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

Misrar Teli Diversion Irrigation Project
(Tigray, South zone, Enderta wereda)
Final Hydrology Study Report

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EXECUTIVE SUMMERY

The project area is located in the east most part of Ethiopia in the regional state of Tigray, in Inderta Woreda at mahbere-genet Tabia with altitude range of 1870 m downstream end of catchment to 2460m highest point in the catchment above sea level. The Weir site is located at a distance of 2 km from mahbere genet having geographic coordinates of 545155.03E latitude and 1500099.6N longitudes its altitude is 1860 m.a.s.l. (GPS location in UTM). The size of the watershed area is 322km2 and the total stream length up to Weir axis is 40.6 kilometers.

Hydrologic analysis is done with 15 years of rainfall data from Mekelle meteorological station. Hydrological engineering planning, design, and management problems require a detailed analysis and knowledge of flood event characteristics, such as watershed catchment area, flood mark or flood peak, stream flow or base flow data, volume of water and time duration. Flood frequency analysis often focuses on flood peak values, and hence, provides a limited assessment of flood events. This report analyses a 50 year return period time series of daily precipitation. A comparison of observed and estimated maximum peak flood risk of (50 year return period) showed that the Gamble Extreme type I Value Distribution gives better results fitted to design flood or design storm than the other distributions. The results reported here could be applied in estimating the climatic data and peak flood in Misrar Teli Irrigation project and it is analyzed by using the SCS method.

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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

1. INTRODUCTION

1.1 Background

Tigray Region is found in the Northern part of Ethiopia, which is the most injured due to its arid semi-arid climate hit by repeated and severe drought. It is not only the total amount of the rains, which is short, but also its spatial and temporal distribution is highly variable. Misrar Teli is located in Tigray National Regional State in wereda inderta at Tabia Mahbere genet and 10 km from the capital city of regional state Tigray, Mekelle along the main road of Mekelle-Hagereselam.

For any engineering application including Weir, culvert, urban drainage, bridge and road construction, hydrological analysis of extreme storm events, such as floods is critically important to safeguard any kinds of structural failures.

1.2 Description of the Project area

Misrar Teli Irrigation project area is found in Tigray Regional State in Enderta wereda at tabia Mahbere genet. Geographically the proposed area is located in the coordinate of 545155.03E latitude and150099.60 N longitudes, its altitude is 1860 m.a.s.l. And has a Weir height of 0.6m with its length of the Weir axis or crest length is 32.5m .Since The River has a perennial flow of 200l/s, it will serve as a main source for irrigation demand.

