DESIGN OF FOURTH DAM IN NUST AND ANALYSIS OF ITS EFFECT ON NEARBY BUILDINGS

FINAL YEAR PROJECT UG 2012

By

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A thesis submitted in the partial fulfillment of the requirements for the degree of

Bachelors in Engineering

In

Department of Civil Engineering

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This is to certify that the

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for the undergraduate degree

in

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ACKNOWLEDGEMENT

First of all we would like to thank Al-Mighty Allah for giving us the strength to accomplish this gargantuan task. We would also like to thank our parents whose countless prayers and blessings strengthened us in times of difficulty.

We are also grateful to our advisor Lecturer Sajid Iqbal for his co-operation and providing inspired suggestions that form the essence of this project.

We are thankful to Assistant Professor Abdul Jabbar and Dr. Shakil Ahmad whose specialties were utilized in making critical decisions through the course of our project.

We express our appreciation to the staff of Geotechnical Laboratory and Survey Laboratory for their assistance in performing various tasks related with the project.

Lastly we would like to thank Dr. Kamran Akhtar, our ex-project advisor and former head of geotechnical department whose contributions were vital in the completion of our project.

Authors.

DESIGN OF FOURTH DAM IN NUST AND ANALYSIS OF ITS EFFECT ON NEARBY BUILDINGS

ABSTRACT

Pumping ground water by means of tube wells is a popular way of meeting water requirement but it runs the risk of lowering the water table thus causing water scarcity. Sector H-12, Islamabad, employed the same technique to fulfill the water demands of the university and after sometime the tube wells became dry. A successful attempt to raise the water table was made via construction of a series of small earthen dams. As an insurance, a fourth dam is proposed upstream of the third dam.

The dam is located behind the Ghazali Hostels and the squash court. A topographic map of the site was developed after performing a detailed survey of the site. Samples were collected from 5 boreholes and the soil properties were discovered by means of various field and lab tests. Hydrological analysis of the site provided the catchment area size i.e. 1.96 km2 and the reservoir capacity of approximately 9500 cubic meters. With abundant sandy lean clay available near the site, a homogenous dam has been designed with the crest level as high as 20 feet above the ground level. Analyses have been carried out to ensure safety in terms of slope stability, seepage and rapid drawdown.

Taking into account the present water table depth and expected increase due to proposed dam, it has been made sure that the nearby buildings do not suffer with any ill effects.

The dam economically and efficiently serves its purpose in the long run ensuring self-sustainability of NUST in terms of water requirement.

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INTRODUCTION

1.1 Background

The world is witnessing the emergence of knowledge based economy in which the educated workforce plays a critical role in economic growth and development of a nation. Development of institutes of higher education is critical for acquiring the required knowledge and joining the league of knowledge based economy.

The government is realizing the importance of higher education and has developed a series of public sector universities across the country. The most notable among them is National University of Science and Technology constructed in sector H-12 Islamabad during the Musharraf regime. The campus was opened in 2008 and hosts a variety of academic programs. . It is spread over 707 acres and hosts about 6000 undergraduate and postgraduate students along with faculty members, administration and security staff.

Meeting water requirements of the populace is a challenge being faced by NUST. The municipal authority of the area (Capital Development Authority) has not provided any fresh water supply to the university due to ever increasing water demand of the Islamabad city. Therefore NUST had to develop its own sources. Currently, ground water is being utilized through the ten tube wells built around the premises. The supplied water is also tested in IESE water laboratory before being supplied around the campus.

1.1.1 Problem Statement

However, this system led to the fall of ground water level. One tube well dried up and became unfit for use. Moreover, development in the campus' infrastructure has led to the increase in strength of students, staff and faculty and hence amplified consumption and demand for water.

To cure these problems NUST administration had decided to build a series of earthen dams over a stream at the back of Ghazali and Attar hostels. Faculty members of Geotechnical and Hydrological department provided the expertise for the development of these dams and local material was utilized to reduce the expenditure.

Earthen dams were preferred over other forms due to: -

1. They are cheaper than other form of dam especially if material is available locally
2. They can be built on all types of foundation
3. They are earthquake resistant

By building these dams, the intent was to: -

1. Recharge the ground water supplies. To prevent further drop down of ground water level it was essential to build these dams. These dams intercept the run off generated by rainfall in the catchment area. The stored water then infiltrates gradually and raises the ground water level. This ensures that the water demands are fully met via the tube well system. An important thing to note is that these dams do not provide water directly to the campus (Storage Headwork Scheme)
2. Mitigate the flooding in the region. The steam flowing in this campus is actually a tributary of Nullah Lai. Run off generated in it eventually flows of to the Lai. In case of extreme rainfall these dams will hold the water that will otherwise cause flooding in the downstream region of Lai.
3. Perform landscaping of the campus. Aesthetics is an important attribute of any university. It provides a pleasant scenery to the inhabitants of the campus that will release their stress and allows them to be more productive.

At the moment three dams have already been constructed and are in functioning order. A fourth dam has been proposed on the upstream of other dams. The proposed dam will increase the water storage capacity and enhance the efficiency of the system. Due to its proposed location, the improved water table height may or may not affect the foundations of nearby buildings hence a study of the after effects of the proposed dam shall also be made.

1.1.2 Dam Site Location

The proposed dam is located adjacent to the Ghazali Hostels, upstream of Dam-3. The coordinates being **33°38'28.828"N** Latitude and **72°59'14.78"E** Longitude.

1.1.3 Educational Outcomes

Civil engineering projects are usually large in magnitude and complex in nature requiring knowledge and expertise of different subjects. In this project we have utilized knowledge of several subjects we have studied in our 4 year academic program and converted this knowledge into a practical application which provided us a valuable experience in our field.

Subject applied in the project are

1. **Survey 1 & 2**:- Establishing a traverse control in the region and use the traverse control to draw a topographical map of the area where the dam site is proposed. A combination of prism staff & total station were used to find horizontal and vertical co-ordinates of the area which were then fed into **Micro Survey Cad** to draw a map.
2. **Engineering Geology**:- To get familiar with geological characteristics of the region and identify critical features that have a substantial impact on the stability and functioning of the dam such as
3. **Geo Informatics**:- To analyze the spatial data provided by the topographical map. For this **Arc GIS** is utilized. It is also used to draw a 3d map of the region.
4. **Soil Mechanics 1 & 2**:- To prepare the geotechnical investigation report. Various soil tests are performed in the geotechnical laboratory including classification, permeability and soil strength. **Microsoft Excel** is used to analyze the data attain by these experiments and plot the required charts. **Settle 3-d** is used to perform the settlement analysis.
5. **Engineering Hydrology**:- To attain all the hydrological parameters such as catchment area, peak discharge which are required to design the earthen dam. **Global Mapper** is used for this purpose.

6. **Computer Aided Civil Engineering Design and Graphics**:- To draft the design sheets for the dam. **Auto Cad** is used for it.
7. **Slope Stability**:- To analyze the upstream and downstream slope of against different conditions. **Slide** is used to perform these analysis.
8. **Design of Earthen Dams**:- To calculate various dimensions of dam including height, crest width, free board, filter characteristics and analyze the predicted seepage that will occur in the dam structure. **Slide** is used for seepage analysis.

1.1.4 Working Plan and Methodology

The Project stretches over a course of about ten month including two semesters. Initially the project is divided in four sections:

1. Literature review
2. Site investigations and analysis
3. Dam Design and Stability Analysis
4. Analysis of effects on surrounding buildings
5. Cost estimation

In the first phase, literature regarding small earth dams was studied from various books and an outline was established regarding the process of designing a dam. Necessary formulae and methods were marked according to which, the necessary data was collected in the later phases.

The second phase consisted of:

1. Topographic & Geological Survey in which topography of the area was determined. Certain prominent geological features were marked.
2. Soil and site Investigation in which testing, both In-Situ and laboratory was carried out to characterize the soil.
3. Hydrological Analysis dealt with manipulation of rainfall data, estimation of catchment size, approximation of Peak Maximum Precipitation, Peak Maximum Flood, Catchment Yield and Reservoir Capacity.

Third phase is the design phase. A dam design was obtained through calculation of different dam components like freeboard, crest width, rip rap, filter design, depth of cut-off trench, crest level and design of spillway.

Fourth phase involved the analysis of the proposed design w.r.t

1. Slope Stability
2. Seepage
3. Seismic safety
4. Settlement

In the final phase, feasibility study of the dam was made in terms of construction cost.

A review of how and when work was done is as follows:

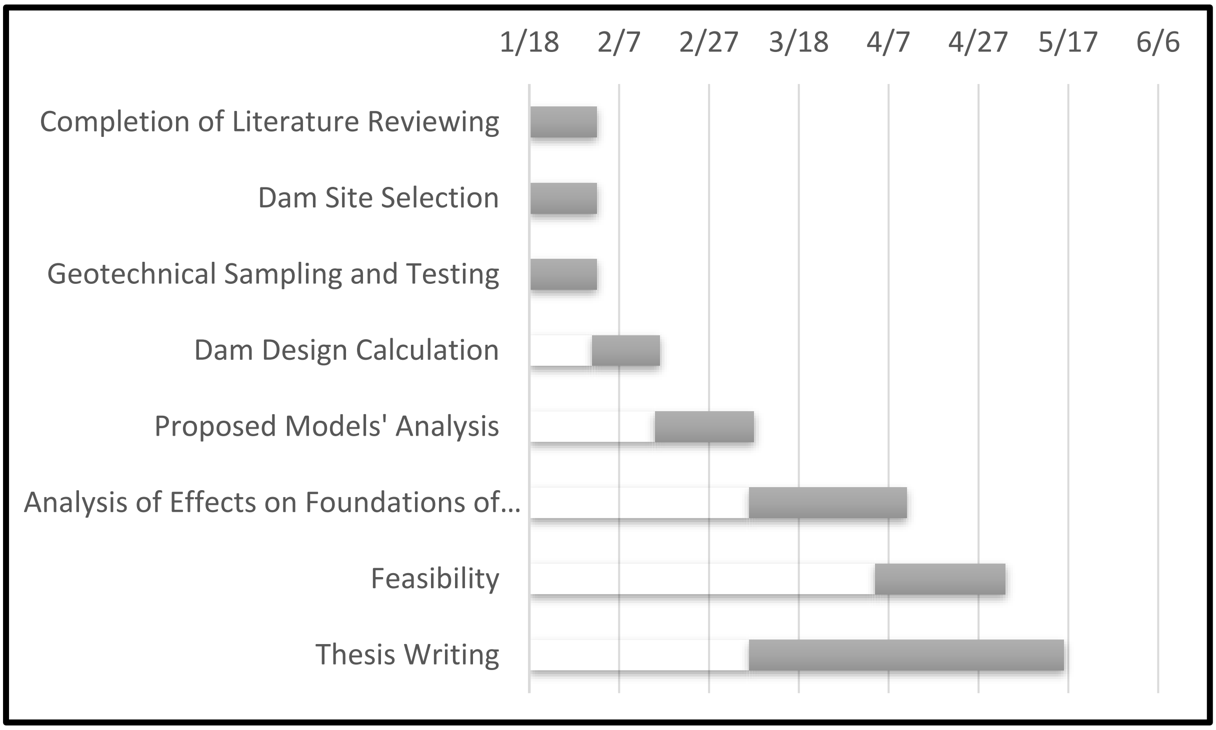

Fig 1 Gantt chart

1.2 Literature Review

1.2.1 Dams

Dams are structural barriers built to obstruct or control the flow of water in rivers and streams.

1.2.2 Uses of dams

Dams are designed to serve two broad functions. The first is the storage of water to compensate for fluctuations in river discharge (flow) or in demand for water and energy. The second is the increase of hydraulic head, or the difference in height between water levels in the lake created upstream of the dam and the downstream river.

Other purposes include: -

1. generating electricity
2. supplying water for agricultural, industrial, and household needs
3. controlling the effect of floodwaters
4. enhancing river navigation

1.2.3 Types of dams (based on structure)

1. Embankment (Earth, Rock or a combination)
2. Buttress
3. Gravity
4. Arch

1.2.4 Earthen Dams

It is a dam created by placement and compaction of soil.

1.2.5 Advantages of Earthen Dams

1. Local natural materials are used.
2. Design procedures are straightforward.
3. Comparatively small plant and equipment are required.
4. Foundation requirements are less stringent than for other types of dam. The broad base of an earth dam spreads the load on the foundation.
5. Earth fill dams resist settlement and movement better than more rigid structures and can be more suitable for areas where earth movements are common.

1.2.6 Types of Embankments

1. **Homogenous Embankments**: Cheaper to build. Susceptible to excessive pore water pressure and seepage.
2. **Zoned Embankments**: Layers of different permeability are provided. With this the possible seepage hazard are reduced to minimum. Costlier than homogenous embankment.

1.2.7 Failures of Earthen Dam

Failure of earthen dams is usually categorized into 3 categories

1. **Overtopping Failure**:- Earthen dams are not designed as an overflow section. If the water flows on the top, around and adjacent to the dam excessive erosion would take place which will be uncontrollable. To avoid this spillway can be designed and free board can be provided.
2. **Seepage Failure**:- It occurs when water percolates slowly through the dam and its foundation. Its velocity and quantity should be controlled otherwise it will progressively erode the embankment or the foundation resulting in rapid failure of the dam. This phenomenon is also called piping.

3. **Structural Failure**:- Structural failure of an embankment, spillway, lake drain, or other appurtenance may lead to failure of the embankment. Cracking, settlement, and slides are the signs of structural failure of embankments.

These failures are often interrelated in a complex manner and remedial measures should be recommended after a careful study by a professional engineer.

1.2.8 Components of Earthen Dam

1. **Shell**:- These are constructed with pervious or semi-pervious materials upstream or downstream of the core. The upstream fill is called the upstream shell and the downstream portion is the downstream shell.
2. **Core**:- It is an impervious wall provided in the center of the dam. It is usually made of compacted clay, masonry or concrete.
3. **Riprap**:- Broken stones or rock pieces which are positioned on the slopes of embankment mainly on the upstream side for protecting the slope against the action of water mainly wave action.
4. **Cutoff**:- It is a wall which is provided to reduce percolation of water through porous strata. It is provided in the foundation. It is located at the upstream side or at the center of the embankment. Cutoffs can be
    a. Sloping/Vertical cutoff trenches: Trenches are backfilled with impervious material. Covers the whole pervious strata.
    b. Partial cutoff trenches: It does not cover the whole pervious strata. It acts as an obstruction in a pipe and reduces the flow by reducing the head of seeping water
    c. Sheet piling: Very expensive method. Used with the combination of partial cutoff trench to increase the cutoff length.
    d. Grouted cutoff: Grout is injected in the foundation strip to provide cutoff. Preferred for rocky foundations
    e. Slurry trench cutoff: The slurry trench method uses a water bentonite slurry to seal and support the trench wall. Used in alluvial valleys where wet conditions prevail.

5. **Drainage Filter**:- It is a wall of pervious material made at the foundation or downstream side to allow the discharge of seepage water and avoid the possibility of piping failure. Drainage filter includes
    a. Vertical/Chimney filter: It is provided just downstream slope of the core
    b. Horizontal filter: It collects the seeping water from the chimney filter and foundation and pass it to the toe drain
6. **Transition Filter**:- It is given with core and is made of an intermediate grade of materials placed between the core and the shell. It serves as a filter and prevents lateral movement of fine material from the core.
7. **Toe Drain**:- It is constructed at the downstream side of the dam and it drains away the water which is collected by the filter.
8. **Upstream Blanket**: - It is provided at the upstream side above the porous strata to reduce seepage and increase the path of flow.
9. **Berms**:- Provided at the downstream to enhance the stability and reduce the uplift pressure.
10. **Relief Wells**:- Provided at the downstream side to prevent excessive uplift pressure. Used where pervious foundations has a natural impervious cover.

1.2.9 Components of Earthen Dam

1. **Free board**:- It is the vertical distance of a dam crest above the maximum reservoir water elevation adopted for the spillway design flood. The freeboard must be sufficient to prevent overtopping of the dam by wind setup, wave action, or earthquake effects. Initial freeboard must allow for subsequent loss in height due to consolidation of embankment.
2. **Crest width**:- Crest width of an earth dam has little effect on stability and is governed by whatever functional purpose the top of the dam must serve. Depending on the height of the dam, the minimum top width should be between 25 and 40 ft.
3. **Alignment**:- If axes of embankment are long with respect to their height the alignment is usually straight. Otherwise the most economical alignment according to the topography and foundation conditions is used. Sharp changes

in alignment should be avoided because downstream deformation at these locations would be high.

4. **Embankment**:- Embankment sections adjacent to abutments can be widen up to increase stability of sections built on weak soils.
5. **Abutment**:- Grouting can be performed to reduce seepage across the abutments.
6. **Side slopes**:- Slopes of an embankment can be flatten to increase the stability when foundation conditions are not very good.
7. **Spillway**:- Section that allows controlled release of water. (Important note "Sluices cannot be provided in earthen dams")

1.3 Topographical, geological and hydrological survey

1.3.1 Topographical survey

Though site selection is primarily a field exercise, analysis of aerial photography and large scale map is pretty beneficial. The poorest sites are excluded out which saves field time. Sites with difficult access are also excluded out unless overriding reasons demand that dam should be placed there. Distance of irrigable land should be determined and sites which are closer to them should be preferred. Flatter areas for dam embankments should be given a higher priority than steeper areas due to better storage capacity. Other factors which should be considered are availability of material, labor and environmental impacts.

A good site should not have either, very large catchment area that an expensive spillway is required or very small catchment area that it would be unable to provide sufficient supply of water.

Once the sites have been located, a field visit to the area is then planned to allow the most suitable site to be chosen. A rough reconnaissance of every possible site within the involved area, includes estimates of levels and gradients, checks on spillways, borrow areas and foundation conditions, allows the relative merits of each site to be assessed. The most favorable site is determined and preliminary surveys are carried out.

