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Dam Break Analysis
(The Case Study of Nashe Dam)

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in partial Fulfillment of the Requirement for the Degree of Master Science in Civil Engineering (Hydraulic Engineering)

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August, 2015

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DECLARATION

I declare that I have elaborated my M.Sc. thesis aimed at “Dam Break Analysis (The Case Study of Nashe Dam)” independently under the leadership of my advisor, Dr. Ing. Asie Kemal. I have used only the literature and other information sources that are cited in the work and listed in reference at the end of this work. As the author of the thesis, further I declare that I am related to its creation and did not infringe the copyright of the third parties.

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ABSTRACT

Nashe earth fill dam was constructed in recent time for the purposes of hydroelectric power and irrigation. During construction of this project the peoples around Dam was resettled at different places including the downstream of the dam. This research focused on the dam break analysis on downstream of Nashe Dam if it breaks by overtopping and piping failure mode.

For this research the input data were collected from Water and Energy Minister of FDRE concerning the dam, breach parameters are calculated by Von Thun and Gillette and the cross-sections were from Digital elevation model (DEM) for hydraulic engineering model.

In dam break analysis the first step is model setup by using cross sections. After that the flow data, breach parameters and other such as boundary values are inserted as input data in the HEC-RAS model and the model result is exported to Arc-GIS for inundation map.

The peak discharge by overtopping mode is 8761.23m^3/sec which is 7.33 times greater than the probable maximum flood and by piping mode of peak discharge 8620.85 m^3/sec which is 7.21 times greater than probable maximum food at the location of the dam. This means that the maximum peak discharge out flow and risk due to overtopping is greater than maximum peak out flow and the risk of failure by piping mode. We observe the difference in the peak discharge values as the dams have the same storage capacity. The reason behind that is since the breach parameter is the same; the inflow discharge flood (IDF) which is used as upper boundary condition plays the crucial role in the development of peak out flow difference. So we can conclude that dam break by overtopping mode will develop high peak out flow and risk to downstream compare to dam break by piping mode. As from the sensitivity analysis we conclude that the effect of breach time on discharge is much pronounced than the water level. This is because of that the increment of water level is insignificant since the surface is flat and it flows to the both side and the top width is increased. Even if the degree of sensitivity analysis of other parameter is less than breach time, their effect on discharge is more pronounced than the water level.

Our Dam Break modeling results can be used as flood hazard maps and can assist communities in planning future developments in areas that are prone to flooding.

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ACRONYMS

USACE	United states army corps engineering
HEC-RAS	hydraulic Engineering Center River analysis system
1-D	One Dimensional
2-D	Two Dimensional
3-D	Three Dimensional
IDF	Inflow Design flood
PMF	Probable maximum flood
h_b	Breach Depth
B_{avg}	Average Breach width
EAP	Emergency action plan
GIS	Geographical information system
HEC-GeoRAS	hydraulic Engineering Center georeferenced River analysis system
MWIE	Ministry of Water, Irrigation and Energy
MWSP	Maximum Water Surface Profile
MWL	Maximum Water Level
D/S	Downstream
B/n	between
Km	kilometer
M	meter
hr.	Hour

m^3/sec	cubic meter per second
WSP	water surface profile
min.	Minute
WL	Water Level
RS	River cross-section
NPH	No public hazard
BOT	By overtopping
BP	By piping

1 INTRODUCTION

1.1 Back ground

There is an old Chinese proverb “the great levee ruined by ant nest” (Xiong, 2011). This means it warns peoples may result in big troubles. To prevent this fear Engineers reminds the probability of dam failure that affect the communities and resources those located at the downstream. Dam provides many benefits for our society. Among these it can be constructed for the purposes such as hydropower, irrigation, water supply, recreational purposes and extra. Now days, the construction of earth dams is familiarized in Ethiopia. So that the number of these earth dams exceed other types of dams. However, we have to give deep attention for breaking of earth dams comparing with other types of dams because the floods resulting from the failure of constructed dams produced some of the most devastating disaster of the last two centuries (Xiong, 2011). Simulation of dam break and resulting floods are essential to characterizing and reducing negative effects due to dam failure. Development of emergency action plan requires exact prediction of inundation level and the time of flood wave arrive at a given location which are located at the downstream. Different studies illustrated that the breakage frequencies in operated earth dams is almost four times greater than concrete dams or masonries (Shahraki et al., 2012).

Dam failure results from external force and internal erosion. The USACE hydrologic Engineering center (HEC) research document 13 lists the list of dam failure causes as 1) earth quake 2) land slide 3) extreme storm 4) piping 5) equipment malfunctioning 6) structure Damage 7)foundation failure and Sabotage (Xiong , 2011). Different Case studies show that dam failure may arise due to different reasons ranging from seepage, piping (internal erosion), over topping due to insufficient free board and to settlement.

Piping is a flow of water in porous parts of the dam especially through high permeability regions, cavities, fissures or strata of sand and gravel. Such concentrated flow at hydraulic gradient may erode the soil part of the dam which causes the breakage of the earth dam.

Overtopping is defined as uncontrolled flow of water over the crest of the dam or embankment. Since the non over flow (other than the spillway) portion of the dam are not usually designed for erosion effect of flowing water. Overtopping may lead to failure of the dam due to excessive erosion or saturation of downstream slope.

According to Jabir (2013), the main causes of overtopping are:

- Under estimation of the design flood and inadequate spillway capacity,
- Large and rapid landslides in the reservoir,
- Insufficient free board and
- Malfunctioning of the spillway gates.

Due to the gradual occurrence of the earth dam break, informing downstream inhabitants about the problem and sudden failure of dam as well as finding mitigation by transferring them to safer places in upstream is possible.

Generally, Dam break analyses can be carried out by either scaled physical hydraulic models or mathematical simulation using computer. In mathematical modeling of dam break floods either 1-D analysis or 2-D analysis can be carried out.

In 1-D analysis, the time series of discharge and water level and velocity of flow through breach are obtained in the direction of flow while in case of 2-D analysis with the results of 1-D extra and important information about the flood inundated map, variation of surface elevation and velocities in two directions can be analyzed.

1.2 Statement of problem

Nashe dam is recently constructed dam for hydropower and irrigation purposes by resettling thousands of peoples to different areas including to downstream of the dam. This situation initiates us to do a research to identify unfortunately if the dam breaks whether it has risk or not.

The other one is that research is not done on this dam concerning dam break analysis and if we do this research a number of researchers may participate to study the problems that affect downstream community that is caused by dam break in order to give future action plan.

Since the embankment dam is sensitive to break either for overtopping and piping mode of failure the study of dam break analysis needed.

1.3 Objective of the study

The overall goal of the study is to analyze the Nashe dam break using hydraulic models. In light of this the specific objectives are:

- To predict peak outflow discharge hydrograph during dam failures by either overtopping or piping mode of failure;
- To estimate the hydraulic conditions at different downstream points of the Dam, and;
- To develop downstream flood map of dam break.

1.4 Significance of the study

Studying of the Nashe dam break analysis helps to give effective emergency action plan that requires accurate prediction of inundation levels. Thus the findings of the study are significant for the following reasons:

- If the dam fails unfortunately, the peoples living in Fincha'a valley can be affected;
- The flood that comes from this failure can affect the agricultural land including irrigated areas at the downstream (that is sugar-cane produced for Fincha'a sugar factory) and infrastructure constructed in Fincha'a valley;
- It can affect the natural resources such as forests and animals;

1.5 The Scope of the study

The scope of the study is limited to 26km downstream of the Nashe Dam. It does not include up to the end of the Nashe River at which it joins Abbay River due to the budget constraints, limited data and unavailability of material used for data preparation. The cross section is limited to 124 starting from Nashe Dam to the downstream up to the measured distance and the other is interpolated between them in hydraulic model (HEC-RAS).

