A DESSERTATION ON

SIZING OF NOA-DEHING RESERVOIR SYSTEM BY SIMULATION AND DESIGN OF THE GRAVITY DAM

Submitted in Partial Fulfilment of the Requirement for the award of degree

of

MASTERS OF TECHNOLOGY
CIVIL ENGINEERING

Specialization in
WATER RESOURCES ENGINEERING

UNDER

Assam Science and Technology University

For the session: 2022-2024

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This is to certify that the dissertation entitled **“SIZING OF NOA-DEHING RESERVOIR SYSTEM BY SIMULATION AND DESIGN OF THE GRAVITY DAM”** is a project report prepared by Arnab Sarma, Roll no-220620061002, a student of M. Tech. 4th Semester, Civil Engineering Department (Water Resources Engineering), Assam Engineering College under my supervision and guidance in partial fulfillment for the requirement of the award of the degree of Masters of Technology in Civil Engineering with specialization in Water Resources Engineering under Assam Science and Technology University.

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ACKNOWLEDGEMENT

I would like to express my deepest gratitude and sincere thanks to my respected guide Dr. Bibhash Sarma, Professor, Department of Civil Engineering, Assam Engineering College for his constant guidance, constructive suggestion and full co-operation throughout the study and preparing the finalized dissertation.

I also express my sincere thanks to Dr. Jayanta Pathak, Professor & Head of the Department of Civil Engineering, Assam Engineering College for the kind departmental support and facility for carrying out my work.

I also thank all the faculty members and staff of Department of Civil Engineering, Assam Engineering College for their free exchange of idea and lending their helping hand whenever I needed them.

I would like to express my deepest gratitude and sincere thanks Brahmaputra board for helping me in collecting the data regarding noa-dehing river.

Lastly, I thank all my classmate, family members and well- wishers for their constant encouragement, valuable advice and inspiration during the course of my study.

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CONTENTS

LIST OF FIGURES

FIGURE NO. **PAGE NO.**

LIST OF TABLES

TABLE NO. **PAGE NO.**

ABSTRACT

The earth is filled with 70 percent of water, but all the water can't used by people of the world. The ocean's holds about 96.5 percent of earth's water, 1 percent is in the form of saline water and rest of the 2.5 percent is only available as freshwater. With increasing rate of population the water demand among people is also rising. The water that is available for use is not homogeneously distributed; therefore in some regions water is available below requirement whether in some regions water is available in excess amount.

The study of the project is to prepare a simulation of reservoir system of Noa-Dehing river to regulate water according to the demand for optimum utilization. The aim of the project is to find plant capacity of the hydropower plant, gross storage capacity of the reservoir, firm power of the hydropower plant, annual irrigation demand of the command area that needs to be irrigatd by the river and the maximum amount of irrigation water that can be released by the reservoir. Then after getting the parameters of the reservoir system a gravity dam is also designed considering selfweight, water pressure and uplift forces for overturning, sliding and shear friction factor of safeties.

The simulation to find the reservoir system parameters of the Noa-Dehing river dam and gravity dam design analysis has been done with the help of cell referencing techniques.

CHAPTER 1

INTRODUCTION

1.1 PROLOGUE:

The river Noa-Dehing originates Eastern Himalayas particularly known as Patkai hills in Arunachal Pradesh and flows through Tinsukia and Dibrugarh districts in Assam to its convergence point with the Brahmaputra river at Dihingmukh. The National Projects of india has total of 16 projects under their list for constructing a hydropower plant and one of them is on the river Noa-Dehing. The construction cost for the hydropower plant is estimated to be 1086.06 crore rupees by the National Project scheme of india. This project aims to find the various factors related to construction of the hydro power plant.

1.2 MULTI-PURPOSE WATER RESOURCES PROJECTS:

The amount of water of the world is about 75 percent, but a little amount of water is only available as freshwater which can be utilized. Multipurpose water projects are water assests projects which can be used for different purposes like water system, hydropower generation, water supply for drinking and irrigation, flood control purposes etc. It can be observed that most of the multipurpose water resource projects of India are a combination of water system and hydropower generation. The Noa-Dehing project is also a multipurpose project for the purpose of generating hydropower and supply irrigation water.

1.3 MOTIVATION FOR THE WORK:

The northeastern states of India have mountainous topography and there exist a large amount of perennial streams in these regions. Therefore the northeastern states of India have the largest hydropower potential in all over India. Assam, Arunachal Pradesh, Sikkim, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, all these states together can account for almost 40 percent of the total hydropower potential for the country. The climatic conditions of these states are suitable for generating a very high amount of hydropower. But the present scenario of the hydropower generation is not reaching its full potential. This study is conducted to obtain maximum amount of hydropower that can be generated for the hydropower plant to be constructed in the Noa-Dehing river.

1.4 SIMULATION MODEL:

A simulation model which act as an approach for engineers and designer to abstain from repeated building of multiple physical prototypes to analyze for new and existing parts. It helps to study digital prototype of a physical model to predict performance of the model in the real world. Fluid flow patterns of the real world can be predicted in precise way in the simulation model. With the help of simulation model different results can be reviewed and engineering judgement can be obtained based on the results. Reservoir working table is a simulation model which is created based on various factors. The driving factors of the reservoir working table are monthly inflow data from the year 1981 to the year 2008, evaporation data on monthly basis, and relationship established from elevation, area and capacity of the reservoir. With the help of above data the simulation model is created and it is regulated to find gross storage capacity of the reservoir, plant capacity of the reservoir and firm power that can be generated from the reservoir.

1.5 STABILITY OF GRAVITY DAM:

The simulation of reservoir working table provides the gross storage capacity and height of the reservoir. From these data the different forces acting on the gravity dam is determined which are self weight forces, water pressure forces and uplift forces. Then for different conditions of upstream and downstream slopes stability analysis of the gravity dam is done. The stability is checked based on overturning failure, sliding failure and shear failure. For all the stability factors based on different conditions the optimum condition is obtained for which the gravity dam needs to be designed.

1.6 STUDY AREA:

The study area of the for the report of the project is Noa-Dehing river. The coordinates of Noa-Dehing river is located at latitude 27.7798N and longitude 95.6741E.

Figure 1.1: River map of Arunachal Pradesh

1.7 OBJECTIVE OF THE STUDY:

The proposed Noa-Dehing reservoir is a multipurpose one. The objective of the study is stated to be:

a. To find the gross storage capacity of the reservoir.
b. To determine the plant capacity and firm power of the hydropower plant.
c. To assess whether the reservoir system can meet the existing irrigation demand for the command area.
d. To find the extent of water that can be conveyed for irrigation above the demand.
e. To find the required and safe dimensions of the dam from the obtained reservoir parameters.

1.8 METHODOLOGY:

The following methodology is followed:

a. Determination of irrigation demand procedure.
b. A simulation model is formed to find the required reservoir capacity, plant capacity, firm power, irrigation reliability and hydropower reliability.
c. The simulation model is run making several trials to get the desired optimal reservoir parameters, keeping the hydropower reliability at minimum 90 percent and irrigation release reliability at minimum 75 percent.
d. From the obtained dam height, the required and safe dimension of the dam is determined keeping the dam safe against different horizontal and vertical forces.

1.9 CHAPTERWISE SCHEME:

Chapter 1: This chapter discusses objective of the study with a brief introduction of the part of work of the project.

Chapter 2: This chapter discusses about different literature reviews.

Chapter 3: This chapter is included with the study area its history and present scenario.

Chapter 4: This chapter discusses about irrigation water demand and defining different parameters of the reservoir.

Chapter 5: This chapter is included with the design of the gravity dam.

Chapter 6: This chapter is about conclusion obtained from the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION:

The study of the project is based on defining irrigation demand, determining gross storage, plant capacity, firm power of the reservoir and design of gravity dam for safe conditions based on obtained value from simulation of reservoir working table. There are a few literature review is mentioned corresponding to the study of the project.

2.2 LITERATURE REVIEW ON IRRIGATION DEMAND:

Abdelhafidh (2022) et.al have estimated price elasticity of irrigation water demand in public and private areas of Nadhour using Ordinary Least Squares Regression. They have determined the economic performences of farming system and compared the value of marginal productivity of irrigation water to the prices of water. They have collected the data from 140 farmers. The results show that irrigation water demand is less responsive to water price variation and estimated elasticities are -0.69 and -0.44 respectively in the public and private schemes. The total area irrigated and farmers status are most significant determinants of water demand and water productivity in private farming systems is higher than recorded public farming system and VMP of irrigation water exceeds the prices paid for water.

Dalai (2022) et.al have studied the canal command area required for long term planning and management of water resources in their study area of Phulnakhara distributary command of the Puri main canal system distributed in Cuttack and Khurda districts of Odisha. They have taken the data of area of crop coverage of Phulnakhara distributary for both kharif and rabi season for different crops from the year 2008 to 2018. The crops of kharif season taken are paddy, maize, other vegetables, chilly, ginger and turmeric. The rabi crops taken are paddy, wheat, maize, green gram, black gram, gram, field pea, ground nut, sesamum, sunflower, mustard, potato, onion, other vegetables, chilly, sugarcane. They have also taken different crop co efficient data for all the above mentioned crops for both kharif and rabi seasons. After that they have taken data of canal release from the Assistant Executive Engineer (2018) on the monthly basis. For evapotranspiration data they have used relationship using FAO Penman-Monteith equation. They have found that during rabi season, the canal does not flow at full supply level as a result of which the total irrigation demand of the canal command area does not meet due to lower cropping intensity and poor crop productivity. The year-wise maximum irrigation water demand in kharif season is found to be 48646195 m^3 during 2015-16 and the minimum was 22291100 m^3 in 2017-18. Whereas the highest kharif irrigation supply at the head regulator was 43402176 m^3 during 2015-16 and the minimum were 29831328 m^3 during 2013-14. The maximum rabi irrigation water demand was found to be 21700766 m^3 during 2008-09 and the minimum was 9570257 m^3 in 2017-18. Whereas the maximum rabi irrigation supply at head regulator was 26379648 m^3 during 2008-09 and the lowest was 615168 m^3 during 2009-10. From above data it is observed that there is a contradiction between the supply and demand in both the seasons and it is more eminent in the rabi season. In order to solve it, homogeneouse use of canal water with groundwater is found to be a promising solution.

Sun (2017) et.al have studied estimates of price elasticities of irrigation water demands in Zhangye Basin which is an inland river basin in China. They have performed the study based on most recent data then they compare the values of marginal product (VMPs) of water to the prices of water which the farmers are paying. The data has been collected in 2009 and 2014 with household fixed effects models to estimate water demand and crop production functions. VMPs imputed for the full sample and by sources of irrigation are all around 0.5 Yuan/m^3. The VMP values are 0.51 and 0.45 Yuan/m^3 when irrigation is done for wheat through surface water and groundwater respectively. The VMP drops slightly to 0.41 Yuan/m^3 when wheat is irrigated conjunctively by surface water and groundwater, but the difference is not statistically different (t-test = 1.61). The lower VMP is likely due to the higher irrigation application rate used under conjunctive irrigation. The marginal product of an input tends to decrease when more of it is used in production.The estimation results are then used for estimation of price elasticities and VMPs. The economic returns of irrigation water are defined as the value of marginal product

(VMP) of irrigation water in crop production. One of the most important findings of their study shows that the VMPs of irrigation water exceed the prices rural households are paying for water, which is more likely to occur in areas with more groundwater irrigation. The gap between VMP and water price rises up to 66% of current water price. The estimated VMPs provide policy makers with some guidelines of the minimum increments in water prices required to induce water savings. If the value of marginal product is above water price then farmers need to use the maximal possible amount of water that is available to them. If the government wants to stimulate farmers to save water further in this situation then price of water needs to increase significantly, so it can at least reach the value of a marginal product. In addition, policy makers should be aware of the two distinctive groups of water uses.

Abdullah A. A. (2021) and Zuhal R. Kadhim have studied the optimal allocation of irrigation water which is used to irrigate agricultural crops at Iraq. For this study they have formulated two economic models based on simplex algorithm. A total of forty agricultural crops were taken into consideration. They have found that for both actual crop composition plan and proposed basic plan the two estimated models there was a surplus of water about 30.943, 35.357 and 31.097 billion cubic meters for each plans respectively, compared to quantities of water available for agricultural use. They have found that for maximizing the total profit margin during the average period (2017-2020), the model with legislative restrictions can be selected with a high profit margin which is estimated to be 152 thousand Iraqi dinars per dunum, with an increase amount of about 11.5% compared to the current crop composition. Irrigation water required for the actual composition amounted to about 4.737 billion m^3, while the amount of irrigation water required for the optimal composition was about 4.730 billion m^3, with a decrease of about 0.15% compared to the actual crop composition, and the total surplus quantities of irrigated water was about 31 billion cubic meters distributed over the various months of the year.