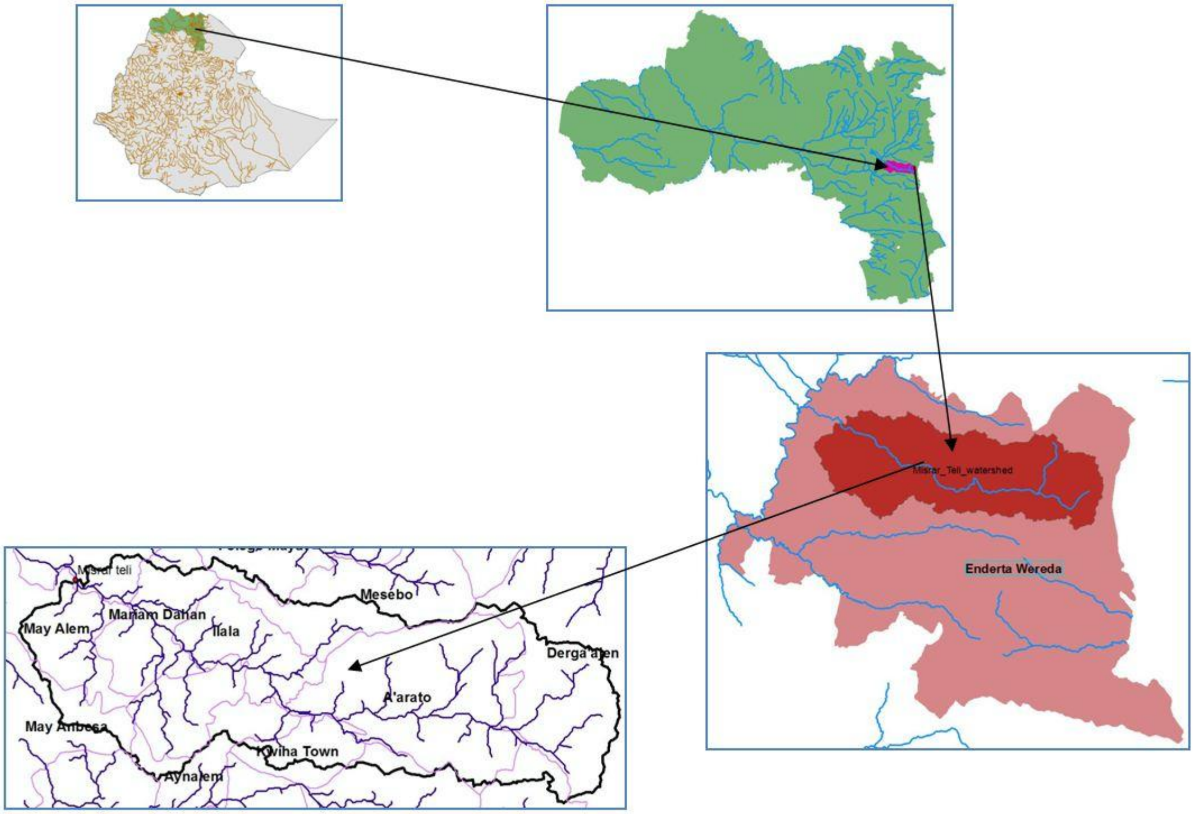

Figure 1, the general description of the Misrar Teli Irrigation scheme

1.2.1 Accessibility

The site is accessible by asphalt road of Mekelle –hagereselam at a distance of 10 km from Mekelle city. Additional 2km branches to the project site.

1.3 Drainage Basin and catchment Characteristics

The catchment area is determined with the help of GIS software with 30m resolution DEM. It is processed with the help of arc Hydro tool which is an extension of Arc GIS software. The size and shape of a drainage area, as well as the length and of its slopes have an effect on the run-off rate and amount of surface water. Therefore, all topographic characteristics should be studied in detail and design hydrologic parameters for estimation of design flood has to be carefully extracted from available data sources. Also the shape of the watershed has a strong relationship with the time of concentration and peak runoff rate. even if two catchments have the same area and have symmetrical drainage pattern, they may produce different rate of runoff as the distance to the outlet in one catchment is longer or shorter than the other, because the long catchment's gathering time (time of concentration) will be longer, its corresponding intensity lower, and its maximum run-off rate (Q max) is less. As a result, if all other factors are equal, long narrow catchments have fewer flash floods than square or round catchments. Thus, important drainage basin characteristic factors have been extracted for estimation of peak floods at different outlets.

The DEM map and drainage catchment area of Misrar Teli Weir Irrigation project is listed in the following figure below:-