1.6 Limitation of the study

The problem faced in the process of this research is lack of primary data. During secondary data collections the problem we encountered includes the following:

- Some government offices were not interested to give the required information.
- Many times the documentary officers were not available at their offices.
- The government employees who were responsible for releasing the documented data are newly assigned and do not know much about the issue.
- Due to poor documentation of the data in the government offices, it was difficult to get the necessary and relevant information.

1.7 Thesis organization

Chapter 1describes the back ground of the dam break analysis, statements of the problem, general objective, specific objectives, and scope and limitation of the research. Chapter 2 includes literature review and conceptual frame of dam break analysis, purpose of Dam breach analysis, dam Hazard classification, types of failure mode and inundation map. Chapter 3: describe methods and material used description of the study area in detailed and location points of study area were explained. The result and discussion of the research in detailed are studied under chapter 4.Chapter 5: describes the conclusion and recommendation of the research

2 LITERATURE REVIEW

2.1 Introduction

In dam safety programs and flood forecast, dam break modeling is essential to evaluate dam induced risk and to support emergency plan, optimizing response efforts and directing first response teams the area that may be damaged due to the consequence if the Dam will break. However, a better understanding of flood predictability and model efficiency is needed before system can be effectively implemented. The dam is represented as a structure in the river setup when the dam break, the momentum equation is replaced by the broad crested weir flow equation which describes the flow through the structure (SACHIN, 2014). Using the standard dam breach methods the breach is initiated either as a trapezoidal breach or if the erosion based method is used as a circular piping failure (Sachin, 2014). The dam break tool in HEC-RAS was applied to Foster Joseph Sayers Dam break simulation and analysis based on the given geometry data (Xiong , 2011).

Dam break has a greater impact on the downstream location where is closer to the dam in accordance with the comparison of the hydrographs at different downstream locations (Xiong, 2011).

Since HEC-RAS is a 1-dimensional model, adding cross sections to the model that were located at wide area of the flood plain and extending into back water areas would overestimate flood plain conveyance since, HEC-RAS would assume the entire cross section to convey flood waters, which would be un realistic (Colorado dam safetybranch, March 27–29, 2007). Therefore ineffective flow areas were used to define conveyance areas (Colorado dam safetybranch, March 27–29, 2007).The addition of ineffective flow to the cross sections allowed the entire floodplain to be considered as storage but without considering areas of slow water as conveyance (Colorado dam safetybranch, March 27–29, 2007).

Kamanbedast & Bryanvand , 2014 showed that the numerical modeling of earth dam break should be performed in two stages: firstly, we should pay attention to dam gradual break mechanism and also computing outlet hydrograph due to dam break. Secondly we should study result of this hydrograph in dam downstream.

Dam break is a complicated and comprehensive process and actual failure mechanics are not well understood (Xiong, 2011). Neither current physical based models nor empirical models could fully explain dam break mechanisms and impacts (Xiong, 2011).

Simulation of Embankment dam breach events and resulting floods are crucial to characterizing and identifying threats due to potential dam failures (Colorado Dam safety branch, 2010). 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 (Colorado Dam safety branch, 2010).

2.2 Purposes of dam breach Analysis

The way and rate at which a dam breach can affect the timing of the breach, the rate and magnitude of the flood water released and the size of the breach itself. Therefore, breach affects the analysis of flood risk and can change the way in which flood events might be managed.

According to West Consultants, March, 2009, the results of dam breach analysis are typically used to develop inundation map which can have a variety of uses planning

- Emergency action planning,
- Emergency response,
- Mitigation planning and
- Consequence assessment

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.

2.3 Classification of hazard

According to FEMA, 2013 hazard caused by dam failure is classified as:

- High Hazard Dam
- Significant Hazard Dam
- Low Hazard Dam
- No Public Hazard (NPH)Dam

2.3.1 High Hazard Dam

High Hazard Dam is a dam for which loss of human life is expected to result from failure of the dam. Designated recreational sites located downstream within the bounds of possible inundation should also be evaluated for potential loss of human life. It is important to note that the potential of loss of a single life is sufficient to classify a dam as high hazard (Claudia C & Mark, 2010).

2.3.2 Significant Hazard Dam

Significant Hazard Dam is a dam for which significant damage is expected to occur, but no loss of human life is expected from failure of the dam. Significant damage is defined as damage to structures where people generally live, work, or recreate, or public or private facilities. Significant damage is determined to be damage sufficient to render structures or facilities uninhabitable or inoperable.

2.3.3 Low Hazard Dam

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 of the dam.

2.3.4 No Public Hazard (NPH) Dam

No Public Hazard (NPH) Dam is a dam for which no loss of human life is expected, and which damage only to the dam owner's property will result from failure of the dam.

2.4 Dam Breach Analysis Approach

There are two approaches that are commonly used for dam breach analysis: an event based approach and a consequence based approach.

2.4.1 Event Based Approach

An event-based approach is a deterministic method. It uses a specific or series of specific non-precipitation and precipitation events for the evaluation of dam failure and downstream inundation mapping. The non-precipitation and precipitation events are also referred as non-hydrologic (fair weather / sunny day) and hydrologic events (rainy day) respectively. Non hydrologic events describe a situation when the dam-break occurs unexpectedly due to collapse of the dam body, piping or stability loss (Dr. Greg & Darre, August, 2007). Several non-hydrologic and hydrologic events are evaluated in a typical breach analysis.

2.4.1.1 Fair Weather Failures

A fair weather (sunny day) breach is a dam failure that occurs during fair weather (i.e. non-hydrologic or non- precipitation) conditions. The breach is analyzed by establishing an initial reservoir water level and commencing a breach analysis without additional inflow from a storm event. A fair weather breach is typically used to model piping failures for hydrologic, geologic, structural, seismic and human- influenced failure modes (FEMA, 2013).

According to FEMA three initial reservoir water level elevations are commonly used for fair weather breach analyses.

In the first, the reservoir water level is set at normal pool level. The volume and associated discharge that would result from a failure event during fair weather condition are then estimated. For an embankment dam, this type of event is modeled as piping /internal erosion failure, whereas for a concrete dam, this event is modeled as a monolith collapse resulting from sliding, foundation instabilities or a seismic event.

In the second, the reservoir water level is set at the invert of the Auxiliary spillway (also referred to as an emergency spill way). This condition is commonly used to simulate a breach during mis-operation of the primary outlet works. Initial of dam failure is typically the same as for the reservoir level at normal pool.

In the third, the reservoir level is set to the top of the dam to represent the maximum amount of volume that may be stored in the reservoir. This condition may be selected to evaluate the most conservative non-hydrologic event. In practice, dams without adequate spillways or pump storage facilities, where the water level during non-hydrologic events is maintained at the top of dam, are unique situations subject to this conservative assumption. A breach event when the water level is at the top of dam may be modeled as a piping / internal erosion failure or as an overtopping failure with the water level just above the top of dam invert.

2.4.1.2 Hydrologic Failure

Hydrologic breaches that occur with extreme precipitation and runoff are termed “rainy day” or hydrologic failures. Hydrologic failures that cause dam breach events are generally analyzed based on the IDF is used established by the dams hazard potential and hazard size classification. Typically a PMF is used for high-hazard potential dams; whereas, values ranging from 1-percent annual-chance flood event (often called the 100-year flood) to a percentage of the PMF is used for significant hazard dams. This condition is commonly used to simulate a breach during overtopping of the dam.

