Nashe Dam Fail and Risk Analysis

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Abstract: Nashe earth fill dam was constructed for the aim multi-purpose use (hydroelectric power and irrigation). While the construction of this dam many peoples around Dam were immigrated from their residential to another places including to the town. This research focused on the dam fail analysis by considering overtopping and piping failure mode. The input data were collected from Min. of Water and Energy, Federal Democratic Republic of Ethiopia (FDRE). The dam breach parameters were determined by applying the principle with Von Thun and Gillette. In dam break analysis the first step is model setup by using three dimensions (x, y and Z) of the downstream. By applying overtopping model, the peak discharge $8761.23 m^3$/sec was obtained, which was more than 7.33 times the probable maximum flood and by applying piping mode, the peak discharge was obtained is 8620.85 m^3/sec which was more than 7.21 times the probable maximum food at the nearby location of the dam. This indicates that, the peak outflow development during raining season was greater than inflow discharge flood (IDF) used as upper boundary condition for breach parameters. So it was summarized that high peak outflow and risk were developed to downstream by overtopping mode as compare by piping mode during occurrence of dam breach. As from the sensitivity analysis it was concluded, the effect of breach time on discharge is more sounded than the water level increase. This Dam Break modeling results obtained by studies could be used as flood mappings to assist the societies/communities for future planning developments in the flood prone areas/zones in advance.

Keywords: Dam Fail, Analysis, HEC-RAS, Hydrograph, HEC-Geo RAS, Sensitivity Analysis

1. Introduction

Dam provides many benefits like-hydropower, irrigation, water supply, recreational purposes etc. currently, the construction of earth dams is familiarized in Ethiopia due to availability of suitable and huge construction materials as well as topography. However, it is more concentration to be taken for breaking of earth dams comparing with other types of dams because of disappointment of constructed earthen dam due to serious flood, causing mass disaster of life as well as properties for the last two centuries [18]. Imitation of dam break and impacts of flood are essential to characterizing and reducing harmful effects due to dam collapse. Development of tragedy (emergency) action plan requires during stream level and the time of flood wave arrives to the downstream effected people to shift at the safe locations. All dams and reservoirs subject to this regulation shall be classified according to their size and hazard potential [19].

Different Case studies show that dam failure may arise due to different reasons. In this research two cause of failure conditions as due to Piping & Overtopping have been analyzed. Piping is a flow of water in porous parts of the dam body especially through high permeability regions, cavities, fissures or strata of sandy and gravelly materials. Such concentrated flow at hydraulic gradient may erode the soil part of the dam which causes the breakage of the earth dam.

Overtopping is uncontrolled flow of water over the crest of the dam or embankment. Overtopping may lead to failure of the dam due to excessive erosion or saturation of downstream slope. The main causes of overtopping are generally due to:

i. Insufficient rainfall data available more that 25-30 years
ii. Large and rapid landslides in the reservoir
iii. Insufficient free board and
iv. Malfunctioning of the spillway gates.

2. Literature Review

In dam safety programs, dam break modeling is essential to evaluate dam induced risk and to support emergency plan and optimizing response efforts by teams to that affected areas due to the consequences if the Dam may break. However, a better understanding of flood predictability and model efficiency is needed before system effectively implemented. The dam break tool in HEC-RAS was applied to Foster Joseph Sayers Dam break simulation and analysis based on the given geometry data [18]. Dam break has a greater impact on the downstream location closer to the dam in accordance with the comparison of the hydrographs at different downstream locations [18].

Since, HEC-RAS assumes the entire cross section to convey flood waters that may be unrealistic [3]. Therefore ineffective flow areas were used to define conveyance areas [3]. The addition of ineffective flow area may be allowed to the entire floodplain to be considered as storage [3].

Kamanbedast & Bryanvand, 2014 showed that the numerical modeling of earthen dam break performed in two stages; firstly, pay attention to dam gradual break mechanism and computing outlet hydrograph and secondly, study impact of results due to this hydrograph in dam downstream. Dam break is a complicated and comprehensive process and actual failure mechanics are not well understood [18]. Neither current physical based models nor empirical models fully explained about dam break mechanisms and impacts [18].

Simulation of Embankment dam breach events and its results in form of floods are crucial to characterizing and identifying threats due to dam failures potential [3]. Depending on this simulation it is possible to give emergency action plan for peoples those live in downstream of the dam. Among design parameters, the hazard classification of a dam determines the inflow design flood (IDF) which is the base for spillway sizing [3].

3. Study Details

3.1. Objective of the Study

The overall goal of the study is to analyze the Nashe dam break using hydraulic models by HEC-RAS model. The specific objectives are:

i. To forecast peak outflow discharge hydrograph during dam failures by either overtopping or piping mode of failure, and;

ii. To estimation the hydraulic sensitive analysis at different downstream locations of the Dam.

3.2. Significance of the Study

Studying of the Nashe dam crack analysis helps to give effective tragedy action plan. Thus the findings of the study are significant for the following reasons:

i. If the dam fails unluckily, the peoples living in Fincha'a valley could be exaggerated with loss of human life, properties etc;

ii. The flood due to breakdown of dam can affect the agricultural land including irrigable cultivated areas at the downstream (that is sugar-cane produced for Fincha'a sugar factory) and infrastructure constructed in Fincha'a valley;

iii. It can affect the ordinary resources such as forests and animals;

3.3. Purposes of Dam Breach Analysis

The way and rate at which a dam break can affect the timing of the fall foul of, the rate and magnitude of the flood water released and the size of the breach itself. Therefore, this analysis could be used to control the flood and avoid the loss of life as well as damage of properties.

Each use has unique information requirements and may be used in different manners ranging from multi-year office based planning efforts by mitigation planners and Dam safety officials to field-based emergency responders responding to a developing dam breach.

Low Hazard Dam is a dam for which loss of human life is not expected, and significant damage to structures and public facilities as defined for a "Significant Hazard" dam is not expected to result from failure.

3.4. Dam Breach Mechanisms

3.4.1. Overtopping Failure of Embankment Dam

Overtopping failures of earthen dams typically begins with head cutting at the downstream toe and advancing upstream erosion up to the dam crest and reservoir surface. A dam failure at embankment slide can also lead to an overtopping type of failure when the slide encroaches upon high water line. Once the reservoir is continue to ongoing breach, down cutting of erosion of the embankment occur until the breach expands to the final dimension.

3.4.2. Piping and Internal Erosion of Embankment Dam

Generally, piping and internal erosion occurs when concentrated seepage develops within an embankment dam. The seepage slowly erodes the dam, leaving large voids in the soil. Piping is inter-granular seepage that occurs through a soil body along with flow paths as followed to backward erosion because the erosion typically occurs from downstream to upstream (analogous to head cutting). The internal cracks developed within a compacted fill, foundation, or a contact between a fill materials and foundation. This occurs when the water flowing through the cracks or defective erodes, the clay as well as other fill materials start flowing.

Piping failures are typically modeled in two phases, before and after the dam crest collapses. Water flow through the piping hole is modeled as orifice flow before the dam crest collapses and as weir flow after the dam crest collapses. For small dams constructed from cohesive soils, it is possible for the reservoir to completely empty before the dam crest collapses.

3.4.3. Dam Failure Inundation Map

Dam failure inundation map is depicting the area of

downstream from a dam that would reasonably be expected to be flooded in the event of a failure of the dam. Inundation mapping of water surface profile from a dam failure models may be used for a preliminary assessment of the flood hazard and also used to provide insight for emergency preparedness.

3.4.4. The Nashe Dam

The Nashe Dam is located on the Blue Nile River Basin about 310km north-west of Addis Ababa, in the Oromia Region, The topography of dam is on valley elevation 2200m above mean sea level (msl) and the surrounding ridges extending to over 2500m msl and average annual rainfall in the area is about 1350 mm. Th eNashe dam is a homogenous earth fills (embankment) dam followed by spillway, constructed with protection of horizontal and vertical inclined filter blanket on the Nashe River located near the village Igu in district of Abbay Choman, Ethiopia. The lateral length of Nashe dam is 1000m with a maximum height of 35m and protected by random rip rap rock fills on upstream and downstream faces. The dam is constructed for the purpose of hydropower and irrigation.

Construction material like blasted rocks and clay for the dam construction are used from the rock quarry site and borrow pits from the right and left banks of the dam. The type of the dam has been decided based on the topographical, geological conditions of the area and availability of the construction materials nearby the site.