In preliminary surveys an economic and design proposition of the selected site is determined. It is performed by using a level/theodolite or accurate GPS equipment. Control is established using traversing. Line of spot heights across the profile close to where the proposed embankment center line and spillway are estimated. It also gives a suggestion of streambed gradient which required to estimate the throwback of the dam (fetch). To estimate gradients for large dams in a flatter terrain, contoured topographic map of 1:50000 scale can be used.

The survey should be fairly accurate so that a comparative estimates for various heights of dam ca be established. Economy of the dam is based upon cost per unit volume of stored water.

1.3.2 Geological survey

Geological investigations must be carried out at dam site and possible burrow areas adequately to determine the suitability of foundations and abutments. It is important because: -

1. It governs specific type and site of dam. Also important in determining the feasibility of the dam.
2. Knowledge of the regional and local geology is essential in developing a plan for the subsurface investigation, interpreting conditions between and beyond boring locations, and revealing possible sources of trouble
3. It also determines the location and magnitudes of cracks, faults, karst features, cavities, fissures, joint orientation from where high flow of seepage water is possible. This in turn gives the suggestion for the treatment required.

Scope of geological survey includes: -

1. **Types of rock**:- 3 basic types of rock on the basis of formation are sedimentary rocks (formed by accumulation of sediments) metamorphic

rocks (modified by heat, pressure and chemical processes) and igneous rocks (formed by solidification of molten lava). These rocks are disintegrated by weathering process and forms residual. Residuals can be alluvial, aeolin, colluvial, glacial and marine. Rocks can also be classified on the basis of mineral composition. These are silicates, quartz, sulfates, carbonates, oxides, halides, sulfides, phosphates, elements and minerals.

2. **Faults**:- A fault is a fracture or zone of fractures between two blocks of rock. Faults allow the blocks to move relative to each other. This movement may occur rapidly, in the form of an earthquake - or may occur slowly, in the form of creep. Faults may range in length from a few millimeters to thousands of kilometers. Most faults produce repeated displacements over geologic time. During an earthquake, the rock on one side of the fault suddenly slips with respect to the other. Faults can be normal faults, thrust faults or strike slip faults.
3. **Dip and strike**:- Dip is the acute angle that a rock surface makes with a horizontal plane. Strike is the direction of the line formed by the intersection of a rock surface with a horizontal plane. Strike and dip are always perpendicular to each other on a map.
4. **Groundwater**:- Ground water is water that fills pores and fractures in the ground. The top of ground water is called the water table. Between the water table and the land surface is the unsaturated zone or vadose zone. In the unsaturated zone, moisture is moving downward to the water table to recharge the ground water. The water table can be very close to the surface (within a few feet), or very deep (up to several hundred feet). Important terminologies related to ground water are:-
   a. **Aquifer**:- It is the saturated formation which not only stores water but also yield in sufficient quantity. Unconsolidated deposits of sand and gravel forms aquifer.
   b. **Aquitard**:- It is the saturated formation through which only seepage is possible but its yield is insufficient. It is partly permeable in nature. A sandy clay soil is an example of aquitard.
   c. **Aquiclude**:- It is the saturated formation which only stores water but never yields it. Thus it is impermeable in nature. A clay soil is an example of aquiclude.

d. **Aquifuge**:- It is the saturated formation which neither stores water nor yield it in sufficient quantity.

1.3.3 Hydrological survey

This survey is used by hydrological engineers in the preparation of flood hydrology studies necessary for the design of dams and their appurtenant features. It includes determining the magnitude and frequency of floods which will be used to determine dam height and storage capacity of the dam. Terminologies used for the survey are: -

1. **Catchment area**:- It is the area from which the water flows towards the river or streams. It is determined through aerial photography or large scale topographic maps. Shape of the catchment also has an influence on the flow characteristics. In the case where a series of small dams are built, the size of the catchment area for each dam should be taken as the total catchment area above the dam under consideration
2. **Runoff**:- Portion of precipitation that is not evaporated is known as runoff, which ultimately runs to ocean through surface or sub-surface streams.
3. **Annual Rainfall**:- It is a rainfall occurring over a year. It is a metrological data obtained from the metrological department of the respective city or country. Both the historical and recent data are acquired. More rain gauges operate in recent times which gives us more accurate data.
4. **Throwback/Fetch**:- Fetch is the maximum uninterrupted straight line over water distance for a particular wind direction. In some cases small capes, headlands and cliffs makes the fetch slightly shorter and waves refract and diffract around them. These interruptions will be ignored while calculating the fetch length.
5. **Storage Capacity**:- It is worked out by the equation “Q = LTH/6” in which Q refers to storage capacity in m^3. L refers to the length of the wall of dam at full supply level and T refers to throwback/Fetch.
6. **Depth/Capacity curve**:- From a detailed topographical survey we have a more accurate estimates of quantities and the necessary data for design work to be undertaken. A curve is drawn from which determine capacity of a reservoir for varying heights of a dam. This is the depth/capacity curve.

7. **Hydrograph**:- A hydrograph is a continuous graph showing the properties of stream flow with respect to time. Usually refers to water flow in river with respect to time.
8. **Probable maximum flood (PMF)**:- Flood that might occur under the worst meteorological & hydrological conditions. PMF is based on probable maximum precipitation (PMP) studies on the concerned basin. It is used for the design of the spillway. On bigger dams and catchments, where it is more important that the spillway is correctly and properly dimensioned, it is economic to study the hydrology, climate, topography and so on to arrive at reasonably accurate estimates of PMFs. If such information is not available we can use the rational method. It is most appropriate for areas under $15km^2$. For this first we measure time of concentration (Tc) which is "$Tc = (0.87\ L^3/h)\ 0.385$". H is difference in elevation in between dam site and main source of stream. L is length of river at upstream. (PMF) is given by "Qp = 0.278 A P R Cr/Tc" where Cr is runoff co-efficient, A is catchment area, R is storm depth ratio and P is mean annual rainfall.
9. **Catchment yield**:- Given by the formula "Y = Rr x A x 1 000". A is catchment area. Rr annual run-off.

1.4 Geotechnical Investigation

Soil tests are performed to establish certain parameters which determines the stability and functionality of the dam and also helps in designing an appropriate filter. All these tests follow a prescribed standard provided by **American Society of Testing Materials (ASTM)** and **American Association of State Highway and Transportation Officials (AASHTO)**. Tests included in our analysis are: -

1. Determination of Moisture Content by Oven Drying Method: - Standards followed are **AASHTO T 265** and **ASTM D 2216-71**. A very simple procedure requiring a sample to be weighted, placed in an oven, taken out after 24 hours and weighted again. Moisture content is determined by equation" Moisture content = (Ww/Ws) x100 (%)"

2. Sieve Analysis of Coarse Grain Soil: - Standards followed are **AASHTO T 88** and **ASTM D 422**. It is used for identification and classification of soil. Set of ASTM sieves containing sieve # 4, 10, 20, 40, 60, 100, 200, lid and pan are placed in a correct order. Sieve shaker is used for more accuracy in the results. Lumps of soil are usually broken with grinder before sieving otherwise results will be inaccurate. From the data obtained via sieve analysis % passing for all sieves are calculated and graph is plotted against grain diameter. Co-efficient of uniformity(Cu) and co-efficient of curvature(Cc) are also determined using equations "Cu= D60/ D10" and "Cc =(D30)2/(D60 X D10)"
3. Determination of Grain Size Distribution by Hydrometer Analysis: - Standards followed are **AASHTO T 87-70, T 88-70** and **ASTM D 421-58, D 422-63**. With this test we determine the particle size distributions of soil passing No.200 sieve. This test is applicable only if more than 10% of sample soil passes sieve # 200. Take 50 gram of soil passing #200 sieve and mix it with 125ml of dispersing agent solution. Allow it to stand for 1 hour and transfer it to mixing cup and max it for 10 minutes. Make sure all the soil is washed out. Then transfer it to cylinder and add water to fill the cylinder to $1000cm^3$. Turn the cylinder upside down and back for 1 minute to allow the agitation of the slurry. Take hydrometer and temperature reading at 1, 2, 4, 8, 15, 30 minutes and 1, 2, 4, 24 hours. Use the reading to determine effective depth (L). Also determine "K" and "a" using specific gravity and temperature readings. Find diameter of soil "D" and soil in suspension "P" using equations "K x $\sqrt{\ }$L/T" and "Ra/Wxl00".
4. Determination of Atterberg Limits (Liquid Limit & Plastic Limit) of Soil: - Standards followed are **AASHTO T 89-68, T 90-70** and **ASTM D 423-66, D 424-59**. It is used to obtain general information regarding soil and its strength, compressibility, permeability, swell and shrinkage. Usually used for cohesive soil.
   a. For liquid limit we collect 250g of soil passing #4 sieve. Add water in it until it becomes a paste, place it in the cup and smooths it. Cut a groove in the paste and turn the crank of the liquid limit device. Count the number of blows until the two parts of soil come into contact. Also

calculate moisture % for each sample. Moisture content corresponding to 25 blows is the Liquid Limit of soil.

b. For plastic limit take 40g of soil passing #4 sieve. Mix water to make it plastic. Take 8g of plastic, make a ball and roll it between hand palm and glass surface until it just crumbles at 3mm dia. find the moisture content (Plastic Limit). Plasticity Index is (Liquid Limit – Plastic Limit)

5. Determination of Specific Gravity of Soil Sample: - Standards followed are **AASHTO T100-70** and **ASTM D 854-58**. Specific gravity is the weight of given volume of material to the weight of equal volume of water. To determine it first we wash weigh the flask (W_1). Add 50 to 100gram of soil in the flask and weigh it (W_2). Add distill water until it reaches the neck of flask and weigh the mixture (W_3). Then remove the mixture, add only water and weigh it (W_4). Determine correction factor K using temperature reading Specific gravity is given by equation "G_s = ((W2 -W1) / (W4 -W1) - (W3 - W2)) x K"

6. Determine the in situ density of soil by Core Cutter method: - Standard followed is **ASTM D3017**. It measures the density of the soil in its natural or compacted state. First measure the inside dimension and volume of the core cutter. Put the dolly on top of the cutter and drive the assembly into ground until the top of dolly remains 1cm above the surface. Remove the core cutter from the soil. Trim both of the ends. Weigh the core cutter with and without the soil. Find bulk density using "weight/volume" formula.

7. Standard penetration Test: - Standard followed is **ASTM D1586-08.** This experiment gives us N value which is an important indicator for stiffness and bearing capacity of soil. First a bore hole is driven to a specific depth. Then a split spoon sampler is attached with the steel rod. The hammer is then raised to the height of 2.5ft and released. Repeat this step until the sampler is driven 18 inches inside the soil. Number of blows for every 6inch interval is recorded. The summation of second and third count gives N value. Various correction factors are then applied for more accuracy. This sample collected is taken to laboratory for further testing.

8. Unconfined Compression Test: - Standard followed is **ASTM D2166.** It gives us unconsolidated and undrained shear strength under unconfined conditions which helps us to determine bearing capacity of soil. It requires

an undisturbed sample with length over diameter ratio of 2 to 2.5. Measure the precise diameter and length of the sample. Weigh the sample. Place the sample in the device and set load and deformation dial on zero. Apply the load so that the device produces an axial strain at a rate of 0.5% to 2.0% per minute, and then record the load and deformation dial readings on the data sheet at every 20 to 50 divisions on deformation the dial. Keep on applying load until it decreases significantly. Plot the graph. Calculate strain and cross sectional area and stress. Determine peak stress (q_u) and divide it by 2 to obtain unconfined compressive strength of soil.

9. Direct shear stress of soil: - Standard followed is **ASTM D3080.** This test is performed to determine shear strength parameters (c and φ). It provides drained shear strength. Assemble the shear box. Place soil in the box and place porous filter at the top. Open the gap between shear box halves. Compute the mass of soil used. Set the horizontal and vertical gauge to zero. Apply a selected vertical load on the sample. Start the motor at a constant shearing rate and record readings until horizontal value peaks and the sample fails. Repeat the experiment at different vertical loads. Plot the graphs (Mohr circles). Draw a line tangential to these circles. Y intercept gives us cohesion (c) and the angle of the drawn line gives us friction angle (φ).

10. Permeability Test for Cohesive Soil (Falling head method): - Standards followed are **AASHTO T215-66** and **ASTM D 2434-68**. Used to determine co-efficient of permeability for fine grained soils. Determine length, diameter and weight of the sample to be placed. Attach the permeater with the water supply and allow water to flow until it gets saturated. Fill the burette and record the initial head. After some time the head will drop. Measure the dropped head and time taken to reach the head. Coefficient of permeability is determined by equation “k= (2.3aL/ At) log h1 / h2”. Apply correction for temperature.

CHAPTER 2

TOPOGRAPHY

2.1 General

The terrain of the Islamabad consists of plains and mountains whose total relief exceeds 1,175 m. Three physiographic zones trend generally east-northeast. The northern part of the area lies in the mountainous terrain of the Margala Hills, a part of the lower and outer Himalayas, which also includes the Hazara and Kala Chitta Ranges. The Margala Hills, which reach 1,600-m altitude near Islamabad, consist of many ridges of Jurassic through Eocene limestone and shale that are complexly thrusted, folded, and generally overturned.

South of the Margala Hills is a southward-sloping piedmont bench underlain primarily by folded sandstone and shale of the Miocene Rawalpindi Group. Buried ridges of sandstone are generally covered by interbedded sandy silt and limestone gravel that locally exceed 200 m in thickness; these deposits, in turn, have been dissected and then buried under a layer of eolian loess and reworked silt that locally exceeds a thickness of 40 m. West of Rawalpindi, plains of thick, easily eroded loess are extensively dissected into shallow badland valleys. East of Rawalpindi, the folded ridge of Rawalpindi Group rocks rise above the alluvial cover to form prominent hills. Urban development is concentrated in the piedmont bench area, which is little dissected in its northern part, where Islamabad is located, but is more deeply dissected toward the south near the Soan River where Rawalpindi is located.

In the southernmost part of the area, the Soan River valley extends generally along the axis of the Soan syncline at an altitude of about 425 m. The Soan is incised more than 40 m below the level of extensive silt-covered plains north and south of the river. Beds of fluvial sandstone, mudstone, and conglomerate of the Pliocene to Pleistocene Siwalik Group underlie the southern area and crop out along the many steep-side stream valleys that dissect the land. The beds dip steeply on the north limb of the syncline north of the Soan River, and more gently on the south limb. The piedmont bench and Soan valley make up the northern edge of the Potohar Plateau, which extends southwestward for 150 km.

2.2 Dam Site

The dam site is located behind the Ghazali hostels and the squash court with the coordinates **33°38'28.828"N** Latitude and **72°59'14.78"E** Longitude. Extensive survey was performed to map the site. The minimum ground level measured was 1788 feet above sea level.

Fig 2 Dam site

2.3 Site Geology

A visual survey of the site was carried out and expert opinion of Assistant Professor Abdul Jabbar was taken into account. The site mainly consists of Murree formation.

2.3.1 Murree formation

Continental sandstone and claystone. Sandstone is reddish gray to purple gray, fine to medium grained, thick bedded, micaceous, cross-bedded, jointed, and calcareous. Claystone is purple to dark red and contains mottled lenses of pseudo-conglomerate. Epidote is common in sandstone of the Murree Formation. Contact with overlying Kamlial Formation is conformable. Measured thickness ranges from 2,000 to 2,895 m in the area.

2.4 Topographical Map

Topographical survey of the site yielded a map showing contours and all the features present on site.

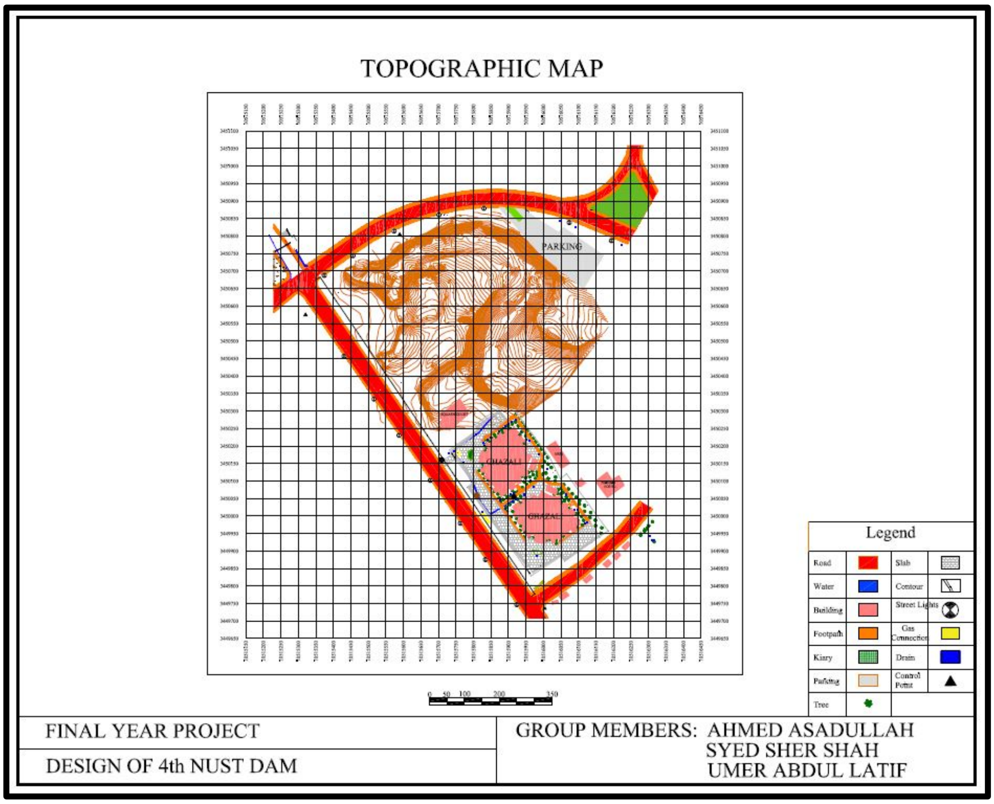

Fig 3 Topographical map

2.5 3D Modelling

The topographical data was manipulated in Revit and 3DSMax to obtain a 3D model to get a better understanding of the site morphology.