2.4.2 Consequence Based Approach

A risk based approach to dam design and dam safety evaluations has been developed to account for the downstream consequences of a potential dam failure. The consequences evaluation is not based on the probability failure, but instead on the potential loss of life or increase in economic losses caused by a potential dam failure.

2.5 Breach Parameters Estimation

A key element for calculating a dam breach hydrograph for a specific dam involves estimating the dam breach parameters (e.g. width, depth, shape and time of failure). It is to be noted that the shape of the peak breach outflow hydrograph is influenced by the storage in the impoundment at the time of breach, reservoir inflow at the time of breach, size of the dam and most importantly, the dam type’s erodibility and/or mode of assumed failure. For instance, a brittle concrete or structural failure will have a much faster time of breach development as compared to an overtopping failure of a large, cohesive, well compacted and well vegetated embankment. Since the outflow hydrograph can vary widely depending upon these factors, careful consideration should be given to the dam breach modeling inputs. Ideally dam breach analyses should be performed for a specific failure mode.

A number of methods are available for estimating breach parameters for use in dam breach studies. Since the selection of the breach parameters is specific to each dam, guidance is provided describing methods currently applied by dam safety professionals without recommending a standardized method (FEMA, 2013).

2.5.1 Breach Parameter Definition.

The term breach parameters is commonly used to describe the parameters needed to physically describe the breach (breach depth, breach width, and slope angles) as well as parameters that define the time required for breach initiation and development. These parameters are key in calculating the dam breach outflow hydrograph. Estimation of the breach parameters, such as width and development time, is done external to the model (Michael Gee, July 1, 2010).

The following definitions are commonly accepted for use in calculating and selecting dam breach parameters.

- Breach depth (h_b) - It is the vertical extent of the breach measured from a specific elevation to the invert of the dam breach.
- Breach width (B_{avg}) – it is average of the final breach width, typically measured at the vertical center of the breach.
- Breach side slope factor – The breach side slope is a measure of the angle of the breach sides represented as z horizontal to vertical (zH: 1V).
- Breach formation time (also time-to-failure) – The duration of time between the first breaching of the upstream face of the dam (breach initiation) and when the breach has reached its full geometry.

According to FEMA, 2013 dam breach usually occurs in two distinct phases starting with the breach initiation followed by the breach formation.

Breach initiation: - during the breach initiation phase, flow through the dam is minor and the dam is not considered to have failed. It may be possible to prevent a dam breaching during this phase if flow is controlled.

Breach formation: - breach formation begins when the flow through the dam has increased and progressed from the upstream face to the downstream face of the dam is uncontrolled and will result the failure of the dam.

2.6 Dam breach mechanisms

According to Office of the state Engineer, 2012 breach forming mechanisms can be classified in two general categories. These are;

1. breach formed by sudden removal of all or portion of the impounding structure as a result of some over stressing of the structure, and
2. Breach formed by erosion of embankment materials

2.6.1 Failure Rigid dam Structure

The failure mode of rigid dams those constructed from concrete or masonry material is characterized by sudden partial or concrete failure or catastrophic displacement of the structure (Colorado Dam safety branch, 2010). According to this study failure modes include the following:-

- ➢ Extreme loading conditions such as overtopping that lead to structural failure of the dam.
- ➢ Extreme loading conditions that overloads a drainage system outright drainage system failure leading to uplift and movement of the structure to downstream.
- ➢ Excessive deformation of structure due to settlement of foundation materials, or structural failure due to loss of support from foundation or abutment.

2.6.2 Overtopping failure of Embankment dam

Overtopping failures of earthen dams typically begins with head cutting at the downstream toe and advance upstream until the erosion reaches the dam crest and reservoir surface (Colorado Dam safety branch, 2010). A dam failure resulting from an embankment slide can also lead to an overtopping type of failure when the slide encroaches upon high water line. Once the reservoir is connected to ongoing breach, down cutting of erosion of the embankment occur until the breach expands to the final dimension.

Generally, breach due to overtopping is considered to begin when erosion occurs across the width of the dam crest. After the breach initiates at the top of the dam crest, it enlarges to its ultimate extent. If there is no physical reason to believe the embankment would fail at a certain location, the breach should be modeled as initiating at the maximum section typically located at the centerline of the stream main channel. A generalized trapezoidal breach progression is illustrated in figure 2-1.

Figure 2-1 overtopping trapezoidal breach progression (FEMA, 2013)

The breach may stop growing when the reservoir has emptied and there is no more water to erode the dam or the dam has completely eroded to the bottom of the reservoir or has reach bedrock (FEMA, 2013). The breach regression may be modeled as either a linear progression or sine wave progression:

- Linear progression: rate of erosion remains the same for the duration of erosion development.
- Sine wave regression: breach grows very slowly at the beginning and end of the development and rapidly in between.

2.6.3 Piping and Internal erosion of Embankment dam

The terms “piping” and “internal erosion” are often synonymous (Colorado Dam safety branch, 2010). It defines piping as intergranular seepage that occurs through a soil body which has no preferential flow paths. It is also sometimes referred to as backward erosion piping because the erosion typically occurs from downstream to upstream (analogous to head cutting). It also defines internal cracks within a compacted fill, a foundation, or a contact between a fill and foundation. This occurs when the water flowing through the crack or defect erodes the soil from the walls of the crack or defect.

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. Typically, piping begins near the downstream toe of the dam and works its way toward the upper reservoir. As the voids become larger, erosion becomes more rapid. Water flow through the embankment will appear muddy as erosion increases. Once the erosion reaches the reservoir, the piping hole can enlarge and cause the dam crest to collapse. Figure 2-2 shows a schematic of a fully formed piping hole.

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 (Colorado Dam safety branch, 2010).

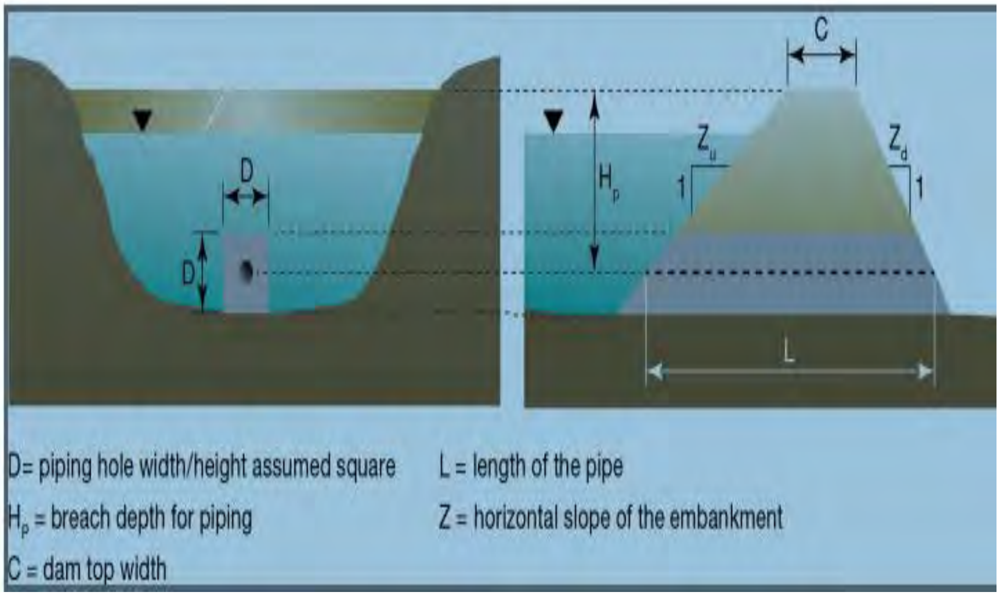

Figure 2-2 piping hole (Colorado Dam safety branch, 2010)

2.7 Envelop curve

Several researchers have developed peak flow regression equations from historic dam failure data (Gary , August, 2014). The peak flow equations where derived from data for earthen, zoned earthen, earthen with impervious core and rock fills dams only, and do not apply to concrete dams. In general the peak flow equations should be used for comparison purposes (Gary , August, 2014).