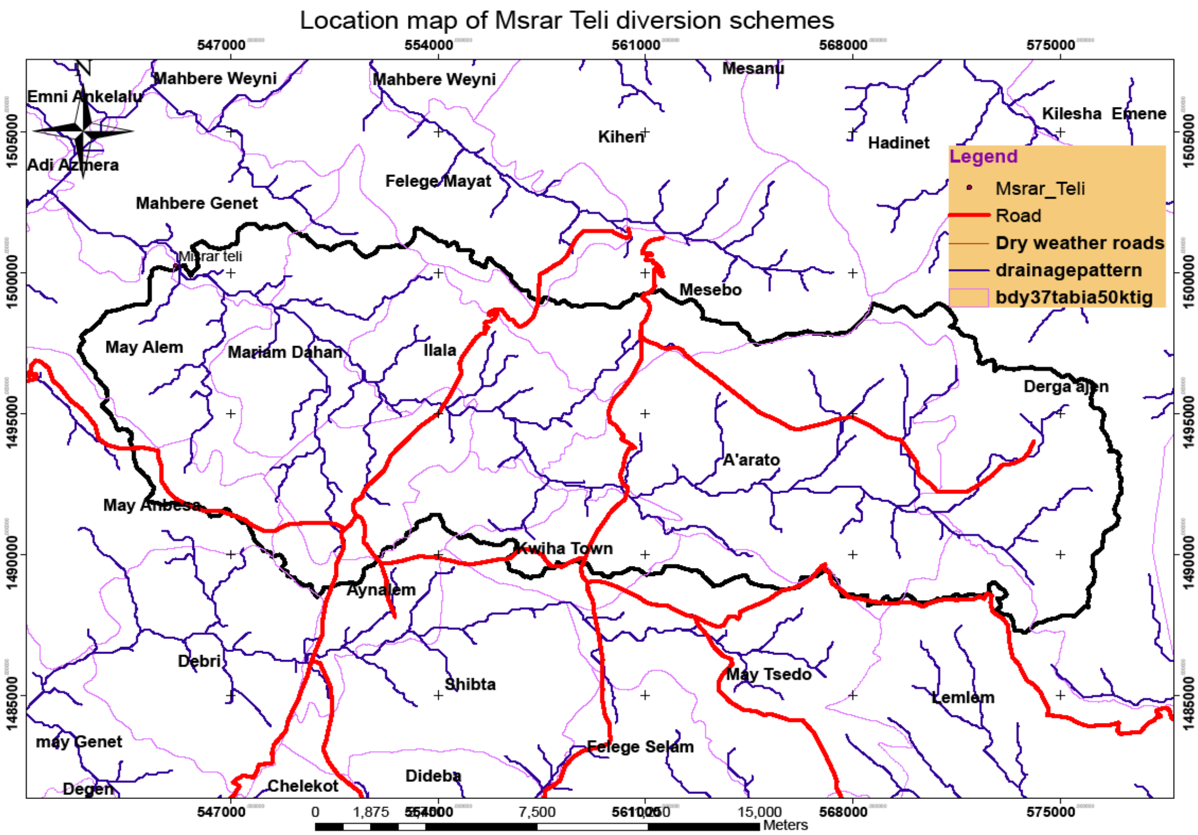

Figure 2, the catchment and drainage area

1.4 Land use type/land cover

The role of vegetation cover in a drainage basin is to intercept rainfall, to keep the soil covered with litter, to maintain soil structure and pore space, and to create openings and cavities by root penetration. The drainage basin of the study area is dominantly covered by cultivated agricultural lands with hydrologic condition ranging from poor to Good.

1.5 Stream Flow Data

There is no gauged station in and around the Misrar Teli but, the river is perennial flow throughout the year. In order to know the potential of the stream flow we used the floating method to collect the river data at two months of the year.

1.5.1 Base Flow Measurement

Date of measurement	Discharge(l/s)
10/11/2017 G.C	204
12/12/2017 G.C	196
Minimum of the two measurement	196

1.6 Soil type and Hydrologic Condition

Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration. Permeability and infiltration are the principal data required to classify soils into Hydrologic Soil Groups (HSG).

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.

1.7 Objectives of the Study area

Pursuant to the identification and reconnaissance study conducted by Tigray Water Works Study design and Supervision enterprise as consultant with the ownership of Tigray water resource bureau in 2007 it was then part of the development endeavor of the region to undertake study and design Irrigation projects so that to play a major role in minimizing the food and Irrigation insecurity of the region. In this regard the objective of the study is to conduct feasibility and detail design of Misrar Teli Irrigation project in integrated and interdisciplinary manner to come up with feasible and sustainable Irrigation project by deploying experienced and competent professionals.

The Study Area Involves: -

- Estimation of water resources potential of the watershed upstream of it based on available meteorological data,
- Identify and estimate catchment area, tributaries and its characteristics,
- Develop and define criteria and computational methods to be used for the hydrological analysis,

In order to identify, analyze, characterize and describe the watershed, it was tried to review some of the previous studies related to the present study. The necessary information for the project area was gathered in four ways:-

- Study of literatures /study reports relevant to the present study.
- Interpretation of topographic maps.
- Field verification of the information.
- Undertaking field investigations (Collection of technical, social and environmental data).

The topographic map with a scale of 1:50000 (printed in 1979 by Ethiopian Mapping Authority, EMA) was used to get the over view of the watershed area. Meteorological data were also collected from the Data Base Section & Irrigation Study and Design Department of our bureau and also recent data was obtained from the National Meteorological service agency (NMSA) Mekelle Branch. Finally, the data on the project area was combined with Arc-Hydro and Arc View GIS, and a map of the area showing drainage patterns is produced.

1.8 Scope of the Study

The scope of the study is the surface water assessment and analyses have been conducted in detail levels. The different aspects of hydrological studies such as annual series of stream flow generation and the subsequent analysis of water availability and dependability, derivation of probable maximum flood from maximum precipitation, are dealt in detail. Detailed potential assessment of surface water of the selected Weir axis has been carried out.

2 METHODOLOGY OF HYDROLOGICAL DATA ANALYSIS

The following Methodologies were applied for the hydrological study Area:-

- Collect relevant primary and secondary data from all sources and assess previous studies conducted on the study area;
- Collect primary data from field and respective offices and relevant hydrological and meteorological data (i.e. rainfall flow data) analysis using excel software.
- Check the screened data consistency and adequacy and analysis it by using the double mass curve, D-Index and statistical method to selected the design flood.
- Data organizing, pre-processing, producing relevant maps i.e. DEM, drainage system, sub-catchments area delineation from DEM data and Global map using Arc Map GIS Version 10.2.1 Software.
- Estimate the peak flood of the proposed catchment area based on long term daily hydrological data and assess the magnitude of design flood.