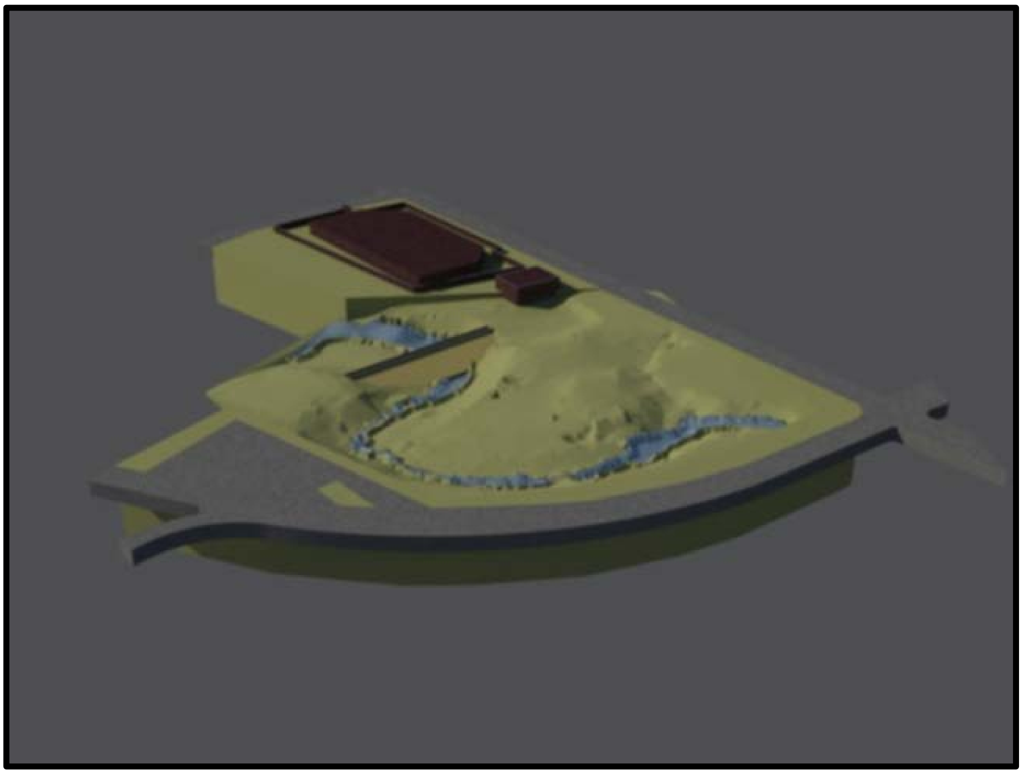

Fig 4 3D Model

CHAPTER 3

GEOTECHNICAL INVESTIGATION REPORT

This sections provide results of series of test performed on the soil samples collected from the site. Maximum depth of the sample is 5 feet. Borrow area was selected adjacent to the site area. The results are as follow:-

3.1 Standard Penetration Test

Standard followed is **ASTM D1586-08.** This experiment gives us N value which is an important indicator for stiffness and bearing capacity of soil.

Results: -

N value = 40

N (corrected) = 28.875 ≈ 29

Bearing capacity = q = 4.92 kips/ft^2

3.2 In-Situ Core Cutter Method

Standard followed is **ASTM D3017**. It measures the density of the soil in its natural or compacted state.

Result: -

Density of soil is 2.10 kg/m^3

3.3 Soil Gradation Test

3.3.1 Sieve analysis of coarse grained soil

Standards followed are **AASHTO T 88** and **ASTM D 422**. It is used for identification and classification of soil.

3.3.2 Grain size distribution by hydrometer analysis

Standards followed are **AASHTO T 87-70, T 88-70** and **ASTM D 421-58, D 422-63**. With this test we determine the particle size distributions of soil passing No.200 sieve.

Result: -

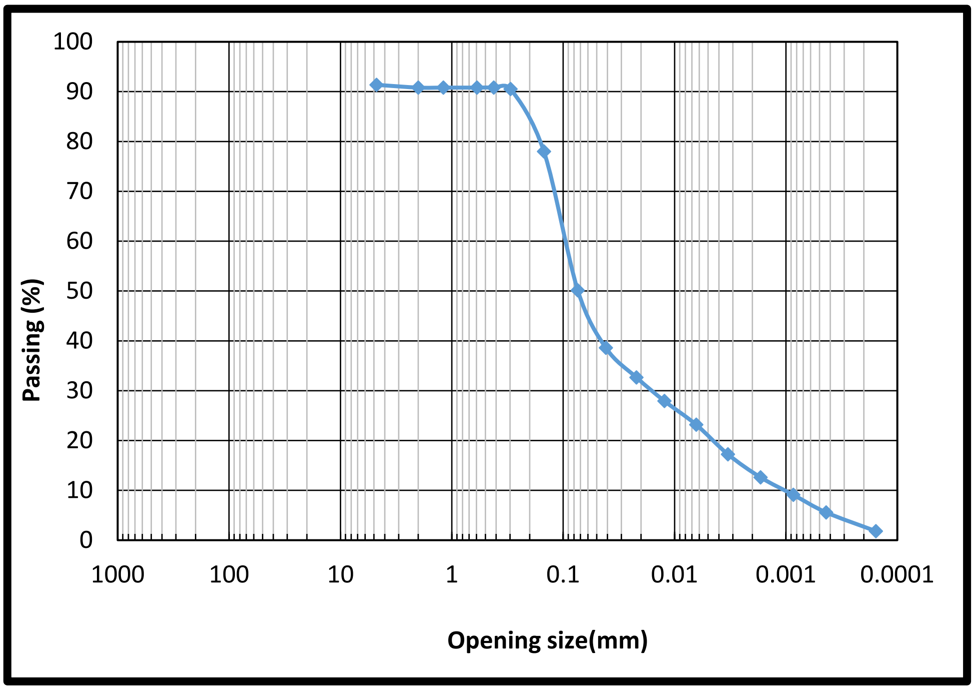

Fig 5 Soil gradation curve

Soil Classification:

- **Sandy Lean Clay (CL with gravel < 15%)** in USCS
- **A – 6 (6)** in AASHTO

3.4 Atterberg Limits (Liquid Limit & Plastic Limit) of Soil

Standards followed are **AASHTO T 89-68, T 90-70** and **ASTM D 423-66, D 424-59**. It is used to obtain general information regarding soil and its strength, compressibility, permeability, swell and shrinkage.

Result: -

Liquid Limit = 29.5%

Plastic Limit = 12.5%

.

3.5 Unconfined Compression Test of soil

Standard followed is **ASTM D2166.** It gives us unconsolidated and undrained shear strength under unconfined conditions which helps us to determine bearing capacity of soil.

Result: -

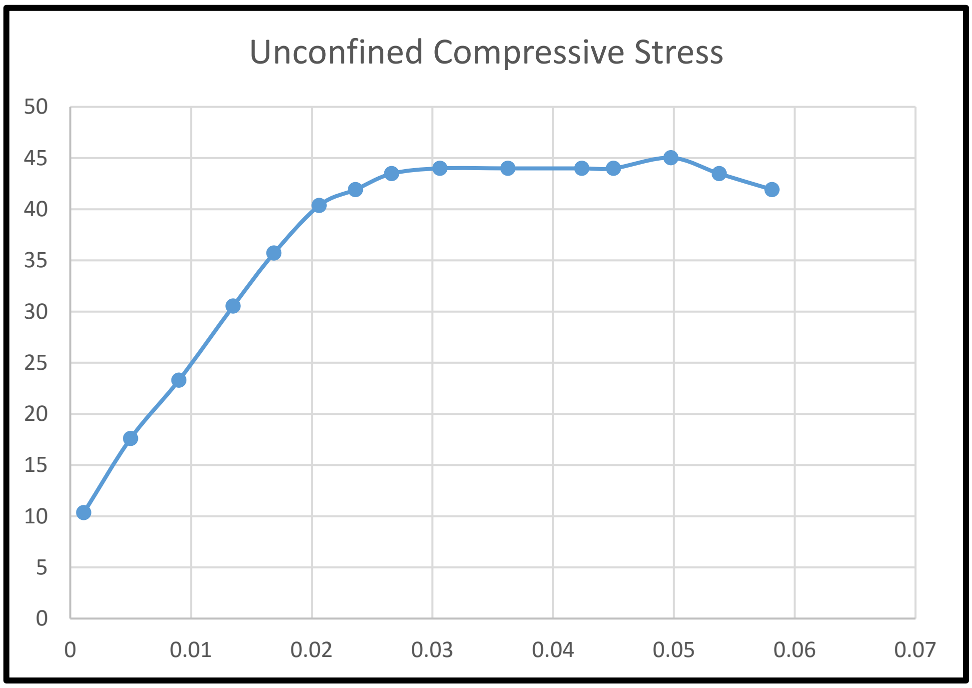

Fig 6 Unconfined Compression test

The unconfined compressive stress, q_u is 45.02 kPa and the undrained shear strength, S_u is 22.51 kPa.

3.6 Direct Shear Test

Standard followed is **ASTM D3080.** This test is performed to determine shear strength parameters (c and φ). It provides drained shear strength.

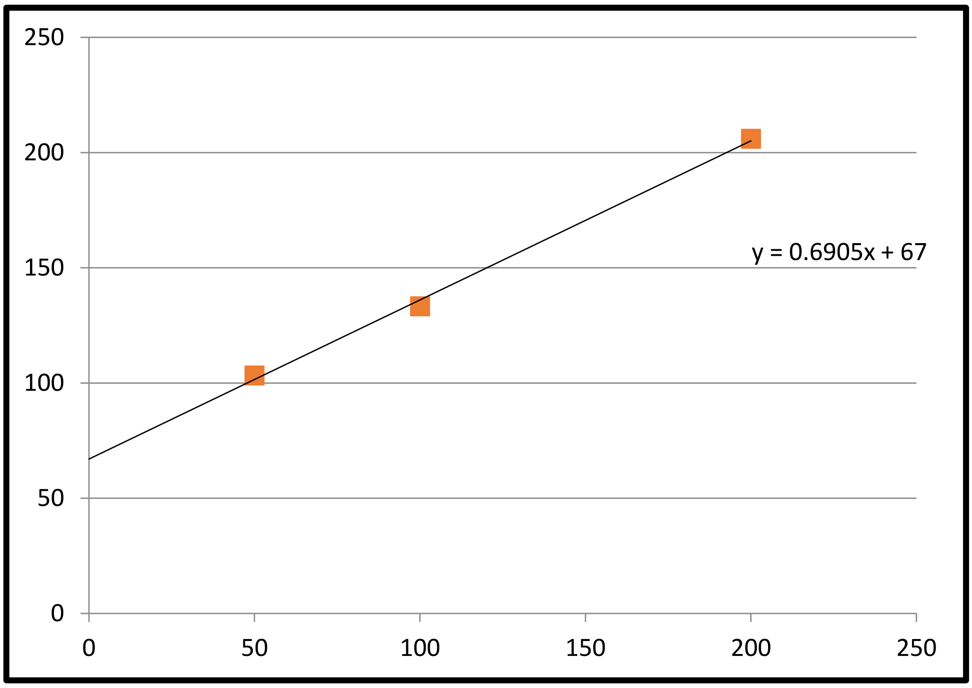

Fig 7 Direct Shear Envelope

The friction angle (φ) is 34.6˚ and cohesion (c) is 67 kPa.

CHAPTER 4

EMBANKMENT DAM

4.1 General

Embankment dams are made up of naturally occurring soil or earth material, compacted and modified to suitable requirements. These dams rely on their weight to hold the reservoir water. The primary reason of employing an embankment dam is the availability of natural material near or close to the dam site which makes them cost-effective and economical. This is the reason embankment dams are the most common type of dams found in the world today.

Some of the oldest structures used for water storage and irrigation purposes were embankment dams. Proserpina Dam and Cornalvo Dam are Roman earth dams in Spain built in 1st or 2nd century AD and are still in use today. In Syria, Lake Homs Dam is a 2 kilometers long and 7 meters high masonry dam built in around 284 AD and still in use. With a capacity of 90 MCM, it was the largest constructed reservoir of its time.

There are generally of two types of embankments;

- Earth-filled Dam
    - Zoned dam
    - Homogeneous dam
- Rock-filled Dam
    - Concrete faced, rock-filled dam

Rock-filled embankments are composed of compacted granular or coarser material provided with an impervious face often in the form of concrete layer on upstream slope. Earth -filled dams are made up of well-compacted earth and can be homogeneous (made up of only single material) or zoned (with layers of different materials making up core, filter, shoulder etc). Tarbela Dam in Pakistan is the largest earth-filled dam in the world.

The proposed dam is a homogenous earth-filled embankment dam. Filter and drainage mechanism are provided for seepage measures.

4.2 Design Methodology

4.2.1 Design Parameters

For a long time small earth dams were designed using empirical methods which lead to a large number of failures. Now, these empirical methods are being replaced by rational engineering for both design and construction. New developments in soil mechanics have greatly improved the design procedures which include;

- Preconstruction investigations of foundation conditions
- Investigation for construction materials
- Application of engineering skills
- Planned and controlled methods of construction

The design of earth-fill dams should be realistic and according to conditions and requirements of the site. It is necessary that each dam be built after detail survey and site studies.

4.2.2 Design Criteria

Basic principle of design is a safe functional structure fulfilling the requirements at minimum cost. This cost includes both initial planning and construction cost and maintenance cost at later stages. Therefore dam must be built by optimum utilization of local materials. For earth and rock-fill dams the criteria are:

- Embankment must be safe against overtopping.
- Slopes of embankment must be stable - including rapid drawdown conditions

- Seepage flow through embankment, abutments, and foundations must be controlled
- Upstream slope must be protected against erosion
- Earthquakes must not impair the function of the structure

4.3 Design Data

4.3.1 Weather Conditions

Islamabad has an extreme climate very hot in summer very cold in winter. Summer starts from April to August while winter sets in at around late November to the end of January. Temperature may fall to 0.5^{0}C in winter and rise to 42^{0}C in summer. Average temperature in summer is 28.30^{0}C and in winter 12.37^{0}C. And relative humidity varies from 31% to 77%. Annual mean rainfall is 1095 mm. In Potohar area two third of the total annual rain precipitates occur during the three monsoon months of summer i.e. July, August & September, while the remaining nine months are nearly dry and get only one-third of the annual precipitation. Moreover the delayed monsoon and erratic winter rainfall, which are common features, make the crops very uncertain. On the other hand the topography of the hilly area with steep slopes helps the rain water to form numerous streams running at high velocities, which erode the good land and causes wastage of water. Apart from damaging the land and the erosion of soil the rain water thus does not get a chance to soak down and develop any ground water reservoir.

4.3.2 Metrological and Rainfall Data

Average precipitation and the maximum temperature recorded for every month in Islamabad over the last 30 years is given below.

Climate data for Islamabad (1961–1990)													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Record high °C (°F)	30.1 (86.2)	30.0 (86)	34.4 (93.9)	40.6 (105.1)	45.6 (114.1)	46.6 (115.9)	45.0 (113)	42.0 (107.6)	38.1 (100.6)	37.8 (100)	32.2 (90)	28.3 (82.9)	46.6 (115.9)
Average high °C (°F)	17.7 (63.9)	19.1 (66.4)	23.9 (75)	30.1 (86.2)	35.3 (95.5)	38.7 (101.7)	35.0 (95)	33.4 (92.1)	33.5 (92.3)	30.9 (87.6)	25.4 (77.7)	19.7 (67.5)	28.6 (83.5)
Daily mean °C (°F)	10.1 (50.2)	12.1 (53.8)	16.9 (62.4)	22.6 (72.7)	27.5 (81.5)	31.2 (88.2)	29.7 (85.5)	28.5 (83.3)	27.0 (80.6)	22.4 (72.3)	16.5 (61.7)	11.6 (52.9)	21.3 (70.3)
Average low °C (°F)	2.6 (36.7)	5.1 (41.2)	9.9 (49.8)	15.0 (59)	19.7 (67.5)	23.7 (74.7)	24.3 (75.7)	23.5 (74.3)	20.6 (69.1)	13.9 (57)	7.5 (45.5)	3.4 (38.1)	14.1 (57.4)
Record low °C (°F)	−3.9 (25)	−2.0 (28.4)	−0.3 (31.5)	5.1 (41.2)	10.5 (50.9)	15.0 (59)	17.8 (64)	17.0 (62.6)	13.3 (55.9)	5.7 (42.3)	−0.6 (30.9)	−2.8 (27)	−3.9 (25)
Average precipitation mm (inches)	56.1 (2.209)	73.5 (2.894)	89.8 (3.535)	61.8 (2.433)	39.2 (1.543)	62.2 (2.449)	267.0 (10.512)	309.9 (12.201)	98.2 (3.866)	29.3 (1.154)	17.8 (0.701)	37.3 (1.469)	1,142.1 (44.966)
Mean monthly sunshine hours	195.7	187.1	202.3	252.4	311.9	300.1	264.4	250.7	262.2	275.5	247.9	195.6	2,945.8

Fig 8 Climate Data for Islamabad

4.3.3 Rainfall Data

The Pakistan Metrological Department (PMD) provided a chart of the **Mean Annual Rainfall** for the entire country.

