Islamic Emirate of Afghanistan

MINISTRY OF WATER AND ENERGY
DEPUTY OF WATER
GENERAL DIRECTORATE OF ENGINEERING SERVICES OF WATER
DIRECTORATE OF SURVEY AND DESIGN
DEPARTMENT OF DAM, CANAL AND RIVER PROTECTION PLANNING & DESIGN





PRE-FEASIBILITY STUDY REPORT
ZAMBAR DAM , KHOST PROVINCE
MAY 2025

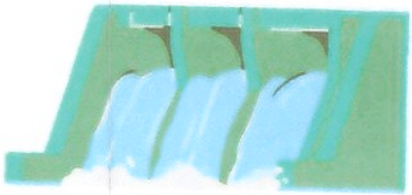
DEPARTMENT OF DAM DESIGN CANAL AND RIVER PROTECTION

• DAM DESIGN TEAM •

Islamic Emirate of Afghanistan
Ministry of Energy and Water
Directorate of Survey and Design of Water Infrastructure

80 Pages

DEPARTMENT OF DAM DESIGN CANAL AND RIVER PROTECTION



• DAM DESIGN TEAM •



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Executive Summary:

The Ministry of Energy and Water (MEW) in the Islamic Emirate of Afghanistan is intending to utilize national development funds to finance consultancy services to improve the technical capacity of the Ministry through a major on-the-job training program, whilst at the same time undertaking surveys, detailed designs and the preparation of tender documents for a number of small dams, mini-hydropower installations and other infrastructure.

The Islamic Emirate of Afghanistan is currently rehabilitating and constructing new water resources infrastructure in the provinces, through the local authorities and other agencies.

The intention is to target small dams and water resources projects with localized benefits and minimal negative environmental and social impacts. In addition, it is anticipated that the works will be funded by the GoA, consequently.

Khost province. Its geographical coordinates at the dam axis and river bed are N33° 34' 47.70", E69° 52' 27.44" and at an altitude of about 1421 MASL

The total catchment area of the Zambar Dam Site is 45.24 km^2. The reservoir volume at Maximum Level is 1.08 Mm3. The reservoir volume will reduce to 0.722 Mm3 after 50 years of service due to sedimentation for 32-meter Dam Height with Foundation.

Since rock is the abundantly available material around the site and its use will pose minimal social and environmental impacts, and based on the actual physical/ engineering characteristics of the site, all two dams' gravity dam and dam embankment dam types are found to be suitable dam types. Embankment type is recommended at this preliminary level. The rock material can be borrowed from the reservoir area upstream of the dam site. However, the rock engineering characteristics shall be checked in subsequent studies. The final design shall be based on the actual laboratory and detailed field investigation results.

The project area is generally mountainous and valley; hence irrigation development potential and Drinking Water were available in the valley adjacent to the river banks. The proposed irrigable land including the river course is located in the low-lying area from the dam axis. The available irrigable land from 5 m resolution DEM is 3708 ha. The irrigable lands are available both left and right sides of the river, except, there are locations where river runs very close to one edge of the valley. This causes discontinuity among the agricultural lands in each side of the river. The cropping pattern for the project is worked out in two seasons considering that the farmers practice will be improved and follows proper cropping system management. The Total Cost of the proposed project works is Afg **174.6** million. the mean Prepose of dam is Flood mitigation, Irrigation and Water supply.

The MEW is expected to review the pre-feasibility of the Zamar Dam site and provide any comments they may wish to make. After agreement on the prefeasibility report the Design team will then proceed with the Feasibility and detailed designs of the project. **Recommendations**, Detailed geotechnical, and Geological investigation are required for the next stage which needs boreholes and laboratory detail reports to be submitted for the Feasibility and detail Design stages.

Summary table:

1	Coordinates: N33° 34' 47.70", E69° 52' 27.44"
2	Structure type is Storage Dam for Flood Control, Irrigation, ground water recharging and Water Supply
3	Irrigable area after construction of the project is about 1180 ha.
4	The project cost is estimated about Afg 174.6million.
5	Total beneficiaries of the project are estimated about 3500 Families.

List of Acronyms/ Abbreviations

Table 1: Acronyms

AMA:	Afghan Meteorological Authority
B:	Dam crest width
CLIMWAT:	FAO's climate database
CN:	Curve Number
DEM:	*Digital Elevation Model*
DS:	Down Stream
DSL:	Dead Storage Level (In the reservoir)
ETO:	Crop Reference Evapo-transpiration
FAO:	Food and Agricultural Organization of the United Nations
GIS:	Geographical Information System
GoA:	Government of Afghanistan
H:	Dam height
HEC:	Hydrologic Engineering Center of United States
HMS:	Hydrologic Modeling System
Kc:	Crop Coefficient
Lf:	Reservoir Fetch Length
MAR:	Mean Annual Runoff
MEW:	Ministry of Energy and Water
MWL:	Maximum Water Level (In the reservoir)
NWL:	Normal Water Level (In the reservoir)
RBL:	Original River Bed Level
SCS:	Soil Conservation Service of United States
SEI:	Stockholm Environmental Institute
WEAP:	Water Evaluation and Planning model of SEI
US:	Up Stream

1. Introduction:

1.1 General Information about the Site:

The Ministry of Energy and Water (MEW) in the Islamic Emirate of Afghanistan is intending to utilize national development funds to finance consultancy services to improve the technical capacity of the Ministry through a major on-the-job training program, whilst at the same time undertaking surveys, detailed designs and the preparation of tender documents for a number of small dams, mini-hydropower installations and other infrastructure.

The Islamic Emirate of Afghanistan is currently rehabilitating and constructing new water resources infrastructure in the provinces, through the local authorities and other agencies.

The intention is to target small dams and water resources projects with localized benefits and minimal negative environmental and social impacts. In addition, it is anticipated that the works will be funded by the GoA, consequently.

The water resources sub-projects could include flood protection works and associated infrastructure and in such cases the scope of the work shall be comparable with a small dam project.

1.2 Project Location:

Khost Province is situated in the southeastern part of Afghanistan, bordering Pakistan. It is characterized by the Khost Valley, which is a lower elevation area surrounded by higher mountainous terrain, providing it with more moderate weather conditions compared to the surrounding highlands. Khost consists of thirteen districts and has a diverse geography that influences its climate and environment.

Khost is bordered to the southeast by Pakistan, making it strategically important. It lies approximately 150 kilometers southeast of Kabul.

and is located between 33°59 ′ and 33°46 ′ North latitudes and 69°19 ′ and 70°21 ′ East longitudes to study this project a team comprising from MEW has visited the site. The site visit of Zamar Dam site in Khost province. The Zambar Dam is located 46 kilometers from the center of Khost province in the Sebri district of the village of Zambar.

and the geographical coordinates of the selected site are latitude 33° degrees 34' minutes and 47.70" seconds North and located at longitude 69° degrees 52' minutes and 27.44"seconds Eastern.

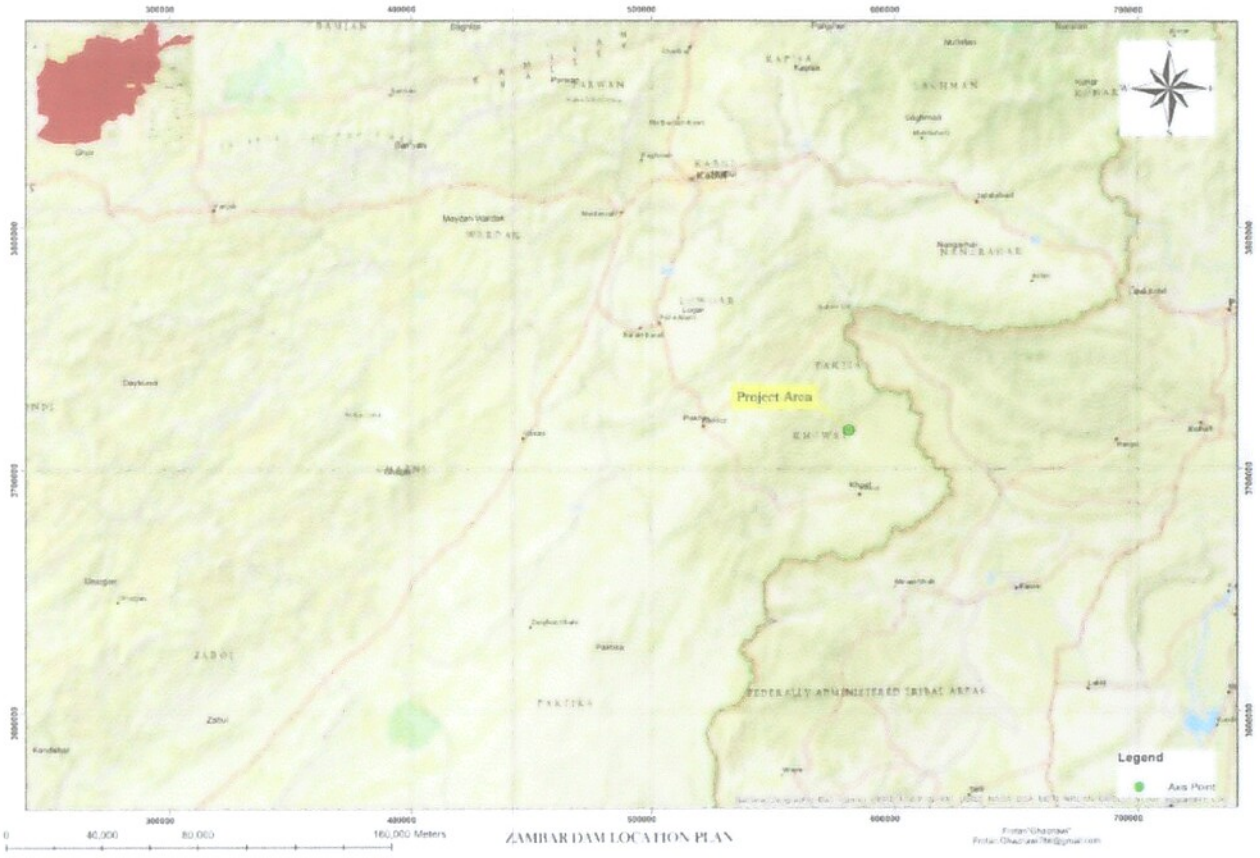


Figure 1 Zambar Dam Site Location Map

2. Dam Site Assessment: Hydrology:

2.1 Catchment Characteristics

The proposed area of the Zambar dam is located above the seasonal Zambar River, which is considered a tributary of the northern river. The water of this river is seasonal. Its water sources include snow, rain, and springs that originate from the mountains of Liji, Miyanoor Dara, Defa Marcha, Shena Dand Dara, Ghondi Dara, Serka Watha, Tagha Saruna, Paka, Arghun, Jawa, and Gulghondi.

During the reconnaissance study, the area has relatively low vegetation, which helps prevent soil erosion and damage to agricultural and non-agricultural lands during flood events. Snowfall in these areas is less compared to other parts of the country, and it remains on the ground for a short duration. In the high altitudes, the snow thickness is about 50 centimeters. Khost province has a relatively warm climate, and rainfall often occurs intermittently. Both forms of precipitation, which supply water resources, are particularly important and should be used wisely and appropriately in every aspect of life.

Zambar Dam is located at coordinates of 33° 34' 47.606" N and 69° 52' 27.81" E. The catchment area to the dam site is about 45.24 km^2. The catchment area is delineated from DEM 5×5 meter using Arc GIS software as shown in Figure 10. The dam site is located at an altitude of about 1450 m but the catchment extends upstream above 2750 m.a.s.l. The mainstream length of the dam site is about 6.53 km.

The hydrological analysis deals with the study of the hydrometeorological characteristics of the basin and the methodology adopted for establishing various hydrometeorological parameters required for the project design. The hydrological studies for the Zambar Dam project have been conducted to:

- Assess the availability of water for irrigation by establishing a long-term series of average monthly discharge for the project site
- Prepare Reservoir Elevation-Area-Capacity curve for determining the capacity of the reservoir and the area of submergence
- Flood frequency analysis for different return periods and estimating the design flood
- Develop the rating curves at different elevations
- Study the reservoir sedimentation

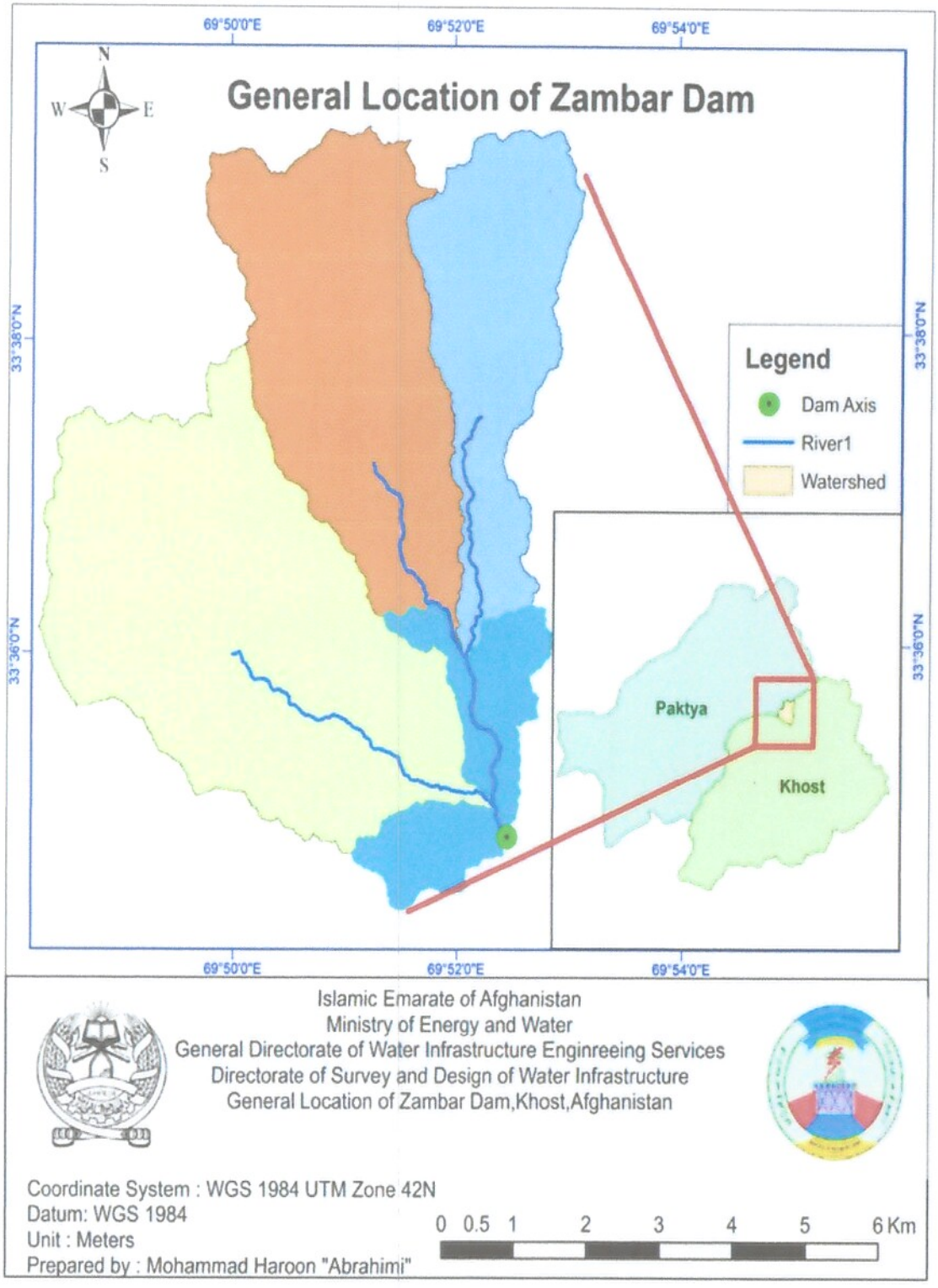


Figure 2 General Location of Zambar Dam

2.2 3.2 Climate

Afghanistan is located within the triennial subtropical dry regions of southwestern Asia which is characterized by a desert-steeper precipitation regime. Annual mean rainfall is generally very low. The closest meteorological station to the project area is Maton station with an elevation of 1177 meters and its coordinates are 33.3505° N and 69.9398° E. According to the data obtained during the 12 years between 2013 and 2024, the maximum recorded temperature is 42.5C°and the minimum temperature is -5.8 C°. At the same period, the mean annual precipitation is calculated as 517.2 mm.

2.3 Temperature

The nearby meteorological station operated by MEW is Maton Which is located at an altitude of 11771m.a.s.l. The max monthly temperature is shown in Table 1 and the min monthly temperature of the stations is shown in Table 2.The monthly minimum air temperature recorded by the Maton Hydrometeorology station between 2013 to 2024 is -5.8 C° which was recorded in December 2013 while the Max temperature was measured in June 2021 as 42.5°C.

Table 1 Monthly Max Air Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	17.9	17.7	24.8	27.8	38.0	38.8	36.3	33.4	32.4	31.3	23.8	24.0
2014	18.8	18.5	23.2	32.8	32.6	35.7	36.8	35.7	32.6	31.1	23.7	21.8
2015	20.3	25.8	27.1	33.1	36.0	34.9	37.7	35.5	32.6	31.8	22.2	23.2
2016	18.0	26.5	26.5	33.0	37.8	37.9	38.3	34.4	33.8	30.8	25.4	23.8
2017	22.0	21.0	28.0	34.8	38.6	42.4	36.2	34.5	33.8	32.4	25.3	21.6
2018	21.5	20.8	31.3	34.1	37.3	40.9	38.5	35.6	36.0	30.1	23.6	21.5
2019	15.5	15.6	24.9	30.3	35.0	37.1	37.3	35.3	35.7	28.6	24.1	20.0
2020	14.6	23.0	22.2	28.1	38.5	38.1	38.3	36.0	34.1	30.1	26.3	23.6
2021	21.0	22.2	29.5	32.1	37.6	42.5	39.9	34.8	34.9	33.1	26.3	21.2
2022	16.7	20.5	31.2	36.2	37.9	39.3	35.8	34.0	32.7	29.8	24.9	20.8
2023	17.8	23.0	26.1	31.8	36.2	39.8	36.3	37.2	35.9	33.0	23.9	21.4
2024	19.2	21.1	26.3	27.5	38.8	39.3	38.7	36.4	36.3	35.0	29.9	18.6

Table 2 Monthly Min Air Temperature Data at Maton Hydro-Meteorological Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	-0.7	1.80	3.50	10.9	13.4	17.9	18.5	18.9	17.7	10.4	6.70	-5.8
2014	-1.6	-1.0	3.40	8.90	7.46	12.2	13.6	13.9	14.6	11.0	6.60	1.10
2015	-1.1	1.60	0.50	8.90	12.0	11.5	18.4	17.3	15.3	8.10	5.60	-0.5
2016	2.30	2.10	6.80	9.80	13.7	19.0	18.3	18.5	15.1	11.9	6.20	4.50
2017	-1.7	0.00	1.80	7.30	14.8	18.9	19.9	18.0	15.4	12.7	4.70	0.30
2018	1.80	0.80	7.60	8.60	14.0	18.7	18.8	18.1	15.5	11.6	6.80	1.90
2019	-1.1	0.10	0.30	10.2	11.7	16.2	19.7	20.2	19.2	11.9	-1.9	1.60
2020	-0.5	0.60	3.90	8.10	14.4	16.2	18.2	19.5	14.4	10.0	2.90	-0.8
2021	1.00	3.00	8.50	9.60	14.5	19.0	18.7	16.2	18.9	8.70	7.00	0.20
2022	0.10	1.40	6.20	13.9	13.1	13.1	18.9	18.1	15.4	11.8	5.30	1.80
2023	-3.0	0.30	7.20	7.70	11.7	14.6	17.1	17.7	14.1	10.4	7.20	3.60
2024	2.70	1.00	-0.1	8.20	7.80	15.6	19.6	18.3	17.8	13.4	7.20	1.10

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Directorate of Survey and Design of Water Infrastructures

2.4 Precipitation

Monthly precipitation distribution in the studied area has been mostly rely on Maton station. Accordingly, the maximum percentage of monthly rainfall belongs to July and is equal to 20.48 percent of annual precipitation. Meanwhile, the minimum monthly precipitation belongs to December to 0.68 percent of annual precipitation. Based on the seasonal distribution of precipitation in the Maton station, Summer is the highest precipitation season of the year, which is attributed to 38 percent of annual precipitation. Meanwhile, Autumn is the lowest precipitation season of the year, which contributes to only 6 percent of annual precipitation. Average Monthly precipitation values in Maton station from 2013–2024 have been provided in Figure 3. Meanwhile, seasonal percentages in the precipitation have been provided in Figure 4.