The power generation of dam is 100MW and irrigating around 5200 hectares area to downstream of the dam after development. The location of dam in Ethiopia map is given below.
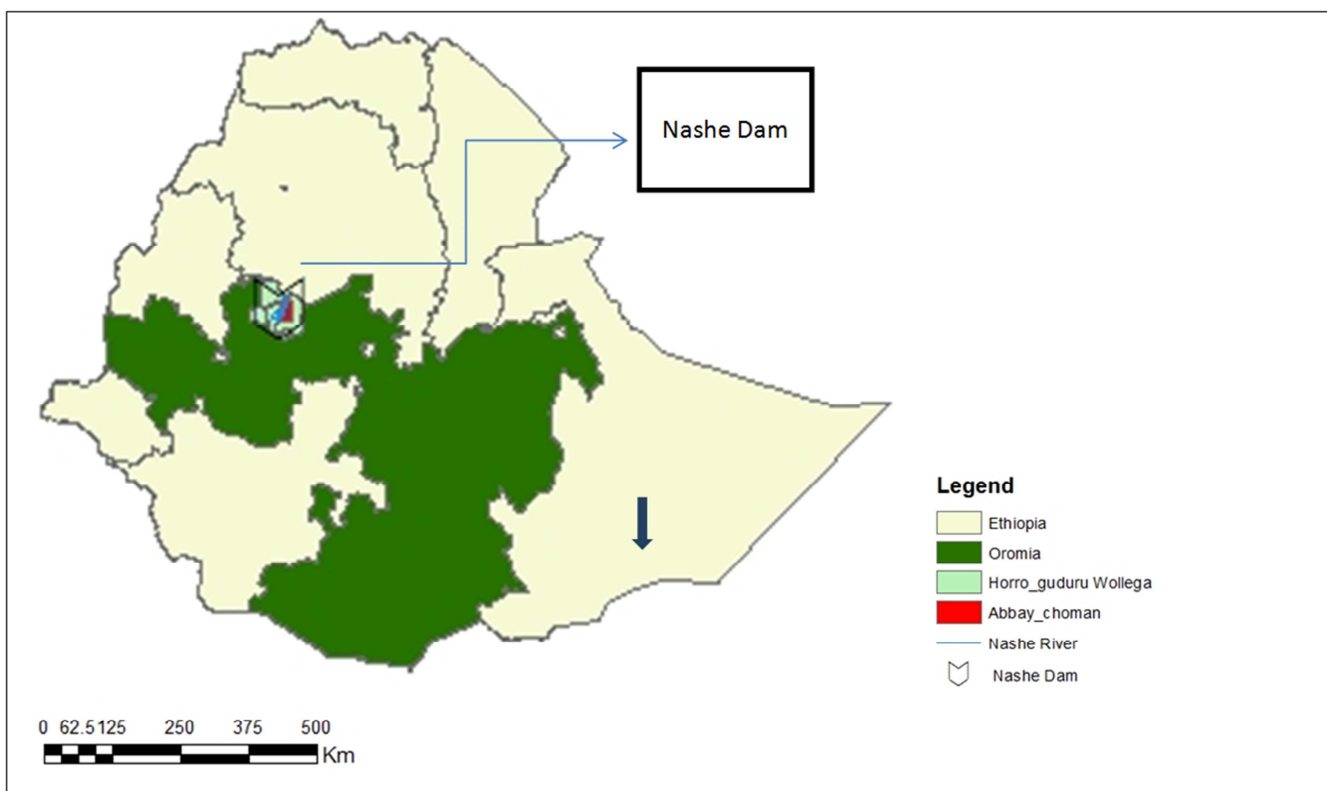

Figure 1. Location of Nashe Dam.

4. Methodology of Study

This research on the dam break analysis using by Hydraulic Engineering Center-River Analysis System (HEC-RAS) model has focused on the risk of overtopping and piping effects on the dam for which different parameters are used to analyze the failure phenomenon. The all relevant and necessary required information and data have been collected from different government organizations. After getting the all relevant data, dam break analysis has been used by apply and setup the Hydrologic Engineering Center River Analysis System (HEC-RAS) software as a Hydraulic model of the studies.

4.1. Data Requirements

4.1.1. General Information

Data related to dam failure are generally significantly needed. The information that included in the dam break analysis are as follows:
i.   Available historic flood levels.
ii. Hydrographical data.
iii. Dam information such as height, length, width and types of dam.
iv. Reservoir impoundment.
v.   Downstream cross sections

The all above information are collected from different department of Federal Govt. of Ethiopia for purpose of

research study as mentioned with their respective analysis below.

4.1.2. Data Collection

The appropriate data are collected from Ministry of Water, Irrigation and Energy and Ethiopian Electric Power Corporation.

i. Probable Maximum Flood (PMF)

Table 1. *PMF for Nashe River [13].*

Time (hr.)	Inflow (m^3/s)	Time (hr.)	Inflow (m^3/s)
0:00	125	13:00	1146
1:00	140	14:00	850
2:00	150	15:00	725
3:00	180	16:00	600
4:00	225	17:00	500
5:00	300	18:00	400
6:00	400	19:00	300
7:00	500	20:00	225
8:00	600	21:00	180
9:00	725	22:00	150
10:00	850	23:00	140
11:00	1146	24:00	140
12:00	1196		

The probable maximum flood (PMF) shown in Table 1 is used for the design of dam spillway, which is used to remove/exit the excess water during different purposes such as emergency case.

ii. Peak Flood Flow

Annual flood for different return period and probable maximum flood (PMF) are listed in the following table.

Table 2. *Peak Discharge at different return Period [13].*

Return period [Years]	Peak discharge [m^3/s]
25	219
50	247
100	276
PMF	1196

iii. Reservoir

The reservoir is normally modeled in HEC-RAS as elevation versus volume curve of the Nashe Reservoir. Table 3 shows the elevation versus volume curve data for reservoir

Table 3. *Elevation volume Curve of Nashe Reservoir [13].*

Elevation (m)	Volume (1000m^3)
2083.08	0
2090	90000
2100	210000
2105.2	360000
2110.75	448000

4.2. Dam Break Analysis

4.2.1. General

The all dam has a risk and damage to downstream side. Generally the risk regions are classified into four grades including low risk, average risk, high risk and very high risk. These risks can be measured by three parameters such as escape of time, speed and depth of annealing as appropriate criteria for risk of dam break. To overcome these risks in terms of the listed parameters we used different research studies by Hydraulic Engineering Model (HEC-RAS) with different methodology.

4.2.2. Hydraulic Model: HEC-RAS

Hydrologic Engineering Center River Analysis System (HEC-RAS) is an integrated system of software designed for interactive use in multi-tasking comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities and graphics facilities.

The HEC-RAS program contains four 1-dimensional river analysis components for the following:

i.   Steady flow water surface profile computation
ii. Unsteady flow simulation
iii. Moveable boundary sediment transport computations and
iv. Water quality analysis.

In addition to the four river analysis components, the model contains several hydraulic design features that has been invoked after the basic water surface profile computed.

4.2.3. Model Setup

For setting up hydraulic model for dam break analysis as per the requirement, different components of the project have been represented in the model as follows:

i. Nashe River

Cross Section

This study is carried out by digital elevation model (DEM) of Ethiopia with the shape profile of Nashe River. This cross section is used as input data for HEC-RAS software.

In hydraulic model setup the first step is creating the Nashe River in HEC-RAS. The Nashe River downstream of dam with 26 km long and cross sections at 124 points (locations) at different varying distance perpendicular to the river channel have been taken and used for setting up of the HEC-RAS Model. Out of 124 cross sections of the river, 5 locations are for Upstream of the dam and remaining 119 cross sections to the Downstream of dam divided at different varying distance having maximum distance of 500m depending upon topography considering as highly sensitive, unstable and unsteady in nature of that river geometry close to the real conditions shown in Figure 2.

In the present study the river is traced with the help of HEC-RAS software using Digital Elevation Model (DEM) of that location. The river cross sections are auto generated in the software with the use of the cross sections prepared from DEM.
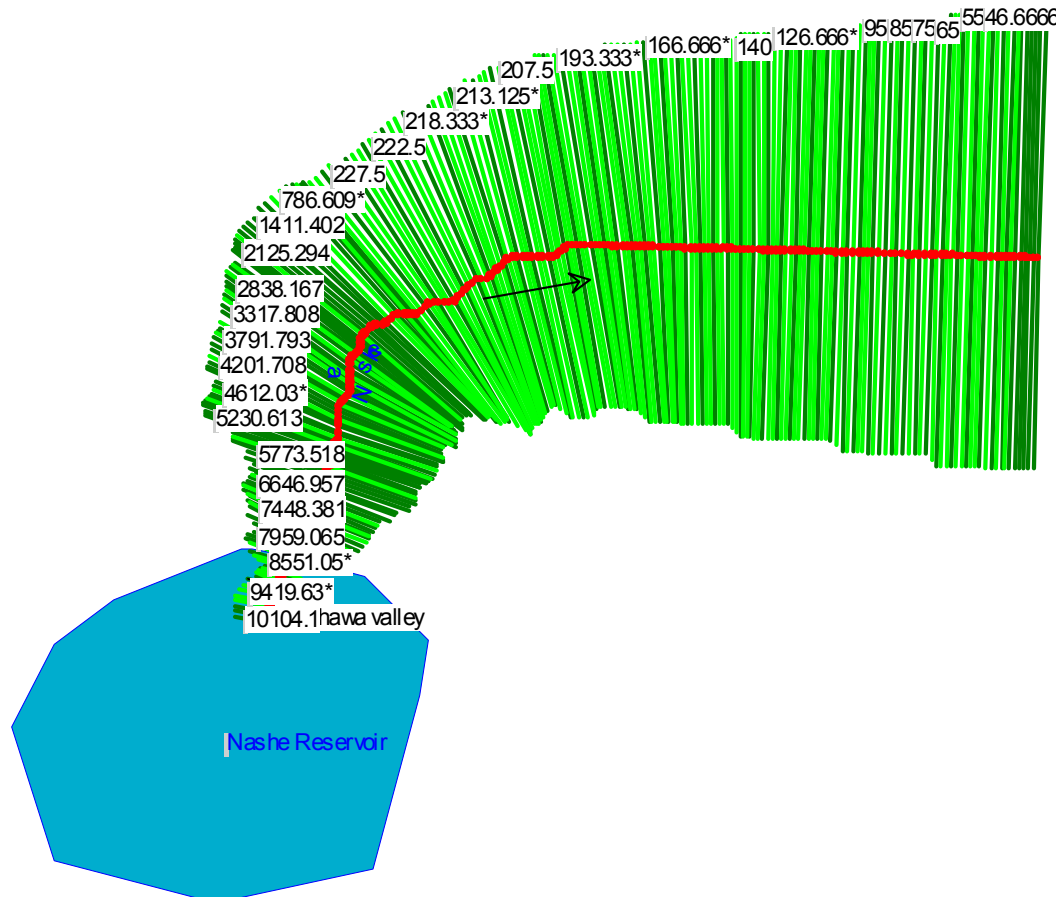
Figure 2. *River Network for Nashe River in HEC-RAS Model.*