Page (2021) et.al have estimated the future evolution of irrigation water requirements in Tensift, Morocco. They have obtained monthly synthetic crop coefficient of different irrigated areas from a time series of remote sensing observations. An empirical model using synthetic crop coefficient and rainfall was developed and was fitted in actual data for each irrigated area within the study area. The model appears with an average r^2 value of 0.69 for observation period from 2000-

2016. When sub-sampling was done to one-third of 16 years data r^2 value was reduced to 0.45. The performance of the model was acceptable in most irrigated areas where monthly correlation coefficient of crop coefficient value is obtained up to 0.92, but with significant differences between irrigated areas. They have found that a simple ordinary least square adjustment has been used to fit the coefficient but other more sophisticated techniques could also be used.

2.3 LITERATURE REVIEW ON SIMULATION:

Madeti (2022) et.al have prepared a simulation model with the input data of reservoir inflow, potential evapotranspiration, rainfall in the irrigated area, and cropping pattern. "Harabhangi irrigation project" is an interbasin irrigation project in Orissa state, India. It was used as a case study to show the simulation study for obtaining the almost optimal value and application of it in reservoir planning by sampling data regarding the design variables of single-purpose reservoir systems. The study area taken was southern part of Orissa state, which are the Rushikulya basin and the Vansadhara basin. Harabhangi reservoir serves as a source of water for irrigation project and was formed by the construction of a dam on the river Harabhangi. The dam at Adava is located at about longitude 84.08° east and latitude 19.30° north with the MWL (mean water level) of the reservoir at 387.5m above sea level. The catchment area at the dam site is 503.8 Km^2 and extends from longitude 84.03° to 84.22° east and latitude 19.17° to 19.34° north. The elevation of the command area under the Soroda and Badagada blocks varies from 130m to 90m above sea level. From the results, it is found that with a projected provision of reservoir capacity equal to 141.25 MCM for 0 percent allowance in the annual irrigation deficit, about 205 MCM annual irrigation can be satisfied with about 80 percent dependability. The value of irrigation reliability for a 5 percent allowance may be about 210 MCM and, for 10 percent, it may be even higher than a value of about 220 MCM. It was found that a lower capacity of 120 MCM may be sufficient to satisfy the future annual irrigation requirement of 220 MCM.

Liu (2021) et.al have used generative adversarial network (GAN) which is a new method that has capabilities of pattern learning and generation and widely used for image generation. Due to the similarity between content and structure of facies models and specific images, various images generated by GANs are often complex than reservoir facies models; it has potential to be used in reservoir facies modeling. Therefore, they have proposed a reservoir facies modeling method which is based on GANs for unconditional modeling. They have tested the method for both synthetic data and oil field data. They have found that this method can overcome the limitations of traditional geostatistics that are difficult to deal with. For the application of the method for future researches they have used deep learning models for verification and it obtains good performances. But for handling new cases they have concluded that trial and error is more suitable even if it is hard to determine the optimum result. GANs have the ability to create strong pattern for complex reservoir facies modeling but it still needs improvement.

Galletti (2021) et.al have found that hydrological and water resources modelling in mountaneous catchments is difficult due to alterations of natural stream flows. Also hydropower production are often notable, while capturing their changes in space and time. Because it requires critical data concerning the hydraulic infrastructures and their operational schedules. These data are difficult to acquire and also creating a simulation of interaction between the natural hydrological cycle and water uses is complex. To overcome these problems they have proposed a framework that depends on publicly available data which gives accurate simulation of both stream flow and hydropower production. The proposed framework is done by the HYPERstreamHS hydrological model applied to the Adige catchment, a large watershed of the south-eastern Alpine region. The stream flow of the study area is strongly impacted by 39 large hydropower systems. Out of these 39, 22 are connected to storage reservoirs, with an overall mean annual production of about 14% of the total Italian hydropower production. They have analyzed the impact on modelled hydropower production which is commonly adopted for simplifications in the production schedule as well as of the hydropower systems and often characterized by a complex infrastructure with several interlinked derivations and conveyance intakes. They have found that total hydropower production of the Adige river at annual scale has the difference with the measured production with only – 4%. The differences of the order of – 10% were observed with the other configurations. The comparison with commonly adopted simplifications showed that an accurate data which is publicly available is worth the investment of the financial resources and time required to perform it.

Abdullah Al Mahfazur Rahman (2021) and Md. Rakibul Hasan have studied the grid-connected mini-hydropower plants in Bangladesh due to its provision for generating clean source of energy.

They have demonstrated a simulation model of a mini-hydropower plant which is able to connect with the distribution system under steady-state and dynamic condition. When the system starts to oscillate a circuit breaker reaction occurs making the system back to stability. The simulation was carried out in the MATLAB/Simulink platform. The system was observed by the waveforms of voltage, current, and rotor speed at the generator's terminal. The system is simulated under various steady-state and faulty conditions of the distribution grid. To observe the dynamic behavior of the system a three-phase fault is created on the HT side of the transformer. The behavior of the system after installing a circuit breaker is also observed. The system behavior before and after clearing the fault was stable by observing the responses of current, voltage, and rotor speed waveforms. They have observed that energy storage systems combining with mini-hydropower plants can increase the effectiveness of the system. So, that type of system can also be included for analysis in the existing model.

Gbadamosi S. L (2015) and Ojo O. Adedayo have done modeling and simulation of hydropower plant with a view of increasing the efficiency and stability of the generating station. The model was developed using Matlab/Simulink software. The designed model consists of hydraulic turbine (PID governor, servomotor and turbine), Synchronous generator and an excitation system. They have studied dynamic response of the system with the disturbances on the system network. A three phase fault was installed in the SHPP model at 0.1 sec and cleared at 0.2 sec. The simulated result shows that the generated voltage stability is obtained when fault is removed and the stator currents behaves as transient when the fault was cleared and it became stable at 0.4 sec. The excitation voltage also gains stability but with a slower rate and the speed of the rotor was not stable when disturbance occurred in the system. The modeling and simulation of SHPP in Nigeria, if somehow becomes fully operational then it could be replicated for other generating stations such as thermal, nuclear, wind etc.

2.4 LITERATURE REVIEW ON DAM DESIGN:

Prasad (2024) et.al have analysed stability of dam using modern technique with the help of software STAAD PRO. They have done the stability analysis for sliding, overturning, compression and tension. The forces taken into consideration were weight of the dam, water pressure, uplift pressure, seismic pressure, silt pressure, wave pressure. They have performed the stability analysis for different conditions which are- Reservoir empty condition, Reservoir full with no uplift and Reservoir full with uplift. As a result they have found that in manual calculations the stability analysis against water pressure, uplift pressure and seismic pressure is acceptable but using STAAD Pro they have performed analysis for one gate width of dam and using new technique and software's it is easy to perform analysis comparing to manual procedures and the results are accurate. So it is easy to use software for design and analysis of large structure to reduce human effort.

Khan (2019) et.al have designed a gravity dam at Vykuntapuram using analytical method and also they have showed population forecasting. By this study they have shown that the storage capacity of the dam can fulfill all the needs up to forcasted population of 2121. They forces on gravity dam taken into consideration were self weight of gravity dam, water pressure forces and uplift forces. They have done stability analysis of the gravity dam on the basis of crushing, overturning and sliding. For flood forcasting Gumbell's method has been used. For population forcasting geometric mean method has been used. The dam is designed for 31 meter height to store the excess water during peak floods which was initially discharged into the sea for avoiding the submergence of low lying areas. After design it was estimated by them that 16 TMC of water can be stored without any disturbances. The dam was designed considering maximum flood during past 500 years so that it can with stand for any peak flood.

Farzin Salmasi (2011) have performed the design of a gravity dam through an interactive process which involves a preliminary layout of the structure followed by a stability and stress analysis. This study presents determination of top width of gravity dam with the help of genetic algorithm. Types of forces taken into consideration were self weight of gravity dam, water pressure forces and uplift forces of gravity dam. The computation of eccentricity is done for two conditions. First one for reservoir empty condition and second one for reservoir full condition. In the study the top width is taken as function of water depth. First the top width is assumed as percentage of the height of dam, for this top width, the extension of bottom width at upstream side is determined for no tension at the toe in reservoir empty condition. Then net required material is calculated for the dam for no tension condition. After that for design all the parameters and constraints are taken into consideration. After that the results were found as ratio of base width of the dam and dam height is 0.85 and ratio for top width of the dam and dam height is 0.13. The obtained design is most economical and safest in which no tension is developed anywhere near the dam section.

Samayak Jain (2023) have done stability analysis of gravity dam structures in India. The aim of the study is to provide an idea of design consideration, loading conditions and failure mechanism analysis of Indian gravity dams. For the study geometrical layout of the dam, foundation conditions, material selection properties and structural design codes were taken into consideration. Water pressure, seismic loads, temperature effects and flood and spillway design considerations have done in the study. Stability analysis was done by limit equilibrium analysis, finite element analysis and force moment analysis. The results showed that lowest safety factor is 2.26 and safety factor of the most critical surface increases from 2.26 to 2.36.

Xuhua (2008) et.al have studied anti-slide stability of a concrete gravity dam on a complicated foundation with multiple slide planes. Overload and material weakening is considered for the study and a partial safety factor based on reliability method was developed. Method of safety evaluation is done by stress analysis method and strength reverse coefficient method. The study area was located in southwest of China which has a plant capacity of 165 megawatt, height of the dam is 60.2 meter and dam axis length is 300 meter. They have drawn the result that in strength reverse coefficient method taking overload and material weakening into consideration, it matches the method in current specification and it is more scientific and rational then traditional safety coefficient method and strength reduction finite element method.

CHAPTER 3

STUDY AREA

3.1 INTRODUCTION:

In Upper Assam northeastern India a large tributary of Dihing River about 380 kilometer is situated. This river is also known as ‘Burhi-Dihing River’. Dihing river originates from Eastern Himalayas in Himalayas in Arunachal Pradesh and flows through Tinsukia and Dibrugarh district in Assam to its confluence with the Brahmaputra at Dihingmukh. The river is at a sea level of 2,375 meters. Watershed of the dihing river is about 6000 square kilometres. The Joy-Dihing Rainforest, numerous petroleum fields, wet-paddy fields, bamboo orchards and tea gardens creates an unique landscape along its course. The study area originates directly from the Patkai hills across Tiger Reserve and National Park. The area is a true wilderness and enchanting beauty of lush green vegetation and virgin forest which is spread over an area of 1985 square kilometres in the international border between India and Burma within Changlang District in the state of Arunachal Pradesh in the northeast India. Noa Dehing lies across the tropical rain forest flows down along Assam, touching various towns like Margherita, Tinsukia and Dibrugarh which finally end up in the river Brahmaputra in the state of Assam at Dihingmukh.

Figure 3.1: Map of Noa-Dehing river

3.2 HISTORY OF THE STUDY AREA:

According to historical as well as geographical records, Dihing once flowed through entire Upper Assam and met the Brahmaputra at Mahuramukh in Bokakhat. During that period Disang, Dikhou, Disai, Dhansiri were all tributaries to the Disang. In 17^{th} century the river dried out and changed its course to join Brahmaputra at Dihingmukh. Before that the river met Brahmaputra near the confluence of Subansiri river. At that time the Dikhou river had an independent route and flowed as Kolong and joined the Brahmaputra at Kajalimukh in Nagaon district.

3.3 CLIMATE OF THE STUDY AREA:

The climatic condition of the area is "tropical monsoon" type and is a temperate region which is humid during the rainy seasons. Winter seasons starts from the end of the October month of the year and continues till February. The minimum temperature varies between 6 to 14 degree Celsius and maximum temperature varies between 23 to 38 degree Celsius. The nights and early mornings are foggy and rain is scanty and summer starts in mid-May with high humidity and rainfall. Monsoon season starts from mid-June to August. During afternoon hours Bordoicila which is a form of Thunderstorm occurs in there. The area also lies in seismic zone V as incorporated by Indian Standard Criteria for Earthquake Resistant Design of Structure (IS: 1893 Part 1-2002).

3.4 PRESENT SCENARIO OF THE STUDY AREA:

With rise in water levels, the Noa-Dehing River which has started widening its banks and the river has flooded the entire Lekang circle while the entire Namsai Township and its adjoining villages are badly affected. A report from Namsai stated that Noa-Dehing river is flowing above danger level. Massive erosion of many of the river banks has damaged cultivable lands, paddy fields, tea gardens, horticultural fields and livestock. Water resources development (WRD) assistant engineer G Pertin said that the threat has increased abundantly because Noa-Dehing river is in spate after incessant rains lashed parts of the Lekang area in Lohit district and the threat of erosion and flood is looming large on people residing in the region. The river eroded the

Namsai and Mahadevpur circle badly. New Seela-2 and Filobari village in Mahadevpur cicle are destroyed 15 years ago due to erosion by the Dihing river and now it's eroded the Kharbari villages of Namsai circle. Landslide is a natural phenomenon in Arunachal Pradesh so in the upper course of Dihing River it is frequently found. During rainy seasons it happens frequently and the loose materials of the hills comes directly by surface runoff and gets deposited in the middle or lower portion of the river course. The river changes its course time to time. Due to high deposition rate of silted material small islands are building between Namsai and Mahadevpur circle. This island causes problems during the rainy seasons. The flood and erosion are a cyclic process going on in the river.