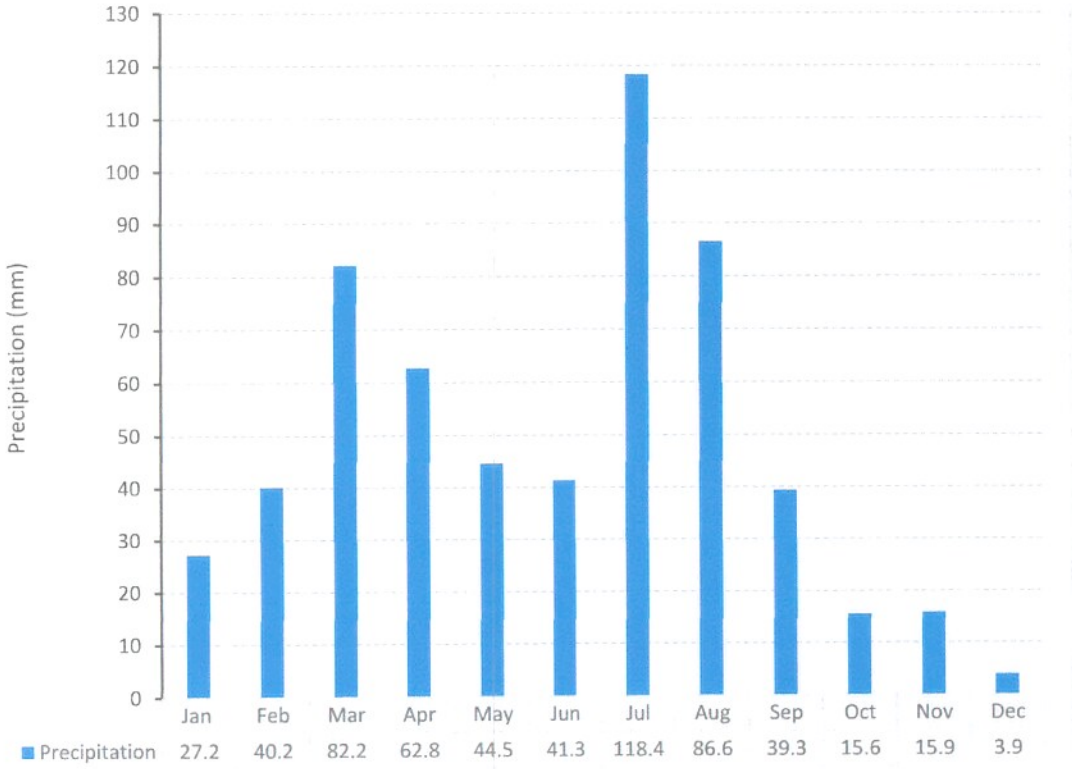


Figure 3 Mean Monthly Precipitation Recorded at Maton Meteorological Station (2013-2024)

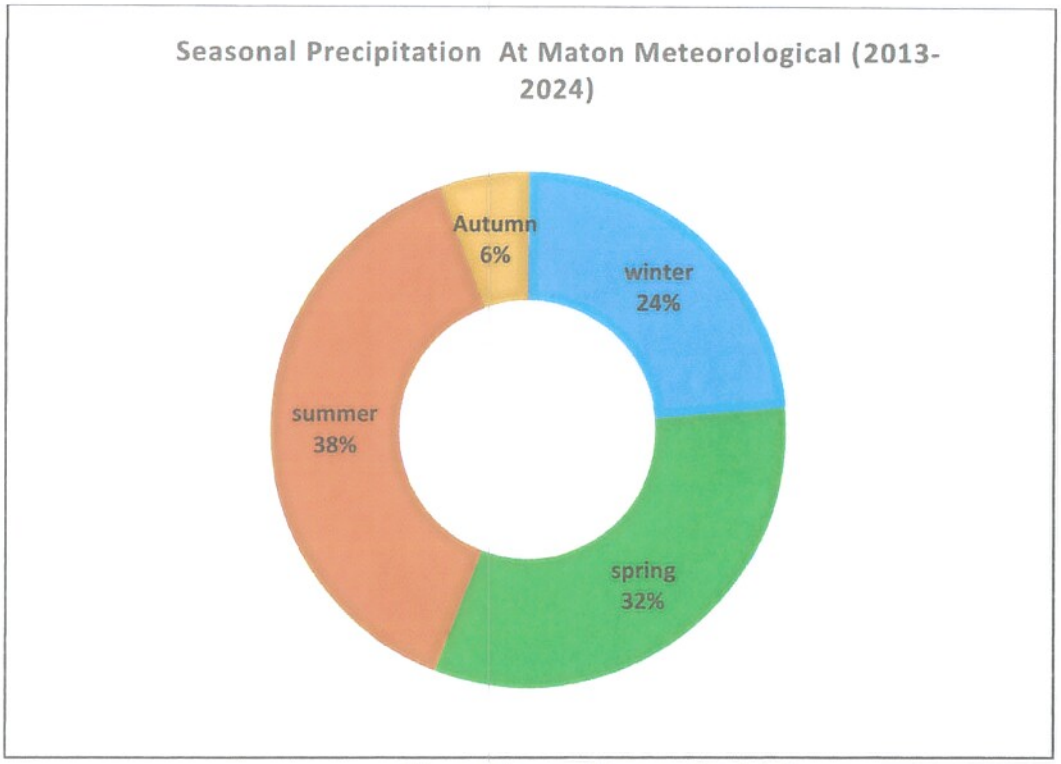


Figure 4 Seasonal Average. Precipitation

2.5 Maximum 24-hr Precipitation

The maximum hourly precipitation at Maton station Based on the existing recorded data for 13 years was 52.4 mm in 2016. The total yearly rainfall from 2013 – 2024 is tabulated below.

Table 3 Total Yearly Precipitation at Maton Station

Total Yearly Precipitation at Maton Station)	
Year	**Precipitation**
2013	432.0
2014	447.3
2015	482.6
2016	334.2
2017	404.6
2018	543.8
2019	537.4
2020	627.8
2021	459.8
2022	667.3
2023	707.4
2024	562.3

2.6 Relative Humidity

Air humidity content or existing water vapor in the atmosphere follows air temperature variations. The relative humidity indicates the ratio of the actual humidity of the air to the humidity under saturated vapor conditions (at the same temperature). Variation of relative humidity is opposite to that of temperature, so that on clear and sunshine days it has a descending trend from morning to the mid-day, with the lowest value in noon time, and an ascending trend from the afternoon to the night, with the maximum value before sunset. The values of this parameter are used in most calculation methods of the plant perspiration potential and its water requirement.

Figure 5. provides the mean monthly values at Maton meteorological station. The average relative humidity at this station is 50.4 percent, varying from 67.5 percent in July to 36.6 percent in December.

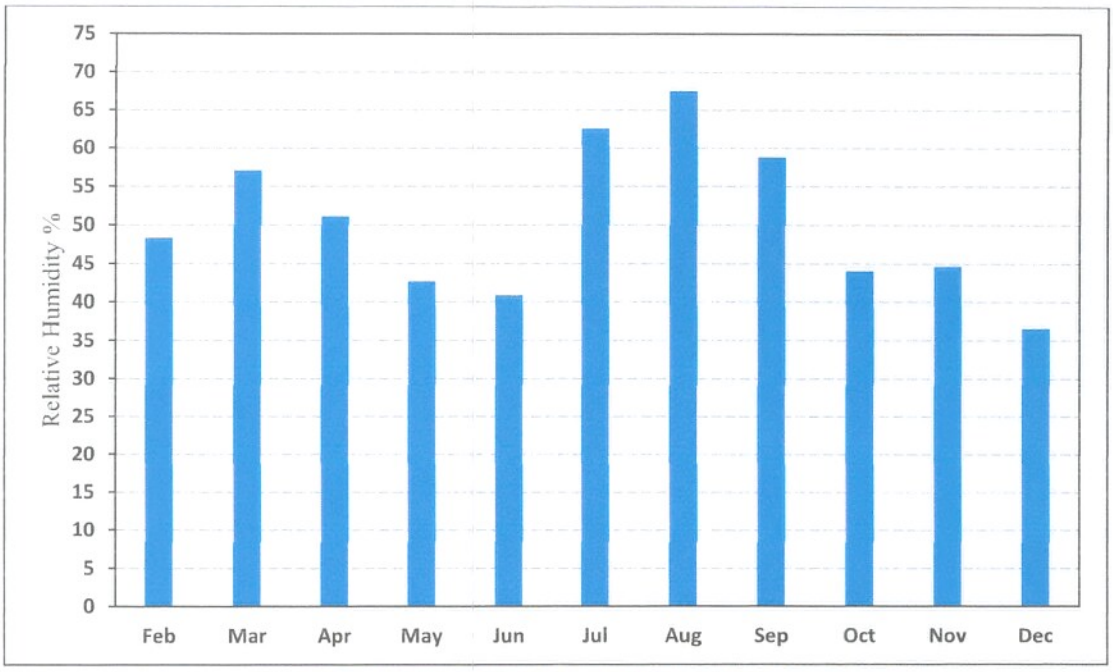


Figure 5 Average Monthly Relative Humidity at Maton Station

2.7 Land cover

The land cover data retrieved from the FAO 2016 is shown in Table 4 and Figure 6. Table 4. indicates that land cover for the study area contains Irrigation Agriculture land, Rainfed agriculture land, Forests/shrubs, Rangeland, and Water Bodies. From the table, it can be seen that Rangeland covered most of the watershed 32.61 km2 after that the Forest and Shrubs covered around 10.63 km2. The Irrigated agricultural land and Rainfed agricultural land contain less coverage of the study area.

Table 4 Land cover type for the Zambar Dam watershed

Land cover type	Area(km²)
Rangeland	32.619683
Forest and shrubs	10.634227
Rainfed agricultural land	0.06953
Irrigated agricultural land	1.010186
Water body and marshland	0.918826

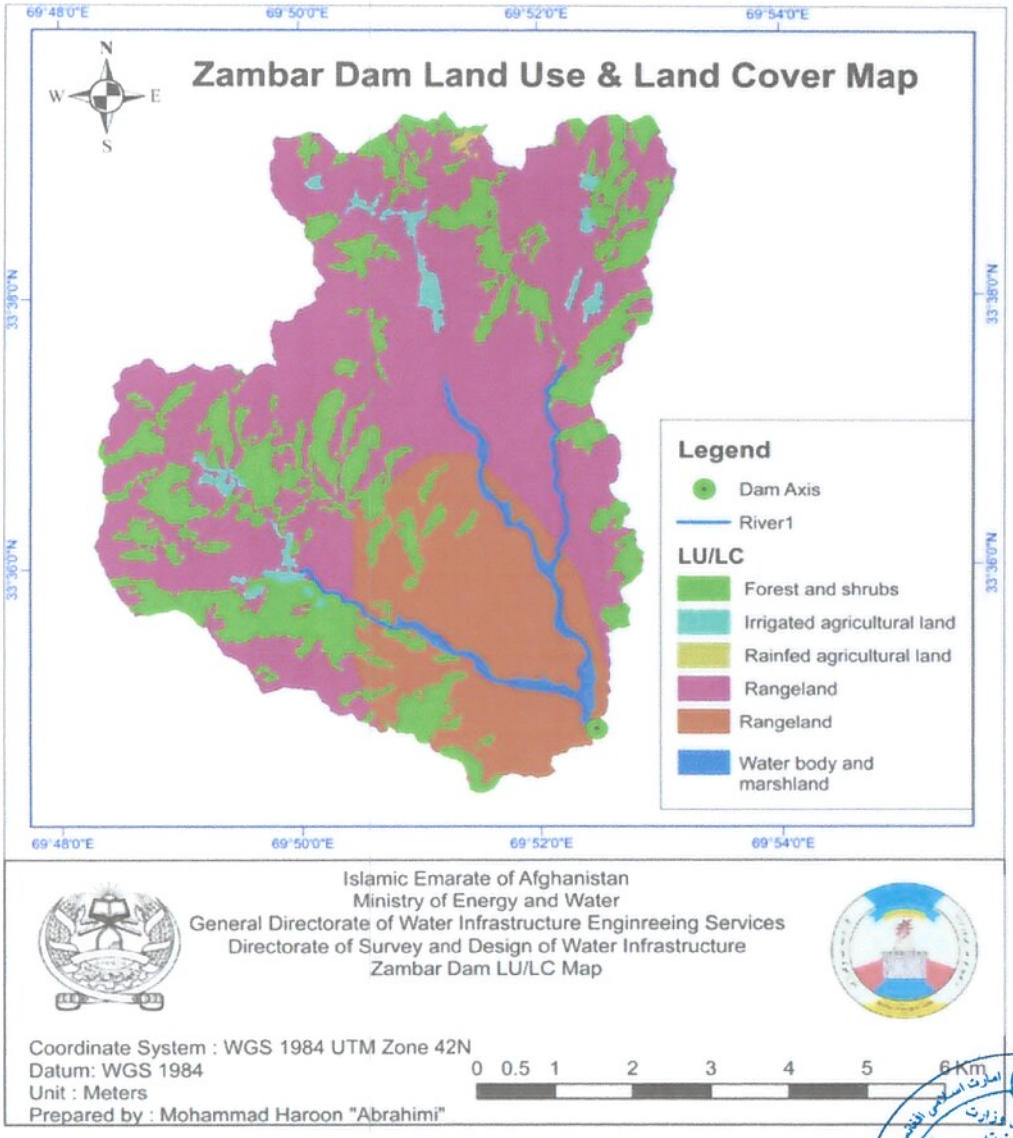


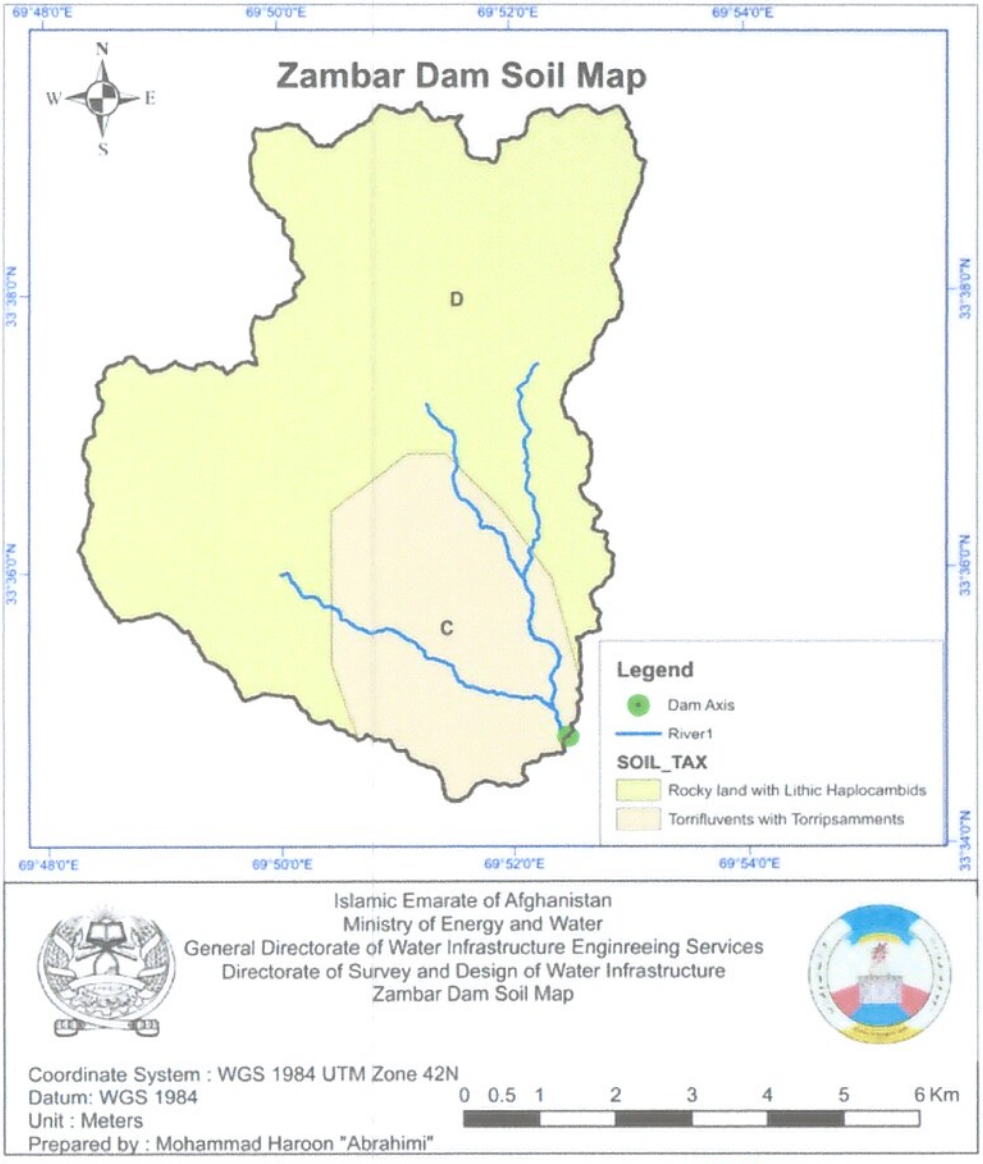
Figure 6 Land Cover Map of the Study Area

2.8 Soil

The soil resource data of the basin are classified into different hydrologic soil groups by ArcGIS based on using lookup tables. Hydrologic soil groups are groups of soils having similar runoff potential under similar storm and cover conditions. A hydrological soil group was assigned for each soil type which was later used for the computation of Curve Number (CN) to be used in the SCS method of runoff estimation.