Downstream Boundary Condition

Normal depth is used as downstream boundary condition for this research. For this frictional slope 0.02 is used as normal depth.

ii. Dam Reservoir

Upstream Boundary Condition

Probable Maximum Flood (PMF) is considered as upstream boundary condition for the HEC-RAS dam break simulation model and it has been considered as inflow to the reservoir which is used for design of spillway capacity.

iii. Evaluation of Breach Parameters for Dam

In dam break analysis the estimation of the breach location, size and time are crucial in order to evaluate an accurate outflow hydrograph and downstream inundation. HEC-RAS software requires the user to enter the following information:

i.   Location: center line station of the breach in the Dam.
ii. Failure mode: overtopping or piping
iii. Shape: bottom elevation, bottom width, left and right side slope H:V
iv. Time: critical breach development time
v.   Trigger mechanism: pool elevation, pool elevation plus elevation or clock time
vi. Weir or pipe coefficient:
  1. Weir coefficient are used to compute if the failure mode is overtopping and

  2. Pipe or orifice coefficient for piping failure mode

Failure Location

The breach failure location is based on many factors such as type and shape of dam, failure type, mode and driving force of the failure. For this study if considered as the failure is at center of the dam and expands equal in both direction.

Failure Mode

While HEC-RAS hydraulic computations are limited to piping and overtopping modes, all other type of failures is simulated by one of these two mechanisms for starting and growing breach for both overtopping and piping method. Overtopping failure start at a top of the dam and grow to the maximum extents while, piping failure mode start at any elevation/location and grow to the maximum extent up to the river bed.

The breach parameters such as breach width and breach development time have been calculated empirically by the regression analysis method other than the HEC-RAS and entered into the program by following scientists:

i.   Froehlich (1995a)
ii. Froehlich (2008)
iii. MacDonald and Langridge-Monopolis (1984)
iv. Von Thun and Gillette (1990)
v.   Xu and Zhang (2009).

Among these regression equations the Froehlich (2008) and Von Thun and Gillette are compared for this study to determine the breach parameters such as critical breach width

and breach development time both for overtopping and piping method.

Determination Breach Width and Time by Froehlich (2008)

Froehlich utilized 63 earthen dam data sets to develop as set of regression equations to predict average breach width, side slope and time of failure. According to this regression analysis it is found suitable to satisfy the following conditions:

i. Height of dams: 3.05 -92.96 meters

ii. Volume of water at breach time: 0.0139- 660.0 $X10^6$ m^3

Depending on the above conditions the following regression equations have been developed for average breach width and failure time are:

$$B_{ave} = 0.27 K_o V_w^{0.32} h_b^{0.04} \qquad (1)$$

$$t_f = 63.2 \sqrt{\left(\frac{V_w}{gh_b^2}\right)} \qquad (2)$$

Where,

B_{ave}= average breach width (meters)

K_o= constant (1.3 for overtopping and 1 for piping failure)

V_w =volume of reservoir at time of failure (cubic meter)

H_b=height of final breach (meters)

g = Gravitational acceleration (9.80665 meters per second squared)

t_f = breach formation time (seconds)

The average side slope taken as 1H:1V for overtoppingand 0.7H:1V for piping failure respectively.

Determination of Breach width and Time by Von Thun and Gillette (1990)

Von Thun and Gillette used 57 earthen dam data sets to develop as set of regression equations to predict average breach width, side slope and time of failure with same side slope of 1H:1V and established the regression equation suitable for the following ranges:

i. Height of dams: 3.66-92.96 meters

ii. Volume of water at breach time: 0.027 - 660.0 $X10^6$ m^3

The equation developed by Von Thun and Gillette for average breach width:

$$B_{ave} = 2.5h_w + C_b \qquad (3)$$

Where,

B_{ave} =Average breach width (meters)

H_w= Depth of water above the bottom of the breach (meters).

C_b = Coefficient is a function of the reservoir size of the dam. Its value is ranged between 6.1 and 54.9m depending on the value listed in the Table 4.

Table 4. Coefficient as a function of reservoir size [12].

Reservoir Size (cubic meters)	C_b (meters)	Reservoir size (acre-feet)	C_b (feet)
$< 1.23 \ x \ 10^6$	6.1	<1000	20
$1.23 \ x10^6 - 6.17 \ x10^6$	18.3	1000-5000	60
$6.17 \ x10^6 - 1.23 \ x10^7$	42.7	5000-10000	140
$> 1.23 \ x10^7$	54.9	>10000	180

Since the storage capacity is greater than $1.23 \ x10^7$, so its C_b valueis taken as 54.9m.

As per regression calculation, the average breach width is 142.4m and bottom breach width is 107.4m.

They also derived two equations for breach time depends on the degree of erosion resistance as follows.

$$t_f = 0.02h_w + 0.25 \qquad (4)$$

$$t_f = 0.015h_w \qquad (5)$$

Where,

t_f =Breach formation time (hours)

h_w =Depth of water above the bottom of breach (meters)

Breach Weir Discharge coefficient (C)

This is required as input data in the HEC-RAS model to get magnitude of peak outflow hydrograph for any given breach. During piping breach failure the rate of flowing water through the dam is modeled by applying an orifice pressure flow equation to get discharge coefficient and measure the flow efficiently into the pipe orifice.

Recommended values for the piping/pressure flow coefficients and over flow/overtopping weir coefficients is tabulated in table 5.

Table 1. Dam Breach Weir and piping coefficients [12].

Dam type	Over flow/overtopping weir coefficients	Piping/pressure flow coefficient
Earthen clay/clay core	2.6 – 3.3	0.5 – 0.6
Earthen sand and gravel	2.6 – 3.0	0.5 – 0.6
Concrete arch	3.1 – 3.3	0.5 – 0.6
Concrete gravity	2.6 – 3.0	0.5 – 0.6

Since the storage capacity of the embankment dam is medium height type, the selected value of weir coefficient taken for overtopping as 2.6 and piping flow coefficient as 0.5.

Determination of manning coefficient

Manning's roughness coefficient value is used for flow calculation during flood as in open flow channels.

Manning roughness coefficient for Nashe river course which has Rocky River bed with Grassy banks usually steeps, trees and brush along banks submerged has been taken as 0.0333 as suggested between the range of 0.03 and 0.05.

5. Results and Discussions

5.1. Breach Width and Breach Development Time

The calculated breach width and breach development time by Froehlich (2008) are 237.4m, 3.39 hour for overtopping and 182.6m, 3.39 hours for piping respectively

The calculated breach width and breach development time by Von Thun and Gillette are 142.4m and 1 hr for both overtopping as well as piping

The bottom breach width is calculated by using average breach height, average breach width and side slope. By using these parameters the calculated bottom width used for HEC-RAS model as input is 202.4m and 134.04m for overtopping and piping respectively used by Froehlich (2008). The bottom width and breach development time used for HEC-RAS model as input by VonThun and Gillette are 107.2m and 1hr for both overtopping and piping failure mode.

By comparing this two regression equations, the Von Thun and Gillette is selected for Dam break analysis of Nashe Dam, because of less breach time and more the risk involvement.

5.2. Overtopping Failure Mode

In this mode the most critical situation for the dam break is if the reservoir is at full reservoir condition and probable maximum flood (PMF) impinges over the reservoir. As the spillway capacity is 1196 cumec (m³/sec) which is similar to the peak value of PMF. So it is obvious that spillway will discharge the peak of PMF without overtopping the dam crest level. For this study under this method it is assumed that due to malfunction of the spillway at the time of PMF, the dam is just slightly overtopped by PMF and then the dam is failed due to overtopping. Parameters such as bottom width of dam breach and breach formation time calculated by Von Thun and Gillette regression equation are used as input data in hydraulic model (HEC-RAS). The water level at the dam when dam breach started was found to be 2110m and breach continued up to bed level by the hydraulic model (HEC-RAS) software.