CHAPTER 4

DETERMINATION OF IRRIGATION WATER DEMAND AND PARAMETERS OF HYDROPOWER PLANT

4.1 INTRODUCTION:

Irrigation water demand for the suggested area to be irrigated is defined with the help of district irrigation plan of the districts in downstream areas of Noa-Dehing river. After that a simulation model is prepared to determine plant capacity, gross storage capacity, firm power, power reliability and irrigation reliability to obtain the maximum amount of water that can released for irrigation demand.

4.2 SOURCE OF DATA FOR CROPS:

The Noa-Dehing flows through the Changlang district and it ends in Dibrugarh district of Assam. It passes through five major districts of both the state Assam and Arunachal Pradesh. The districts of Arunachal Pradesh are Changlang, Namsai and Lohit. The districts of Assam are Tinsukia and Dibrugarh. In this project the data of the crops produced in these five districts has been collected from the district irrigation plan for each of each of the district. In the district plans the data available is about the type of crop produced and area where these crops are produced. For Changlang district the the data available for the crops in the district irrigation plan is of the year 2011-12. The source of the data has been collected from Statistical Hand Book of changlang, Office of the Deputy Commissioner, changlang District, Arunachal Pradesh. For Namsai district the the data available for the crops in the district irrigation plan is of the year 2016-17. The source of the data has been collected from District Statistical Hand book, Namsai District - 2016-17, Arunachal Pradesh**.** For Lohit district the data available is of the year 2009 and source of the data is from District Statistical office, Lohit- dist., Tezu, Arunachal Pradesh. For Tinsukia district the data has been taken from The district Irrigation Plan of Tinsukia district 2016-20. In this plan the data is available in blockwise version of Tinsukia district those are

Kakapathar, Itakhuli, Sadiya, Saikhowa, Hapjan, Guijan and Margherita. For Dibrugarh district the data has been taken from the district Irrigation Plan of Dibrugarh district 2016-20. In this plan the data is available in blockwise version of Tinsukia district those are Joypur, Khowang, Lahoal, Panitola, Tengakhat, Tingkhong, Borbaruah. The irrigation water supplied from the dam irrigates downstream areas which mainly consist of 5 districts. Out of the 5 districts 2 are from Assam which are Tinsukia and Dibrugarh and rest of the 3 are from Arunachal Pradesh which are Changlang, Namsai and Lohit district. From the district irrigation plan data for the types of crop produced and area occupied by those crops are collected. Some of the crops have their particular irrigation water need based on daily, weekly or yearly basis and irrigation water need for rest of the crop have been obtained with the help of a relationship which is given below,

Duty x Delta = 864 x Base period

Duty: Duty is known as the number of hectares of land irrigated for full growth of a given crop by 1 m^3/s of water during the base period. Generally duty is expressed in hectare per m^3/s.

Delta: Delta is defined as the depth of water required to raise a crop over a unit area during the base period of the crop. Generally delta is expressed in cm.

Base period: It is the time period between the first watering of a crop during sowing of the crop and last watering done during the harvesting of the crop. Generally base period is expressed in days.

With the help of above relationship the irrigation water requirement for all the crops are determined in terms of m^3/s. This operation is done for crops of all the five districts. Every crop have different growing period. So for every month according to their growing period irrigation water requirement is defined.

4.3 DETERMINATION OF IRRIGATION WATER DEMAND:

The districts which lie in downstream part of the Noa-Dehing river are Changlang, Namsai, Lohit, Tinsukia and Dibrugarh. From the district irrigation plan of each districts the type of crop produced and area where these are produced has been obtained. Types of crops produced in

Tinsukia and Dibrugarh districts of Assam are kharif crop, rabi crop, summer crop and horticulture and plantation crop. The table below shows name of crops produced for the above mentioned types of crops and area occupied these crops for Tinsukia and Dibrugarh district.

Table 4.1: Crops produced in districts of Assam

Districts of Assam				
Types of crop	Tinsukia		Dibrugarh	
	Crop name	Area (ha)	Crop name	Area (ha)
Kharif	Rice	62422	Rice	74319
	Maize	817	Maize	80
	Pigeon pea	1004	Pigeon pea	233.5
	Soybean	57	Sesame	182
	Jute	4	Jute	25
Rabi	Wheat	13641	Wheat	1909
	Barley	320	Barley	223
	Chickpea	4340	Green Pea	1190
	Mustard	8598	Mustard	1820.5
			Mesta	120
Summer crop	Maize	5335	Rice	1027
	Green gram	14	Maize	94
	Sesame	2	Green gram	244
	Jute	25	Sesame	26
			Jute	23
Horticulture and plantation crop	Pineapple	14596.25	Tea	12017.5

Table below shows area occupied and types of crops produced in Changlang, Namsai and Lohit districts of Arunachal Pradesh which are major field crop, horticulture crop fruit and horticulture crop vegetables.

Table 4.2: Crops produced in districts of Arunachal Pradesh

Types of crop	Districts of Arunachal Pradesh					
	Changlang		Namsai		Lohit	
	Crop name	Area (ha)	Crop name	Area (ha)	Crop name	Area (ha)
Major field crops cultivated	Paddy	15260	Rice	9375	Paddy	10500
	Maize	1240	Maize	1475	Maize	8024
	Rapeseed	4550	Mustard	1438	Mustard	11430
	Lentils	905	Black gram	512	Lentil	1559
	Millets	2210				
Horticultural Crops fruits	Orange	316	Orange	960	Orange	2175890
	Pineapple	63	Pineapple	130	Pineapple	135380
	Banana	76	Banana	300		
	Litchi	7	Litchi	5	Banana	111290
			Arecanut	30		
Horticulture crops vegetables	Tapioca	16	Cabbage	593.88	Tomato	105789
	Ginger	122	Tomato	593.88	Cabbage	105789
	Potato	149.7	Brinjal	593.88	Cauliflower	105789
	Tomato	149.7	Garlic	593.88	Carrots	105789
			Chilli peppers	593.88	Beans	105789
	Cabbage	149.7	Leafy greens	593.88	Peas	105789
					Radishes	105789
	Carrot	149.7	Pumpkin	593.88	Spinach	105789
					Bitter gourd	105789
	Spinach	149.7	Onion	593.88	Brinjal	105789
					Pumpkin	105789
	Cauliflower	149.7	Beans	593.88	Cucumber	105789
					Green leafy vegetable	105789
	Onion	149.7	Potato	405	Chillies	105789
					Okra	105789
	Beans	149.7	Ginger	1420	Onion	105789
					Garlic	105789
	Peppers	149.7	Turmeric	1420	Turnip	105789
					Lettuce	105789
	Broccoli	149.7	Black pepper	30	Potato	625000
					Ginger	895000

From all the crops produced in these five districts a table has been formed showing the growing period of all the crops. The table below shows the growing period of crops produced in all the districts.

Table 4.3: Growing period of all the districts

Crop Name	Growing period	Crop Name	Growing period
Rice	May-Aug	Turmeric	Apr-Jan
Maize	Jun-Sep	Black pepper	Apr-Jan
Pigeon pea	Jun-Oct	Peas	Oct-Dec
Soybean	Jun-Oct	Radishes	Sep-Nov
Jute	Mar-Sep	Lettuce	Sep-Nov
Wheat	May-Oct	Turnip	Mar-May
Barley	Apr-Oct	Banana	Feb-Dec
Chickpea	May-Oct	Litchi	Sep-May
Mustard	Apr-Oct	Tapioca	Apr-Jan
Green gram	Feb-May	Ginger	Mar-Nov
Sesame	Jul-Nov	Potato	Jan-May
Pineapple	May-Aug	Tomato	Jul-Oct
Green Pea	Oct-Jan	Cabbage	Jul-Nov
Mesta	May-Oct	Carrot	Aug-Nov
Tea	Mar-Dec	Spinach	Jan-Apr
Bitter gourd	Feb-May	Cauliflower	May-Sep
Cucumber	Feb-Apr	Onion	Dec-Mar
Paddy	May-Sep	Okra (lady finger)	Jun-Aug
Rapeseed	Oct-Jan	Beans	Apr-Jun
Lentils	May-Aug	Peppers	May-July
Millets	July-Oct	Broccoli	Sep-Nov
Orange	July-Sep	Black gram	Jun-Sep
Chilli peppers	Jul-Nov	Arecanut	May-Sep
Leafy greens	Mar-May	Brinjal	Jul-Oct
Pumpkin	Apr-Sep	Garlic	Oct-May

Now for all the districts the amount of water required for all the crops have been determined with the help of relationship between duty, delta and base period. The delta value is taken considering all the natural incoming and losses for all the districts. Some of the crops have their unique intensity if irrigation on daily, monthly and yearly basis. After determining the irrigation water requirement of all the crops, monthly water requirement for all the crops have been determined.

The table below shows water requirements for the crops of each district and from data of the irrigation water requirements of the crops the monthly requirement of irrigation water for each district is obtained.

Table 4.4: Irrigation water requirements for the crops of Tinsukia district

Tinsukia district						
Crop Name	Growing period	Area (ha)	Base period (days)	Delta (cm)	Irrigation water need	Irrigation water need (cubic meter/second)
Rice	May-Aug	62422	NA	NA	10 mm/day	72.24768519
Maize	Jun-Sep	817	90	25	NA	0.262667181
Pigeon pea	Jun-Oct	1004	130	25	NA	0.223468661
Soybean	Jun-Oct	57	100	50	NA	0.032986111
Jute	Mar-Sep	4	116	50	NA	0.00199553
Wheat	May-Oct	13641	120	40	NA	5.262731481
Barley	Apr-Oct	320	90	30	NA	0.12345679
Chickpea	May-Oct	4340	100	NA	2.54 cm/week	1.822685185
Mustard	Apr-Oct	8598	105	35	NA	3.31712963
Maize	Jun-Sep	5335	90	25	NA	1.715213477
Green gram	Feb-May	14	90	40	NA	0.007201646
Sesame	Jul-Nov	2	100	45	NA	0.001041667
Jute	Mar-Sep	25	116	50	NA	0.012472063
Pineapple	May-Aug	14596.25	365	NA	188.29 cm/year	8.714890641

Table 4.5: Monthly water requirement for Tinsukia district

Month	Irrigation water need (cubic meter/second)
Jan	0
Feb	0.007201646
Mar	0.021669239
Apr	3.462255658
May	91.51024815
Jun	93.73738194
Jul	93.7384236
Aug	93.7384236
Sep	12.77584778
Oct	10.78349953
Nov	0.001041667
Dec	0

Table 4.6: Irrigation water requirements for the crops of Dibrugarh district

Dibrugarh district						
Crop Name	Growing period	Area (ha)	Base period (days)	Delta (cm)	Irrigation water need	Irrigation water need (cubic meter/second)
Rice	May-Aug	74319	NA	NA	10 mm/day	86.01736111
Maize	Jun-Sep	80	90	37.66	NA	0.038744856
Pigeon pea	Jun-Oct	233.5	135	20	NA	0.040037723
Sesame	Jul-Nov	182	100	45	NA	0.094791667
Jute	Mar-Sep	25	116	50	NA	0.012472063
Wheat	May-Oct	1909	120	40	NA	0.736496914
Barley	Apr-Oct	223	75	30	NA	0.103240741
Green Pea	Oct-Jan	1190	NA	NA	0.54 cm/day	0.74375
Mustard	Apr-Oct	1820.5	105	35	NA	0.702353395
Mesta	May-Oct	120	140	50	NA	0.049603175
Rice	May-Aug	1027	NA	NA	10 mm/day	1.188657407
Maize	Jun-Sep	94	90	37.66	NA	0.045525206
Green gram	Feb-May	244	90	40	NA	0.125514403
Sesame	Jul-Nov	26	100	45	NA	0.013541667
Jute	Mar-Sep	23	116	50	NA	0.011474298
Tea	Mar-Dec	12017.5	NA	NA	152.4 cm/year	5.80754376

Table 4.7: Monthly water requirement for Dibrugarh district

Month	Irrigation water need (cubic meter/second)
Jan	0.74375
Feb	0.125514403
Mar	5.957004523
Apr	6.762598659
May	94.75471727
Jun	94.75351065
Jul	94.86184398
Aug	94.98735838
Sep	7.655825462
Oct	8.29135904
Nov	6.785141496
Dec	6.55129376

Table 4.8: Irrigation water requirements for the crops of Changlang district

Changlang district						
Crop Name	Growing period	Area (ha)	Base period (days)	Delta (cm)	Irrigation water need	Irrigation water need (cubic meter/second)
Paddy	May-Sep	15260	150	120	NA	14.12962963
Maize	Jun-Sep	1240	90	25	NA	0.398662551
Rapeseed	Oct-Jan	4550	95	NA	18.83 cm/year	0.271678399
Lentils	May-Aug	905	145	NA	12.55 cm/year	0.036015189
Millets	July-Oct	2210	75	NA	12.55 cm/year	0.087948694
Orange	July-Sep	316	210	60	NA	0.104497354
Pineapple	May-Aug	63	365	NA	188.29 cm/year	0.037615011
Banana	Feb-Dec	76	365	NA	1900 mm/year	0.04578894
Litchi	Sep-May	7	365	NA	1600 mm/year	0.003551497
Tapioca	Apr-Jan	16	365	NA	100 cm/year	0.005073567

