Technical Note

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Pre-Feasibility Study and Design of a Multipurpose Reservoir: A Case of H Project

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Abstract: This is a technical note to discuss that numerous initiatives are underway to reach the aim, including the building of multifunctional reservoirs, planning of water supply and sanitation infrastructure, irrigation, and hydropower development for the H project. The key data provided for this work included rainfall data, flow data, catchment area, base population for water delivery, and so on. This report especially covers the preliminary analysis and design of water supply, irrigation, and hydropower development for the project, which is carried out in compliance with the scope of works for the stochastic hydrological feasibility study. To carry out this job, the major data provided were rainfall data, flow data, catchment area, base population for water delivery, and so on. This paper details the preliminary analysis and design of water supply, irrigation, and hydropower development for the project, which was completed in compliance with the scope of works for the stochastic hydrological feasibility study. The project's goal is to suggest and construct a cost-effective water supply system, irrigation, and hydropower development in order to offer dependable, adequate, and safe water to the H project from a defined water source. The investigation works have specific objectives such as assessing potential water source alternatives for water supply, selecting an appropriate size for the reservoir that can meet all water demand, assessing and selecting suitable irrigation development and hydropower potential, and preliminary study and design of all reservoir components and appurtenant structures.

Keywords: hydropower; irrigation; water supply; pre-feasibility

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1. Introduction

1.1. General

The main purpose of this project is to enable us work and make exercise on multipurpose reservoir planning. And, this project is undertaken and worked according to the specific guidelines and science of water science and engineering in the study and design of a multipurpose reservoirs.

1.2. Project background

In order to achieve the target several activities are undergoing with the development of multipurpose reservoir planning of the water supply and sanitation infrastructure, irrigation and hydropower development for H project. To undertake this, work the main data given was rainfall data, flow data, catchment area, base population for water supply and so on.

This report presents specifically preliminary study and design of water supply, irrigation and hydropower development for the project, which is carried out in accordance with the scope of works given by our professor. The preliminary study and design is therefore to investigate scenarios, alternatives, and prepare the document of water supply, irrigation and hydropower infrastructures for the provision of the assignment.

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This report, as required in the assignment, contains: project background, water sources assessment, selection of suitable hydropower potential, and irrigation sizing, design criteria, descriptions of the proposed scheme, preliminary design of water supply components.

1.3. Project objective

The objective of the project is to recommend and design cost effective water supply system, irrigation and hydropower development; to supply reliable, sufficient and safe water from defined water source to the H project. Specific objectives of the investigation works are;

- To assess potential water source alternatives for water supply
- Selecting appropriate size for the reservoir which could satisfy all water demand
- Assess and select suitable irrigation development and hydropower potential.
- Preliminary study and design of all components of the reservoir and appurtenant structures

1.4. The scope of the project

The scope of the project generally focuses on preliminary study and design of water supply, irrigation and hydropower development components from water sources potential and the water balance output.

1.5. Limitations of the study

There are some data limitations encountered during the study and preliminary studies including;

- Longest path, rigidity/slope of the catchment
- Lack of topographic data as with required scale and accuracy.

2. Approaches and materials used in the study

2.1. Materials Used

The following materials were used during the study, these are spreadsheet models are developed for all works as follows

- Filling missing data
- Flood frequency analyses
- Catchment yield calculation
- Flood routing
- Water balance and demand analyses
- Estimation of hydropower potential and irrigation sizing

2.2. Approaches used

2.2.1. Field Work

Since this assignment is worked out from the given data so, no any fieldwork is undertaken.

2.2.2. Office/ Desk Work

In the office/desk work different activities have been carried on including;

- Identification of secondary data requirement of the project area.
- Collection of relevant secondary data
- Review of previous studies conducted, relevant documents pertaining to the assignment.
- Identify potential water sources for water supply, irrigation & hydropower
- Summarizing, analysis, interpretation of collected data, Conduct preliminary design of water supply, irrigation & hydropower.

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2.2.3. Results of Field and Desk work

After performing intensive office work, outputs and result of the different aspects of water supply system: reservoirs options, hydropower potential, and spillway appurtenant structures are identified and presented below. The design will be based on the Federal Ministry of Water Resource Design guideline, different design reports, text books and field work conducted in similar projects to collect important data for the design work.

2.2.4. Stakeholder consultation

Stakeholders like for such mega projects are critical in making stakeholder consultation. The aim was to get ideas and views, how they understood the proposed project and consider their feedback and say towards successful selection, design and implementation of the project. Presentation of the preliminary phase of study with client representatives in project office will be significant to consider additional water source options.

3. Project Description

3.1. Location

The project H is a multipurpose reservoir for water supply, hydropower and irrigation development located in X and Y Coordinate.

3.2. Accessibility

The accessibility of the project is unknown.

3.3. Climate

Before undertaking any analyses of climate data homogeneity, consistency and normality test of climate data are mandatory[1]. The climatic condition of the project area has warm climatic condition. The project areas mean rainfall series estimated from 50 years’ (1951-2000) record of stations. These estimations revealed that the annual average rainfall over the project is estimated to be **1284 mm**.

3.4. Estimation of stream flow missing data

The main purposes of this part of study are to evaluate missing stream flow data using several interpolation methods which are arithmetic average (AA) method, normal ratio (NR) method, inversed distance (ID) method, and coefficient of correlation (CC) method[2]. However, if the data are still missing and information from surrounding stations cannot be utilized due to a lack of data, the mean for the same day and month but in a different year is used to estimate the missing values on that specific day. To assess missing values at the target station using information from surrounding stations, the analysis would be separated into four or more distinct percentages, such as 5%, 10%, 15%, and 20%, to reflect various types of missing data [2]. However, just 20% (10 years' worth of missing data from 50 years) is considered for this experiment. Additionally, the Mean Absolute Error (MAE), Correlation Coefficient (R), and Root Mean Square Error (RMSE) tests are used to compare the effectiveness of various strategies [2].

3.4.1. Estimation Methodology

There are two primary subsections in this section. We'll talk about missing data estimation techniques in the first subsection. The target and a few carefully chosen nearby stations were included in the analysis. In the meanwhile, the second part will cover evaluating the effectiveness of the employed techniques. The target station contains all of the data in the first part. Next, data at the target station are taken to be missing in order to evaluate the estimating techniques. The target station's missing stream flow and rainfall data are compared to the actual records using interpolation techniques.

3.4.2. Interpolation methods

(i) Arithmetic Average Method

The arithmetic average (AA) Two major subsections comprises this section. The first topic will provide techniques for estimating missing data. A study was conducted with a target and a few carefully chosen nearby stations. The second subsection will include evaluating the effectiveness of the employed techniques in the interim. The target station possesses the entire collection of data in the first segment. Afterwards, data at the target station are taken to be missing in order to evaluate the estimating techniques [3, 4].. The missing stream flow and rainfall data at the target station are compared to the real records using interpolation techniques.

$$P_t = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \textbf{Equation for AAM……..Equation 3-1}$$

Where xi is the observed data at ith neighboring stations or the date of the same date with various years, n is the number of nearby stations or number of years, and pt is the predicted value of the missing data at the t target station/date.

(ii) Normal Ratio Method

The target station's and its surrounding station's ratio mean of accessible data is the basis for the weighting of the normal ratio (NR) approach. This approach is applied if any nearby stations have data on typical annual rainfall and stream flow that surpasses ten percent of the station under consideration [5, 6].. Given by is the estimated missing value.

$$P_t = \frac{1}{n}\sum_{i=1}^{n} \frac{N_t}{N_i} x_i \qquad \textbf{Equation for NRM……..Equation 3-2}$$

Where N_t is the annual rainfall and stream flow amount at the target station and N_i is the annual rainfall and stream flow amount at the i^{th} nearby station.

(iii) Inverse Distance Method

The approach that is most frequently used to estimate missing data is the inverse distance (ID) method. The target station's distance from the neighboring station is the basis for this strategy. Compared to further stations, the nearby stations have a stronger correlation with the target station[5, 6]. Given by is the estimated missing value.

$$P_t = \frac{\sum_{i=1}^{n} \frac{x_i}{d_{it}}}{\sum_{i=1}^{n} \frac{1}{d_{it}}} \qquad \textbf{Equation for IDM……Equation 3-3}$$

where d_{it} is the distance between target station and the i^{th} nearby station.

(iv) Coefficient of Correlation Method

correlation coefficient (CC) Using this strategy, the correlation coefficient is employed as the weighting value instead of the distance [7]. Given by is the estimated missing value [8].

$$P_t = \frac{\sum_{i=1}^{n} x_i r_{it}}{\sum_{i=1}^{n} r_{it}} \qquad \textbf{Equation for CCM………Equation 3-4}$$

where r_{it} is the correlation coefficient of daily time series data between the target station and the i^{th} nearby station.

3.4.3. Performance of the estimation methods

Three performance criteria are applied in this study [9]. To assess spatial interpolation techniques, statistics such as the correlation coefficient (R), mean absolute errors (MAE), and root mean square errors (RMSE) are computed. The difference between the estimation values and the matching observed values is measured by the error. Better results will be shown by RMSE and MAE, which show lower values. Meanwhile, correlation coefficient indicates the strength of the relationship between observations and estimates which the higher positive coefficients estimate the best results.

$$\mathbf{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{Y}_i - y_i\right)^2} \quad \textbf{Equation for RMSE........ Equation 3-5}$$

$$\mathbf{MAE} = \frac{1}{n}\sum_{i=1}^{n}|\hat{x}_i - x_i| \quad \textbf{Equation for MAE ....Equation 3-6}$$

$$\mathbf{R} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(\hat{x}_i-\bar{x})}{\sqrt{\sum_{i=1}^{n}(x-\bar{x})^2\sum_{i=1}^{n}(\hat{x}_i-\bar{x})^2}} \quad \textbf{Equation for R...........Equation 3-7}$$

where x_i is the observed rainfall and stream flow at nearby station, $x_i\hat{}$ is the estimated value and is the number of nearby station.

3.4.4. Results and discussion of estimation methods

We shall touch on the analysis's findings in this part. We tried each of the four interpolation techniques on a single percentage at 20 percent. The table below, Table 3-1, presents the findings of the approaches' overall performance. The comparison of flow data estimating techniques is presented in Table 3-1. For G, I, and J stations, the ID approach is proven to be the most effective. NR is the most effective approach for N station. Additionally, it is demonstrated that for all stations that produced the lowest RMSE, the CC technique is the second-best approach. Additionally, Table 3-2 just compares the estimating techniques with four distinct percentages of missing values—that is, five, ten, fifteen, and twenty percent.

Table 3-1. Comparison of estimation methods based on RMSE, MAE and R with 20% missing value for stream flow data.

Station	Method	RMSE	MAR	R
		20%		
G	AA	176	75	8.0
	ID	150	72	7.8
	NR	155	73	7.9
	CC	154	73	7.7
I	AA	170	76	7.9
	ID	146	71	8.2
	NR	152	72	7.7
	CC	150	74	7.6
J	AA	171	76	7.9
	ID	151	71	7.8
	NR	158	73	8.1
	CC	152	74	7.83
N	AA	166	75	7.9
	ID	159	71	8
	NR	150	73	7.7
	CC	155	73	7.6

Table 3-2. Comparison of estimation methods based on RMSE, MAE and R with four different percentages of missing values for stream flow data.

Station	Method	RMSE				MAR				R			
		5%	10%	15%	20%	5%	10%	15%	20%	5%	10%	15%	20%
G	AA	140	171	173	176	66	69	71	75	5.1	6.2	7.1	8.00
	ID	144	145	146	150	64	67	70	72	5.2	6	7	7.80
	NR	150	151	153	155	65	68	71	73	5.2	6.1	7.1	7.90
	CC	148	150	151	154	64	69	70	73	4.9	5.9	6.8	7.70
I	AA	141	168	172	170	65	67	69	76	4.8	5.7	6.8	7.90
	ID	140	141	143	146	64	65	68	71	5.4	6.3	7.1	8.20
	NR	142	145	150	152	65	67	68	72	5.3	6.1	6.9	7.70
	CC	140	142	145	150	66	68	73	74	4.6	5.4	6.4	7.60
J	AA	138	142	155	171	67	69	72	76	5.1	6.2	7.1	7.90
	ID	140	145	150	151	65	66	68	71	5.1	6.3	7.1	7.80
	NR	145	150	155	158	66	67	69	73	5.5	6.4	7.3	8.10
	CC	142	146	149	152	67	69	72	74	5.6	6.2	7.2	7.83
N	AA	148	157	159	166	65	67	69	75	5.5	6.1	7.1	7.90
	ID	139	155	157	159	64	65	68	71	5.7	6.2	7.2	8.00
	NR	141	147	148	150	63	66	69	73	5.5	6.1	6.9	7.70
	CC	143	150	152	155	67	68	71	73	5.1	5.8	6.6	7.60

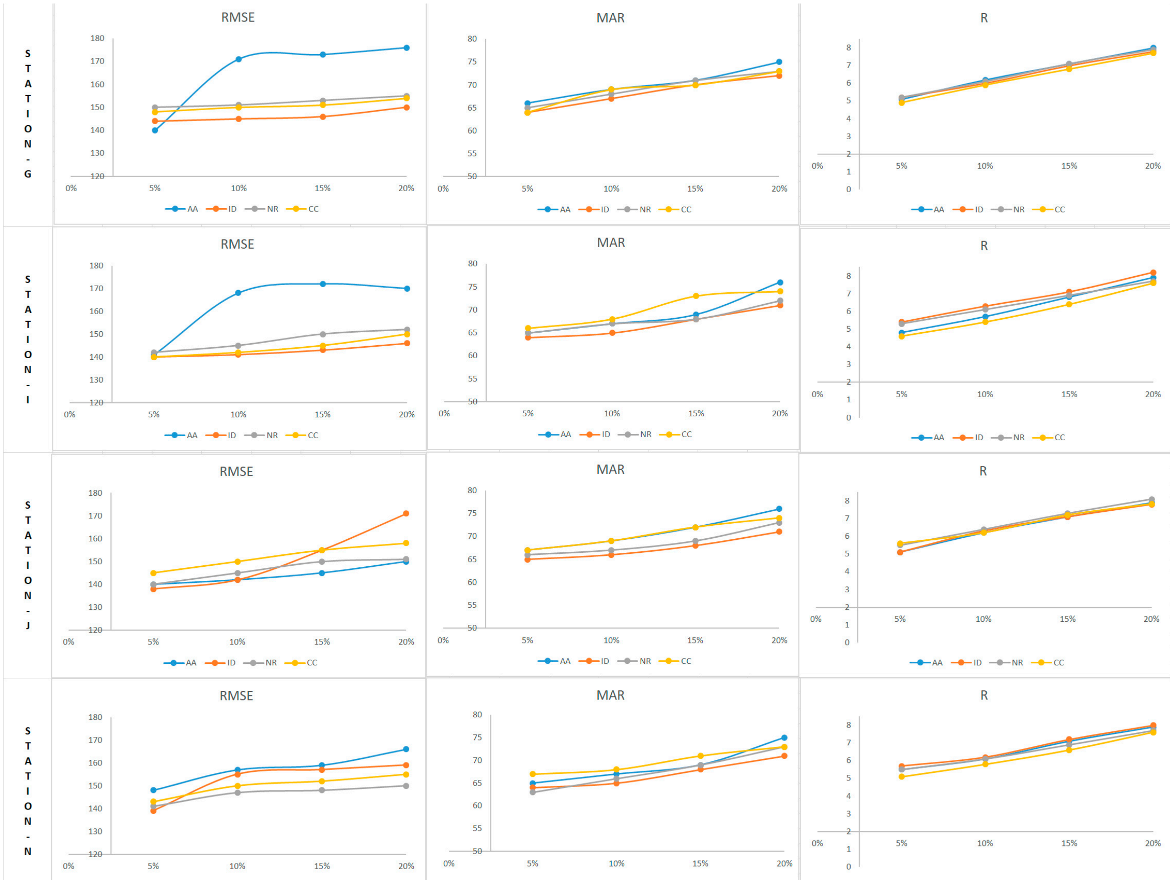

Figure 3-1. Comparison of RMSE, MAE and R method with various percentages of missing values for G. I, J and N Stations.

4. Water Demand, Sources and Storage

4.1. Water Demand of the Project

The design basis for the sizing of any water resource planning is first of all an estimate of the amount of water expected to be used by the project [10]. Accurate estimate of water demand is a basic consideration to the sizing of storage facilities, this involves consideration of a number of factors depending on the nature of the project [11].

The water demand required for the development of water supply, irrigation and hydropower has been fixed and estimated by the following procedures.

Based on client provision the project water supply demand is estimated to be 100lit/day/cap and crop water and irrigation requirement is given below in Table 4-1 and for the hydropower it is to be decided at later stage after analyses.

Table 4-1. Crop water and irrigation requirement of different crops (m^3/ha).

Crop	Planting Date	Growing period (days)	Seasonal Etc/m3/ha	Irrigation req/m3/ha
Onion	01-Feb	95	4624	4226
Tomato	01-Jan	145	7421	6649
Wheat	15-Jan	130	6083	5445

4.2. Surface Water Sources

The project must have water source with sufficient capacity and reliably to full fill the water demand.