5.2.1. Dam Breach and Flood Hydrograph at Dam Site by Overtopping

The dam breached at water level of 2112.69m at the stage of overtopping of PMF of the dam. The maximum discharge flow out from the breached dam is 8761.23cumec (m³/sec) which is 7.33 times the PMF. The maximum discharge is attained within 20min by the hydraulic model (HEC-RAS) software from the start of dam break and the water is coming out with a maximum velocity 10.21m/secas per HEC-RAS software applied. The result obtained as shown in Figure 3.

5.2.2. Routing of Flood Hydrograph at Different Chainages by Overtopping

Routing of flood hydrograph are analyzed at four chainages points, 5.09Km, 10.09Km, 20.49Km and 25.71Km downstream of the dam site. At dam site the peak discharge of 8761.23m³/s was found within 20 minutes from the starting time of dam break. At 5.09km downstream location, the peak flood discharge 8463.07 m³/s that was 3.4% less than the peak discharge flow out during the breach of dam and it reached within 25minutes. This flood reaches 10.09km within 30 minutes with flow discharge 8012.37 m³/s. Now, if go further downstream of the dam then it is seen that the arrival of peak discharge 6565.35m³/s occurs at 20.49km within 50 minutes and at 25.71km downstream, the peak discharge 5474.66m³/s occurs in 60minutes as shown in Figure 4.

Generally starting from dam site to further downstream of the dam the peak discharge decreases. This shows that the disaster and its risks go decreasing. The data is further analyzed with the longitudinal bed profile, water level and cross sections of the river and flood map in further followed section.
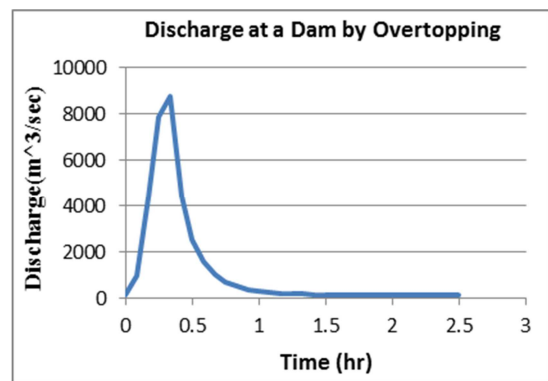
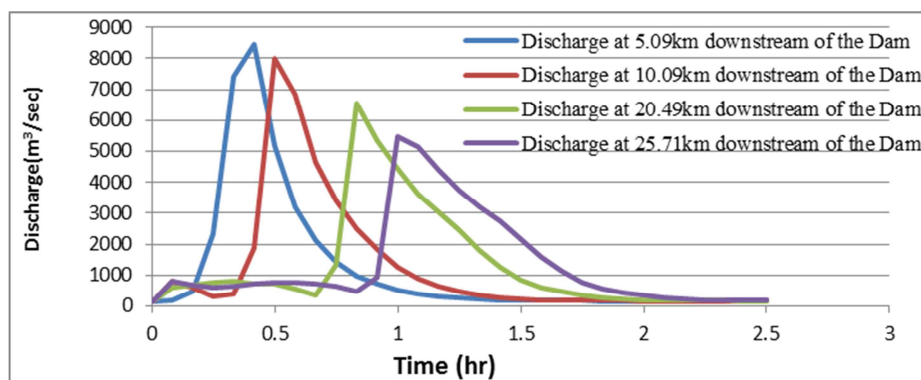**Figure 3.** *Flood Hydrograph at Dam site by Overtopping.*

Figure 4. *Flood hydrograph at different Ch.by Overtopping at d/s.*

5.2.3. Longitudinal River Bed and Flood Cross Section Profile

Figure 5 shows the longitudinal profile of Nashe River including bed level, minimum bank level, and maximum water level during dam break period. It was observed during longitudinal profile study as per topography that the flood water flows out from dam and enters into plains area of around 250m downstream. From 250m to 4.2km at downstream, it runs through steeply longitudinal bed and at further downstream, the longitudinal bed slope become flat.
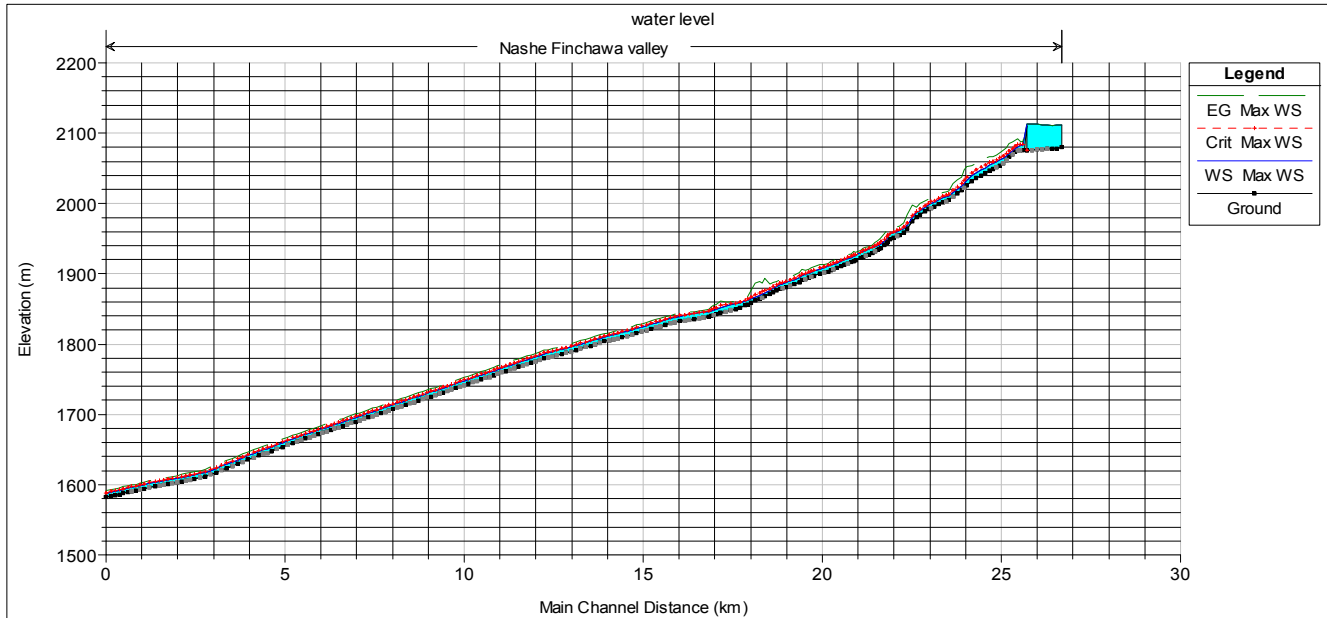
Figure 5. *Longitudinal bed profile of Nashe River showing MWL.*

