The Federal Democratic Republic of Ethiopia Regional State of Tigray Bureau of Water Resources

Ruba Chemiet Pump Irrigation Project (Tigray, Central Zone, Were Leke Wereda)

Final Report Hydrology Study

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List of Acronyms and Abbreviations

Arc map GIS	Arc map geographical information system
Amsl.	Above Main Sea Level
CN	Curve Number
DEM	Digital Elevation Model
UTM	Universal Transverses Marcater
Km	Kilometer
Km^2	Kilometer Square
m	Meter
min	Minutes
mm/hr	milimeter per hour
m/s	Meter per second
M^3/s	Meter cubic per second
mm	Milimeter
ha	hectar
HSG	Hydrological Soil Group
P	Design Rainfall (mm)
Q	Discharge in (m^3/s)
MPF	maximum probable flood
ITCZ	Inter-Tropical Convergence Zone
RP	Return Period in Year
SCS	Soil Conservation Service
T_C	Time of concentration
TWWSDSE	Tigray Water Works Study Design and Supervision Enterprise.
TWRB	Tigray Water Resource Bureau

Executive summery

The hydrological engineering planning, design, and management problems require a detailed knowledge of flood event characteristics, such as flood peak, volume of water and duration. Flood frequency analysis often focuses on flood peak values, and hence, provides a limited assessment of flood events. This report analyses are a 50 year return period time series of daily precipitation in a region of the Tigray, werie leke wereda Ruba-chemiet pump irrigation project in order to predict extreme peak flood risk estimation. A comparison of observed and estimated maximum peak flood (50 year return period) showed that the Log Pearson Type III distribution is the best fit combined with partial duration series gives better results fitted to daily maximum rainfall as compare to the other distributions. The partial duration series approach was successfully applied in the study of extreme hydro-climatic variable values.

1. Introduction
1.1 General
The interaction of the flood waves and hydraulic structures, such as pump station, levees, weirs, bridges and culverts are very sensitive so that, it needs the hydrological detail knowledge. Hydrological engineering planning, design, and management problems require a detailed knowledge of flood event characteristics, such as flood peak, volume and duration.

Engineering hydrology is often defined as the science that focuses on the physical properties, occurrence, and movement of water in the atmosphere, on the surface of, and in the outer crust of the earth. This is an inclusive and somewhat controversial definition as there are individual bodies of science dedicated to the study of various elements contained within this definition. Meteorology, oceanography, and geo-hydrology, among others, are typical. For the irrigation designer, the primary focus of hydrology is the water that moves on the earth's surface and in particular that part that ultimately crosses (i.e., Pump station).

By application of the principles and methods of modern hydrology, it is possible to obtain solutions that are functionally acceptable and form the basis for the design of location of pump station at the at the river bank structures. First, however, it is desirable to discuss some of the basic hydrologic concepts that will be utilized throughout the project and to discuss hydrologic analysis as it relates to the channel crossing stream problem.

1.2 Location of the Project
Geographical location of Ruba- Chemiet project site is situated at 526737 E and 1548921N at elevation of 1716.00m m.a.s.l. The command area of these irrigation schemes is situated along the main road running from Edagarbi to nebelet to the right and Right side of Ruba- Chemiet. the Ruba-Chemiet project location is proposed in the following figure bellow: -

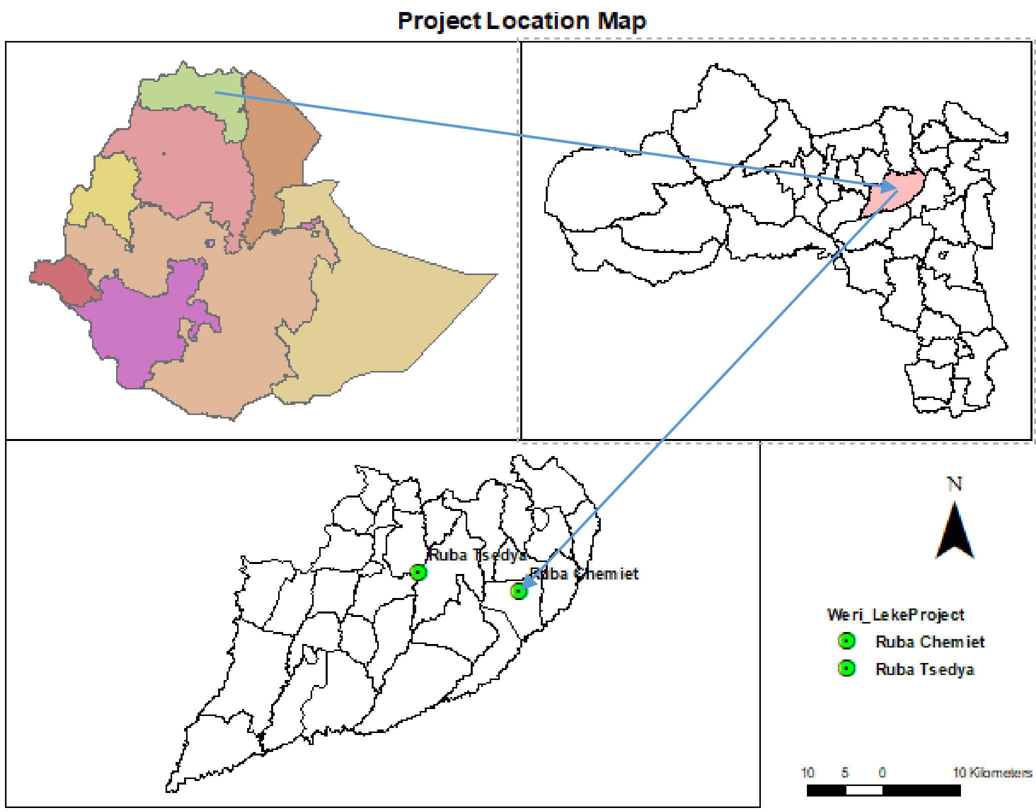

Figure 1:Location map of the project

1.3 Methodology of the study

- Review of the literatures of previous works of the around the project area;
- Collect relevant secondary data from all sources and assess previous studies conducted in the study area;
- Analyze data gaps;
- Collect primary data from field and respective offices on land use, soil type, and relevant hydro meteorological data.
- Data organizing, pre-processing, producing relevant maps (i.e. DEM, drainage system, catchment and sub-basin area delineation from DEM data and from relevant maps) using Arc View GIS 10.2.1;
- storm water management and design aid (SMADA) software method was used to select the design storm or design flood using the Gumbel EVI distributions;

- Understand from the previous works and present interpreted data,
- Rational Method for small catchments if they do not exceed 12.8 km2 (or 5 square mile) at the most (Gray, 1971)
- Soil Conservation Services (SCS) unit hydrograph method for catchments area greater than 12.8km2.

2. Data collection and analysis

2.1 General

Above 13 years' maximum daily rainfall & temperature data collected from NMA, which include daily maximum rainfall data of Edaga Arbi station. In addition, topographic maps, soil data and land use/ cover maps also acquired and analyzed for the study.

The collected data for the study are listed as follow:

- Digital Elevation Model (DEM) of the project area (30m by 30m resolution)
- Land use/cover map of the project area
- Rainfall and temperature data of the Edaga Arbi Rainfall Station from the NMA (attached as appendix)
- Data collected on river morphology around the pump station river bank.

2.2 Watershed Area and Catchments Parameters

Catchments area, stream length and stream slope are determined from topographic map scale 1: 10,000 and DEM. Using the map of the sub catchments of each crossing points is identified. The watershed divide is delineated and streamlines are drawn using the DEM grid as background on global map.