The hydrologic group designation for any soil type can be either A, B, C, or D, where the runoff potential increases from A to D. The soil of the Zambar dam watershed includes Rocky land with lithic Haplocambids and Torrifluvents with Torripsamments which are shown with it is related HSG in figure 7.

Figure 7 Zambar Dam Soil Map



2.9 Estimating CN Values for Each Sub-Basin

To convert the rainfall data to the runoff data, the SCS curve number method was used. CN map was prepared by integrating the maps of land use/cover and hydrologic soil groups in Arc GIS 10.4.1 software.

The objective is to use soil and land use/cover data to create a curve number grid using Arc GIS.The land use land cover data of the basin, along with the soil information obtained has been used while producing the polygon runoff curve number for the entire sub-basin. Later the CN values were summarized to a single mean value for each sub-basin using the spatial analysis tools.

The Zambar watershed originally had 5 different land use land cover classes. The majority of cells represent Rangeland followed by Forest and shrubs, Irrigated agricultural land, and then water bodies.

By considering the average value for recommended hydrologic soil groups with land use value for the normal condition, the CN lookup table is prepared to generate the curve number of the watershed which is shown in Table 5, and the Curve number grid is shown in Figure 8.

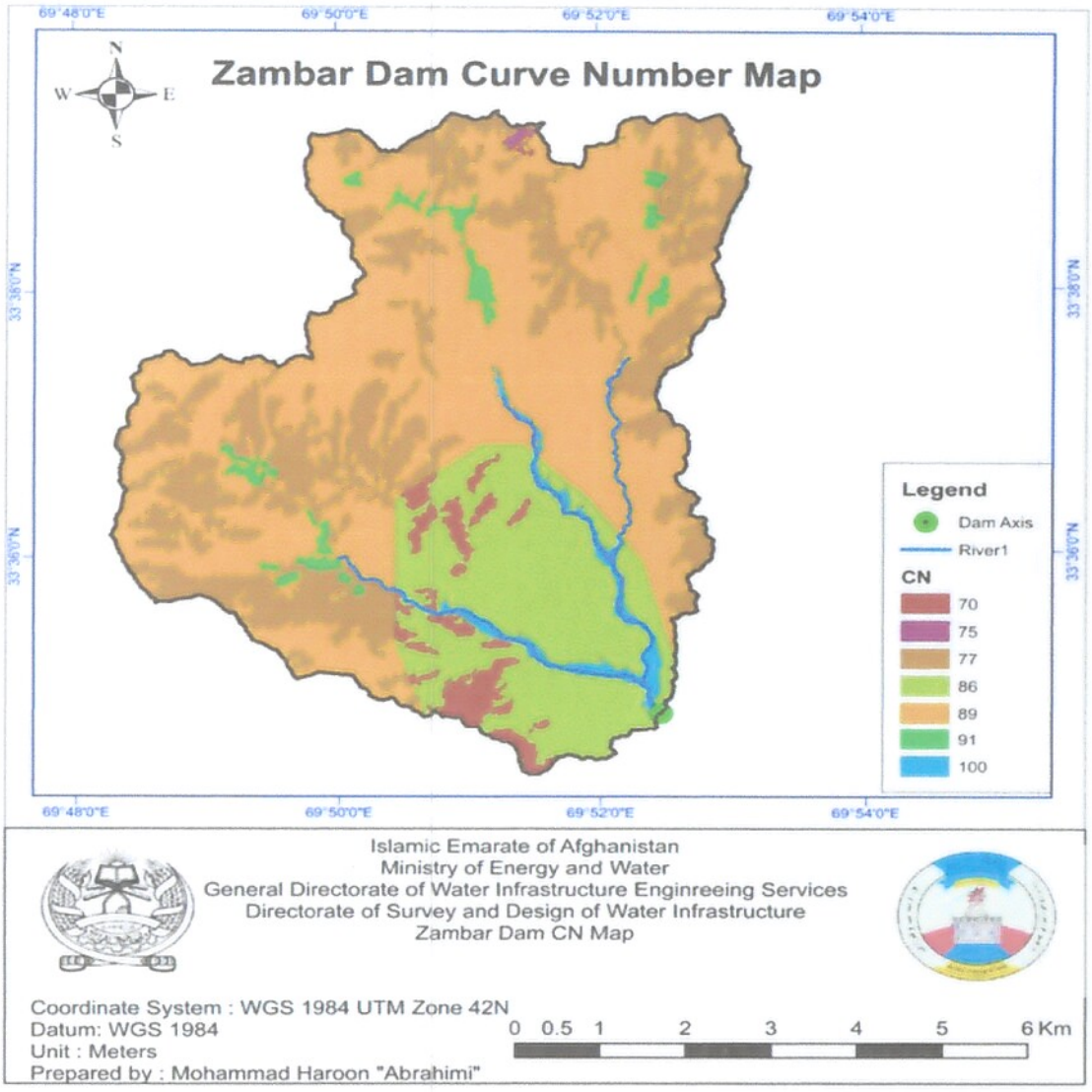


Figure 8 Zambar Dam Curve Number Map

Table 5 Average CN For Each Subbasin

Sub Basin	Land Use/Land Cover	Area(km^2)	HSG	CN	CN Average
W60	Rangeland	5.46	D	89	85.66
	Rangeland	0.09	C	86	
	Forest and shrubs	2.35	D	77	
	Irrigated agricultural land	0.23	D	91	
	Water body and marshland	0.02	C	100	
W70	Rangeland	9.33	D	89	87.26
	Rangeland	0.93	C	86	
	Forest and shrubs	1.81	D	77	
	Forest and shrubs	0.06	C	70	
	Rainfed agricultural land	0.07	D	75	
	Irrigated agricultural land	0.39	D	91	
	Water body and marshland	0.11	D	100	
	Water body and marshland	0.15	C	100	
W80	Rangeland	8.30	D	89	84.48
	Rangeland	5.00	C	86	
	Forest and shrubs	4.79	D	77	
	Forest and shrubs	1.17	C	70	
	Irrigated agricultural land	0.39	D	91	
	Water body and marshland	0.33	C	100	
W100	Rangeland	0.65	D	89	86.19
	Rangeland	2.86	C	86	
	Forest and shrubs	0.27	D	77	
	Forest and shrubs	0.18	C	70	
	Water body and marshland	0.31	C	100	

2.10 Time of Concentration and Lag Time

Time of concentration is a concept used in hydrology to measure the response of a watershed to a rain event. It is defined as the time needed for water to flow from the most remote point in a watershed to the watershed outlet. It is a function of the topography, geology, and land use within the watershed. For the calculation of the time of concentration for the Zambar dam, the Kirpich method is utilized. Lag time is defined as the time from the centroid of rainfall excess to the centroid of direct runoff. The data characteristics, t_c, and lag times for the subbasins are tabulated below in Table 6.

Table 6 Time of Concentration for Each Subbasin

No	Basin number	River Length m	L (km)	Up Elevation	Down Elevation	S	Time of Conc. (hr)	Tc (min)	T lag (min)
1	W60	7918.7	7.919	2531	1519	0.13	0.74	44.31	26.59
2	W70	8591.29	8.591	2794	1519	0.15	0.74	44.55	26.73
3	W80	10114.23	10.114	2510	1437	0.11	0.96	57.48	34.49
4	W100	4407.09	4.407	1763	1423	0.08	0.57	34.27	20.56
5	R10	3550.4	3.550	1691	1519	0.05	0.58	34.71	20.83
6	R20	3613.4	3.613	1737	1519	0.06	0.54	32.34	19.40
7	R30	5122.9	5.123	1641	1437	0.04	0.83	49.65	29.79
8	R40	2379.2	2.379	1518	1436	0.03	0.48	29.08	17.45
9	R50	540.3	0.540	1437	1423	0.03	0.17	10.36	6.22

2.11 Base Flow

Baseflow is the sustained or "fair-weather" runoff of prior precipitation that was stored temporarily in the watershed, plus the delayed subsurface runoff from the current storm. Some conceptual models of watershed processes account explicitly for this storage and the subsurface movement. For calculation of the baseflow gauge, station recording is essential unfortunately, the Zambar dam is an ungauged watershed and baseflow is considered According to Ghazni subbasin directorate staff and inquiries of the elders for each month, this river has a Maximum of 150 lit/sec from April to December and a minimum Jan to March which are shown below in Table 7.

Table 7 Base Flow for Each Month of the Year

Month	Base flow (cumecs)
Jan	0.1
Feb	0.1
Mar	0.1
Apr	0.15
may	0.15
Jun	0.15
Jul	0.15
Aug	0.15
Sep	0.15
Oct	0.15
Nov	0.15
Dec	0.15

2.12 Monthly Runoff

For the calculation of the flood water volume the HEC-HMS hourly precipitation result is exact and accurate because the input data is hourly. For the calculation of water volume for Various purposes, the hourly precipitation data and base flow are utilized.

By considering the results, the mean total annual runoff is 28.51 Mm^3 and the mean Monthly varies from 5.04 Mm^3 in July to 0.1 Mm^3 in November which is tabulated in Table 8.

year\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	0.11	1.63	1.23	0.98	0.49	0.91	1.43	2.56	0.75	0.23	0.39	0.42
2014	0.18	1.16	1.95	1.08	1.76	0.49	0.36	1.10	1.11	0.81	0.36	0.15
2015	0.42	1.03	1.60	1.07	0.34	1.42	1.63	1.51	1.63	1.22	0.55	0.20
2016	0.26	0.10	1.68	0.65	0.93	0.48	2.99	0.72	1.15	0.15	0.15	0.15
2017	0.78	1.46	0.50	0.55	0.62	1.38	1.81	1.30	0.21	0.15	0.84	0.19
2018	0.12	1.02	0.66	1.11	0.98	0.57	2.07	2.05	0.92	0.49	0.36	0.26
2019	0.63	1.05	1.90	1.88	0.80	0.66	0.91	0.65	0.50	0.47	0.78	0.21
2020	0.60	0.74	2.00	1.20	0.76	1.07	1.68	1.93	0.72	0.15	0.59	0.23
2021	0.19	0.17	1.78	0.63	0.79	0.24	3.00	1.36	0.25	0.34	0.15	0.22
2022	1.23	0.45	0.56	0.30	0.75	1.12	2.22	2.94	1.94	0.34	0.43	0.23
2023	0.33	0.57	2.12	1.32	1.63	1.85	2.97	0.59	0.92	0.60	0.31	0.15
2024	0.30	1.22	1.03	2.08	0.42	0.35	2.30	1.79	0.57	0.43	0.23	0.15
Average flow (cumecs)	0.43	0.88	1.42	1.07	0.86	0.88	1.95	1.54	0.89	0.45	0.43	0.21
Run off (Mm^3)	1.11	2.28	3.67	2.77	2.22	2.27	5.04	4.00	2.305	1.16	1.10	0.55

Table 8 Mean Monthly Runoff at Study Area

2.13 Flow Duration Curve

The Flow Duration Curve (FDC) is a critical tool that illustrates the relationship between streamflow rates and the duration for which those rates are equaled or exceeded over a specified period, typically a year. In the context of the Zambar Dam, located in Khost province, the FDC helps to understand the variability of river flows in the region. This curve visually represents how often different flow rates occur, providing essential data for effective water resource management.

By analyzing the curve, planners can identify periods of high flow that can be harnessed for irrigation purposes. This information is particularly important for agricultural regions that rely on consistent and adequate water supply to maximize crop yields. Understanding flow variability allows farmers to plan their planting and irrigation schedules more effectively, optimizing water use and improving agricultural productivity.

For the Zambar Dam, the flow duration curve has been generated using HEC SSP software (Hydrologic Engineering Center's Statistical Software Package). The results of the analysis in shown below in figure 9.

Duration Analysis
20 May 2025 01:38 PM

--- Input Data ---
Input DSS File Name: C:\Users\M.Ebrahimi\Desktop\Zambar\Estimation\HEC\flow duration curve
DSS Pathname: /inflow/data///1MON/for project/
Duration Analysis Method: Standard
Duration Plot Position Method: Rank/(N+1)
--- End of Input Data ---
Annual Duration Analysis
Number Valid Values: 105191
Minimum Value: 0.100
Maximum Value: 151.850

100	0.100
90.0	0.100
80.0	0.100
75.0	0.150
70.0	0.150
60.0	0.150
55.0	0.150
50.0	0.150
40.0	0.150
30.0	0.150
20.0	0.150
10.0	0.170
5.00	3.040
2.0	11.560

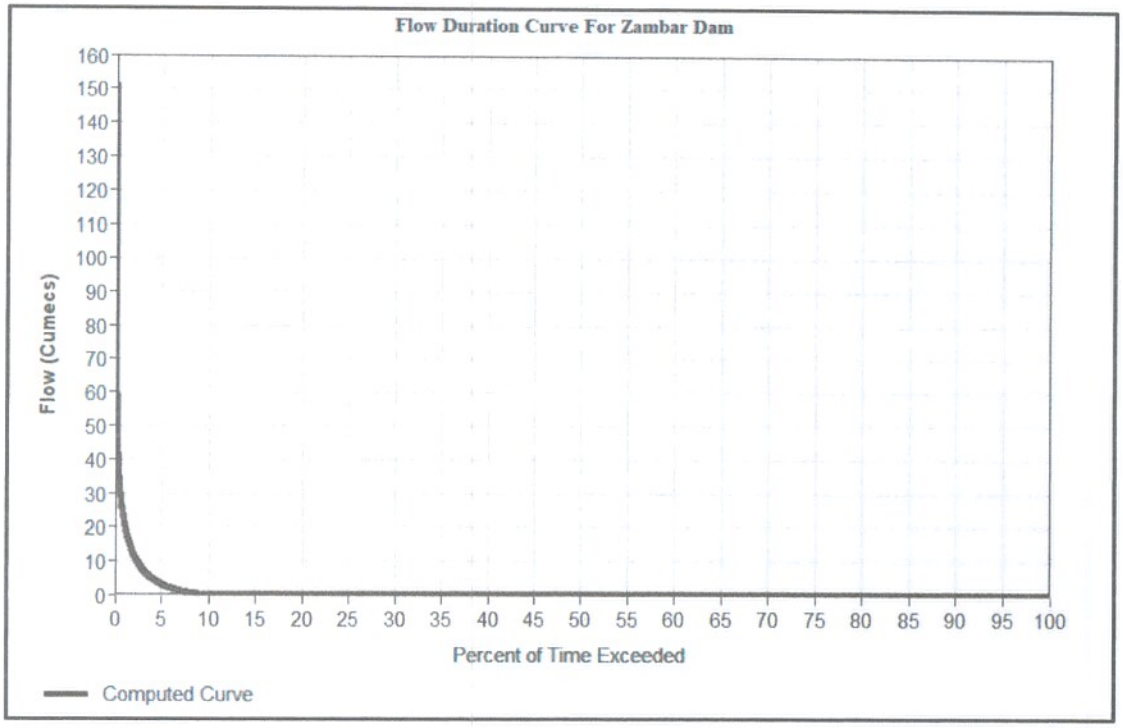


Figure 9 Flow Duration Curve at Study Area

2.14 Flood Discharges

Concerning the lack of data from the studied area, the discharge of the area is calculated from hourly rainfall with the HEC-HMS model. This stream is ungauged. In an ungauged stream, the discharge is calculated by empirical methods, catchment area ratio method, or generates models with HEC-HMS, GIS. Using the model with HEC-HMS is the best and most accurate method than others and the USACE recommends it. The model result is directly connected with input data to the model, if the input rainfall duration data is in less time, the accuracy of the model is getting high. For example; hourly rainfall data accuracy is better than daily rainfall data, and minute rainfall data is better than hourly rainfall data. Finally, we officially received the hourly rainfall data from GDoWR for the Maton meteorological station. All hydrological and metrological data that were needed in the Zambar dam model are from Maton station.

Table 9 Annual Peak Discharge

The maximum instantaneous Discharge of 151.95 m^3/sec occurred on July 13, 2016. The yearly peak discharges are tabulated below in Table 9.

