.08	0.33	0.56	0.02	0	0	0.0012	1.22
0.07	0.32	0.54	0.02	0	0	0.0012	1.26

Where A------------------------Canal flow cross section (m^2)

b-------------------------canal bed width (m)

d-------------------------canal flow depth (m)

P-------------------------wetted perimeter (m)

R-------------------------hydraulic radius (m)

n-------------------------Manning's roughness coefficient

$S_{cal/grd}$--------------------calculated and land slope respectively

v-------------------------assumed and/or calculated velocity

F-------------------------free board (m)

D-------------------------total depth (m)

7.15. Design of Unlined Canals

The shape of the canals for the soil type of the project area is nearly trapezoidal. The principle of design is that the cut depth should be economical one. This happens on ideal land. At this cut depth cut volume is equal to fill volume. The side slopes are 1:0.5 (1:z) V:H. Some parameters are assumed first and the others are calculated based on the continuity and Manning's formulae, and the steps are:

- Based on the nature of topography and soil type, the values of velocity, slope and Manning's n are assumed. The maximum permissible velocity is 0.75m/s.
- Hydraulic radius will be determined from the Manning's equation,
- Flow sectional area is then determined,
- As the land is precious to farmers, minimum practical canal cut width is required, and hence minimum cut perimeter will be determined. This happens at $b = 2d*((\sqrt{1+z^2})-z)$ where z is the cut side slope,
- Substituting the above expression in place of b, we can solve for d from R = A/P,
- The cut soil will be used for fill where the land allows, and the two balance each other, and the fill height is determined from equating cut section area and fill section area,
- The upper base of the fill is first assumed and the lower base is expressed in terms of it to be simultaneously solved with the one equation formed above from which the cut depth is determined and then fill height,
- In some cases where discharge is very low, e.g. 2 l/s, the cut sections dimensions calculated become very small, like 7cm, which is not practical. In these cases, some adjustments are made to make the dimensions practical.

The unlined canals in this project area secondary canals, tertiary canals, field ditches and drains. Tertiary channels run along contour and hence no expectation of bed scour. We have to see seriously secondary canals and introduce drop structures where necessary. The detail design dimensions of the canals are attached to the Document on separate file *Gudayesso SSIP Unlined Canals Sizes* with 26 columns.

7.16. Design of Drops and Stilling Basins

Secondary canals run across ground contours and hence the flow in them has high velocities which obviously cause scour. To avoid this, the energy should be dissipated.

Few drop structures are found on main canals, the majority on secondary canals in the project. The design procedure is as follows (sample done for secondary canal 1, SC1):

- Length of canal requiring fall = 596m;
- End elevation difference = 9.0m;
- Average ground slope = 0.015
- Design canal bed slope = 0.006
- Fall in the length = 0.006*596m = 3.58m
- Elevation requiring drop = 9.0m-3.58m = 5.42m
- Let single energy loss ΔH = 1.3m
- Required # drop structure = 5.42m /1.3m = 4

There are thirty division boxes in the project; the information of their locations is found in the design of unlined secondary canals in "Gudayesso SSIP Unlined Canals Design" file of the project.

7.17. Design of Water Division Structures

There are two types of the water division structures in this project:

i) Division boxes

These structures are found on main canals at their junctions with secondary canals to divide flows among them. The water coming in the main canal enters the structure and is divided among the secondary canal, and two opposite tertiary canals. There are four gates required. The design principle is based on the fact that outflow from the box should have the required elevation upon entering the off-taking channel. The height of the wall is limited by the total depth of the entering canal. There are nine division boxes in the project.

The width of the openings of the structures depends on the bed size of the out-going canals.

ii) Turnouts

These are found on secondary canals to divide the water between tertiary canals. They are located according to their spacing. In this project there are 33 turnouts.

For the details see the drawings in annexes.

These structures are found on main canals and secondary canals to divide flows among branching canals. The design principle is based on the fact that outflow from the box should have the required elevation upon entering the off-taking channel. The height of the wall is limited by the total depth of the entering canal. There are twelve division boxes in the project.

The detail design calculation in the division boxes targets to determine the width of the openings for the outgoing canals. The detail calculations result in the dimension differences of 3cm-10cm depending on the canals capacity differences. Hence I have not shown the calculations. But it suffices to take typical size division box for the project and to quantify it.