3 Data Acquisition and Methods

3.1 Determination of Design Storms

A design storm is a precipitation pattern defined for use in the design of a hydrologic system. Usually the design storm serves as the system input, and the resulting rates of flow through the system are calculated using rainfall-runoff procedures. Immediately after we collected the daily max rainfall data, the design rainfall for 50 years of return period is to be computed using different frequency distributions. This constitutes the mean maximum daily flow out of 365 days for every year for which the flow record is available. The quantity of flood expected within the catchment and in particular at the Weir site can only be estimated using some of the existing method. Among the methods considered the stochastic hydrology to estimate the best fit from all distribution for the flood design storm.

A design storm can be defined by a value for precipitation depth at a point, by design hyetograph specifying the time distribution of precipitation during a storm, or by using the isohyet map specifying the spatial pattern of the precipitation. Design storms can be based upon historical precipitation data at site or can be constructed using the general characteristics of precipitation in the surrounding region. Their application ranges from the use of point precipitation values in the least square method for determining peak flow rates in this study of the project the hydrologic analysis make use of the development of point precipitation data of Mekelle meteorological station, statistical and D-index analysis relationships, and estimated limiting storms based on probable maximum precipitation. Point precipitation is a precipitation occurring at a single point in space as opposed to aerial precipitation, which is precipitation over a region.

For point precipitation frequency analysis, the annual maximum precipitation for a given duration is selected by applying all storms in a year, for each year of historical record. This process is repeated for each of a serious of duration. For each duration the frequency analysis is performed on the data, as indicated in the section of Gumble Extreme value distribution to derive the design precipitation depths for various return periods; then the design depths are converted to intensities by dividing by the precipitation duration.

After the maximum of the day for different rainfall events and intervals is calculated, follows a statistical analysis of extremes that applies to the data set composed by the serious of absolute maximum intensities and duration. The statistical analysis is usually done using the Gumble method although could be possible any other method of extremes(for these specific project the average value is taken after performing Gumble, Log Pearson, Log Pearson Type III & Log Normal Distributions). At the end the return period of each depth can be calculated for certain duration. Frequency analysis of precipitation over an area has not been well developed as analysis of point precipitation. In the absence of information on the true probability distribution of aerial precipitation, point precipitation estimates are usually extended to develop an average precipitation depth over an area.

3.2 Rainfall Runoff Modeling

3.2.1 The SCS Method

Design floods are estimated using the SCS methods. Only part of the rainfall will contribute directly to runoff (i.e. will be effective). In wet or less dry regions some of the rainfall remained or losses return to streams as base flow. Losses are generally categorized as initial and continuing. These losses are much dependable on the soil structure, soil texture and its permeability. The land cover and use are also playing an important role in producing the runoff, in addition to land slope.

The SCS Method is widely used procedure that tried to correlate the runoff with precipitation and the soil type. It estimates the initial losses based on a curve number, which depends on land use, soil type, the hydrologic condition and land development. A high curve number yields low losses and hence high effective rainfall and runoff. It is widely applied method in most regions for computing abstraction from storm rainfall. For the storm as a whole, the depth of excess precipitation (i.e., effective precipitation Pe) or direct runoff is always less than or equal to depth of precipitation P. The SCS method uses three variables in estimating runoff (Q):

- ✓ Rainfall (P)
- ✓ Antecedent moisture conditions(CN) and
- ✓ Hydrologic soil cover complex

There are many interrelated factors, climatic and watershed related, that influence infiltration volumes and rainfall excess. Thus, infiltration and rainfall excess will vary during a storm event. At the start of precipitation, the intensity of rainfall is usually less than the rate at which water is stored. As depression storage becomes filled, and the soiled vegetative cover becomes saturated, rainfall excess increases. When soil, depression area, and vegetation storage approach ultimate saturation, storage will approach a potential saturation value (S′) and infiltration rate approaches zero. Then, the rainfall excess rate will equal the precipitation and the soil type.

Rainfall excess (R) is expressed as:

$$R = P - S$$

Where: - R = Rainfall excess

P = Rainfall volume

S = Storage volume on and within the soil (initial abstraction plus infiltration)

At saturation, the rate of rainfall excess is equal to the intensity of precipitation. A proportional relation can be developed as

$$\frac{S}{S'} = \frac{R}{P}$$

Where:-S = Storage at time (mm or inch)

S′ = Storage at saturation (mm or inch)

R = Rainfall excess at any time (mm or inch)

P = Precipitation at any time (mm or inch)

The infiltration as a continuous loss, initial losses and the resulted rainfall excess are tightly relevant to soil moisture content. When the soil has deficit in its moisture, then some of the precipitation will be lost in order to cover this deficit before the runoff starts.

The initial abstraction is the total loss of the rainfall occurring before the start of the runoff. It includes the interception, the filling of surface depressions, and filling of soil moisture deficit.