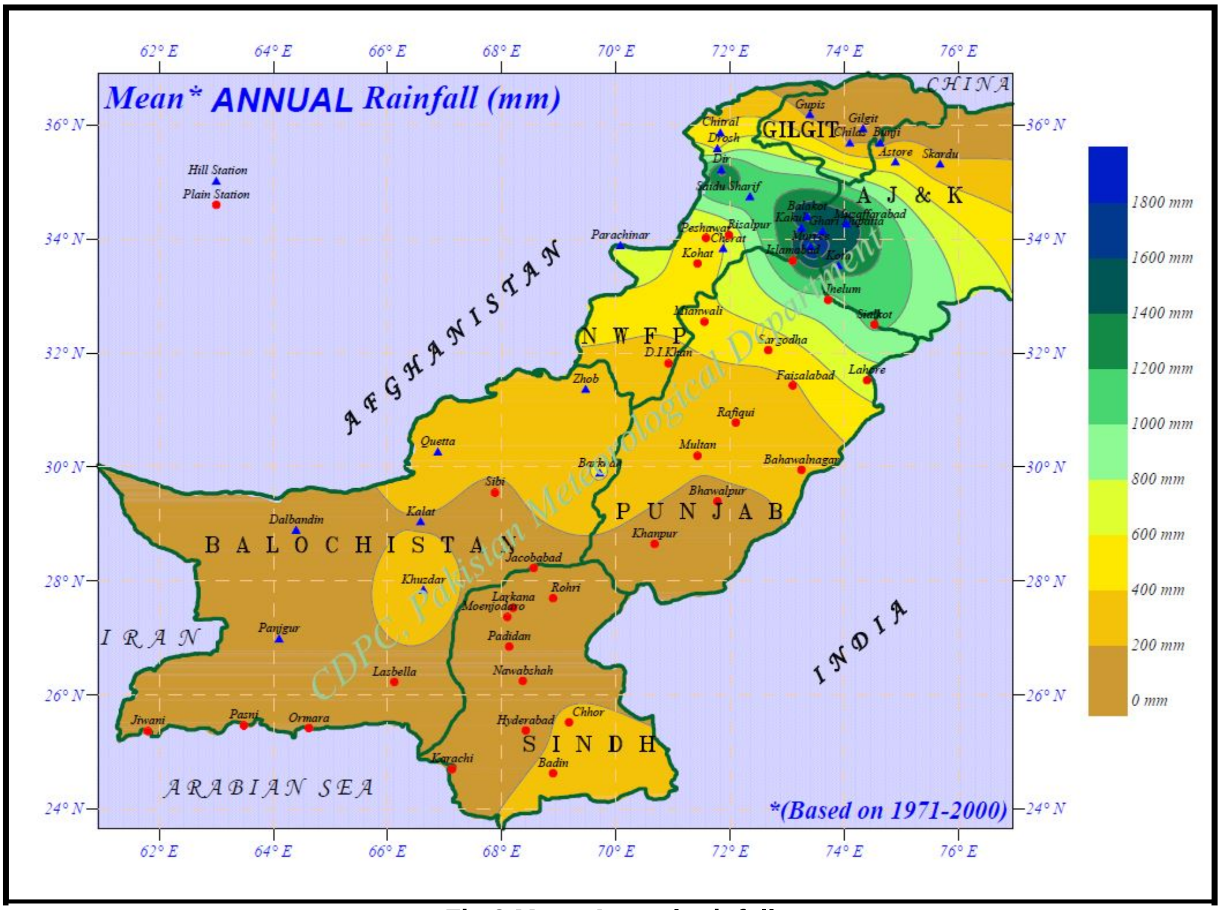

Fig 9 Mean Annual rainfall

For Islamabad, the mean annual rainfall was taken as 1000 mm.

4.3.4 Catchment Area

The catchment area for the proposed dam was calculated from Digital Elevation Model (DEM) of resolution 30 x 30 for the city of Islamabad, by using ArcGIS software, which automatically delineates watershed by getting input in the form of “Pour Points” and a raster image.

4th DAM, Sector H-12

Catchment Area = 1.96 km^2

Fig 10 Catchment Area

The catchment size came out to be 1.96 sq. km. which is less than 5 sq. km. thus classifying it as small catchment. The time of concentration (**T_c**) was calculated using the equation

$$\mathbf{Tc = (0.87\ L^3/h)^{0.385}}$$

T_c came out to be 0.6 hours or 35 mins.

4.3.5 Topographic Data

Topography of the area was determined by processing Digital Elevation Model (DEM) in ArcGIS and GlobalMapper to work out the necessary design parameters like Fetch and reservoir area for the dam.

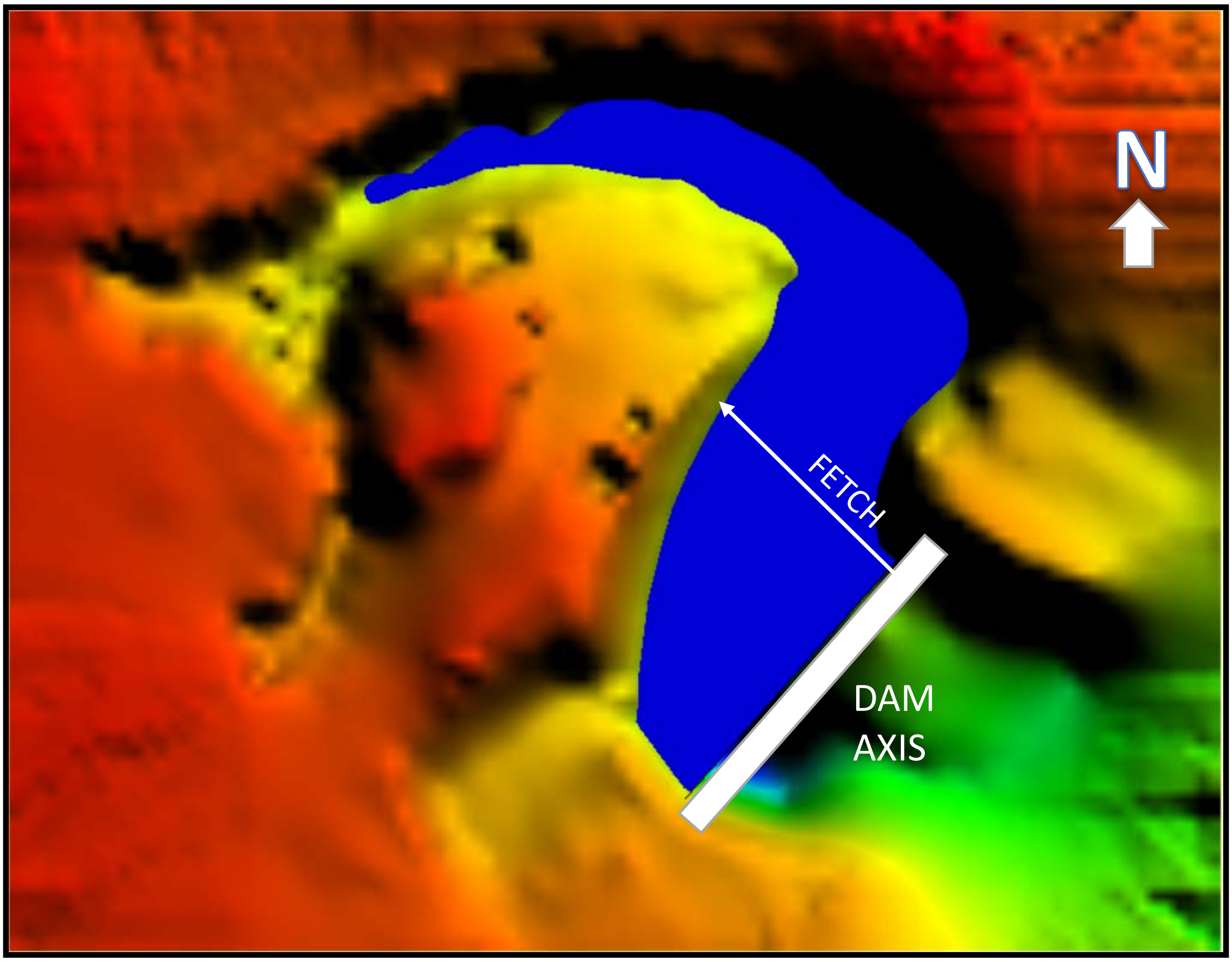

Fig 11 Dam Reservoir

The Full Supply Level (**FSL**) was set at **16 feet.** The reservoir size was calculated as 0.00528 sq. km. **Fetch** length was **47.4 m**. Volumes were calculated for every 5 feet rise in elevation from lowest point till the point when the reservoir size became so large that it started to invade the premises of the squash court. A depth-capacity curve was drawn and the FSL of 16 feet was selected. The reservoir volume a.k.a. **storage capacity** came out to be approximately **9555 m^3**.

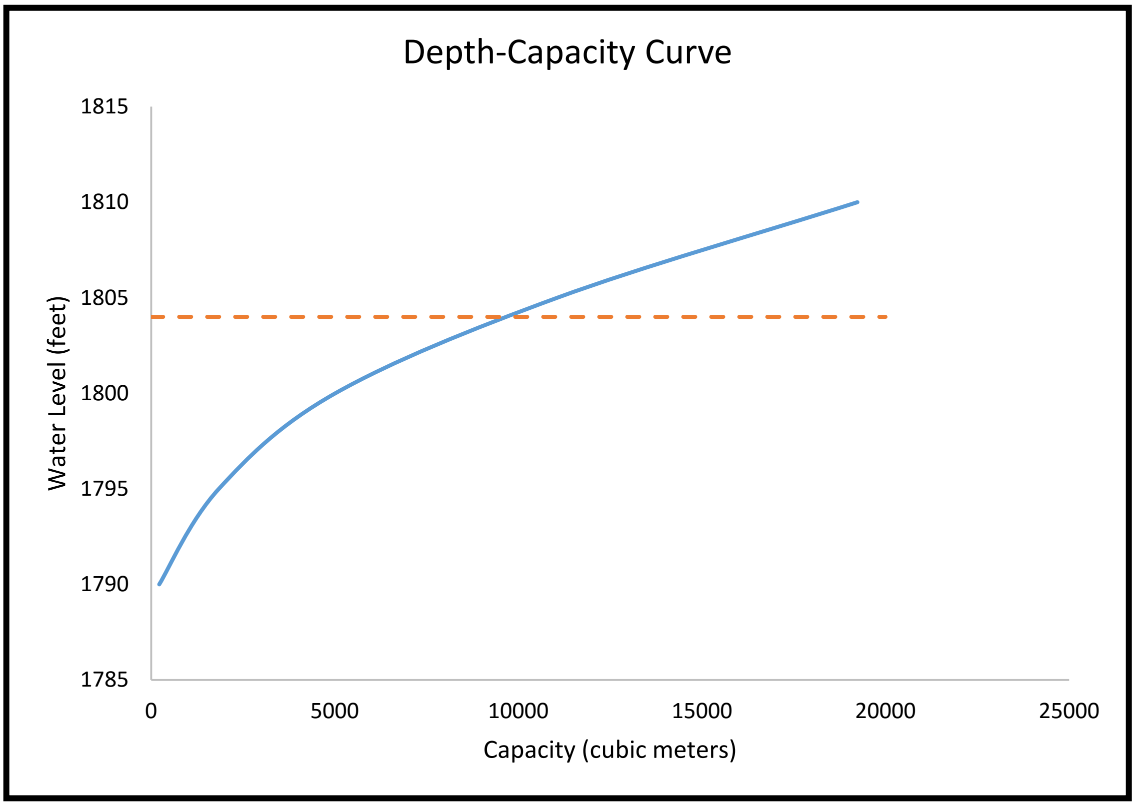

Fig 12 Depth-Capacity Curve

Using AutoCAD Civil3D, the topographical data was imported and transformed into a contour map. Along the proposed dam axis, a profile was generated with stations at every 100 feet. The dam length measured as 240 feet.

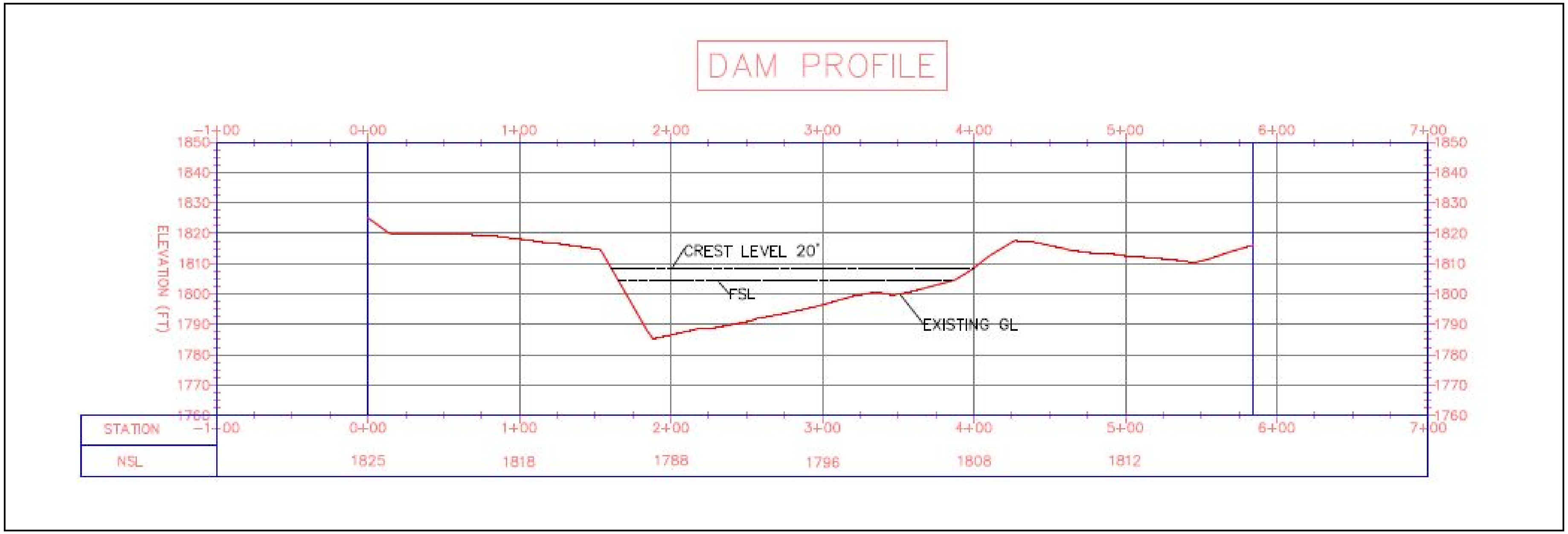

Fig 13 Dam Profile

4.3.6 Probable Maximum Flood

Taking into account the hydrological and geological information and static data, rainfall and runoff are estimated and probable maximum is determined. PMF calculation is very important in determining the size one of the most important features of dam, the spillway. Like in large dam in small dams it is important to properly design and dimension the spillway which depends on accurate estimate of PMFs.

To determine PMF, using rational method owing to less hydrological information it is an important technique used to estimate PMF based on catchment area, assumed runoff and intensity of rainfall.

Following formulae is used to calculate PMF

$$\mathbf{Q_p = 0.278\ A\ P\ R\ C_r/T_c}$$

Here

Q_p is probable maximum flood in m^3/s

A is catchment area equal to 1.96 km^2

R is storm depth ratio

C_r is runoff coefficient

T_c is time of concentration = 0.6 hours

One day storm rainfall, P = 309.9 mm from the chart provided earlier (Climate of Islamabad)

R, storm depth ratio can be found from figure 6b. For Tc = 0.6 h, R= 0.5

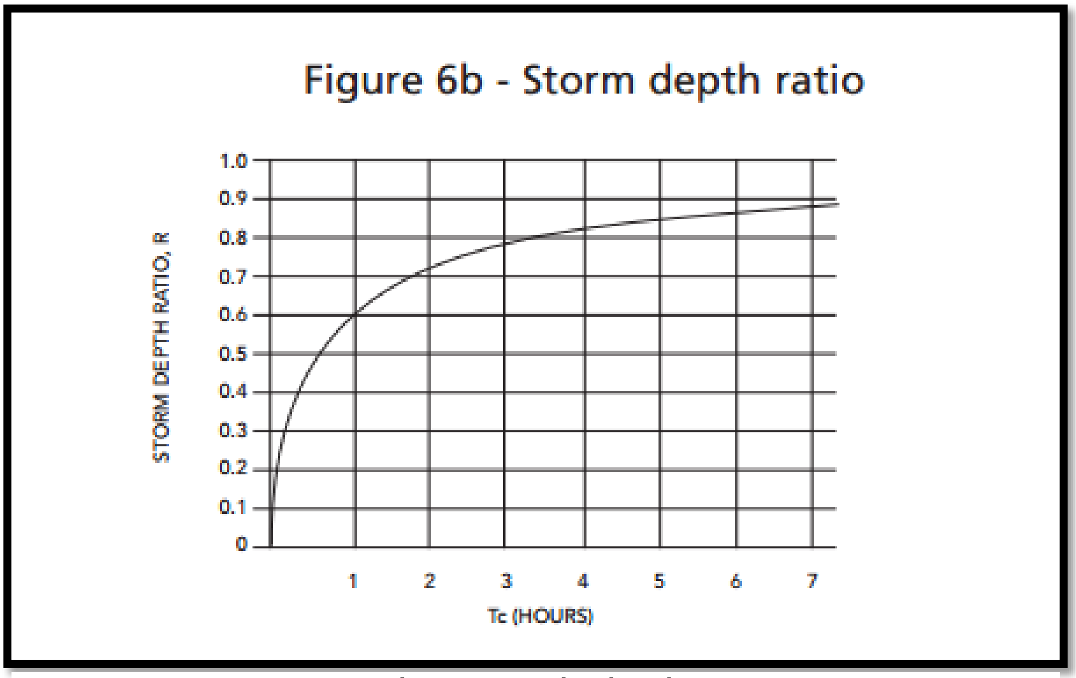

Fig 14 Storm depth ratio

Using Figure 6c to determine runoff coefficient C_r. Here extreme height slope (%) = [100 h/(1 000 litres)] which is equal to 2% and taking 20 year return period. C_c = 0.2