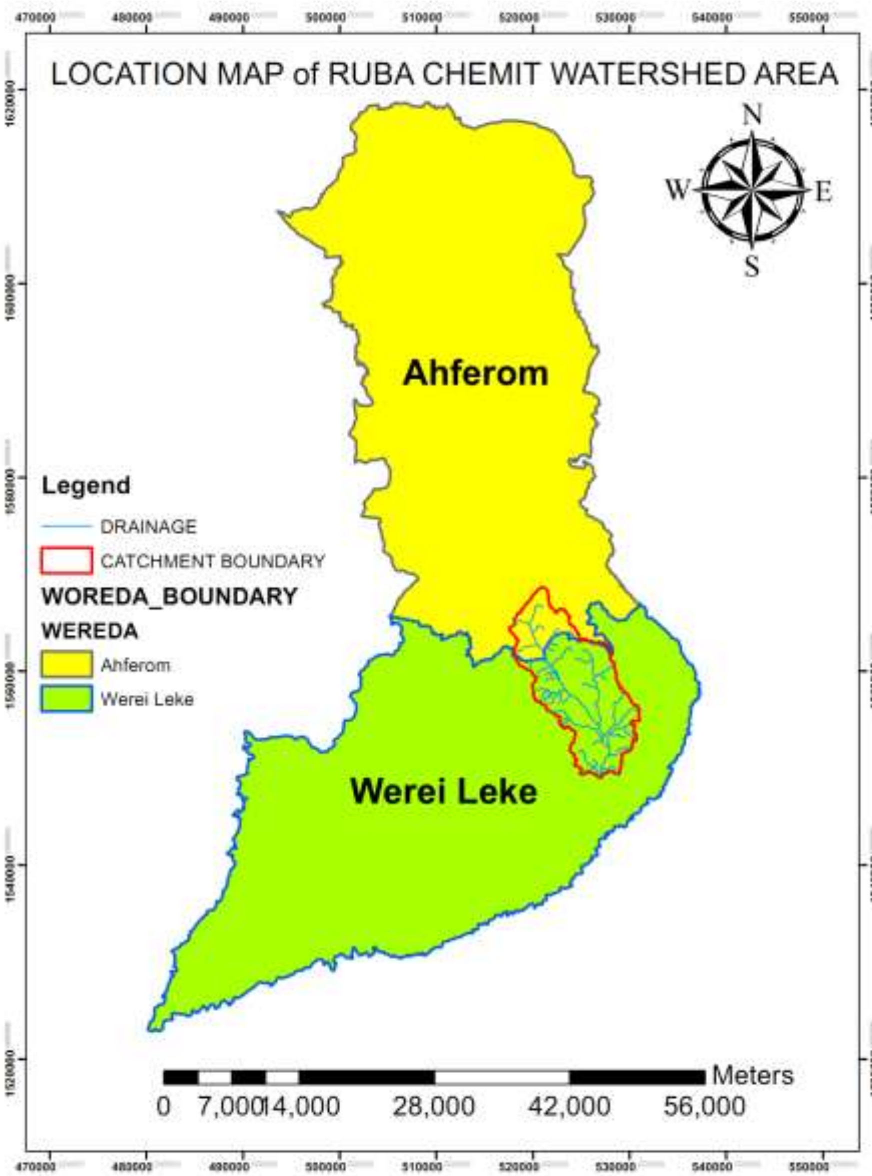

Figure 2: Location Base Map of the Watershed Area

2.3 Data from Field Investigation

The following information is collected from the site visit and interviews with the residents

- Geomorphologic characteristics of the river at the crossing points
- High Water Mark Observed at the
- Land uses/cover of the catchments area
- Soil type of the catchments area
- Upstream and downstream development

2.4 Climate

Climatic conditions in Ethiopia are largely governed by altitudinal variations that are controlling rainfall distributions to some degree and the temperature variation to a very large extent. Based on Mean Seasonal Precipitation and Mean Seasonal Temperature variations, three operational seasonal periods are commonly known in Ethiopia. These are named as "**Bega"**, "**Belg"** and "**kiremt"** and are occurring in months of October - January, February - May and June - September, respectively. The long rainy season in the summer from May to September known locally as Kiremt, is primarily controlled by the seasonal migration of the inter-tropical convergence zone (ITCZ), which lies to the north of Ethiopia at that time.

According to the National Atlas of Ethiopia (1981), and Ethiopian climatic zone (Daniel G, 1977) respectively the climatic condition of the country is classified into the following zones:

- "Kur"; 3300m a.s.l. and above (annual mean temp. of <10 ^{o}C.)
- "Dega"; 2300 – 3300 meters m.a.s.l. (annual mean temp. of 10 to 15 ^{o}C.)
- "Weina Dega"; 1500 – 2300 meters m.a.s.l. (annual mean temp. of 15 to 20 ^{o}C.)
- "Kola", 500 – 1500m a.s.l. (annual mean temp of about 30 ^{o}C)
- "Berha", below 500-m. a.s.l. (with annual mean temperature of 30-40C.)

Table 1:Ethiopian climatic Zones (Daniel G, 1977)

Altitude(masl)	Annual mean temp (^{0}c)	PE(cm)	Class name (traditional)
>3000	13-16	80	Alpine(wirch)
2300-3000	16-20	80-110	Template (dega)
1500-2300	20-24	110-125	Sub-tropical (Weina dega)
800-1500	24-28	125-160	Tropical (Cola)
<800	>28	>160	Desert(Bereha)

From the above classification the project area falls within "Weina Dega"; climatic zones because the altitude of the Ruba-Chemiet lies between 1718.953 and 1773.00 meters m.a.s.l.

2.5 Rainfall Regimes

The NMA is prepared a useful standard description of the rainfall regimes. Based on this description the rainfall regimes of the country divided into four rainfall regimes types. **Mono-modal:** is characterized by a single peak rainfall pattern. The length of this single rainfall is varying 3-8 months. In general, the duration of the wet period is decease from south to north in this rainfall region. Based on the duration of the wet period, this rainfall regime is further classified into three sub-divisions.

Bi-modal Type I: is characterized by a quasi-double peak rainfall pattern with a small peak in April and Maximum peak in August. This region is therefore characterized as a semi-bi-modal rainfall pattern.

Bi-modal Type II: The area in this rainfall region dominated characterized by a double peak rainfall pattern with similar peaks during April and October. Generally, the annual rainfall decrease from west to east in this rainfall region.

Diffused pattern: the region is characterized by an irregular rainfall pattern. Though erratic rainfall occurs through the period from August/September to January / February, the pattern is diffused and not well defined.

With this general description of the rainfall regimes of the country, Ruba-Chemiet project area is grouped in the rainfall regime of mono-modal. Therefore, it has one distinctive rainfall season that gives a peak rainfall at July.

2.6 Hydrological Soil Type of the Watershed Area

The soil types of the catchments area are determined from site visit as well as soil map from GIs data. Soil type of the drainage areas have different rate of infiltration. Based on infiltration rates, the soil conservation service (SCS) has divided soil into four hydrologic soil groups as follows: -

Group A: Sand, loamy sand or sandy loam and soils having a low runoff potential due to high infiltration rates. These soils primarily consist of deep, well-drained sands and gravels.

Group B: Silt loam, or loam and soils having a moderately low runoff potential due to moderate infiltration rates. These soils primarily consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C: Sandy clay loam and soils having a moderately high runoff potential due to slow infiltration rates. These soils primarily consist of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.

Group D: Clay loam, silty clay loam, sandy clay, silty clay or clay. Soils having a high runoff potential due to very slow infiltration rates, these soils primarily consist of clays with high swelling potential, soils with permanently-high water tables, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

2.7 Vegetation and Land Use

The land use data of the Ruba-Chemiet project areas which is the location of the pump station near the river bank were collected from site visit and GIs data. In addition to the land use acquired from the site map, the data acquired from the map is verified by the site visit. In general, the vegetation is fairly to moderate (forest area) in the basins.

3. Design Flood Estimation for Stream location of pump station

The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to locate the pump station. Errors in the estimates will result in a location of the pump station putting the structure that is either very near to the river of the flood mark or away the river flood mark and causes flooded pump station or have long section head with high pump capacity and costs more than necessary. On the other hand, it must be realized that any hydrologic analysis is only an approximation. The relationship between the amount of precipitation on a drainage basin and the amount of runoff from the basin is complex, and too little data are available on the factors influencing the rural and urban rainfall-runoff relationship to expect exact solutions.

In the hydrologic analysis for a pump station location it must be recognized that there are many variable factors that affect floods. Some of the factors that need to be recognized and considered on an individual site-by-site basis are:

- Rainfall amount and storm distribution;
- Catchment area size, shape, and orientation;
- Land use and land cover;
- Type of soil;
- Slopes of terrain and stream(s);
- Antecedent moisture condition;
- Storage potential (overbank, ponds, wetlands, reservoirs, channel, etc.); and
- Catchment area development potential.

3.1 Precipitation

Precipitation is one of the components of hydrological cycle for which the most records are available. The rainfall data available is too sparse to develop highly accurate intensity-duration-frequency curves. The 24-hour rainfall depth records were generally adequate to project the frequency of 24-hour rainfall depths

In this project area, the nearest and most contributing rain gage among the stations are identified the Edaga Arbi meteorological station. These gauging stations have records of 13 years of daily rainfall records data.