SCS method is applied for watershed areas greater than 0.5 km^2. Peak discharge is estimated using

$$q_p = \frac{0.208 A r_d}{0.5D + 0.6t_c}$$

Where: - q_p = Peak discharge (m^3/s)
r_d = The Excess Rainfall Depth (mm)
A = Watershed Area (km^2)
t_c = Time of Concentration (hr)
D = Duration of Excess Rainfall (hr)

It is to be noted that the constant in the equation varies from catchment to catchment with an average value of 0.208. 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 depth having a duration t_c corresponding to T years return period (mm), and S (mm) is estimated using

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

The curve number will be estimated from the land use and land cover information based on the estimated from a classification among the four hydrological soil groups (A, B, C or D) with the relevant hydrologic soil condition (poor, fair and good).

Given the curve number (to estimate Ia = 0.2S) of a catchment and time of concentration (tc) unit peak discharge is read for the given return period of rainfall (P) from which peak discharge of a given return period is estimated by multiplying with catchment area A and direct runoff (rd.).

The SCS runoff equation is therefore a method of estimating direct runoff from 24-hour or 1-day storm rainfall. The equation is:

$$Q = (P - I\,a)^2 / (P - I\,a) + S$$

Where: Q = accumulated direct runoff, mm

P = accumulated rainfall (potential maximum runoff), mm

Ia = initial abstraction including surface storage, interception, and infiltration prior to runoff, mm

S = potential maximum retention, mm

The relationship between I_a and S was developed from experimental catchment area data. It removes the necessity for estimating I_a for common usage. The empirical relationship used in the SCS runoff equation is:

Substituting 0.2S for I_a in equation, the SCS rainfall-runoff equation becomes:

$$Q = (P - 0.2S)^2 / (P + 0.8S)$$

S is related to the soil and cover conditions of the catchment area through the CN.

CN has a range of 0 to 100,

The parameter curve number (CN) is a function of soil type and land use (land cover), treatment and hydrological or drainage condition.

4 CLIMATE DATA AND CONDITION OF THE AREA

4.1 Climate characteristics of the project area

The climate of the project area is governed by its physiographic position, temperature regime, amount and distribution of rainfall, humidity and wind regime. The main factors that influences the climate of the area are; the seasonal variations of the Inter Tropical convergence Zone (ICTZ), the northern trade winds and the south western monsoon.

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)

Table 2, Climatic Zones which are traditionally recognized in Ethiopia (National Atlas of Ethiopia 1996)

Zone	Altitude(masl)	Mean Annual temp(o_c)	Classification
Berha	<500	>27.5	Hot Arid
Kola	500-1500	20-27.5	Warm Semi –Arid
Woina Dega	1500-2400	16/17-20	Cool Semi-Arid
Dega	2400-3200	11.5-16/17	Cool and humid
Wirch	>3200	<1.5	Cool and moist

The altitude variation of the project area ranges from 1800 masl to 1860 masl and Temperature ranges 13(^{0}C) and 31.99(^{0}C) and the mean is 22.5(^{0}C).

Therefore, the climate of the area is categorized under woina dega.

4.2 Data Availability

Precipitation and temperature data is collected from the compilation of Bureau water resources mines and Energy and of course its sources are from National Metrological services Agency. We have used a 15years of data from Mekelle metrological station for hydrological analysis.

4.3 Source of rainfall

The Seasonal distribution of rainfall over Ethiopia is mainly due to the position of the inter-Tropical Convergence Zone (ITCZ). In March, the ITCZ is located south of Ethiopia moving northward. A low-pressure system in the Sudan and high pressure system over the Gulf of Aden and Indian Ocean develop. The high pressure generates a moist and easterly air current with south east and North West axis. These air masses produce rain from March to April over the whole eastern area of Tigray.

In June, the ITCZ is located over northern Ethiopia. The high pressure system over Ethiopia has a south east and North West direction. Most of the time the air mass produces the main summer rain in all parts of Tigray, which extends from June to September.

The rainfall for project area is as shown below:-

Table 3, Mean and Annual rainfall of the (Project area)

Year (GC)	**Annual Rainfall (mm)**
2003	324
2004	464.3
2005	648
2006	610
2007	752.5
2008	458.6
2009	533.7
2010	500.8
2011	624.2
2012	647.9
2013	396.6
2014	769.4
2015	324.6
2016	669.1
2017	451
Average	**544.98**

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Table 4, Daily Max annual Rainfall

No	Year	Max RF
1	2003	27.40
2	2004	36.30
3	2005	56.30
4	2006	34.00
5	2007	78.80
6	2008	55.80
7	2009	55.00
8	2010	34.00
9	2011	52.50
10	2012	38.00
11	2013	30.20
12	2014	36.50
13	2015	34.00
14	2016	60.20
15	2017	43.10

5 HYDROLOGICAL ANALYSIS

5.1 General

Hydrological data analysis is the main task of hydrological study for the determination of peak discharges for design of the Weir and hydraulic structures and for the estimation of water resource potential of the river which is vital for the optimization of the resource versus the water demand for the command area. To undergo this process it is mandatory to obtain these values, the flow record for as many years as possible is needed that In areas like the project area where there is no standard gauging stations or in the absence at all due to the effect of under-development it is evident that correlation of rain fall with catchment characteristics is to be worked out.