Changlang district						
Crop Name	Growing period	Area (ha)	Base period (days)	Delta (cm)	Irrigation water need	Irrigation water need (cubic meter/second)
Ginger	Mar-Nov	122	240	NA	1400 mm/day	19.76851852
Potato	Jan-May	149.7	95	NA	0.54 cm/day	0.0935625
Tomato	Jul-Oct	149.7	68	NA	0.73 cm/day	0.126482639
Cabbage	Jul-Nov	149.7	75	NA	0.54 cm/day	0.0935625
Carrot	Aug-Nov	149.7	75	NA	0.36 cm/day	0.062375
Spinach	Jan-Apr	149.7	45	NA	0.36 cm/day	0.062375
Cauliflower	May-Sep	149.7	80	NA	0.45 cm/day	0.07796875
Onion	Dec-Mar	149.7	116	NA	0.36 cm/day	0.062375
Beans	Apr-Jun	149.7	60	45	NA	0.129947917
Peppers	May-July	149.7	75	45	NA	0.103958333
Broccoli	Sep-Nov	149.7	75	45	NA	0.103958333

Table 4.9: Monthly water requirement for Changlang District

Month	Irrigation water need (cubic meter/second)
Jan	0.544404902
Feb	0.267652936
Mar	20.03261996
Apr	20.10526644
May	34.43162985
Jun	34.73317841
Jul	35.01572168
Aug	34.97413834
Sep	35.00801797
Oct	20.56893809
Nov	20.41180819
Dec	0.388467402

Table 4.10: Irrigation water requirements for the crops of Namsai district

Namsai district						
Crop Name	Growing period	Area (ha)	Base period (days)	Delta (cm)	Irrigation water need	Irrigation water need (cubic meter/second)
Rice	May-Aug	9375	NA	NA	10 mm/day	10.8506944
Maize	Jun-Sep	1475	90	25	NA	0.4742155
Mustard	Apr-Oct	1438	105	NA	31.38 cm/year	0.1430887
Black gram	Jun-Sep	512	73	35	NA	0.2841197
Orange	July-Sep	960	210	60	NA	0.3174603
Pineapple	May-Aug	130	365	NA	1882.9 mm/year	0.0776183
Banana	Feb-Dec	300	NA	NA	1900 mm/year	0.1807458
Litchi	Sep-May	5	NA	NA	1600 mm/year	0.0025368
Arecanut	May-Sep	30	365	NA	350 mm/year	0.0033295
Cabbage	Jul-Nov	593.88	80	NA	3.175 cm/week	0.3117674
Tomato	Jul-Oct	593.88	73	NA	3.81 cm/week	0.3741208
Brinjal	Jul-Oct	593.88	78	NA	3.175 cm/week	0.3117674
Garlic	Oct-May	593.88	270	NA	2.54 cm/week	0.2494139
Chilli peppers	Jul-Nov	593.88	NA	NA	3.81 cm/week	0.3741208
Leafy greens	Mar-May	593.88	50	NA	3.175 cm/week	0.3117674
Pumpkin	Apr-Sep	593.88	100	NA	3.175 cm/week	0.3117674
Onion	Dec-Mar	593.88	115	NA	2.54 cm/week	0.2494139
Beans	Apr-Jun	593.88	60	45	NA	0.5155208
Potato	Jan-May	405	95	NA	5.4 mm/day	0.2531250
Ginger	Mar-Nov	1420	240	NA	1400 mm/crop cycle	0.9587191
Turmeric	Apr-Jan	1420	220	69	NA	0.5154672
Black pepper	Apr-Jan	30	NA	NA	1625 mm/year	0.0154585

Table 4.11: Monthly water requirement for Namsai district

Month	Irrigation water need (cubic meter/second)
Jan	1.29
Feb	0.9352354
Mar	2.0249761
Apr	3.4576105
May	14.3892528
Jun	14.3307450
Jul	14.7927894
Aug	15.5044609
Sep	4.5786850
Oct	3.4372064
Nov	2.6082295
Dec	1.2130361

Table 4.12: Irrigation water requirements for the crops of Lohit district

Lohit district						
Crop Name	Growing period	Area (ha)	Base period (days)	Delta (cm)	Irrigation water need	Irrigation water need (cubic meter/second)
Paddy	May-Sep	10500	150	120	NA	9.72
Maize	Jun-Sep	8024	90	25	NA	2.58
Mustard	Apr-Oct	11430	105	35	NA	4.41
Lentil	May-Aug	1559	145	17.5	NA	0.22
Orange	July-Sep	2175890	NA	NA	1150 mm/year	793.47
Pineapple	May-Aug	135380	365	25	NA	10.73
Banana	Feb-Dec	111290	365	120	NA	42.35
Tomato	Jul-Oct	105789	68	26	NA	46.82
Cabbage	Jul-Nov	105789	75	44	NA	71.83
Cauliflower	May-Sep	105789	80	35	NA	53.57
Carrots	Aug-Nov	105789	75	40	NA	65.30
Beans	Apr-Jun	105789	60	23	NA	46.94
Peas	Oct-Dec	105789	65	22	NA	41.44
Radishes	Sep-Nov	105789	25	10	NA	48.98
Spinach	Sep-Nov	105789	45	18	NA	48.98
Bitter gourd	Feb-May	105789	70	26	NA	45.48
Brinjal	Jul-Nov	105789	78	50	NA	78.49
Pumpkin	Apr-Sep	105789	100	36	NA	44.08

Lohit district						
Crop Name	Growing period	Area (ha)	Base period (days)	Delta (cm)	Irrigation water need	Irrigation water need (cubic meter/second)
Cucumber	Feb-Apr	105789	60	20	NA	40.81365741
Green leafy vegetable	Mar-May	105789	50	18	NA	44.07875
Chillies	Jul-Nov	105789	75	95	NA	155.0918981
Okra (lady finger)	Jun-Aug	105789	58	10	NA	21.11051245
Onion	Dec-Mar	105789	116	45	NA	47.49865302
Garlic	Oct-May	105789	270	59.2	NA	26.84631687
Turnip	Mar-May	105789	45	2.54	NA	6.911112654
Lettuce	Sep-Nov	105789	60	5.08	NA	10.36666898
Potato	Jan-May	625000	105	14.3	NA	98.51741623
Ginger	Mar-Nov	895000	120	0.76	NA	6.560570988

Table 4.13: Monthly water requirement for lohit district

Month	Irrigation water need (cubic meter/second)
Jan	172.86
Feb	301.5019119
Mar	332.2060287
Apr	406.9778708
May	440.4043122
Jun	242.2628860
Jul	1341.0203055
Aug	1406.3221573
Sep	1524.0227002
Oct	647.4546653
Nov	596.2292772
Dec	158.1343227

Now a table is prepared with agricultural area of all the districts and the area that has been proposed to be irrigated by the reservoir of the Noa-Dehing river.

Table 4.14: Districts agricultural areas and proposed agricultural area

<table>
<tr><th>Districts</th><th>Agricultural area (Ha)</th><th>Total area (ha)</th><th>Area to be irrigated (Ha)</th></tr>
<tr><td>Tinsukia</td><td>111175.25</td><td rowspan="5">6237879.67</td><td rowspan="5">3605</td></tr>
<tr><td>Dibrugarh</td><td>93533.5</td></tr>
<tr><td>Changlang</td><td>26262</td></tr>
<tr><td>Namsai</td><td>22844.92</td></tr>
<tr><td>Lohit</td><td>5984064</td></tr>
</table>

Now another table is prepared to determine the total monthly water requirement for all the districts. But for every month the total irrigation water requirement for the proposed area to be irrigated can be determined by dividing the total monthly irrigation water requirement of the entire districts with total agricultural area which is 6237879.67 hectare and multiplying that term with the proposed area to be irrigated which is 3605 hectare. Table below shows monthly water requirement for the proposed area.

Table 4.15: Monthly water requirement for the proposed area

Month	Irrigation demand (cubic meter/second)	Irrigation demand for total area (MCM)	Irrigation demand for the area to be irrigated (MCM)
Jan	175.44	469.8876653	0.271557825
Feb	302.8375163	732.6245194	0.4233989
Mar	360.2422985	964.8729722	0.557620097
Apr	440.7656021	1142.464441	0.660253889
May	675.4901603	1809.232845	1.045593175
Jun	479.8177021	1243.687484	0.718752784
Jul	1579.4290841	4230.342859	2.444802852
Aug	1645.5265386	4407.378281	2.547115293
Sep	1584.0410764	4105.83447	2.372846872
Oct	690.5356683	1849.530734	1.06888216
Nov	626.0354981	1622.684011	0.937782735
Dec	166.2871199	445.3834221	0.257396314

So, total annual water requirement for the proposed area is 13.3060029 million cubic meters.

4.4 SIMULATION MODEL:

Simulation model helps to determine various parameters of a reservoir system. In this study, with the help of simulation model, plant capacity of the hydropower plant, gross storage capacity of the reservoir, firm power of the hydropower plant is determined along with maximum amount of total annual irrigation water demand so that power reliability does not reach a value below 90 percent and irrigation reliability does not reach below 75 percent. Discharge data from 1981 to 2008 of Noa-Dehing river is used in this simulation model, the data has been collected from Brahmaputra board but the data of the river discharge is classified so it cannot be mentioned in this study. Other data that were used in the simulation model have also been collected from Brahmaputra board. Those data are monthly evaporation rate data, elevation-area-capacity data, efficiency of the power plant and tail water level of the reservoir.

4.5 EVAPORATION RATE DATA:

The evaporation rate data has been collected on monthly basis from Brahmaputra board for Noa-Dehing river. The following table shows the evaporation rate data on monthly basis.

Table 4.16: Evaporation rate data on monthly basis

Month	Evaporation rate (m)
Jan	0.04
Feb	0.05
Mar	0.07
Apr	0.08
May	0.08
Jun	0.08
Jul	0.08
Aug	0.07
Sep	0.07
Oct	0.07
Nov	0.06
Dec	0.06

4.6 ELEVATION-AREA-CAPACITY DATA:

Elevation-area-capacity data has been collected for the river Noa-Dehing, then relationship between area and capacity, elevation and capacity is determined. These two relationships are used for determining the initial elevation and area of the reservoir for monthly basis based on discharge data of the river.

The following table is showing data related to elevation, area and capacity of the reservoir.

Table 4.17: Elevation, area and capacity data

Elevation (m)	Area (ha)	Capacity (ha m)	Capacity (MCM)
242	0	0	0
250	475.5	1902	19.02
260	645.9	7509	75.09
270	1159.5	16536	165.36
280	1391.4	29290	292.9
282	1487.04	32169	321.69

With the help of data of the above table two graphs has been prepared between area and capacity and elevation and capacity. Figures below are showing the two graphs.