4.2.1. General site selection criteria for the reservoir

The following factors should be kept in mind while selecting the site for a reservoir[12-15]:

- The reservoir site should be such that the leakage of water through the ground is minimum
- Sites having permeable rocks reduce the water tightness of the reservoir. The rocks which allow less passage of water include shales, slates, schists, gneiss, and crystalline igneous rocks such as granite.
- A suitable site for the darn must exist. The dam should be founded on sound watertight rock base, and percolation below the dam should be minimum. The cost of the dam depends on the suitability of a site and is often a controlling factor in the site selection.
- The reservoir basin should have a narrow opening in the valley so that the length of the dam is the least possible.
- The cost of the real estate for the reservoir, including road, railway, rehabilitation and resettlement etc. must be as small as possible.
- The topography of the reservoir site should be such that, it has adequate storage capacity without submerging excessive land and other properties.
- The site should be such that a deep reservoir is formed. A deep reservoir is preferable to a shallow one because of the lower cost of the land submerged per unit of capacity, less evaporation losses due to reduction in the water spread area, and less likelihood of weed growth.
- The reservoir site should be such that it avoids or excludes water from those tributaries which have a high concentration of sediments in water.

4.3. Elevation-Area-Capacity Curves

According the given formula Reservoir surface area=6H^$^{1.5}$ [16] is used to produce the capacity curve shown in Figure 4-1 below. Thus, a curve may be drawn with elevation on the Y-axis and area on the X-axis. Such a curve for a reservoir is shown in following figures. The contour plan also shows the water spread corresponding to the maximum water level in the reservoir. This information is used to determine the area likely to come under submergence.

The reservoir capacity or the volume of storage corresponding to a given water level may be calculated by the trapezoidal formula [17]. Thus, if A1 and A2 are the areas between two successive contours, and h is the contour interval, the intermediate storage volume V can be calculated using the formula:

$$\mathbf{V = (A1 + A2) * h/2}$$

The total reservoir capacity at a given elevation is computed by adding the incremental volumes up to that elevation. The storage volumes corresponding to various water-surface elevations may be

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calculated and a curve, called capacity curve, may be plotted between elevation and storage as shown in the following tables and figures for this option.

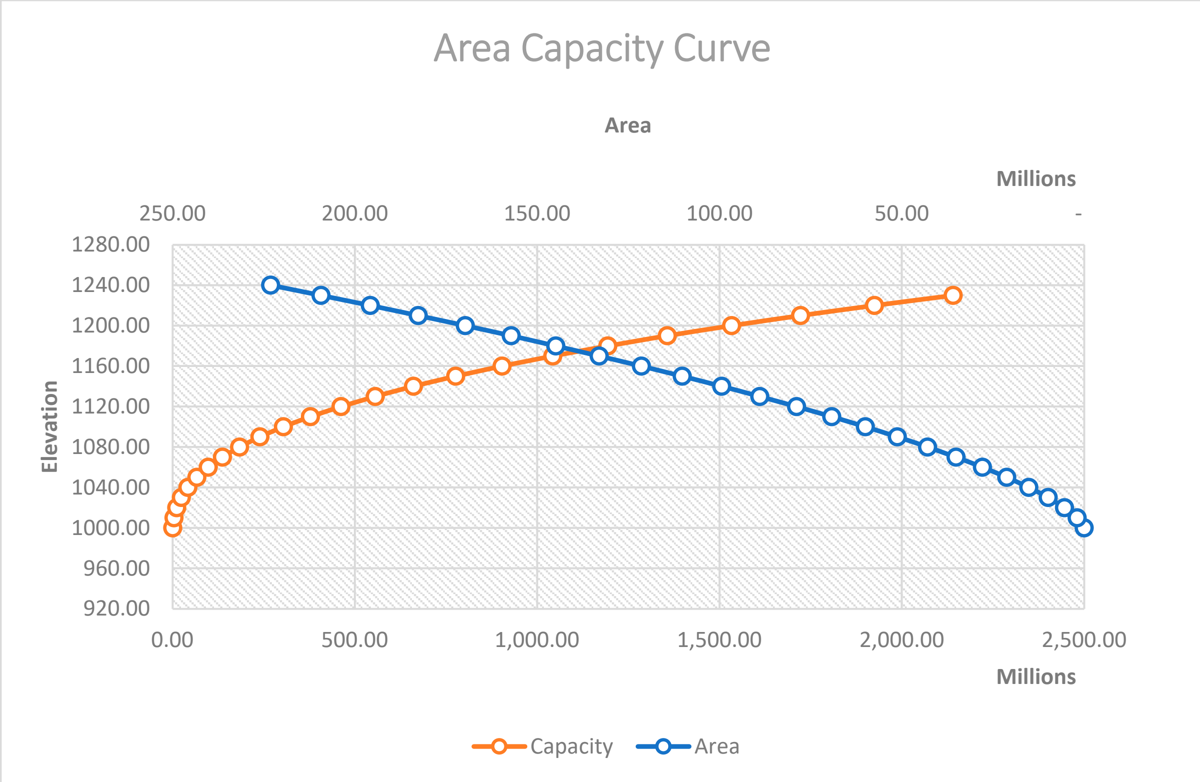

Figure 4-1. Elevation-Area-Capacity Curve for Dam Site.

Table 4-2. Summary of Computed reservoir storage capacity.

S/N	Dam Site	Reservoir Capacity, Mm^3
1	Dam Site H	1,357.11

4.4. Downstream release estimation

In order to compute the water balance for further design analyses Q_{95} is tabulated from the given data for downstream release from the flow duration curve developed[18, 19] and shown in Figure 4-2 and tabulated in Table 4-3 below.

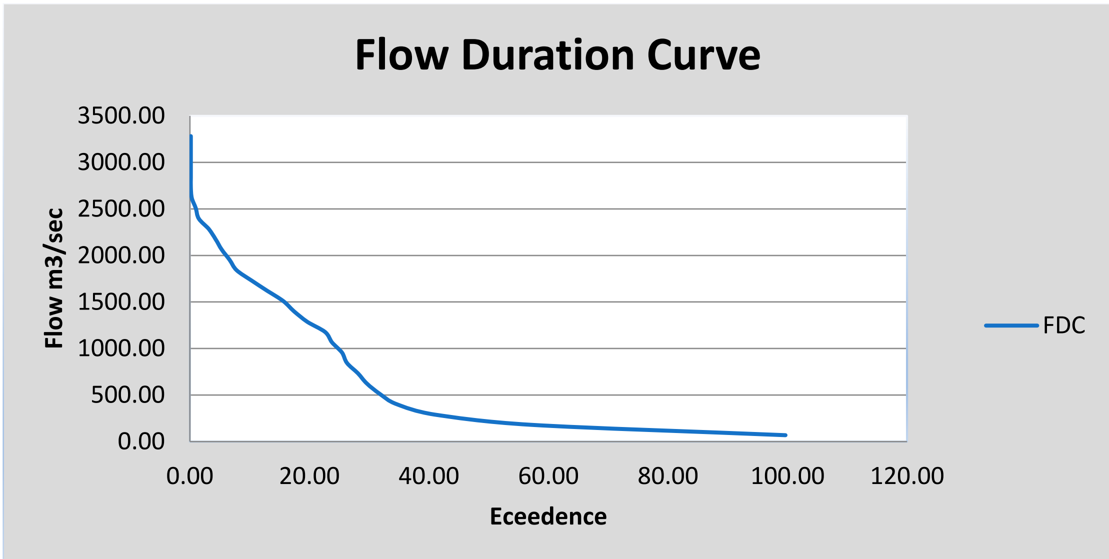

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Figure 4-2. Flow duration curve.

Table 4-3. Q95 for downstream release.

Q_{70}	Q_{80}	Q_{95}
147.49	**121.49**	**82.50**
Monthly Volumetric water requirements for downstream release in m^3 Q_{95}		**213,839,358.75**

5. Population and Water Supply Demand Estimation

5.1. Population

5.1.1. General

A water supply scheme includes huge and costly structures, which cannot be replaced or increased in their capacities easily and conveniently[20]. Hence all scenarios affecting the water supply system should have to be thoroughly accessed before the system is designed. One of the scenarios that have great impact on estimating the water demand of a particular project is the projection of the population sizes [21]. Hence, the planning of any water supply system has to be based on the forecast of population size, population growth rate and distribution.

There are a number of factors that should be taken in to consideration in projecting the future population size of a project, some of which are fertility, mortality, economic activity in and around the project town, availability of natural resources, and status of the town in the region, i.e. its political and economic significance, relative location of the town with respect to main highways and availability of reliable urban infrastructure facilities and etc [22].

5.1.2. Base Population

The use of a reliable base population figure is very important for optimizing the project costs and sustaining the project's service year. Over and under estimation of the populations could result in a higher investment cost and a lower service run period respectively. Hence it is very important to initially get a realistic base population figures not to come with the above-mentioned problems. This design has taken the base population of 5 million given for this exercise.

5.1.3. Population Projection

The Central Statistical Authority has established an annual growth rates for population projection from 1995 up to the year 2030. Hence, in projecting the future population sizes of the town and the rural, the country level CSA's growth rates as presented in the table below have been used. The projected populations using the base populations presented above; and in this report the annual population growth rate is fixed in three scenarios low, medium and high variant. The growth rates presented below are shown in the table and chart presented underneath. For water supply design projects, the medium annual growth rate scenario is adopted.

Table 5-1. Fertility Rate Set by CSA for Urban Population and For Projections.

Years	Low variants	Medium variants	High variant	Average	Remark
1995-2000	6.53	**6.72**	6.95	6.7	
2001-2005	5.28	**5.97**	6.72	6.0	
2006-2010	4.76	**5.42**	6.27	5.5	
2011-2015	4.24	**4.86**	5.75	5.0	
2016-2020	3.8	**4.29**	5.22	4.4	
2021-2025	3.36	**3.73**	4.69	3.9	
2025-2030	2.92	**3.24**	4.2	3.5	

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Table 5-2. Projected Populations of the given project.

Year	H project	Rural	Total
2020	5,000,000	0	5,000,000
2021	5,271,000	0	5,271,000
2022	5,556,688	0	5,556,688
2023	5,857,861	0	5,857,861
2024	6,045,183	0	6,045,183
2025	6,338,978	0	6,338,978
2026	6,647,053	0	6,647,053
2027	6,970,100	0	6,970,100
2028	7,308,846	0	7,308,846
2029	7,664,056	0	7,664,056
2030	8,036,529	0	8,036,529

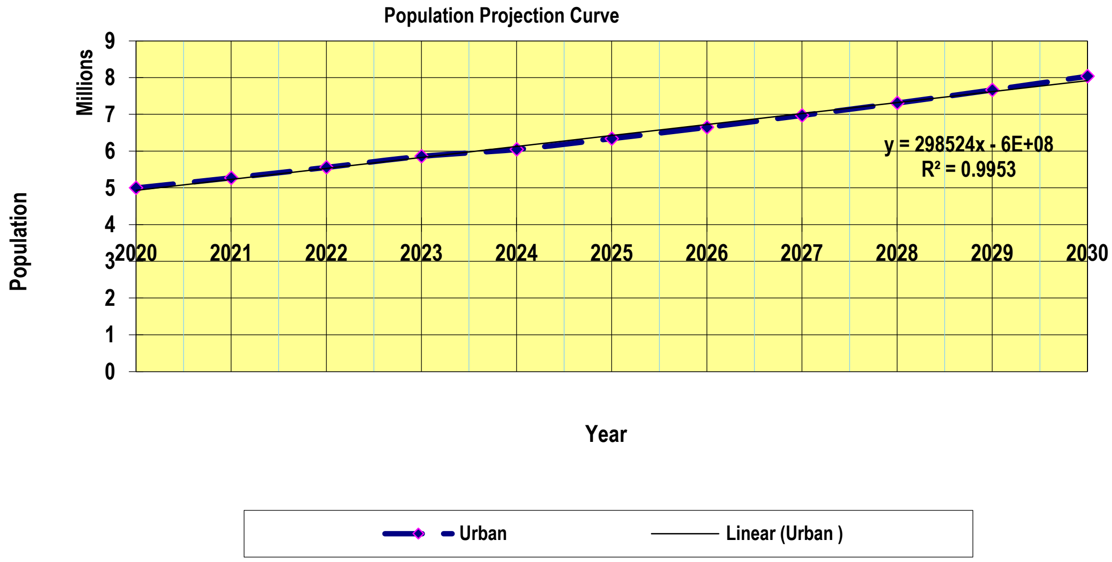

Figure 5-1. Population Projection Curve for H project.

5.2. Water Demand

Development of reliable water demand is not a straight forward process, but requires detailed socio-economic survey in the supply area, as the potential consumers ability and willingness to pay for the water depends of the tariff, which again depends of the number of people using the improved water supply. The process to develop the demand is hence iterative.

5.2.1. Domestic Water Demand

The Domestic water demand is the daily water requirement for use by human being for different domestic purposes like drinking, cooking, bathing, cleaning, gardening and etc. The domestic water demand required by human being could be supplied or obtained through different modes of services depending on the economic level and facilities owned by the individual.

2.2.1.1. Modes and Level of Services

In a conventional water supply system, there are five modes of services in which an individual could be served. These are:

- House Tap Users [23]
- Yard Tap Users (YTU)

- Neighbor Hood Tap Users (NTU)
- Traditional Sources Users (TSU)

However, in most water supply system feasibility studies for urban centers here in Ethiopia, the modes of services are generally stick to the first three classical modes of services because of their simplicity from the viewpoint of service giving institutions. Hence, for this project, it is assumed all the public to be served by one of the first three modes of services described above.

In estimating the future water demand, it is determined all the rural peoples to be served by public taps as their economic condition doesn't allow them to use either of the other two modes of services. For the case of this assignment, it is assumed all the three modes of service to prevail and serve the dwellers of the town.

Hence, using the three modes of services namely: Yard Connection, House Connection, and Public Tap and their respective per capita water consumption are described based on the design criteria (willingness and affordability to pay) as stated below: the future water requirement of the town will be estimated in the proceeding section.

- Public Tap users 100litter/day
- Yard Connection 100litter/day
- House Connection 100litter/day

5.2.1.2. Growth Rate of Domestic Water Demand

It is evident that as the socioeconomic condition and the living standard of the people improves; their water consumption will increase depending on their mode of service. The demand of the public tap users will increase very little as the distance involved for fetching water will not encourage the collection of more water and the collection time is limited to day time only, as a result the growth rate has been limited here to 1% per annum. For HCU and YCU, the water demand growth rate per annum could be as high as 2% as it is stated in the design criteria.

Using the above assumptions, the projected per capita water demand for the three demand categories over the expected design period is given in the table hereunder.

5.2.1.3. Projected Level of Service

The percentage of population to be served by each demand category will vary with time. The variation is caused by changes in living standards, improvement of the Service level and the capacity of the water supply service.

Although the standard approach of projecting would normally involves a detail analysis of past consumption trends by consumers group to which alternative economic development scenarios would be applied to produce future consumption levels, this approach requires detail information on the present consumption pattern and future economic development scenarios, which is difficult to get for H town with limited water supply system in the past. However, for this exercise estimation of percentages of each demand category is assumed.

As per the assumption from the willingness and affordability to pay, 50% of the population needs to be served by public taps, 40% of the population need to be served by yard tap connection and 10 % needs to be served house connection.

Table 5-3. Percentage of Population by Mode of Services in the (2007).

Mode of Service	Percentage of population
House Tap Users	10.00
Yard Tap Users	40.00
Public Tap Users	50.00
Total	**100.00**

The percentage of population to be served by each demand category is therefore, estimated taking the condition stated above as well as to consider the impact of increasing tariff rate on demand for the future; and assuming that the percentage for the yard taps users and the house tap users will increase gradually during the project service period while that of the public tap users will reduce as people shift to the next demand category. This is because of the expectation that the economic and living standard of the town will increase in the future. Those who previously using public tap will shift their mode of service to either yard connection or house connection.

Table 5-4. Percentages of Population Served by each demand Category (%).

Demand	Year									
Category	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
PTU	50%	47%	44.%	41.5%	39.%	36.7%	34.5%	32.4%	30.5%	28.6%
YCU	40%	41%	41.4%	41%	40.2%	38.4%	35.6%	31.7%	26.5%	19.7%
HCU	10%	12 %	14.4%	17.3%	20.74%	24.9%	29.8%	35.8%	43%	51.6%
Total	**100%**	**100%**	**100%**	**100%**	**100.%**	**100%**	**100%**	**100%**	**100%**	**100%**

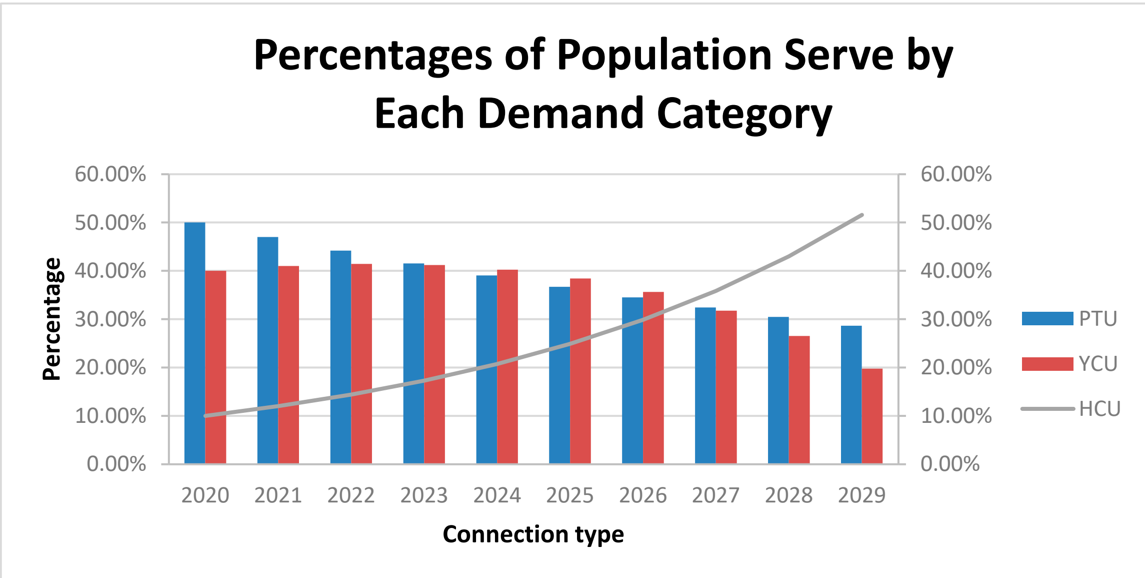

Figure 5-2. Percentage of population served by each demand category.