Therefore in order to come up with peak discharge ,hydrologic analysis to be made using rainfall and watershed characteristics for the rainfall-runoff relationships which depends size, shape, relief ,channel characteristics, soils, vegetation cover and land use pattern has to be dealt.

5.2 Rainfall Data Analysis

5.2.1 Check for outliers of yearly and Daily maximum rainfall

In order to check the reliability of data, outliers should be checked. The formula used to check outliers is:-

Where, XH = Higher outlier

$$XH = e^{\bar{y}} + Kn \; Sy$$

$$XL = e^{\bar{y}} - Kn \; Sy$$

XL = Lower outlier

Y = Mean annual rainfall (Log)

S_Y = Standard deviation (Log)

K_n = Tabular value in function of number of records

The metrological data has no outlier to deal with . for more detail see on annex volume

5.2.2 Check for Variance Of annual rainfall

After checking the outliers and consistency, the data should be checked for variability.

For Misrar teli annual rainfall, the variability of the data used the formula is:-

$$\alpha = \frac{\partial n - 1}{P\sqrt{N}}$$

$$\alpha = \frac{14.31}{544.98\sqrt{15}} = 0.00678$$

Where, 2n-1 = standard deviation (14.31)

N = No of recorded data (N=15)

P = Mean rainfall (544.98)

Hence, since $\alpha<0.1$ the data show no variability.

5.3 Selection of Return period

The design point rainfall can be selected based on the suitable return period. The return period design frequency of any scheme depends mainly on type or standard of the structure, the economic status of the project area, the degree of risk to be accepted, and the importance of the structure. In most practical applications for Weirs, a return period of 50 years is proposed.

5.4 Estimation of Design Rainfall

To calculate design storm of certain-years return period and thus to estimate the maximum possible flood (design flood) from the watershed of the project site, different statistic methods are used and the best fit distribution is taken. Daily maximum amount of precipitation for 15years (from the mekelle meteorological station) was collected and analyzed by Hydro frequent and SMADA software's. We found Gumble extreme type 1 distribution to be a best fit for this site.

5.5 Design Flood Estimation

Design flood for un-gauged catchments can be determined using different empirical formula, which correlates catchments size, land cover, slope, soil texture etc and rainfall parameters. Even though formulas, which maximize measured input parameters are believed to simulate the local situations, in the absence of such measured data formulas developed for local situations shall be given next priority. Therefore, design flood estimation for this project is carried out by using the following three methods i.e:-

I- Tekeze basin formula

II- Dr. Admasu method

III- Composite hydrograph method

Exceedance Probability	Return Period	Calculated Value	Standard Deviation
0.9950	200.0	110.5080	19.3090
0.9900	100.0	100.9521	16.8768
0.9800	50.0	91.3611	14.4477
0.9600	25.0	81.6988	12.0200
0.9000	10.0	68.6743	8.8072
0.8000	5.0	58.3660	6.3751
0.6670	3.0	50.1793	4.6272
0.5000	2.0	42.7967	3.4251

5.6 Peak Flood Estimation Using Tekeze Basin and Dr. Admasu

Both Tekeze basin and Dr. Admasu empirical formula are some of regional approach empirical formula developed peculiar to high lands of our country.

5.6.1 Flood estimation developed for Tekeze basin

From the empirical formula developed for Tekeze basin

$q = 33.3A^{-0.609}$

For catchment area of 322km^2

Where: - q =discharge intensity

$q = 1.69$A=catchment area in km^2

Then, Q=1.69*322 = 544.18m3/sec

5.6.2 Flood estimation for Ethiopian highlands

Dr. Admasu established this equation for estimating the maximum daily and instantaneous flow based on regionally determined factors such as Catchment size and slope.