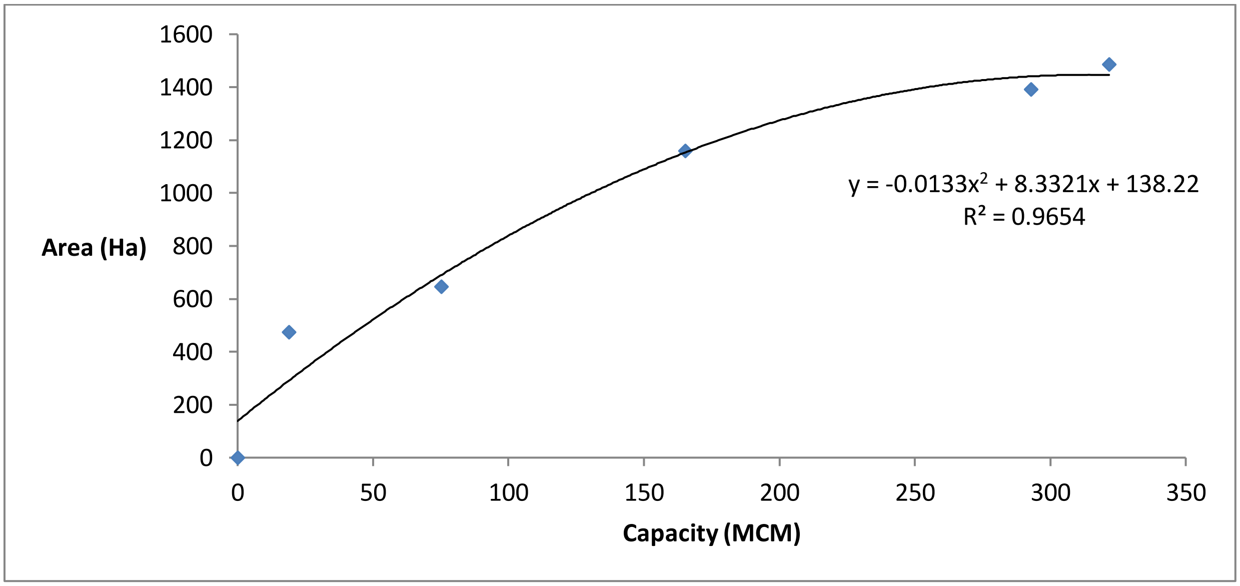

Figure 4.1: Graph between area and capacity

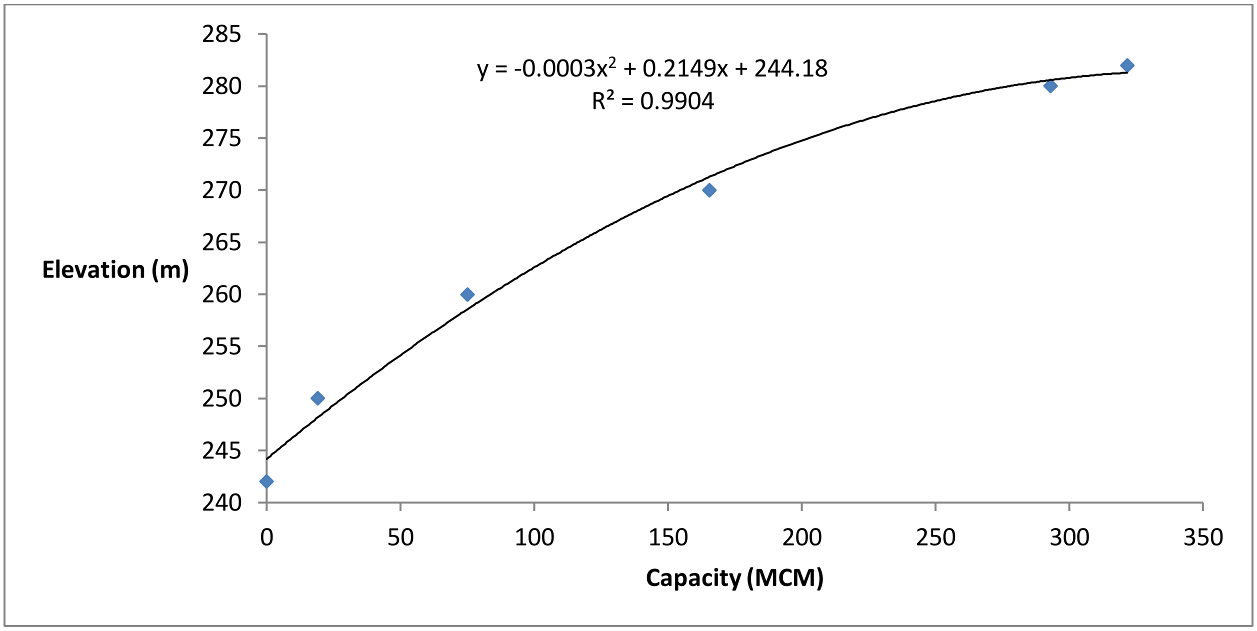

Figure 4.2: Graph between elevation and capacity

From the above two graphs the relationship between elevation, area and capacity is determined. That are-

From the first graph: $Y = -0.013X^2 + 8.332X + 138.2$

Where, Y = Area in hectare and X = Capacity in million cubic meters. So, the relationship becomes -

$$\text{Area} = -0.013(\text{Capacity})^2 + 8.332\ (\text{Capacity}) + 138.2$$

From the second graph: $Y = 0.214X + 244.1$

Where, Y = Elevation in meter and X = Capacity in million cubic meters. So, the relationship becomes –

$$\text{Elevation} = 0.214(\text{Capacity}) + 244.1$$

4.7 POWER GENERATION EQUATION:

The power that is generated is a function of for factors which are gravitation acceleration, discharge, power head and efficiency of the hydropower plant. The power equation is-

P = g x Q x h x e

Where, P = Power in kilowatt,

g = Gravitational acceleration= 9.81 m/s^2,

Q = Discharge in m^3/s,

h = Power head = (Initial elevation – tail water level) in meters and

e = Efficiency of the hydropower plant.

From the data collected from Brahmaputra board the tail water level is 47 meters and efficiency of the hydropower plant is 0.8. But all the discharge is in million cubic meters per month. So equation needs to be modified.

So, number of hours in a month = $\frac{365 \text{ x } 24}{12}$ = 730 hours

Therefore, Q (m^3/s) x g (m/s^2) = $\frac{\text{Q (MCM) x } 10^6}{\text{Months in hours}}$ x 9.81 (m/s^2)

$$= \frac{\text{Q x } 10^6}{\text{730 hours x (60 x 60)}} \text{ x } 9.81$$

= 3.7 x Q (MCM/month)

So, the modified power equation becomes

P (megawatt) = (3.7 x Q x h x e)/1000

P = 0.0037 x Q x h x e

Active storage: Active storage is the amount of water that is available in the reservoir considering all the losses. The expression for active storage is –

Active storage = Initial storage + inflow – evaporation loss - dead storage

Final Storage: Final storage is the amount of water stored in the reservoir after releasing all the demands such as irrigation demand, firm power demand etc. The expression for final storage is –

Final storage = Active storage – total release + dead storage

Spill: Spill is defined as the amount of water that got out of the reservoir when final storage reaches gross storage capacity of the reservoir. The expression for spill is –

Amount of spilled water = Final storage – Gross storage, when final storage > gross storage and

Amount of spilled water = 0, when final storage $<$ gross storage.

Firm power demand in terms of MCM: The amount of water that is required to generate the required firm power capacity of the hydropower plant is termed as firm power demand. The expression for firm power demand is –

$$\text{Firm power demand (MCM)} = \frac{\text{Firm power (MW)}}{0.0037 \text{ x Power head at reservoir full condition(m) x efficiency}}$$

4.8 DETERMINATION OF PLANT CAPACITY OF THE HYDROPOWER PLANT:

For determining the plant capacity of the hydropower plant, at first a higher amount of gross storage capacity equal to 1000 million cubic meters is considered for the reservoir and plant capacity is taken as 350 Megawatt. Then without considering the irrigation water requirements, power is generated directly from the active storage available in the reservoir. After that generated powers are put in descending order and dependability percentages are determined. The power corresponding to 90 percent dependability is obtained as plant capacity of the hydropower plant. The table below shows results of power produced in hydropower plant against percentage of dependability around 90 percent

Table 4.18: Power generation and dependability percentage

Power generation (MW)	Dependability (%)
198.38	88.37
198.45	88.70
200.70	89.04
201.73	89.37
202.15	89.70
203.30	90.03
205.80	90.37
206.57	90.70
212.19	91.03
217.13	91.36

So, from the above table it is observed that 90.03 or approximately 90 percent dependability is determined for a power generation of 203.30 Megawatt. So plant capacity is obtained as 200 Megawatt.

4.9 DETERMINATION OF GROSS STORAGE CAPACITY:

When plant capacity of the hydropower plant is obtained as 200 Megawatt, after that gross storage capacity of the reservoir is determined by fixing the plant capacity as 200 Megawatt in the simulation model. Since the irrigation and hydropower water demands are compatible, the higher demand between irrigation hydropower is considered for release. If this demand is less than active storage then amount of water in the demand is released and if it is more than active storage then the amount of water available in the active storage is released. Amount of water released is the total release from the reservoir. Firm power is generated from the release and if there is any spill, the spilled water is also used to generate surcharge power. The sum of firm power and surcharge power gives the total power generated from the reservoir. From that average power is calculated. Now with the change in gross storage change is average power is observed. The table below shows the observations:

Table 4.19: Determination of gross storage capacity

Gross storage, S (MCM)	Average power, P (MW)	Change in storage, ΔS (MCM)	Change in power, ΔP (MW)	ΔP/ΔS (MW/MCM)
200	108.85	NA	NA	NA
220	109.76	20	0.91	0.0455
240	110.64	20	0.88	0.044
260	111.5	20	0.86	0.043
280	112.43	20	0.93	0.0465
300	113.29	20	0.86	0.043
320	114.17	20	0.88	0.044
340	115.04	20	0.87	0.0435
360	116.02	20	0.98	0.049
380	117.14	20	1.12	0.056
400	118.24	20	1.1	0.055
420	119.3	20	1.06	0.053
440	120.32	20	1.02	0.051
460	121.44	20	1.12	0.056
480	122.6	20	1.16	0.058
500	123.58	20	0.98	0.049
600	128.81	100	5.23	0.0523
700	132.82	100	4.01	0.0401
800	136.56	100	3.74	0.0374
900	140.09	100	3.53	0.0353
1000	142.69	100	2.6	0.026

A graph is prepared between the slope of change in power-change in gross storage and gross storage capacity of the reservoir which is shown below.

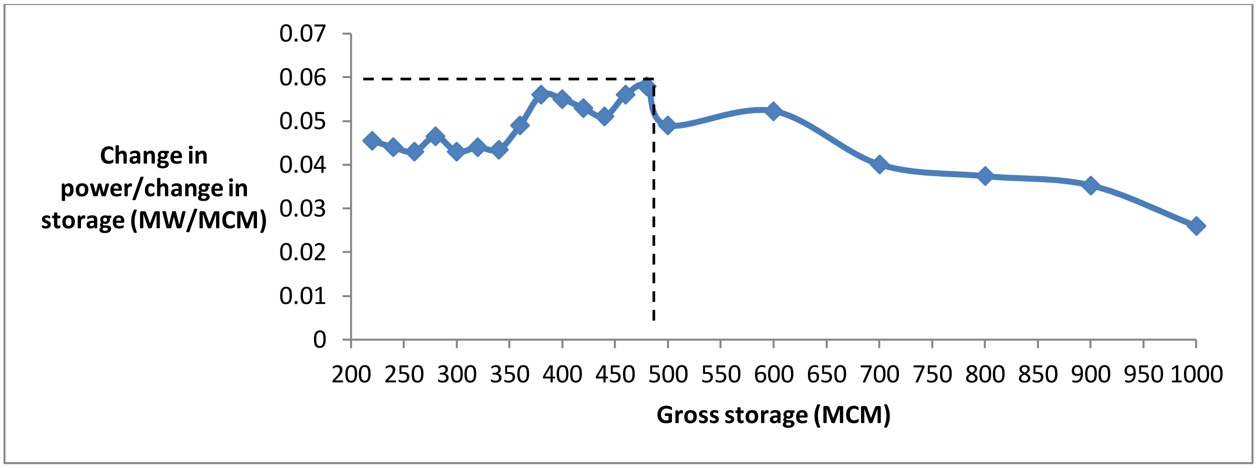

Figure 4.3: Relation between slope of change in power-change in gross storage and gross storage

From the above table it is observed that highest value of slope 0.058 is obtained for a gross storage capacity value of 480 MCM. From the graph above also it is certain that the maximum value of slope which is 0.058 is obtained for a gross storage value of 480 MCM. So the calculated gross storage capacity of the reservoir is obtained as 480 million cubic meters.

4.10 DETERMINATION OF FIRM POWER OF THE HYDROPOWER PLANT:

After determining the plant capacity and gross storage capacity of the reservoir as 200 Megawatt and 480 million cubic meters firm power needs to be determined. Firm power is determined with the help of reliability percentages of power and irrigation. The condition of reliability for power is that it should not be less than 90 percent and that for irrigation is that it should not be less than 75 percent. Now with the change of firm power, reliability values are observed. The table below shows the reliability percentage values of power and irrigation with different firm power values.

Table 4.20: Firm power, power reliability and irrigation reliabilities

Firm power (MW)	Power reliability (%)	Irrigation reliability (%)
91	98.34	99.67
92	98.34	99.67
93	98.01	99.67
94	97.34	99.67

Firm power (MW)	Power reliability (%)	Irrigation reliability (%)
95	95.02	99.67
96	94.35	99.67
97	93.69	99.67
98	93.02	99.67
99	92.03	99.67
100	91.36	99.67
101	89.7	99.67

A graph has been prepared on the basis of values between firm power and power reliability percentages.