Table 2:Edga Arbi Daily Maximum Rainfall

S.no.	Year (Gc)	Max Daily Rainfall (mm)
1	2005	45.5
2	2006	36.3
3	2007	50.6
4	2008	24.6
5	2009	70.1
6	2010	51.7
7	2011	50.3
8	2012	46.3
9	2013	29.7
10	2014	34.3
11	2015	45.3
12	2016	42.3
13	2017	56.3

Table 3: Data consistency

Method of least square

T=return period
N=no.samples

Year	X(mm)	Rank (m)	Dec. order	p=m/(N+1)	T=(N+1)/m	(T/T-1)	log(T/T-1)	Y=loglog (T/T-1)	X^2	X*Y	Y^2
2005	45.5	1	70.1	0.0714	14.0000	1.0769	0.0322	-1.4924	2070.250	-67.902	2.227
2006	36.3	2	56.3	0.1429	7.0000	1.1667	0.0669	-1.1743	1317.690	-42.626	1.379
2007	50.6	3	51.7	0.2143	4.6667	1.2727	0.1047	-0.9799	2560.360	-49.583	0.960
2008	24.6	4	50.6	0.2857	3.5000	1.4000	0.1461	-0.8353	605.160	-20.548	0.698
2009	70.1	5	50.3	0.3571	2.8000	1.5556	0.1919	-0.7170	4914.010	-50.259	0.514
2010	51.7	6	46.3	0.4286	2.3333	1.7500	0.2430	-0.6143	2672.890	-31.761	0.377
2011	50.3	7	45.5	0.5000	2.0000	2.0000	0.3010	-0.5214	2530.090	-26.226	0.272
2012	46.3	8	45.3	0.5714	1.7500	2.3333	0.3680	-0.4342	2143.690	-20.103	0.189
2013	29.7	9	42.3	0.6429	1.5556	2.8000	0.4472	-0.3495	882.090	-10.381	0.122
2014	34.3	10	36.3	0.7143	1.4000	3.5000	0.5441	-0.2643	1176.490	-9.067	0.070
2015	45.3	11	34.3	0.7857	1.2727	4.6667	0.6690	-0.1746	2052.090	-7.908	0.030
2016	42.3	12	29.7	0.8571	1.1667	7.0000	0.8451	-0.0731	1789.290	-3.092	0.005
2017	56.3	13	24.6	0.9286	1.0769	14.0000	1.1461	0.0592	3169.690	3.335	0.004
	13										

Consistency check **total**

Mean **x**	44.9
st.dev **s**	11.94
N	13
Consistency (**k**)	0.074
K<0.1 =ok	ok !

A=	1.0673	interceptor	B=	-0.037 slope
Correlation	-0.9742			
Y=	-0.0368	x **+**	1.067299	

Table 4:Data Adequacy

TEST FOR DATA ADEQUACY	
S/N	24 hr Rainfall depth
1	45.5
2	36.3
3	50.6
4	24.6
5	70.1
6	51.7
7	50.3
8	46.3
9	29.7
10	34.3
11	45.3
12	42.3
13	56.3
N	13
total	583.3
mean	44.87
stdv.	11.94
coffe. Var.	0.244
stand. Error	6.76 <10
test	**Adequate data**

3.2 Design Storm

In flood analysis, one has to deal with the natural phenomena, such as heavy rainfall and floods whose occurrence is essentially random. Since the cost of engineering structures tends to increase rapidly with the rarity of adopted design event. The choice of an appropriate design frequency is ideally based upon an economic analysis in which the benefit of the work, in term of the damage costs avoided, are balanced against construction costs. For schemes whose capital value does not justify the time and effort involved in cost –benefit analysis certain design standards have come to be accepted as being sufficient to ensure that the works will withstand a reasonably wide range of stresses during their working lives. These design standards for pump station structures ranges from 10 to 50 years' design periods.

To estimate peak design storm of certain years, return period and thus to find out the maximum possible design flood from the main canal stream watershed different statistic methods were used. Daily maximum amount of precipitation for 13 years (from the Edaga Arbi meteorological station) was collected and analyzed by using different statistical methods:

To estimate peak design storm of certain years, return period and thus to find out the maximum possible design flood from the Ruba-Chemiet watershed different statistic methods are used.

3.2.1 Gumbel Extreme Value Distribution

Gumbel Extreme value distribution is one of the most widely used probably distribution function for extreme value in hydrology and meteorology studies for prediction of peak flood, maximum rainfall, wind speed etc.

$$XT = Xave + K\delta$$

Where XT = design rainfall with 100, 50, 25, 10 and 5-year reoccurrence interval

Xave = Average rainfall of series

K = frequency factor

δ = standard deviation of sample

3.2.2 Log- Pearson Type - III Distribution

The design storm of 50 years returns using Log_Person_III distribution is:

$Zr = Zave + Kz*\delta$

Where = Z = Log X, X = the rainfall series

Zave = Average of the log X value

Zr = Design rainfall with T year reoccurrence i.e. 50 years’ return

δ = Standard deviation of the log value

Kz = Frequency factor depend on re-occurrence, T and skewness, Cs

Using SMADA software we analysis and we select the best approaching the actual data to the distribution as tabulated below.

Table 5: Distrubution analysis: two parameter log normal

Distribution Analysis: 2 Parameter Log Normal				
Summary of Data				
First Moment (mean) = 44.8692				
Second Moment = 1.426e02				
Skew = 2.069e-01				
Point	Weibull	Actual	Predicted	Standard
Number	Probability	Value	Value	Deviation
1	0.0714	24.6000	29.5507	3.7362
2	0.1429	29.7000	32.7930	3.3029
3	0.2143	34.3000	35.2500	3.0761
4	0.2857	36.3000	37.3957	2.9679
5	0.3571	42.3000	39.4037	2.9516
6	0.4286	45.3000	41.3686	3.0166
7	0.5000	45.5000	43.3597	3.1589
8	0.5714	46.3000	45.4464	3.3802
9	0.6429	50.3000	47.7127	3.6886
10	0.7143	50.6000	50.2746	4.1030
11	0.7857	51.7000	53.3349	4.6641
12	0.8571	56.3000	57.3310	5.4698
13	0.9286	70.1000	63.6214	6.8386
Predictions				
Exceedance	Return	Calculated	Standard	
Probability	Period	Value	Deviation	
0.9950	200.0	85.0760	11.8737	
0.9900	100.0	79.7009	10.5851	
0.9800	50.0	74.2147	9.2835	
0.9600	25.0	68.5566	7.9628	
0.9000	10.0	60.6346	6.1772	
0.8000	5.0	54.0375	4.8007	
0.6670	3.0	48.5379	3.8154	
0.5000	2.0	43.3597	3.1589	