Using Dr. Admasu empirical formula

$$Q_{ip} = cf\ Q_{md}$$

Where, $Q_{md} = 0.87\ (A)^{0.7} = 0.87^*\ (322)^{0.7} = 49.54$

$$C_f = 1+5\ (A)^{-0.2} = 1+5\ (322)^{-0.2} = 2.57$$

$$Q = 49.54 \times 2.57 = 127.6\ m^3/s$$

5.7 Peak Flood Estimation Using The Scs Method

The flood peak and the time distribution of runoff from a drainage basin during a rainfall depend on the meteorological conditions and physical characteristics of the basin. The United States Bureau of Reclamation (USBR) developed a relationship between rainfall and runoff from soil and land cover data. This method is known as Curve-Number Method (CN-Method). The method can predict, with reasonable degree of accuracy, the flood peak and its time distribution for small catchments area (50 to 700 km^2). Due to its wide usability, popularity and ability to incorporate different scenarios we have used this method for further analysis.

5.8 Estimation of the Time of Concentration

The time of concentration is the time it takes for flow to reach the basin outlet from the hydraulically most remote point on the watershed. For the Misrar Teli catchment basin, the hydraulically remote point is the starting point of the stream from the outlet (Weir site).

The River is divided in to thirty one reaches from the proposed out let towards upstream (See table 5). The time of concentration for each reach is estimated. The total time of concentration from the remotest end (along the longest river route) to the out let is estimated by summing up the flow time for the thirty one segments (reaches) towards the out let.

There are different formulas to estimate the time of concentration. However, for this case the relation developed by Kerpitch (1940) is considered:

Tc= (TC= (1/3000)*(L/(S) ^0.5) ^0.77)

Where Tc = the time of concentration (hours)

L = maximum length of flow (m)

S = Channel slope (m/m)

Table 5, Results of the time of concentration

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(hr)**
1	0	2460	0	0	0	0
2	179	2440	20	11.17318	0.111732	0.042075322
3	2904	2420	20	0.688705	0.006887	1.051340232
4	1794	2400	20	1.114827	0.011148	0.602763733
5	1534	2380	20	1.303781	0.013038	0.503049229
6	2181	2360	20	0.917011	0.00917	0.755317402
7	2205	2340	2205	100	1	0.125113266
8	1273	2320	20	1.571092	0.015711	0.405563632
9	3148	2300	20	0.635324	0.006353	1.154017256
10	956	2280	20	2.09205	0.020921	0.291347343
11	1167	2260	20	1.713796	0.017138	0.366816646
12	635	2240	20	3.149606	0.031496	0.181629275
13	37	2220	37	100	1	0.005375193
14	1620	2200	20	1.234568	0.012346	0.535762162
15	836	2180	20	2.392344	0.023923	0.249534413
16	1115	2160	20	1.793722	0.017937	0.348004347
17	659	2140	20	3.034901	0.030349	0.189581018
18	555	2120	20	3.603604	0.036036	0.15546785
19	1365	2100	1365	100	1	0.086483028
20	1559	2080	20	1.282874	0.012829	0.512530199
21	1236	2060	20	1.618123	0.016181	0.391979659
22	1794	2040	20	1.114827	0.011148	0.602763733
23	50	2020	20	40	0.4	0.009644785

Reach	Length (m)	Elevation (m)	Elevation Difference (m)	Slope (%)	Slope (m/m)	Time of concentration
24	142	2000	20	14.08451	0.140845	0.032201436
25	3318	1980	3318	100	1	0.171377404
26	2346	1960	20	0.852515	0.008525	0.82169576
27	2350	1940	20	0.851064	0.008511	0.823314147
28	369	1920	20	5.420054	0.054201	0.097028127
29	2303	1900	20	0.868432	0.008684	0.804325236
30	834	1880	20	2.398082	0.023981	0.248845038
31	196	1870	196	100	1	0.019405102
						11.58

The total time of concentration for the basin is: the summation of the segment travel time. The Time of concentration is calculated and used in the complex hydrograph flood determination. The Time of concentration calculated is 11.58hr.

5.9 Design Flood selection

In or near the project area there is no hydrological stream gauge but, there is meteorological stations data available. Using this limited data and the watershed characteristics such as catchment type and size, slope of the river bed, soils and vegetation cover are considered to calculate the MPF by applying empirical formula. The slope of the watershed was estimated from topographical map of scale 1:1000000 and 20m contour intervals. Moreover the size and type of watershed coverage was determined from aerial photographs of scale 1: 1000,000 and from intensive site visits. To determine the weir dimension, a recurrence interval of 50 years was used and SCS method was adopted. The design flood for the design of the weir is estimated by using HEC-HMS software. Therefore a design flood of **220m³/s** is taken for the Design of the weir.

6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Hydrology Extension was developed for determining hydrologic parameters of watersheds, and peak flows for return periods of 50 years. An extreme peak flow distribution in the site for events with recurrence period of 50 years is used. Gumble extreme type I distribution using the statistical analysis was performed of the meteorological rainfall data for estimating extreme peak discharge as maximum daily rainfall, rain intensity and flood peak flow in Misrar teli.