Figure 6 to Figure 9shows the cross section of river at 5.09km, 10.09km, 20.49km and 25.71km respectively with maximum water level profile. As it was obsreved from these cross sections that their water stage is decreasing as we go to downstream. The water depth of these cross sections are 6.34m, 6.88m, 5.93m and 5.47m and their coresponding top flooded widthwith water are 205.00m, 211.97m, 199.81m and 193.90m respectivelytothe affected flood area due to dam break.
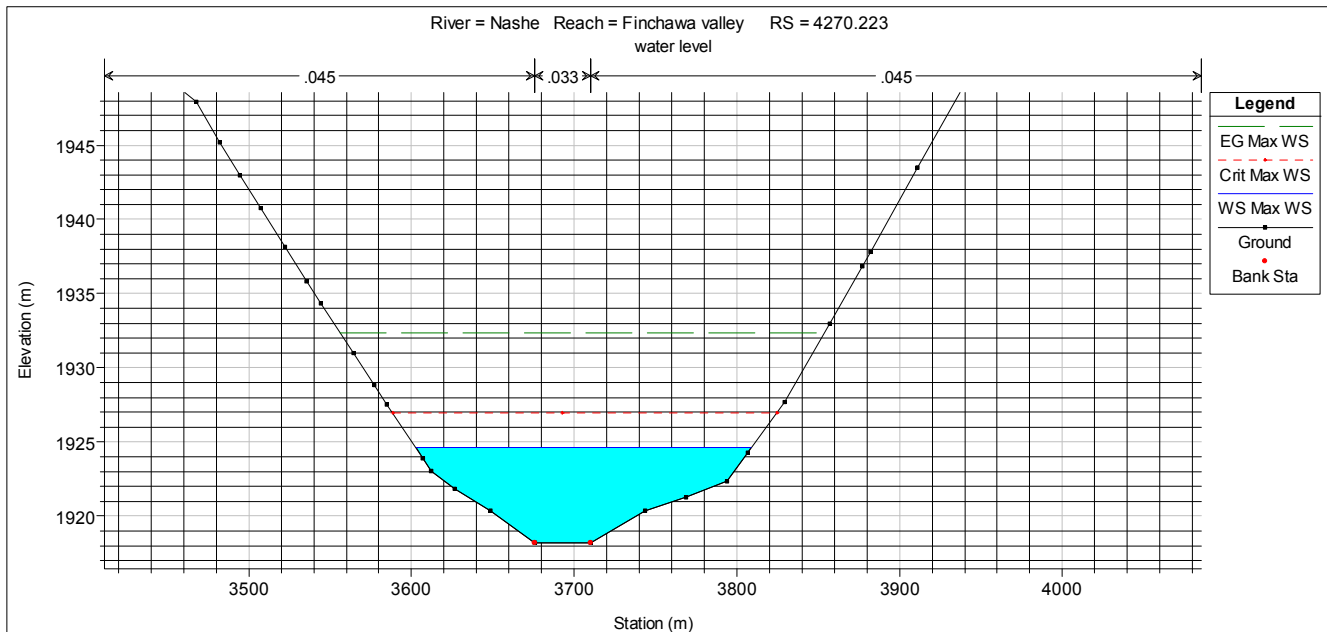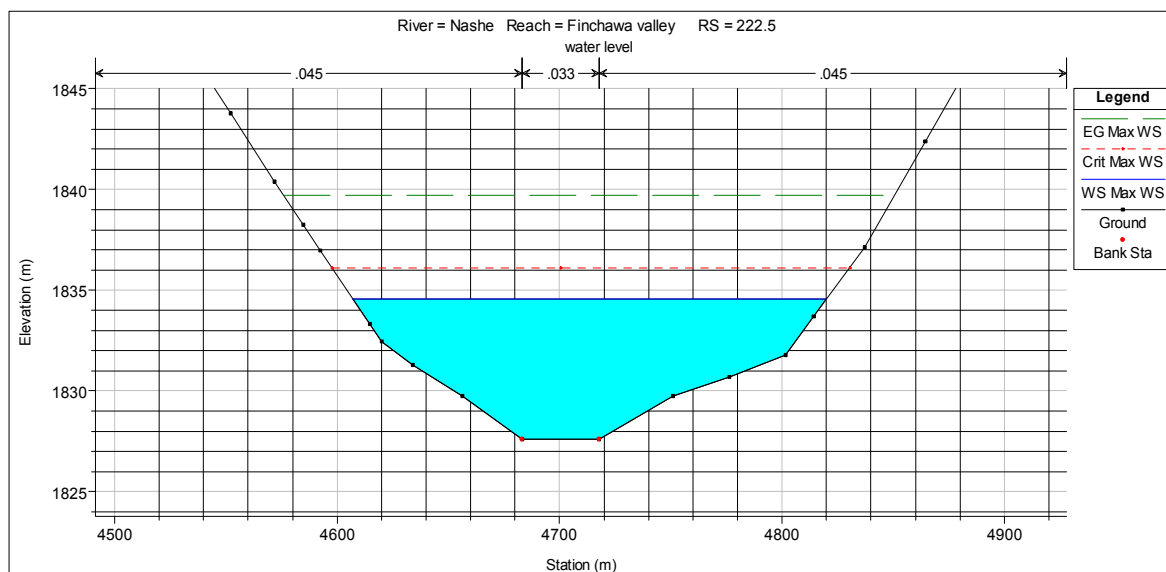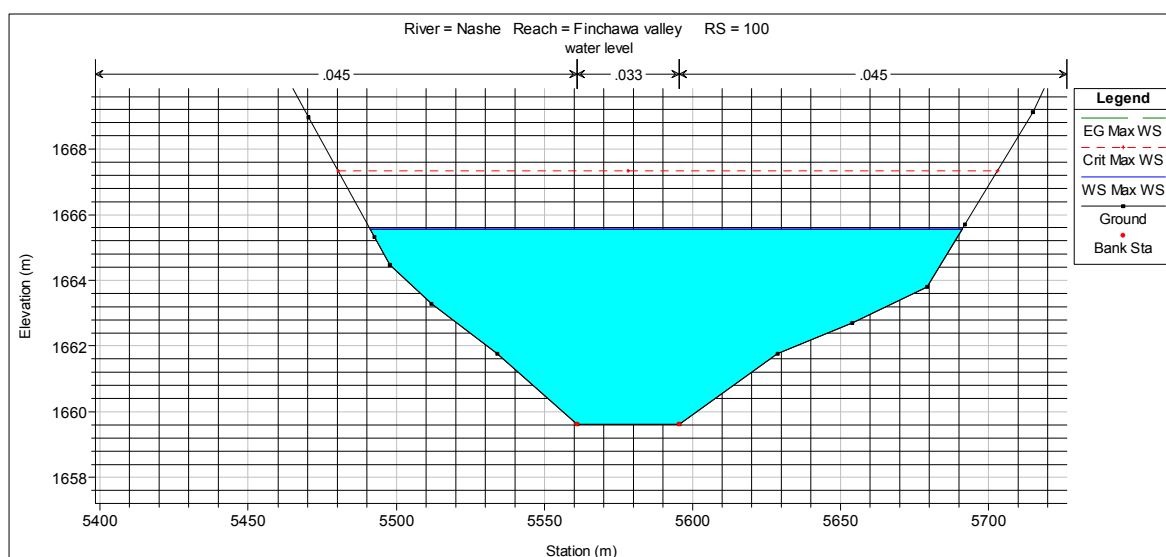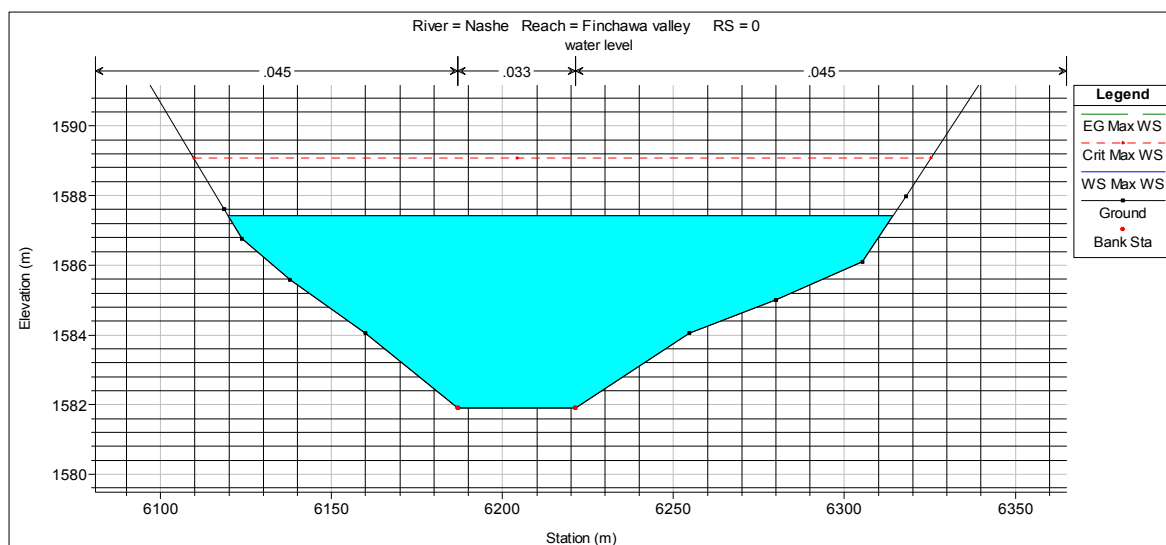

Figure 6. *River C/S at 5.09km from the Dam.*

Figure 7. *River C/S at 10.09km from the Dam.*

Figure 8. *River C/S at 20.49km from the Dam.*

Figure 9. *River C/S at 25.71km from the Dam.*

The water surface profile with their discharge up to 5.09km have been drawn and shown in Figure 10 below and peak discharge in the whole cross section is shown in Figure 11. But since figure 11 represent the whole cross section that is not as much visible like other.
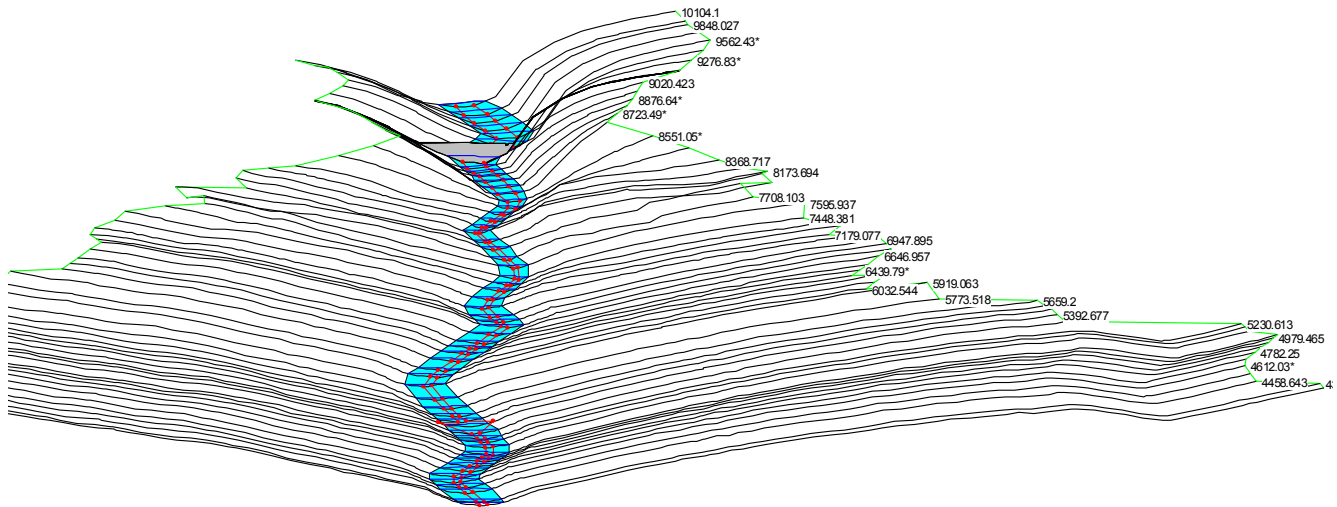