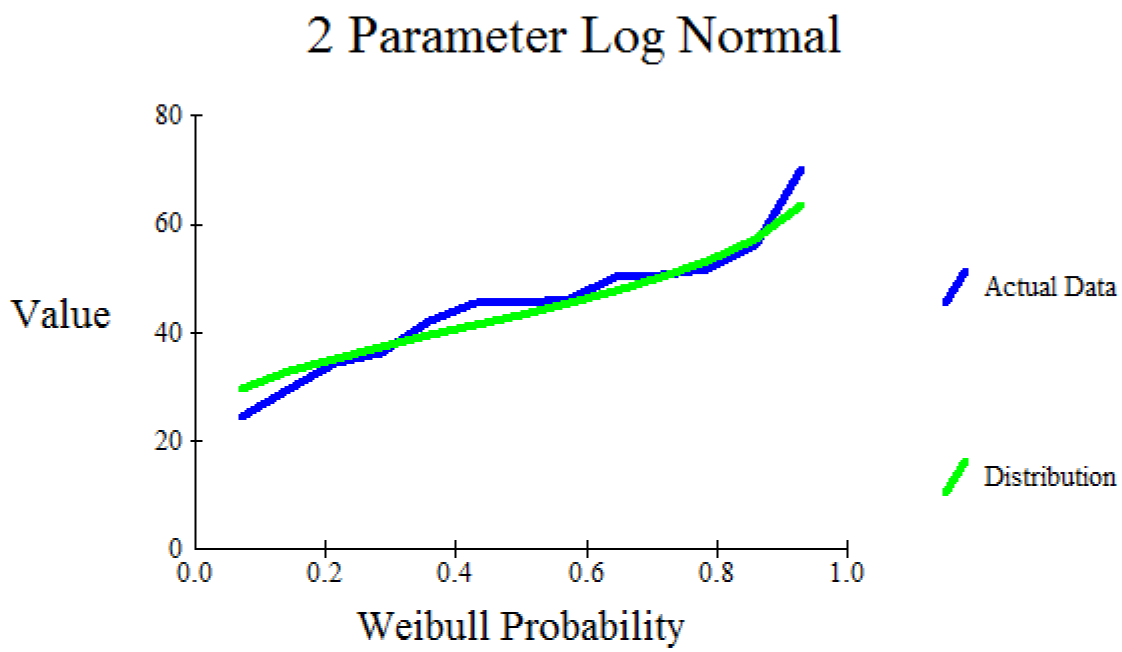

Figure 3: Two parameter log normal

Table 6: Distribution analysis: three parameter log normal

Distribution Analysis: 3 Parameter Log Normal				
Summary of Data				
First Moment (mean) = 44.8692				
Second Moment = 1.426e02				
Skew = 2.069e-01				
Point Number	Weibull Probability	Actual Value	Predicted Value	Standard Deviation
1	0.0714	24.6000	27.8691	4.5248
2	0.1429	29.7000	32.2097	3.8451
3	0.2143	34.3000	35.2927	3.6228
4	0.2857	36.3000	37.8581	3.5486
5	0.3571	42.3000	40.1622	3.5350
6	0.4286	45.3000	42.3346	3.5495
7	0.5000	45.5000	44.4597	3.5803
8	0.5714	46.3000	46.6110	3.6266
9	0.6429	50.3000	48.8664	3.6968
10	0.7143	50.6000	51.3229	3.8126
11	0.7857	51.7000	54.1391	4.0242
12	0.8571	56.3000	57.6426	4.4586
13	0.9286	70.1000	62.8091	5.5540
Predictions				

Exceedance	Return	Calculated	Standard
Probability	Period	Value	Deviation
0.9950	200.0	78.0016	12.1464
0.9900	100.0	74.4878	10.2028
0.9800	50.0	70.7164	8.3852
0.9600	25.0	66.6049	6.7408
0.9000	10.0	60.4053	4.9712
0.8000	5.0	54.7688	4.0866
0.6670	3.0	49.6681	3.7291
0.5000	2.0	44.4597	3.5803

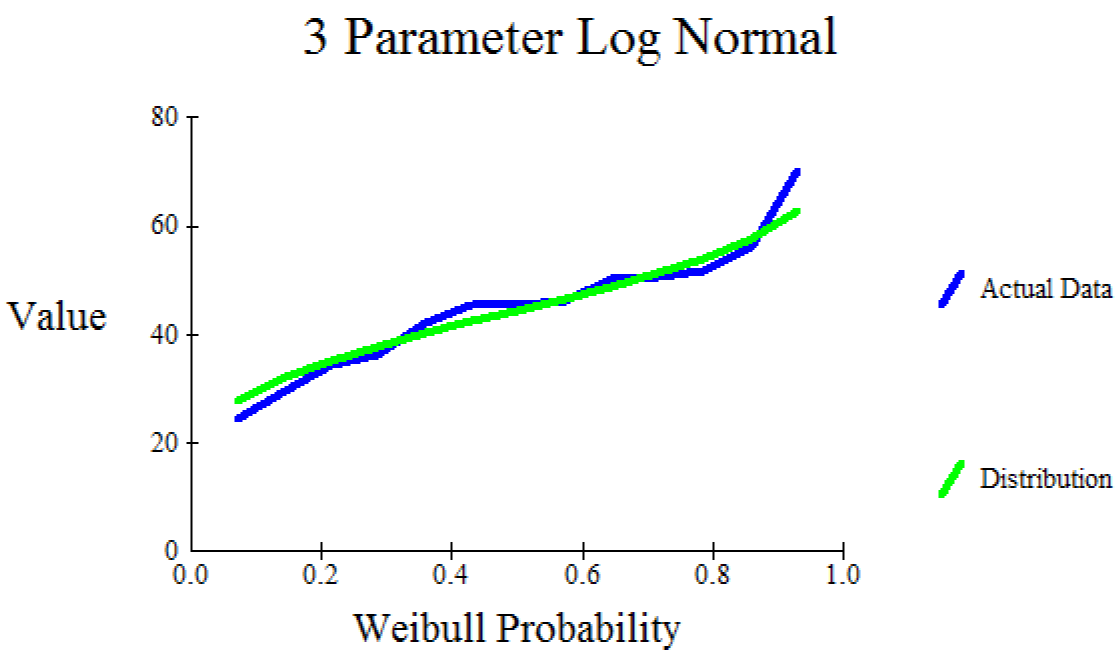

Figure 4:Three parameter log normal

Table 7: Distribution analysis: Pearson type III

Distribution Analysis: Pearson Type III				
Summary of Data				
First Moment (mean) = 44.8692				
Second Moment = 1.426e02				
Skew = 2.069e-01				
Point Number	Weibull Probability	Actual Value	Predicted Value	Standard Deviation
1	0.0714	24.6000	28.4814	4.0023
2	0.1429	29.7000	32.3500	3.4875
3	0.2143	34.3000	35.1832	3.4051
4	0.2857	36.3000	37.5928	3.4335
5	0.3571	42.3000	39.7962	3.4921
6	0.4286	45.3000	41.9070	3.5573
7	0.5000	45.5000	44.0021	3.6244
8	0.5714	46.3000	46.1531	3.6993
9	0.6429	50.3000	48.4397	3.7976
10	0.7143	50.6000	50.9661	3.9517
11	0.7857	51.7000	53.9073	4.2297
12	0.8571	56.3000	57.6309	4.7956
13	0.9286	70.1000	63.2477	6.1881
Predictions				
Exceedance Probability	Return Period	Calculated Value	Standard Deviation	
0.9950	200.0	80.5609	14.1096	
0.9900	100.0	76.4573	11.8163	
0.9800	50.0	72.1173	9.6482	
0.9600	25.0	67.4656	7.6560	
0.9000	10.0	60.6162	5.4529	
0.8000	5.0	54.5713	4.3115	
0.6670	3.0	49.2602	3.8411	
0.5000	2.0	44.0021	3.6244	

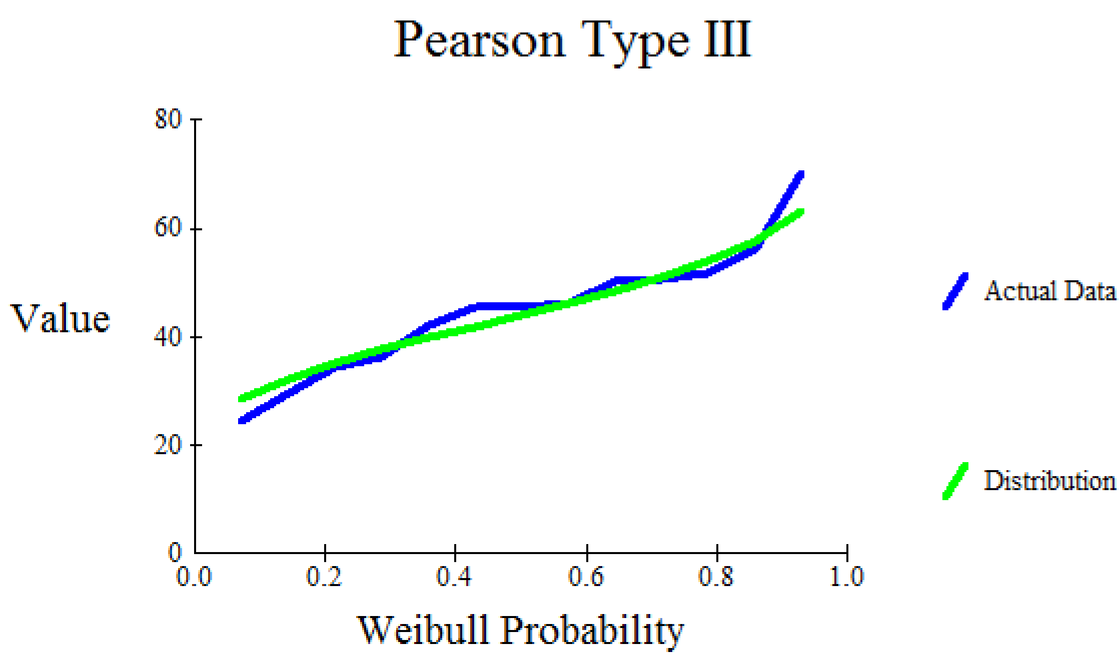

Figure 5:Pearson type III

Table 8: Distribution analysis: Pearson type III

Distribution Analysis: Log Pearson Type III				
Summary of Data				
First Moment (mean) = 44.8692				
Second Moment = 1.426e02				
Skew = 2.069e-01				
Point	Weibull	Actual	Predicted	Standard
Number	Probability	Value	Value	Deviation
1	0.0714	24.6000	26.8982	4.8100
2	0.1429	29.7000	31.4703	4.1695
3	0.2143	34.3000	34.8184	3.9863
4	0.2857	36.3000	37.6455	3.9875
5	0.3571	42.3000	40.2028	4.0632
6	0.4286	45.3000	42.6193	4.1591
7	0.5000	45.5000	44.9795	4.2456
8	0.5714	46.3000	47.3569	4.3061
9	0.6429	50.3000	49.8282	4.3326
10	0.7143	50.6000	52.4854	4.3296
11	0.7857	51.7000	55.4749	4.3392
12	0.8571	56.3000	59.0899	4.5428
13	0.9286	70.1000	64.1671	5.7681
Predictions				
Exceedance	Return	Calculated	Standard	