5.2.1.4. Projected Per capita Average Domestic Water Demand

The projected per capita average domestic water for a particular year is obtained by multiplying the per capita demand in each category for the year under consideration obtained from Table 4-5 with the corresponding population figure for the same year obtained from Table 4-3 and summing the results for all the demand categories. The proceeding tables show the projected per capita average domestic water demand for H project.

Table 5-5. Projected Average per capita Domestic Water Demand for H project town.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Demand (l/c/d)	100.0	101.5	103.1	104.8	106.6	108.5	110.4	112.4	114.5	116.6

5.2.1.5. Climatic Grouping

In addition to the already discussed factors which influence the quantity of water consumption, climatic of the area is also directly related to the consumption and for this reason, the design criteria consider three climatic group[24, 25]. Hence to consider climatic conditions, factors are adopted and applied to the average demands obtained from Table 4-8. The climatic grouping and corresponding factors are shown in Table 4-9 below.

Table 5-6. Climatic Grouping.

Group	Mean annual Precipitation	Factor
A	<600	1.1
B	601-900	1.0
C	>900	0.9

From the hydro-metrological data, H project has a mean annual rainfall of 1248 mm. Therefore, a climatic adjustment factor of 0.9 is used to adjust the per capita average domestic water demand.

5.2.1.6. Socio-Economic Adjustment Factor

The Socio-economic condition of a town also plays a role in determining the water consumption of an individual town. The design criteria provide for this in the form of categories for the various degrees of development. It is however difficult to quantify many aspects of development and consequently the classification of particular town is made relatively to the others.

Hence, the socioeconomic adjustment factor is determined based on the degree of the development of the particular town under study. The determination of the degree of the existing development and future potential of the town depend on personal judgment due to difficult conditions in quantifying them in short time. The town of H project for this exercise i.e. town under normal Ethiopian condition is asumed. Therefore, socioeconomic adjustment factor of 1.00 is adopted. Table 4-10 below shows the factors of socioeconomic grouping.

Table 5-7. Socio-Economic Grouping Factor.

Group	Description	Factor
A	Towns enjoying high living standard and with very high potential for development	1.10
B	Towns having a very high potential for development but lower living standard at present	1.05
C	Towns under normal Ethiopian Condition	1.00
D	Advanced Rural town	0.90

Applying the climatic and socio-economic adjustment factors to the average domestic water demand calculated in Table 4-8 above, the adjusted average daily domestic water demand for H project town is shown in the Table 4-11 below.

Table 5-8. Adjusted Average Daily per Capita Demand for H project Town.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Average per capita demand l/c/d	100.00	101.53	103.14	104.84	106.61	108.46	110.39	112.39	114.46	116.60
Climatic adjustment factor	1	1	1	1	1	1	1	1	1	1
Socio-economic adjustment factor	1	1	1	1	1	1	1	1	1	1
Adjusted per capita demands l/c/d	100.00	101.53	103.14	104.84	106.61	108.46	110.39	112.39	114.46	116.60

5.2.1.7. Summary of Projected Population and Growth in Domestic Water Demand by Mode of Service

Table 5-9 here under shows summary of population projection; percentages of population served by different modes of service, water demand determination and its growth in the expected service year of the new system are also indicate the calculated adjusted average domestic water demand.

Table 5-9. Adjusted Domestic Water Demand for H project Town.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Population	5,000,000	5,271,000	5,556,688	5,857,861	6,045,183	6,338,978	6,647,053	6,970,100	7,308,846	7,664,056	8,036,529
Mode of Service in %											
PTU	50.00%	47.00%	44.18%	41.53%	39.04%	36.70%	34.49%	32.42%	30.48%	28.65%	
YTU	40.00%	41.00%	41.42%	41.19%	40.23%	38.42%	35.65%	31.74%	26.52%	19.75%	
HTU	10.00%	12.00%	14.40%	17.28%	20.74%	24.88%	29.86%	35.83%	43.00%	51.60%	
Population By Mode of Service											
PTU	2,635,500	2,611,643	2,588,003	2,510,516	2,474,575	2,439,149	2,404,231	2,369,812	2,335,885	2,302,445	
YTU	2,108,400	2,278,242	2,426,326	2,490,059	2,549,952	2,553,904	2,484,608	2,320,143	2,032,767	1,587,412	
HTU	527,100	666,803	843,532	1,044,608	1,314,451	1,653,999	2,081,261	2,618,892	3,295,404	4,146,673	
Per capita Demand (l/c/d)											
PTU	50.00	47.47	45.07	42.79	40.62	38.57	36.62	34.76	33.00	31.33	
YTU	40.00	41.82	43.09	43.71	43.54	42.42	40.14	36.46	31.08	23.61	
HTU	10.00	12.24	14.98	18.34	22.45	27.47	33.63	41.16	50.38	61.66	
Demand By Modes of Service (m^3/d)											
PTU	131775.0	123974.7	116636.2	107418.9	100523.5	94070.7	88032.2	82381.3	77093.1	72144.3	
YTU	84336.0	95276.1	104558.6	108845.5	111031.3	108338.0	99742.0	84602.2	63171.0	37472.5	
HTU	5271.0	8161.7	12637.6	19155.7	29503.3	45440.4	69986.6	107792.2	166019.8	255701.1	
Total Domestic Water Demand (m^3/d)	221382.0	227412.5	233832.3	235420.0	241058.1	247849.2	257760.8	274775.7	306283.9	365317.9	
Climatic Adjustment Factor	1	1	1	1	1	1	1	1	1	1	
Socioeconomic Adjustment Factor	1	1	1	1	1	1	1	1	1	1	
Adjusted Domestic Water Demand	221382.0	227412.5	233832.3	235420.0	241058.1	247849.2	257760.8	274775.7	306283.9	365317.9	
(l/s)	2562.29	2632.09	2706.39	2724.77	2790.02	2868.62	2983.34	3180.27	3544.95	4228.22	

5.2.2. Public Water Demand

The Water required for schools, hospitals, hotels, public facilities, parks, offices, commercial establishments, military camps, small-scale industries and etc. are included in this demand category. Public demand is usually expressed as a percentage of the average day domestic demand.

The general situation related to the public demand is that it is high at the initial stage of the service installation and gradually reduces as the number of connections increase. It is also understood that the percentage of public demand is high in smaller towns as compared to large towns where there could be high number of domestic connections.

The studies in towns having metered water supply system shows that the public water demand ranges between 10 to 20% of domestic consumption depending on the size of the town, type and extents of commercial, economic and industrial activities[26]. For this town, it is considered adequate to assume public demand to be 10% of domestic demand. Table 4-13 below presents the estimated public water demand.

Table 5-10. Public Water Demand as % of Domestic Water Demand.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Domestic Water Demand (m^3/d)	221382.0	227412.5	233832.3	235420.0	241058.1	247849.2	257760.8	274775.7	306283.9	365317.9
(l/s)	2562.29	2632.09	2706.39	2724.77	2790.02	2868.62	2983.34	3180.27	3544.95	4228.22
Public Water Demand (m^3/d) (10% of Domestic Water Demand)	22138.2	22741.2	23383.2	23542.0	24105.8	24784.9	25776.1	27477.6	30628.4	36531.8
(l/s)	256.23	263.21	270.64	272.48	279.00	286.86	298.33	318.03	354.50	422.82

5.2.3. Livestock Water Demand

As it is well known, the H project town a town Therefore, the inclusion of the livestock water demand is not obligatory.

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5.2.4. Industrial Water Demand

The establishment of an industry is very rare at H project and hence the industrial water demand is not accounted. Even if there could be some industrial development in the future, which is beyond cottage industries, it has to develop its own water supply system not to compete with the new system and impose a higher tariff rate for the customers. Industries, which require water only for domestic use, could take water from the town system and this demand has already been covered under the public water demand.

5.2.5. Water Requirement for Fire Fighting

No extra capacity for firefighting to be considered in small to medium size towns. In case of fire, water required shall be met by stopping supply to consumers for the required time.

5.2.6. Unaccounted for Water [27]

All the water that goes in the distribution pipe does not reach the consumer. Some portion of this is wasted in the pipelines due to defective pipe joints, cracked and broken pipes, faulty valve and fittings. Some consumer keep open their taps or public taps even when they are not using the water and allow continuous wastage of water which also includes illegal connection, unmetered usages such as flushing, firefighting, cleaning the system and overflow from components of the water supply system and etc.

To calculate the future distribution loss it is considered appropriate to relate the percentage of losses to both the age of the distribution system and to the percentage of the total pipeline length, which made up the new distribution system. Water loss relationship curve, which had been adopted by Alexander GIBB'S in 12 towns' water supply study and from the records of the Water Service office of the town, is utilized in this study to estimate the future water loss of the system. Accordingly, the loss coefficients used for the entire design horizons of the system are presented in the table below.

Table 5-11. Water Losses Coefficient.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
% of losses	20%	21%	21%	22%	22%	23%	23%	24%	24%	25%

5.2.7. Average Day Demand

The average day water demand is the sum of adjusted domestic water demand, non-domestic water demand and system water loss. The values calculated in the previous sections are summarized and added to estimate the total average day water demand of the project as shown in the Table 4-15 hereunder.

Table 5-12. Summary of Average Day Water Demand.

Description	Year									
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
A- Domestic Demand, X Town (m3/d)	221382.00	227412.47	233832.31	235420.04	241058.09	247849.18	257760.77	274775.73	306283.93	365317.86
C- Public Water Demand =10%*A (m^3/d)	22138.20	22741.25	23383.23	23542.00	24105.81	24784.92	25776.08	27477.57	30628.39	36531.79
E- Losses coefficient	20%	21%	21%	22%	22%	23%	23%	24%	24%	25%
F- Loss=(A+C)*E (m^3/d)	48704.04	51281.51	54047.41	55774.76	58538.27	61692.09	65763.16	71856.84	82098.99	100371.03
G- Average Day Demand=A+C+E (m3/day), X	***292224.24***	***301435.22***	***311262.95***	***314736.81***	***323702.17***	***334326.18***	***349300.01***	***374110.15***	***419011.32***	***502220.68***
(l/s)	***3382.23***	***3488.83***	***3602.58***	***3642.79***	***3746.55***	***3869.52***	***4042.82***	***4329.98***	***4849.67***	***5812.74***

*Note: it is assumed major loss to occur in the distribution pipeline only.

5.2.8. Variations of Water Use

The rate of water demand keeps changing from season to season, from day to day and from hour to hour. In hot season, more water is consumed for drinking, bathing and washing clothes than in wet season. The consumption of water is high at weekends and holidays than on normal days, and also more water is required in morning and evening than early in the afternoon and late at night. Therefore, to account these fluctuating water demands, it is necessary to step up the average day demand by certain factor to get the maximum day demand and the peak hour demand. These scaled up water demand figure are used to design the capacities of pumping station, rising main and distribution network.

5.2.8.1. Maximum Day Water Demand

The maximum day water demand is the highest demand of any one 24-hour period over any specified year. If there is sufficient water and enough daily consumption record, it is possible to assume a realistic maximizing factor, however, since there is no any conventional water supply system in the past, the maximizing coefficient are taken from the design guideline of Cost effective Water Supply and Sanitation Project, and are presented on Table 4-16 below.

Table 5-13. Maximum Day Factor.

Population	Maximum Daily coefficient (Cd max.)
0-50,000	1.2
50,000-100,000	1.15
>100,0000	1.1

From Table 5-13 and the calculated average day water demand, the maximum daily coefficient to be adopted for H project town and the calculated maximum day demand is presented on Table 5-14 below.

Table 5-14. Maximum Day Water Demand for H project Town.

Year	Average Day water Demand (m^3/d)	Maximum Day Coefficient (Cd max.)	Maximum Day Demand	
			m^3/d	l/s
2020	292224.24	1.2	350669.09	4058.67
2021	301435.22	1.2	361722.27	4186.60
2022	311262.95	1.2	373515.54	4323.10
2023	314736.81	1.2	377684.17	4371.34
2024	323702.17	1.2	388442.60	4495.86
2025	334326.18	1.2	401191.42	4643.42
2026	349300.01	1.2	419160.01	4851.39
2027	374110.15	1.2	448932.18	5195.97
2028	419011.32	1.2	502813.58	5819.60
2029	502220.68	1.2	602664.81	6975.29

5.2.8.2. Peak Hour Demand

The peak hour demand is the highest demand in any one hour over the year. It represents the diurnal variation in water demand resulting from behavioral patterns of the local population.

The size, mode of service and social activities of the town significantly influence the peak hour demand. Further, studies show that the peak hour factor is greater for smaller population than bigger population. A peaking factor suiting the town is selected from the design criteria correlating peaking factor with number of population as stated in the table below.

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Table 5-15. Peak Hour Factor.

Town Population	Peak Hour Factors
0-10,000	2.5-3.0
10,001 - 50,000	2.0-2.2
50,001-100,000	1.8
>100,000	1.6

Hence, since the population of H project town is in the range of >100,000 up to the end of the design period, a peaking factor of 1.6 is adopted to estimate the peak hour demand of the town.

5.2.9. Summary of Water Demand

The calculated water demands are summarized in the form tables and Charts as shown hereunder.

Table 5-16. Summary of Water Demand.

Description	Year									
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Population	5,271,000	5,556,688	5,857,861	6,045,183	6,338,978	6,647,053	6,970,100	7,308,846	7,664,056	8,036,529
Domestic Water Demand (m^3/d)	221382.00	227412.47	233832.31	235420.04	241058.09	247849.18	257760.77	274775.73	306283.93	365317.86
Public Water Demand (m^3/d)	22138.20	22741.25	23383.23	23542.00	24105.81	24784.92	25776.08	27477.57	30628.39	36531.79
Losses (m^3/d)	48704.04	51281.51	54047.41	55774.76	58538.27	61692.09	65763.16	71856.84	82098.99	100371.03
Demand(m^3/d)	292224.24	301435.22	311262.95	314736.81	323702.17	334326.18	349300.01	374110.15	419011.32	502220.68
(l/s)	3382.23	3488.83	3602.58	3642.79	3746.55	3869.52	4042.82	4329.98	4849.67	5812.74
Maximum Day Factor	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Maximum Day Demand (m^3/d)	350669.09	361722.27	373515.54	377684.17	388442.60	401191.42	419160.01	448932.18	502813.58	602664.81
(l/s)	4058.67	4186.60	4323.10	4371.34	4495.86	4643.42	4851.39	5195.97	5819.60	6975.29
Peak Hour Factor	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Peak Hour Demand m^3/d)	730560.60	753588.06	778157.38	786842.02	809255.43	835815.46	873250.02	935275.37	1047528.30	1255551.69
(l/s)	8455.56	8722.08	9006.45	9106.97	9366.38	9673.79	10107.06	10824.95	12124.17	14531.85

Table 5-17. Summary of Total Water Demands.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Maximum Day Demand of X Town in (m3/d)	350669.09	361722.27	373515.54	377684.17	388442.60	401191.42	419160.01	448932.18	502813.58	602664.81
(l/s)	4058.67	4186.60	4323.10	4371.34	4495.86	4643.42	4851.39	5195.97	5819.60	6975.29
Total Design Water Demand (m^3/d)	**350669.09**	**361722.27**	**373515.54**	**377684.17**	**388442.60**	**401191.42**	**419160.01**	**448932.18**	**502813.58**	**602664.81**
(l/s)	**4058.67**	**4186.60**	**4323.10**	**4371.34**	**4495.86**	**4643.42**	**4851.39**	**5195.97**	**5819.60**	**6975.29**

Table 5-18. Summary of Total Monthly Water Demands.