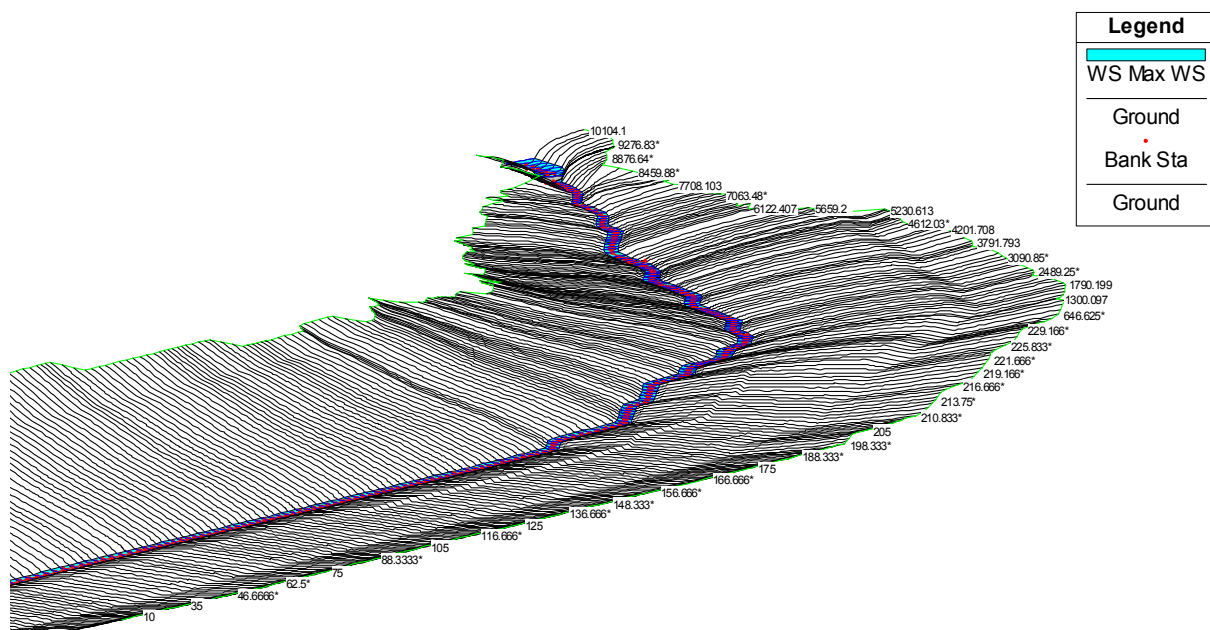*Figure 10. WSP of peak discharge up to 5.09km d/s from Dam.*

Figure 11. WSP of peak discharge of the whole cross section at d/s from dam.

5.3. Piping Failure Method

The breach by this method depends on the sunny day condition rather than rainy day condition which is most critical condition for piping asstated by Von Thun and Gillette method after putting the all input parameters in the HEC-RAS model studies for the dam break analysis. It was observed by HEC-RAS software model study that the water level attained at RL 2106m when dam breach just started and breach was eroded up to the river bed level.

5.3.1. Dam Breach and Flood Hydrograph by Piping Method

The maximum discharge 8620.85m³/s was observed during the breached dam, which was 7.21 times the PMF flows out by piping method the water level attained 2102.82m. The maximum discharge flow observed within 15min from starting of dam breach and the water was flowing with max. Velocity of 13.54m/s. The peak discharge attained by this mode is 1.6% less than the peak discharge attained during overtopping. This indicates that dam breached by overtopping is more devastating than breached by piping. The result obtained as shown in Figure 12 below at dam site.
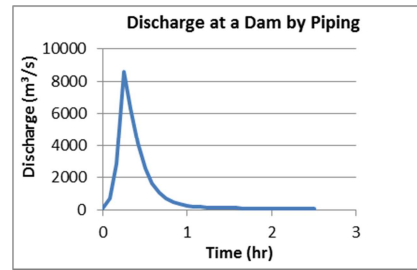
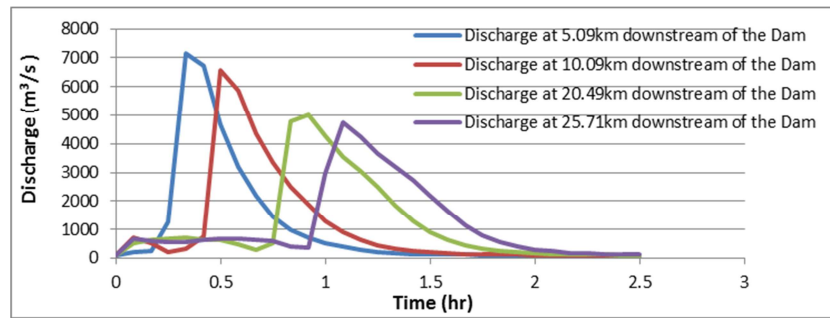**Figure 12.** *Flood routing at Dam site by piping.*

Figure 13. *Flood hydrograph at different Ch. d/s of dam by piping.*

5.3.2. Routing of Flood Hydrograph at Different Chainages by Piping Method

The flood hydrograph under this piping routing is analyzed at four chainage points: 5.09km, 10.09km, 20.49km, and 25.71km downstream of the Nashe dam. At dam site the peak discharges 8620.85m³/s is attained within 15 minutes from the starting time of the dam breach. At 5.09km the peak discharge 7148.99m³/s observed which is 17.07% less than

the peak discharge at the dam and attained within 20 minutes during dam breach. As going further distance to 10.09km, 20.49km and 25.71km downstream of the dam, the corresponding peak discharges are: 6591.09m³/s, 5021.39m³/s and 4729.99m³/s and flows out within 30 minutes, 55 minutes and 65 minutes respectively. Figure 13 shows flood hydrograph at 5.09km, 10.09km, 20.49km and 25.71km downstream of the dam.
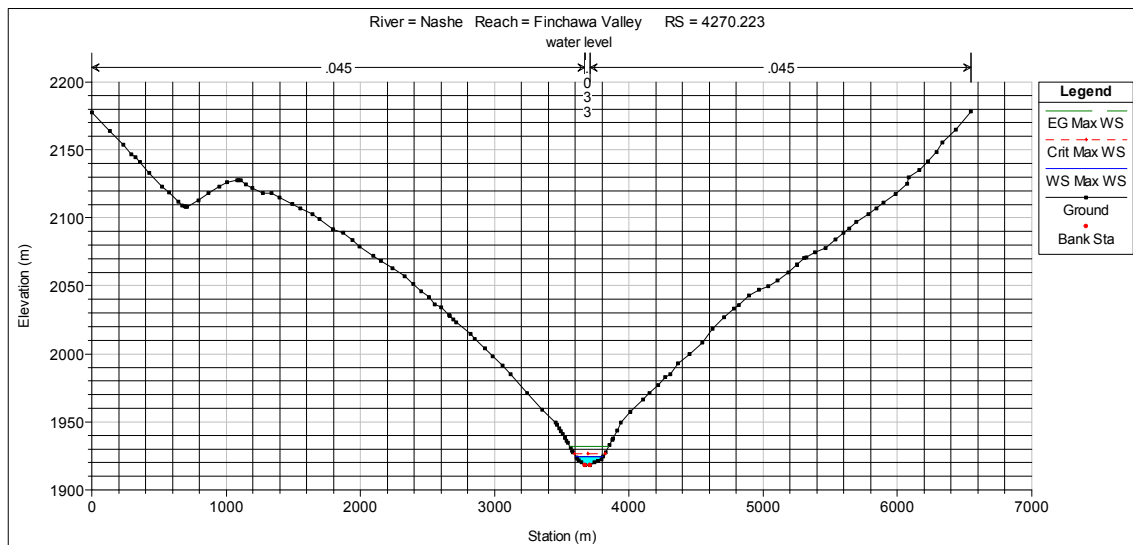

Figure 14. *River cross-section at 5.09km from the Nashe River.*

5.3.3. Flood Cross Section Profile

Figure 14 to Figure 17 show the cross sections of each location with their water level and top width. The water depth were obtained as 6.08m, 6.40m, 5.44m and 5.14m respectively with their respective location at 5.09km, 10.09km, 20.49km and 25.71km and attained the corresponding top width as 198.06m, 204.35m, 191.41m and 189.58m.