Probability	Period	Value	Deviation
0.9950	200.0	76.9314	16.8344
0.9900	100.0	74.2908	13.4770
0.9800	50.0	71.2430	10.3402
0.9600	25.0	67.6756	7.5808
0.9000	10.0	61.8456	5.0264
0.8000	5.0	56.1337	4.3534
0.6670	3.0	50.6999	4.3340
0.5000	2.0	44.9795	4.2456

Table 9:Distribution Analysis: Gumbel Extremal Type I and it is the best fit method

Distribution Analysis: Gumbel Extremal Type I				
Summary of Data				
First Moment (mean) = 44.8692				
Second Moment = 1.426e02				
Skew = 2.069e-01				
Point	Weibull	Actual	Predicted	Standard
Number	Probability	Value	Value	Deviation
1	0.0714	24.6000	27.1234	4.0765
2	0.1429	29.7000	30.7833	3.3894
3	0.2143	34.3000	33.5900	2.9916
4	0.2857	36.3000	36.0730	2.7776
5	0.3571	42.3000	38.4293	2.7240
6	0.4286	45.3000	40.7703	2.8236
7	0.5000	45.5000	43.1823	3.0699
8	0.5714	46.3000	45.7527	3.4578
9	0.6429	50.3000	48.5913	3.9917
10	0.7143	50.6000	51.8635	4.6965
11	0.7857	51.7000	55.8640	5.6374
12	0.8571	56.3000	61.2397	6.9803
13	0.9286	70.1000	70.0372	9.2760
Predictions				
Exceedance	Return	Calculated	Standard	
Probability	Period	Value	Deviation	
0.9950	200.0	102.3917	18.0476	
0.9900	100.0	94.0356	15.7604	
0.9800	50.0	85.6489	13.4753	
0.9600	25.0	77.1998	11.1903	
0.9000	10.0	65.8107	8.1626	
0.8000	5.0	56.7967	5.8653	
0.6670	3.0	49.6379	4.2087	
0.5000	2.0	43.1823	3.0699	

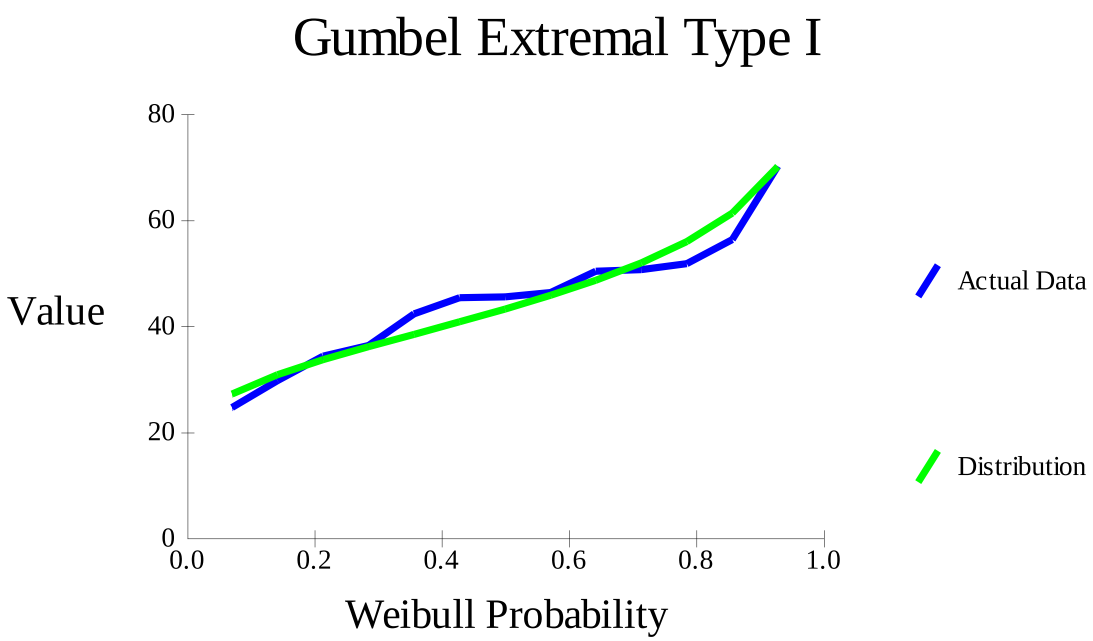

Figure 6:Gumbel Extremal value type I distribution which is best fit

The frequency factor K, can be obtained from the equation:

K = YT - Yn/Sn

Where YT = - (ln * ln (T/T-1))

Yn = reduced mean obtained from table

Sn = reduced deviation obtained from table

Table 10:Gamble Extreme value optional analysed best fit point rainfall using the statistical method.

Average Rainfall =		44.87
Standard deviation =		11.94
YT =	3.9019	
Yn =	0.50576	
Sn =	0.9922	
K =	3.42	
XT = Xave + Kδ		85.75

3.3 Peak Design Floods

Many hydrologic methods for peak flood estimation are available. The methods to be used and the circumstances for their use are listed below. If possible, the method shall be calibrated to local conditions and tested for accuracy and reliability. Among the hydrologic methods adopted in our country and limitations on their use follows:

1. Rational method shall be used only for catchment areas less than 12.8 km^2;
2. SCS and other unit hydrograph methods for catchment areas greater than 12.8 km^2;
3. Gumbel Extreme Value Distribution Type I analyses shall preferably be used for all routine designs provided here is at least 10 years of continuous or synthesized record for 5-year discharge, 10-year discharge, 25-years and 100-year discharge estimates; Of these possible hydrologic methods, only the Rational and SCS methods are employed considering their limitation, due to the availability of data's.

Finally, since our catchment area is greater than 12.8km2 we choose SCS method to analysis our data.

3.4 Runoff Coefficient

The ground cover and a host of other hydrologic abstractions considerably affect the coefficient. The rational equation in general relates the estimated peak discharge to a theoretical maximum of 100% runoff. The Values of C vary from 0.05 for flat sandy areas to 0.95 for impervious urban surfaces, and considerable knowledge of the catchment is needed in order to estimate an acceptable value. The coefficient of runoff also varies for different storms on the same catchment, and thus, using an average value for C, gives only a rough estimate of Qp in small uniform urban areas. On top of this the Rational Formula has been used for many years as a basis for engineering design for small land drainage schemes and storm-water channels.