7.18. Design of Road Crossings, Over-canal Cattle and Foot Passages

These facilitate the access to each and every corner to the command area. The expected yields from the irrigation may be taken to the market. Vehicles are expected to enter the command, but domestic animals are common to walk in our country's agricultural fields. Besides, the farmers should easily walk through the command area.

The design of the structures is based on the criteria that the structure should convey the canals flow and at the same time it should carry the load over it. Hence the conveying structure is a rectangular barrel over which RCC slabs are to be put over thick side masonry walls to carry the traffic load.

The three mentioned structures differ in their slab thickness, in their span, and the sizes and spacings of the reinforcing bars in the slabs. For the details see the drawings in annexes.

7.19. Design of Runoff Passages

Based on the topography of the command area across which the canals traverse, there happens the floods coming from higher lands to cross the canals. There are two possible ways to allow the floods pass:-

i) Culverts:- Where there are small, medium or large natural water channels which come across the canals route, culverts are introduced to safely handle the flood. The structure's opening is large enough to allow the flood size to pass, and its bed should be hard to resist erosion. In the project, there are up to three such locations which require these structures.

ii) Over-canal Passages:- Where flood comes/or made cross over the canals, super passages are designed to handle them. These are almost similar in span and size to foot brides designed under the previous section. There are about three locations in this project that require these structures.

For the details see the drawings in annexes.

7.20. Bill of Quantities and Cost Estimates

In the table below care has been taken to the utmost not to ignore important item in the list.

Table 7.7 List of activities in the project cost estimation

No	Types of Work	Unit	Qtty.	Unit Cost (Birr)	Total Cost (Birr)	Community Share
1	Mobilization & Demobilization (fifty-fifty in weight)	LS	1	40,000.00	40,000	
2	Access Road Clearance into and within the project area	km	3	3,000.00	Community	9,000
3	Camp Construction				0	
	Living Rooms 2 (4m x 4m)				0	
	Office 1 (4m x 4m)				0	
	Store 1 (5m x 5m)				0	
	Kitchen (3m x 3m)				0	
	Toilet (2m x2m)				0	
	Guard House (2m x 2m)				0	
	Fence (50m x 50m)				0	
3.1	Site clearance	m^2	96	6.00	576	
3.2	Excavations on soft formations	m^3	45	55.00	2475	
3.3	Cart away surplus excavations	m^3	13	40.00	520	

3.4	Masonry (1:3 mortar)	m^3	32	1,050.00	33600	
3.5	Hard coring with hard rock	m^3	26	480.00	12480	
3.6	Concrete (1:3:4)	m^3	10	1,700.00	17000	
3.7	Plastering (1:2 mortar, 3cm thick in two rounds)	m^2	50	130.00	6500	
3.8	CIS walling (G-32)	m^2	290	135.00	39150	
3.9	CIS roofing (G-32)	m^2	160	140.00	22400	
3.10	Fencing with 10cm diameter termite resistent poles of 3m tall at 1m spacing with barbed wires of 6-lines	m	160	8.00	1280	
3.11	Back filling and compactions	m^3	12	46.00	552	
	Sub Total A				**176,533.00**	**9,000**
4	Suitable temporary water diversion channel excavation, dewatering any water during all construction activities and compacted refilling the diversion channel after construction (Their Weights: 0.4, 0.15, 0.45, respectively)	LS	1	35,000.00	35,000.00	
	Sub Total B				**35,000.00**	
5	Water Diversion Structure and Retaining wall Construction				0	
5.1	Excavations on soft formations	m^3	50	50.00	2,500.00	
5.2	Excavations on soft rock formations	m^3	40	140.00	5,600.00	
5.3	Excavation on hard rock formation	m^3	80	200.00	16,000.00	
5.4	Hard coring (20cm) with very hard rock	m^3	20	480.00	9,600.00	
5.5	Masonry (1:2 mortar) for the retaining walls, and weir body	m^3	56	1,150.00	64,400.00	
5.6	Concrete (1:2:4) for the floor bed, sandwich and cutoffs	m^3	37	2,000.00	74,000.00	