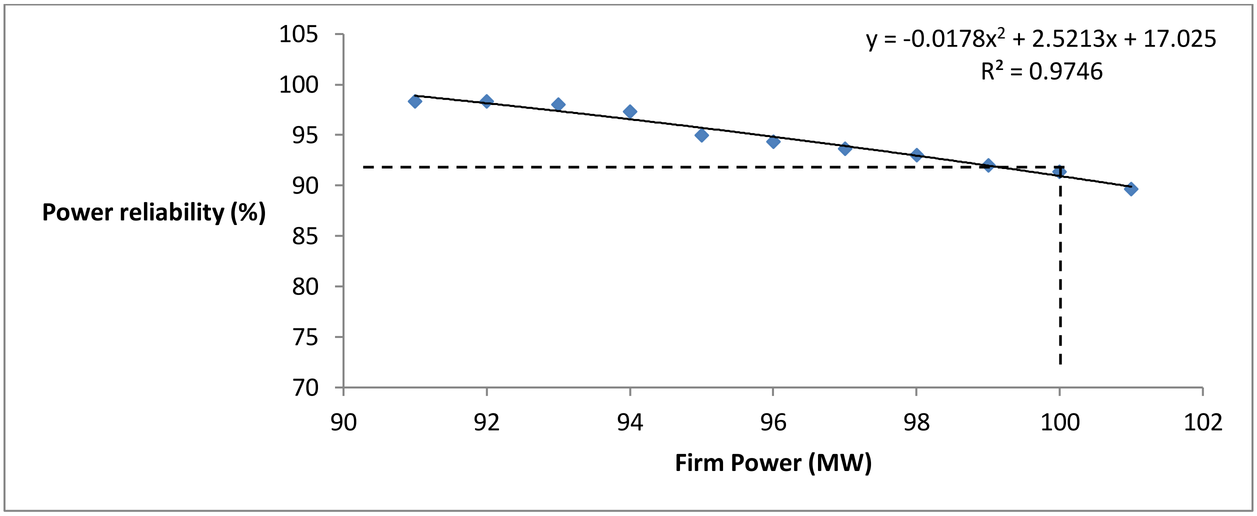

Figure 4.4: Relation between firm power and power reliability percentage

So from the above table and graph it is observed that 91.36 percent or approximately 90 percent power reliability percentage is obtained for firm power value of 100 MW. So, firm power of the hydropower plant is obtained as 100 Megawatt.

4.11 DETERMINATION OF TOTAL ANNUAL IRRIGATION WATER DEMAND:

The irrigation demand on the monthly basis obtained from district irrigation plan of each districts is put in the simulation model and from that total release values are determined. Now from obtained total release values for all the years from 1981-2008, 75 percent dependability values are taken for all the months. The table below shows the 75 percent dependability values of all the months.

Table 4.21: 75 percent dependability values of all the months from the year 1981-2008

Month	Total release (MCM) for 75% depandibility
May	112.6802207
Jun	116.1792153
Jul	112.6802207
Aug	112.6802207
Sep	112.6802207
Oct	112.6802207
Nov	112.6802207
Dec	112.6802207
Jan	117.6985335
Feb	123.4130697
Mar	118.2300366
Apr	123.2840729

From the 75 percent dependability values of monthly data, another table is prepared to determine the maximum amount of irrigation water that can be released. A monthly factor is obtained from the above data. The expression for monthly factor is –

$$\text{Monthly factor for any month} = \frac{\text{75 percent dependability value for that particular month}}{\text{Sum of 75 percent dependability values for all the months}}$$

Now irrigation water demand for a particular month can be defined as –

Irrigation demand for any month = Total annual demand x monthly factor of that month

Table 4.22: Irrigation water that can be released for 75 percent dependability

Month	75 % dependability (MCM)	Monthly factor	Irrigation release (MCM)
May	112.6802207	0.081207079	112.6802207
Jun	116.1792153	0.083728756	116.1792153
Jul	112.6802207	0.081207079	112.6802207
Aug	112.6802207	0.081207079	112.6802207
Sep	112.6802207	0.081207079	112.6802207
Oct	112.6802207	0.081207079	112.6802207
Nov	112.6802207	0.081207079	112.6802207
Dec	112.6802207	0.081207079	112.6802207
Jan	117.6985335	0.084823708	117.6985335
Feb	123.4130697	0.088942095	123.4130697
Mar	118.2300366	0.085206755	118.2300366
Apr	123.2840729	0.088849129	123.2840729
Total =	1387.566473 MCM		

Now from the above table it is observed that the total annual release for 75 percent dependability is 1387.566473 MCM. Now a table is prepared for target irrigation and power reliability which is shown below.

Table 4.23: Relation between annual demands, irrigation reliability and power reliability

Total annual irrigation demand (MCM)	Irrigation reliability (%)	Power reliability (%)
1387	95.34883721	91.36
1400	95.34883721	91.36
1410	95.34883721	91.36
1420	95.0166113	90.7
1430	94.68438538	90.7
1440	94.68438538	90.7
1450	94.35215947	90.03
1460	94.35215947	90.03
1461	94.35215947	90.03
1462	94.35215947	90.03
1463	94.35215947	90.03
1464	94.35215947	89.7

From the data of the above table two graphs are prepared. The graph below is showing power reliability percentage values for various total annual irrigation demand values.

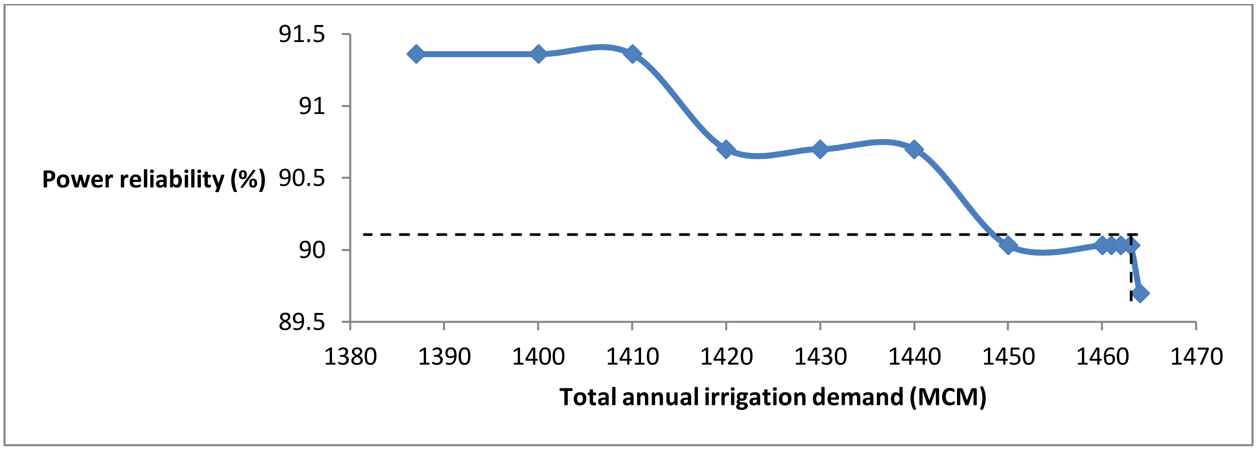

Figure 4.5: Graph between power reliability and total annual irrigation demand

From the above graph it is observed that for a power reliability of 90.03 percent the maximum amount of total annual irrigation demand that can be supplied is 1463 million cubic meters. After that if the total annual irrigation demand is increased, then power reliability percentage becomes 89.7 percent which is not acceptable because target power reliability is taken as 90 percent. Now from the above table another graph is prepared between irrigation reliability and total annual irrigation demand.

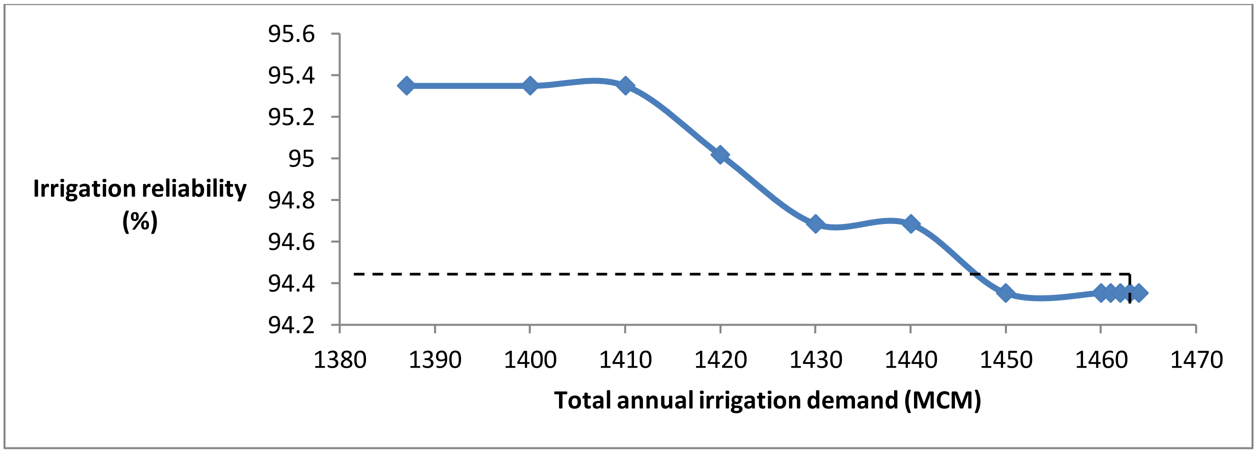

Figure 4.6: Graph between irrigation reliability and total annual irrigation demand

From the above graph it is observed that the value of total annual irrigation demand for which power reliability is 90.03 percent is 1463 MCM and for this value the irrigation reliability percentage is 94.35. So, power reliability is not less than 90 percent similarly irrigation reliability is not less than 75 percent, hence both the values are under their limit. So, total annual irrigation demand that can be supplied is 1463 million cubic meters whereas field requirement of annual irrigation water demand is 13.3060029 million cubic meters.

CHAPTER 5

DESIGN OF GRAVITY DAM

5.1 INTRODUCTION:

The gravity dam is designed on the basis of forces of self-weight of the dam, water pressure forces and uplift forces. The stability analysis is done on the basis of overturning moment, sliding and shear friction factor. For different combinations of downstream slope, upstream slope and co-efficient of uplift the stability analysis is performed; among those combination for which all the stability analysis factors are safe is obtained as the dimensions of the dam and accordingly the dam is designed.

5.2 DIFFERENT PARAMETERS OF GRAVITY DAM:

Gravity dam is consisting of different parameters which are height, base width, top width, downstream slope, upstream slope, uplift coefficient, coefficient of friction, tail water level, unit weight of water, unit weight and shear strength of concrete.

a. Height of dam: The height of the gravity dam is determined with the help of relationship between elevation and capacity relationship obtains from elevation-area-capacity data used in simulation of reservoir working table. The relationship between elevation and capacity is –
   Elevation = 0.214 (Capacity) + 244.1
   In this relationship by putting the capacity as gross storage capacity which is 480 MCM the height of the dam is determined. So, the height of the dam is found to be 346.82 meter, which is taken as 347 meter.
b. Base width of dam: Base width of the gravity dam is taken as 85 percent of the height of the gravity dam. So, base width of the dam is obtained as 294.80 meter, which is taken as 295 meter.

c. Top width of dam: Top width of the dam is a function of height of the dam. The relationship is –

Top width of dam = 1.65 x$(\text{height of dam} + 1.5)^{\frac{1}{3}}$, for dam height > 30 meters

So, with the help of above relationship for a dam height of 346.82 meter the top width of the dam is obtained as 11.609 meter, which is taken as 12 meter.

d. Downstream slope: The slope lying on downstream side of the dam varies for different site conditions. The downstream slope values which are generally considered for gravity dam is shown in the table below.

Table 5.1: Downstream slope of gravity dam

Downstream slope	
Horizontal	Vertical
1	1
1	1.25

e. Upstream slope: The slope lying on upstream side of the dam varies for different site conditions. The upstream slope values which are generally considered for gravity dam is shown in the table below.

Table 5.2: Upstream slope of gravity dam

Upstream slope	
Horizontal	Vertical
1	1
1	2
1	3
1	4
1	5
1	6
1	7
1	8
1	9
1	10

f. Uplift coefficient: Uplift coefficient is multiplying factor which is used to determine the uplift pressure force on the gravity dam. The uplift coefficient value generally considered for gravity dam is 0.7.
g. Coefficient of friction: Coefficient of friction is used to measure the sliding safety factors and shear fraction factors of gravity dam. The Noa-Dehing river dam is to be constructed in Changlang district. The type of soil present in Changlang district is mostly alluvial soil. The coefficient of friction between concrete and alluvial soil is 0.8. So, coefficient friction is taken as 0.8.
h. Tail water level: For the Noa Dihing river dam, the tail water level is 47 meter.
i. Unit weight of water: The unit weight of water is taken as 9.81 kN/m^3.
j. Unit weight of concrete: As per IS: 456 – 2000 the unit weight of plain concrete is 24 kN/m^3.
k. Shear strength of concrete: Shear strength of concrete is taken as 0.3 time's compressive strength of concrete. Compressive strength of concrete is taken as 17236.89 kN/m^2.

Therefore, shear strength of concrete = 0.3 x compressive strength of concrete

= 5171.067 kN/m^2

5.3 FORCES ACTING ON GRAVITY DAM:

There are many forces which act on gravity dam. But more importantly there are 3 forces which mostly impact the safety factors of gravity dam. Those are forces due to self weight of gravity dam, forces due to water pressure of gravity dam and the uplift force of the gravity dam. Based on these forces the safety factors are defined for gravity dam.

If the force is in downward direction then it is taken as positive otherwise negative. Then distance of forces from the toe of the dam is measured. The product of the forces with the distance gives the moment about toe of the dam. Anticlockwise moment is taken as positive and clockwise moment is taken as negative.

The terms used are V_i = sum of the vertical forces

H_i = sum of the horizontal forces

MR_i= sum of the anticlockwise moment

MO_i = sum of the clockwise moment

$M_i = MR_i - MO_i$

Self weight of gravity dam: The gravity dam divided into 3 parts which are the downstream part, the middle part and the upstream part. The forces due to each part of the gravity dam can be determined by the product of area of the particular part with the unit weight of concrete. Figure below shows the forces on gravity dam.