Coefficient of runoff C for the formula is given by many soil and water conservation texts. Information on rainfall intensity I in a time of concentration (time period required for flow to reach the outlet from the most remote point in the catchment) is required and can be estimated by the following formula. The selection of the correct value of 'C' presents some difficulty. It represents a parameter that can influence runoff including soils type, antecedent soil conditions, land use, vegetation, and seasonal growth. Therefore, the value of 'C' can vary from one moment to another according to changes, especially soil moisture conditions. If the basin contains varying amount of different land cover or other abstractions, a coefficient can be calculated through areal weighing as shown in equation bellow.

$$\text{Weighted C} = \sum \left(\frac{Cx * Ax}{A\ total} \right)$$

Where x = subscript designating values for incremental areas with consistent land cover

I. Time of Concentration

The time of concentration is the amount of time from the beginning of a rainfall event until the entire sub-basin area is contributing to flow at the outlet. In other words, the time of concentration is the time for a drop of water to flow from the remotest point in the sub-basin to the sub-basin outlet. The time of concentration is calculated by Kirpich time of concentration (T_c) formula

$$T_c = 0.00032 L^{0.77} S^{-0.385}$$

Where, L = Length of the longest watercourse (m)

S = Watershed average slope (m/m)

T_c = Time of concentration (hr)

Table 11: Time of Concentration Water shade Ruba-Chemiet project

Reach	Length (m)	Elevation (m)	Elevation difference (m)	Slope (%)	Slope (m/m)	Time of concentration
(TC= (1/3000) *(L/(S)^0.5) ^0.77)						TC
1	0	1719	0	0	0	0
2	1787	1750	31	1.735	0.017	0.507
3	5053	1800	50	0.990	0.010	1.401
4	2818	1850	50	1.774	0.018	0.714
5	913	1900	50	5.476	0.055	0.194
6	3555	1950	50	1.406	0.014	0.933
7	3031	2000	50	1.650	0.016	0.776
8	1845	2050	50	2.710	0.027	0.438
9	1211	2100	50	4.129	0.041	0.269
10	1048	2150	50	4.771	0.048	0.228
11	161	2200	50	31.056	0.311	0.026
12	1556	2250	50	3.213	0.032	0.359
13	711	2300	50	7.032	0.070	0.145
14	329	2350	50	15.198	0.152	0.060
15	121	2400	50	41.322	0.413	0.019
16	518	2450	50	9.653	0.097	0.101
17	151	2500	50	33.113	0.331	0.024
18	167	2550	50	29.940	0.299	0.027
19	239	2600	50	20.921	0.209	0.041
20	175	2650	50	28.571	0.286	0.029
21	90	2700	50	55.556	0.556	0.013
22	86	2750	50	58.140	0.581	0.013
Total	**25,565.00**					**6.32**

3.5 SCS Method

The SCS unit hydrograph techniques are used to convolute effective rainfall estimated based on SCS Curve Number (CN) method. This method has been widely used in estimating effective rainfall and Peak flood discharge. Time lag T_L is used as a parameter to generate the SCS UH.

The equation used for deriving the parameters given in Table16: is elaborated in Annex:

$$T_p = \frac{D}{2} + 0.6T_c$$

Where, T_p = Time in hour from start of rise to peak rate (hr)

D = Rainfall excess duration: D= Tc/6 if Tc<3hr & D=1 if Tc>3hr

T_b= 2.67T_p

Where, T_b = Time of base of hydrograph

$$T_L = 0.6T_c$$

Where, T_L = time from center of excess rainfall to time of peak (hr) Peak discharge is estimated using:

$$q_p = \frac{0.208A}{T_p}$$

Where q_p = Peak rate of discharge created by 1mm rainfall excess on whole of the catchment

A = watershed area (km^2)

T_p = Time in hour from start of rise to peak rate (hr)

D = duration of excess rainfall (hr)

Qp = qp * r_d

Where Q_p = peak discharge (m^3/s)

r_d = the excess rainfall depth (mm)

The depth of runoff resulting from a required return period rainfall depth of duration corresponding to the time of concentration T_c is estimated by

$$r_d = \frac{(P - 0.2S)^2}{P + 0.8S}$$

Where, S = the potential retention (mm)

P = design rainfall amount of duration T_c corresponding to T years return period (mm), and S (mm) is estimated using

$$S = 254\left(\frac{100}{CN} - 1\right)$$

Where, CN = Curve number

3.6 Estimating Curve Numbers (CN)

The CN for the five watersheds have been estimated based on Ministry of Water Resources ETHIO-GIS digital soil map, land use and land cover obtained from different topographic map and field observations. The catchments all stream cover one or more land cover and soil of the heavy clay, clay loam, clay, loam and loamy sand. Hydrologic Soil Group (HSG) Estimated CN values, are different for different catchment size and area.

Table 12:Land Use, Hydrological group and curve number of the Ruba-Chemiet Project

S/N	Land Use Type	Sub Unit	Area Ratio		Slope in %	Soil Texture	Hydrologic Soil group	Stream Flow Potential	Curve No. 'CN'	Weighted "CN"	Sum weighted "CN"		C (Runoff Coefficient)	Weighted C
			Area in Km^2	Ratio							AMC	CN		
1	Cultivated Land	CL2	5.80	0.0443	2-8%	clay loam	D	Good	91	4.03			0.3	0.01
		CL2	2.92	0.0223	2-8%	light clay	D	Good	91	2.03			0.3	0.01
		CL2	1.97	0.0151	2-8%	loam	B	Fair	81	1.22			0.3	0.00
		CL2	10.89	0.0831	2-8%	loamy sand	A	Low	72	5.99			0.25	0.02
		CL2	17.04	0.1302	2-8%	silt loam	B	Fair	81	10.54			0.25	0.03
		CL3	2.52	0.0192	8-15%	clay loam	D	Good	91	1.75			0.35	0.01
		CL3	3.08	0.0235	8-15%	light clay	D	Good	91	2.14			0.35	0.01
		CL3	2.16	0.0165	8-15%	loam	B	Fair	81	1.33			0.35	0.01
		CL3	6.66	0.0508	8-15%	loamy sand	A	Low	72	3.66			0.3	0.02
		CL3	13.68	0.1045	8-15%	silt loam	B	Fair	81	8.46			0.3	0.03
		CL4	0.47	0.0036	15-30%	clay loam	D	Good	91	0.32			0.4	0.00
		CL4	3.31	0.0252	15-30%	light clay	D	Good	91	2.30			0.4	0.01
		CL4	4.09	0.0312	15-30%	loam	B	Fair	81	2.53			0.4	0.01
		CL4	9.61	0.0734	15-30%	loamy sand	A	Low	72	5.29			0.35	0.03
		CL4	12.99	0.0992	15-30%	silt loam	B	Fair	81	8.03			0.35	0.04
		CL5	0.06	0.0005	30-50%	light clay	D	Good	91	0.04			0.45	0.00
		CL5	0.27	0.0021	30-50%	loam	B	Fair	88	0.18			0.45	0.00
		CL5	0.40	0.0031	30-50%	loamy sand	A	Low	72	0.22			0.4	0.00
		CL5	0.52	0.004	30-50%	silt loam	B	Fair	81	0.32			0.4	0.00
S/N	Land Use Type	Sub Unit	Area Ratio		Slope in %	Soil Texture	Hydrologic Soil group	Stream Flow	Curve No.	Weighted "CN"	Sum weighted		C (Runoff	Weighted C

								Potential	**'CN'**		**"CN"**		**Coefficient)**	
			Area in Km^2	**Ratio**							**AMC**	**CN**		
2		FL2	0.04	0.0003	2-8%	light clay	D	Good	83	0.02			0.25	0.00
		FL2	0.06	0.0004	2-8%	loamy sand	A	Low	45	0.02			0.2	0.00
		FL2	0.04	0.0003	2-8%	silt loam	B	Fair	66	0.02			0.2	0.00
		FL3	0.06	0.0005	2-8%	light clay	D	Good	83	0.04			0.3	0.00
		FL3	0.27	0.002	2-8%	silt loam	B	Fair	66	0.13			0.25	0.00
		FL4	0.07	0.0005	15-30%	clay loam	D	Good	83	0.04			0.35	0.00
		FL4	0.78	0.006	15-30%	light clay	D	Good	83	0.50			0.35	0.00
	Forest Land	FL4	0.64	0.0049	15-30%	loam	B	Fair	66	0.32			0.35	0.00
		FL4	2.73	0.0209	15-30%	loamy sand	A	Low	45	0.94			0.3	0.01
		FL4	2.34	0.0179	15-30%	silt loam	B	Fair	66	1.18			0.3	0.01
		FL5	2.17	0.0166	30-50%	light clay	D	Good	83	1.38			0.4	0.01
		FL5	2.63	0.0201	30-50%	loam	B	Fair	66	1.33			0.4	0.01
		FL5	5.78	0.0441	30-50%	loamy sand	A	Low	45	1.99			0.35	0.02
		FL5	2.46	0.0188	30-50%	silt loam	B	Fair	66	1.24			0.35	0.01
		FL6	1.57	0.012	>50%	light clay	D	Good	83	0.99			0.45	0.01
		FL6	2.63	0.0201	>50%	loam	B	Fair	66	1.32			0.45	0.01
		FL6	4.80	0.0367	>50%	loamy sand	A	Low	45	1.65	II	74.6	0.4	0.01
		FL6	2.15	0.0164	>50%	silt loam	B	Fair	66	1.08			0.4	0.01
3	**Miscellaneous**		1.31							**74.59**				
	TOTAL AREA		**130.95**											**0.33**

4. Catchments Characteristics

Estimating the peak flood discharge based on the rational and SCS method of canal crossing streams, watershed has been at point intersection point of the stream and canal. Physical characteristics have been processed from 1:10,000 scale map supported by 30x30 DEM of SRTM (Shuttle Radar Thematic Mission) is used. Table below gives X-Y Coordinate Location and discharge of main canal crossing streams by considering their catchment size.