Once the breach hydrograph is computed in HEC-RAS, the computed peak flow from the model can be compared to these regression equations as test for reasonable test (Gary , August, 2014).

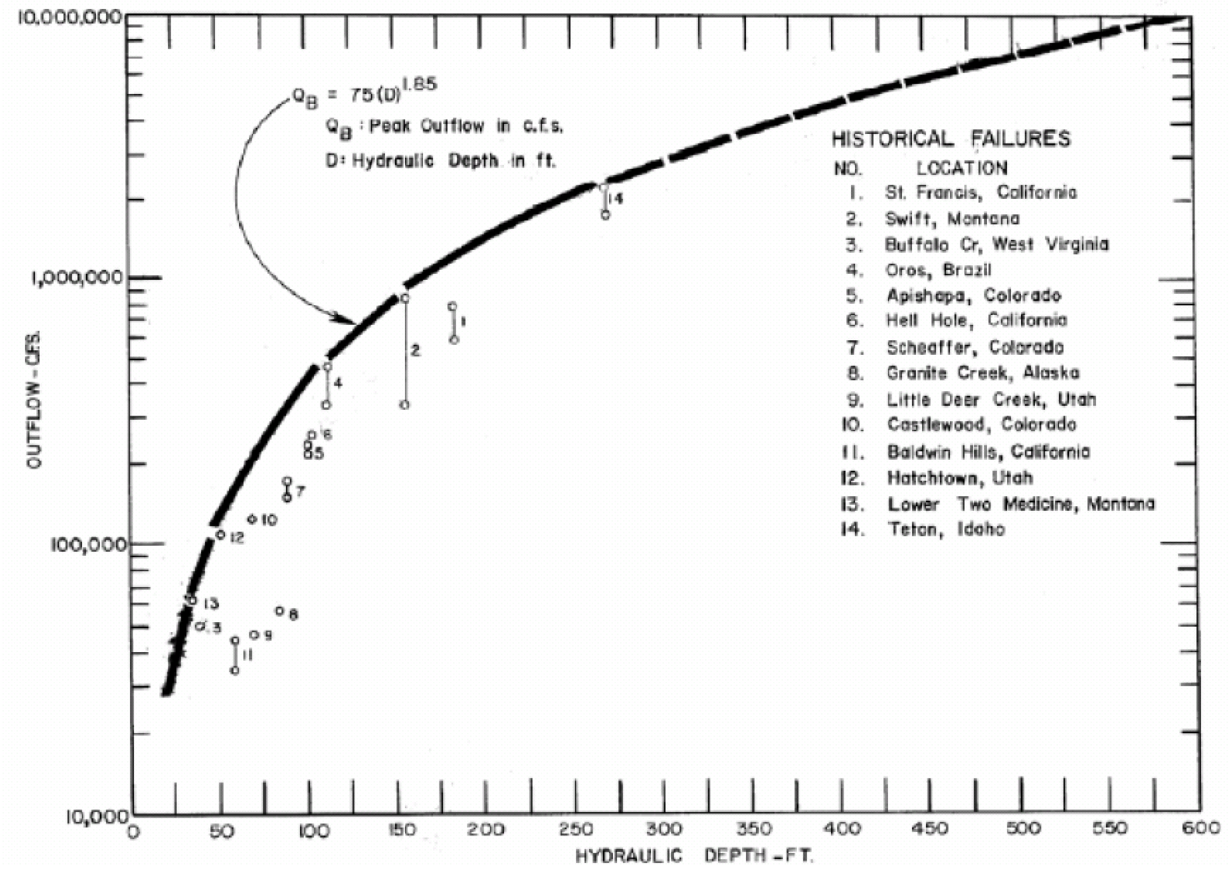

Figure 2-3 envelope of experienced outflow rates from breached dam (Gary , August, 2014)

2.8 Dam failure inundation map

Dam failure inundation map is a map 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 (Colorado Dam safety branch, 2010). Inundation mapping of water surface profile results from a dam failure models used for a preliminary assessment of the flood hazard and used to provide insight for emergency preparedness. The dam break inundation zone is defined as the area downstream of a dam that would be inundated or otherwise directly affected by the failure of a dam.

Generally dam breach inundation maps are maps that are produced to show geographical areas which could be flooded in the event of dam breaching. The maps show the water depth or water levels, and as appropriate flood arrival times and the flow velocities.

Although many dam safety regulatory bodies have produced important guidance on dam breach modeling, they have limited guidelines for developing inundation maps reflecting dam failure incidents. Where guidelines are available they are inconsistent in how a dam breach is modeled and how the results are shown on a map. According to FEMA, 2013 guidance for dam breach inundation mapping is summarized as follow.

2.8.1 Uses of inundation mapping

Inundation maps can have a variety of uses including emergency action plans, mitigation planning, and Emergency response and consequence assessment.

2.8.1.1 Emergency Action Plans (EAP)

According to FEMA, 2013 EAP is a formal document that identifies potential emergency conditions at a dam and specifies preplanned actions to be followed by the dam owner in coordination with emergency management authorities to minimize property damage and loss of life. The EAP usually includes inundation maps to assist the dam owner and emergency management authorities with identification of critical infrastructure and population at risk sites that may require protective measures and warning and evacuation planning. Since EAP maps are intended to be used in an emergency, it is critical for these maps to be easily reproducible without loss of critical information.

2.8.1.2 Emergency Response

Emergency response embodies the actions taken in the immediate aftermath of an incident to save and sustain lives, meet basic human needs, reduce the loss of property and the effect on critical infrastructural and the environment. Actions may include warning and evacuating population at risk. Given the short warning times typically encountered with dam failures and incidents, dam emergency evacuation plans should be developed before the occurrence of an incident. It is recommended that plans be based on a worst case scenario and address the following elements, including identifying the roles and responsibilities for all action items:

- Identification of critical facilities and sheltering
- Initiating emergency warning systems (who is responsible and what is the method)
- Specific evaluation procedures, including flood wave travel time considerations (for examples, evacuation of special needs populations and lifting evacuation orders)
- Distance and routes to high ground
- Traffic control measures and traffic routes

- Potential effect of weather or dam releases on evacuation routes (for example, identify whether portions of the evacuation route may be flooded before the dam incident occurs)
- Vertical evacuation/sheltering in place
- Emergency transportation
- Safety and security measures for the dam perimeter and affected areas
- Re-entry into affected areas

Since inundation maps included in the EAP may help in developing the warning and evacuation plans, they should be shared with emergency management authorities.

2.8.1.3 Hazard mitigation planning

Mitigation is the proactive effort to reduce loss of life and property by lessening the effect of disasters. This is achieved through identifying potential hazards and the risks they pose in a given area, identifying mitigation alternatives to reduce risk and risk analysis of mitigation alternatives. The result is the selection of proactive measures, both structural and non-structural, that will reduce economic losses and potential loss of life when implemented. In the case of dam failures and incidents, hazard mitigation planning involves identifying the population at risk and identifying actions to reduce the vulnerability.

Hazard mitigation planners need digital data that defines the dam breach. Information needed includes the breach inundation zone boundary, depth of flooding, velocity and timing.