During analysis of the dam breach for Nashe Dam by applying both failures mode. It was observed that overtopping has greater water depth and top width as compared to piping. So by comparing these two values we conclude that the risk that caused by dam breach has high risk if the dam is failed by overtopping mode rather than piping mode.
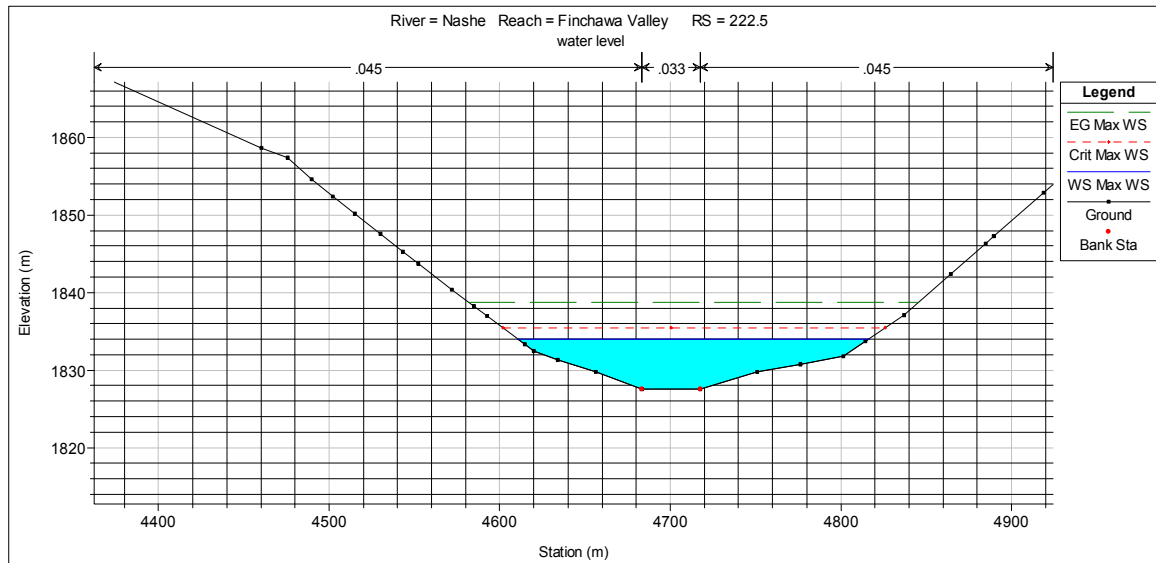
Figure 15. *River cross-section at 10.09km from Dam.*
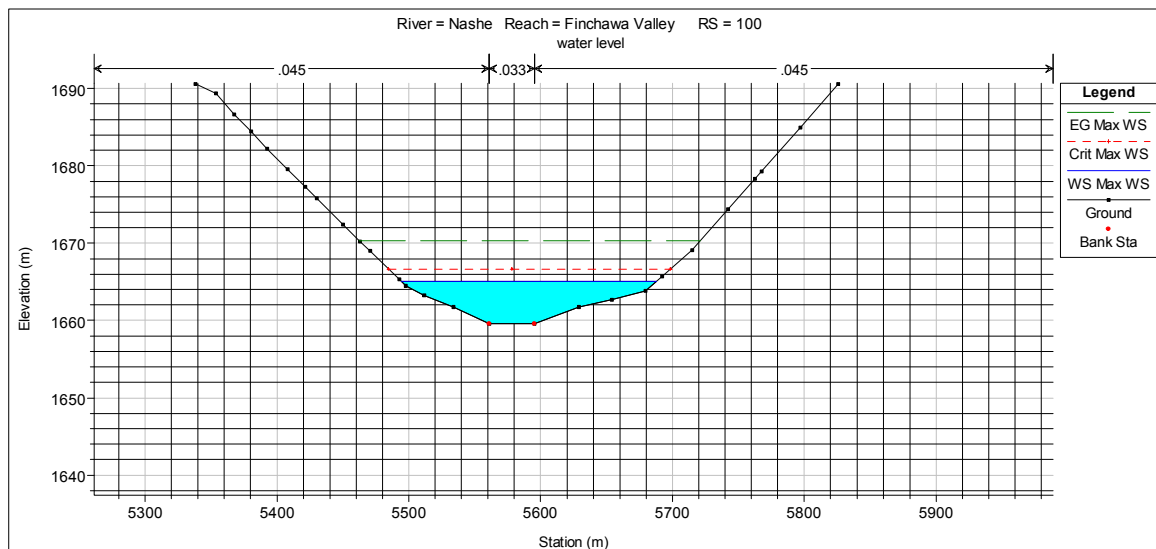
Figure 16. *River cross-section at 20.49km from Dam.*
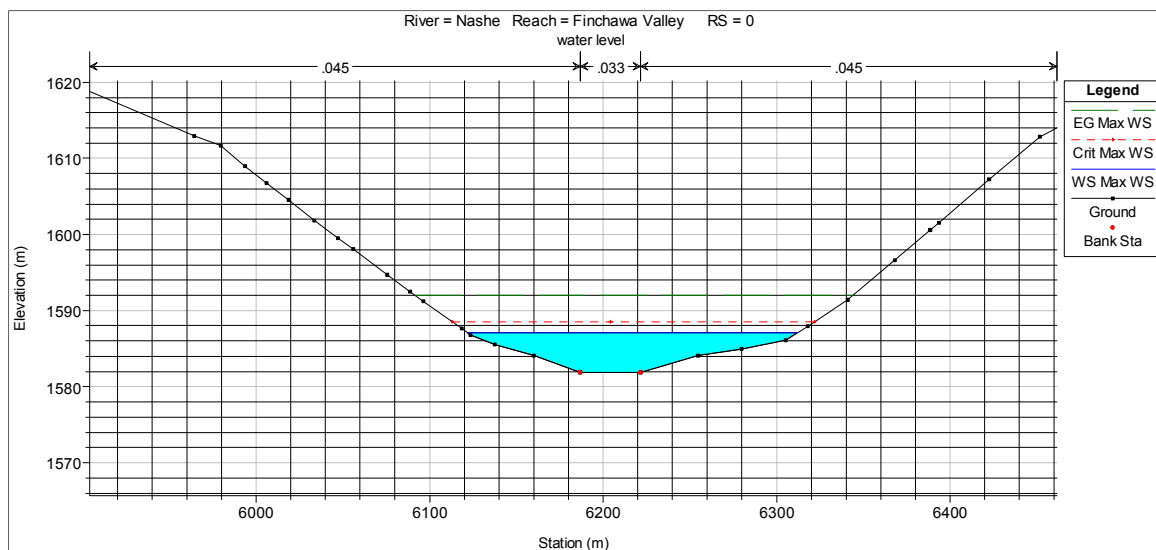
Figure 17. *River cross-section at 25.71km from the Dam.*

5.4. Hydraulic Condition by Sensitive Parameters in Terms of Peak Discharge and Water Level

It is well known that the selections of input parameters are very important for analysis for the dam break model. If the values of its input parameters change to the model setup then the effect of discharge values and water levels under this analysis is going to change the value is generally known as sensitivity analysis. So Input parameters considered for the sensitivity analysis are follows:

i.   Breach time
ii. Breach width
iii. Side slope
iv. Manning's roughness

For the full study of Nashe Dam break the results obtained are analyzed and compared with different dam break scenarios as explained in Table 6. Further the whole analysis

is done on the different scenarios as explained bellow for dam break analysis by overtopping and it follows the same principle for piping mode.

5.4.1. Effect of Breach Time

In this section setup 1 and setup 3 are compared with setup 2. Setup 1, setup 2 and setup 3 represents when the time breach is 0.9hr, 1hr and 1.1hr respectively.

Sensitivity of discharge is analyzed by changing time parameters which are explained in table 6 as breach time has more impact on peak discharge than the other breach parameters. When the breach width is constant (107.4m) as for the present study then with the 10% increase in breach time there was decrease in peak discharge by 24.21% at dam site and with 10% decrease in breach time there was increase in peak discharge by 5.36%.

Table 6. DamBreak modeling for different breach parameters for Nashe River.