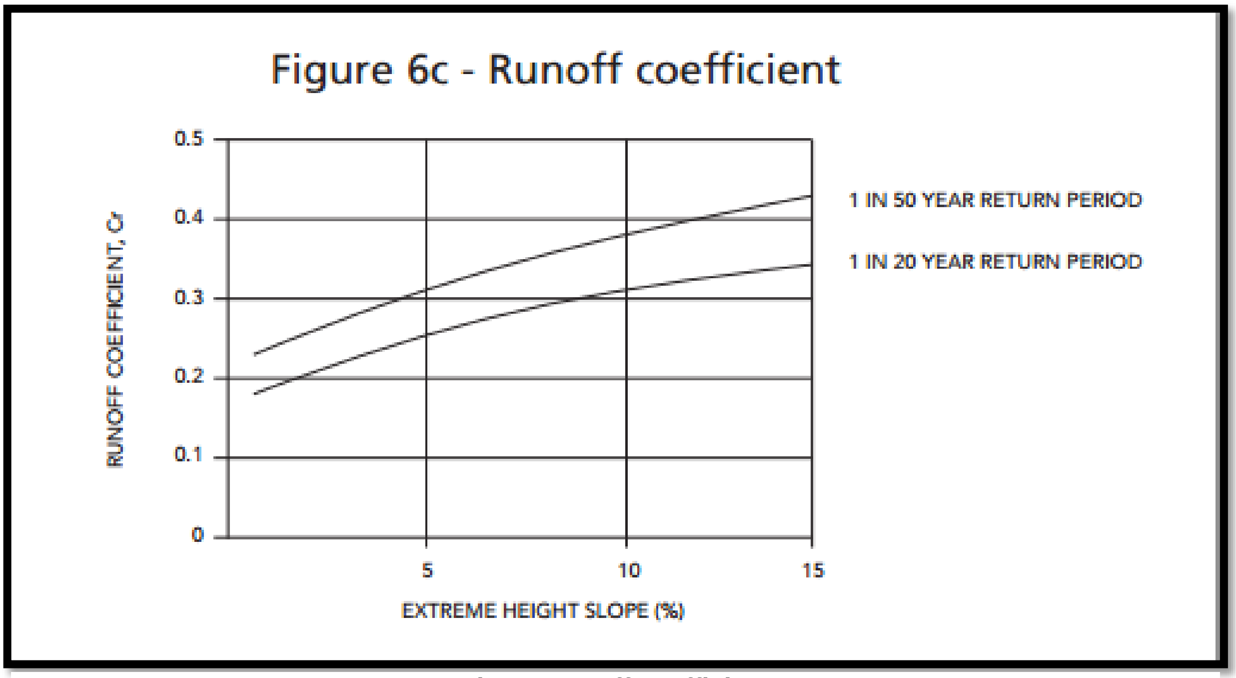

Fig 15 Runoff coefficient

Putting values of A, R, P, C_c and T_c in the mentioned equation. $Q_P = 7.22\ m^3/s$.

4.4 Design Feasibility

4.4.1 Catchment Yield

Catchment yield is the water that recharges the reservoir in including stream flow and runoff. It should be greater than storage capacity. It is calculated as

$Y = 10\%\ R_R * A * 1000$

Here R_R is runoff in mm, which has been taken to be 10% of mean annual rainfall and giving a value of 100 mm, A is total catchment area in km^2 which is equal to 1.96 km^2, and Y is catchment yield equal to 196,000 m^3.

4.4.2 Volume of Earth Work

Volume of earth is the total volume of soil that is needed for the construction of different components of dam. Volume of earthwork is determined from the formula

$$\mathbf{V = 0.216\ HL\ (2C_w + HS)}$$

Where:

- S is the combined slope = 4.5
- H is height of dam = 6.096 m
- L is length of dam = 73.15 m
- C_w is crest width = 3.657 m

Therefore,

$$\mathbf{V_e = 2500\ m^3}$$

4.4.3 Storage Ratio

The storage ratio is the ratio of the amount of water retained to the amount of soil used to retain it. It is used to determine site rating and compare sites in a cost per benefit analysis. Site is rated as:

<2 Poor

2-4 Moderate

4.1-6 High

>6 Excellent

For the proposed dam, storage ratio is;

Storage Ratio= Storage capacity/Volume of earthwork

Storage Ratio = 3.8 **Site Rating = Moderate**

4.5 Structural Components

4.5.1 Embankment

4.5.1.1 Estimate of free board

Freeboard is provided to prevent overtopping of the embankment due to wave action. It also provides factor of safety against contingencies such as dam settlement, greater inflow flood than design flood, malfunction of spillways etc.

Freeboard generally requires a determination of height and action of waves. The wave height depends upon wind velocity, fetch, depth of water, width of reservoir etc. Based on these criteria, empirical relationships are developed to estimate freeboard. Dam should satisfy most critical requirements as below

Fetch (miles)	Normal Free Board (ft)	Minimum Free Board (ft)
<1	4	3
1	5	4
2.5	6	5
5	8	6

Fig 16 Freeboard Requirments

FAO manual uses an empirical relationship to compute free board for small dams which is

$$\mathbf{F.B = 0.014\ (F)^{0.5}}$$

Where **F** is the fetch of dam in **Km.**

$$\mathbf{F.B = 0.3\ ft < 4\ ft}$$

Therefore, used **F.B = 4 ft**

4.5.1.2 Crest Width

The crest width for a dam should be such that it should allow the passage of at least single lane road. Moreover it should be sloping towards the upstream side of the dam so as to drain towards upstream. Surfacing is important to prevent crest from erosion, wave action and weather conditions. For an estimate of crest width FAO and USBR manual gives the following criteria:

USBR: $C_w = (Z/5) + 10 > 12$ ft "Z" is height of ham in ft

FAO, Manual: $C_w = 0.4H + 1 > 5$ m "H" is height of dam in meters

$C_w = (16/5) + 10 = 11.2 < 12$ ft Therefore, **C_w = 12 ft (3.657 m)**

4.5.1.3 Slopes

According to Guideline for Design of Dams, downstream slope of earth dam without seepage control measures should be no steeper than 1 vertical on 3 horizontal. If seepage control measures are provided, the downstream slope should be no steeper than 1 vertical on 2 horizontal. For zoned embankment dams the downstream slope can be as steep as 1V:1.75H and upstream slope as 1V:2H.For the proposed dam, both upstream and downstream slopes are taken as 1V: 3H. The primary reason for taking flatter slopes is the seismically active nature of the dam site and the vicinity.

Slopes chosen,

Upstream 2.5H:1V

Downstream 2H:1V

4.5.1.4 Filter Design

Seepage through dam is one the main problems. Water from reservoir dissipates through embankment and reaches to downstream. During this it carries embankment materials and causes piping failure. To solve this problem filter and drainage are constructed inside the dam.

Filter and drainage is one of the most important features in dam structure. Filter are required on the downstream side of a dam to efficiently control the movement of water through and out of the embankment It enhances the efficiency and let the seepage water to properly drain.

There are two criterions that must meet, while designing filter for a dam.

- **Restraint criteria**: Meeting this criterion will help to stop the migration of materials.
- **Permeability criteria**: Applying this criterion will control the movement of water through and out the embankment.

Filters have been designed using all 3 methods;

1. Terzaghi
2. Sherard
3. US Army Corps. of Engineers (USACE)

4.5.1.4.1 Base Curve

After sieve analysis and hydrometer analysis, following is the gradation of the soil material present at the site.

Particle Size (mm)	% Finer
4.75	91.3649
2	90.8078
1.19	90.8078
0.595	90.8078
0.42	90.8078
0.297	90.52925
0.149	77.99443
0.074	50.13928
0.041427	38.60626
0.021989	32.6569
0.012333	27.92086
0.006386	23.16806
0.003325	17.24981
0.00169	12.6071
0.00086	9.113107
0.000436	5.580821
0.000156	1.818792

Fig 17 Gradation of Base Soil

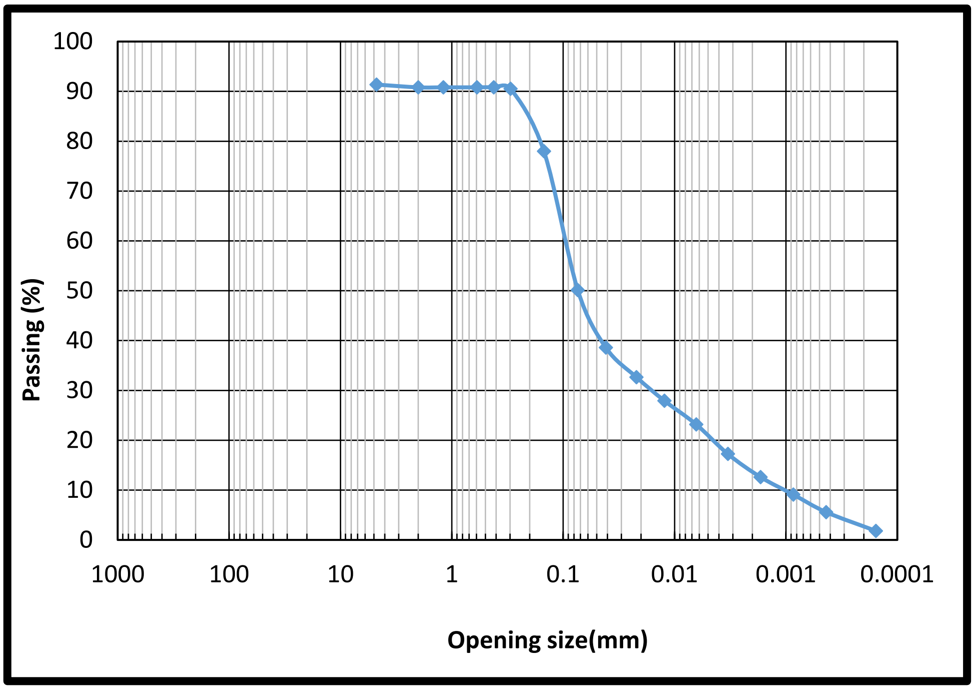

Fig 18 Base Curve

4.5.1.4.2 Filter Limits

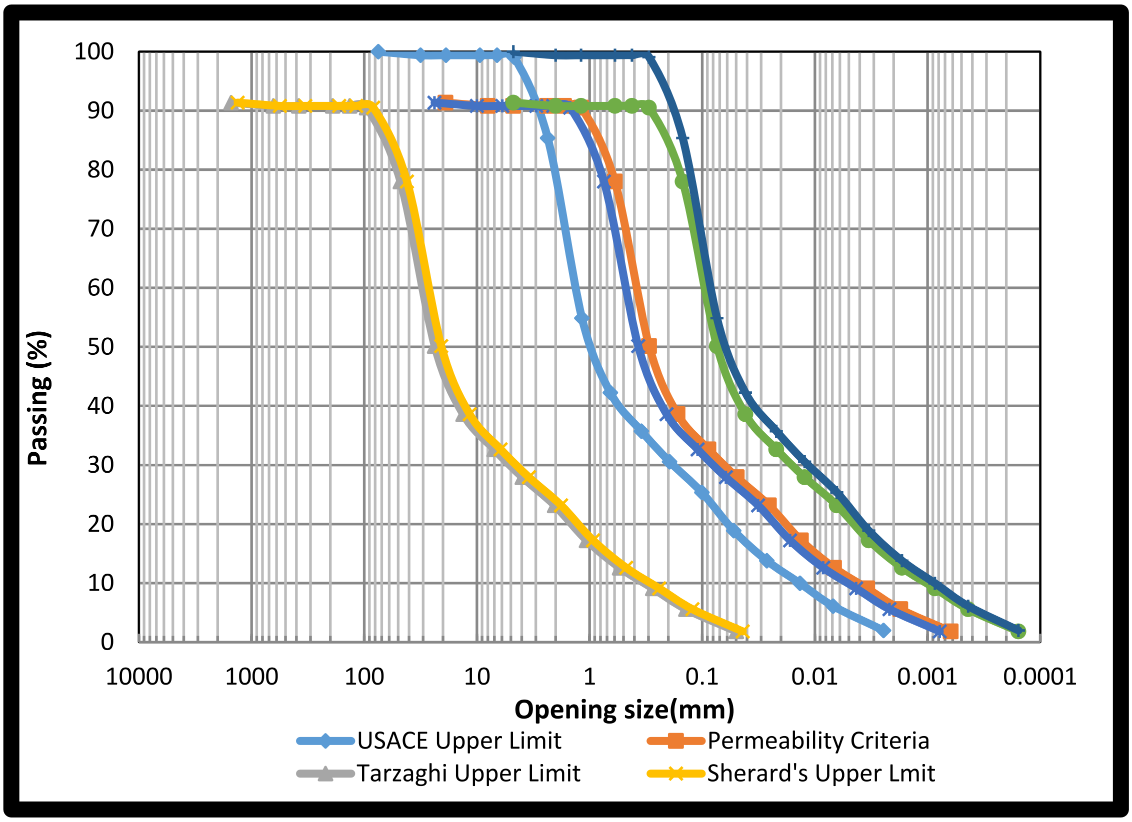

Fig 19 Filter Limits

The filter should be located between these limits after selecting any one of the three methods. To avoid segregation, filter's curve should be well graded and should lie nearer to the permeability limit. According to Table B-3

Table B-3
D_{10} and D_{90} Limits for Preventing Segregation

If minimum D_{10}, mm	Then maximum D_{90}, mm
<0.5	20
0.5 - 1.0	25
1.0 - 2.0	30
2.0 - 5.0	40
5.0 - 10	50
10 - 50	60

Fig 20 Segregation check

4.5.1.5 Riprap Design

In order to protect the slopes from wave action, erosion and scouring a blanket of hard rock is provided on the faces of the slopes. The purpose on the downstream is sometimes served by vegetation.

Using the significant wave height (h_s), Specific Gravity (G) and Rock Weight (W_{50}) are found using the graph.

Thickness of the Riprap layer was calculated using USACE method.

W_{50} = 17.5 lbs

W_{max} = $4*W_{50}$ = 70 lbs

W_{min} = $0.125*W_{50}$ = 2.8 lbs

$T = 20(W_{50}/\gamma)^{1/3}$ = 0.75 ft.

Thus, a layer of 9 inches on either slopes was provided to safeguard against erosion

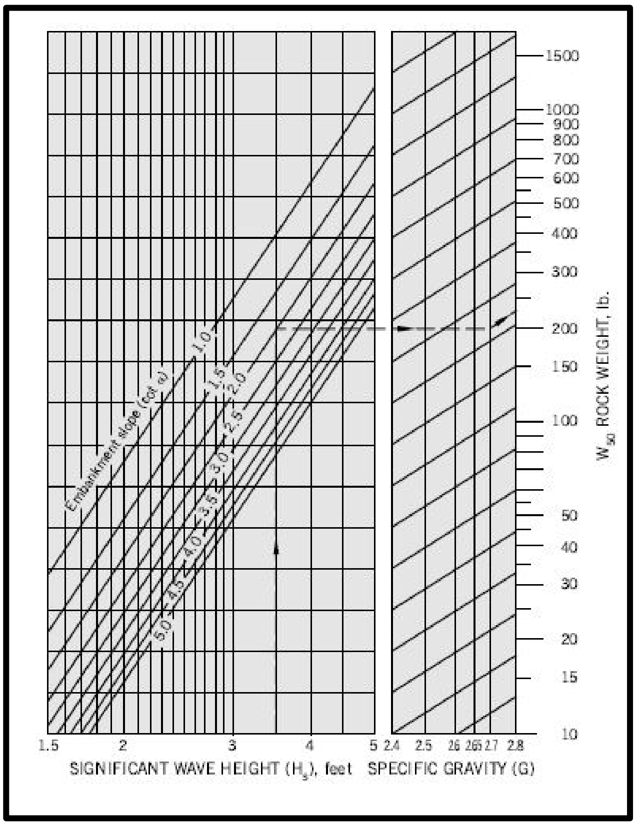

Fig 21 Riprap size

4.5.2 Spillway

When the capacity of dam is reached excess water needs to be spilled over for the normal functioning of dam. Spillways dimensions are function of size and shape of catchment, its behavior, slopes, maximum rainfall and peak flood. For proposed dam some of the above parameters are known while some are assumed.

Spillway dimensions are calculated by using,

$$\mathbf{Q_p = 1.7*B*D^{1.5}}$$

Where,

Q_p = Probable Maximum Flood = 7.22 cumecs

B = Width of spillway

D = Depth of spillway = usually equal to freeboard = 4 feet

‘1.7’ is a factor derived for concrete ogee type crests and can vary up to 2.25 according to site conditions and factors of safety. 1.7 is generally used for spillways for small dams on small catchments.

The dimensions of the spillway come out to be,

B = 11 ft

D = 4 ft

4.5.2 Cutoff Trench

Most dams, homogenous or zoned, can benefit from the construction of a cutoff in the foundation. A cutoff will reduce seepage and improve stability. Whether stable clay, or other material is being used, the cutoff trench must be excavated to a depth that will minimize all possible seepage.

The minimum cutoff width should be **3 m** so that the machines can work easily. The slopes of the cutoff can be **0.5H:1V** but usually **1H:1V** are preferred which allow for easy compaction.