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Maximum Monthly Demand of X Town in (m3/d)	**10520072.64**	**10851668**	**11205466.3**	**11330525**	**11653278.1**	**12035742.6**	**12574800.3**	**13467965.3**	**15084407.5**	**18079944.4**

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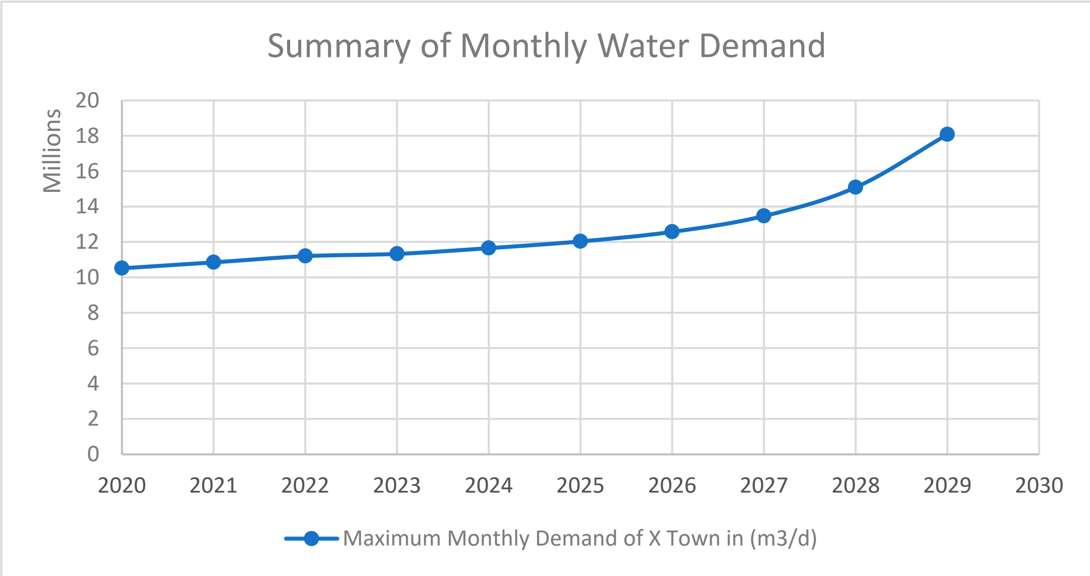

Figure 5-3. Summary of monthly water demand. NB: This monthly water demand analyses at the end of first phase of water supply system at year 2030 will be used for water balance analyses this project.

6. Irrigation Potential Estimation and Water Demand Analyses

The irrigation potential for this assignment is estimated from the water balance analyses tabulated in table below as per the give data in Table 4-2.

The first step is to calculate the water requirement of the given data by summing up the loss (Etc m3/ha) and the irrigation requirements in to daily bases as shown in table below[9]. Then after, the daily irrigation water requirement will be tabulated again in to total monthly water demand per hectare analyses as shown in table. Therefore, finally the irrigation potential is set by try and error / goal seek approach in excel to estimate the total irrigable command area. Accordingly, the irrigable area is estimated to be 23,500ha as tabulated in water balance analyses.

Table 6-1. Summary of Total Water Demand for all Crops per hectare.

S/N	Crop	Planting Date	Growing period (days)	Daily Irrigation water req. (m3/ha)	Irrigation water req. in the specified month(m3/ha)
1	Onion	01-Feb	30	93.16	2794.74
	Onion	March	30	93.16	2794.74
	Onion	April	30	93.16	2794.74
	Onion	May	5	93.16	465.79
2	Tomato	01-Jan	30	97.03	2911.03
	Tomato	Feb	30	97.03	2911.03
	Tomato	March	30	97.03	2911.03
	Tomato	April	30	97.03	2911.03
	Tomato	May	25	97.03	2425.86
3	Wheat	15-Jan	15	88.68	1330.15
	Wheat	Feb	30	88.68	2660.31
	Wheat	March	30	88.68	2660.31
	Wheat	April	30	88.68	2660.31
	Wheat	May	25	88.68	2216.92
Total water irrigation requirement per hectare					**34,448.00**

Table 6-2. Summary of Total Monthly Water Demand for all Crops for the optimum hectare.

S/N	Month	Planting Date	Irrigation water req. per month (m3/ha)	Irrigation water req. for 23,500 ha
1	Jan	Jan	4,241.19	99,667,925.73
2	Feb	Feb	8,366.08	196,602,856.90
3	March	March	8,366.08	196,602,856.90
4	April	April	8,366.08	196,602,856.90
5	May	May	5,108.57	120,051,503.56
Total Project Monthly Irrigation Water Demand for Water Balance Analyses				809,528,000.00

Table 6-3. Runoff coefficient calculator.

61,276.00	Km^2
0.22	
1,284.00	mm
17,096.000	Mm^3
1,000.00	$m^3/km^2/year$
50.00	years
3,063,800,000.00	m^3

Author:
Calculated Runoff cof. by goal seek from the given data using rational formula $Q_{m3}=CP_{mm}A \sim C=Q_{m3}/P_{mm}$

Table 6-4. Water Balance Sheet.

Month	75% dep. rainfall (mm)	Runoff coeff.	Monthly inflow volume m^3	Base Flow lit/sec	Monthly base flow volume m^3	Total volume in the reservoir m^3	Reservoir area m^2	Evaporation loss: penman evap. m/month	Evaporation loss: monthly Loss m^3	seepage loss m^3	D/S release per month m^3	Irrigation Req. per month/ha m^3	Total Irrigation Req. for 23,500ha	Water supply Req. per month. m^3	Net storage Volume m^3	REMARK
															66,626,454.71	DS
Jun	18.1	0.22	244,001,032.00	0.00	0.00	310,627,486.71	320,299,985.63	0.100	32,029,998.56	709,895.29	213,129,463.46		0.00	18,079,944.35	47,388,080.34	BDS
Jul	45.6	0.22	614,720,832.00	0.00	0.00	662,108,912.34	680,463,002.48	0.100	68,046,300.25	709,895.29	213,129,463.46		0.00	18,079,944.35	362,853,204.29	ok
Aug	71.2	0.22	959,827,264.00	0.00	0.00	1,322,680,468.29	1,357,350,675.85	0.100	135,735,067.59	709,895.29	213,129,463.46		0.00	18,079,944.35	955,735,992.89	ok
Sep	93.4	0.22	1,259,099,248.00	0.00	0.00	1,357,106,445.03	1,392,626,974.22	0.100	139,262,697.42	709,895.29	213,129,463.46		0.00	18,079,944.35	986,634,339.80	ok
Oct	100.1	0.22	1,349,420,072.00	0.00	0.00	1,357,106,445.03	1,392,626,974.22	0.100	139,262,697.42	709,895.29	213,129,463.46		0.00	18,079,944.35	986,634,339.80	ok
Nov	142.8	0.22	1,925,046,816.00	0.00	0.00	1,357,106,445.03	1,392,626,974.22	0.100	139,262,697.42	709,895.29	213,129,463.46		0.00	18,079,944.35	986,634,339.80	ok
Dec	277.0	0.22	3,734,159,440.00	0.00	0.00	1,357,106,445.03	1,392,626,974.22	0.100	139,262,697.42	709,895.29	213,129,463.46		0.00	18,079,944.35	986,634,339.80	ok
Jan	289.1	0.22	3,897,276,152.00	0.00	0.00	1,357,106,445.03	1,392,626,974.22	0.100	139,262,697.42	709,895.29	213,129,463.46	4,241.19	99,667,925.73	18,079,944.35	886,966,414.07	ok
Feb	190.8	0.22	2,572,121,376.00	0.00	0.00	1,357,106,445.03	1,392,626,974.22	0.100	139,262,697.42	709,895.29	213,129,463.46	8,366.08	196,602,856.90	18,079,944.35	790,031,482.89	ok
Mar	30.2	0.22	407,117,744.00	0.00	0.00	1,197,149,226.89	1,228,718,812.80	0.100	122,871,881.28	709,895.29	213,129,463.46	8,366.08	196,602,856.90	18,079,944.35	646,465,080.90	ok
Apr	17.2	0.22	231,868,384.00	0.00	0.00	878,333,464.90	902,028,301.49	0.100	90,202,830.15	709,895.29	213,129,463.46	8,366.08	196,602,856.90	18,079,944.35	360,318,370.05	ok
May	8.5	0.22	114,586,120.00	0.00	0.00	474,904,490.05	488,634,630.95	0.100	48,863,463.09	709,895.29	213,129,463.46	5,108.57	120,051,503.56	18,079,944.35	74,780,115.58	ok
	1284.00		**17,309,244,480.00**		-				**1,333,325,725.45**	**8,518,743.54**	**2,557,553,561.46**		**809,528,000.00**	**216,959,332.22**		

NB: Here the calculation of catchment yield using the given monthly rainfall data as shown in Table 6-4 and the calculated **C=0.22,** as shown in Table 6-3 gives a catchment yield = **17,309,244,480 m³** which is almost the similar with the given annual catchment yield **17,096,000,000 m³.**

Table 6-5. Reservoir Characteristics.

Res capacity, Cs		1,357,106,445.03	
Total in flow		17,309,244,480.00	
Sum of outflow(including losses		1,558,803,801.20	
Dead storage		66,626,454.71	
Total sum		1,625,430,255.92	Ok
Surplus		-268,323,810.89	

Asus:
If total inflow is > sum of all outflows including loses and dead storage

7. Hydropower Potential and Energy Generation

7.1. Energy of Hydropower

7.1.1. Hydropower Generation

The waters of lakes, reservoirs located at high elevation and water flowing in a river all provide potential energy or kinetic energy[28]. The energy produced by water is termed water power. Power generation methods which produce electric energy by using water power are called hydropower generation.

7.1.2. Electric Power Output

Hydro power plants are equipped with turbines and generators which are turned by water power to generate electric power[29]. Here, the water power is first converted into mechanical energy then into electric energy. In this form of energy conversion process, there is a certain amount of energy loss due to the turbine and generator. The power output is expressed by the following equation.

$P=\varrho 9.8QH_e$

Where

P: Power output（kW）

ϱ: Water density = 1,000kg/m^3 (at 4 ºC, elevation 0m and 1atm)

9.8: Approximate value of free fall acceleration/sec^2)

Q: Power discharge （m^3/sec ）

H_e: Effective head (m)

η: Combined efficiency of turbine and generator

The MW unit is also used to express the power output. 1,000 kilowatt (kW) is equal to 1 megawatt (MW.

Maximum output1, rated output, firm output, and firm peak output are used to express the performance of the power plant.

7.1.3. Energy Generation

Power output (P) is the magnitude of the electric power generated. The electric energy generated by continuous operation of P (kW) for T (hours) is termed generated energy and is expressed by kilowatt hour (kWh).

The following Table 7-1 shows the discharge taken from water balance analyses. Therefore, according to the topography condition the following discharges can be used for hydropower development plant. However, for the illustration of this example only downstream release for power generation is taken.

Table 7-1. Outlet discharges for multipurpose reservoir of the project .

S/N	Description	Discharge in m³/sec
1	$Q_{d/s\ release}$	82.23
2	Q_{irr}	25.32
3	Q_{ws}	6.98
4	Total	114.52

Hence, according the above formula and the tabulated data in Table 7-1 the design is calculated as follows:

$$KW = 9.81 \times Q \times H \times \eta$$

Where,

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KW = electric power in kW

Q = quantity of water flowing through the hydraulic turbine in cubic meters per second. Discharge (quantity of water) flowing in a stream and available for power generation has daily and seasonal variation. Optimum discharge for power generation is determined on the basis of energy generation cost.

H_e = Net available head in meters (gross head – losses)

H_d = net head resulting between river-bed and reservoir level =2000m

H_e = 150 + H_d = 350m

η = overall efficiency of the hydro power plant. For general estimation purposes, η is normally taken as 0.85, a hydropower station has a gross head of He = 150 +H_d meter. Head loss in water conductor system is neglected for this exercise. Optimum discharge in m^3 is 82.23 cubic meter per second.

KW = 9.81 x 82.23 x 350 x 0.85

KW = 239,974.16

MW = 240

Energy generation E = average power x 24 x 365 in (MWh) units= 2,102,400.00

Accordingly 3 units of 3 x 80 MW can be installed.

8. Frequency Analyses and Flood Routing

8.1. Introduction

Flood routing is the technique of determining the flood hydrograph at a section of a river by utilizing the data of flood flow at one or more upstream sections [30]. The hydrologic analysis of problems such as flood forecasting, flood protection, reservoir design and spillway design invariably include flood routing. In these applications two broad categories of routing can be recognized. These are reservoir routing and channel routing. In reservoir routing the effect of a flood wave entering a reservoir is studied. In channel routing the change in the shape of a hydrograph as it travels down a channel is studied. In this project a flood frequency analyses and reservoir routing is undertaken to see the behaviour of the reservoir while incoming the design flood (peak flood) under certain return period 100, 500 and 1000 years return period[31].

The term flood routing refers to procedures to determine the outflow hydrograph at a point downstream in a river (or reservoir) as a function of the inflow hydrograph at a point upstream. As flood waves travel downstream they are attenuated and delayed. That is, the peak flow of the hydrograph decreases and the time base of the hydrograph increases. Again design flood is the flood discharge adopted for the design of a structure after careful consideration of economic and hydrologic factors. As the magnitude of the design flood increases, the capital cos t of the structure also increases but the probability of annual damages will decrease.

8.2. Reservoir routing

Let I and Q be the inflow into and outflow from a reservoir, and S the storage in the reservoir, the continuity equation in the differential form for the reservoir[32] is given by

$$I - Q = \frac{dS}{dt} \quad \text{.......... \textbf{Equation 8-1}}$$

Alternatively, the same can be written as

$$\bar{I}\Delta t - \bar{Q}\Delta t = \Delta S \quad \text{.........\textbf{Equation 8-2}}$$

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Where, I is the average inflow rate in a small time interval Δt , Q is the average outflow rate in the same time interval and ΔS is the corresponding change in the storage of the reservoir during the same time interval. If suffixes 1 and 2 are used to denote a given quantity at the beginning and the end of the time interval and if the inflow and outflow have straight line variation within the time interval, Eq. (2) can be written as

$$\left(\frac{I_1 + I_2}{2}\right)\Delta t - \left(\frac{Q_1 + Q_2}{2}\right)\Delta t = S_2 - S_1$$

............Equation 8-3

8.3. Design flood

Flood is the unusual high stage of a river due to runoff from rainfall and or melting of snow in quantities too great to be confined in the normal water surface elevations of the river or stream, as the result of unusual meteorological combination[33]. The maximum flood that any structure can safely pass is called the 'Design flood' and is selected after consideration of economic and hydrologic factors. The design flood is related to the project feature and may be arrived by considering the cost of constructing the structure to provide flood control and the flood control benefits arising directly by prevention of damage to structures downstream, disruption communication, loss of life and property, damage to crops and under -utilization of land. The design flood is usually selected after making a cost-benefit analysis and exercising engineering judgment. In general the methods used in the estimation of the design flood can be grouped as below.

(ì) Increasing the observed maximum flood by a certain percentage
(ìì) Envelope curves
(ììì) Empirical flood formulae
(ìv) Rational method
(v) Unit hydrograph application
(vì) Frequency analysis (or Statistical methods)

8.4. Frequency analyses

In this project frequency analysis will be used to determine the design flood. The analyses makes use of the observed data in the past to predict the future flood events along with their probabilities or return periods. It is based on the assumption that combination of the numerous factors which produce floods are a matter of pure chance and therefore are subject to analysis according to the mathematical theory of probability.

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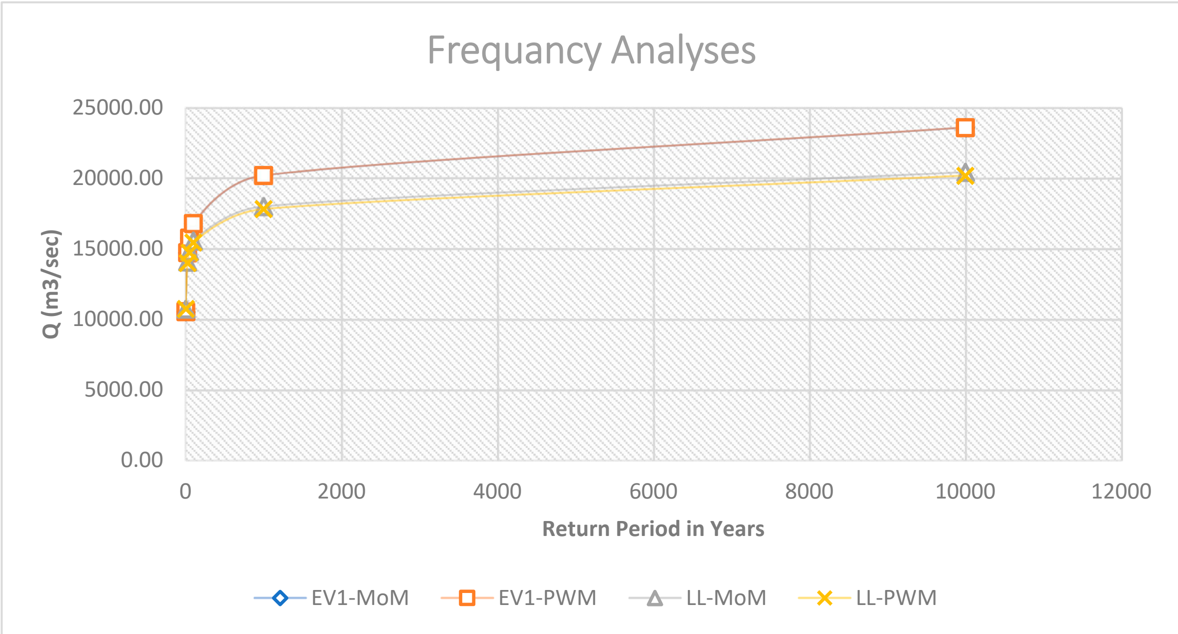

Figure 8-1. Flood frequency analyses of different statistical distributions.