Year	Maximum Discharge (Cumecs)
2013	141.93
2014	83.6
2015	138.6
2016	151.95
2017	94.44
2018	92.97
2019	119.7
2020	81.82
2021	145.23
2022	142.94
2023	133.88
2024	116.99

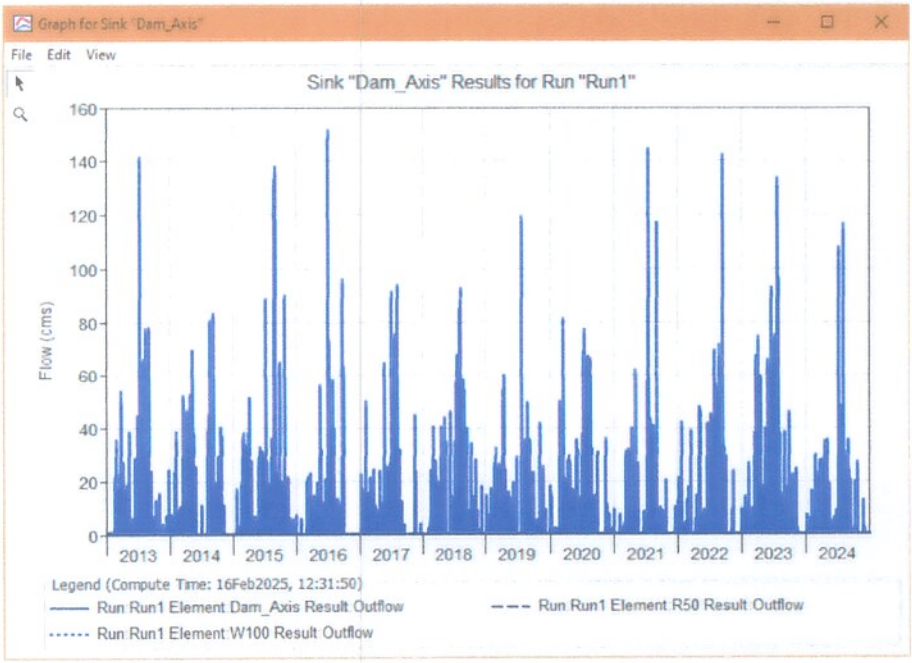
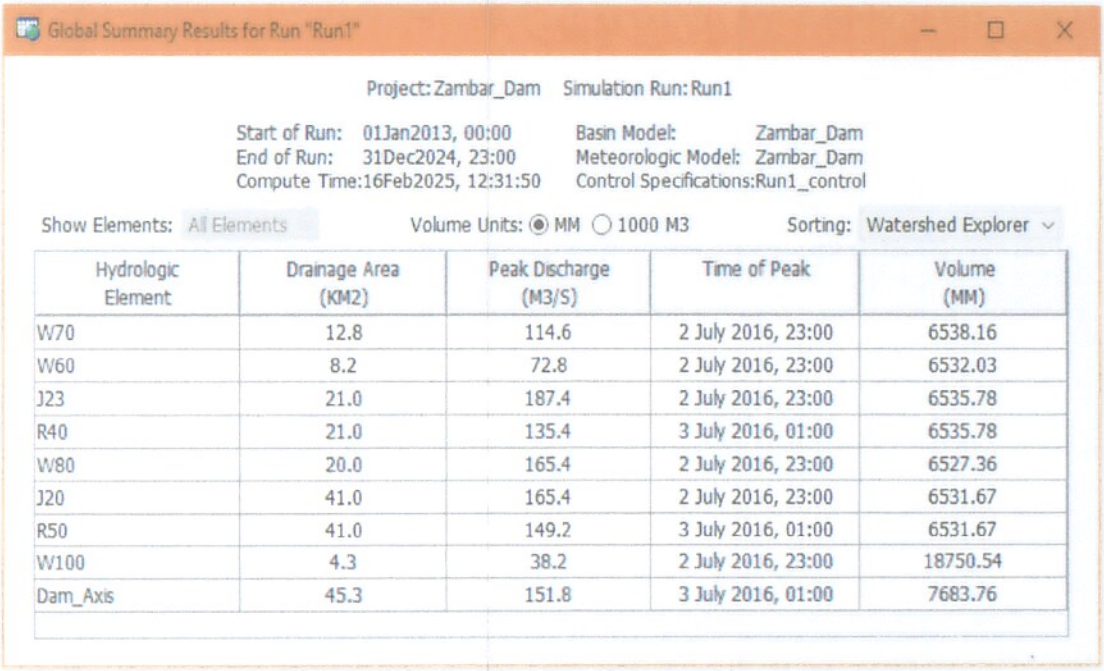


Figure 10 shows Hydrograph from the HEC-HMS Model (2013-2024)



Global Summary Results for Run "Run1"

Project: Zambar_Dam Simulation Run: Run1

Start of Run: 01Jan2013, 00:00 Basin Model: Zambar_Dam
End of Run: 31Dec2024, 23:00 Meteorologic Model: Zambar_Dam
Compute Time: 16Feb2025, 12:31:50 Control Specifications: Run1_control

Show Elements: All Elements Volume Units: (•) MM ( ) 1000 M3 Sorting: Watershed Explorer

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
W70	12.8	114.6	2 July 2016, 23:00	6538.16
W60	8.2	72.8	2 July 2016, 23:00	6532.03
J23	21.0	187.4	2 July 2016, 23:00	6535.78
R40	21.0	135.4	3 July 2016, 01:00	6535.78
W80	20.0	165.4	2 July 2016, 23:00	6527.36
J20	41.0	165.4	2 July 2016, 23:00	6531.67
R50	41.0	149.2	3 July 2016, 01:00	6531.67
W100	4.3	38.2	2 July 2016, 23:00	18750.54
Dam_Axis	45.3	151.8	3 July 2016, 01:00	7683.76

Figure 11 shows a Summary Result of the model.

For getting the high accuracy result in the HEC- HMS model the Zambar watershed is divided into 4 sub-basins. The smaller the watersheds, the better the accuracy of the model result and the discharge for all 4 sub-basins is calculated by the model, and only for sample one sub-basin W100 discharge model calculation shown in Figure 12.



Figure 12 Shows Subbasin #100 Result

2.15 Flood Frequency Distribution Analysis Using HEC-SSP Software

Hydrologic Engineering Centers Statistical Software Package (HEC-SSP) is designed and developed by the U.S. Army Corps of Engineers to perform statistical analysis of hydrological data. The first version of HEC-SSP software was released in August of 2008 while version 2.2 released in 2019 includes improvements to nearly all previously released analyses, two new analyses (distribution fitting and mixed population), redesigned curve combination analyses, and enhanced data usage and manipulation.

Many distributions have been suggested for annual maximum series models. Some of them are Normal and related distributions (Normal distribution, Lognormal II parameter distribution, Lognormal III parameter distribution), The Gamma group (Exponential distribution, Two parameters Gamma distribution, Pearson III distribution, and Log Pearson III distribution), Extreme value distribution (Generalized extreme value distribution, Extreme value type I distribution, Extreme value type II distribution, Weibull distribution), Wake-by distribution (Five parameters wake-by distribution, Four parameters wake-by distribution and Generalized Pareto distribution) and Logistic distribution (Log-logistic distribution and Generalized logistic distribution).

The results of the goodness of fit tests are used to select a distribution for frequency analysis of stations. These parameters are used to calculate the quantiles related to return periods of T years and for this specific study, HEC-SSP statistical software and the Standard Product Moments method of parameter estimation were selected.

The test statistics for the Kolmogorov-Smirnov test and the Chi-square test (x_2) for yearly discharge data were computed for various probability distributions. The probability distribution having the first rank along with their test statistic is presented by HEC SSP software in Figure 21.
Since Goodness-of-Fit statistics are in the form of distance between data and fitted distributions, clearly the distribution with minimum statistics value has been best fitted with data. Based on this fact, HEC SSP was attributing a ranking number to each distribution.
Additionally, distributions are sorted based on results from Kolmogorov-Smirnov test (D) statistics, and the best-fitted distribution Log Pearson type three distributions governs with minimum statistical values which are shown in the below report.

Distribution Fitting Analysis.

--- Input Data ---
Description: Zambar Dam Distribution Fitting Analysis

Data Set Name: Zambar Dam-Location-FLOW-PEAK
Input DSS File Name: C:\Users\M.Ebrahimi\Desktop\Zambar\Estimation\HEC\Zamar_Dam\DistributionFitting\Zambar_Dam\Zambar_Dam.dss
DSS Pathname: /Project/Location/FLOW-PEAK//1YEAR/inflow/
Number of Original Data Values: 12
--- End of Input Data ---
--- Analysis ---

Statistic	Original Data	Processed Data
Sample Size	12	12
Min	81.820	81.820
Max	151.950	151.950
Median	126.790	126.790
Mode	81.820	81.820

Product Moments

Statistic	Original Data	Processed Data
Mean	120.337	120.337
Standard Dev	25.898	25.898
Skew	-0.423	-0.423
Kurtosis	-1.567	-1.567

Fitting Method: Standard Product Moments

Distribution	Parameter	Kolmogorov-Smirnov (Test Statistic)
Empirical (PM)	User-defined	NaN
Ln-Normal (PM)	MeanLn=4.767 ,StDvLn=0.229	0.214
Normal (PM)	Mean=120.337 ,StDv=25.898	0.199
Pearson III (PM)	Mean=120.337 ,Skew=-0.423	0.195
Log-Pearson III (PM)	*M,StDvLog=0.100 ,Skew=-0.577*	*0.192*

Plotting Position Type: WEIBULL
--- End Of Analysis --
--- Results ---
Selected Distribution: Log-Pearson III (PM)
--- End Of Results ---

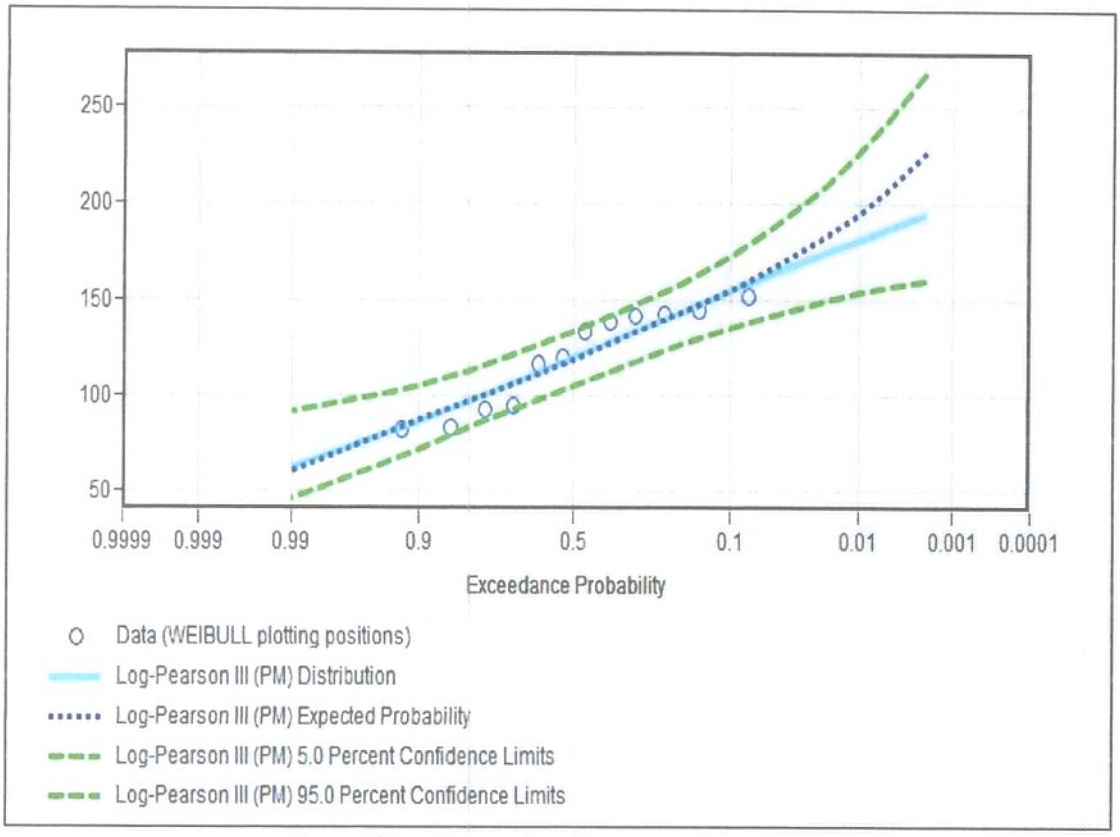


Figure 13 Log Pearson type three exceedance Probability curve

2.16 Flood Frequency Analysis

Flood frequency analysis for the Zambar Dam is essential for understanding and managing flood risks associated with the dam's operations. Utilizing HEC-SSP (Hydrologic Engineering Center's Statistical Software Package) allows hydrologists and engineers to analyze historical flood data effectively. By applying statistical methods within HEC-SSP, they can estimate flood magnitudes for various return periods, which is crucial for dam stability analysis and designing spillways.

The analysis generates flood frequency curves that depict the probability of different flood events occurring over time. These curves provide valuable insights into the hydrological behavior of the river system feeding the dam.

Furthermore, the findings from this analysis help enhance the resilience of the Zambar Dam and the surrounding communities, ensuring that appropriate measures are in place to mitigate potential flood impacts. Continued use of HEC-SSP for ongoing flood frequency analysis is vital as climate conditions evolve and hydrological patterns change.

Finally, the result of flood frequency analysis using annual maximum peak which are obtained from HEC HMS results are shown below report and Figure 14.

General Frequency Analysis
16 Feb 2025 10:05 AM

--- Input Data ---
Analysis Name: Zambar Dam flood frequency analysis

Data Set Name: Zambar-dam-FLOW-PEAK
Input DSS File Name: C:\Users\M.Ebrahimi\Desktop\Zambar Dam before review\HEC SSP\Distribution_fitting_analysis_for_zambar_Dam
Project Path: C:\Users\M.Ebrahimi\Desktop\Zambar Dam before review\HEC SSP\Distribution_fitting_analysis_for_Zambar_Dam
Probability Distribution Type: Pearson Type III 17B
--- Final Results ---
<< Plotting Positions >>
Zambar-dam-FLOW-PEAK

Events Analyzed		Ordered Events		
		Water		Median
Year	FLOW	Rank	Year	FLOW	Plot Pos
2013	141.9	1	2016	151.9	5.65
2014	83.6	2	2021	145.2	13.71
2015	138.6	3	2022	142.9	21.77
2016	151.9	4	2013	141.9	29.84
2017	94.4	5	2015	138.6	37.90
2018	93.0	6	2023	133.9	45.97
2019	119.7	7	2019	119.7	54.03
2020	81.8	8	2024	117.0	62.10
2021	145.2	9	2017	94.4	70.16
2022	142.9	10	2018	93.0	78.23
2023	133.9	11	2014	83.6	86.29
2024	117.0	12	2020	81.8	94.35

<< Skew Weighting >>

Based on 12 events, the mean-square error of station skew = 0.435

<< Frequency Curve >>

Computed Curve FLOW	Percent Chance Exceedance	Confidence Limits 0.05 FLOW	0.95	Return Period
185.1	0.1	223.2	165.2	1000
181.8	0.2	218.2	162.5	500
176.8	0.5	210.8	158.6	200
172.4	1.0	204.4	155.1	100
167.5	2.0	197.1	151.1	50
159.6	5.0	185.6	144.6	20
152.1	10.0	174.9	138.3	10
142.5	20.0	161.4	129.8	5
122.2	50.0	135.6	109.3	2
99.2	80.0	111.9	80.7	1.25
86.2	90.0	100.4	62.5	1.11
74.9	95.0	90.9	46.1	1.05
52.2	99.0	72.9	12.4	1.01
43.4	99.5	66.1	-0.8	1.005

--- End of Analytical Frequency Curve ---

--- End of Preliminary Results –

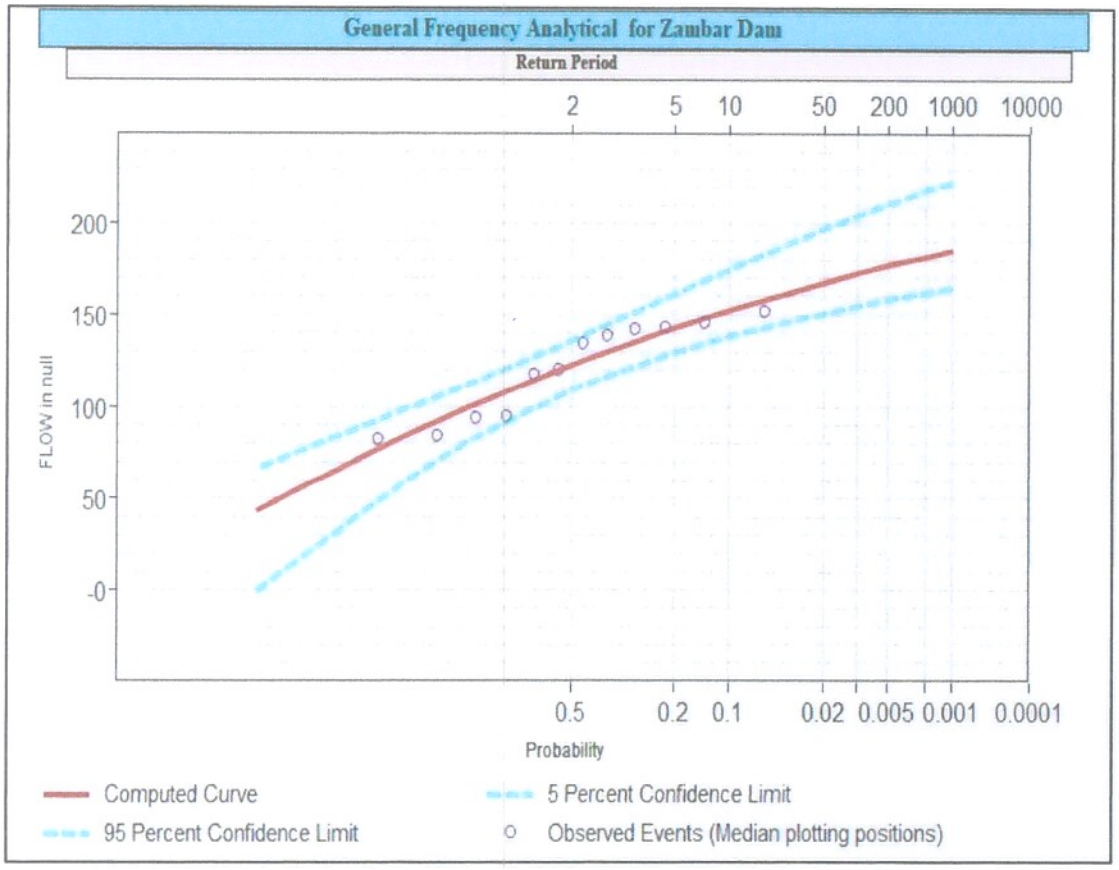


Figure 14 General Frequency Curve based on Log Pearson type 3

2.17 Return Period

The return period of an event of a given magnitude may be defined as the average recurrence interval between events equaling or exceeding a specific magnitude. The probability (p) of occurrence of an event is the inverse of its return period (1/T). The following general guidelines will be adopted for determining design return periods for the dam design.

The generalized design criteria for water-control structures as adopted from Applied Hydrology, Ven Te Chow, 1988 is given in Table 11.

Table 10 generalized design criteria for water control structures

	Type of structure	Return Period (years)	PMF (Probable Maximum Flood or Estimated Limited Value)
1	Dams with no likelihood of loss of life (low hazard)		
	Small dams	50-100	-
	Intermediate dams	100+	-
	Large dams	-	0.5 – 1.0 PMF
2	Dams with probable loss of life (significant hazard)		
	Small dams	100+	0.5 PMF
	Intermediate dams	-	0.5-1.0 PMF
	Large Dams	-	1.0 PMF
3	Dams with high likelihood of considerable loss of life (high hazard)		
	Small dams	-	0.5-1.0 PMF
	Intermediate dams	-	1.0 PMF
	Large dams	-	1.0 PMF

The dams are classified as small, Intermediate, and Large according to the dam height and reservoir volume for the design of the spillway and determine return periods as shown in Table 12.

The PMF, mostly considered as the 10,000-year flood, is adopted as the standard project design flood to determine the spillway crest length and maximum water level in the reservoir.

Table 11 Dam classifications for spillway design

	Storage Volume (Mm^3)	Dam height (m)
Small dam	0.06 – 1.2	7.5 – 12
Intermediate dam	1.2 - 6.2	12 – 30
Large dam	> 6.2	> 30

The Probable Maximum Flood (PMF) is the greatest flood to be expected assuming a complete coincidence of all factors that would produce the heaviest rainfall and maximum runoff. It is based on the concept of Probable Maximum Precipitation (PMP). For economic reasons usually the PMF is scaled down to determine the Standard Project Flood (SPF) for the design of the spillway. In this case, the PMF is considered as the Standard Project Flood.

2.18 Reservoir Volume

The elevation area volume relationship is derived from a topographical survey. The tool available in Civil 3D and Auto CAD is used to determine the reservoir area. The results are shown in Table 12 and Figure 15 shows the elevation volume relationship.