5.7	Supply and properly fix reinforcing bars with stirrups (10mm diameter, single layer and at 25cm spacings) extending under the retaining walls and into the cutoffs	Kg	502	40.00	20,080.00	
5.8	Plastering two rounds the inner faces and wall top (1:2 mortar, 3cm thick)	m^2	130	130.00	16,900.00	
5.9	Pointing the outer wall faces (1:2 mortar)	m^2	52	85.00	4,420.00	
5.10	Intake gate (3mm thick, 60cm X 70cm, and supported by 10mm bars, with 1.80m high frame of 5mm thickness and 40mm spindle) supply and proper installation	Pcs	1	15,000.00	15,000.00	
5.11	Silt sluice gate (3mm thick, 1.00m X 1.20m, and supported by 10mm bars, with 2.30m high frame of 5mm thickness and 40mm spindle) supply and proper installation	Pcs	1	17,000.00	17,000.00	
5.12	Construction of two (each 2.30m high) rectangular (50cm x 60cm) silt sluice pier columns and operation platform (2m x 0.60m x 0.25m) with concrete (1:2:3) reinforced by 10 vertical lines of 12mm bars, 8mm rounding bars at 25cm in the columns; and 10mm crossing bars at 25cm spacings in a single layer in the platform	LS	1	6,000.00	6,000.00	
5.13	Concrete (1:2:3) columns at intake (30cm x 30cm) 2.30m high for the gate frame embedment	m^3	1	2,200.00	2,200.00	
5.14	Reinforcing bars for the columns at intake (the vertical bars of 10mm at corners, and the rounding bars of 8mm at 20cm spacing)	Kg	22	40.00	880.00	
5.15	Compacted back filling	m^3	35	46.00	1,610.00	
	Sub Total C				**256,190.00**	
6	Approach Channel Construction				0	
6.1	Excavations on soft formations	m^3	22	50.00	1,100.00	
6.2	Excavations on soft rock	m^3	10			

	formations			140.00	1,400.00	
6.3	Excavations on hard rock formations	m³	45	200.00	9,000.00	
6.4	Hard coring with hard rock	m³	3	480.00	1,440.00	
6.5	Concrete (1:2:4) for the bed extending under the walls and for buttress at entry	m³	4	2,000.00	8,000.00	
6.6	Reinforced concrete slabs (1:2:4) of 10cm thickness and 1m x 1.5m size with single layer 8mm crossing bars (with stirrups) at 20cm in each directions	Pcs	8	2,000.00	16,000.00	
6.7	Masonry (1:2 mortar)	m³	5	1,150.00	5,750.00	
6.8	Reinforcement bar for the channel bed (10mm dia, single layer, at 20cm spacings) with stirrups	Kg	88	40.00	3,520.00	
6.9	Plastering (1:2 mortar, 3cm thick at two rounds)	m²	20	130.00	2,600.00	
6.10	Compacted back filling	m³	43	46.00	1,978.00	
	Sub Total D				**50,788.00**	
7	Suction Pool Construction					
7.1	Excavations on soft formations	m³	60	50.00	3,000.00	
7.2	Excavation on hard rock formation	m³	75	140.00	10,500.00	
7.3	20cm selected material fill	m³	4	110.00	440.00	
7.4	20cm thick hard core with hard rock	m³	4	480.00	1,920.00	
7.5	20cm concrete for pool bed and under the walls (1:2:4)	m³	3	2,000.00	6,000.00	
7.6	Masonry (1:2 mortar)	m³	30	1,150.00	34,500.00	
7.7	Supply and proper fixation of reinforcing bars for pool bed (diameter = 10mm; single layer at 25cm spacings with stirrups)	Kg	58	40.00	2,320.00	
7.8	Plastering (1:2 mortar, 3cm thick at 2 rounds)	m²	70	130.00	9,100.00	