Table 13: Ruba-Chemiet location and return period and peak flood

Ruba-Chemiet	Catchment Area (Km2)	Easting(m)	Northing(m)	Return Period(T)	Discharge (m3/s)
Pump station of Ruba- Chemiet	130.95	526737	1548921	50	62.31

5. Hydrology

5.1 Hydrological description of Ruba-Chemiet

The main purpose of updating the hydrology study for engineering design is to reassess the availability of surface water resources and estimates of floods in the pump stations site and Irrigation Development project areas as well as the distribution of these resources in time and space. For the management of surface water resources for the irrigation, it is important to assess:

- Climatic data (rainfall, temperature, wind speed, relative humidity, sunshine hours and evaporation) within the project area and nearby station surrounding the project area example Edaga Arbi.
- Average surface water yield and the flows depending on given statistical occurrences, and the low flow characteristics of the river at the proposed locations.
- Flood magnitude and flood frequency for the design of different hydraulic structure such as pump stations and intake structure.
- The present water use in the sub-basin both upstream and downstream of the proposed projects.

5.2 River flow and Flood Estimation

The availability and quality of hydrologic and meteorological data shall be ascertained and thoroughly checked. Computation of various frequencies of storm rainfall with different return period and durations, which are relevant for the design of pump stations, drainage works and other structures, is done. At this time (mean taking the data during December 2010 E.C) the river flow we measure using floating method for Ruba-Chemiet 0.154 m^3/sec pulse the 25% downstream release.

5.3 Tail Water Depth Computation

The analysis of tail water depth is very important for the determination of maximum water depth before the construction of a hydraulic structure. It is also used to determine the required river training work to prevent the entrance of flood to the pumping station. The tail water depth is determined based on manning's equation. Hence, the wetted area, perimeter, manning's roughness coefficient and the river slope are the main important data required for the analysis. Wetted area and perimeter can be easily determined from the river cross-section with the specified depth of flow.

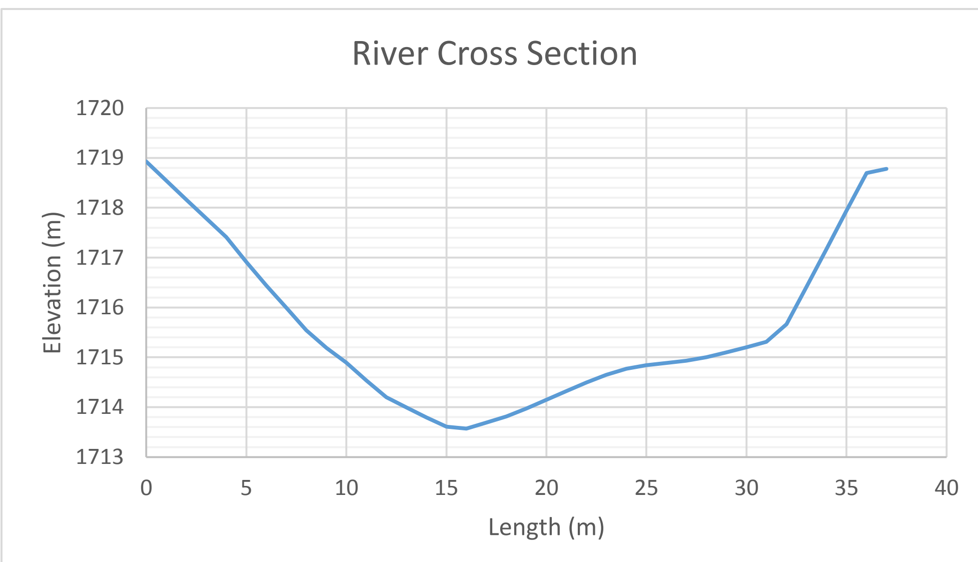

Figure 7: Cross section of Ruba-Chemiet

5.4 Average river bed slope

As there is a pumping station, there is a need to determine the slope of the river Hence, the Average river bed slope at the proposed pumping station of Ruba-Chemiet is estimated by using the surveying data and it was found to be 0.009691. and also the bed profile near the pump station incorporated at the annex.

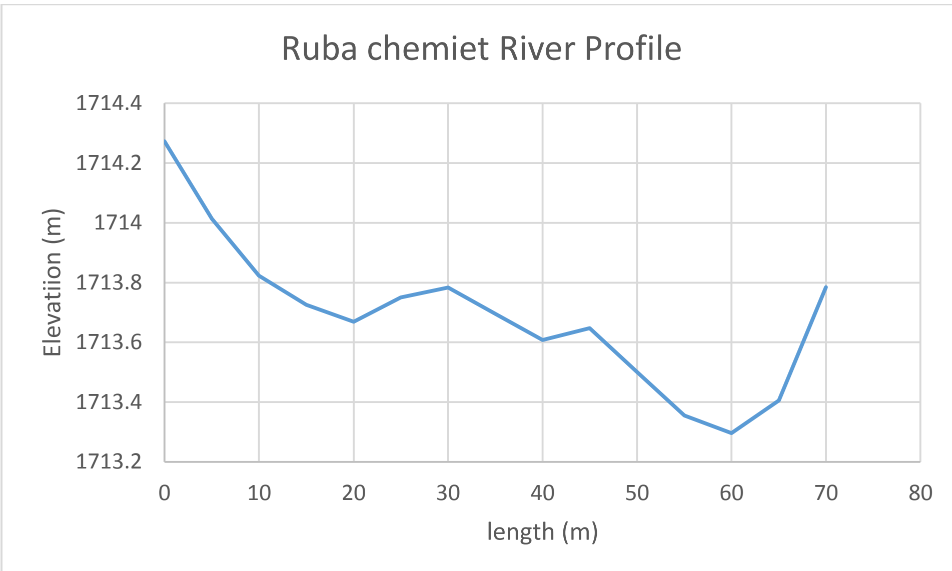

Figure 8:Ruba-chemiet River longitudinal profile

5.5 Manning's Roughness Coefficient

The river channel is well defined and the river bed is covered with recently transported materials while the river banks are covered with highly fragmented sand stone. The river has defined banks and the pumping station is located at the bank of the river to minimize the suction head. In addition, the pumping station should be free from flooding.

The Manning`s roughness coefficient is taken from standard table based on the river nature. The river reach at the headwork site has straight nature and made of alluvium deposits for this site. The banks are also defined and it is stable. Hence, a Manning`s roughness coefficient (n = 0.035) has been adopted.

5.6 Tail Water depth analysis

Input data: Manning's roughness coefficient, n =0.035 and Average river bed slope, S = 0.009691

Manning Equation for velocity: $V = \frac{1}{n} \times R^{2/3} \times \sqrt{S}$

Where, R = Hydraulic radius = (Area/Perimeter)

Discharge: $Q = V \times A$

Table 14:Tail Water Depth for Pumping Station of Ruba-Chemiet

Depth	Elevation	Area	Perimeter	R	S	n	V	Q
0	1713.5	0	0	0	0.009691	0.035	0	0
0.5	1714	1.577	6.223	0.253415	0.009691	0.035	1.126343	1.776244
1.5	1715	12.876	18.571	0.693339	0.009691	0.035	2.203332	28.37011
2.5	1716	35.856	26.162	1.370537	0.009691	0.035	3.470379	124.4339
3.5	1717	63.092	30.198	2.089277	0.009691	0.035	4.596709	290.0156
4.5	1718	93.779	34.656	2.705996	0.009691	0.035	5.461782	512.2005
5.27	1718.77	123.425	38.614	3.19638	0.009691	0.035	6.103166	753.2832