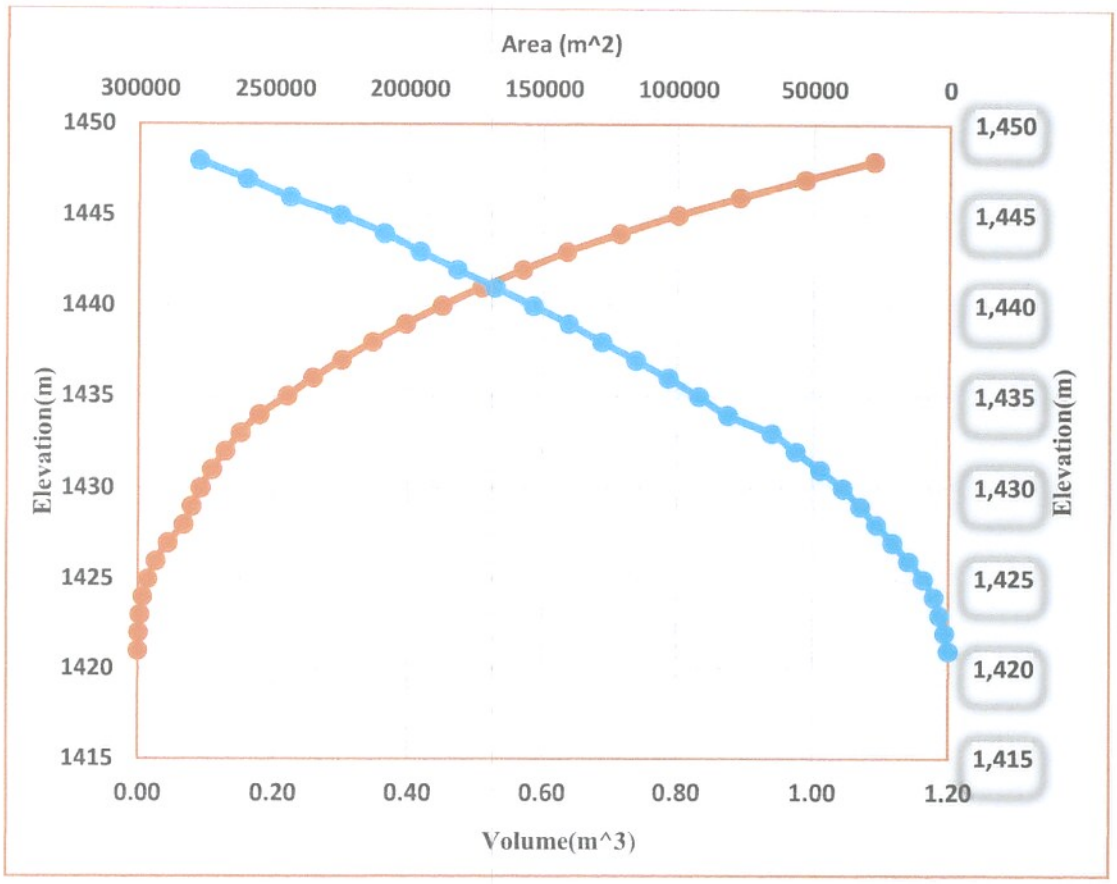


Figure 15 Elevation Volume relationship at Zambar Dam

Contour (Elevation)	Contour Area (sq.m)	Depth (m)	Incremental Volume Avg.(cu.m)	Cumulative Volume End.(cu.m)	Incremental Volume Avg.(cu.m)	Cumulative Volume End.(cu.m)
1,421.00	86.82	N/A	N/A	0	N/A	0
1,422.00	1,381.86	1	734.34	734.34	605.02	605.02
1,423.00	3,283.43	1	2332.65	3066.98	2265.12	2870.14
1,424.00	5,525.30	1	4404.36	7471.35	4356.02	7226.16
1,425.00	9,615.11	1	7570.2	15041.55	7476.39	14702.56
1,426.00	14,848.72	1	12231.91	27273.47	12137.52	26840.07
1,427.00	20,684.02	1	17766.37	45039.84	17685.97	44526.04
1,428.00	26,692.55	1	23688.29	68728.12	23624.53	68150.57
1,429.00	32,502.15	1	16263.89	84992.01	11146.77	79297.34
1,430.00	38,872.96	1	19437.17	104429.18	13035.16	92332.49
1,431.00	47,330.96	1	23735.18	128164.35	16679.62	109012.12
1,432.00	56,402.54	1	28245.24	156409.59	19572.53	128584.65
1,433.00	65,365.49	1	32703.49	189113.08	22351.22	150935.87
1,434.00	81,530.71	1	40766.72	229879.8	27335.21	178271.07
1,435.00	92,216.74	1	49753.55	279633.36	41811.91	220082.99
1,436.00	103,395.17	1	52231.13	331864.49	38322.06	258405.05
1,437.00	115,297.68	1	58060.9	389925.38	41956.5	300361.54
1,438.00	127,821.75	1	64221.54	454146.93	45784.98	346146.53
1,439.00	140,364.98	1	70399.66	524546.59	49535.81	395682.34
1,440.00	153,699.65	1	76997.66	601544.25	53578.85	449261.19
1,441.00	168,124.81	1	84157.58	685701.82	57990.7	507251.89
1,442.00	182,088.91	1	91097.36	776799.18	62194.64	569446.53
1,443.00	195,928.70	1	97977.6	874776.78	66077.88	635524.41
1,444.00	209,299.51	1	106332.46	981109.24	79735.03	715259.44
1,445.00	225,625.97	1	114326.84	1095436.08	84930.15	800189.59
1,446.00	244,224.78	1	123468.47	1218904.55	90891.2	891080.79
1,447.00	260,171.35	1	131292.07	1350196.62	95879.61	986960.41
1,448.00	277,682.94	1	139906.77	1490103.39	101378.99	1088339.4

Table 12 Elevation, Area, and Volume Relationship at Zambar Dam

2.19 Sedimentation

Runoff results from rainfall throughout catchment areas and river flows are always accompanied by soil erosion and sediment takes. As the dead capacity of reservoirs and desilting activities are affected by sediment data, it is of high importance to determine this parameter.

Sediment yield is highly variable from catchment to catchment according to the topography, geologic, and geo-morphologic situation.so the Sediment yield has been calculated based on the Dendy-Bolton formula and is around 194.68 tons/km^2/yr. Which are shown below.

The catchment area at the dam site is 45.24 km^2, therefore, the total sediment transport per year is 8807.32 tons/year. The specific weight of sediment is assumed 1.359 Tons/m3 and the accurate specific weight will be considered after geotechnical studies, so to convert it into volume an annual volume of 6523.94 m3 will be transported to the reservoir.

The capacity inflow ratio of the Zambar dam is about 0.038 with a mean annual flow of 28.516 Mm3 and the reservoir capacity is 1.088 Mm3 at the elevation of 1448 m which is shown in Figure 16. The sediment trapping efficiency of the reservoir, therefore, is about 0.95 from Brune's equation which is shown below. Therefore, about 95% of the annual sediment reaching the reservoir will be deposited. Calculation 95% trapping efficiency, the annual sediment deposition at the reservoir will be 6523.94 m^3. In addition, about 10% of the bed load is assumed to be transported therefore, the total annual sediment deposition will be 7176.33m3. In 25 years, the total sediment deposition in the reservoir will be 0.179 Mm^3 and in 50 years the total sediment deposition in the reservoir will be 0.358 Mm^3.

$S = 1965\ e^{-0.055Q}[1.43 - 0.26 \log(A)]$

[Q (in), A (mi^2), Y (tons/mi^2/yr)]

$$TE = a[1 - 2e^{-bV_*^{0.35}}]$$

$$V_* = \frac{V_{res}}{V_{inflow}}$$

$V_* = Capacity/Annual\ Inflow\ Ratio$

$V_{res} = Reservoir\ Capacity$

$V_{inflow} = Annual\ Inflow$ (A user specified initial value is required)

a = Constant (recommended range: Minimum :95, Medium: 97, Maximum: 100)

b = Constant (recommended range: Minimum: 5.37, Medium: 6.42, Maximum: 7.71)

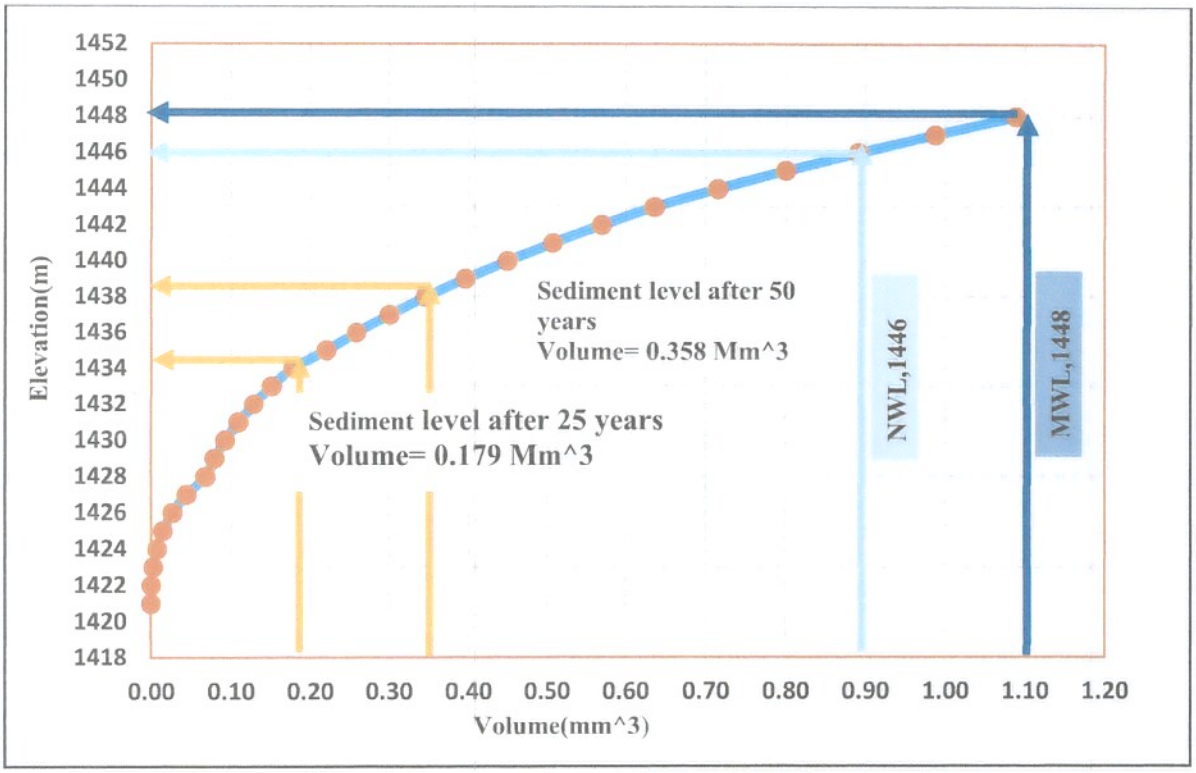


Figure 16 Elevation vs Reservoir Volume and Sediment Level

2.20 Zamar Dam height Optimization:

Large water reservoirs often serve several purposes, such as for hydropower production, irrigation control, flood-control, navigation and other flow regulation objectives. Reservoirs may include natural water bodies such as lakes or man-made structures such as dams. Due to climate change, the importance of reservoirs is likely to increase – not only for the water storage purposes, but also, for maximizing water use benefits and mitigating climate extremes. Optimizing storage reservoir operations aims to ensure that all planned reservoir objectives are met, without compromising those of ecological water requirements. It takes into account a variety of objectives and variables, including cost and revenue considerations of water allocation for various socioeconomic uses. Various computer simulation models can be used for optimization. The models use algorithms to calculate the optimal balance between water release and reservoir storage volumes.

Dam optimization refers to the methods and processes employed to manage and operate dams in an efficient manner. This encompasses a variety of dimensions, including water resource management, hydroelectric power generation, flood control, irrigation, and environmental protection. The goal is to maximize the benefits derived from the dam's operations while minimizing negative impacts on the surrounding environment and communities.

For Zamar Dam Optimization the Parameter were used is (Reservoir Elevation, Area Elevation, Max, Mean, Min Discharges, sediment data, reservoir life. Max Storage, Live Storage and Dead Storage) are used to Optimization Zamar Dam.

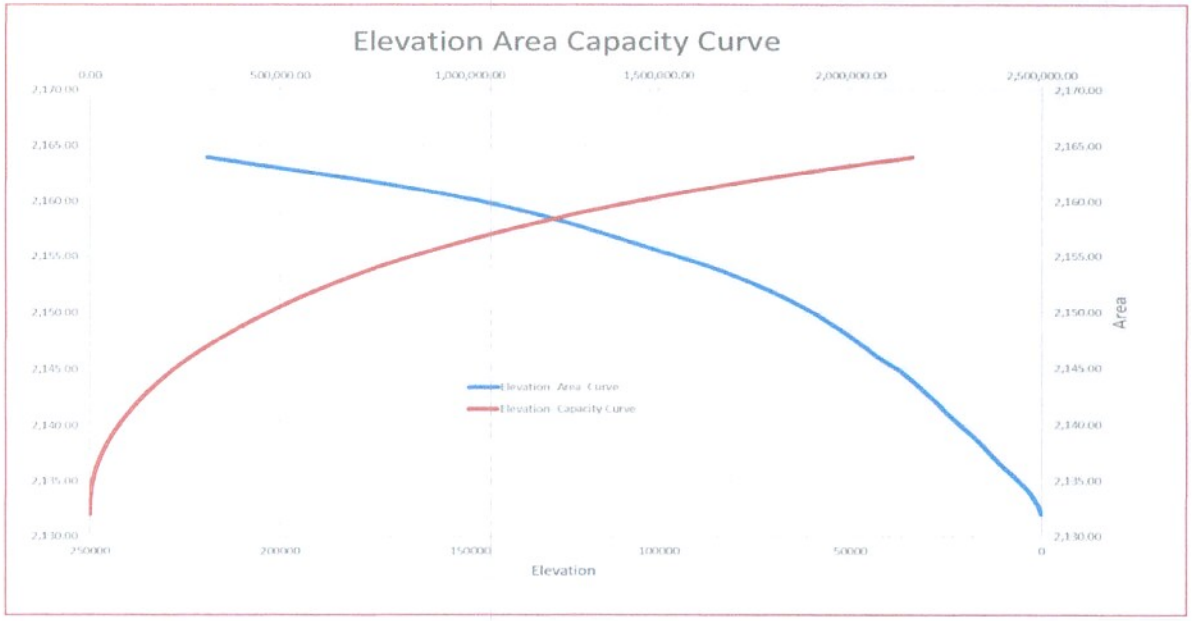


Figure 18 Elevation vs Reservoir Volume and Sediment Level

3. Dam Sites Assessments: Geology

3.1 General geology of the area:

As the aforementioned area was closely surveyed and observed in terms of geological studies, this area has an almost flat relief consisting of agricultural lands, forests, residential houses, and a large basin. Within this large basin, there are other sub-basins. On one side of this basin are high and semi-high mountain ranges with heights of about (45-50) meters. Its constituent materials include sedimentary rocks such as shale, siltstone, claystone, and granular and medium-grained sedimentary materials (telos). Most of these materials are alluvial sediments. It is also worth mentioning that at a distance of approximately (200-250) meters towards the upper part of the dam axis, at a height of (30-35) meters, there are sedimentary hills consisting of granular and medium-grained materials (telos) and gravelly ash mud in a semi-dense, unstable and slippery form. In terms of tectonics in this area, it should be noted that tectonic movements and earthquakes have acted and caused a number of seams and fractures in the rocks of the dam.

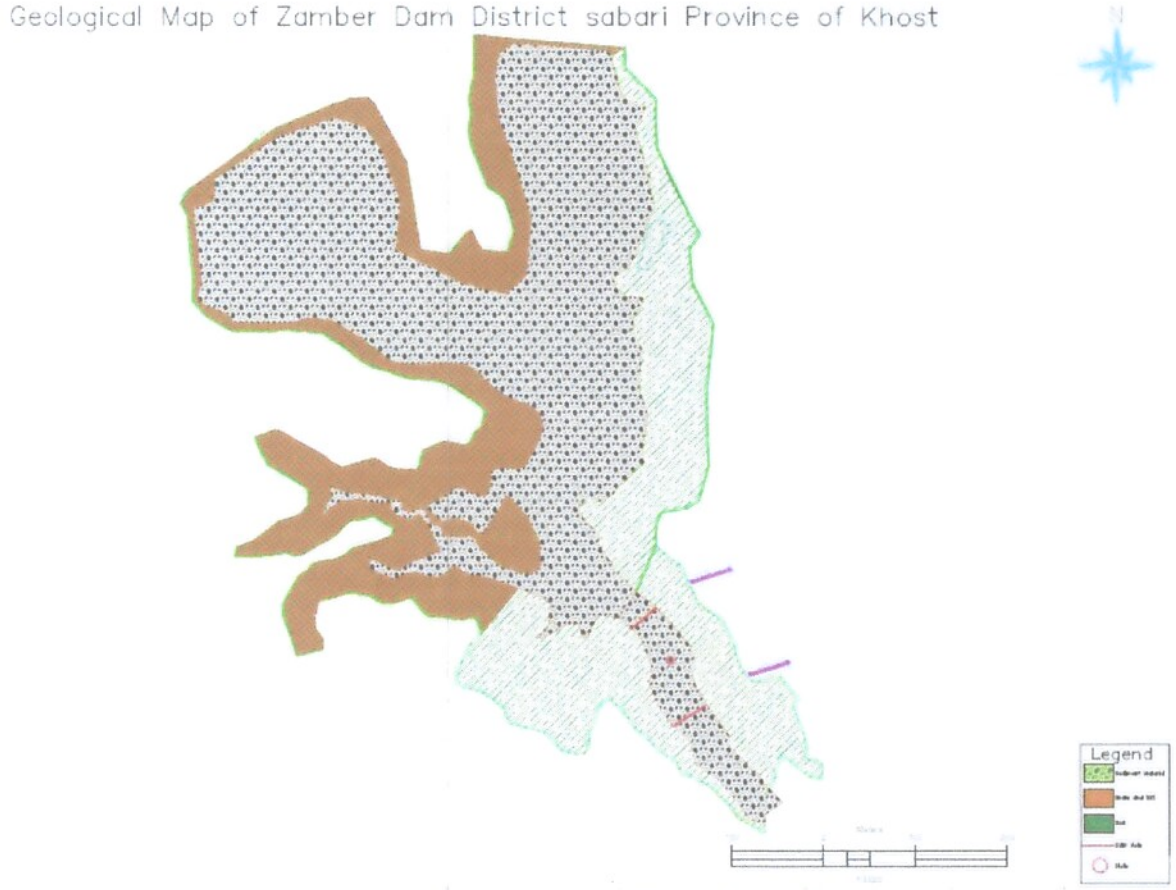


Figure 19 Geological Map of Zambar Dam

3.2 Geology of the Area:

3.3 Right Abutment of The Axis (Option 1)

The right abutment of the axis consists of a semi-high mountain with a height of (40) meters (65) degrees. The geographical coordinates of the dam axis are 3715921.91 North and 581135.18 East and at an altitude of about 1421.8 meters. It has been determined. Its constituent stones are shale, which is a type of igneous rock that is almost solid and resistant, and its resistance was determined by the Schmidt mechanical hammer to be (40 kg/cm2). These stones are in the form of a sheet of sand with an inclination of (70) degrees to the southwest. There are very few seams in these stones. These seams are horizontal, inclined, and the size of the seams in the upper abutment is (0.5-4 mm) and they are seamed.