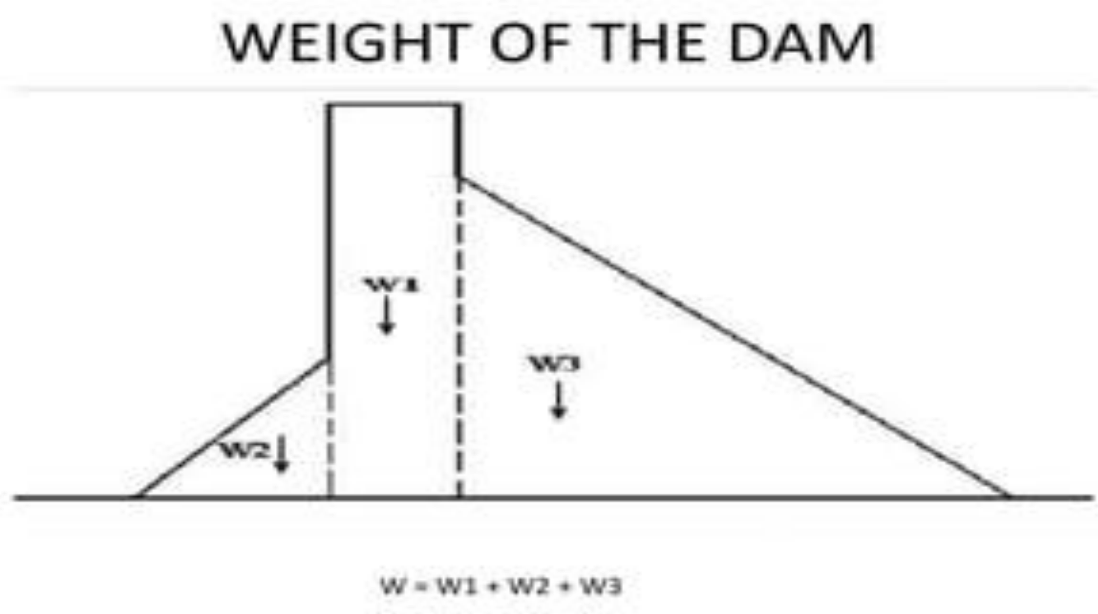

Figure 5.1: Self weight of gravity dam

The table below shows the how the self weight force acts on gravity dam.

Table 5.3: Forces of self weight

Forces	Description
W_1	0.5 x Height of dam x Top width of dam x Unit weight of concrete
W_2	0.5 x Base of upstream surface x Height of upstream surface x Unit weight of concrete
W_3	0.5 x Base of downstream surface x Height of downstream surface x Unit weight of concrete

Water pressure forces of gravity dam: Water pressure generated in gravity dam can be divided into 4 parts. Those are hydrostatic pressure in the upstream side, hydrostatic pressure in the downstream side, vertical force in the upstream side and vertical force in the downstream side. But vertical force in the upstream side can be further divided into 2 parts for easier calculation. Because it forms a trapezoidal shape, that is why it can be divided into 2 parts forming a rectangle and a triangle. Figure below shows a general idea of water pressure generated in the gravity dam.

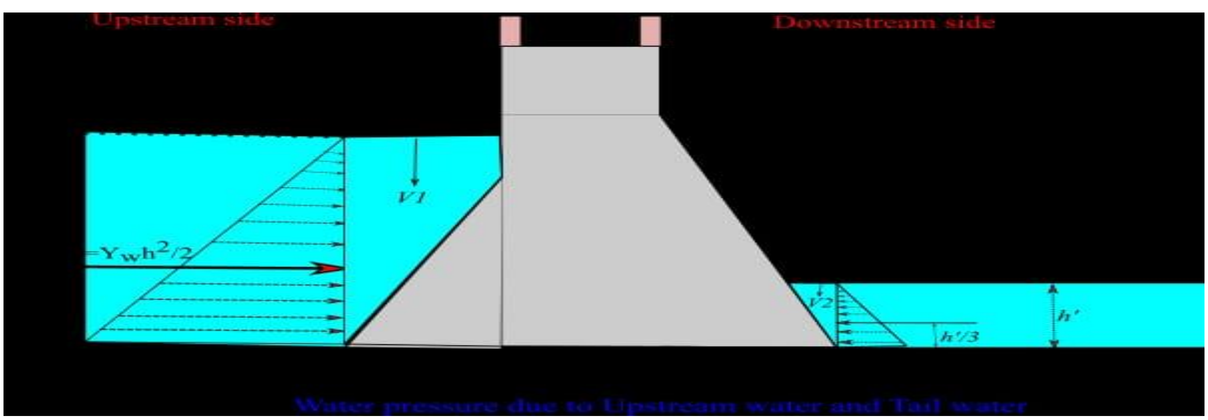

Figure 5.2: Water pressure forces on gravity dam

The table below shows the how the water pressure force acts on gravity dam.

Table 5.4: Forces of water pressure

Forces	Description
PH	0.5 x Unit weight of water x (Height of dam)^2
PH'	0.5 x Unit weight of water x (Tail water level)^2
PV1	Base of upstream side x (Height of dam-Height of upstream side) x Unit weight of water
PV2	0.5 x Base of upstream side x Height of upstream side x Unit weight of water
PV3	0.5 x Tail water level x (Tail water level/Downstream slope) x unit weight of water

Uplift forces of gravity dam: Uplift forces generated in the gravity dam can be divided into 2 parts. But for easier calculation it can be divided into 4 parts forming 2 pairs of rectangles and triangles. Figure below shows a general idea of uplift force on gravity dam. In the first figure uplift pressure is showing when there is no drainage gallery and in the second figure uplift pressure is showing when there is a drainage gallery exist in the gravity dam.

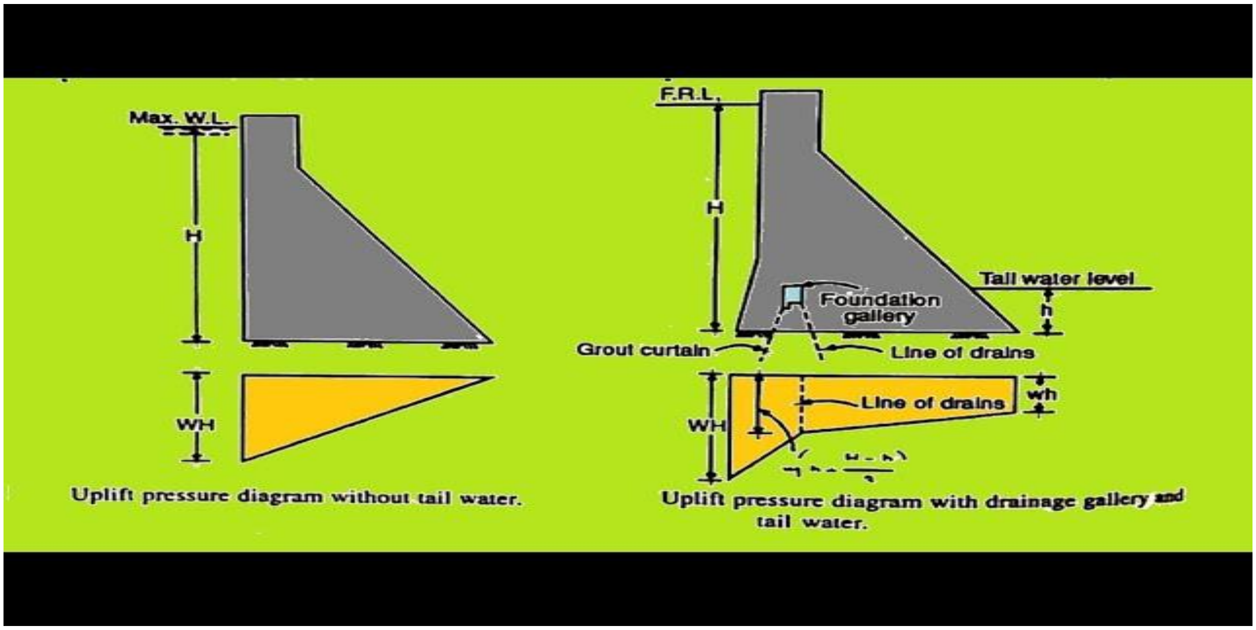

Figure 5.3: Uplift forces on gravity dam

The table below shows the how the uplift force acts on gravity dam.

Table 5.5: Forces of uplift

Forces	Description
U1	(Base width of dam-distance of drainage gallery from toe) x Height of drainage gallery x Unit weight of water x Uplift coefficient
U2	0.5 x (Base width of dam-distance of drainage gallery from toe) x (Height of dam-Height of drainage gallery) x Unit weight of water x Uplift coefficient
U3	Distance of drainage gallery from toe x Tail water level x Unit weight of water x Uplift coefficient
U4	0.5 x (Height of drainage gallery - Tail water level) x Distance of drainage gallery from toe x Unit weight of water x Uplift coefficient

5.4 CONDITIONS FOR SAFETY FACTORS:

Overturning: The factor of safety against overturning is defined as the ratio of sum of all the resisting moment against overturning and sum of all the overturning moment. If factor of safety is greater than 1.5 then it is safe against overturning.

Factor of safety for overturning = $\frac{MR_1+MR_1+MR_1}{MO_3+MO_3+MO_3}$

Factor of safety against sliding: The factor of safety against sliding is defined as ratio of sum of the entire vertical forces and sum of the entire horizontal forces with a multiplying constant which is coefficient of friction. If factor of safety is greater than 1.2 then it is safe against sliding.

Factor of safety for sliding = $\frac{\text{coefficient of friction x } V_3}{H_3}$

Factor of safety against shear strength: It is defined as the safety of gravity dam against shear failure. It is the ratio of two terms; first term is the sum of product of coefficient of friction, sum of all the vertical forces and base width of dam, shear stress of concrete. The second term is the sum of all the horizontal forces. If this value is greater than or equal to 4 then it is safe against shear failure.

Shear friction factor = $\frac{[(\text{coeffcient of friction x } V_3)+(\text{base width of dam x shear stress of concrete})]}{H_3}$

5.5 STABILITY ANALYSIS OF GRAVITY DAM:

Stability analysis is performed on the basis of different combinations of downstream slopes and upstream slopes. For different combination of these factors the stability of overturning, sliding and shear friction factor is observed.

a. At first downstream slope value is taken as 1H: 1V. For this downstream slope value upstream slope values are taken as 1H: 1V, 1H: 2V, 1H: 3V, 1H: 4V, 1H: 5V, 1H: 6V, 1H: 7V, 1H: 8V, 1H: 9V and 1H: 10V. Now for these combinations factor of safeties are obtained. Table below shows combinations of slope.

Table 5.6: First combination of upstream and downstream slopes

Downstream slope		Upstream slope	
Horizontal	Vertical	Horizontal	Vertical
1	1	1	1
1	1	1	2
1	1	1	3
1	1	1	4
1	1	1	5
1	1	1	6
1	1	1	7
1	1	1	8
1	1	1	9
1	1	1	10

For the combination of above table the obtained factor of safety values for overturning, sliding and shear friction factor are listed in the table below.

Table 5.7: Result of factor of safety for first combination

FOS		
Overturning	Sliding	Shear friction factor
1.77	1.09	3.72
1.78	1.09	3.72
1.78	1.1	3.73
1.79	1.1	3.73
1.8	1.1	3.73
1.81	1.11	3.74
1.81	1.11	3.74
1.82	1.12	3.75
1.83	1.12	3.75
1.84	1.12	3.75

From the above table it is observed that at one time not all the four factor of safety values are safe together.

b. Now downstream slope value is taken as 1H: 1.25V. For this downstream slope value upstream slope values are taken as 1H: 1V, 1H: 2V, 1H: 3V, 1H: 4V, 1H: 5V, 1H: 6V, 1H: 7V, 1H: 8V, 1H: 9V and 1H: 10V. Now for these combinations factor of safeties are obtained. Table below shows combinations of slope.

Table 5.8: Second combination of upstream and downstream slopes

Downstream slope		Upstream slope	
Horizontal	Vertical	Horizontal	Vertical
1	1.25	1	1
1	1.25	1	2
1	1.25	1	3
1	1.25	1	4
1	1.25	1	5
1	1.25	1	6
1	1.25	1	7
1	1.25	1	8
1	1.25	1	9
1	1.25	1	10

For the combination of above table the obtained factor of safety values for overturning, sliding and shear friction factor are listed in the table below.

Table 5.9: Result of factor of safety for second combination

FOS		
Overturning	Sliding	Shear friction factor
2.1	1.37	4
2.11	1.38	4.01
2.12	1.38	4.01
2.12	1.38	4.01
2.13	1.39	4.02
2.14	1.39	4.02
2.15	1.39	4.03
2.15	1.4	4.03
2.16	1.4	4.03
2.17	1.41	4.04

From the above table it is observed that all the combinations of downstream and upstream slopes are safe from overturning, sliding and shear friction factor point of view. The downstream slope is fixed, which is 1H: 1.25V. But the upstream slope is varying, if the slope is less then cross sectional area of the dam also reduces hence the construction cost of the dam also decreases. So, the most optimal combination of downstream and upstream slope for which dam is safe against all the factors are, downstream slope equals to 1H: 1.25V and upstream slope equals to 1H: 1V.