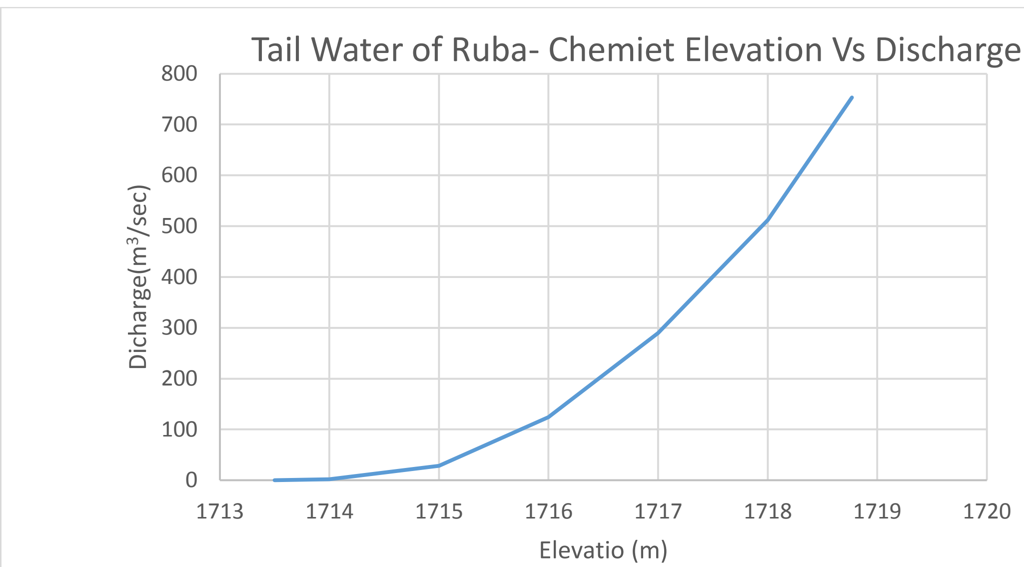

Figure 9:Tail water rating curve at Pump Station Ruba-Chemiet

From the above table and Tail water rating curves, the tail water depth equivalent to the peak flood discharge (i.e. Q =62.31m3/sec) is found to be 1.853m.

5.7 Water Balance

The water balance of is done excluding the summer from June to august is don as tabulated below:

Table 15:Water balance for Ruba-chemiet pump irrigation system

Month	**February**			**March**			**April**			**May**		
Decade	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
Measured Q (lit/sec)	186	186	186	154	138	122	106	90	73	57	41	25
Command(ha)	88	88	88	97	97	97	97	97	97	97	97	97
duty(lit/sec/ha)	1.57	1.57	1.57	0.37	0.37	0.37	0.17	0.17	0.17	0.16	0.16	0.16
Req Q (lit/sec)	138.16	138.16	138.16	35.89	35.89	35.89	16.49	16.49	16.49	15.52	15.52	15.52
Environmental release	46.5	46.5	46.5	38.5	34.5	30.5	26.5	22.5	18.25	14.25	10.25	6.25
Difference	1.34	1.34	1.34	79.61	67.61	55.61	63.01	51.01	38.26	27.23	15.23	3.23
	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Month	**October**			**November**			**December**			**January**		
Decade	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
Measured Q (lit/sec)	396	380	364	348	332	315	154	195	192.5	190	190	188
Command (ha)	97	97	97	97	97	97	97	97	97	93	93	92
duty(lit/sec/ha)	0.17	0.17	0.17	0.13	0.13	0.13	0.94	0.94	0.94	1.52	1.52	1.52
Req Q (lit/sec)	16.49	16.49	16.49	12.61	12.61	12.61	91.18	91.18	91.18	141.36	141.36	139.84
Environmental release	99	95	91	87	83	78.75	38.5	48.75	48.125	47.5	47.5	47
Difference	280.51	268.51	256.51	248.39	236.39	223.64	24.32	55.07	53.195	1.14	1.14	1.16
	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

6. Conclusion and Recommendation

the hydrologic methods adopted in our country due to limitations on their use and data accuracy we use the SCS method is used to estimate the peak flood. The pump station location at the bank river of the structure estimation of peak flood runoff detail analyze using the SCS. To compute the discharge using the SCS methods is based on the listed or stated in the above equations.

Finally; I would like to recommend that as the catchment area is big and the catchment area has a natural stream all the flow created in this catchment area is drains through the river axis of the pump station structure. Therefore, we conclude the calculated of the maximum flood of the river is as calculated and the location of the pump will not harm by the flood and it is safe.

Annex

Table 16:Peak Flood Analysis

Peak flood Analysis			
Step	**Parameters**	**Unit**	**Value**
1	Catchment Area	**Km^2**	**130.95**
2	Length of main river	**m**	**25,565.00**
3	Time of concentration, Tc	**hr**	**6.32**
4	Rain fall exess duration, D = Tc/6	**hr**	**1.00**
5	Time to peak, Tp= 0.6 Tc + 0.5 D	**hr**	**4.29**
6	Time base of hydrograph, Tb = 2.67Tp	**hr**	**11.46**
7	Peak rate of discharge created by 1mm runoff excess on the whole of the catchment, Qp, Qp = (0.21* A) / Tp	**Cumec/mm**	**6.41**
8	Lag time, te= 0.6 Tc	**hr**	**3.79**

9	10	11	12	13	14	15	16	17
Duration	**Daily point Rainfall**	**Rainfall Profile**		**Areal to point rainfall ratio**	**Areal-rainfall**	**Incremental rainfall**	**Descending order**	**Descending order**
hr	**mm**	**%**	**mm**	**%**	**mm**	**mm**	**mm**	**No.**
0.00-0.30	85.65	43.75	37.47	62.60	23.46	23.46	23.46	1
0.30-0.60		57.89	49.58	71.68	35.54	12.08	12.08	2
0.60-0.90		66.24	56.74	75.76	42.98	7.44	7.44	3
0.90-1.20		71.88	61.56	78.76	48.49	5.50	5.50	4
1.20-1.50		75.97	65.07	80.76	52.55	4.06	4.06	5
1.50-1.80		78.55	67.28	81.84	55.06	2.51	2.51	6

18	19	20	21	22	23
Rearranged order	**Rearranged incremental order**	**Cummulative order**	**Times of incremental hydrograph**		
			Time of beginning	**Time to peak**	**Time to end**
No.	**mm**	**mm**	**hr**	**hr**	**hr**
6	2.51	2.51	0.0	4.29	11.46
4	5.50	8.01	1.00	5.29	12.46
2	12.08	20.10	2.00	6.29	13.46
1	23.46	43.55	3.00	7.29	14.46
3	7.44	51.00	4.00	8.29	15.46
5	4.06	55.06	5	9.29036	16.455

24	**The maximum potential difference b/n Rainfall (p) and direct runoff (Q), S = (25400/CN) - 254, CN=Value corresponding to AMC II**	mm	86.54	
			22	**34**
25	**Q=(P-0.2S)2/(P+0.8S)**	mm	p (mm)	Q (mm)
			2.51	0.00
			8.01	0.00
			20.10	0.09
			43.55	6.11
			51.00	9.44
			55.06	11.47

35	36	37	38	39		
Duration	**Cumulative run off**	**Incremental run off**	**Peak run off for increment**	**Time of beginning**	**Time to peak**	**Time to end**
hrs	**mm**	**mm**	**m^3/sec**	**hrs**		
0.00-0.30	0.00	0.00	0.00	0.00	4.29	11.46
0.30-0.60	0.00	0.00	0.00	1.00	5.29	12.46
0.60-0.90	0.09	0.09	0.56	2.00	6.29	13.46
0.90-1.20	6.11	6.02	38.59	3.00	7.29	14.46
1.20-1.50	9.44	3.33	21.36	4.00	8.29	15.46
1.50-1.80	11.47	2.03	12.99	5.00	9.29	16.46

Time	**Ordinate of Hydrograph (m^3/Sec)**						
(hr)	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
0.00	0						**0.00**
1.00	0	0					**0.00**
2.00	0	0	0				**0.00**
3.00	0	0	0.13	0			**0.13**
4.29	**0.00**	0	0.30	11.61	0		**11.91**
5.29	0	**0.00**	0.43	20.60	5.34	0	**26.37**
6.29	0	0	**0.56**	29.60	10.68	3.25	**44.08**
7.29	0	0	0.45	**38.59**	16.02	6.49	**61.55**
8.29	0	0	0.33	30.87	**21.36**	9.74	**62.31**
9.29	0	0	0.22	23.16	17.09	**12.99**	**53.46**
10.29		0	0.11	15.44	12.82	10.39	**38.76**
11.29			0	7.72	8.54	7.79	**24.06**
12.29				0	4.27	5.20	**9.47**
13.29					0	2.60	**2.60**
14.29						0	**0.00**

Ordinate of Hydrograph m3/s	
Time(hr)	**Total**
0.00	0.00
1.00	0.00
2.00	0.00
3.00	0.13
4.29	11.91
5.29	26.37
6.29	44.08
7.29	61.55
8.29	62.31
9.29	53.46
10.29	38.76
11.29	24.06
12.29	9.47
13.29	2.60
14.29	0.00

Figure 10:Complex hydrograph