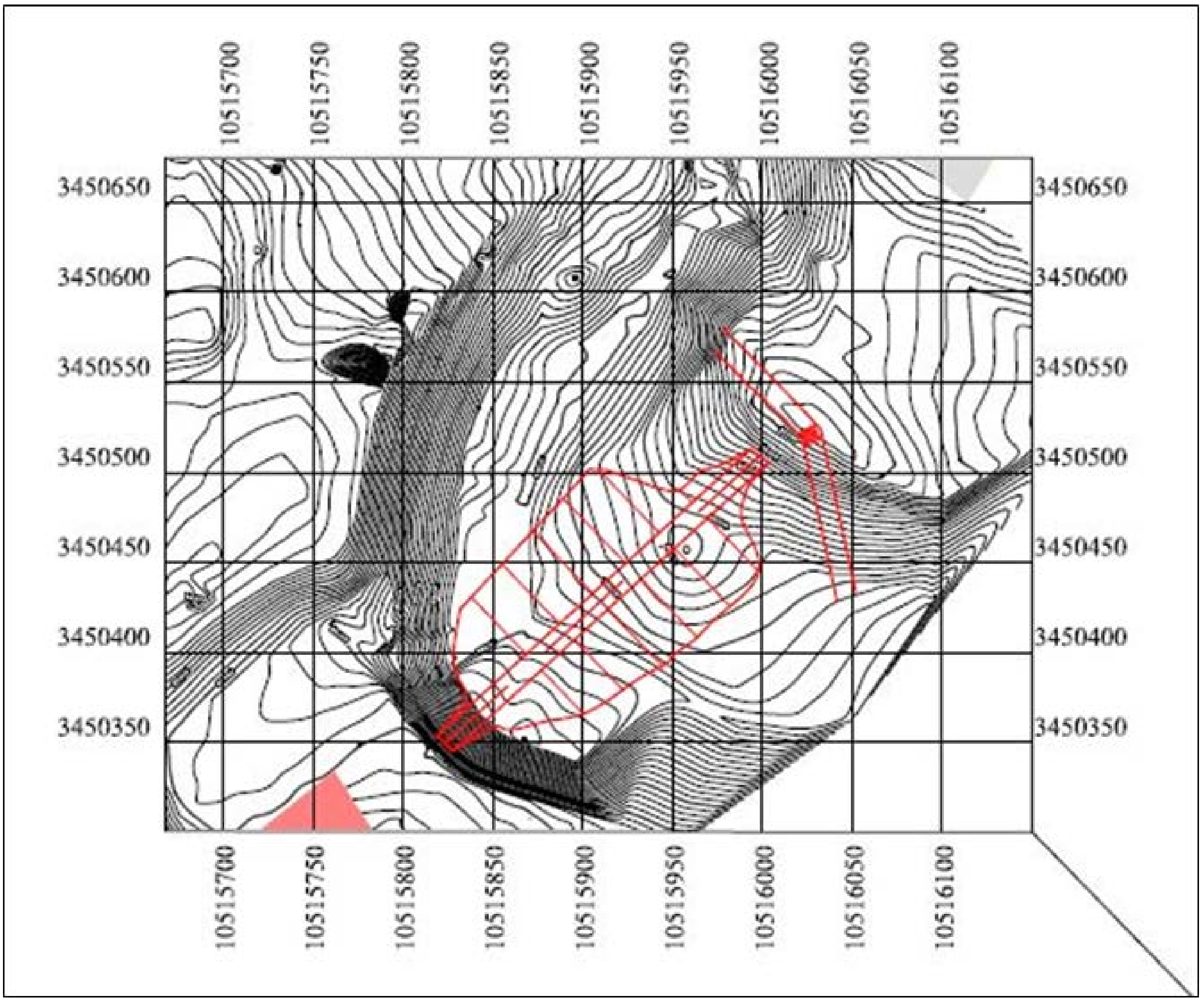

Fig 22 Dam and Spillway orientation

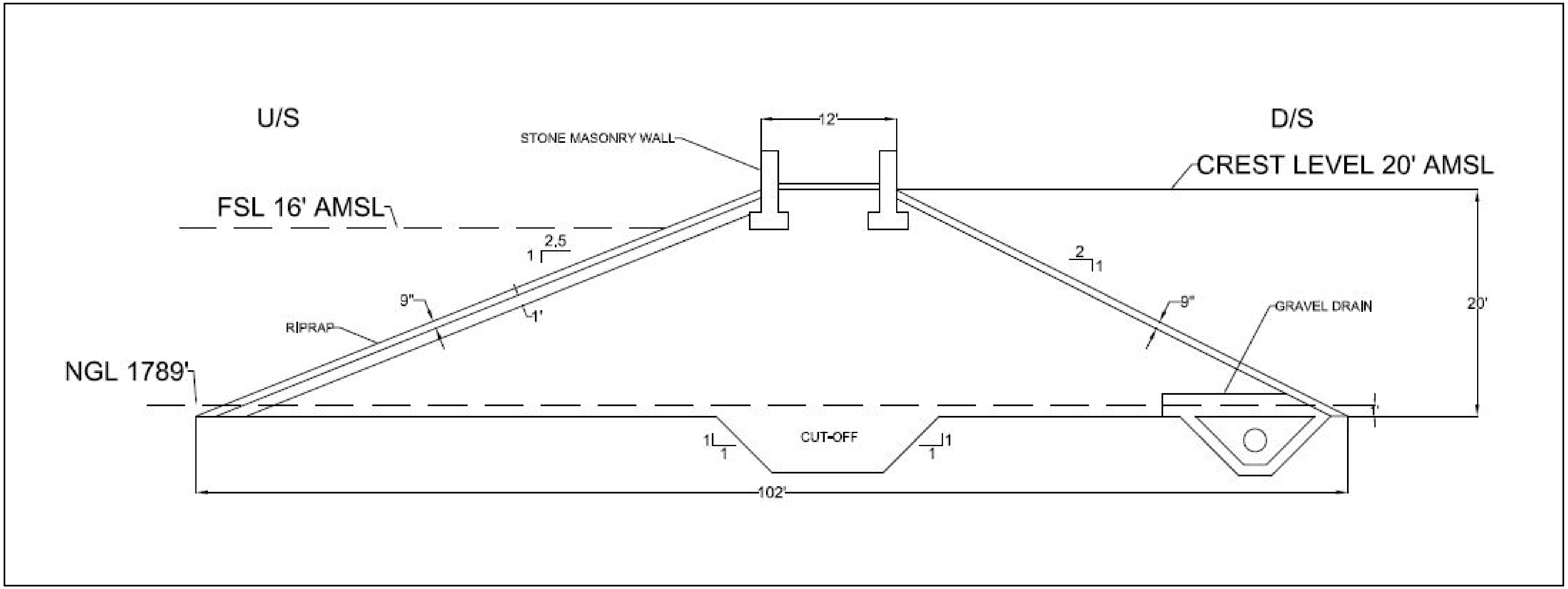

Fig 23 Adopted Embankment Design

4.7 Safety Considerations:

4.7.1 Stability Analysis:

The stability of the slopes of dam is of great importance for normal operation of dam. Engineers with good knowledge of soil and site and sound laboratory testing can easily achieve a higher factor of safety.

In present case the slope stability of dam is determined using RocScience Slide. Followings are the results of analysis performed in slide.

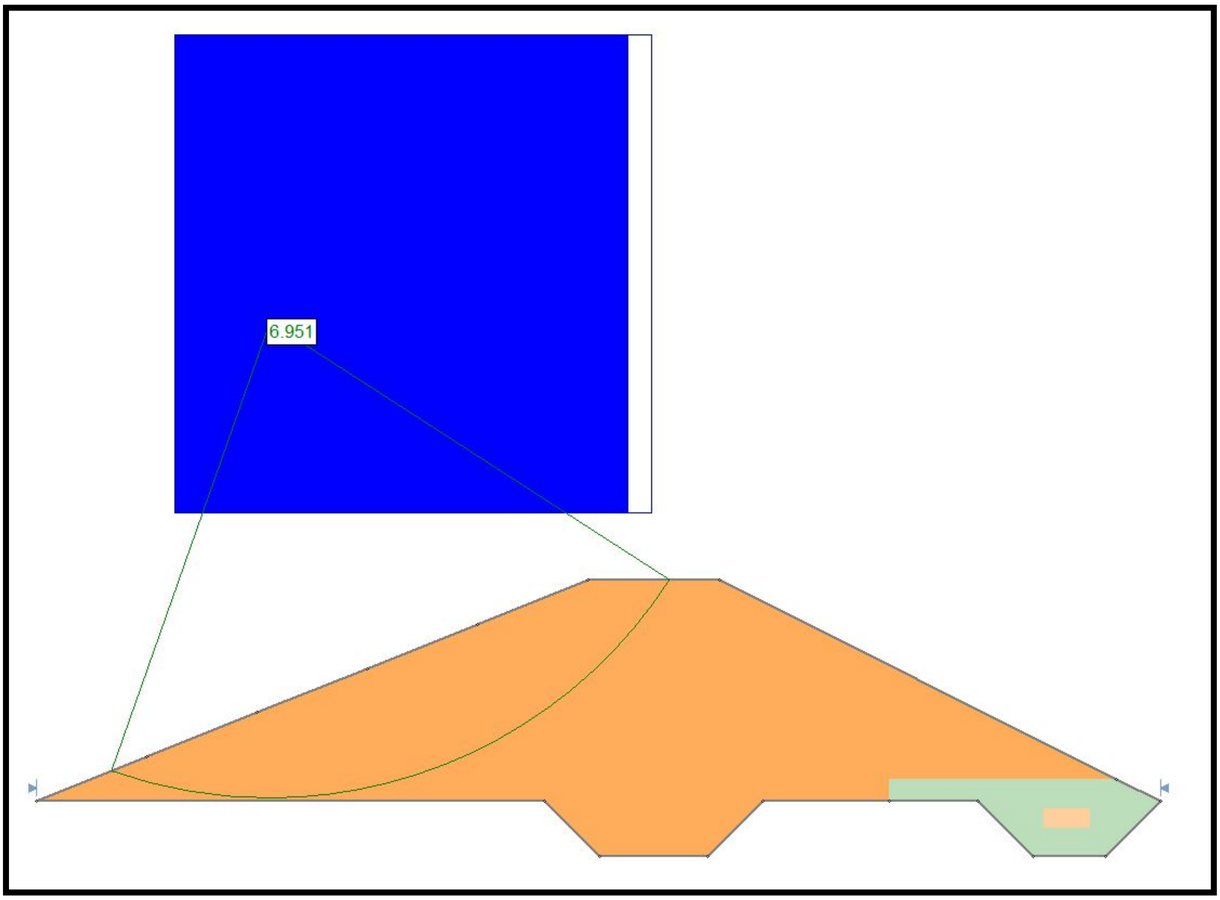

Fig 24 FOS w/o seismic loading

When a seismic load is applied, the factor of safety for upstream reduces considerably but still remains well above the minimum threshold of 1.5

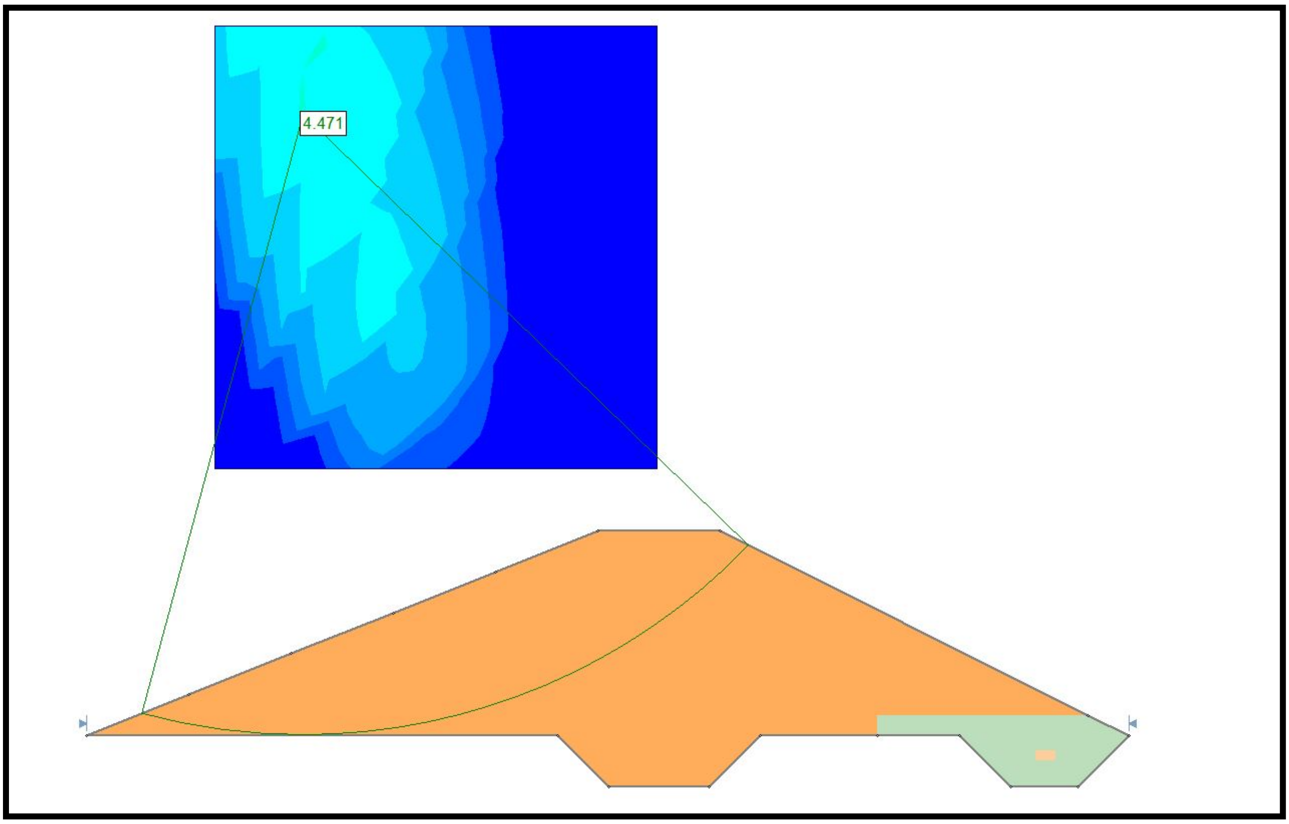

Fig 25 FOS with seismic loading

4.7.2 Seepage Analysis:

For the normal functioning of a dam it should be water tight with ample filters to prevent water losses as well as for the prevention of increase in pore water pressure. The seepage analysis for the proposed dam was performed in RocScience Slide. The two aspects of the seepage analysis covered are:

- Steady State seepage
- Transient condition with Rapid Draw Down

A period of ten (10) days is assumed for rapid draw down of the proposed dam and factor of safety against each stage is measured. The same analysis is performed again along with the application of seismic load and factor of safety for each stage was measured again.

4.7.2.1 Steady State Seepage

The image represents the stage when the reservoir is filled and a steady state has developed. The discharge at downstream is $5.87\text{x}10^{-4}$ m^3/day.

The higher water level acts as a stabilizing load and the Factor of Safety (FOS) rises very high i.e. 9.96.

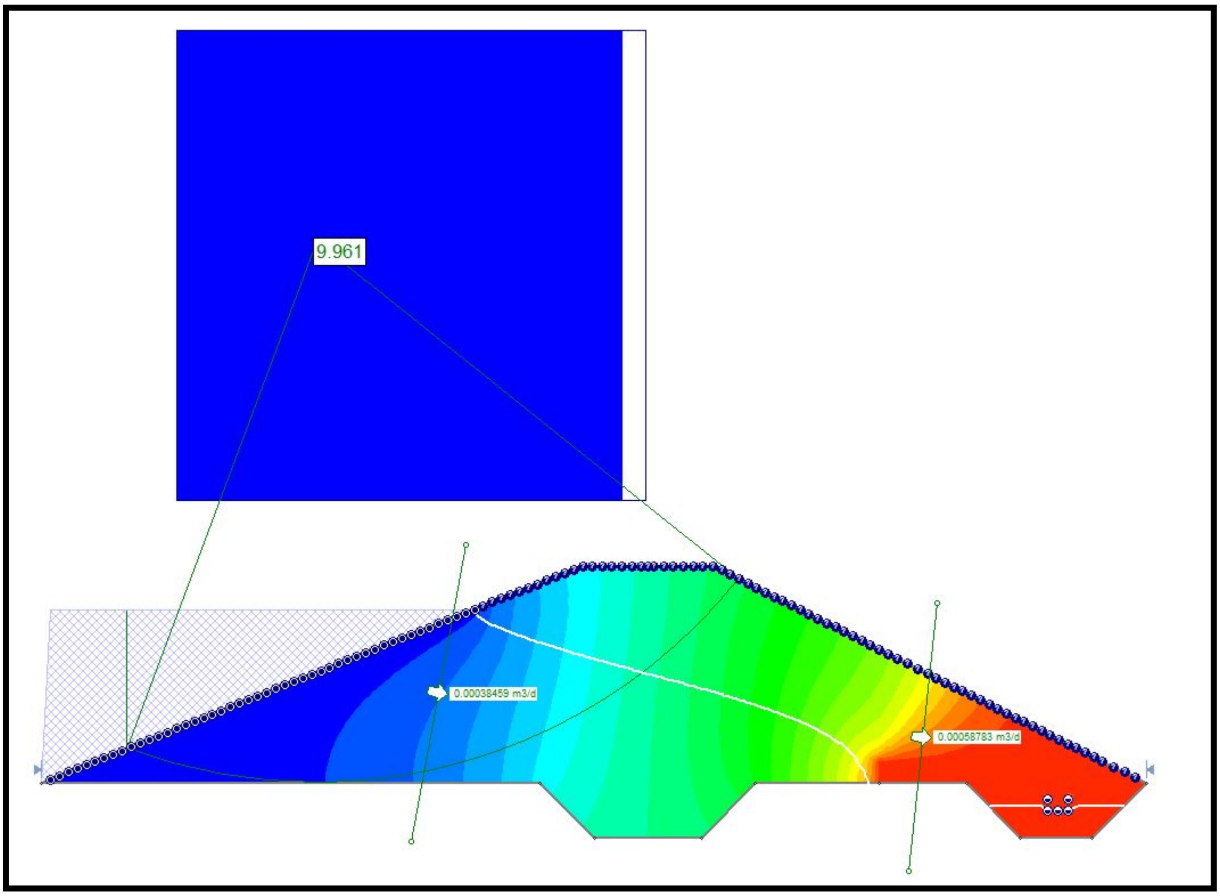

Fig 26 FOS – Steady State Seepage

4.7.2.2 Rapid Drawdown

The rapid draw down period of 10 days is assumed for the proposed dam. Factor of safety is determined at mid stage and at the end of rapid drawdown.