Scenario	Breach time (hr.)	Bottom breach width (m)	Breach slope
Setup 1	0.9	107.4	1H:1V
Setup 2	1	107.4	1H:1V
Setup 3	1.1	107.4	1H:1V
Setup 4	1	96.66	1H:1V
Setup 5	1	118.14	1H:1V
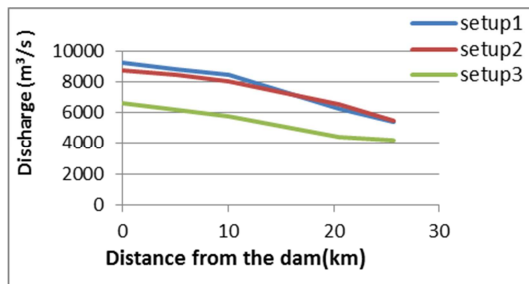
**Figure 18.** Sensitivity of breach time on Max. Peak Discharge.
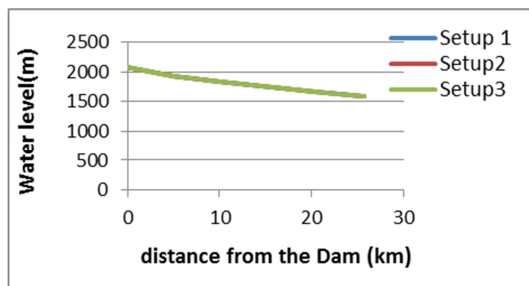
Figure 19. Sensitivity of Breach Time on Max. WL.

The development of Breach time during dam break is fully depending upon the dam structure and we know that earthen dams are assumed to be breached gradually. If the breach time is increased or decreased almost the same peak water level along the downstream location is observed as shown in Figure 18 and Figure 19 with their discharge along with distance for the dam.

5.4.2. Effect of Bottom Breach Width

It is analyzed by changing breach bottom width and keeping the other parameters constant. The setup 4 and setup 5 show the change of bottom breach width by keeping breach time constant and the results obtained from these setups is compared with change and development of bottom breach width and affecting the peak discharge and water level downstream of the valley comparing with setup 2. These setups represent decrement and increment of bottom breach width by 10% respectively. If it is increased from 107.4m to 118.14m means by 10% there is 4% increment in the peak discharge noticed at dam and if it decreased by 10% then 5.56% decrement in peak discharge is noticed. So, with the change of bottom breach width there is slightly increment and decrement of peak discharge with almost same peak water level along the downstream location are observed as shown in Figure 20 and Figure 21.
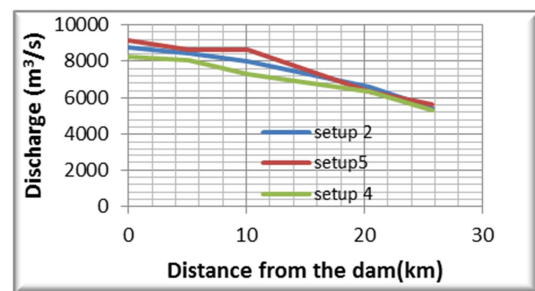
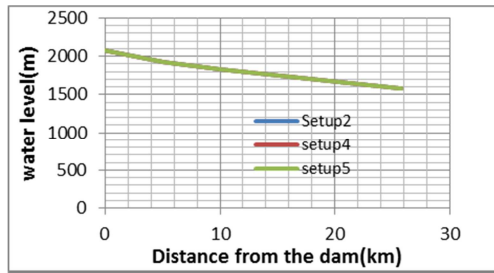**Figure 20.** Sensitivity of bottom Breach width on Peak Discharge.

Figure 21. Sensitivity of bottom breach width on Max. WL.

5.4.3. Effect of Side Slope

The side slope is the lateral slope of trapezoid of the breach section. The model is tested for the side slopes of 0.75, 1 and 1.25. Results obtained from these models show not much change in the value of maximum water level and discharge for the downstream location.

So, it is concluded that sensitivity of this parameter has

insignificant effect on the peak values of water level and discharge.

5.4.4. Effects Manning Roughness Value

If the Manning's Roughness Coefficient (N) increases, there is loss of energy going to affect the wave speed. This loss of energy is dissipated in the atmosphere through the bounding walls of the channel or the water surface. Chow, 1959 has suggested the value of Manning's value (N) in the range of 0.03 to 0.05 for the regions showing gravels, cobbles and few boulders at the bottom with no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage given in Table 7 and discharge with distance is shown in Figure 22. As expected the velocities reduce with increase in Manning's value (N) and vice versa. This is affecting the maximum water level and discharge value also.

Table 7. Effects of Manning Values on Discharge.

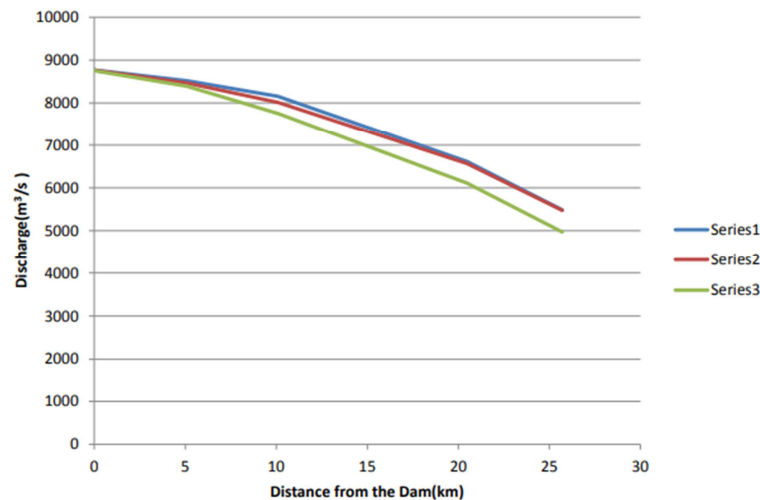| Location from Dam (Km)	Discharge		
	N1=0.04=N3 N2=0.03	N1=0.045=N3 N2=0.033	N1=0.05=N3 N2=0.04
0	8766.14	8761.23	8754.95
5.09	8517.78	8463.07	8389.66
10.09	8153.49	8012.37	7754.63
20.49	6610.82	6565.35	6107.58
25.71	5484.14	5474.66	4969.98

Figure 22. Sensitivity of manning roughness on Peak discharge of Nashe dam.

5.5. Emergency Action Plan by Developing Flood Mapping

Development of effective emergency action plans require accurate prediction of inundation levels, bottom width and the time of flood wave arrival at a given location where there is infrastructures and population at risk. Depending on this,

Dam owners and Emergency management authorities give protective measures by having Global Positioning System (GPS). Table 8 shows that the maximum water level, time arrival and top width of the peak of discharge at the specified place downstream of the dam if it break.

Table 8. Maximum water level, Top width and time arrival at different location d/s of the Dam When Dam break.

Distance d/s (km)	Water level Elevation (m)		MWL (m)		Time arrival (min.)		Top width (m)	
	BOT	BP	BOT	BP	BOT	BP	BOT	BP
5.09	1924.53	1924.27	6.34	6.08	25	25	205.00	198.06
10.09	1834.49	1834.01	6.88	6.4	30	30	211.97	204.35
20.49	1665.54	1665.05	5.93	5.44	50	55	199.81	191.41
25.71	1587.38	1587.05	5.47	5.14	60	65	193.90	189.58

6. Conclusion and Recommendations

6.1. Conclusion

In this failure simulation study of Nashe dam as carried out on earth fill dam having height of 35m. The impact of dam break in the downstream area by both failure modes (over toping & piping) are observed in terms of flood hydrograph, flood duration, water level. Further the sensitivity analysis of Breach time, Breach width and manning roughness is carried out for overtopping failure mode. Since the results measured in terms of hydrograph and water level is much greater than piping mode. So, conclusions are drawn by comparing the results as written below.

i. In case of Nashe the peak discharge by overtopping mode is 8761.23m³/sec which is 7.33 times greater than the probable maximum flood (1196 m³/sec) and by piping mode of peak discharge 8620.85m³/sec, which is 7.21 times greater than probable maximum food at the location of the dam creating more risk and hazards.

ii. The population those resettled downstream of the dam can be affected if the dam break occurred.

iii. The Fincha'a sugar factory located at 15km downstream as well as laterally from the dam is safe and may not be affected if the dam breaks.

iv. The Irrigated area around river bank throughout the River would be affected.

v. It is clear from the study that the difference in the peak discharge values as the dams has the same storage capacity with the inflow design flood (IDF) used as upper boundary condition plays the crucial role in the development of peak out flow difference. So during dam break by overtopping has high peak out flow and risk to downstream compare to dam break by piping mode.

vi. From the impact study by sensitivity analysis, the effect of breach time on discharge is more sensitive than the water level. This is because of that the increment of water level is insignificant due to flat surface and flows spread in wide width to both side.

vii. The flood mapping for dam break modeling may be used to avoid flood hazard and assist communities in future plan development by flood affected prone areas..

6.2. Recommendation

i. For obtaining best results the accuracy of data are most important. So, correct and accurate data are required by DEM to get the real time condition for dam break analysis.

ii. Since the water pass over main channel the free space up to 500m for semi hilly and 2000m for plain from both side should not to be allowed for public settlement and keep reserved along this channel.

iii. The population those live downstream of the dam should be resettled far apart from a River bank to prevent and avoid the risk and hazards.

iv. The power house which is located downstream of the dam may be affected if the dam is failed either by overtopping or piping mode of failure and require to rethink.

v. Since the Nashe dam is a very sensitive for breach failure risk, so this study may help to apply flood mapping for safety concern.

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