2.8.1.4 Dam Breach consequence Assessment

Dam breach consequence assessment includes identifying and quantifying the potential consequences of a dam failure or incident. While hazard mitigation planning focuses on specific projects to reduce flood risk, consequence assessment focuses on the economic and social impacts of a potential disaster and the organizational and government actions needed in the aftermath of a dam breach to respond and recover. Data compiled for a consequence assessment can also be used in risk assessments. Consequence assessment requires the same basic data as used in hazard mitigation planning, with addition of data related to communicating the hazard to community elected officials and the public. Advanced mapping products that allow state-of-the-art visualization is a key to communicating the hazards and consequences of potential dam failure.

2.8.2 Mapping guidance

2.8.2.1 Recommended Inundation Map Elements

A. Map Collar Information

Latitude and longitude coordinates can be referenced at the corners of the neat line. Other useful information displayed on the map collar can be horizontal reference grid ticks (e.g. universal transverse Mercator or state plane) to help to orient map users to real world coordinates. Adjacent map panel numbers should also be listed along the neat line borders that correspond with adjacent map panels.

B. Base Map Data

Base map data provide the back ground from which inundation hazard information is overlaid and interpreted. Clear, easy-to-interpret base maps are critical for the effective use of an inundation map.

C. Inundation Polygons

The key information on an inundation map is provided by one or more inundation polygons that define the horizontal limits of the inundated area for one or more breach events. The inundation polygons show the intersection of the peak water surface elevations from the dam breach model with ground elevations from the train source. If multiple breach events will be shown on the inundation map, the polygon representing the event that would result in smallest inundation area should be displayed on top of those representing events with larger inundation areas.

D. Inundation Elevation

Inundation elevation can be annotated at key locations along the inundation polygon if desired. The inundation elevations can be extracted directly from dam breach model. Elevations are always not critical element for an inundation map. Emergency responders are primarily interested in the extent and depth rather than the elevation of flooding. Elevation may be important for flood warnings, however, particularly if early warnings are possible.

E. Flood Wave Arrival Time

Flood wave arrival times can be annotated at key locations along the inundation polygon if desired. The flood wave arrival time is the time (usually in minutes) from dam breach initiation until the leading edge of the inundation arrives at a specific location.

For a fair weather failure, the arrival time can be considered the first time that a notable change in the base flow is observed. For a hydrologic failure event, the arrival time is best determined by comparing two situations for the same hydrologic event. The first simulation would be a non-breach hydrologic event, while the second simulation would be the exact same hydrologic event but with the dam breaching. The downstream hydrograph of both events can be overlaid to identify what time the effects of the dam breach would be first observed. The separation of the two hydrograph at the point of the interest indicates the effect of the dam breach at that location. The arrival time for hydrologic events is normally defined as the time lapse from breach initiation until the differential stage for width and without failure simulation for river to exceed defined depth.

Table 2-1 shows the recommended intervals for flood arrival times that should be included on inundation mapping; also judgment should be applied when selecting mapped intervals and should be commensurate with the population at risk and map scale.

Table 2-1 Time intervals to include on inundation map (source: FEMA 2013).

Time after breach	Mapped arrival time intervals
0-30 minutes	5 minutes
30-90 minutes	10 minutes

3 Materials and Methods

3.1 Study Area

3.1.1 Nashe Dam and its Location

The Nashe dam is homogenous earth fill (embankment) with horizontal and vertical inclined filter blanket that is constructed on the Nashe River in the village of Igu that is located in Abbay Choman woreda. The lateral length of the Nashe dam is 1000m with a maximum height of 35m that is protected by rip rap and random rock fills on upstream and downstream faces. This dam is constructed for hydropower and irrigation purposes (EEPCO, 2011).

Construction material such as blasted rocks and clay soil for the dam construction are extracted from the borrow pits on the right and left banks of the dam and quarry site (EEPCO, 2011). The type of the dam is determined based on the geological conditions of the area and availability of the construction materials in closer distance to the site (EEPCO, 2011).

The bottom outlet/intake and spillway structure are arranged to associate within the dam body and the spillway is located at one side (EEPCO, 2011).

According to MWIE the spillway consists of:

- an ungated morning-glory crest,
- a shaft connecting the crest and the diversion conduit below, and
- An energy dissipater at the downstream end of the conduit.

Nashe Dam is located about 310km north-west of Addis Ababa, in oromia region, horro Guduru Wollega Zone, Abbay Choman woreda in the Blue Nile River Basin. The *Nashe* River starts on a highland plateau with valley elevation 2200m above sea level (asl) and the surrounding ridges extending to over 2500m asl. Average annual rainfall in the area is about 1350 mm, 85%, of which falls during the 3-month rainy season from mid-June to mid-September (Galata, 2012).

According to Galata (2012), the proposed 5200 hectares of irrigation area would be located downstream of the dam development.