7.9	Supply and proper installation of 5mm thick steel plate (3.3m X 3.3m) cover supported by networked steel bars of 14mm dia at 50cm distances	Ls	1	3,000.00	3,000.00	
7.10	Compacted back filling	m^3	36	46.00	1,656.00	
7.11	Compacted enbakment (of 1m) formation with existing soil	m^3	65	45.00	2,925.00	
	Sub Total E				**75,361.00**	
8	Suction Side Pump Accessories of appropriate size supply and installation				0	
8.1	300mm inner diameter steel suction pipe	Pcs	2	3,400.00	6,800.00	
8.2	Foot valve with strainer	Pcs	1	1,500.00	1,500.00	
8.3	Elbows	Pcs	3	800.00	2,400.00	
8.4	Tee	Pcs	1	900.00	900.00	
8.5	Dismantling unit	Pcs	2	1,200.00	2,400.00	
8.6	Reducers	Pcs	2	1,000.00	2,000.00	
8.7	Flat gaskets for all joints	LS	1	800.00	800.00	
	Sub Total F				**16,800.00**	
9	Pump House and Guard House Construction (6m x 4m; 2m x 2m)					
9.1	Site clearance	m^2	34	6.00	204.00	
9.2	Excavations on soft formations	m^3	60	50.00	3,000.00	
9.3	Excavation on soft rock formation	m^3	15	140.00	2,100.00	
9.4	Cart away surplus excavations	m^3	30	40.00	1,200.00	
9.5	Masonry for foundation and part of wall (1:3 mortar)	m^3	13	1,150.00	14,950.00	
9.6	25cm thick hard core with hard rock	m^3	10	480.00	4,800.00	
9.7	30cm thick reinforced concrete	m^3	12			

	(1:2:4)			2,000.00	24,000.00	
9.8	10cm selected material fill under hard core	m^3	5	110.00	550.00	
9.10	Reiforcement bars for the house foor bed (10mm dia., stirrups, double layer at 20cm c/c distances)	Kg	330	40.00	13,200.00	
9.11	3cm thick plastering over wall surfaces with 1:2 mortar over two rounds	m^2	44	130.00	5,720.00	
9.12	CIS (G-32) (with appropriate horizontal and vertical poles) for walling, roofing and guard house	m^2	200	150.00	30,000.00	
9.13	Fencing with termite resistent poles of 10cm diameter with distances in between 1m, 2.5m height and barbed wire of 6-lines	m	80	12.00	960.00	
9.14	Mesh wire (with thick wire network) for ventilation embedded in the wall body (above 3m height)	m^2	10	45.00	450.00	
9.15	Supply and fix 3mm-thick steel plate with appropriate frames for 2 windows (1mX1m)	Pcs	2	750.00	1,500.00	
9.16	Supply and fix 5mm-thick steel plate gate with appropriate frames for the door (2.5mX2m wide)	Pcs	1	2,000.00	2,000.00	
9.17	150mm ID PVC pipes installation for drainage around the house and nearby	m	24	170.00	4,080.00	
9.18	Compacted embankment formation	m^3	30	46.00	1,380.00	
9.19	Back filling and compactions	m^3	16	46.00	736.00	
	Sub Total G				**110,830.00**	
10	Diesel Centrifugal Pumps (Japan or Italy-made) (Discharge = 80 l/s; Total Head = 70m; Water Raising Power 55kW = 75hp; Motor Mechanical Power = 92kW; Minimum NPSH 2.40m) supply and proper installation	Set	2	1,060,000.00	2,120,000.00	
	Sub Total H				**2,120,000.00**	

11	**Discharge Side Pump Accessories of appropriate size Supply, Installation and Activities**				0	
11.1	Excavations on soft formations	m³	140	50.00	7,000.00	7,000
11.2	Excavation on soft rock formation	m³	5	140.00	700.00	
11.3	20cm thick concrete (1:3:4) over 20 masonry anchor blocks	m³	4	1,700.00	6,800.00	
11.4	20 masonry (1:3) anchor blocks	m³	8	1,050.00	8,400.00	
11.5	Discharge UPVC pipe of ID 250mm and 16PN	m	585	120.00	70,200.00	
11.6	Elbows	Pcs	6	750.00	4,500.00	
11.7	Water meter	Pcs	1	4,100.00	4,100.00	
11.8	Gate valves	Pcs	2	2,050.00	4,100.00	
11.9	Check valves	Pcs	3	2,700.00	8,100.00	
11.10	Gaskets for all joints	LS	1	3,000.00	3,000.00	
11.11	Flanged GIS pipe (1m)	Pcs	1	1,600.00	1,600.00	
11.12	Dismantling unit	Pcs	2	1,300.00	2,600.00	
11.13	Tee	Pcs	1	900.00	900.00	
11.14	Reducer	Pcs	1	1,500.00	1,500.00	
11.15	UPVC adapter	Pcs	1	1,600.00	1,600.00	
11.16	Rubber seals for all pipes	LS	1	1,000.00	1,000.00	
11.17	Refilling line set (Of 1/2 inch GIS pipe with 2 gate valves, 2 unions, 2 elbows and other accessories)	LS	1	2,000.00	2,000.00	
11.18	Fill and compaction	m³	117	46.00	5,382.00	
	Sub Total I				**133,482.00**	**86,930**
12	**Storage Pond (31mX31m; Construction depth 1.5m)**				0	