8.5. Flood routing calculation

Table and Figure 8-1 shows the relationship between head, discharge and storage of the reservoir above NPL for the analyses of reservoir routing of Table 8-6.

Table 8-1. Reservoir characteristics above NPL.

ELEVATION (masl)	TOTAL VOLUME (MMC)	Surcharge Head, H(m)	Storage(MMC)	cumulative Storage(MMC)	Q(m^3/s)	2S/Δt +Q
1200.00	1357.11	0	0.00	0.00	0	0
1210.00	1533.22	10	176.11	176.11	1075	432715
1220.00	1722.37	20	189.15	365.26	3041	898287
1230.00	1924.87	30	202.50	567.76	5587	1397156
1240.00	2141.02	40	216.15	783.91	8601	1929948

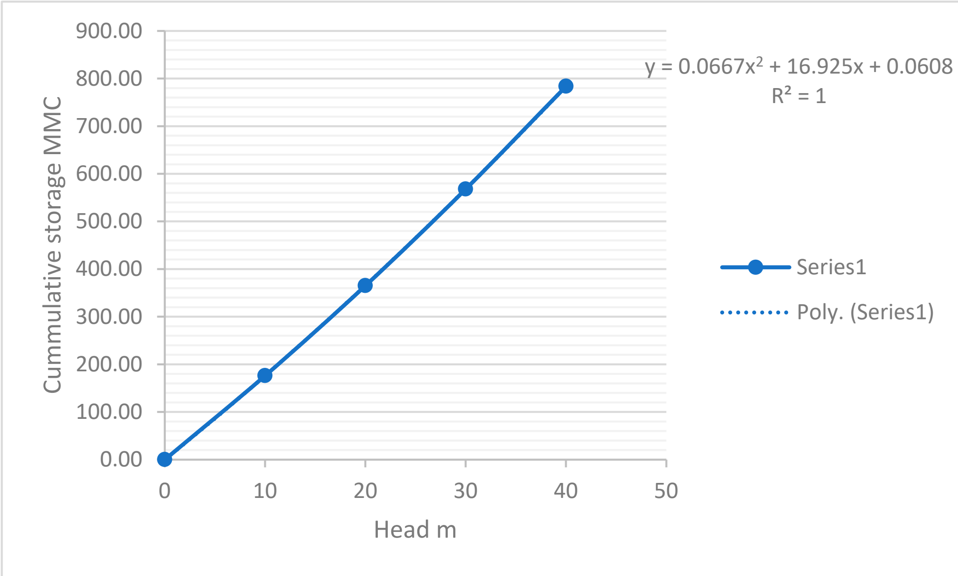

Figure 8-2. Stage Vs cumulative storage relationship.

Because of data limitation on the project Tc is calculated from the Empirical formula below.

$$T_c = 0.0418A^{0.324}$$

where:
T_c = time of concentration, h
A = the drainage area, acre

According the above formula a table below is tabulated to calculate Tc and other important parameters as stated below to develop the input hydrograph for flood routing propose. The flow to be routed is also taken from the frequency analyses result of the 1000 and 10000 return period just to see how the damping effect of the reservoir will behave.

Table 8-2. Parameters calculation table.

Step	*Parameter*	*Unit*	*Value*
1	Catchment Area	Km²	61276.00
2	Length of main water course	m	
3	Time of concentration, Tc	hr	8.86
4	Rain fall excess duration	hr	
	D = Tc/6	hr	1.00
5	Time to peak, Tp	hr	
	Tp = 0.6 Tc + 0.5 D	hr	5.82
6	Time to base, Tb	hr	
	Tb = 2.67 Tp	hr	15.53
7	Peak rate of discharge created by 1mm runoff excess on whole of the catchment, Tp	m³/sec/mm	
	p = (0.21* A) / Tp		2211.96
8	Lag time, t_l	hr	
	$t_l = 0.6\ T_c$		5.32

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Table 8-3. Time of incremental Hydrograph.

Time of incremental hydrograph		
Time of beginning	Time to Peak	Time to End
hr		
0.00	5.8	15.5
1.00	6.8	16.5
2.00	7.8	17.5
3.00	8.8	18.5
4.00	9.8	19.5
5.00	10.8	20.5

Table 8-4. Inflow hydrograph plotting table.

Incremental run off to develop the complex hydrograph		**Time of begin**	**Time to peak**	**Time to end**
Tr (Years)	Qp (m^3/sec)		hrs	
0	0.00	0.00	5.82	15.53
25	4530.90	1.00	6.82	16.53
50	4850.42	2.00	7.82	17.53
100	5167.59	3.00	8.82	18.53
1000	6215.60	4.00	9.82	19.53
10000	7261.76	5.00	10.82	20.53

Table 8-5. Ordinate of Input hydrograph.

(hr)	Ordinate of Hydrograph (m^3/Sec)					
	1	2	3	4	5	6	7
0	0.00						0.00
1.00	0.00	0.00					0.00
2.00	0.00	940.52	0.00				940.52
3.00	0.00	1881.04	1006.84	0.00			2887.88
4.00	0.00	2821.56	2013.69	1072.68	0.00		5907.93
5.00	0.00	3762.07	3020.53	2145.36	1290.23	0.00	10218.20
5.82	0.00	4530.90	3843.58	3022.23	2344.92	1232.21	14973.84
6.82	0.00	4064.52	4850.42	4094.91	3635.15	2739.60	19384.60
7.82	0.00	3598.15	4351.16	5167.59	4925.37	4246.99	22289.26
8.82	0.00	3131.77	3851.89	4635.68	6215.60	5754.37	**23589.32**
9.82	0.00	2665.40	3352.63	4103.77	5575.82	7261.76	22959.37
10.82	0.00	2199.02	2853.36	3571.86	4936.03	6514.29	20074.57
15.53		0.00	499.26	1063.82	1919.35	2989.87	6472.31
16.53			0.00	531.91	1279.57	2242.41	4053.89
17.53				0.00	639.78	1494.94	2134.72
18.53					0.00	747.47	747.47
19.53						0.00	0.00

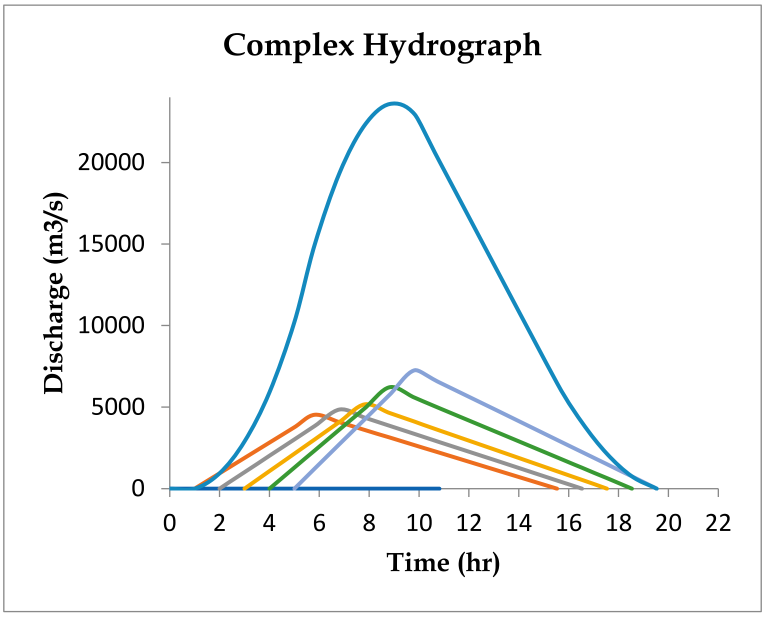

Figure 8-3. Inflow Hydrograph.

Table 8-6. Reservoir routing tables.

FLOOD ROUTING

1) Inspect the inflow hydrograph and select a routing interval : Δt<(1/6) time to peak
2) Establish the Q-G relation
3) Carry out the routing according to equation $G_{i+1} = G_i + I_{m,i} - Q_i$
4) Compute Q from the Q-G relation

Spillway crest length =		**300.00**
Cd =		**1.70**
dt <=Tp/6	*0.22667*	**0.23**
Base flow =	*R*	**0.00**

Y=S = 0.0667x2 + 16.925x + 0.0608

H (m)	Q (m^3/sec)	S (m^3)	G (m^3/sec)	LogQ	LogG	
1	2	3	4	5	6	
-	-	60,800.00	-	-	-	
0.10	16.13	1,753,967.00	2,157.53	1.21	3.33	
0.50	180.31	8,539,975.00	10,555.81	2.26	4.02	
0.90	435.45	15,347,327.00	19,025.72	2.64	4.28	
1.30	755.94	22,176,023.00	27,554.47	2.88	4.44	
1.70	1,130.43	29,026,063.00	36,136.37	3.05	4.56	
2.10	1,552.03	35,897,447.00	44,767.98	3.19	4.65	
2.50	2,015.95	42,790,175.00	53,446.92	3.30	4.73	
2.90	2,518.65	49,704,247.00	62,171.39	3.40	4.79	
3.30	3,057.32	56,639,663.00	70,940.01	3.49	4.85	
3.70	3,629.72	63,596,423.00	79,751.65	3.56	4.90	
4.10	4,233.95	70,574,527.00	88,605.37	3.63	4.95	
4.50	4,868.43	77,573,975.00	97,500.36	3.69	4.99	
4.90	5,531.77	84,594,767.00	106,435.94	3.74	5.03	
5.30	6,222.77	91,636,903.00	115,411.51	3.79	5.06	
5.70	6,940.37	98,700,383.00	124,426.54	3.84	5.09	
6.10	7,683.60	105,785,207.00	133,480.54	3.89	5.13	
6.50	8,451.62	112,891,375.00	142,573.09	3.93	5.15	
6.90	9,243.66	120,018,887.00	151,703.80	3.97	5.18	
7.30	10,058.99	127,167,743.00	160,872.32	4.00	5.21	
7.70	10,896.98	134,337,943.00	170,078.32	4.04	5.23	b
8.10	11,757.03	141,529,487.00	179,321.51	4.07	5.25	a

Summary result :-			
Qd =	**4914.56**	b	0.840
He =	**4.528**		
Discharge reduction =	**79.17%**	a	0.252

where :- *G =Si/dT +Qi/2*

Im=1/2(Ii+Ii)*

Step 2:- *Obtain a relation between (2) &(4) using regration analysis*

$Q=aG^b$

Step 3:- *Routing of inflow hydrograph through the reservoir*

Time, T (hrs)	Inflow, I (m^3/sec)	0 (m^3/sec)	Q (m^3/sec)	Im-Q (m^3/sec)	G (m^3/sec)
1	2	3	4	5	6
0.00	0.00	0.00	0.00	0.000	0.000
1.00	0.00	470.26	0.00	470.259	0.000
2.00	940.52	1914.20	44.36	1869.840	470.259
3.00	2887.88	4397.90	170.82	4227.086	2340.100
4.00	5907.93	8063.06	406.51	7656.552	6567.186
5.00	10218.20	12596.02	778.17	11817.842	14223.737
5.82	14973.84	17179.22	1293.49	15885.730	26041.580
6.82	19384.60	20836.93	1929.94	18906.986	41927.309
7.82	22289.26	22939.29	2638.56	20300.731	60834.295
8.82	23589.32	23274.34	3360.81	19913.536	81135.026
9.82	22959.37	21516.97	4041.43	17475.542	101048.562
10.82	20074.57	13273.44	4621.06	8652.377	118524.104
15.53	6472.31	5263.10	4902.90	360.204	127176.481
16.53	4053.89	3094.30	4914.56	-1820.258	127536.685
17.53	2134.72	1441.10	4855.56	-3414.464	125716.427
18.53	747.47	747.23	4744.51	-3997.276	122301.963
19.53	747.00	373.50	4613.88	-4240.375	118304.687

Step 4:- Plot (1) against (2) & (4)

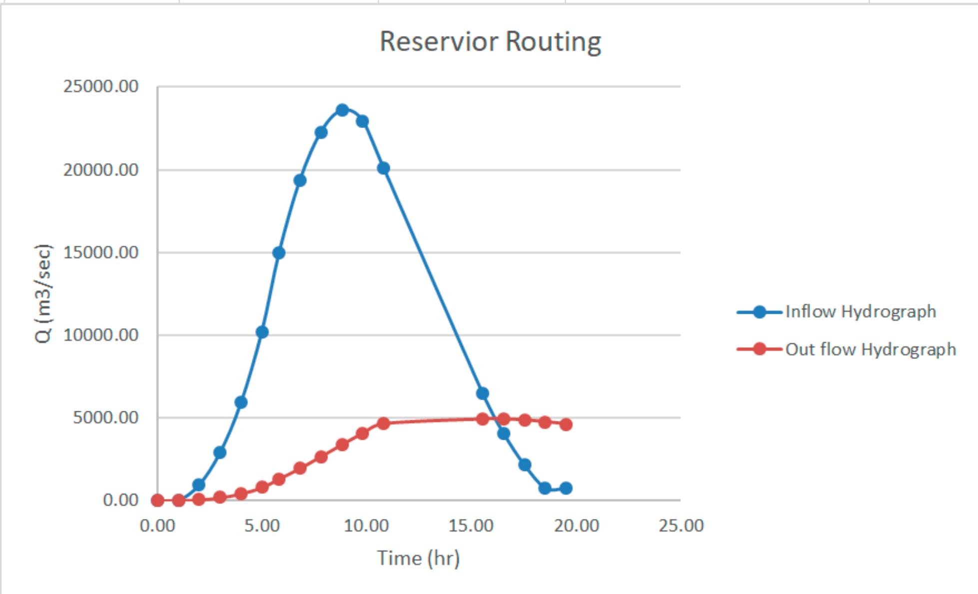

Figure 8-4. Routed hydrograph.

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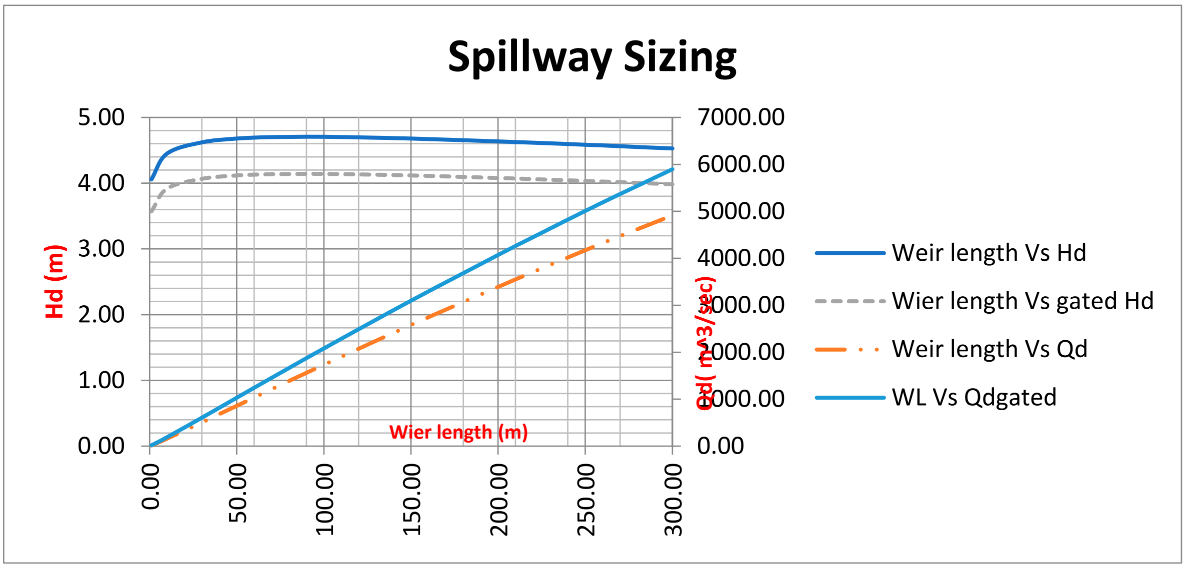

Figure 8-5. Optimum spillway sizing graph.

The above Figure 8-5 shows how to size the spillway of the project, however since we don't have the cost data of the project we cannot be sure to select the optimum one. But, for this this case we can choose the size of the spillway by looking H_d and the design flood magnitude. And, for this exercise it's routed for 300m spillway width, the point wher H_d & Q_d crossed each other. At this stage the damping effect of the reservoir is 79.1% and the design flood of the spillway is selected 4915m^3/sec.

9. Conclusions and Recommendation

In conclusion this is a technical note prepared to assist junior young engineers with practical example, and is recommended for those who are engaged in the study and design of stochastic hydrology, spillway, dam, irrigation, water supply and hydropower projects.