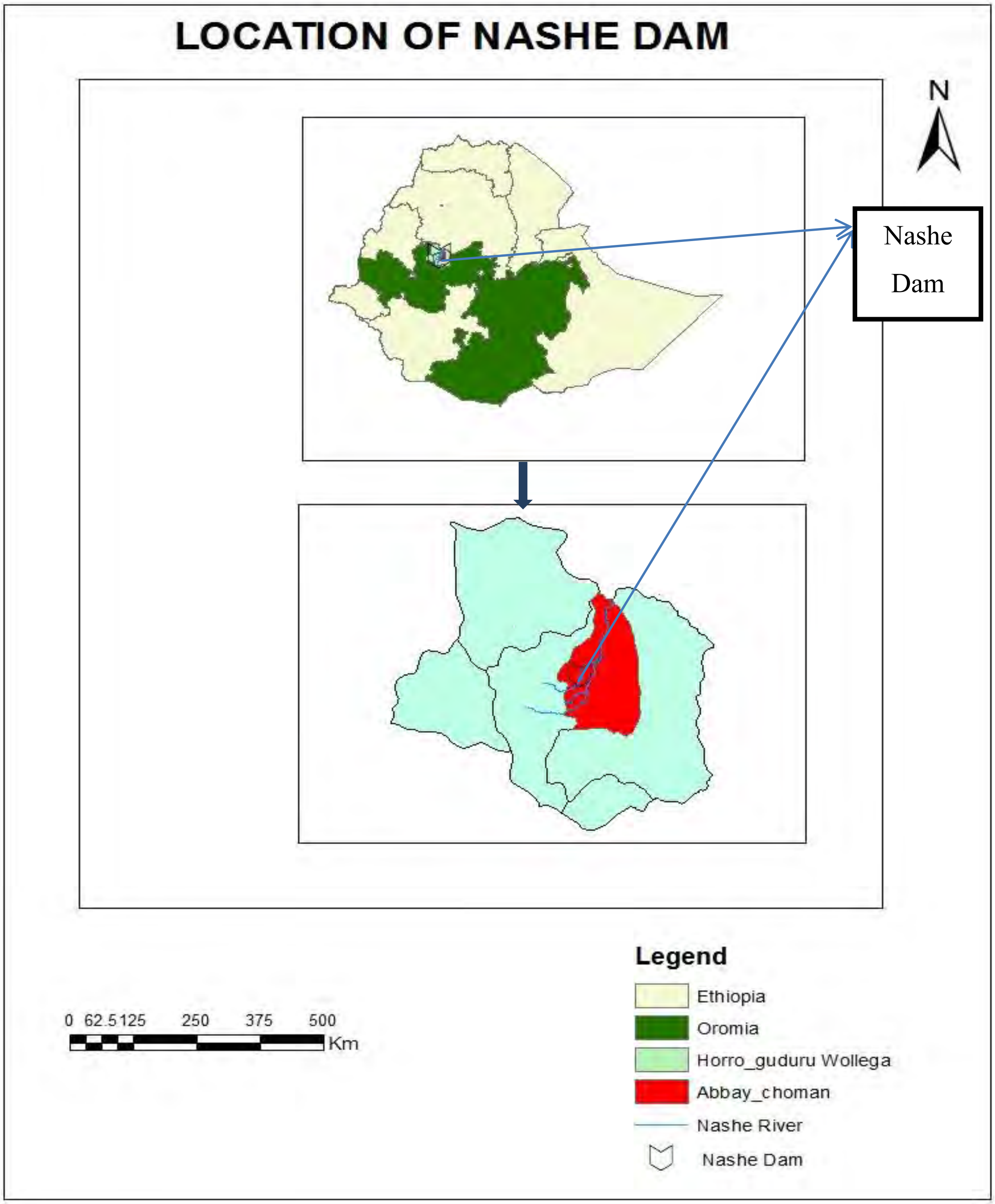

Figure 3-1: Location of Nashe Dam

3.2 Methods of Dam Break Analysis

3.2.1 General

Due to the break of a dam it has a risk to downstream. 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 materials such as hydrologic and hydraulic models and different methodology.

3.2.2 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, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities.

The HEC-RAS program contains four one- dimensional river analysis components for:

- Steady flow water surface profile computation
- Unsteady flow simulation
- Moveable boundary sediment transport computations and
- Water quality analysis.

A key element is that all four components use a common geometric data representation and common geometric and hydraulic computations routines. HEC-RAS have the ability to present hydraulic properties computed during a flow simulation (Davis, 2002).

In addition to the four river analysis components the model contains several hydraulic design features that can be invoked once the basic water surface profile are computed.

3.2.3 Data collection

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

3.2.3.1 General information

Data related to dam failure are generally significantly needed. The information that should be included in the dam break analysis includes:

- Available historic flood levels.
- Hydrographical data.
- Dam information such as height, length, width and types of dam.
- Reservoir impoundment.
- Downstream cross sections.

3.2.3.2 Peak flood flow

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

Table 3-1: Peak Discharge at different return Period (source: (Ministry of water irrigation and Energy, 2005).

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

The probable maximum flood (PMF) shown in table 3-1 is used in the design of dam spillway which is used to remove the excess water during different purposes such as emergency case.

3.2.4 The HEC-RAS 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 follow.

3.2.4.1 Nashe River

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 perpendicular to the river channel were taken and used for setting up of the HEC-RAS Model. Downstream of dam site the river is defined with 119 cross sections divided at a maximum distance of 500m as shown in

Figure 3-2 as dam break flood is highly unstable and unsteady in nature so it is necessary that river geometry must be close to the real world condition.

In the present study the river is traced with the help of HEC-RAS software using DEM of that location. The river cross sections are auto generated in the software with the use of the cross sections prepared from DEM.

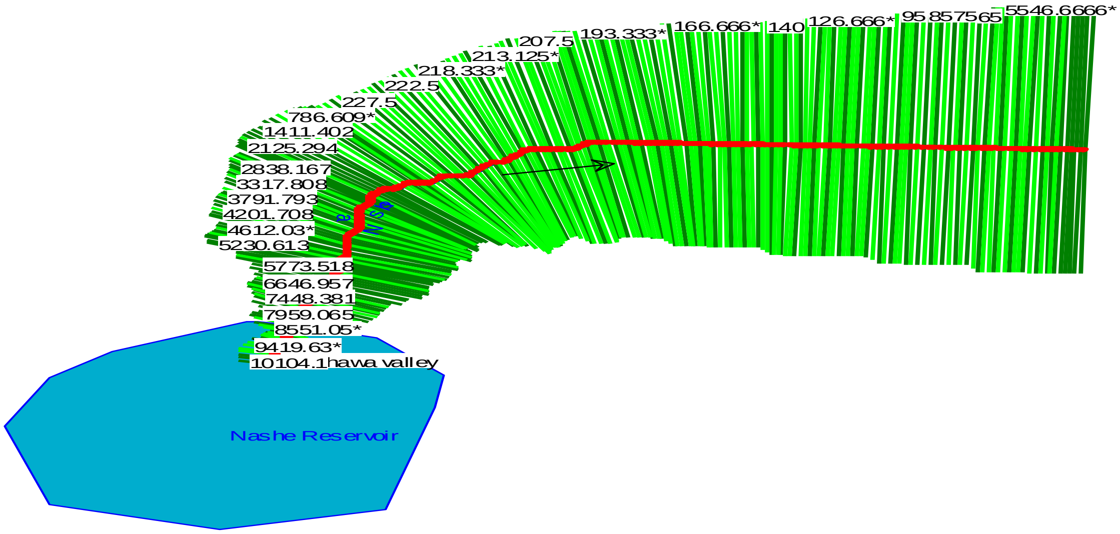

Figure 3-2 River Network for Nashe River in HEC-RAS Model

3.2.4.2 Nashe Reservoir

The reservoir is normally modeled in HEC-RAS as elevation versus volume curve of the Nashe Reservoir. Table 3-2 shows the elevation versus volume curve data for reservoir.

Table 3-2: Elevation volume Curve of Nashe Reservoir (Ministry of water irrigation and Energy, 2005)

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

3.2.4.3 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. Table 3-3 shows the value of PMF.

Table 3-3PMF for Nashe River (Ministry of water irrigation and Energy, 2005)

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		

3.2.4.4 Downstream boundary condition

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

3.2.5 Estimating Breach parameters

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

a. Location: center line station of the breach in the Dam.
b. Failure mode:- overtopping or piping
c. Shape:- bottom elevation, bottom width, left and right side slope H:V
d. Time:- critical breach development time
e. Trigger mechanism:- pool elevation, pool elevation plus elevation or clock time
f. Weir or pipe coefficient
    - ➢ Weir coefficient are used to compute if the failure mode is overtopping and
    - ➢ Pipe or orifice coefficient for piping failure mode.

3.2.5.1 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 our study we assumed that the failure is at center of the dam and expands equal in both direction.

3.2.5.2 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 methods. Failure mode is the mechanism for starting and growing breach. For our analysis the failure mode is both overtopping and piping method. Overtopping failure start at a top of the dam and grow to the maximum extents while, piping failure mode can start at any elevation/location and grow to the maximum extents.

3.2.5.3 Breach development time

In overtopping failure breach starting time is considered to be when the erosion process has been migrated to upstream face of dam. I.e. this is the start of time for the HEC-RAS model. This is the point at which the out flow from the dam will start to increase due to the breach. The end of breach development time for the HEC-RAS model is when the breach is fully formed and significant erosion has stopped.

For piping failure breach starting time is considered to be when a significant amount of flow and materials are coming out of the piping failure hole. The breach ending time is considered to be when breach is for the most part fully formed (significant erosion has stopped, not the time until the reservoir is emptied).

3.2.5.4 Breach shape

The shape of the breach during the dam break for overtopping can be rectangular, triangular and trapezoidal. Most of the time the shape of the breaches from different research is trapezoidal. Therefore trapezoidal shape is selected for our study as shown in figure 3-3.

Trapezoidal shape of the dam breach consists height of the breach, breach width and side slope in H: V.