5.6 DESIGN OF GRAVITY DAM:

Height of gravity dam = 346.82 meter = 347 meter

Base width of the dam = 0.85 x 346.82 = 294.80 meter = 295 meter

Top width of dam = 1.65 x$(\text{height of dam} + 1.5)^{\frac{1}{3}}$, for dam height > 30 meters.

$$= 1.65 \times (346.82 + 1.5)^{\frac{1}{3}} = 11.609 \text{ meter} = 12 \text{ meter}$$

Downstream slope = 1H: 1.25V, upstream slope = 1H: 1V, coefficient of friction = 0.8, coefficient of uplift = 0.7. At first the base of the upstream slope of the dam is assumed after that the dam is designed accordingly.

Base of the upstream side triangle = 20 meter

Base of the downstream side triangle = Base width of dam – base of middle portion of side dam (=top width of dam) – base of upstream triangle

So, base of downstream side triangle = 295 – 12 – 20 = 263 meter

Height of upstream side triangle = Base of upstream side triangle x upstream slope

$$= 20 \times \frac{1}{1} = 20 \text{ meter}$$

Height of downstream side triangle = Base of downstream side triangle x downstream slope

$$= 263 \times \frac{1.25}{1} = 328.75 \text{ meter}$$

A drainage gallery is provided in the middle portion of the dam to drain out the water. Considering drainage gallery to be in the centre of middle portion of dam.

Distance of gallery from downstream surface side = Base of downstream surface + (0.5 x Top width of dam)

= 263+ (0.5 x 12) = 269 meter

Height of drainage gallery = Tail water level + $\frac{\text{(Upstream water level}-\text{tail water level)}}{3}$

$$= 47 + \frac{(347 - 47)}{3} = 147 \text{ meter}$$

Self weight forces:

W_1 = Base of middle portion x Height of middle portion x Unit weight of concrete = 99936 kN

W_2 = 0.5 x Base of upstream side x Height of upstream side x Unit weight of concrete = 4800 kN

W_3 = 0.5 x Base of downstream side x Height of downstream side x Unit weight of concrete = 1037535 kN

Distances from toe of the dam of all the parts are –

d_1= Base of downstream surface + $\frac{\text{top width of dam}}{2}$ = 269 meter

d_2= Base of downstream surface + top width of dam + $\frac{\text{base of upstream surface}}{3}$ = 281.67 meter

d_3= $\frac{2\,x\text{ base of downstream surface}}{3}$ = 175.33 meter

The table below shows moment generated in the toe of the dam due to self weight forces.

Table 5.10: Moment generated due to self weight forces

Force (kN) (vertical)	Force (kN) (horizontal)	Distance from toe of the dam	Anticlockwise moment (kN-m) (positive)	Clockwise moment (kN-m) (negative)
W_1= 99936	NA	d_1 = 269	26882784	0
W_2 = 4800	NA	d_2 = 281.67	1352000	0
W_3 = 1037535	NA	d_3 = 175.33	181914470	0

V_1 = sum of vertical forces = 1142271 KN

H_1 = sum of horizontal forces = 0 kN

MR_1 = sum of anticlockwise moment = 210149254 kN-m

MO_1 = sum of clockwise moment = 0 kN-m

$M_1 = MR_1 - MO_1$= 210149254 kN-m

Water pressure forces:

P_H= 0.5 x Unit weight of water x (Height of dam) ^2= 590606.145 kN

$P_{H'}$= 0.5 x Unit weight of water x (Tail water level) ^2= - 10835.145 kN

P_{V_1}= Base of upstream side x (Height of dam - Height of upstream side) x Unit weight of water = 64157.4 kN

P_{V_2}= 0.5 x Base of upstream side x Height of upstream side x Unit weight of water = 1962 kN

P_{V_3}= 0.5 x Tail water level x (Tail water level/Downstream slope) x unit weight of water = 8668.116 kN

Distances from toe of the dam of all the parts are –

$$d_1 = \frac{\text{Height of water in upstream side}}{3} = 115.67 \text{ meter}$$

$$d_2 = \frac{\text{Tail water level}}{3} = 15.67 \text{ meter}$$

d_3= Base of downstream surface + top width of the middle portion + $\frac{\text{Base of upstream surface}}{2}$ = 285 meter

d_4= $\frac{\text{2 x base of upstream surface}}{3}$ = 283.33 meter

d_5= $\frac{\text{Tail water level}}{\text{3 x downstream slope}}$ = 12.53 meter

The table below shows moment generated in the toe of the dam due to water pressure forces.

Table 5.11: Moment generated due to water pressure forces

Force (kN) (vertical)	Force (kN) (horizontal)	Distance from toe of the dam	Anticlockwise moment (kN-m) (positive)	Clockwise moment (kN-m) (negative)
NA	P_H= 590606.145	d_1= 115.67	0	68313444.1
NA	$P_{H'}$= - 10835.145	d_2= 15.67	169750.605	0
P_{V_1}= 64157.4	NA	d_3= 285	18284859	0
P_{V_2}= 1962	NA	d_4= 283.33	565710	0
P_{V_3}= 8668.116	NA	d_5= 12.53	108640.3872	0

V_2 = V_1 + sum of all the vertical forces = 1217058.516 kN

H_2 = H_1 + sum of all the horizontal forces = 579771 kN

MR_2 = sum of all the anticlockwise moment = 19128959.99 kN-m

MO_2 = sum of all the clockwise moment = 68313444.11 kN-m

M_2 = M_1 + MR_1 - MO_1 = 160964769.9 kN-m

Uplift forces:

U_1= (Base width of dam - distance of drainage gallery from toe) x Height of drainage gallery x Unit weight of water x Uplift coefficient = 26245.67 kN

U_2= 0.5 x (Base width of dam - distance of drainage gallery from toe) x (Height of dam-Height of drainage gallery) x Unit weight of water x Uplift coefficient = 17854.2 kN

U_3= Distance of drainage gallery from toe x Tail water level x Unit weight of water x Uplift coefficient = 86819.48 kN

U_4= 0.5 x (Height of drainage gallery - Tail water level) x Distance of drainage gallery from toe x Unit weight of water x Uplift coefficient = 92361.15 kN

Distances from toe of the dam of all the parts are –

d_1= Distance of drainage gallery from toe +

$$\frac{\text{(Base width of the dam – distance of drainage gallery from toe)}}{2} = 282 \text{ meter}$$

d_2= Distance of drainage gallery from toe +

$$\frac{\text{2 x (Base width of the dam – distance of drainage gallery from toe)}}{3} = 286.33 \text{ meter}$$

$$d_3 = \frac{\text{Distance of drainage gallery from toe}}{2} = 134.5 \text{ meter}$$

$$d_4 = \frac{\text{2 x Distance of drainage gallery from toe}}{3} = 179.33 \text{ meter}$$

The table below shows moment generated in the toe of the dam due to uplift forces.

Table 5.12: Moment generated due to water uplift forces

Force (kN) (vertical)	Force (kN) (horizontal)	Distance from toe of the dam	Anticlockwise moment (kN-m) (positive)	Clockwise moment (kN-m) (negative)
U_1= -26245.67	NA	d_1= 282	0	7401280.07
U_2= -17854.2	NA	d_2= 286.33	0	5112252.6
U_3= -86819.48	NA	d_3= 134.5	0	11677220.2
U_4= -92361.15	NA	d_4= 179.33	0	16563432.9

V_3 = V_2 + sum of all the vertical forces = 993778.011 kN

H_3 = H_2 + sum of all the horizontal forces = 579771 kN

MR_3 = sum of all the anticlockwise moment = 0 kN-m

MO_3 = sum of all the clockwise moment = 40754185.76 kN-m

$M_3 = M_2 + MR_3 - MO_3 = 120210584.1$ KN-m

Factors of safety:

Overturning:

Factor of safety for overturning $= \frac{MR_1+MR_1+MR_1}{MO_3+MO_3+MO_3} = 2.10$

Sliding:

Factor of safety for sliding $= \frac{\text{coefficient of friction x } V_3}{H_3} = 1.37$

Shear strength:

Shear friction factor $= \frac{[(\text{coeffcient of friction x } V_3)+(\text{base width of dam x shear stress of concrete})]}{H_3} = 4$

A figure of the gravity dam is shown below. The figure is drawn not to scale.

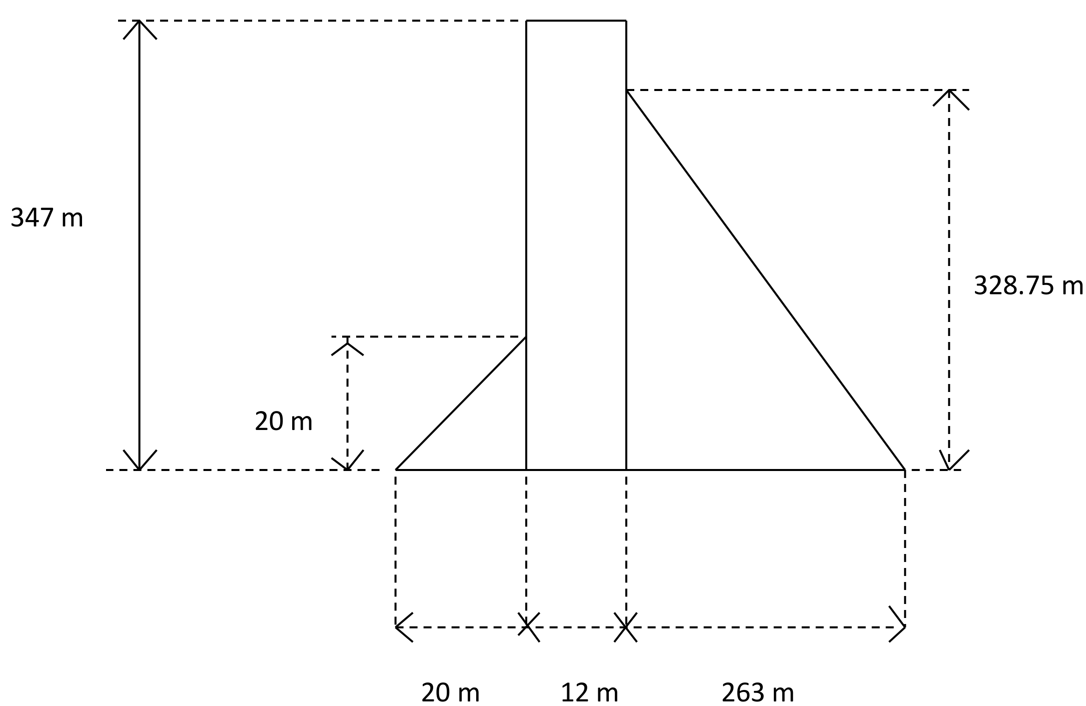

Figure 5.4: Figure of the gravity dam (Figure is not drawn to scale)

CHAPTER 6

CONCLUSION

6.1INTRODUCTION:

The project of the Noa-Dehing river dam is situated 4 km upstream of Miao town of the Changlang district. The dam to be constructed is a multipurpose dam, the purpose of the construction of the dam is to provide irrigation water and power generation through hydropower. Most of the multipurpose projects in India are a mix of both water system and hydropower generation. Nowadays water demand is rising day by day, multipurpose projects helps to regulate the water supply as per the demand. This regulation of water supply can be done with the help of various simulation models. Simulation models are a tool that helps to improve learning and creates a positive environment which helps to encourage experimentation by consideration of flaws. It provides an opportunity for people to experience the dynamics of complex projects and enable them to establish proper project planning, budgeting and scheduling.

6.2 SUMMARY OF RESULTS:

The summary of the results of the projects are given in the table below:

Table 6.1: Summary of results of the project

Plant capacity (MW)	200
Gross storage capacity (MCM)	480
Firm Power (MW)	100
Annual field irrigation demand of the command area (MCM)	13.31
Total annual irrigation demand that can be released (MCM)	1463
Upstream slope of the dam for safe design	1H: 1V
Downstream slope of the dam for safe design	1H: 1.25V
Overturning factor of safety value	2.1
Sliding factor of safety value	1.37
Shear friction factor value	4

6.3 LIMITATIONS OF THE STUDY:

The dam considered for the study of the project is in appraisal state and the exact location of the dam is not yet confirmed. Therefore for stability analysis of the gravity dam the coefficient of friction term has been assumed.

The gauge station from which the discharge data has been collected has data from the year 1981 to 2008. After that the discharge data from the gauge station is not available, so the simulation model has been created based on the limited data.

6.4 SCOPE FOR FUTURE STUDY:

The work of the study for the project can be further extended to find the actual crop water requirement for irrigation use, best canal alignment to transfer the irrigation water, optimal canal sizes so that maximum amount of water can be supplied without any disruption and design of power house.

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