The factor of safety reduces but still remains higher than 1.5 showing that the dam is stable. The following images represent the results of analysis performed. 1st two images represent start and end of rapid drawdown at 10 and 250 days respectively without application of seismic load. Third & fourth image represent the same stages with seismic load applied.

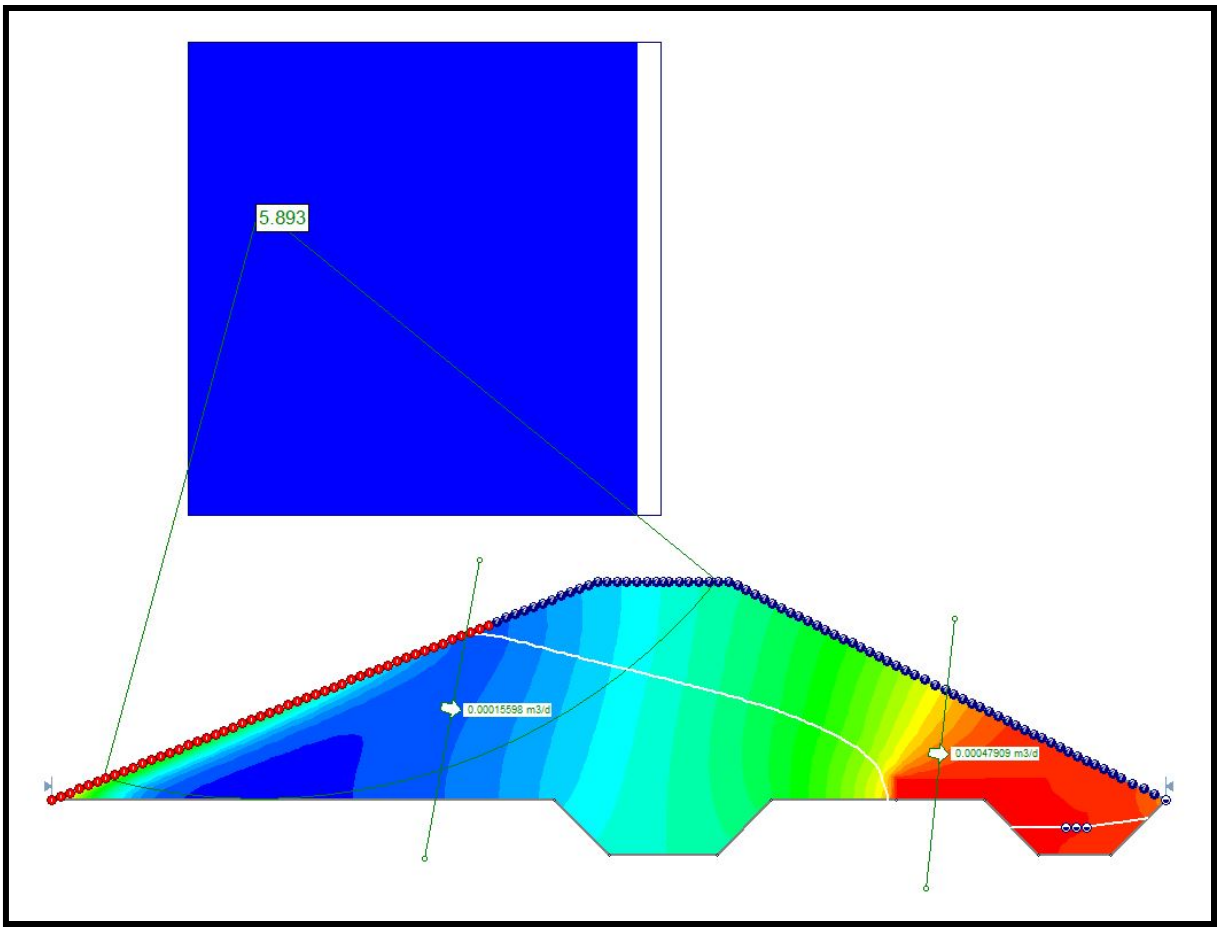

Fig 27 Rapid Drawdown (mid stage) w/o seismic loading

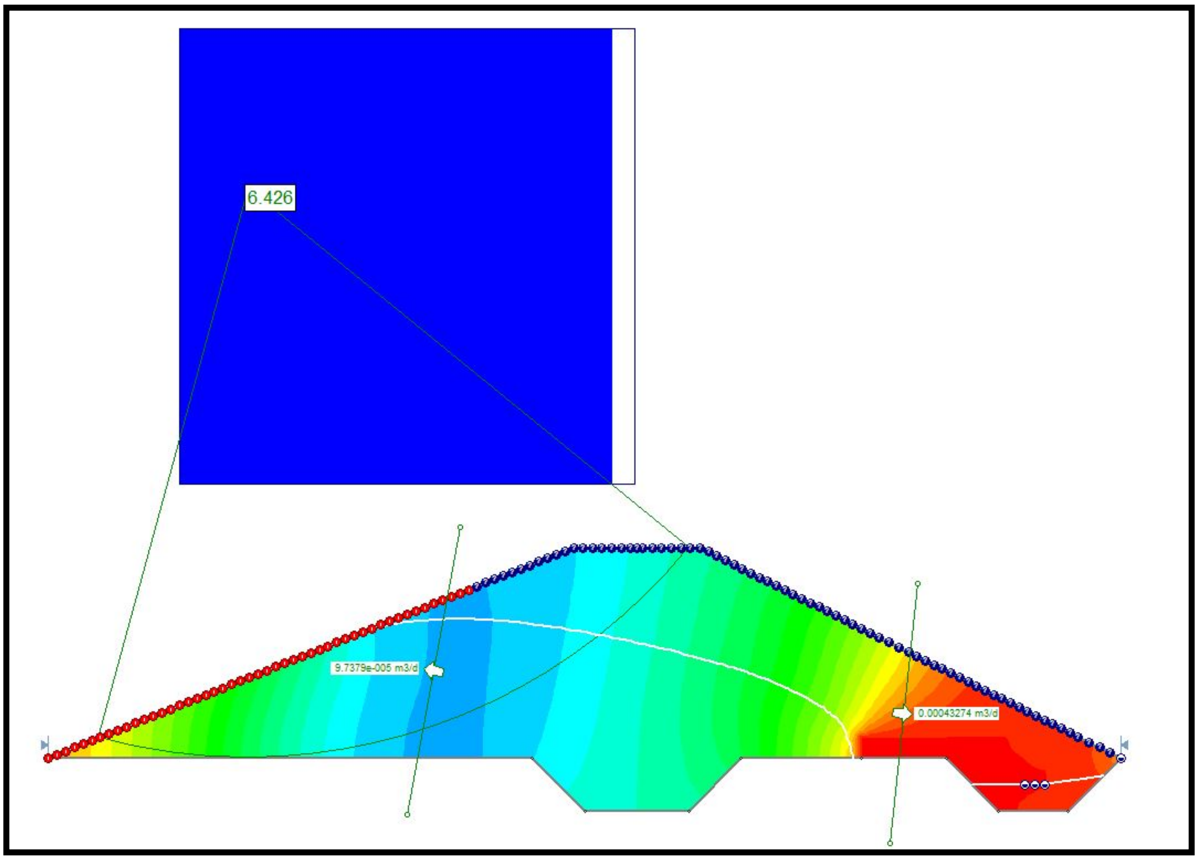

Fig 29 Rapid Drawdown (end stage) w/o seismic loading

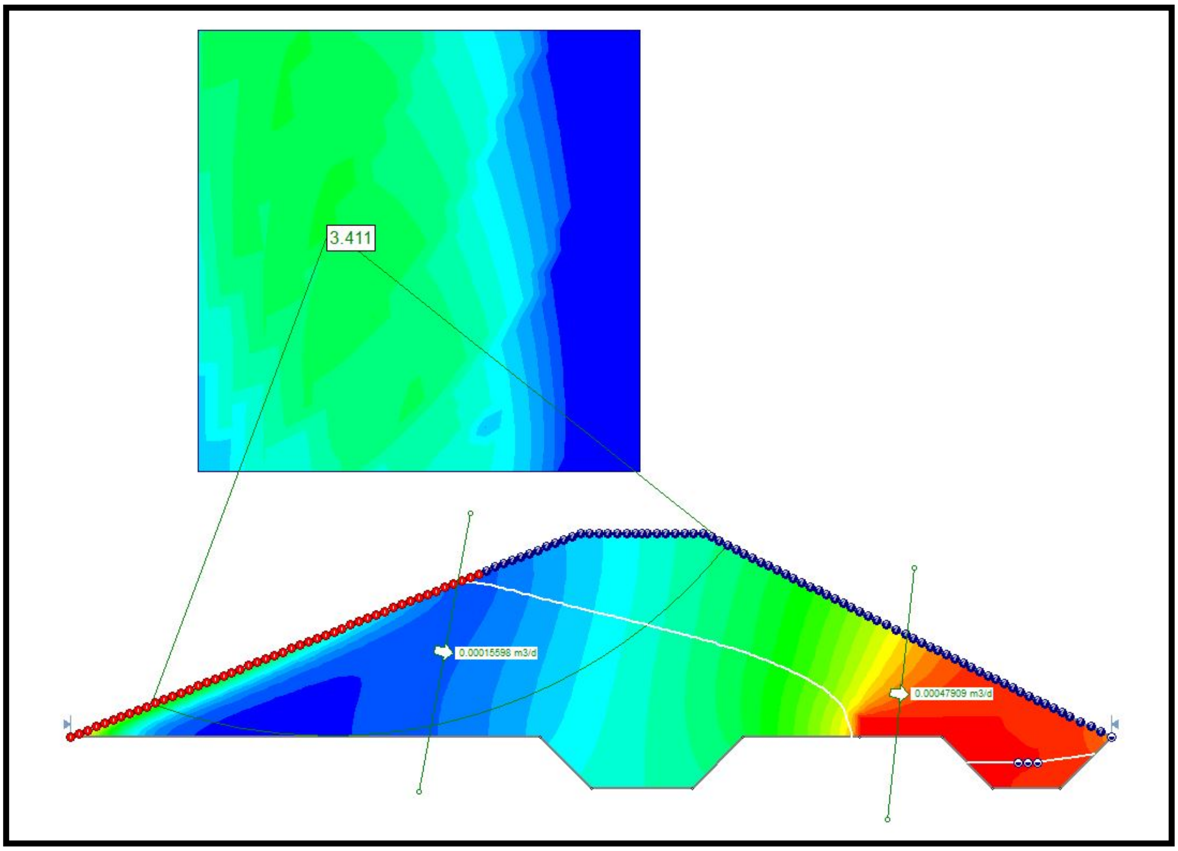

Fig 28 Rapid Drawdown (mid stage) with seismic loading

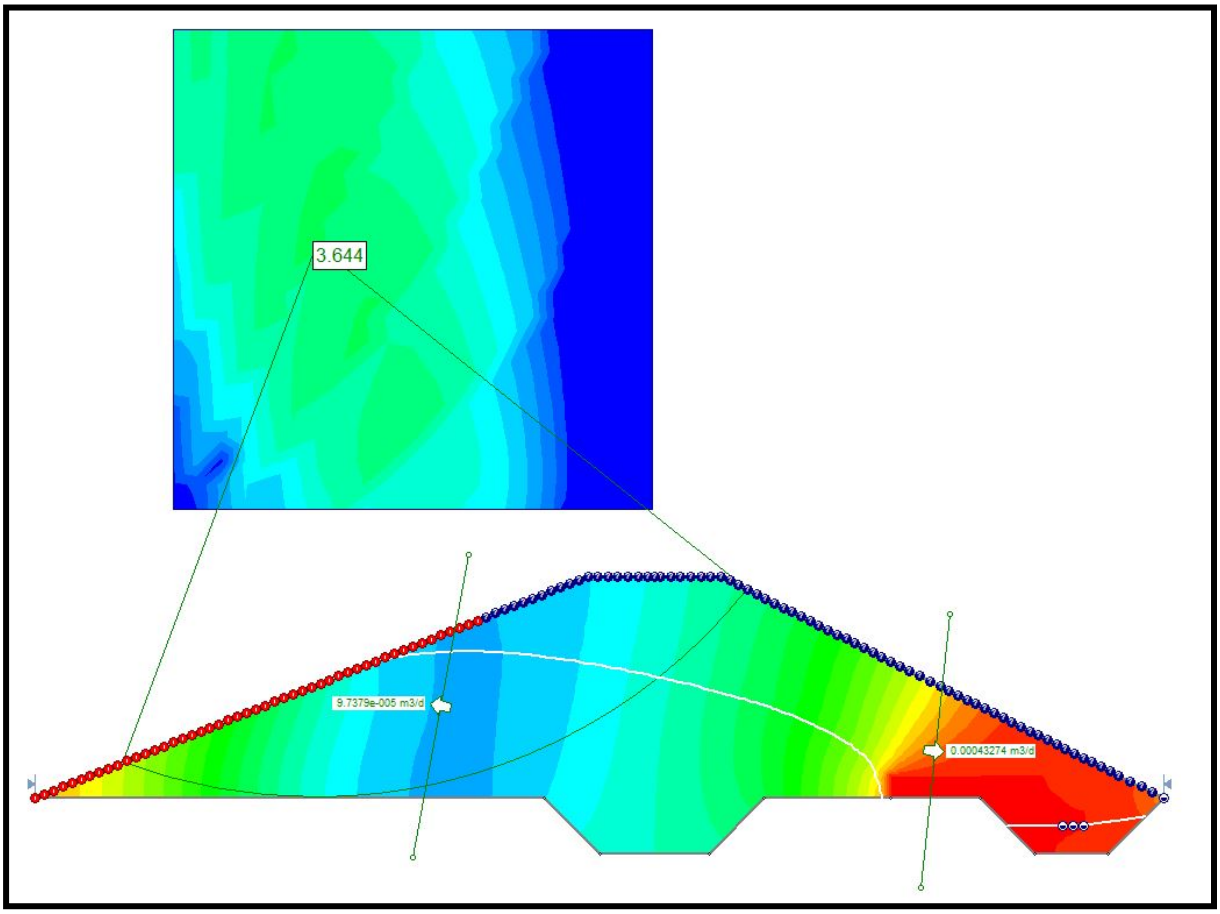

Fig 30 Rapid Drawdown (end stage) with seismic loading

Condition	FOS w/o seismic loading		FOS with seismic loading	
Simple	6.951		4.471	
Steady State	9.961		-	
Rapid Drawdown	At 10 days	5.893	At 10 days	3.411
	At 250 days	6.426	At 250 days	3.644

Fig 31 Summary of FOS

4.7.3 Settlement Analysis:

The settlement analysis for the foundation is performed using RocScience Settle 3D. Settlement at different stages is calculated. The embankment applies a load on the foundation such that the total settlement is achieved at 5th year after the construction of dam. In the following first image represents the settlement at the end of 1st year and second image represents settlement at the end of 5th year.