Breach width is described as the average breach width (B_{ave}) while HEC-RAS requires the breach bottom width (W_b) for input. Therefore, by using different side slopes those recommended by each regression equation we can calculate the bottom width. The breach height (h_b) is vertical extent from the top of the dam to the average invert elevation of the breach. For the mode of failure is overtopping the breach height (h_b) is equal with height of water (h_w), which is vertical extent from the maximum water surface to the invert elevation of the breach. The breach dimensions as well as breach formation time must be estimated outside of the HEC-RAS and entered into the program.

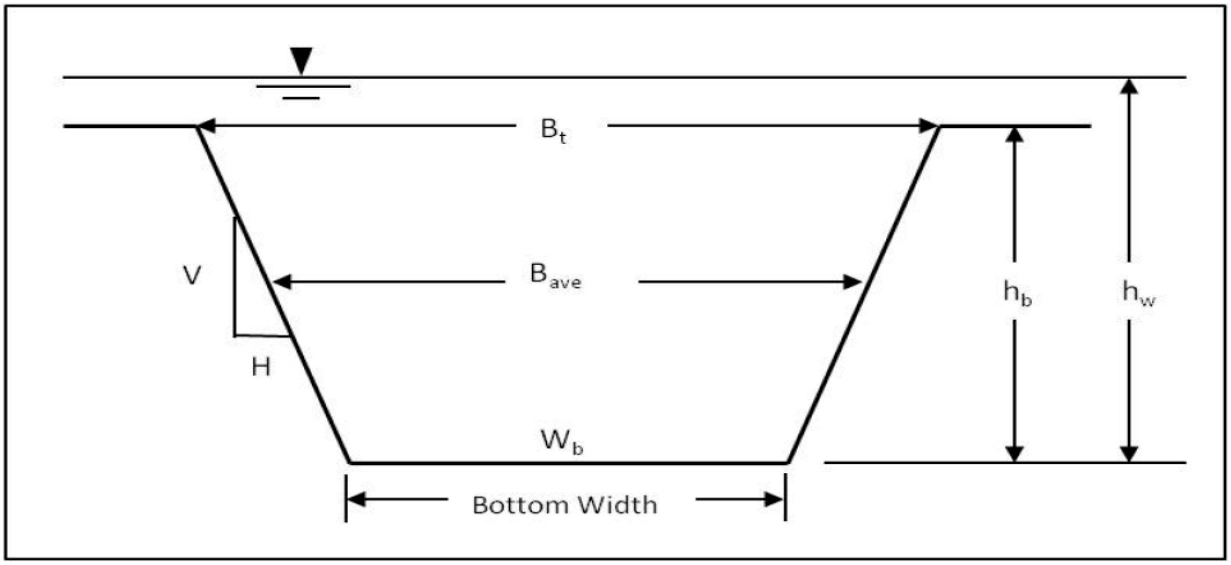

Figure 3-3 Description of breach parameters (Gary , August, 2014)

There are different regression equations used for different dam safety studies found in different literature. These equations are used to determine breach parameters such as breach width and breach development time. These regression equations are:

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

Among these regression equations the Froehlich (2008) and Von Thun and Gillette are compared for our study to determine the breach parameters such as breach width and critical breach development time both for overtopping and piping method.

3.2.5.5 Determination breach width and time by Froehlich (2008)

Froehlich updated his regression breach equation. 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. The data that Froehlich used for this regression analysis had the following ranges:

- Height of dams: 3.05 -92.96 meters
- Volume of water at breach time: 0.0139- 660.0 X10^6 m^3

Depending on this regression equation that has developed for average breach width and failure time are:

$$B_{ave} = 0.27 K_o V_w^{0.32} h_b^{0.04} \text{ --- } 3\text{-}1$$

$$t_f = 63.2 \sqrt{\left(\frac{V_w}{g h_b^2}\right)} \text{ ---} 3\text{-}2$$

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)

Dr. Froehlich stated the average side slope should be 1H: 1V and 0.7H: 1V for overtopping and piping failure respectively.

3.2.5.6 Determination of breach width 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. The method proposes to use the breach side slope of 1H: 1V. The data that Von Thun and Gillette used for this regression analysis had the following ranges:

- Height of dams: 3.66-92.96 meters
- Volume of water at breach time: 0.027 - 660.0 X10^6 m^3

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

$$B_{ave} = 2.5h_w + C_b \text{ ------------------------------------ } 3\text{-}3$$

Where:

B_{ave} –average breach width (meters)

H_w - depth of water above the bottom of the breach (meters).

C_b – coefficient

C_b is a function of the reservoir size of the dam. Its value is ranged between 6.1 and 54.9m. It is selected depending on the value that is listed in the table 3-4.

Table 3-4: coefficient as a function of reservoir size (Gary , August, 2014)

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

For our study since the storage capacity is greater than $1.23\ x\ 10^7$ our C_b is 54.9m. The average breach is equal to 142.4m and bottom breach width is 107.4m.

Von Thun and Gillette developed two different equations. These two equations also depend on the degree of erosion resistance.

The first set of equations shows the breach development time as a function of water depth for erosion resistant and easily erodible respectively are:

$$t_f = 0.02h_w + 0.25 \quad \text{---3-4}$$

$$t_f = 0.015h_w \quad \text{---3-5}$$

Where:

t_f – breach formation time (hours)

h_w – depth of water above the bottom of breach (meters)

The second set of equations shows breach development time is a function of water depth and average breach width. These equations for erosion resistant and easily erodible respectively are:

$$t_f = \frac{B_{ave}}{4h_w} \quad \text{---3-6}$$

$$t_f = \frac{B_{ave}}{4h_w + 61.0} \quad \text{---3-7}$$

Where:

B_{ave} – average breach width

Generally the first regression equations formulated by Von Thun and Gillette used to predict the time failure of embankments is a function of depth of water only while the other is a function of depth of water and the computed average breach width.

3.2.5.7 Breach weir coefficient

The weir coefficient must be entered as input by user in the HEC-RAS model. It directly affects the magnitude of peak outflow hydrograph for any given breach. In order to estimate this coefficient it is necessary to understand the basic failure process.

In general during an overtopping failure of an earthen dam head cut erosion process will first start on downstream of the dam embankment (figure 3-4A). While water is going over the dam crest, the dam crest acts like abroad crested weir. The head cut will erode back towards the center of the dam and widen over time (figure 3-4B). As head cut begins to cut into dam crest, the weir crest length will become shorter and the appropriate weir coefficient will trend towards a sharp crested weir value (figure 3-4C). The time for breach initiation used in HEC-RAS is shortly after what is depicted in figure 3-4C. When head cut reaches the upstream side of the dam crest, the mass failure of the upstream crest may occur and the hydraulic control section will act very much like as sharp crested weir (figure 3-4D). The head cut will continue to erode upstream through the dam embankment as well as erode down through the dam and widen at the same time (figure 3-4E). During this process the appropriate weir coefficient will begin to trend back towards a broad crested weir coefficient.

To estimate the weir coefficient in addition to basic failure process it is necessary to understand the storage capacity of the dam. Earthen dams with medium to very large storage volumes upstream will most likely fail all the way down to the natural stream bed elevation and in the breach widening phase when the peak out flow occurs. This would suggest using a weir coefficient (C) that is a typical of a broad crested weir with a long crest length (i.e. C=2.6). However for dams with relatively low volume water in comparison to the height of the dam, the peak flow may occur during the phase of the breach in which the breach is still cutting down through the dam. For this case a weir coefficient typical of a sharp crested weir would be more appropriate (i.e. C=3.2).

During piping failure breach the rate of flowing water through the dam is modeled with an orifice pressure flow equation. This equation also requires a discharge coefficient which is a measure of how efficiently the flow can get into the pipe orifice.