7 REFERENCE

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8 Appendix

Peak flood analysis parameters

Peak flood Analysis			
Step	**Parameters**	**Unit**	**Value**
1	Catchment Area	**Km^2**	**322**
2	Length of main river	**M**	**40660**
3	Time of concentration, Tc	**Hr**	**11.58**
4	Rain fall excess duration, D = Tc/6	**Hr**	**1.95**
5	Time to peak, Tp= 0.6 Tc + 0.5 D	**Hr**	**7.913**
6	Time base of hydrograph, Tb = 2.67Tp	**Hr**	**20.5738**
7	Peak rate of discharge created by 1mm runoff excess on the whole of the catchment, Tp, Qp = (0.21* A) / Tp	**Cumec/mm**	**8.54**
8	Lag time, te= 0.6 Tc	**Hr**	**6.948**

Consistency check

S.no.	**Year**	**Annual Rain fall**
1	2003	27.40
2	2004	36.30
3	2005	56.30
4	2006	34.00
5	2007	78.80
6	2008	55.80
7	2009	55.00
8	2010	34.00
9	2011	52.50
10	2012	38.00
11	2013	30.20
12	2014	36.50
13	2015	34.00
14	2016	60.20
15	2017	43.10
N	15	

Consistency check

Mean x	44.81
st.dev s	14.31
N	15
Consistency (k)	0.082
K<0.1 =ok	ok !

Outlier check

S.no	*Year*	*Rainfall (x)*	*y=logx*	*(y-Y)^2*	*(y-Y)^3*	*higher*	*lower*
1	2003	27.40	1.437750563	0.045622	-0.009744407	ok	ok
2	2004	36.30	1.559906625	0.008361	-0.000764455	ok	ok
3	2005	56.30	1.750508395	0.009834	0.000975181	ok	ok
4	2006	34.00	1.531478917	0.014367	-0.001722119	ok	ok
5	2007	78.80	1.896526217	0.060115	0.014739208	ok	ok
6	2008	55.80	1.746634199	0.00908	0.000865293	ok	ok
7	2009	55.00	1.740362689	0.007925	0.000705446	ok	ok
8	2010	34.00	1.531478917	0.014367	-0.001722119	ok	ok
9	2011	52.50	1.720159303	0.004736	0.000325897	ok	ok
10	2012	38.00	1.579783597	0.005121	-0.000366432	ok	ok
11	2013	30.20	1.480006943	0.029356	-0.005029717	ok	ok
12	2014	36.50	1.562292864	0.00793	-0.000706152	ok	ok
13	2015	34.00	1.531478917	0.014367	-0.001722119	ok	ok
14	2016	60.20	1.779596491	0.016449	0.002109654	ok	ok
15	2017	43.10	1.63447727	0.000284	-4.79719E-06	ok	ok
N	15						

Rainfall (x)
27.40
36.30
56.30
34.00
78.80
55.80
55.00
34.00
52.50
38.00
30.20
36.50
34.00
60.20
43.10

S.no	Year	Rainfall (x)	y=logx	(y-Y)^2	(y-Y)^3	higher	lower
		Total	24.4824	0.2479	-0.0021		
		N	15				
			Mean Y	1.63			
			St. Deviation	0.1316			
			Coeff. Skew	0.434			

	Rainfall (x)	
N	15	
Total	672.1	
Mean	44.81	1.65
Stdv.	14.31	
Coffe. Var.	0.297	
Stand. Error	7.67	< 10%
Test	Adequate data	

Outlier		Rainfall depth
High	1.93	85
Low	1.34	22

Weighted curve number

Land use type	Slope (%)	Area (km²)	Soil texture/Coverage	Soil condition	AMC-II Curve number
Cultivated land	2-8	81.25	Clay	C	81
	8-15	110.56	Clay	C	82
	15-30	39.29	Clay loam	B	74
Grazing land	8-15	0.34	Clay loam	B	69
	15-30	29.90	Clay loam	B	79
	30-50	7.95	loam	B	79
Forestland (area closures)	8-15	0.73	Clay loam	B	60
	15-30	0.49	loam	B	60
	30-50	0.46	silt loam	A	36
	>50	0.89	silt loam	A	36
Homesteads	2-8	24.70	towns/hard surface	D	86
	2-8	1.76	Clay	C	82
	8-15	13.37	towns/hard surface	D	86
	8-15	1.75	Clay loam	B	74
	15-30	1.81	towns/hard surface	D	86
	15-30	3.26	loam	B	74
Miscellaneous land	___	4.17	Rock outcrops	D	92
Total		**322.68**			80.6

HEC-HMS result