12.1	Pond excavations of 1,500m³ irrespective of the type of material	LS	1	35,000.00	35,000.00	
12.2	Hard coring (20cm) with hard rock	m³	198	480.00	95,040.00	
12.3	Concrete (1:3:4) for bed extending under the walls and 0.3m x 0.30m outlet piers of 1.25m	m³	99	1,700.00	168,300.00	
12.4	Masonry (1:3 mortar) for wall	m³	63	1,150.00	72,450.00	
12.5	Pointing the outer faces 1m from top (1:3 mortar)	m²	126	85.00	10,710.00	
12.6	Plastering the inner and top faces (1:2 mortar, 3cm thick)	m²	205	130.00	26,650.00	
12.7	3mm-thick outlet steel gate (of 0.60m X 0.60m, 1.25m high frame of 5mm thickness, with 40mm spindle rod) supply and proper installation	Pcs	1	11,000.00	11,000.00	
12.8	8mm diameter reinforcing bars for the outlet piers (The vertical ones on the corners, the rounding ones at 30cm spacing)	Kg	15	40.00	600.00	
12.9	Compacted filling	m³	31	46.00	1,426.00	
12.10	Safety bank formation round the whole pond to a height of 0.30m above wall top by compaction with top width 2.5m and bottom width 3m	Ls	1	10,000.00	10,000.00	
12.11	Fencing with 1.5m tall, 15cm dia. thick termite resistent poles with 4-lines of barbed wires	LS	1	6,000.00	6,000.00	
12.12	Cart away surplus excavations irrespective of the volume	Ls	1	2,000.00	2,000.00	
	Sub Total J				**439,176.00**	
13	Main Canals (MC-1, MC-1-1, MC-1-2) Construction					
13.1	Excavations on soft formations	m³	1900	50.00	95,000.00	
13.2	Excavations on soft rock formations	m³	60	140.00	8,400.00	
13.3	Excavations on hard rock formations	m³	15	200.00	3,000.00	
13.4	Hard coring with hard rock (20cm)	m³	244	480.00	117,120.00	

13.5	Concrete (1:3:4) for canal bed and under the walls (10cm thick)	m^3	122	1,700.00	207,400.00	
13.6	Masonry (1:3 mortar) with hard rock	m^3	302	1,050.00	317,100.00	
13.7	Plastering (1:2 mortar, 3cm thick at two rounds) the inner and top of the walls	m^2	1680	130.00	218,400.00	
13.8	Compacted back filling	m^3	580	46.00	26,680.00	
	Sub Total K				**993,100.00**	
14	Water Division Structures Construction (Type I, 5 in No)					
14.1	Excavations for the structure	m^3	86.6	50.00	4,330.00	
14.2	Hard coring with hard rock (20cm)	m^3	13.0	480.00	6,240.00	
14.3	Concrete (1:3:4) for canal bed and under the walls	m^3	6.5	1,700.00	11,050.00	
14.4	Masonry (1:3 mortar) with hard rock	m^3	17.4	1,050.00	18,270.00	
14.5	Plastering (1:2 mortar, 3cm thick at two rounds) the inner and topof the walls	m^2	61.6	130.00	8,011.25	
14.6	Gates (sliding in frames, 3mm thick, 45cm x 45cm) supply and installation	Pcs	20.0	2,500.00	50,000.00	
14.7	Compacted back filling	m^3	19.6	46.00	900.45	
	Sub Total L				**98,801.70**	
15	Water Division Structures Construction (Type II, 5 in No)					
15.1	Excavations for the structure	m^3	69.3	28.00	1,939.84	
15.2	Hard coring with hard rock (20cm)	m^3	10.4	480.00	4,992.00	
15.3	Concrete (1:3:4) for canal bed and under the walls	m^3	5.2	1,700.00	8,840.00	
15.4	Masonry (1:3 mortar) with hard rock	m^3	13.9	1,050.00	14,616.00	
15.5	Plastering (1:2 mortar, 3cm thick at two rounds) the inner and topof the walls	m^2	49.3	130.00	6,409.00	