Figure 20 Geology of the Area

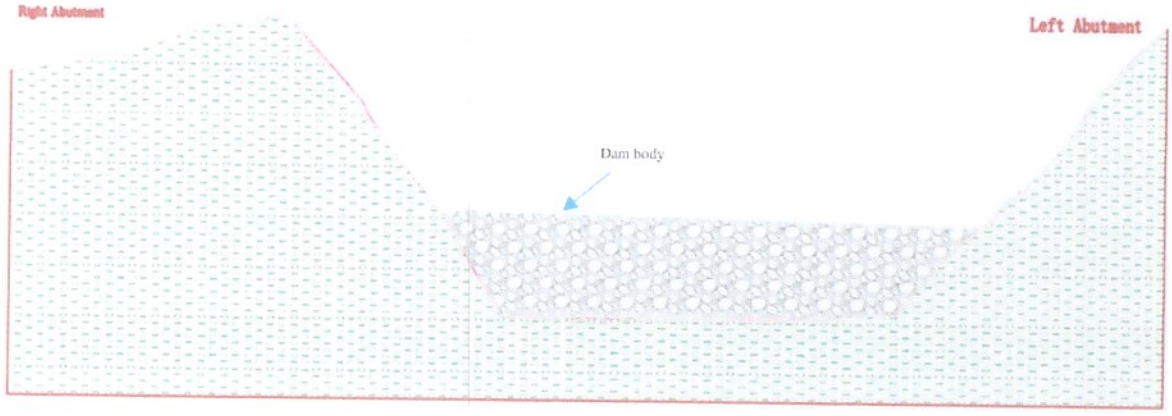


Figure 21 Dam Axis



Figure 22 Right Abutment of the Axis

3.4 Left Abutment of the Axis (Option1)

The left abutment of the axis, which is still composed of a semi-high mountain with a height of (50) meters (65) degrees, is composed of stones such as shale, which is very strong and resistant, but less than the right abutment, whose resistance was determined by the Schmidt mechanical hammer to be 30 kg/cm2 (). These stones are in the form of a sheet of sand with an inclination of (50) degrees to the northeast. The joints in these stones are horizontal, inclined, and the size of the joints in the upper part of the flank is (1-2 mm) and are jointed.



Figure 23 Left Abutment of The Axis

3.5 Right Abutment of the Axis (Option2):

The right abutment of the axis consists of a semi-high mountain with a height of (44) meters (65) degrees. The geographical coordinates of the dam axis are 3715768.84 North and 581218.41 East and at an altitude of about 1416meters. It has been determined. Its constituent stones are such as shale, which is very strong and resistant, and its resistance was determined by the Schmidt mechanical hammer to be (60kgr/cm2). These stones are in the form of a mass with an inclination of (80) degrees to the southwest. The joints in these stones are very few. These joints are horizontal, inclined, and the size of the joints in the upper abutment is (0.2-0.5 mm) and there are fewer joints, and in terms of resistance and joints, it is better than the first area.



Figure 24 Right Abutment of the Axis

3.6 Left Abutment of the Axis (Option2):

The left abutment of the axis, which is still composed of a semi-high mountain with a height of (45) meters (65) degrees, is composed of stones such as shale, which is very strong and resistant, but less than the right abutment, whose resistance was determined by the Schmidt mechanical hammer to be 50 kg/cm2. These stones are in the form of a sheet of sand with an inclination of (50) degrees to the northeast. The joints in these stones are horizontal, inclined, and the size of the joints in the upper abutment is (1-2 mm) and less jointed.



Figure 25 Left Abutment of Axis

3.7 River Bed:

The river bed, which is part of the reservoir bowl, is composed of granular and fine-grained flood (alluvial) sedimentary materials called talons. The depth of sediments in the floodplain According to a research hole ring that was excavated to a depth of (4m) by an excavator to determine the lithology of the layers and the depth of the sediments in the middle part of the dam axis, its constituent materials up to the excavated depth include granular and medium-grained alluvial sedimentary materials (telos) in the form of flakes. In terms of water permeability, it should be said that due to the granularity of the sedimentary materials in this area, it has greater permeability and the depth of possible sediments is approximately more than (10-12m). It is worth noting that in the dam axis section in the pointer of (3m), a curtain-shaped building with a height of (12.5m) was previously constructed for the purpose of collecting and using groundwater. According to the existing map, the bedrock level is shown at a depth of (14.5m), and further geotechnical studies and research are needed.



Figure 26 River Bed Sediments

3.8 Spillway:

A Spill way that has been considered in order to pass the excess water flow during the period of severe flood in this area in a natural way on the left side of the dam axis in a semi-high mountain path with a height of (45m) whose constituent stones include shale rocks in a solid and sheet form. In terms of joints, it should be noted that these joints in these stones are horizontally inclined and the size of the joints is (1-3mm).and also the geographical coordinates of the dam axis are 3715729.50 north and 581365.38 east and at an altitude of about 1420 meters. It has been determined



Figure 27 Spillway

3.9 Borrow Area

The construction materials required during the construction of the dam are rock and clay, which is located 5 km south of the dam, and rock materials, including limestone, which is strong and resistant, and its strength was determined by a Schmidt mechanical hammer to be 50 Kg/cm2, and is located 15 km south of the dam, which is good in terms of resistance.



Figure 28 Clay Borrow Area



Figure 29 Rock Borrow Area

3.10 Seismic

Afghanistan is prone to earthquakes because it is located along the Hindu Kush Mountain range. The Hindu Kush Mountain range is part of the "Alpidic Belt", the second most active seismic zone in the world after the Pacific Ring of Fire.

The Alpidic Belt extends for 15,000 km from southern Eurasia through the Himalayas to the Atlantic Ocean. In addition to the Hindu Kush, this seismic belt includes other mountain ranges, including the Alps, the Atlas Mountains, and the Caucasus Mountains.

In addition, the "earth's crust" in Afghanistan is particularly volatile, as it is the meeting point of the Arabian, Indian, and Eurasian tectonic plates. The earth's crust is made up of 15 tectonic plates, and earthquakes occur when these tectonic plates move against or collide with each other. The boundary between the Indian and Eurasian tectonic plates is located near the Afghanistan-Pakistan border.

Earthquakes in Afghanistan are usually caused by the violent collision of the Indian tectonic plate with the Eurasian tectonic plate. Such tectonic collisions shake the Earth and push it upwards. In addition to causing earthquakes, such collisions of tectonic plates create mountains such as the Himalayas, Hindu Kush, and Pamirs.

Since Afghanistan is divided into four zones of strong, medium, weak and very strong earthquakes, which include four major faults, including the Chaman and Maqor faults, the Harirud faults, the Darwaz faults and the central Badakhshan faults, Khost province is aligned with the active Chaman and Moqor faults, which cross the Pakistani border and enter the territory of Afghanistan. Khost province also borders Pakistan and is included in the above tectonic plates. The earthquakes that occurred in 1401 AH 46 km from Khost province with an intensity of 6.1 on the Richter scale caused more damage and loss. Therefore, in areas where the intensity of earthquake waves was higher, it is necessary to conduct more geophysical and geotechnical studies during the construction of large buildings such as water storage dams so that the buildings are more protected from natural disasters.



Figure 30 Rock Borrow Area

4. Zamar Dam Preliminary design:

Dam Site and Type Selection

4.1 Dam site selection

During the reconnaissance site visit the technical team with local provincial officials has been investigated different dam site options on the same river. However no other dam site is found attractive, other than presented in this prefeasibility report dam site.

4.2 Dam type selection parameters

The present project dam type is selected based on the purpose of the dam, for what purpose it will be built and based on physical characteristics of the selected dam site, such as: topography, geology and foundation, dam construction materials availability, hydrology, climate, earthquake activity, etc. Potential options of spillway locations, location of irrigation outlet works, the problem of diverting the stream during construction, availability of labor and equipment, accessibility of the site and dam safety issue, all affect the final choice of the dam type.

4.3 Selected dam type

The present Zamar Dam is planned to be used primarily for storage, Flood Control and Groundwater recharging purposes. It is planned to be constructed to impound water during periods of surplus supply for use during periods of deficient supply.

Generally, types of embankments (earth fill or rock fill) dam is the most common type of dam, principally because their construction involves the use of locally available natural materials, requiring a minimum of processing. Second to the embankment option of dam masonry dams are those dams which use local materials as a major part of their body. Considering the large quantities of required dam body materials, locally available borrow materials and masonry rocks are positive economic factors related to other concrete type of dam.

In the light of the above, for Zamar Dam the following two dam types can be recommended as options:

In addition to the dam site geological, geotechnical and hydrological parameters, and material availability, the dam type shall be selected considering the possibility of accommodation of all necessary dam appurtenant structures (spillway, irrigation outlets, diversion during construction, etc.). However, the main factor when choosing the dam type is that, for having minimum cost of the project, the dam must be designed for utilization of available local construction materials as much as maximum.

OPTION-1- Gravity dam

This option has the following main advantages and disadvantages:

Advantages:

- Spillway & other structures accommodation is simpler than embankment option, spillway (weir and chute part) cost can be fully avoided by having dam overflow spillway.
- Rock and other concrete material (sand and gravel) can be quarried near to the dam site.
- Diversion during construction cost will be minimized by allowing high floods through constructing Gravity dam,

Disadvantages:

- Material production requires, which make the structure costly than other embankment options,
- Compared to earthen dams, gravity dams require a stronger foundation, often necessitating deeper excavation to reach bedrock. This increases the overall height of the dam, the complexity and Cost of construction due to the need for more extensive foundation preparation.

OPTION-2- Embankment Dam

This option has the following main advantages and disadvantages:

Advantages:

- Material production is simpler than for gravity dam options, which make the dam cost lesser than gravity option,
- Embankment dams have the ability to tolerate weaker or more variable foundation conditions, reducing the need for deep excavation and complex foundation treatment. This flexibility in foundation requirements makes Embankment dams simpler and more cost-effective to construct.

Disadvantages:

- Spillway & other structures accommodation is difficult, spillway with required weir require outside of the dam body, since no good site for spillway, its accommodation require special approach,
- Diversion during construction cost will be higher than for gravity dam option.

Analyzing the above merits and demerits of the Two dam type options, since the present Zamar Dam site, the main factor on deciding the dam type is management of the design flood, that is about 237 m3/sec, Embankment dam has been recommended as the main dam type options.

However, suitability of the rock material for such dam construction and good foundation depth and its strength for such a gravity dam shall be investigated during subsequent studies. The final design shall be based on the actual laboratory and detailed field investigation results of the same.

4.4 Recommendation for feasibility level study

During the next phase study of the present Zamar Dam both the above-mentioned dam options shall be equally investigated based on site conditions (topography, geology, etc.), material quality and its availability, and finally the dam type shall be selected based on final cost comparisons of options. The possibility of rock fill concrete gravity dam shall be seen against foundation strength and depth. The bed rock shall have adequate strength and bearing capacity to meet the necessary stability requirements which will be clear after geotechnical report.

At this level of study, the main dam type option recommended Embankment dam with side Spillway.

4.5 General Layout of the Project Dam Site

The present dam site is including the following structures:

- An Embankment Dam
- A side Spillway Mass Concrete and RCC structures
- Bottom conduit structure for flood diversion during construction
- One Irrigation outlet

The dam and its appurtenant structure's locations and layout of the project area are as shown in drawings.

4.6 Preliminary Level Dam Design

4.6.1 Preliminary section of the dam

In this pre-feasibility level of design, the study concentrates on the recommended main option of the dam type. The main material for the dam body construction is rock and sand, which is available near the dam site. However, for having the proposed dam detailed design, detailed investigation of foundation material strata mainly their ability to support the superimposed load and abutments water tightness shall be investigated in detail, during the next phase of study.

4.6.2 Preliminary dam sizing

(a) Dam height fixation

Generally, the main parameters that have to be considered for deciding the height of all types of dams, include topography of the area, the geological and geotechnical set up of the foundation rock, the river inflows, irrigation and other demands of water, siltation rate in the reservoir during the active life of the reservoir and the evaporation losses from the reservoir. The reservoir fetch length and the maximum wind speed in the area also other main factors during determination of the dam free board and accordingly the dam height.

At this level of study after having dam site topographical and geological suitability from the reconnaissance field visit and preliminary geological and geotechnical investigation reports, and after having establish the reservoir Normal Water Level (NWL) and Maximum Water Level (MWL) from the hydrology analysis of the present project, the height of the present dam at this level of study has been fixed considering recommended free board and potential settlement allowances.

Freeboard

Generally, freeboard is the distance from the top of the water to the top of the dam. It is a safe guard against overtopping by floods and/or by wave action. For gravity dam according to IS Code usually minimum free board is taking (1.5) m of height of dam at this level of study, based on previous experiences and according to IS Code the minimum free board for the Zambar Embankment dam fixed to be 2m.

Settlement allowance.

Dam foundation will always settle a little after construction and the finished crest should be given a settlement allowance that raises it above its design height. 0.5% of the dam height is considered as a settlement allowance. Accordingly, the total free board above the Maximum Reservoir Water Level (MWL) considered is 2m. accordingly the dam crest planned to be at elevation of 1450 masl.

River Bed Elevation=	1421	Masl
Reservoir Normal Water Level (NWL)=	1446	Masl
Reservoir Maximum Water Level (MWL)=	1448	Masl
Recommended Minimum dam free board above MWL=	2	m
Expected dam crest settlement allowance	0.50%	m
Preliminary Dam Height from foundation(H)= (Height, from foundation to dam crest)	32	m
Dam crest elevation=	1450	masl

(b) Dam crest width

Since the dam type is rock fill concrete dam with overflow spillway, comparing to embankment dams, overtopping of the dam crest is not critical issue. For Embankment dam according to IS Code usually top width or crest width is taking 6-12m, In No case the crest should less then 4m the present dam crest provided to be 6 m.

(c) Proposed dam body materials and shapes

The Zamar Dam is Embankment Dam. The upstream face of the dam (Slope) of 1.5H to 1 V up to the end level, for dam stability purpose. The downstream face of the dam will have slope of 1.5H to 1 V. At this level of study, the dam main (maximum) cross section is shown in drawing.

4.7 Preliminary Level Spillway Design:

4.7.1 Design flood:

As detailed in the hydrology part of the current report, the Zamar Dam spillway routed flood considered more than +100 years of probability flood-based on Applied Hydrology, Ven Te Chow, 1988. Hence, the maximum discharge for the design of the spillway is 237 m3/sec with a return period of 10,000 years. After analysis of water accumulation, the spillway design discharge is 237 m3/sec

4.7.2 Spillway type:

One of the key elements for the selection of Embankment type of dam for the current project is the topographical and physical condition of the site. There is no saddle located near the dam's axis, nor is there any saddle around the reservoir rim. Hence the dam type is considered an Embankment dam whit Side spillway.

4.7.3 Preliminary sizes and material of the spillway:

Based on the current study level, the preliminary crest length for the proposed spillway is 45 m with a hydraulic head of 1.75 m over the spillway crest. The spillway will include a chute-type spillway part for the transition of floods into the downstream stream of the proposed dam, necessary energy dissipation facilities, a stilling basin, channel and wing walls, and a retaining wall.

4.8 River Diversion during Construction:

4.8.1 Option of diversion during construction and diversion

Structure design discharge:

According to the preliminary hydrology reports, peak discharge for the return period of 2, 5, 10, and 50 years is continuously (135, 161.4, 174.9, and 197.1 cube meters); hence, construction of dams without river diversion work facilities is not recommendable.

However, constructing a diversion structure for a 50-year return period will be expensive for a dam type like the Zambar embankment dam. The benefit of these types of dams is that the diversion during construction can be taken into consideration for the lower flood, while the higher flood is permitted to side spillway dam body at this level of investigation. The diversion structure is planned for managing the 135-cube-meter return period for two years.

4.8.2 Preliminary sizes of the diversion conduit and associated it structures:

Only the main dam and irrigation outlet development will require the proposed diversion conduit. When the river dries up during the dry season, the downstream spillway energy dissipation basin can be built. Thus, the necessary conduit length is around 90 meters. The following structural components will be included in the diversion structure, according this level preliminary design: entrance section, the conduits will be positioned at the rock bed foundation.

4.8.3 Required upstream cofferdam:

The necessary upstream cofferdam must be appropriately designed in order to allow the design flood to pass through the diversion conduits during construction. The cofferdam height is set at around seven meters. After the dam construction is finished and before the reservoir filling process begins, the U/S cofferdam will be destroyed.

4.9 Irrigation Outlet Structure Conceptual Design:

4.9.1 Design discharge:

The irrigation section of this study will address the amount of design discharge for irrigation purposes.

4.9.2 Irrigation outlet type:

The left and Right side of the river banks will need irrigation water. As a result, the left bank of the river will have one irrigation outlet structures. The outlets will be fixed at this stage of the research according to the reservoir dead storage level position.

4.10 Preliminary Dam and Its Appurtenant Structures Cost Estimate:

Generally, at this preliminary level of study the dam and dam appurtenant structures cost estimates have been done mainly by using present construction costs of Khost (Afghanistan) construction works unit rates (October 2024).

A computation has been done based on preliminary work volume estimations. Dam, spillway, irrigation outlet structure and diversion work volume has been computed preliminarily. Based on other site visits and survey forms of the projects costs and based on expert's experience, other costs are estimated as a percentage of the main dam body construction cost, see Table 13.

Table 13 Preliminary Cost table of Zamar Dam

BOQ of Zambar Dam						
S/No	Item Description	Unit	Quantity	Unit Rate (AF)	Amount (AF)	Remark
1	**Mobilization/Demobilization**	LS	1.00	2,500,000.00	2,500,000.00	
2	**Ordinary Soil Excavation (dry):** Excavation of dam body foundation,spill way and Ratining wall	m^3	10,589.00	100.00	1,058,900.00	
3	**Excavation in rock (dry):** Excavation of dam body	m^3	40,916.00	450.00	18,412,200.00	
4	**Stone massonry M 250: Stone massonry ratining wall of Spillway**		1,641.60	3,500.00	5,745,600.00	
5	**Mass concrete (M250): mass concrete for bed of Spillway**		4,460.00	5,000.00	22,300,000.00	
6	**Reinforced Cement Concrete (M300):** dam body ficing ,Spillway and ratining wall	m^3	478.50	15,000.00	7,177,500.00	
7	**Dry Stone Pitching:**	m^2	200.00	800.00	160,000.00	
8	**Compacted Backfilling Dam body in Rock**	m^2	112,299.00	1,000.00	112,299,000.00	
9	**Compacted Backfilling (95%):** compacted bacfilling of sadal dam and ratining wall	m^3	14,460.00	200.00	2,892,000.00	
10	**Conduit:**	m	90.00	22,000.00	1,980,000.00	
11	**Water Stop 30cm :**	m	300.00	350.00	105,000.00	
12	**Trash Rack:**	m^2	1.00	3,000.00	3,000.00	
Total(AF)					**174,633,200.00**	
Total($)					**2,494,760.00**	

5. Agriculture and Irrigation Development Potential:

5.1 Agriculture

The project area is generally mountainous and valley; hence irrigation development potential only available in the valley adjacent to the riverbanks. The proposed irrigable land including the river course is located in the low-lying area stretched along the river. The total agricultural land calculate by GIS from satellite imagery is 3708 ha from which 453.5 ha is irrigable.