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10. ANNEX

10.1. Annex 10-1 Consistency Test

			Method of least square								
	T=return period										
	N=no.samples										
Year		Rank	Dec.			(T/T-1)			X^2	X*Y	Y^2
	m3/sec	(m)	order	p=m/(N+1)	T=(N+1)/m		log(T/T-1)	Y=loglog (T/T-1)			
1951	4913	1	26665	0.0196	51.0000	1.0200	0.0086	-2.0655	24137569.000	-10147.766	4.266
1952	5623	2	19754	0.0392	25.5000	1.0408	0.0174	-1.7601	31618129.000	-9897.030	3.098
1953	6022	3	18232	0.0588	17.0000	1.0625	0.0263	-1.5796	36264484.000	-9512.150	2.495
1954	6274	4	17908	0.0784	12.7500	1.0851	0.0355	-1.4501	39363076.000	-9097.993	2.103
1955	6450	5	17474	0.0980	10.2000	1.1087	0.0448	-1.3486	41602500.000	-8698.485	1.819
1956	6589	6	17018	0.1176	8.5000	1.1333	0.0544	-1.2647	43414921.000	-8333.367	1.600
1957	6647	7	15962	0.1373	7.2857	1.1591	0.0641	-1.1930	44182609.000	-7930.027	1.423
1958	7033	8	15451	0.1569	6.3750	1.1860	0.0741	-1.1302	49463089.000	-7948.498	1.277
1959	7038	9	14938	0.1765	5.6667	1.2143	0.0843	-1.0741	49533444.000	-7559.268	1.154
1960	7360	10	14291	0.1961	5.1000	1.2439	0.0948	-1.0233	54169600.000	-7531.152	1.047
1961	7561	11	13949	0.2157	4.6364	1.2750	0.1055	-0.9767	57168721.000	-7384.871	0.954
1962	7685	12	13565	0.2353	4.2500	1.3077	0.1165	-0.9337	59059225.000	-7175.126	0.872
1963	7749	13	13186	0.2549	3.9231	1.3421	0.1278	-0.8935	60047001.000	-6923.846	0.798
1964	7947	14	12853	0.2745	3.6429	1.3784	0.1394	-0.8558	63154809.000	-6801.325	0.732
1965	8081	15	12570	0.2941	3.4000	1.4167	0.1513	-0.8203	65302561.000	-6628.472	0.673
1966	8146	16	12240	0.3137	3.1875	1.4571	0.1635	-0.7865	66357316.000	-6406.638	0.619
1967	8146	17	11872	0.3333	3.0000	1.5000	0.1761	-0.7543	66357316.000	-6144.220	0.569
1968	8146	18	11592	0.3529	2.8333	1.5455	0.1891	-0.7234	66357316.000	-5892.890	0.523
1969	8226	19	11231	0.3725	2.6842	1.5938	0.2024	-0.6937	67667076.000	-5706.756	0.481
1970	8276	20	10827	0.3922	2.5500	1.6452	0.2162	-0.6651	68492176.000	-5504.593	0.442
1971	8296	21	10516	0.4118	2.4286	1.7000	0.2304	-0.6374	68823616.000	-5288.080	0.406
1972	8296	22	10093	0.4314	2.3182	1.7586	0.2452	-0.6105	68823616.000	-5064.947	0.373
1973	8411	23	9751	0.4510	2.2174	1.8214	0.2604	-0.5843	70744921.000	-4914.873	0.341
1974	8426	24	9408	0.4706	2.1250	1.8889	0.2762	-0.5588	70997476.000	-4708.164	0.312
1975	8686	25	9005	0.4902	2.0400	1.9615	0.2926	-0.5337	75446596.000	-4635.982	0.285
1976	9005	26	8686	0.5098	1.9615	2.0400	0.3096	-0.5092	81090025.000	-4584.956	0.259
1977	9408	27	8426	0.5294	1.8889	2.1250	0.3274	-0.4850	88510464.000	-4562.652	0.235
1978	9751	28	8411	0.5490	1.8214	2.2174	0.3458	-0.4611	95082001.000	-4496.399	0.213
1979	10093	29	8296	0.5686	1.7586	2.3182	0.3651	-0.4375	101868649.000	-4416.007	0.191
1980	10516	30	8296	0.5882	1.7000	2.4286	0.3854	-0.4141	110586256.000	-4355.135	0.172
1981	10827	31	8276	0.6078	1.6452	2.5500	0.4065	-0.3909	117223929.000	-4232.237	0.153
1982	11231	32	8226	0.6275	1.5938	2.6842	0.4288	-0.3677	126135361.000	-4129.958	0.135
1983	11592	33	8146	0.6471	1.5455	2.8333	0.4523	-0.3446	134374464.000	-3994.321	0.119
1984	11872	34	8146	0.6667	1.5000	3.0000	0.4771	-0.3214	140944384.000	-3815.319	0.103
1985	12240	35	8146	0.6863	1.4571	3.1875	0.5035	-0.2980	149817600.000	-3648.052	0.089
1986	12570	36	8081	0.7059	1.4167	3.4000	0.5315	-0.2745	158004900.000	-3450.640	0.075
1987	12853	37	7947	0.7255	1.3784	3.6429	0.5614	-0.2507	165199609.000	-3222.183	0.063
1988	13186	38	7749	0.7451	1.3421	3.9231	0.5936	-0.2265	173870596.000	-2986.451	0.051
1989	13565	39	7685	0.7647	1.3077	4.2500	0.6284	-0.2018	184009225.000	-2737.030	0.041
1990	13949	40	7561	0.7843	1.2750	4.6364	0.6662	-0.1764	194574601.000	-2460.744	0.031
1991	14291	41	7360	0.8039	1.2439	5.1000	0.7076	-0.1502	204232681.000	-2146.944	0.023
1992	14938	42	7038	0.8235	1.2143	5.6667	0.7533	-0.1230	223143844.000	-1837.614	0.015
1993	15451	43	7033	0.8431	1.1860	6.3750	0.8045	-0.0945	238733401.000	-1459.882	0.009
1994	15962	44	6647	0.8627	1.1591	7.2857	0.8625	-0.0643	254785444.000	-1025.637	0.004
1995	17018	45	6589	0.8824	1.1333	8.5000	0.9294	-0.0318	289612324.000	-540.976	0.001
1996	17474	46	6450	0.9020	1.1087	10.2000	1.0086	0.0037	305340676.000	64.986	0.000
1997	17908	47	6274	0.9216	1.0851	12.7500	1.1055	0.0436	320696464.000	780.122	0.002
1998	18232	48	6022	0.9412	1.0625	17.0000	1.2304	0.0901	332405824.000	1642.039	0.008
1999	19754	49	5623	0.9608	1.0408	25.5000	1.4065	0.1482	390220516.000	2926.597	0.022
2000	26665	50	4913	0.9804	1.0200	51.0000	1.7076	0.2324	711022225.000	6196.374	0.054
	50										

Consistency check	
Mean x	10727.6
st.dev s	4393.890583
N	50
Consistency (k)	0.058
K<0.1 =ok	ok !

$$\frac{\sigma - 1*100}{Xmean\sqrt{n}} \leq 10\%$$

interceptor	A=	0.620294726	slope	B=	-0
Correlation	-0.9819618				
Y=	-0.0001138 x	+	0.620294726		

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10.2. Annex 10-2 Outliers test

Testing outliers of maximum discharge data (data screening)

						Outlier	
s.no	year	rainfall	y=logx	(y-Y)^2	(y-Y)^3	higher	lower
1	1951	4913	3.6913	0.0950	-0.0293	ok	ok
2	1952	5623	3.7500	0.0623	-0.0155	ok	ok
3	1953	6022	3.7797	0.0483	-0.0106	ok	ok
4	1954	6274	3.7975	0.0408	-0.0082	ok	ok
5	1955	6450	3.8096	0.0361	-0.0069	ok	ok
6	1956	6589	3.8188	0.0326	-0.0059	ok	ok
7	1957	6647	3.8226	0.0313	-0.0055	ok	ok
8	1958	7033	3.8471	0.0232	-0.0035	ok	ok
9	1959	7038	3.8474	0.0231	-0.0035	ok	ok
10	1960	7360	3.8669	0.0176	-0.0023	ok	ok
11	1961	7561	3.8786	0.0146	-0.0018	ok	ok
12	1962	7685	3.8856	0.0130	-0.0015	ok	ok
13	1963	7749	3.8892	0.0122	-0.0013	ok	ok
14	1964	7947	3.9002	0.0099	-0.0010	ok	ok
15	1965	8081	3.9075	0.0085	-0.0008	ok	ok
16	1966	8146	3.9109	0.0078	-0.0007	ok	ok
17	1967	8146	3.9109	0.0078	-0.0007	ok	ok
18	1968	8146	3.9109	0.0078	-0.0007	ok	ok
19	1969	8226	3.9152	0.0071	-0.0006	ok	ok
20	1970	8276	3.9178	0.0067	-0.0005	ok	ok
21	1971	8296	3.9189	0.0065	-0.0005	ok	ok
22	1972	8296	3.9189	0.0065	-0.0005	ok	ok
23	1973	8411	3.9248	0.0056	-0.0004	ok	ok
24	1974	8426	3.9256	0.0055	-0.0004	ok	ok
25	1975	8686	3.9388	0.0037	-0.0002	ok	ok
26	1976	9005	3.9545	0.0020	-0.0001	ok	ok
27	1977	9408	3.9735	0.0007	0.0000	ok	ok
28	1978	9751	3.9890	0.0001	0.0000	ok	ok
29	1979	10093	4.0040	0.0000	0.0000	ok	ok
30	1980	10516	4.0219	0.0005	0.0000	ok	ok
31	1981	10827	4.0345	0.0012	0.0000	ok	ok
32	1982	11231	4.0504	0.0026	0.0001	ok	ok
33	1983	11592	4.0642	0.0042	0.0003	ok	ok
34	1984	11872	4.0745	0.0056	0.0004	ok	ok
35	1985	12240	4.0878	0.0078	0.0007	ok	ok
36	1986	12570	4.0993	0.0100	0.0010	ok	ok
37	1987	12853	4.1090	0.0120	0.0013	ok	ok
38	1988	13186	4.1201	0.0145	0.0018	ok	ok
39	1989	13565	4.1324	0.0177	0.0023	ok	ok
40	1990	13949	4.1445	0.0210	0.0031	ok	ok
41	1991	14291	4.1551	0.0242	0.0038	ok	ok
42	1992	14938	4.1743	0.0306	0.0053	ok	ok
43	1993	15451	4.1890	0.0359	0.0068	ok	ok
44	1994	15962	4.2031	0.0414	0.0084	ok	ok
45	1995	17018	4.2309	0.0536	0.0124	ok	ok
46	1996	17474	4.2424	0.0590	0.0143	ok	ok
47	1997	17908	4.2530	0.0643	0.0163	ok	ok
48	1998	18232	4.2608	0.0683	0.0178	ok	ok
49	1999	19754	4.2957	0.0877	0.0260	ok	ok
50	2000	26665	4.4259	0.1819	0.0775	higher	ok
		Total	**199.9750**	**1.2801**	**0.0967**		
		n	**50**				
outlier		**Discharge**	Mean Y	3.9995			
high	4.344	22101	St. Deviation	0.1616			
low	3.655	4514	Coeff. Skew	0.487			

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10.3. Annex 10-3 Adequacy test

TEST FOR DATA ADEQUECY	
	4913
	5623
	6022
	6274
	6450
	6589
	6647
	7033
	7038
	7360
	7561
	7685
	7749
	7947
	8081
	8146
	8146
	8146
	8226
	8276
	8296
	8296
	8411
	8426
	8686
	9005
	9408
	9751
	10093
	10516
	10827
	11231
	11592
	11872
	12240
	12570
	12853
	13186
	13565
	13949
	14291
	14938
	15451
	15962
	17018
	17474
	17908
	18232
	19754
	26665
	Total
N	50
total	536378
mean	10727.56
stdv.	4393.890583
coffe. Var.	0.410
stand. Error	5.79
Test	Adequate data

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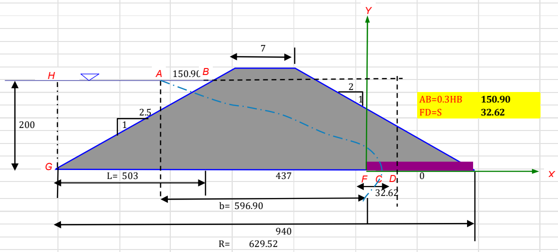
10.4. Annex 10-4 Flood frequency analyses sheet

Date	Flows(m3/s)									
1951	107	max	min		Classes			PLOTTING POSITION		
1951	66	3337	15		Upper	Lower		(m/N+1)*100	Q (m3/s)	Exceedenc
1951	42				3337	3226.267	1	0.166389351	3281.633	0.166389
1951	38				3226.267	3115.533	1	0.166389351	3170.9	0.166389
1951	60				3115.533	3004.8	1	0.166389351	3060.167	0.166389
1951	233	Range	3322		3004.8	2894.067	1	0.166389351	2949.433	0.166389
1951	1690	Interval	110.7333		2894.067	2783.333	1	0.166389351	2838.7	0.166389
1951	2371	Number(N)	600		2783.333	2672.6	1	0.166389351	2727.967	0.166389
1951	1358				2672.6	2561.867	2	0.332778702	2617.233	0.332779
1951	678				2561.867	2451.133	6	0.998336106	2506.5	0.998336
1951	293				2451.133	2340.4	9	1.49750416	2395.767	1.497504
1951	163				2340.4	2229.667	19	3.161397671	2285.033	3.161398
1952	116				2229.667	2118.933	26	4.326123128	2174.3	4.326123
1952	71	**Q70**	**Q80**	**Q95**	2118.933	2008.2	32	5.324459235	2063.567	5.324459
1952	48	**147.4907**	**121.4943**	**82.49975**	2008.2	1897.467	40	6.655574043	1952.833	6.655574
1952	52				1897.467	1786.733	47	7.820299501	1842.1	7.8203
1952	146				1786.733	1676	62	10.31613977	1731.367	10.31614
1952	354				1676	1565.267	78	12.97836938	1620.633	12.97837
1952	1973				1565.267	1454.533	94	15.640599	1509.9	15.6406
1952	2503				1454.533	1343.8	105	17.47088186	1399.167	17.47088
1952	1679				1343.8	1233.067	118	19.63394343	1288.433	19.63394
1952	730				1233.067	1122.333	136	22.62895175	1177.7	22.62895
1952	299				1122.333	1011.6	143	23.7936772	1066.967	23.79368
1952	171				1011.6	900.8667	153	25.45757072	956.2333	25.45757
1953	132				900.8667	790.1333	158	26.28951747	845.5	26.28952
1953	106				790.1333	679.4	169	28.11980033	734.7667	28.1198
1953	62				679.4	568.6667	178	29.61730449	624.0333	29.6173
1953	61				568.6667	457.9333	191	31.78036606	513.3	31.78037
1953	71				457.9333	347.2	208	34.60898502	402.5667	34.60899
1953	207				347.2	236.4667	246	40.93178037	291.8333	40.93178
1953	1643				236.4667	125.7333	343	57.07154742	181.1	57.07155
1953	2172				125.7333	15	599	99.6672213	70.36667	99.66722

10.5. Annex 10-5 Seepage analyses and frequency analyses tables

Given data	Result				
DCL	1206.00				
MPL	1203.00				
NPL	1200.00				
RBL	1000.00				
Seepage Analysis (Graphical Method)					
Depth of water, h =		200.00	m		
Free Board =		6			
Top width=		7	m		
Core Level =		1204.00			
Crest length =		203.00	m		
U/s Slope=		2.5			
D/s Slope =		2			
Berm width	U/S	3	m		
	D/S	3	m		
Dam Bottom width=		946	m		
Width of filter =		0	m		
BC =		150.9			
b =		596.9			
At Point A,	X=	596.9			
	Y=H	200			
at NPL	Yo=S				
(b^2+h^2)^0.5=X+S	Implies	629.52			
Focal Length S=Yo		32.62			
K foundation =		3.00E-04	cm/sec		
K cons material =		8.99E-04	cm/sec	8.99E-06	
q (seepage through the dam body)=		5.95E-02	m^3/sec		
q (seepage through the dam body)=		1,851,900.77	m^3/yr		
q (seepage through the foundation)=		5,555,702.31	m^3/yr		
(Assumed to be three times)					
Total seepage		8,518,743.54	m^3/yr		8.519 Mcm
		709,895.29	m^3/month		



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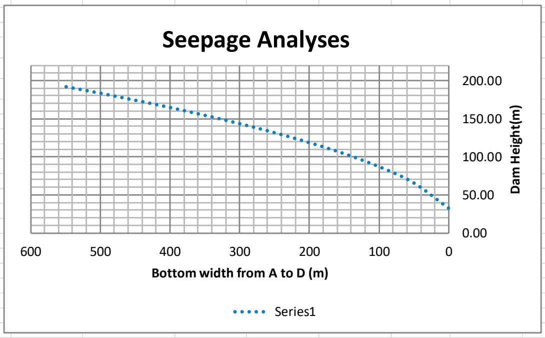
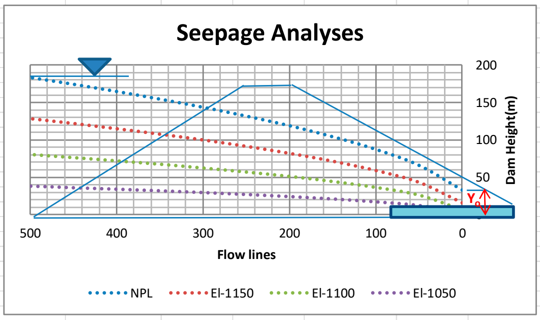
X	0	50	100	150	200	250	300	350	400	450	500	550	596.9
$Y = (2xS+S^2)^{0.5}$	32.62	65.77	87.10	104.16	118.79	131.80	143.64	154.58	164.79	174.41	183.52	192.20	200.00