15.6	Gates (sliding in frames, 3mm thick, 45cm x 45cm) supply and installation	Pcs	28.0	2,500.00	70,000.00	
15.7	Compacted back filling	m^3	15.7	46.00	720.36	
	Sub Total M				**107,517.20**	
16	Road Crossing Structures Construction (6m in span, 2 in No)					
16.1	Excavations for the structure	m^3	28.6	50.00	1,428.00	
16.2	Hard coring with hard rock (20cm)	m^3	3.4	480.00	1,612.80	
16.3	Concrete (1:3:4) for bed and under the walls	m^3	2.5	1,700.00	4,284.00	
16.4	Masonry (1:3 mortar) for the walls with hard rock	m^3	9.7	1,050.00	10,143.00	
16.5	Plastering (1:2 mortar, 3cm thick at two rounds) the inner faces of the walls	m^2	44.8	130.00	5,824.00	
16.6	Reinforced concrete slab (1:2:4) (1.2m x 7m, 16cm thick, 10mm bars with 0.25m spaings in both directions in double layers)	Pcs	2.0	4,000.00	8,000.00	
16.7	Compacted back filling	m^3	7.7	46.00	354.20	
	Sub Total N				**31,646.00**	
17	Cattle Crossing Structures Construction (4m in span, 6 in No)				0	
17.1	Excavations for the structure	m^3	49.0	50.00	2,448.00	
17.2	Hard coring with hard rock (20cm)	m^3	5.8	480.00	2,764.80	
17.3	Concrete (1:3:4) for bed and under the side walls	m^3	4.3	1,700.00	7,344.00	
17.4	Masonry (1:3 mortar) for the walls with hard rock	m^3	16.6	1,050.00	17,388.00	
17.5	Plastering (1:2 mortar, 3cm thick at two rounds) the inner faces of the walls	m^2	76.8	130.00	9,984.00	
17.6	Reinforced concrete slab (1:2:4) (1.2m x 4m, 12cm thick, 8mm bars with 0.25m spaings in both directions in a single layer)	Pcs	6.0	3,000.00	18,000.00	

17.7	Compacted back filling	m³	13.2	46.00	607.20	
	Sub Total O				**58,536.00**	
18	Foot/Flood Passage Structures Construction (2.6m in span, 4 in No)					
18.1	Excavations for the structure	m³	21.2	50.00	1,060.80	
18.2	Hard coring with hard rock (20cm)	m³	2.5	480.00	1,198.08	
18.3	Concrete (1:3:4) for bed and under the side walls	m³	1.9	1,700.00	3,182.40	
18.4	Masonry (1:3 mortar) for the walls with hard rock	m³	7.2	1,050.00	7,534.80	
18.5	Plastering (1:2 mortar, 3cm thick at two rounds) the inner faces of the walls	m²	33.3	130.00	4,326.40	
18.6	Reinforced concrete slab (1:2:4) (1.2m x 4m, 10cm thick, 8mm bars with 0.25m spaings in both directions in a single layer)	Pcs	4.0	2,500.00	10,000.00	
18.7	Compacted back filling	m³	5.7	46.00	263.12	
	Sub Total P				**27,565.60**	
19	Drop Structures Construction (1.30m fall, 37 in No)				0	
19.1	Excavations for the structure	m³	613.3	50.00	30,663.75	
19.2	Hard coring with hard rock (20cm)	m³	63.3	480.00	30,369.60	
19.3	Concrete (1:3:4) for entry, pool and exit bed (15cm thick)	m³	47.5	1,700.00	80,669.25	
19.4	Masonry (1:3 mortar) for the walls with hard rock	m³	165.6	1,050.00	173,892.60	
19.5	Plastering (1:2 mortar, 3cm thick at two rounds) the inner and top faces of the walls	m²	582.8	130.00	75,757.50	
19.6	Reinforcing bar for the pool, the concrete and bar layer extending under the walls (2.2m x 2.3m, 10mm bars with 0.25m spaings in both directions in a single layer)	Kg	1026.8	40.00	41,073.94	
19.7	Compacted back filling	m³	95.2	46.00	4,378.40	