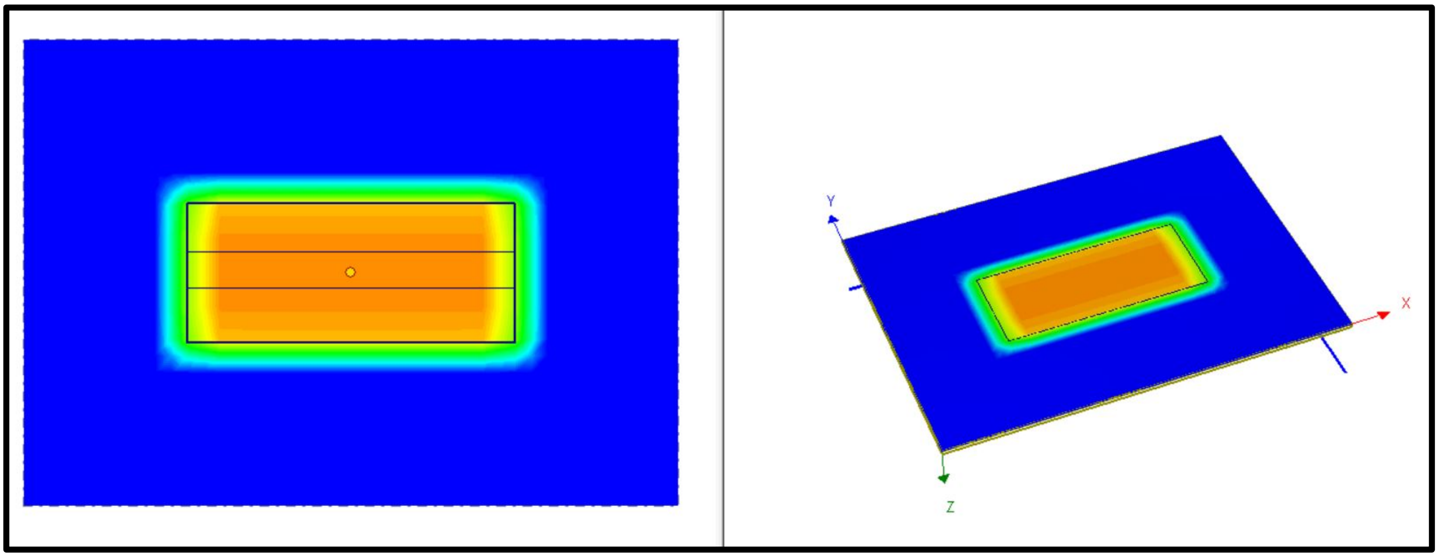

Fig 32 Settlement after 1 year of construction

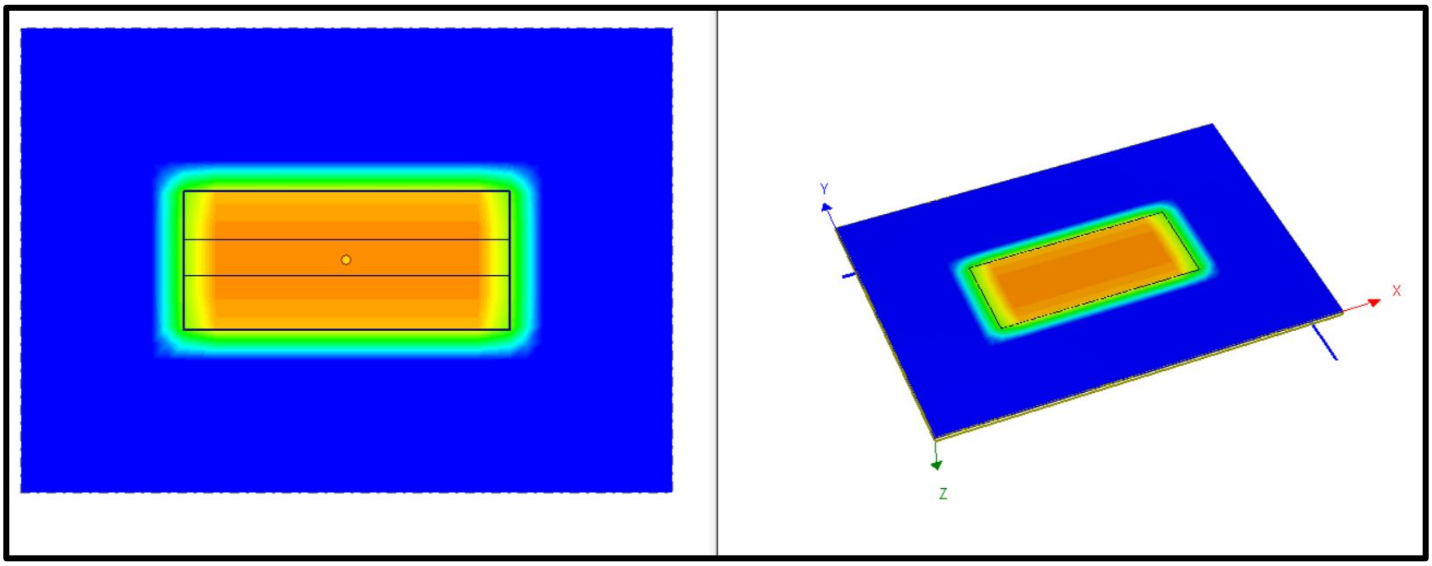

Fig 33 Settlement after 5 years of construction

The total settlement is 1.3 ft. 1 ft of settlement occurs within the 1st year after construction of dam.

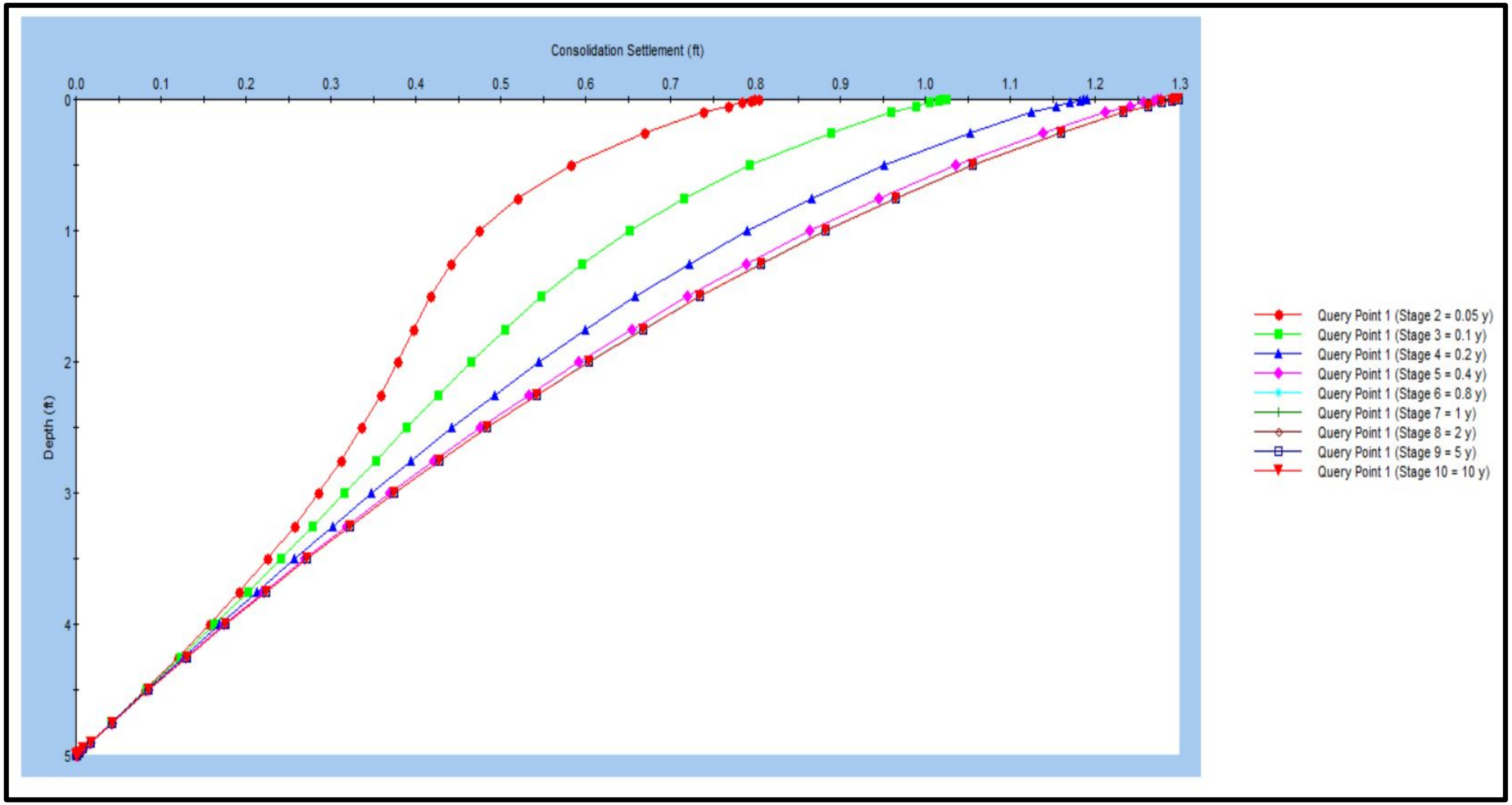

Fig 34 Settlement over time

CHAPTER 5

EFFECTS ON WATER TABLE AND FOUNDATION

5.1 Groundwater Recharge

Dams serve as a source of recharging the aquifer through percolation or infiltration of stored water through the reservoir bed. The amount of water recharged can be monitored through methods like

- Water-Table Fluctuation (WTF) method
- Darcian Method

5.1.1 Water-Table Fluctuation (WTF) method

The water-table fluctuation (WTF) method provides an estimate of groundwater recharge by analysis of water-level fluctuations in observation wells. The method is based on the assumption that a rise in water-table elevation measured in shallow wells is caused by the addition of recharge across the water table.

Recharge by the WTF method is estimated as:

$$\mathbf{R(t_j) = S_y * dH(t_j)}$$

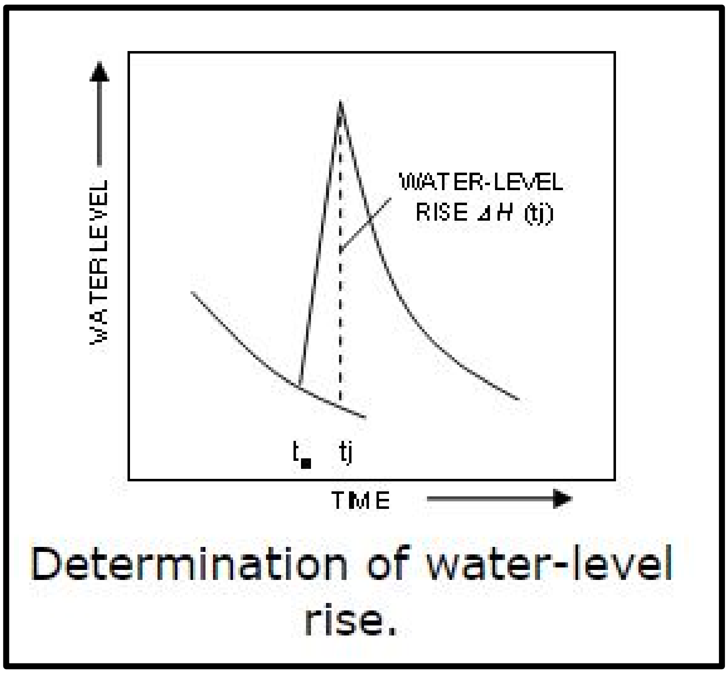

Fig 35 Determination of water level rise

Where,

$R(t_j)$ (cm) is recharge occurring between times t_0 and t_j

S_y is specific yield (dimensionless)

$dH(t_j)$ is the peak water level rise attributed to the recharge period (cm).

5.1.2 Darcian Method

If flow under field conditions is steady and driven by gravity alone, then, according to Darcy's Law, downward percolation rate will be numerically equal to the hydraulic conductivity of the material at the measured in-situ water content.

In the unsaturated zone, Darcy's Law may be represented in head units by the equation:

$$\mathbf{q = -K(\varphi)\ [d\psi/dz+1]}$$

Where,

q = flow rate

K = hydraulic conductivity

φ = volumetric water content [dimensionless]

$d\psi/dz$ = matric potential gradient [dimensionless]

$dz/dz = 1$ = gravitational potential gradient [dimensionless].

5.1.3 Applicability

1. WTF method requires performance data i.e. once the proposed dam has been constructed, an observation well is studied. Since, the dam is yet to be constructed hence the increase in water table cannot be judged through this method
2. Darcian method involves identification of unsaturated zones and also he measurement of hydraulic conductivity. Both require subsurface tests which were not performed. Non availability of data means no means of measurement of recharge rate.

5.2 Effect of Water on Foundations

The position of ground water has a significant effect on the bearing capacity of soil. Presence of water table at a depth less than the width of the foundation from the foundation bottom will reduce the bearing capacity of the soil.

The bearing capacity equation incorporating the ground water table correction factors is given below.

$$\mathbf{q_u = cN_c + \gamma D_f N_q R_{w1} + 0.5B\gamma N_\gamma R_{w2}}$$

Where,

q_u = Ultimate bearing capacity of soil in KN/m^2

c = Cohesion of soil in KN/m^2

Nc, Nq, Nγ are Terzaghi's bearing capacity constants.

D_f = depth of foundation in meters

B = Width of the foundation in meters

R_{w1} and R_{w2} are water table correction factors

The water table correction factors can be obtained from the equations given below.

1. When the water table is below the base of foundation at a distance 'b' the correction 'R_{w2}' is given by the following equation

$$\mathbf{R_{w2} = 0.5 + 0.5(b/B) \leq 1 \ ;}$$

$$\mathbf{\text{when } b = 0,\ R_{w2} = 0.5}$$

2. When water table further rises above base of foundation, correction factor 'R_{w1}' comes in to action, which is given by the following equation.

$$\mathbf{R_{w1} = 1 - 0.5(a/D_f) \leq 1}$$

$$\mathbf{\text{when } a = D_f,\ R_{w1} = 0.5}$$

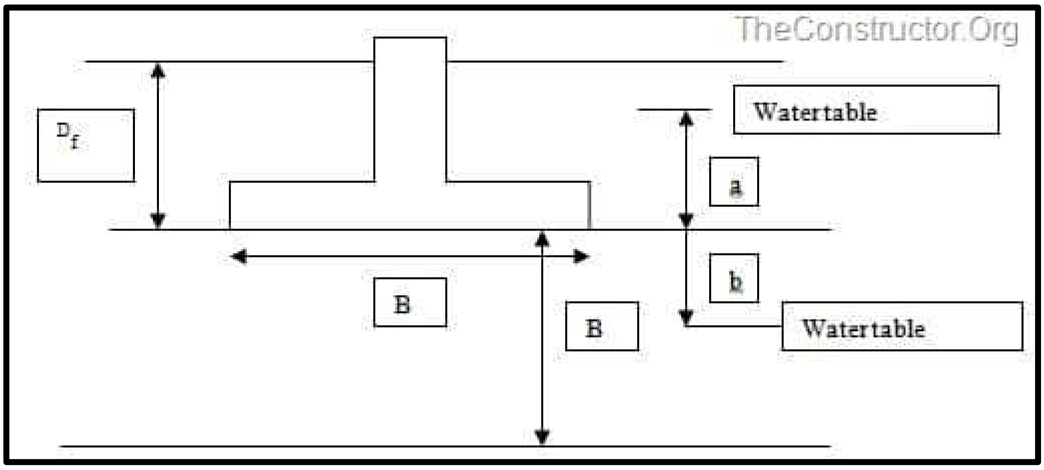

Fig 37 Effect of water on bearing capacity

5.3 Existing Situation

S. No.	Tube Well No & Location	Depth Tube Well Lowering Feet	Static W/Table (Feet)	Draw Down P/Level (Feet)	G-G/H	S/Depth (Feet)	Date of Installation
1	Gate No. 1	315	50	80	5000	150	28-12-2007
2	TIC Building	350	50	140	5000	300	28-02-2008
3	Near HBL	350	90	140	2000	250	28-02-2008
4	Back Side Ghazali - 3	330	80	200	2000	300	27-11-2008
5	Izhar Road	350	20	75	5000	200	02-02-2009
6	Gate No. 8 Round About	360	20	150	3000	250	09-02-2009
7	Back Side Izhar Construction	345	20	170	3000	250	19-06-2009
8	Near Lake	300	35	60	5000	200	18-05-2009
9	Near Ghazali Hostel	300	60	45	1200	250	08-2009
10	Near Loc-3	350	60	40	4000	200	04-2010

Fig 36 Water table data

5.4 Deduction

With the information stated above and the fact that the water table being 80 feet below the natural ground level, it can be safely assumed that even in the worst of conditions the water table will not rise high enough i.e. within 4.5' of the rafts of squash court and Ghazali hostel to cause trouble.

CHAPTER 6

COST ESTIMATION

6.1 Quantity Estimation

The areas and volumes listed in the table below are worked out from the structural drawing of the embankment.

Description		Area (sq. ft.)	Length (ft.)	Unit Weight (lb/cft)	Quantity (tons)	Volume (cft)
Earthwork	Excavation	102	240	131.4	1608.336	24480
	Cutoff Excavation	37.105848	240	131.4	585.0850113	8905.40352
	Cutoff Fill	37.105848	240	131.4	585.0850113	8905.40352
	Embankment Fill	1140	240	131.4	17975.52	273600
	Spillway Excavation	44	100	131.4	289.08	4400
Riprap		73.92975572	240	162.4	1440.743079	17743.14137
Stone Masonry Wall		15	240	180	324	3600
Spillway Masonry		14.25	100	180	128.25	1425
Gravel Drain		27.5	240	152.6	503.58	6600
Sand and Gravel finish		72	240	150	1296	17280

Fig 38 Quantity Estimation

6.2 Cost Estimation

The costs listed in the table below have been calculated on basis of rate provided in the Market System Rates (MSR) 2016 for Rawalpindi released by the Finance Department of Punjab

Item	Quantity (m^3)	Rate	Cost (Rs.)
Total Earthwork	9069.9	154.6	14.02 Lacs
Rip Rap	1644.8	1250	20.56 Lacs
Stone Masonry Wall	101.9	3640.55	3.71 Lacs
Sand and Gravel Finish	40.7	1517	0.62 Lacs
Spillway Masonry	33.3	3540.55	1.18 Lacs
Gravel Drain	186.9	1250	2.33 Lacs
		Contingency (15%)	6.36 Lacs
		TOTAL	48.78 Lacs

Fig 39 Cost Estimation

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Catchment Size = 1.96 sq. km.

Catchment Yield = 196000 m^3

Storage Capacity = 9555 m^3

Storage Rating = 3.8 (moderate)

Minimum FOS = 3.41

Maximum FOS = 9.96

Cost of Construction = 48.78 ≈ 50 Lacs

Dam is safe against

1. Slope Failure
2. Seepage Failures
3. Seismic Loading

Dam has no ill effects on foundations of nearby buildings. It fulfills all the objectives established before i.e.

1. It recharges the aquifer
2. It adds scenic beauty
3. It stores water which can be utilized for various purposes

7.2 Recommendations

Two out of the ten tube wells seasonally become artesian in the presence of the already present three dams even under 24 hour pumping indicating abundance of the groundwater reserve.

Moreover, never has the groundwater risen high enough to cause any sort of damage to buildings located near the dams.

The present dams have run out of room for any future expansion due to site constraints. Therefore, if, in future, need arises the only solution will be the construction the proposed dam.

The proposed dam is safe and easy to construct with the embankment material available in abundancy near the site.

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