Due to the need for water for irrigating agricultural lands and human consumption, groundwater has been directed toward suitable channels in the downstream area. These channels are utilized for irrigating agricultural lands and providing drinking water for the local community.

It should be noted that the water level decreases in the summer season; so far, the irrigated lands do not have enough water in the summer.

If the amount of flow in the dam is stored, it can be used for irrigating agricultural lands in the spring and summer seasons. Which that will be irrigated after the construction of the reservoir dam.it will be 1180 ha is irrigable.

5.2 Current Irrigation Development Practices

Agriculture in the area is traditional irrigation. Irrigation is practiced on left and right-side lands following the river course, with cropping systems including field crops and vegetables, Potential crops can be cultivated in the area under irrigation, based on information from Social and Agriculture Form, beneficiaries, and review of related literature.

Table 14 Existing crops in the project area

Field crops	Vegetables
Wheat, Barley, Corn, beans, Mungo bean, Soybean, Peanuts, Clover	Potato

5.3 Constraints Related with Irrigation Practices

The project area faces significant constraints in irrigated agriculture due to water scarcity, erosion-induced farm land loss, and the absence of a well-designed permanent water conveyance system.

5.4 Proposed Cropping System

The project aims to estimate crop water requirements by preparing a cropping pattern based on existing practices. The cropping pattern is divided into two seasons, with wheat, clover, vegetables and barley growing in winter and remaining field crops in spring and summer. percentage sharing of individual crops is based on the present land use system and beneficiary recommendations (see Table2).

M/Crops	Wheat	Clover	Barley	Potato	Vegetables	Corn	Mungbeen	Soybeen	Been	Peanuts
Jan	64	9	12		6					
	64	9	12		6					
	64	9	12		6					
Feb	64	9	12		6					
	64	9	12		6					
	64	9	12		6					
Mar	64	9	12	9	6					
	64	9		9	6					
	64	9		9	6					
Apr	64	9		9						
	64	9		9						
	64	9		9						
May	64	9		9						
	64	9		9						
	64	9		9						
Jun	64	9		9						
	64	9		9						
	64	9		9						
Jul	64	9		9						
						40	17	13	13	17
						40	17	13	13	17
Aug						40	17	13	13	17
						40	17	13	13	17
						40	17	13	13	17
Sep						40	17	13	13	17
						40	17	13	13	17
						40	17	13	13	17
Oct						40	17	13	13	17
						40			13	17
						40			13	17
Nov						40			13	17
	64	9	12		6					
	64	9	12		6					
Dec	64	9	12		6					
	64	9	12		6					
	64	9	12		6					

Table 15 proposed cropping pattern

5.5 Reference Evapotranspiration

The Penman-Monteith method is used to calculate the reference Evapotranspiration (ETo) for the project area, using data from CLIMWAT (version 2) and CROPWAT (version 8) at the Khost meteorological station and the recently developed CROPWAT (version 8). The summary of ETo computer output for the Zamber storage dam and irrigation project is provided.

Table 16 ETO (mm)

ETo	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
mm/Day	1.7	1.89	2.91	4	5.39	6.39	5.48	5.03	4.69	3.77	2.55	1.83	45.63
mm/month	51	56.7	87.3	120	161.7	191.7	164.4	150.9	140.7	113.1	76.5	54.9	1368.9

Table 17 Climatic data and estimated evapotranspiration

Station: Khost		Longitude: 69.95 °E		Latitude: 33.35 °N		Altitude: 1146 m.	
Month	Min Temp (°C)	Max Temp (°C)	Humidity (%)	Wind (km/day)	Sun (hours)	Rad (MJ/m /day)	ETo (mm/day)
January	-0.9	12.7	61	173	6.6	11.1	1.7
February	1.1	13.8	67	173	6.1	12.8	1.89
March	5.8	19.1	59	173	6.7	16.1	2.91
April	10.4	25.1	56	173	6.5	18.2	4
May	14.3	30.3	48	173	8.4	22.3	5.39
June	19.8	35.4	45	173	8.8	23.3	6.39
July	21.3	33.6	64	173	7.5	21	5.48
August	21.2	32.3	67	173	7.3	19.8	5.03
September	16.5	30.5	60	173	8.1	18.8	4.69
October	10.3	26.4	54	173	8.1	15.8	3.77
November	3.6	20.1	56	173	7.3	12.3	2.55
December	0	14.8	58	173	5.8	9.7	1.83
Average	**10.28**	**24.51**	**57.92**	**173.00**	**7.27**	**16.77**	**3.80**

5.6 Crop Coefficients (Kc)

The crop coefficient (Kc) is a physiological characteristic of plants that explains the impact of crop characteristics on water requirements. It represents the evapotranspiration of a disease-free crop grown in optimal soil water and fertility conditions, achieving full production potential. Kc values vary with growth stages and are represented by a crop coefficient curve within each crop's growing period.

Table 18 Kc Value for Various Crops

Kc Values for various crops										
Month	Wheat	Clover	Barley	Potato	Vegetables	Corn	Mungbeen	Soybeen	Been	Peanuts
Nov II	0.70	0.40	0.30		0.70					
Nov III	0.70	0.40	0.43		0.70					
Dec I	0.70	0.40	0.77		0.70					
Dec II	0.72	0.43	1.10		0.72					
Dec III	0.76	0.55	1.17		0.81					
Jan I	0.79	0.68	1.17		0.90					
Jan II	0.83	0.81	1.17		0.99					
Jan III	0.86	0.93	1.17		1.05					
Feb I	0.90	0.96	1.12		1.06					
Feb II	0.93	0.96	0.85		1.06					
Feb III	0.96	0.96	0.57		1.06					
Mar I	0.99	0.96	0.34	0.50	1.05					
Mar II	1.02	0.96		0.50	1.01					
Mar III	1.06	0.96		0.54	0.97					
Apr I	1.09	0.96		0.76						
Apr II	1.13	0.96		0.98						
Apr III	1.16	0.96		1.15						
May I	1.17	0.96		1.17						
May II	1.17	0.96		1.17						
May III	1.17	0.96		1.17						
Jun I	1.15	0.86		1.16						
Jun II	0.91	0.73		1.06						
Jun III	0.60	0.61		0.93						
Jul I	0.60	0.48		0.83						
Jul II						0.30	0.50	0.40	0.40	0.40
Jul III						0.30	0.50	0.43	0.40	0.40
Aug I						0.42	0.58	0.82	0.43	0.40
Aug II						0.68	0.77	1.14	0.66	0.52
Aug III						0.95	0.96	1.14	0.91	0.74
Sep I						1.19	1.05	1.14	1.13	0.96
Sep II						1.22	1.05	1.14	1.15	1.15
Sep III						1.22	1.05	0.95	1.15	1.16
Oct I						1.22	0.98	0.62	1.15	1.16
Oct II						1.17			1.07	1.16
Oct III						0.90			0.69	1.16
Nov II						0.60			0.41	1.01

5.7 Crop Evapotranspiration (ETc)

The level of crop evapotranspiration is controlled mainly by three factors:

i. Plant characteristics, extent of ground cover and growth stage;

ii. water availability in the soil, and

iii. Meteorological parameters or the evaporation demand.

To calculate ETc, therefore, it requires a three-stage procedure indicated as:

Effect of Climate on Crop Water Requirements: This is given by the reference crop evapotranspiration (ETo). Four methods are usually known to compute ETo in which data availability governs the selection of these methods. In the case of Zamber Storage dam and irrigation project Penman-Montieth method is used to compute ETo.

The Effect of the Crop Characteristics on Crop Water Requirements: Which is given by the crop coefficient as defined by the relationship between reference ETo and crop evaporation, ETc, given as:

$$ETC = KC*ET0$$

The selection of Kc values depends on the crop type, its stage of growth, the growing season and the prevailing weather condition. The Effect of Local Conditions and Agricultural Practices on Crop Water Requirements: includes local climatic variation effects, distance and latitude, soil water availability, method of irrigation, etc. The corresponding crop evapotranspiration is computed using the relationship of crop coefficient and reference evapotranspiration as indicated in the preceding section.

5.8 Effective Rainfall

Effective rainfall is the portion of total rainfall intercepted by crops and stored within the soil root zone, accounting for surface runoff and deep percolation losses. It is estimated using the USDA (SCS) method, following FAO Publication No. 25, article 3.4, and monthly effective rainfall is calculated. and shown in (figure 30).

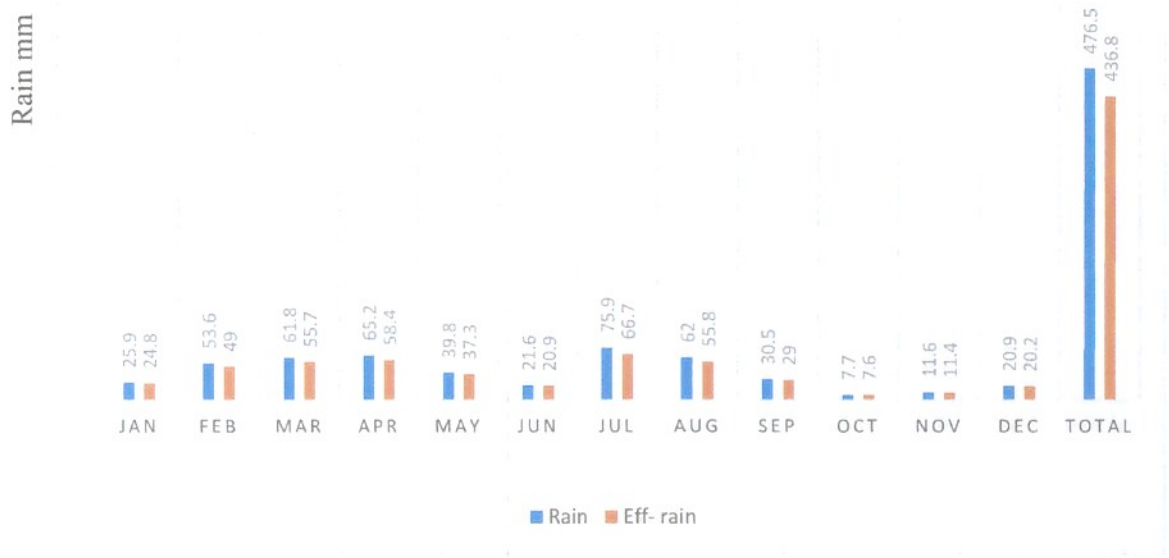


Figure 31 Effective Rain Fall for the Project Area (Station: Khost)

5.9 Net Irrigation Water Requirement (NIR)

The FAO CROPWAT software calculates net irrigation water requirements (NIR) for the project site's growing period, considering factors like crop evapotranspiration (ETC), leaching requirement (LR), effective rainfall (Pe), and ground water contributions.

5.10 Gross Irrigation Water Requirement (GIR)

The gross irrigation requirement accounts losses that would happen in the operation of the system. The losses in the irrigated agriculture system include losses due to seepage and runoff, which are accounted by employing project efficiencies.

To account these losses in the computation of GIR, an overall irrigation/project efficiency of 50% for the selected surface method of irrigation is used. Accordingly, the above water balance equation is reduced to be:

$GIR = NIR/\eta p$

In which ηp stands for project efficiency in consideration of seepage and run-off losses and others remain the same as described in the preceding sections.

Table 19 Project irrigation water requirement for the first proposed cropping pattern

Crop		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total mm
Winter Wheat f.f.		18.7	1.9	36.0	75.9	156.4	167.6	9.9	0.0	0.0	0.0	20.4	21.8	508.6
Clover		19.1	4.8	32.7	59.2	123.8	118.9	13.5	0.0	0.0	0.0	8.9	6.8	387.7
Barley		37.3	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9	35.8	88.6
Potato		0.0	0.0	0.6	59.3	155.9	179.1	19.1	0.0	0.0	0.0	0.0	0.0	414
Small Vegetables		28.4	9.5	30.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	23.4	104.9
Maiz (corn)		0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.8	138.5	119.4	16.6	0.0	326.3
Mungbean		0.0	0.0	0.0	0.0	0.0	0.0	10.5	59.7	117.2	43.9	0.0	0.0	231.3
Soybean		0.0	0.0	0.0	0.0	0.0	0.0	2.2	103.0	123.0	14.1	0.0	0.0	242.3
Dry beans		0.0	0.0	0.0	0.0	0.0	0.0	0.7	54.3	131.3	102.4	2.2	0.0	290.9
Peanuts (Groudnut)		0.0	0.0	0.0	0.0	0.0	0.0	0.7	60.6	131.6	120.9	23.1	0.0	336.9

Table 20 Monthly Net and GIR irrigation water requirement, all crops

CWR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual/ m3
NIR m3/ha	199	30	279	592	1253	1341	116	616	1307	909	266	203	7111
GIR m3/ha	398	60	558	1184	2506	2682	232	1232	2614	1818	532	406	14222

6. Water Balance

The reliability of an irrigation system should be modeled considering water source variability, current resource conditions, irrigation system capacity, soil water holding capacity, local climate variability, and crop type. Failing to consider these variables can lead to a dam that is too small or too big, resulting in poor investment or insufficient crop type. A dataset for calculating monthly discharges at a dam site was generated over 12 years from nearby stations. The available water capacity is estimated to irrigate 1180 ha, the Four Months of Water Shortage will be cover with Dam Reservoir.

Table 21 Water balance computation result

Months	Stream-Flow (m3)	GIR-Demand (m^3)	Balance (m3)
Jan	1112658.4	469640	643018.4
Feb	2280600	70800	2209800
Mar	3672727.1	658440	3014287.1
Apr	2776413	1397120	1379293
May	2222387.42	2957080	-734692.58
Jun	2274891	3164760	-889869
Jul	5046102.58	273760	4772342.58
Aug	4000677.1	1453760	2546917.1
Sep	2305320	3084520	-779200
Oct	1163705.81	2145240	-981534.19
Nov	1107495	627760	479735
Dec	553294.87	479080	74214.87

7. Social and Environmental Assessment

7.1 Background

Afghanistan needs to develop of the large-scale hydropower and irrigation projects, for sustainable and reliable sources of water in the country, mainly the flow regime of the rivers during spring and early summer and often don't have any flows or small flows in late summer and early fall. where the peak flows are happening in the spring and summer it need to be capture by construction of storage reservoir but in Afghanistan there is normally plenty of water and peak flows in many rivers. Therefore, development and regulation of the rivers/streams system is needed to provide reliable water supplies throughout the year, control flood damages, supply of water for domestic use etc.

To achieve the above objectives storage and water diversion dams are needed to be constructed across the rivers in suitable locations; before construction of the dam projects, detail feasibility study and detail design of the projects are needed to be done. Islamic Emarat of Afghanistan has the plan to build storage dam project in Zambar village Sabri District- Khoust province.

Khoust is one of the 34 provinces of Afghanistan, located in southeast Afghanistan. Based on its geographical location, this province is located on the line of 69 degrees, 39 minutes and 58 seconds of longitude and 33 degrees, 5 minutes and 24 seconds of latitude, it is 1146 meters above sea level. This province is divided into 13 districts (Bak, Eni, Tirizai, Jaji Maidan, Khost Matun, Sepirah, Shamal, Sabri (Yaqoubi), Qalandar, Gorboz, Mandozi, Musakhil and Nader Shahkot), encompassing over 1074 small and large villages; the area is about 4235.3 square kilometers. The city of Khoust serves as the capital, located 238 km from Kabul. this province borders with Paktia in the north, Pashtunistan in the south (Bano and Miramshah area), Para Chenar border area in the east, and Paktika provinces in the west.

Sabari district is situated in the northwest part of Khost Province, Afghanistan. It borders Musa Khel district to the west, Paktia province to the north, Bak district to the east and Tere Zayi and Khost districts to the south, The district center is the town of Yaqubi, located in the most eastern part of the district. the proposed project of Zambar (water storage dam) is located in the Zambar valley, which is related to Zambar village, and approximately 12 km from the north of Sabari district and 37 km from the center of Khost.

7.2 Partial Socio-economic Profile of the Province

At this stage of the study detail investigation was not carried out for this particular district and project village, however, the provincial profile can be fairly adopted for this preliminary study stage. The socio-economic indicators of the province are summarized as follows:

7.3 Demography and Population

Khoust province has a total population according to the information of the national statistics office, its estimated 636,522 people, rural districts are home to 98 percent of the population. there are approximately 155 ethnic groups living in Khost province, including Mangal, Zadran, Tani, Sabri, Gorboz, Maton, Lakan, Alishir,Tarizi ,Babakarkhil, Ghiljai, Esmayelkhil Mandozae, Zambar and Zazae. are among the prominent tribes. The gender distribution of the population is roughly 51% male and 49% female. The province also contains a population of Kuchis, or nomads, whose numbers vary according to the season. The elders report that roughly 50000 Kuchis arrive in the Autumn and winter season each year, stay in the area until the end of winter, migrates from a winter to a summer location. and their job is livestock.

Sabari district is one of the 13 districts of Khoust province, population is approximately 89779 people. The number of villages is ....., 99% Pashtun. The mentioned project beneficiaries are not precisely known, but according to the information of the residents of the region, there are 22 villages under the Zambar reservoir dam project, which has 7000 households and a population of approximately 35000 people, most of the people of Sabari district will benefit from this dam. So, the elders of reported in the village of Zambar there are almost 80-100 Kuchis families living in the autumn and winter season each year, who use the water from the wells and springs of the Zambar valley, and most of them their job is livestock.

7.4 Sources of Incomes

Khost is the provincial administrative seat in eastern Afghanistan. Being close to the border with Pakistan, Khost straddles an important transport corridor. So, it is serves as one of Afghanistan's trading centers with neighboring Pakistan. The Ghulam Khan border crossing between the two countries is located about 20 mi (32 km) to the south. has had a positive impact on the economy of Khost. Pine nuts, walnut, wood, bark, are among the noteworthy export products of the province, and its imports are tea, sugar, fibers, machinery, and construction materials.

Business in Pine nuts, walnut, apples, plum, onion and potato are very common in Khost. and sold to Kabul markets and sometimes to Pakistan. The sale of live animals and livestock products is done in Market in the provincial center throughout the week.

From the point of view of agriculture, Khost is covered with vast pine forests, and there are thousands of hectares of valuable fruit trees of the pine tree in its mountains, and it is considered a rich province with a lot of agricultural land. Khost province has a suitable climate and its agricultural lands are cultivated in two seasons (winter/spring, summer), agriculture was reported as the primary source of income in each of the province's thirteen districts; the next most common source of income was livestock,65 % of the people are directly and indirectly involved in the agriculture sector and animal husbandry, 5% are busy in internal and external mercenary work, 7% population employed in production, 23% population employed in services.