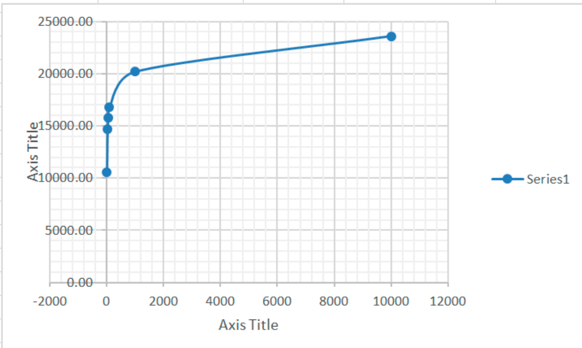


Head Vs Flowlines	0	50	100	150	200	250	300	350	400	450	500	550	596.9
NPL	32.6153771	65.76701706	87.1024583	104.155537	118.785158	131.8008019	143.641878	154.578546	164.790972	174.4064	183.518773	192.199578	200
1150	16.24496002	43.45566393	59.26964425	71.6755658	82.2306678	91.57717366	100.054359	107.867376	115.151495	122.0015	128.486804	134.660145	140.203894
1100	6.45	26.20	36.49	44.46	51.20	57.16	62.55	67.51	72.13	76.47	80.57	84.48	87.99
1050	1.453274374	12.14246449	17.11043194	20.9307028	24.154125	26.99535503	29.564787	31.9281078	34.1281629	36.19474	38.1495266	40.0089217	41.6777033



Rank (m)	Q_{MP}	M2	M3	M4	m	Probability of occurance F(y)=(m/n+1)	Probability of Eceedence p(y)=1-F(y)	Return period T(y)=1/P(y)	YT=-ln(-ln(1-(1/T)))	QT=β+αYt
1	4913	33809107.99	-1.96585E+11	1.14306E+15	1	0.02	0.9804	1.02	-0.232378561	7981.68
2	5623	26056532.79	-1.33007E+11	6.78943E+14	2	0.04	0.9608	1.04	-0.148152143	8267.47
3	6022	22142294.91	-1.04192E+11	4.90281E+14	3	0.06	0.9412	1.06	-0.09006359	8464.58
4	6274	19834196.67	-88332784938	3.93395E+14	4	0.08	0.9216	1.09	-0.043562748	8622.36
5	6450	18297519.55	-78268737742	3.34799E+14	5	0.10	0.9020	1.11	-0.003719038	8757.56
6	6589	17127678.87	-70883926679	2.93357E+14	6	0.12	0.8824	1.13	0.031788488	8878.05
7	6647	16650969.91	-67945281791	2.77255E+14	7	0.14	0.8627	1.16	0.064254927	8988.21
8	7033	13649773.59	-50429907528	1.86316E+14	8	0.16	0.8431	1.19	0.094484646	9090.79
9	7038	13612852.99	-50225437891	1.8531E+14	9	0.18	0.8235	1.21	0.123016082	9187.60
10	7360	11340460.35	-38189680668	1.28606E+14	10	0.20	0.8039	1.24	0.150230481	9279.94
11	7561	10027102.23	-31751420849	1.00543E+14	11	0.22	0.7843	1.28	0.176410046	9368.77
12	7685	9257171.354	-28165499274	8.56952E+13	12	0.24	0.7647	1.31	0.201771474	9454.83
13	7749	8871819.674	-26425247207	7.87092E+13	13	0.25	0.7451	1.34	0.226486483	9538.69
14	7947	7731513.914	-21497938328	5.97763E+13	14	0.27	0.7255	1.38	0.250694993	9620.84
15	8081	7004279.834	-18537246836	4.90599E+13	15	0.29	0.7059	1.42	0.274513959	9701.66
16	8146	6664452.034	-17204682792	4.44149E+13	16	0.31	0.6863	1.46	0.298043488	9781.50
17	8146	6664452.034	-17204682792	4.44149E+13	17	0.33	0.6667	1.50	0.321371236	9860.66
18	8146	6664452.034	-17204682792	4.44149E+13	18	0.35	0.6471	1.55	0.344575649	9939.39
19	8226	6257802.434	-15654268256	3.91601E+13	19	0.37	0.6275	1.59	0.367728436	10017.95
20	8276	6010146.434	-14734234591	3.61219E+13	20	0.39	0.6078	1.65	0.390896524	10096.57
21	8296	5912484.034	-14376559677	3.49575E+13	21	0.41	0.5882	1.70	0.414143643	10175.45
22	8296	5912484.034	-14376559677	3.49575E+13	22	0.43	0.5686	1.76	0.437531674	10254.81
23	8411	5366450.234	-12431703953	2.87988E+13	23	0.45	0.5490	1.82	0.461121839	10334.86
24	8426	5297178.434	-12191773996	2.80601E+13	24	0.47	0.5294	1.89	0.484975802	10415.80
25	8686	4167967.234	-8509155185	1.7372E+13	25	0.49	0.5098	1.96	0.509156732	10497.85
26	9005	2967212.954	-5111202345	8.80435E+12	26	0.51	0.4902	2.04	0.533730386	10581.23
27	9408	1741238.594	-2297668799	3.03191E+12	27	0.53	0.4706	2.13	0.558766244	10666.18
28	9751	953669.4336	-931315422.1	9.09485E+11	28	0.55	0.4510	2.22	0.584338766	10752.95
29	10093	402666.3936	-255515986.7	1.6214E+11	29	0.57	0.4314	2.32	0.610528814	10841.82
30	10516	44757.6336	-9468924.964	2003245765	30	0.59	0.4118	2.43	0.63742532	10933.09
31	10827	9888.3136	983293.9044	97778745.85	31	0.61	0.3922	2.55	0.665127272	11027.09
32	11231	253451.8336	127597791.1	64237831955	32	0.63	0.3725	2.68	0.693746155	11124.19
33	11592	747256.5136	645958420.6	5.58392E+11	33	0.65	0.3529	2.83	0.723408992	11224.85
34	11872	1309742.914	1498922180	1.71543E+12	34	0.67	0.3333	3.00	0.754262201	11329.54
35	12240	2287474.754	3459668316	5.23254E+12	35	0.69	0.3137	3.19	0.786476581	11438.85
36	12570	3394585.154	6254319470	1.15232E+13	36	0.71	0.2941	3.40	0.820253867	11553.46
37	12853	4517495.194	9601664984	2.04078E+13	37	0.73	0.2745	3.64	0.855835524	11674.19
38	13186	6043927.234	14858632468	3.65291E+13	38	0.75	0.2549	3.92	0.893514755	11802.05
39	13565	8051065.754	22844416012	6.48197E+13	39	0.76	0.2353	4.25	0.933653314	11938.25
40	13949	10377675.67	33431059522	1.07696E+14	40	0.78	0.2157	4.64	0.976705616	12084.33
41	14291	12698104.63	45248933976	1.61242E+14	41	0.80	0.1961	5.10	1.02325434	12242.28
42	14938	17727804.99	74641859257	3.14275E+14	42	0.82	0.1765	5.67	1.07406484	12414.69
43	15451	22310885.43	1.05384E+11	4.97776E+14	43	0.84	0.1569	6.38	1.130171708	12605.07
44	15962	27399362.11	1.4342E+11	7.50725E+14	44	0.86	0.1373	7.29	1.193023422	12818.34
45	17018	39569635.39	2.4891E+11	1.56576E+15	45	0.88	0.1176	8.50	1.264739229	13061.68
46	17474	45514452.67	3.07061E+11	2.07157E+15	46	0.90	0.0980	10.20	1.348602335	13346.25
47	17908	51558718.59	3.70214E+11	2.6583E+15	47	0.92	0.0784	12.75	1.450110429	13690.68
48	18232	56316619.71	4.22625E+11	3.17156E+15	48	0.94	0.0588	17.00	1.579566646	14129.95
49	19754	81476619.07	7.35444E+11	6.63844E+15	49	0.96	0.0392	25.50	1.760097781	14742.53
50	26665	254001993.8	4.04814E+12	6.4517E+16	50	0.98	0.0196	51	2.065492875	15778.79
	Sum	946007448.3	5.43688E+12	8.74459E+16	2	0.04	0.9608	2	0.521390228	10539.36
		18920147.97	1.1558E+11	3.95525E+13	25	0.49	0.5098	25	1.751321469	14714.97
					50	0.98	0.0196	50	2.056806117	15752.55
MEAN	10727.56				100	0.99	0.0099	100	2.360035114	16782.47
STDEV	4357.724				1000	1.00	0.0010	1000	3.361998451	20185.65
μ	8279.50				10000	1.00	0.0001	10000	4.362193973	23582.82

δ	18977194		
α	3396.5		
β	8766.584		
MoM		PWM	
α'	3393.19	l2	2361.293852
β'	8770.182	α'	7844.048388
μ'1	10728.78	β'	6199.852119
μ'2	18920148		
Cs	1.36		
Ck	5.31		
cv	0.41		



	Q_{MP} (m3/sec)	M2=(X-Xavg)^2	M3=(X-Xavg)^2	M4=(X-Xavg)^2	Rank (m)	Probability of occurance F(y)=(m/n+1)	Probability of Eceedence P(Y)=1-F(y)	Return period T(y)=1/P(y)	YT=-LOG(-LOG(1-(1/T)))	QT=β+αYt	KT	QT=μ+δKT	standared error squer ST2
1	4913	33809107.99	-1.96585E+11	1.14306E+15	1	0.019608	0.9804	1.020	-0.232378561	7969.89	-0.63118556	7978.252077	241778.9693
2	5623	26056532.79	-1.33007E+11	6.78943E+14	2	0.039216	0.9608	1.041	-0.148152143	8256.78	-0.56551423	8264.429635	244712.012
3	6022	22142294.91	-1.04192E+11	4.90281E+14	3	0.058824	0.9412	1.063	-0.09006359	8464.58	-0.52022258	8461.798118	248266.5264
4	6274	19834196.67	-88332784938	3.93395E+14	4	0.078431	0.9216	1.085	-0.043562748	8622.36	-0.48396587	8619.794834	252013.0777
5	6450	18297519.55	-78268737742	3.34799E+14	5	0.098039	0.9020	1.109	-0.003719038	8757.56	-0.45289973	8755.172498	255860.6805
6	6589	17127678.87	-70883926679	2.93357E+14	6	0.117647	0.8824	1.133	0.031788488	8878.05	-0.42521452	8875.817034	259785.2703
7	6647	16650969.91	-67945281791	2.77255E+14	7	0.137255	0.8627	1.159	0.064254927	8988.21	-0.39990043	8986.128814	263782.621
8	7033	13649773.59	-50429907528	1.86316E+14	8	0.156863	0.8431	1.186	0.094484646	9090.79	-0.37633032	9088.840855	267855.7383
9	7038	13612852.99	-50225437891	1.8531E+14	9	0.176471	0.8235	1.214	0.123016082	9187.60	-0.35408436	9185.78261	272010.6588
10	7360	11340460.35	-38189680668	1.28606E+14	10	0.196078	0.8039	1.244	0.150230481	9279.94	-0.33286529	9278.249442	276254.8693
11	7561	10027102.23	-31751420849	1.00543E+14	11	0.215686	0.7843	1.275	0.176410046	9368.77	-0.31245309	9367.200203	280596.6815
12	7685	9257171.354	-28165499274	8.56952E+13	12	0.235294	0.7647	1.308	0.201771474	9454.83	-0.29267878	9453.371168	285044.9963
13	7749	8871819.674	-26425247207	7.87092E+13	13	0.254902	0.7451	1.342	0.226486483	9538.69	-0.27340849	9537.345782	289609.2399
14	7947	7731513.914	-21497938328	5.97763E+13	14	0.274510	0.7255	1.378	0.250694993	9620.84	-0.25453311	9619.599457	294299.3841
15	8081	7004279.834	-18537246836	4.90599E+13	15	0.294118	0.7059	1.417	0.274513959	9701.66	-0.23596147	9700.529567	299126.0107
16	8146	6664452.034	-17204682792	4.44149E+13	16	0.313725	0.6863	1.457	0.298043488	9781.50	-0.21761549	9780.476256	304100.404
17	8146	6664452.034	-17204682792	4.44149E+13	17	0.333333	0.6667	1.500	0.321371236	9860.66	-0.19942685	9859.73735	309234.6625
18	8146	6664452.034	-17204682792	4.44149E+13	18	0.352941	0.6471	1.545	0.344575649	9939.39	-0.18133437	9938.579384	314541.8311
19	8226	6257802.434	-15654268256	3.91601E+13	19	0.372549	0.6275	1.594	0.367728436	10017.95	-0.16328214	10017.24601	320036.0522
20	8276	6010146.434	-14734234591	3.61219E+13	20	0.392157	0.6078	1.645	0.390896524	10096.57	-0.14521798	10095.96463	325732.7395
21	8296	5912484.034	-14376559677	3.49575E+13	21	0.411765	0.5882	1.700	0.414143643	10175.45	-0.1270922	10174.95176	331648.7792
22	8296	5912484.034	-14376559677	3.49575E+13	22	0.431373	0.5686	1.759	0.437531674	10254.81	-0.10885655	10254.41768	337802.7635
23	8411	5366450.234	-12431703953	2.87988E+13	23	0.450980	0.5490	1.821	0.461121839	10334.86	-0.0904633	10334.57039	344215.265
24	8426	5297178.434	-12191773996	2.80601E+13	24	0.470588	0.5294	1.889	0.484975802	10415.80	-0.07186437	10415.61942	350909.1607
25	8686	4167967.234	-8509155185	1.7372E+13	25	0.490196	0.5098	1.962	0.509156732	10497.85	-0.0530105	10497.77938	357910.017
26	9005	2967212.954	-5111202345	8.80435E+12	26	0.509804	0.4902	2.040	0.533730386	10581.23	-0.03385042	10581.27371	365246.5533
27	9408	1741238.594	-2297668799	3.03191E+12	27	0.529412	0.4706	2.125	0.558766244	10666.18	-0.01432996	10666.33848	372951.2017
28	9751	953669.4336	-931315422.1	9.09485E+11	28	0.549020	0.4510	2.217	0.584338766	10752.95	0.00560894	10753.22668	381060.7908
29	10093	402666.3936	-255515986.7	1.6214E+11	29	0.568627	0.4314	2.318	0.610528814	10841.82	0.02602932	10842.21306	389617.3872
30	10516	44757.6336	-9468924.964	2003245765	30	0.588235	0.4118	2.429	0.63742532	10933.09	0.04700052	10933.59978	398669.3408
31	10827	9888.3136	983293.9044	97778745.85	31	0.607843	0.3922	2.550	0.665127272	11027.09	0.06859973	11027.72318	408272.5969
32	11231	253451.8336	127597791.1	64237831955	32	0.627451	0.3725	2.684	0.693746155	11124.19	0.09091388	11124.96206	418492.36
33	11592	747256.5136	645958420.6	5.58392E+11	33	0.647059	0.3529	2.833	0.723408992	11224.85	0.11404199	11225.748	429405.2284
34	11872	1309742.914	1498922180	1.71543E+12	34	0.666667	0.3333	3.000	0.754262201	11329.54	0.13809824	11330.57848	441101.9682
35	12240	2287474.754	3459668316	5.23254E+12	35	0.686275	0.3137	3.188	0.786476581	11438.85	0.16321579	11440.03383	453691.1689
36	12570	3394585.154	6254319470	1.15232E+13	36	0.705882	0.2941	3.400	0.820253867	11553.46	0.18955194	11554.7995	467304.136
37	12853	4517495.194	9601664984	2.04078E+13	37	0.725490	0.2745	3.643	0.855835524	11674.19	0.21729496	11675.69591	482101.554
38	13186	6043927.234	14858632468	3.65291E+13	38	0.745098	0.2549	3.923	0.893514755	11802.05	0.24667345	11803.71929	498282.7419
39	13565	8051065.754	22844416012	6.48197E+13	39	0.764706	0.2353	4.250	0.933653314	11938.25	0.27796949	11940.09877	516098.7965
40	13949	10377675.67	33431059522	1.07696E+14	40	0.784314	0.2157	4.636	0.976705616	12084.33	0.31153737	12086.37832	535871.7437
41	14291	12698104.63	45248933976	1.61242E+14	41	0.803922	0.1961	5.100	1.02325434	12242.28	0.34783141	12244.53773	558023.2832
42	14938	17727804.99	74641859257	3.14275E+14	42	0.823529	0.1765	5.667	1.07406484	12414.69	0.38744836	12417.17744	583119.4623
43	15451	22310885.43	1.05384E+11	4.97776E+14	43	0.843137	0.1569	6.375	1.130171708	12605.07	0.43119488	12607.81272	611943.0608
44	15962	27399362.11	1.4342E+11	7.50725E+14	44	0.862745	0.1373	7.286	1.193023422	12818.34	0.48020036	12821.36507	645616.953
45	17018	39569635.39	2.4891E+11	1.56576E+15	45	0.882353	0.1176	8.500	1.264739229	13061.68	0.53611718	13065.03511	685827.9941
46	17474	45514452.67	3.07061E+11	2.07157E+15	46	0.901961	0.0980	10.200	1.348602335	13346.25	0.60150524	13349.97824	735267.4224
47	17908	51558718.59	3.70214E+11	2.6583E+15	47	0.921569	0.0784	12.750	1.450110429	13690.68	0.6806511	13694.87405	798595.3562
48	18232	56316619.71	4.22625E+11	3.17156E+15	48	0.941176	0.0588	17.000	1.579566646	14129.95	0.78158811	14134.72968	884899.1102
49	19754	81476619.07	7.35444E+11	6.63844E+15	49	0.960784	0.0392	25.500	1.760097781	14742.53	0.92234824	14748.12344	1015621.314
50	26665	254001993.8	4.04814E+12	6.4517E+16	50	0.98	0.02	51.000	2.07	15778.79	1.16046479	15785.76964	1264252.568
		946007448.3	5.43688E+12	8.74459E+16	2	0.04	0.96	2.000	0.52	10539.36	-0.04347204	10539.34534	361534.3925
		18920147.97	1.1558E+11	3.95525E+13	25	0.49	0.51	25.000	1.75	14712.75	0.91550535	14718.30401	1008987.12
					50	0.98	0.02	50.000	2.06	15749.32	1.15369173	15756.25449	1256702.874
MEAN	10727.56				100	0.99	0.01	100.000	2.36	16778.23	1.39011938	16786.54091	1536788.287
STDEV	4357.723886				1000	1.00	0.0010	1000.000	3.36	20178.08	2.17135019	20190.92908	2704577.678
μ	8279.50				10000	1.00	0.0001	10000.000	4.36	23571.94	2.95120264	23589.31073	4241337.464
δ	18977194.45												