	Sub Total Q				**436,805.03**	
20	Turnouts (Stand-alone) Construction (24 in No)					
20.1	Excavations for the structure	m³	257.3	50.00	12,864.00	
20.2	Hard coring with hard rock (20cm)	m³	34.1	480.00	16,358.40	
20.3	Concrete (1:3:4) for bed and under the walls (10cm thick)	m³	17.0	1,700.00	28,968.00	
20.4	Masonry (1:3 mortar) with hard rock	m³	40.6	1,050.00	42,638.40	
20.5	Plastering (1:2 mortar, 3cm thick at two rounds) the inner and top of the walls	m²	253.0	130.00	32,884.80	
20.6	Gates (sliding in frames, 3mm thick, 40cm x 40cm) supply and installation	Pcs	72.0	1,100.00	79,200.00	
20.7	Compacted back filling	m³	41.4	46.00	1,904.40	
	Sub Total R				**214,818.00**	
21	Culvert Construction (4 in No)					
21.1	Excavations for the structure	m³	22.8	50.00	1,140.00	
21.2	Hard coring with hard rock (20cm)	m³	1.3	480.00	614.40	
21.3	Concrete (1:2:4) for culvert roof, floor and under walls (15cm thick)	m³	1.2	2,000.00	2,400.00	
21.4	Masonry (1:3 mortar) for the walls with hard rock	m³	4.4	1,050.00	4,636.80	
21.5	Plastering (1:2 mortar, 3cm thick at two rounds) the inner and top faces of the walls	m²	19.2	130.00	2,496.00	
21.6	Reinforcing bar for the culvert roof and floor (10mm bars with 0.25m spaings in both directions in a single layer in each slab)	Kg	90.1	40.00	3,603.28	
21.7	Compacted back filling	m³	12.0	46.00	552.00	
	Sub Total S				**15,442.48**	
22	Secondary Canals Excavation (Length = 2,157m; 9 in number)					

22.1	Excavations of the canal with bank sides slopy (1V:0.5H)	m^3	750	50.00	37,500.00	
22.2	Bank formations by very hard compaction	m^3	500	46.00	23,000.00	
	Sub Total T				**60,500.00**	
23	Excavation of drains (Length = 1500m; 6 in number)					
23.1	Excavations of the canal with bank sides slopy (1V:0.5H)	m^3	565	50.00	Community	28,250.00
23.2	Bank formations by very hard compaction	m^3	400	46.00	Community	18,400.00
	Sub Total U				Community	46,650.00
24	Excavation of runoff diversion channel (Length = 1300m)				0	
24.1	Excavations of the canal with bank sides slopy (1V:0.5H)	m^3	490	50.00	Community	24,500.00
24.2	Bank formations by very hard compaction	m^3	330	46.00	Community	15,180.00
	Sub Total V				Community	39,680.00
25	Excavation of tertiary canals (9240m; 66 in No)					
25.1	Excavations of the canals	m^3	1150	50.00	Community	57,500.00
25.2	Bank formations by very hard compaction	m^3	700	46.00	Community	32,200.00
	Sub Total W				Community	89,700.00
	Fund Required				**5,458,892.01**	**93.90**
	Community				**185,030**	**3.18**
	Supervision Cost				**169,318**	
	Grand Total				**5,813,239.67**	
	Capital/Hectar				**96,887.33**	

7.21. Conclusions and Recommendations

The need for market oriented crop production will find its way through irrigation where there is a potential for agriculture. This project area is one of such sites.

The topography of the command area is suitable for irrigation. Gravity diversion is not possible in this project area. Hence pump irrigation is the selected resort. Water should be pumped to an upland from which it is conveyed to field through distribution system. The size of the pump depends on the total head loss which has been calculated seriously. To save the precious pumped water and discharge it to the field, the major canals needs to be lined.

Water abstraction structure, pump type, size and its accessories, and the distribution system have been designed with caution.

Secondary, tertiary and field ditches are earthen, as are drains and flood diversion channel. In designing them economical cut depth has been determined. This saves the farmers precious land. On the average no extra cut is to be carted away, all what has been cut is used for fill purpose.

Water division structures, road crossings, crossing structures for cattle and human foot, drop structures, flood passage structures and other structures have been considered and designed where necessary.

In sum, the designed structures are expected to be easy for construction and manageable by farmers. Sophisticated designs have been tried to be avoided. All what have been designed are listed and quantified based on their designs to be, as much as possible, accurate. Hence the project, I hope, is feasible in these respects.