According to the figure provided by the profile of Khost province 2018: The state of the land, including the area of 4235.3 square kilometers, 54258 hectares of agricultural land, non-agricultural land 12126 hectares, grassland and forest 118240 hectares, mountains and valleys 238609 hectares, also the number of gardens 117, the number of dams and canals 1050 and the number of Kariz 100. the water resources of Khoust province include snow, rain, springs, Kariz, but the total area in which crops were not grown decreased in total cultivated area due to the drought during the past years.

In Sabri district; there are 40 public schools and 5 private schools and a health center. residents of this district have good access to Khost University, government hospitals and health centers.

Zambar valley has seasonal water. The water source is snow, rain and spring, which originates from the mountains of Sarke weta, Tagha Sarone, Peka, Arghun, Jowa and Golo Ghondi and flows through the three valleys (Shene Dand Khwal, Turki or lizhi Khwal, and Sarkei Hota or Rapot Khwal),

The main source of income in the Sabari district is agriculture, which has been seriously affected by drought. under the proposed project, the present irrigated land is around 453.5 ha in winter/spring and 300 ha for summer season. It has been expected that after the implementation of the project will be increase from 453.5 ha to 3708 ha

Based on information collected from agricultural departments and beneficiary representatives, the major irrigated crops under the project area are wheat, barley, potato, corn (maize), grass (clover), mungbean, soybean, bean, peanuts and vegetables. the table below shows the crop yield/ha and the percentage of the cultivated area for each season.

7.5 Community Consultations

The broad objective of the public consultation, is to conduct extensive participatory consultations covering social, environmental and resettlement aspects of the project to create awareness among the people about the project to incorporate their views, ideas and opinions in order to ascertain their preferences, needs and priorities. The public consultation meetings were conducted among the people of the project area, keeping in mind to achieve the following objectives:

- introduce Zambar dam and the proposed interventions and programmed of implementation;
- Coordination is established between the government and the people.
- ascertain the views and preferences of the people adversely affected / benefited by the proposed project;
- assess their views and opinions about the forthcoming project regarding its benefit and losses;
- learn from people and share with them their perception about the project;
- share the stakeholders' experience and to collect suggestions for solution of problems / constraints of the project;
- know people's ideas for mitigation / minimization of negative impacts;
- assess over all support to implement the project;

However, we had consultations with direct and indirect stakeholders on the Zambar water storage dam

project took place between 24th-fib-2024 and 29th-fib-2024. In our initial meeting with Mawlawy Abdul Qayum Sabet, director of the Khost Shamal Khoram Sub-River Basin (SRB), Mawlawy Mahbob Sha deputy governor of Khost province, Mawlawy Haqben deputy Sabari district governor, Mawlawy Sha Hosyen and Jawedullah of environment department, we discussed about the proposed Zanbar dam project ,the discussions started with a brief introduction about the project, likely benefits of the project in term of irrigation, drinking water and prevent damage during the flood season including people's need, aspirations and perception. the beneficiaries of the project are residents of Zamber villages. discussions about the project and location of the dam site were done with local representatives/elders, leaders of communities, and local government officials. the discussion was very fruitful, and the leaders of downstream are very enthusiastic about the project. key points raised in discussions included:

- Since 80% of Khost agriculture is based on traditional canals, Karezes, springs, wells, tube wells, and it has strongly affected the agriculture and life of the people, which is mainly based on agriculture.
- Therefore, the major occupation of the community and livelihood in the village is based on agriculture and livestock. Improvement of the agricultural system, particularly through irrigation, will lead to an improvement of the people's livelihood.
- An endorsement that has affected farmers - those who lose their trees and land downstream as a result of the flood season, also supported the project because their crops and property were the most affected by the flood.
- In addition, current cropping pattern, availability of water for crops, existing water managing such as Mirab, and role of water users and local skills available etc. were discussed during these consultation meetings.
- Meeting with NEPA Khost province, Key points raised: They raised some questions for standard environmental mitigation measure to be considered during project implementation,













Figure 32 Consultations with direct and indirect stakeholders

7.6 Environmental Impacts Assessment

7.7 General

There is no project that is without environmental and social impacts. However, if a project is fair enough to mitigate the environmental/social impacts with physical and non-physical measures, the development of the scheme cannot be objected. Therefore, with this intention, this section of the report addresses the following:

- ✓ Assessment of the current biophysical and socioeconomic features of the project environment,
- ✓ Assessment positive and negative environmental impacts of the proposed scheme proposing a possible Environmental Management Plan that consists of mitigation and environmental enhancement measures

7.8 Project Salient Features

The Zambar Dam Project is an Embankment dam that would be mainly used for irrigation, drinking water, purposes, provide reliable water to irrigable land that has been affected by previous droughts, recharge underground water streams, and flood control. The dam has scheme components like spillway, inlet/outlet structures, and etc.

The other important features of the dam components that need to be mentioned in the social and environmental impacts assessment are the possible quarry sites (rock, soil sources) and new access roads to be provided. Furthermore, there will be some project camp locations and dumping sites, which are necessary while describing salient project features for environmental analyses

7.9 Description of the Project Environment

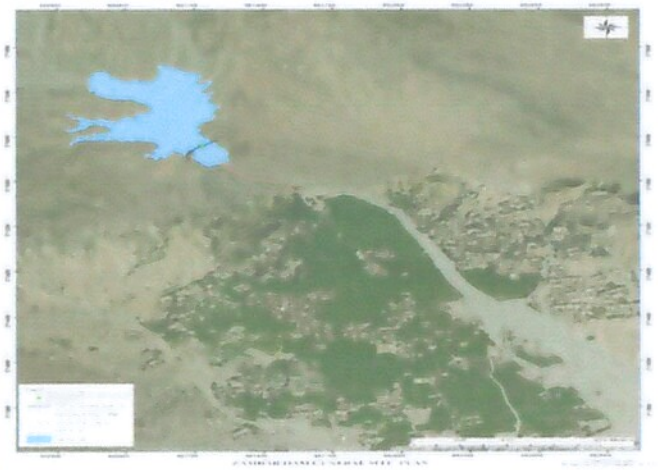
The project is a medium-scale scheme located near a large village of Zamber. The reservoir area at the beginning starts wider at the upstream of the dam axis and then gets narrow. If the axis height is up to 32 meters, there are no affected properties like agricultural land and residential houses near the dam reservoir. There is no agricultural land or residential houses near the dam axis downstream. as well, there is no any cultural property to be damaged. The agricultural land and main canal start approximately/ about 635 m far from the dam axis

Figure 33 Village located in the reservoir area, dam axis, reservoir up/stream and site plan









The biophysical characteristics of the site are mainly grasses and shrubs sparsely distributed throughout the reservoir and the surrounding hills. There are no residential houses, agricultural land, gardens, which needs to be acquisition. There is no distinctive or largely inhabiting fauna (except occasional birds, rodents and some insects) or planned for further expansion or occupancy.

Climate: Khost has a semi-arid climate, most unusually for Afghanistan, Khost receives a substantial proportion of its annual rainfall of 475 millimeter's (19 in) from the South Asian monsoon. The valley being open to the southeast (towards the lower elevation Miranshah), the moisture-laden winds bring much welcomed rain during the summer. The remaining portion of the year Khost remains hot and dry. Sporadic droughts occur when the summer monsoon fails to bring the needed precipitation. Therefore Khost province has a moderate climate, because it rains more in the summer, and the extreme heat of the air reduces the temperature in the summer season to 27 to 32 degrees centigrade. But in the winter season, it is 1 to 4 degrees Celsius.

The agricultural soil in this province has the limits of "alkalinity and acidity" suitable for agriculture and generally has PH 6.2.

There are no critical natural habitats, protected areas, or wildlife reserves to be influenced, as well as non-replicable cultural properties, archaeological sites, or monuments in the area of construction to be affected.

The issue of water quality has been raised during consultation with elders and farmers; according to their information, they confirmed that the quality of water is good for irrigation, domestic as well as drinking purposes. The location in which the project has intervention has no migratory routes for humans (Kuchi), wildlife, or fish, and any area used for hunting, fishing, grazing, and gathering is affected.

7.10 Environmental Impacts of the Proposed Project

During the walk through, (initial visit) an attempt has been made to visualize the extent of impact of this project towards environment and no major negative impact has been anticipated. This project normally has more of positive impacts than the negative impacts. Some of the anticipated positive and negative impacts of the project are as described below.

7.11 Positive Impacts

Major positive impacts of this specific project are:

- Increasing irrigation land from 453.5 ha to 3708 ha will enable beneficiaries to cultivate more land which results more yield. during consultations, farmers under the dam project consistently made the point that increased land brought under irrigation through project interventions will enable them to grow and sell more diverse crops resulting in more disposable income for them and their families
- The possibility of floods damaging agricultural land and homes and destroying crops and livelihoods and transportation roads will be significantly reduced by the construction of dam.
- The proposed project will create mainly temporary employment opportunities for skilled, semiskilled, and unskilled manpower during construction and operation phases.
- Providing safe drinking water for the residents of the region and their livestock.
- The reservoir can be a fish breeding area, used as a recreational area, used to recharge groundwater, Karez, springs, and also regulate local temperature, etc.

7.12 Negative Impacts

The proposed dam project does not involve in any kind of land acquisition, there is no any major negative impact, If the project required soil, 2,000 square meters of land has been donated by the project users in a suitable location. no other negative impacts are anticipated in this project because the intervention is in the end of valley point. The completion of the project will in fact reduce small tensions that used to pop up sporadically by some community members. Such instances will be reduced greatly and farmers, due to the reliability of the source will show civility in all their action. Some general environmental considerations need attentions are given as follows:

7.13 Construction Phase / Short Term Impact

The principal impacts and the corresponding mitigation measures during the construction stage are:

- ✓ **Waste discharges resulting from Contractor's camp:**

In order to avoid negative impacts of solid and liquid waste on the environment, an adequate waste management at the construction site and a controlled disposal of hazardous waste is necessary. The impact of waste discharges and refuse disposal can be limited by imposing appropriate restrictions on the contractor and having suitable clauses included in the contract documents and strict supervision. The construction contractor shall prepare a Waste Management Plan (WMP)

- ✓ **Noise and dust resulting from the construction activity:**

Noise and dust are a short-term and localized problem. The impact of noise pollution can best be limited by imposing maximum noise levels on the Contractor and by restriction of working hours, particularly with respect to locally recognized days of rest or religious festivals. However, the project location, nature and type of activities will not create major environmental issues related to noise and air pollution as the dam site is far from residence areas. Similarly, the level of dust and smock could be raised slightly during construction period. The following are recommendations to avoid the limited impact and disturbance:

- Reduce dust by watering the access roads, in settlement or camps at the construction site,
- Regular maintenance of vehicles and machines, reduced speeds and limited movement of vehicles, and use of tarpaulins.
- Avoid burning of materials such as tiers, plastic, rubber products or other materials that creates heavy smock or nuisance odor,
- Give notice to locals regarding the noise disturbance and accidents that might result from any possible blasting, etc.
- Cover stock-piled spoil with erosion control materials
- Cover materials during transportation by truck
- Sprinkle water on work areas to reduce air pollution caused by dust.
- Ensure equipment and vehicles are fitted with adequate quality of air filters. (Proper maintenance.)
- Avoid disposal of soil, sludge and other wasters into water bodies
- Install barriers to prevent soil slippage at edge of stocked areas.

- ✓ **Spillages of lubricants, fuel, paint, other chemicals and scrap metal:**

A waste management plan should be created indicated how waste oil, lubricants, other chemicals and scrap metal would be transported to a waste management facility where they could be recycled, incinerated, decontaminated and/or decomposed safely. If no such facility is available, the Contractor should propose and demonstrate an environmentally safe system of hazardous waste disposal.

The Contractor should account for the quantities of hazardous (potentially polluting) materials (explosives, acid, paint, and solvents) brought to the site. They are should be reused or removed.

- ✓ **Soil erosion due to digging of trenches and quarries:**
  - Appropriate erosion prevention structures have to be provided wherever necessary,
  - Non-hazardous waste should be compacted and entrenched at an approved landfill sited over impermeable sub-soil, well away from a drainage course, if any, and
  - Disturbed top soil should be preserved and restored and adequate precautions should be taken to prevent soil erosion.
  - A careful selection and survey of adequate sites shall be performed to avoid negative impacts on the soil in an applicable extent.
  - The contractor has to extract the material from the specified and demarcated burrow areas
- ✓ **Interruption to the existing road system:**

Interruptions to the existing local road are inevitable especially when construction of the dam is begun. Therefore, permanent shifting of the road is necessary just at the beginning of the work.

- ✓ **D/S water use:**

During the dry and summer seasons, the current river flow is used by the immediate inhabitants mainly for minor irrigation, animal drinking, etc. There are no such downstream conflicts; however, the minimal currently existing flow shall be released and maintained as before through the bottom outlet. This is essential to conserve the biodiversity existing in the channel.

Also, workers camps/residential villages, borrow pits and quarry areas, lay down and deposit areas may have additional impacts on water resources. A careful final selection and survey of adequate sites shall be performed by the Construction Contractor in order to avoid negative impacts on surface water, groundwater and the existing water flow of the spring.

7.14 Long Term Impacts

The construction of the dam and associated structures has some minor long-term impacts on the surrounding environment. Loss of agricultural area for clay quarrying and inundation of some plants in the reservoir area.

Though the magnitude of the impact is very small, however, proper precautions shall be taken before selection of the final quarrying sites. Measures that should be considered include:

- ✓ The clay source area shall be as much as possible be reduced by economical designs and further site assessment such as nearby free area, grazing land, etc.
- ✓ If free land or minimal use location is not available, arrangement shall be made to the affected individuals to be part of the project. For instance, priority for casual labor or to be as permanent staff as guard, assistant, etc.
- ✓ Strict construction regulations and monitoring to sustain plants and vegetation which are outside of the project site.

7.15 Environmental Management and Monitoring Plan

Environmental management and monitoring aspects of a project are concerned with the implementation of measures necessary to minimize or offset the adverse impacts and enhance the beneficial impacts. An environmental management plan should be integrated into the overall project planning and management in order to supply safe irrigation water in a sustainable manner and ensure high social and economic benefits that would be obtained from the use of water.

The nature and scale of activities envisaged in the proposed project are mainly on free locations and are also small areas, as are the corresponding environmental impacts. The overall project planning and management can effectively handle and incorporate these activities. Environmental control will be the responsibility of the supervisor and the contractor, who together will take the major responsibility to implement the proposed environmental mitigation measures during the project construction period.

It further contains recommendations to improve the Environmental Management Capacity within the concerned Ministry (MEW) and related government agencies. The recommended installation of RB/SRB Department within MEW shall bring the relevant institutions in a position to implement and supervise all mitigation and monitoring actions as outlined within the EMP.

7.16 Environmental Management and Monitoring during Construction Period

Areas where environmental management and monitoring required during the project construction stage are:

- Implementation of preventive measures for soil erosion such as rehabilitation of disturbed areas due to construction activities mainly due to excavation or other activities
- Proper setting of camp site and provision for proper solid and liquid waste disposal areas,
- Establishment of designated solid waste disposal area and proper disposal of waste from construction activities that may include soil/rock mass and dirt excavated, pieces of pipes and other construction materials etc.
- In view of known and unknown historical and cultural sites, a careful final selection and survey for suitable locations for workers camps/residential villages, borrow pits and quarry areas, laydown and deposit areas shall be performed by the Construction Contractor in order to avoid negative impacts on advance in an applicable extent.
- The Project would not impact substantially on religion, culture and customs of the host communities, if the project workers are properly sensitized on the harms that could be caused by an adequate training.
- During the construction phase, the work personnel will be exposed to various health risks and hazards. In order to reach maximum health and safety conditions for the workers at the construction sites, the Construction Contractor shall develop implement a proper HSE Management System

7.17 Environmental Mitigation Measures and Costing

The proposed dam project does not involve in any kind of land acquisition, If the project required soil, 2,000 square meters of land has been donated by the project users in a suitable location the land needed for the soil barrow pit area in one location has been donated by the land owners (total 2,000 sqm). In the subsequent stage, a more detailed assessment shall be done with sound and tangible environmental cost figures.

8. Economic analyses:

8.1 Introduction

During the Phase 1 study, a financial analysis of the Zamar Dam site was undertaken to assess the financial soundness, in terms of benefit cost ratio (b/c ratio) and net present value (NPV) of incremental benefits – both at discounted at 10%, and internal financial rate of return (IFRR).

The cultivation in the command area of the Zamar Dam site is solar pump and gravity Canals, which are using surface and ground water. Irrigation land is in vulnerable during flood periods and the most of the Irrigation land are located near the river Flow path. Dam construction will provide safety and save Irrigation Land for the communities.

8.2 Context

At the proposed sites, the existing yields are more than potential, it is expected that with the reasonably assured supplies from the proposed dam, the yields would increase by about 50%. It is also expected that there may be a shift towards area under high value crops, including fruit trees, after the farmers gain sufficient experience of water reliability, and access to markets is improved.

8.3 Analytical Frame and Assumptions

The financial analysis has been undertaken following the standard methodology as employed internationally for evaluating the irrigation and agricultural projects. The 'with and without' project estimates of crop gross margins were prepared to estimate the incremental value stream of the benefits.

Similarly cost streams were estimated by accounting for construction cost and the incremental O&M cost of the system. Net Present Value (using a discounting rate of 10%) of both the streams was evaluated to estimate the indicative b/c ratio and IFRR. In the case of the MHPUs, the benefits stream represents the value of the electricity consumed at a tariff based on 'willing to pay basis.' To make the schemes comparable at uniform yardsticks despite variations, equalizers were adopted in estimating the benefit and cost streams.

The main assumptions adopted in the analysis are as follows:

- The 'with and without project' cropping pattern has been assumed to remain unchanged except for two schemes, where at present no cultivation was observed.

- Despite regional variations, in the absence of farm household survey and information, yields and per ha cost of production and value of output has been assumed to be the same across the schemes, and the gross margins were estimated attributing one third of the value of outputs as cost of production.
- It is assumed that schemes that comprise of dam structure and irrigation structures both, the yield increase is assumed at 50%, while in schemes limited to irrigation structures, the yield increased has been assumed at 25%.
- To account for the benefits from increased forage production and consequent increase in livestock and dairy production, a factor of five percent was applied to the agriculture benefit stream.
- It is assumed that full development stage in farm productivity would be reached by the fourth year, after the scheme is operational.
- To account for the yearly expenditure on O&M, it is assumed as half a percent of the investment cost of dams and irrigation structures and one percent for the MHPUs.

Predicted Future Annual Irrigation Benefits	**79,849,251.75**
Estimated Dam Body Construction Cost	**174,633,200**
Total Project cost	**174,633,200.00**

IRR	**45%**
NPV	**551,217,565**
BCR	**4.16**

Table 22 IRR, NPV

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