	3396.5		
	8766.584		
MoM		PWM	
α'	3393.190492	l2	2361.024356
β'	8770.181661	α'	3406.238129
μ'1	10728.78449	β'	8761.425874
μ'2	18920147.97		
	230274.8343		
VAR α'	185348.2141		
VAR β'	256249.8356		
VOV(α'β')	52663.8546		

Return period T	Probability of occurance F(y)=(m/n+1)	Probability of Eceedence p(y)=1-F(y)	QT=β+αYt	standared Error ST^2
2	0.04	0.96	10539.35	361534.3925
25	0.49	0.51	14718.30	1008987.12
50	0.98	0.02	15756.25	1256702.874
100	0.99	0.01	16786.54	1536788.287
1000	1.00	0.0010	20190.93	2704577.678
10000	1.00	0.0001	23589.31	4241337.464

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Rank m	Decending order Q(monteray) m3/s	M2	M3	M4	return period, Tr=(n+1)/m	Probability of Exceedance, pex=1/Tr	F	QT	KT	δ	standared error SE^2
1	26665	254001993.754	4048141535328.370	64517012830803900.000	51.0	0.02	0.98	14845.4	0.937166359	1.304847	658098.2
2	19754	81476619.074	735443813470.706	6638439455664520.000	25.5	0.04	0.96	14094.5	0.766275872	1.21233	568085.2
3	18232	56316619.714	422624693643.529	3171561655966240.000	17.0	0.06	0.94	13646.0	0.664202863	1.163156	522935.8
4	17908	51558718.594	370214285338.229	2658301463014030.000	12.8	0.08	0.92	13321.0	0.590242023	1.1308	494246.9
5	17474	45514452.674	307060524095.282	2071565402177380.000	10.2	0.10	0.90	13063.5	0.531633594	1.107297	473915.6
6	17018	39569635.394	248910417265.317	1565756045182440.000	8.5	0.12	0.88	12848.5	0.482691264	1.089217	458565.2
7	15962	27399362.114	143420317021.912	750725044232179.000	7.3	0.14	0.86	12662.5	0.440379233	1.074778	446488.2
8	15451	22310885.434	105384128692.484	497775608831225.000	6.4	0.16	0.84	12497.8	0.402882999	1.062945	436711.1
9	14938	17727804.994	74641859257.253	314275069891109.000	5.7	0.18	0.82	12349.0	0.369029852	1.053065	428630.8
10	14291	12698104.634	45248933975.556	161241861285854.000	5.1	0.20	0.80	12212.8	0.338016807	1.044703	421850.4
11	13949	10377675.674	33431059521.962	107696152386429.000	4.6	0.22	0.78	12086.5	0.309268873	1.037554	416096.5
12	13565	8051065.754	22844416011.895	64819659768790.800	4.3	0.24	0.76	11968.2	0.282359232	1.031398	411173.7
13	13186	6043927.234	14858632468.172	36529056405051.800	3.9	0.25	0.75	11856.6	0.256961456	1.026072	406938.2
14	12853	4517495.194	9601664984.285	20407762824199.100	3.6	0.27	0.73	11750.5	0.23281945	1.021452	403282
15	12570	3394585.154	6254319470.399	11523208365041.500	3.4	0.29	0.71	11649.1	0.209727767	1.017442	400122.1
16	12240	2287474.754	3459668316.335	5232540748357.390	3.2	0.31	0.69	11551.5	0.187518253	1.013968	397394
17	11872	1309742.914	1498922180.040	1715426499725.420	3.0	0.33	0.67	11457.2	0.166050716	1.010969	395047
18	11592	747256.514	645958420.616	558392297117.628	2.8	0.35	0.65	11365.6	0.145206223	1.008399	393040.8
19	11231	253451.834	127597791.108	64237831955.202	2.7	0.37	0.63	11276.3	0.124882175	1.006219	391343.4
20	10827	9888.314	983293.904	97778745.852	2.6	0.39	0.61	11188.9	0.10498859	1.004399	389929.4
21	10516	44757.634	-9468924.964	2003245765.472	2.4	0.41	0.59	11103.0	0.085445244	1.002916	388778.6
22	10093	402666.394	-255515986.723	162140224534.830	2.3	0.43	0.57	11018.3	0.066179409	1.00175	387875.3
23	9751	953669.434	-931315422.076	909485388582.943	2.2	0.45	0.55	10934.6	0.047124025	1.000888	387207.7
24	9408	1741238.594	-2297668798.571	3031911839842.100	2.1	0.47	0.53	10851.5	0.028216168	1.000318	386767.2
25	9005	2967212.954	-5111202345.353	8804352712011.620	2.0	0.49	0.51	10768.8	0.009395735	1.000035	386548.3
26	8686	4167967.234	-8509155185.428	17371950860363.200	2.0	0.51	0.49	10686.3	-0.009395735	1.000035	386548.3
27	8426	5297178.434	-12191773995.636	28060099357396.900	1.9	0.53	0.47	10603.6	-0.028216168	1.000318	386767.2
28	8411	5366450.234	-12431703953.148	28798788109705.500	1.8	0.55	0.45	10520.5	-0.047124025	1.000888	387207.7
29	8296	5912484.034	-14376559676.740	34957467447574.900	1.8	0.57	0.43	10436.8	-0.066179409	1.00175	387875.3
30	8296	5912484.034	-14376559676.740	34957467447574.900	1.7	0.59	0.41	10352.1	-0.085445244	1.002916	388778.6
31	8276	6010146.434	-14734234590.756	36121860153314.800	1.6	0.61	0.39	10266.3	-0.10498859	1.004399	389929.4
32	8226	6257802.434	-15654268255.796	39160091297970.000	1.6	0.63	0.37	10178.8	-0.124882175	1.006219	391343.4
33	8146	6664452.034	-17204682791.860	44414920908155.100	1.5	0.65	0.35	10089.5	-0.145206223	1.008399	393040.8
34	8146	6664452.034	-17204682791.860	44414920908155.100	1.5	0.67	0.33	9998.0	-0.166050716	1.010969	395047
35	8146	6664452.034	-17204682791.860	44414920908155.100	1.5	0.69	0.31	9903.6	-0.187518253	1.013968	397394
36	8081	7004279.834	-18537246836.412	49059935987375.600	1.4	0.71	0.29	9806.0	-0.209727767	1.017442	400122.1
37	7947	7731513.914	-21497938327.600	59776307396190.300	1.4	0.73	0.27	9704.6	-0.23281945	1.021452	403282
38	7749	8871819.674	-26425247206.998	78709184320876.000	1.3	0.75	0.25	9598.5	-0.256961456	1.026072	406938.2
39	7685	9257171.354	-28165499273.609	85695221469912.400	1.3	0.76	0.24	9486.9	-0.282359232	1.031398	411173.7
40	7561	10027102.234	-31751420848.828	100542779203066.000	1.3	0.78	0.22	9368.7	-0.309268873	1.037554	416096.5
41	7360	11340460.354	-38189680668.369	128606041031573.000	1.2	0.80	0.20	9242.4	-0.338016807	1.044703	421850.4
42	7038	13612852.994	-50225437891.067	185309766625364.000	1.2	0.82	0.18	9106.1	-0.369029852	1.053065	428630.8
43	7033	13649773.594	-50429907527.971	186316319156540.000	1.2	0.84	0.16	8957.3	-0.402882999	1.062945	436711.1
44	6647	16650969.914	-67945281790.640	277254799063612.000	1.2	0.86	0.14	8792.6	-0.440379233	1.074778	446488.2
45	6589	17127678.874	-70883926679.126	293357383597164.000	1.1	0.88	0.12	8606.7	-0.482691264	1.089217	458565.2
46	6450	18297519.554	-78268737741.697	334799221814374.000	1.1	0.90	0.10	8391.6	-0.531633594	1.107297	473915.6
47	6274	19834196.674	-88332784937.678	393395357687045.000	1.1	0.92	0.08	8134.1	-0.590242023	1.1308	494246.9
48	6022	22142294.914	-104191897253.640	490281224040836.000	1.1	0.94	0.06	7809.1	-0.664202863	1.163156	522935.8
49	5623	26056532.794	-133007135036.899	678942901223952.000	1.0	0.96	0.04	7360.6	-0.766275872	1.21233	568085.2
50	4913	33809107.994	-196585086975.267	1143055783322910.000	1.0	0.98	0.02	6609.8	-0.937166359	1.304847	658098.2
					2.0	0.50	0.50	10727.6			
					25.00	0.04	0.96	14072.79	0.76		
					50.00	0.02	0.98	14824.10	0.93		
					100.00	0.01	0.99	15564.40	1.10		
					1000.00	0.00	1.00	17997.63	1.65		
Sample					10000.00	0.00	1.00	20422.28	2.21		
mean	10727.56	946007448.320	5436883026364.040	87445885578704100.000							
VaR	14308786.26	19306274.456	115579996308.759	197762622979730.000	standared error for method of Moment						
STDEV	3529.08				r1	r2					
SKEW	0.78				1.31421E-12	5.305755856					
Cv	0.33			T	δ	SE					
				2	1.3	791.9					
				25	1.4	864.5					
Cs	1.36			50	1.4	864.5					
Ck	5.31			100	1.5	943.3					
Cv	0.41			1000	2.0	1234.5					
Method of Moment				10000	2.5	1552.3					
μ'1	10727.56										
μ'2	134386818				Moment of log Logistic distribution						
μ2	19306274.46				M1	M2	m3	M4			
a	2423.707558				10727.56	19306274.456	115579996308.759	197762622979730.000			
Quantiles Estimetion					μ'1=M1	μ'2	μ2	a			
T	QT				10727.56	134386818	19306274.46	2423.707558			
2	10727.56		10727.56		Cs	Ck	Cv				
25	14072.78842				1.362536348	5.305692135	0.409506435				
50	14824.10101										
100	15564.3961										
1000	17997.62955										
10000	20422.28497										

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	Qmo	Fi	M101	M101	M102	β1	β2	β3
1	4913	0.013	4849.131	4786.092297	4723.873097	63.869	0.830297	0.010794
2	5623	0.033	5437.441	5258.005447	5084.491267	185.559	6.123447	0.202074
3	6022	0.053	5702.834	5400.583798	5114.352857	319.166	16.9158	0.896537
4	6274	0.073	5815.998	5391.430146	4997.855745	458.002	33.43415	2.440693
5	6450	0.093	5850.15	5306.08605	4812.620047	599.85	55.78605	5.188103
6	6589	0.113	5844.443	5184.020941	4598.226575	744.557	84.13494	9.507248
7	6647	0.133	5762.949	4996.476783	4331.945371	884.051	117.5788	15.63798
8	7033	0.153	5956.951	5045.537497	4273.57026	1076.049	164.6355	25.18923
9	7038	0.173	5820.426	4813.492302	3980.758134	1217.574	210.6403	36.44077
10	7360	0.193	5939.52	4793.19264	3868.10646	1420.48	274.1526	52.91146
11	7561	0.213	5950.507	4683.049009	3685.55957	1610.493	343.035	73.06646
12	7685	0.233	5894.395	4521.000965	3467.60774	1790.605	417.211	97.21015
13	7749	0.253	5788.503	4324.011741	3230.036771	1960.497	496.0057	125.4895
14	7947	0.273	5777.469	4200.219963	3053.559913	2169.531	592.282	161.693
15	8081	0.293	5713.267	4039.279769	2855.770797	2367.733	693.7458	203.2675
16	8146	0.313	5596.302	3844.659474	2641.281059	2549.698	798.0555	249.7914
17	8146	0.333	5433.382	3624.065794	2417.251885	2712.618	903.3018	300.7995
18	8146	0.353	5270.462	3409.988914	2206.262827	2875.538	1015.065	358.3179
19	8226	0.373	5157.702	3233.879154	2027.64223	3068.298	1144.475	426.8892
20	8276	0.393	5023.532	3049.283924	1850.915342	3252.468	1278.22	502.3404
21	8296	0.413	4869.752	2858.544424	1677.965577	3426.248	1415.04	584.4117
22	8296	0.433	4703.832	2667.072744	1512.230246	3592.168	1555.409	673.492
23	8411	0.453	4600.817	2516.646899	1376.605854	3810.183	1726.013	781.8838
24	8426	0.473	4440.502	2340.144554	1233.25618	3985.498	1885.141	891.6715
25	8686	0.493	4403.802	2232.727614	1131.9929	4282.198	2111.124	1040.784
26	9005	0.513	4385.435	2135.706845	1040.089234	4619.565	2369.837	1215.726
27	9408	0.533	4393.536	2051.781312	958.1818727	5014.464	2672.709	1424.554
28	9751	0.553	4358.697	1948.337559	870.9068889	5392.303	2981.944	1649.015
29	10093	0.573	4309.711	1840.246597	785.7852969	5783.289	3313.825	1898.821
30	10516	0.593	4280.012	1741.964884	708.9797078	6235.988	3697.941	2192.879
31	10827	0.613	4190.049	1621.548963	627.5394487	6636.951	4068.451	2493.96
32	11231	0.633	4121.777	1512.692159	555.1580224	7109.223	4500.138	2848.587
33	11592	0.653	4022.424	1395.781128	484.3360514	7569.576	4942.933	3227.735
34	11872	0.673	3882.144	1269.461088	415.1137758	7989.856	5377.173	3618.837
35	12240	0.693	3757.68	1153.60776	354.1575823	8482.32	5878.248	4073.626
36	12570	0.713	3607.59	1035.37833	297.1535807	8962.41	6390.198	4556.211
37	12853	0.733	3431.751	916.277517	244.646097	9421.249	6905.776	5061.933
38	13186	0.753	3256.942	804.464674	198.7027745	9929.058	7476.581	5629.865
39	13565	0.773	3079.255	698.990885	158.6709309	10485.75	8105.481	6265.537
40	13949	0.793	2887.443	597.700701	123.7240451	11061.56	8771.815	6956.049
41	14291	0.813	2672.417	499.741979	93.45175007	11618.58	9445.908	7679.523
42	14938	0.833	2494.646	416.605882	69.57318229	12443.35	10365.31	8634.306
43	15451	0.853	2271.297	333.880659	49.08045687	13179.7	11242.29	9589.671
44	15962	0.873	2027.174	257.451098	32.69628945	13934.83	12165.1	10620.14
45	17018	0.893	1820.926	194.839082	20.84778177	15197.07	13570.99	12118.89
46	17474	0.913	1520.238	132.260706	11.50668142	15953.76	14565.78	13298.56
47	17908	0.933	1199.836	80.389012	5.386063804	16708.16	15588.72	14544.27
48	18232	0.953	856.904	40.274488	1.892900936	17375.1	16558.47	15780.22
49	19754	0.973	533.358	14.400666	0.388817982	19220.64	18701.68	18196.74
50	26665	0.993	186.655	1.306585	0.009146095	26478.35	26293	26108.95
Sum	536378		209152	125214.5834	88261.71708	327226	243288.7	196304.1
Mean=a0=b0	10727.56							

M100=α0	10727.56	λ1	10727.6	β0	10727.56	λ1	10727.56
M101=α1	4183.039	λ2	2361.5	β1	6544.521	λ2	2361.481
M102=α2	2504.292	λ3	655.1	β2	4865.773	λ3	655.0741
M103=α3	1765.234	λ4	355.2	β3	3926.083	λ4	355.1514

α0	10727.56				
		τ	0.220132	a'	2361.48	2361.481
		τ3	0.2774	m'	10727.56	
		τ4	0.230795			

Quantile estimation

Probability of Exceedance	T	F	QT	KT	SE^2
0.5	2	0.5	10727.6	0.000	334595.7
0.04	25	0.96	13986.9	0.761	485618.8
0.02	50	0.98	14718.9	0.932	561074
0.01	100	0.99	15440.2	1.101	650324.8
0.001	1000	0.999	17811.0	1.655	1047891
0.0001	10000	0.9999	20173.4	2.206	1603015

Var(a')	79198.79
Var(m')	334595.65
cov(a',m')	0.00

Parameter	m	α
MOM	10727.56	2423.708
PWM	10727.56	2361.48

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Abbreviation

H project means Hiben Project

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