Recommended values for the piping/pressure flow coefficients are in the range of 0.5 to 0.6. Guidelines for selecting breach weir and piping flow coefficients are provided in table 3.5.

Table 3-5: Dam Breach Weir and piping coefficients (Gary , August, 2014)

Dam type	Over flow/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 our embankment dam is medium with comparison of height of the embankment dam the selected value of weir coefficient is 2.6 for over topping and 0.5 for piping.

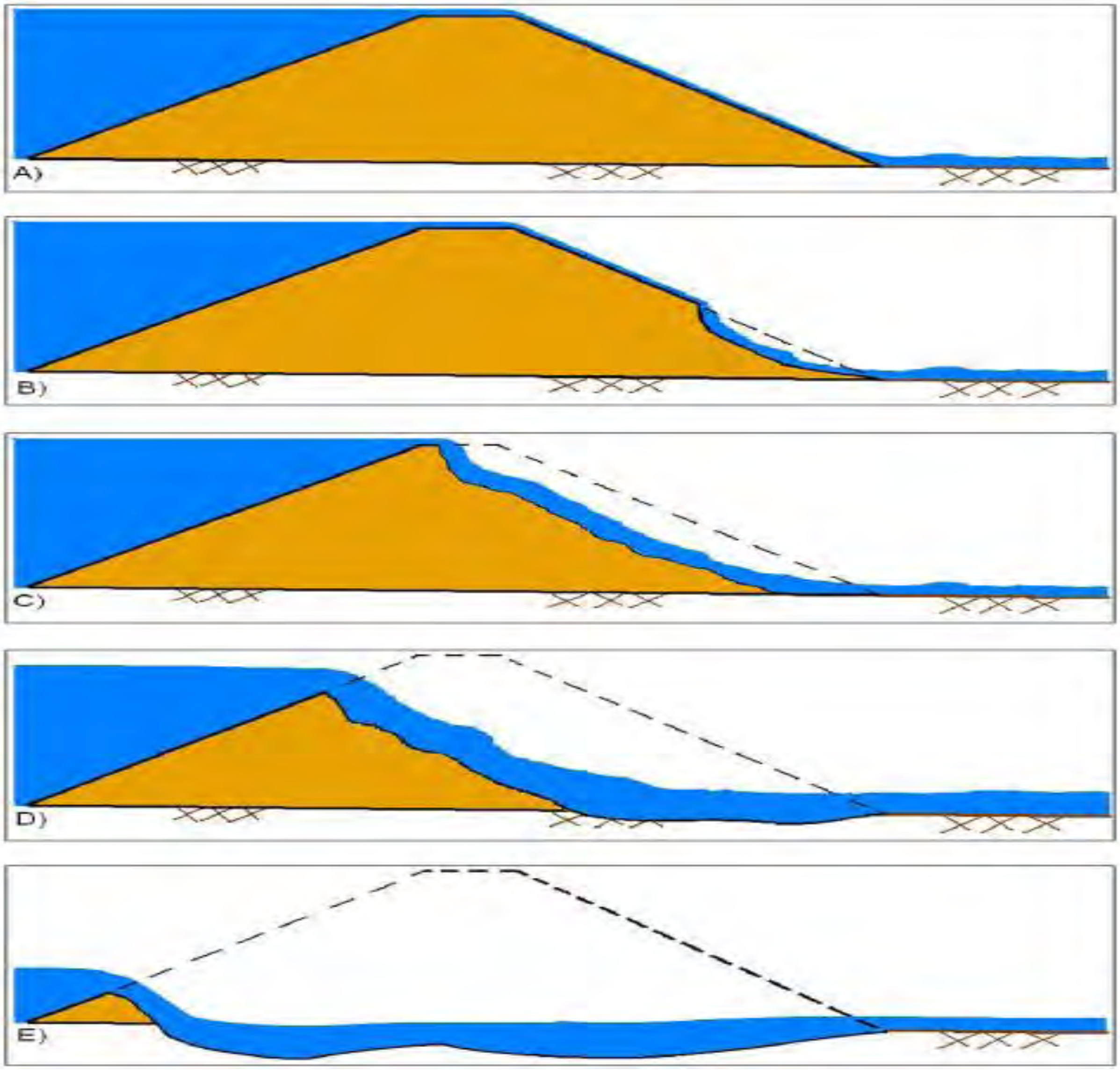

Figure 3-4 Breach process for an overtopping failure **(Gary , August, 2014)**

3.2.6 Determination of manning coefficient

Manning's roughness coefficient values are used in the manning formula for flow calculation in open flow channels. Roughness coefficients represent the resistance to flood flow in open channels and flood plains.

For accurate dam break analysis the values of manning roughness coefficient should be taken in each cross section with the corresponding value. But for our case for the whole river course a constant manning's roughness coefficient is assumed. 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(Chow, 1959) suggested the range for this type is between the range of 0.03 and 0.05).

3.3 Collection of Cross Section

Cross section is collected from digital elevation model (DEM). This is carried out by geo-referencing the digital elevation model (DEM) of Ethiopia with the shape profile of Nashe Dam and River. This cross section is used as input data for HEC-RAS.

3.4 Type of Hazard Dam

During the construction of Nashe Dam thousands of people are resettled. The construction of their residential houses is at downstream of the Dam around the river bank. If the Dam break unfortunately it affects the peoples those live downstream of the dam especially around river bank. Therefore this Dam is high hazard dam for loss of human life is expected to result from failure of the dam.

3.5 Dam Breach Analysis Approach of the Study

Dam breach analysis of the study is based on both hydrologic failure and non-hydrologic failure approach for overtopping and piping failure mode respectively. Under this study it is divided into overtopping and piping method. Overtopping is based on hydrologic event and the PMF after 100 years can be greater than the capacity of the spillway which is used to discharge excess water to the downstream. If the spillway is malfunctioned at this time the dam will be overtopped.

3.6 Inundation map preparation

Floodplain mapping is accomplished in the GIS using HEC-GeoRAS. GIS information is exported from HEC-RAS and read into the GIS with HEC-GeoRAS. The geo-referenced cross sections are imported and water surface elevations attached to the cross sections are used to create a continuous water surface. The water surface is then compared with the terrain model and the floodplain is identified where the water surface is higher than the terrain.

4 RESULTS AND DISCUSSIONS

4.1 Breach width and Breach Development

The average breach width is calculated by inserting the information of case study of the dam in the regression equation of the Froehlich (2008) and Von Thun and Gillette. The calculated breach width and breach development time by Froehlich (2008) are 237.4m, 3.39hour and 182.6m, 3.39 for overtopping method and piping method respectively. 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 which used for HEC-RAS model as input is 202.4m and 134.04m for overtopping and piping respectively as recommended by Froehlich (2008).

The bottom width and breach development time calculated by Von Thun and Gillette are 107.2m and 1hr for 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.

4.2 Overtopping Failure Mode

In this mode the most critical situation for the dam break is the condition when the reservoir is at full reservoir condition and peak of the most severe flood (PMF) impinges over the reservoir. As the spillway capacity is 1196 cumec 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 in put data in hydraulic model (HEC-RAS). The water level at the dam when dam breach started will be 2110m and breach will continue up to bed level.

4.2.1 Dam Breach Statistics and flood hydrograph

When the dam is overtopped by PMF, the dam breached attains the water level of 2112.69m. The maximum discharge flow out from the breached dam is 8761.23m^3/sec which is 7.33 times the

PMF. The maximum discharge is attained at 20min from the start of dam break and the water is coming out with a maximum velocity 10.21m/s. The actuality of this result is checked with envelope curve of experienced outflow rates from breached dam as indicated from figure 4-1.

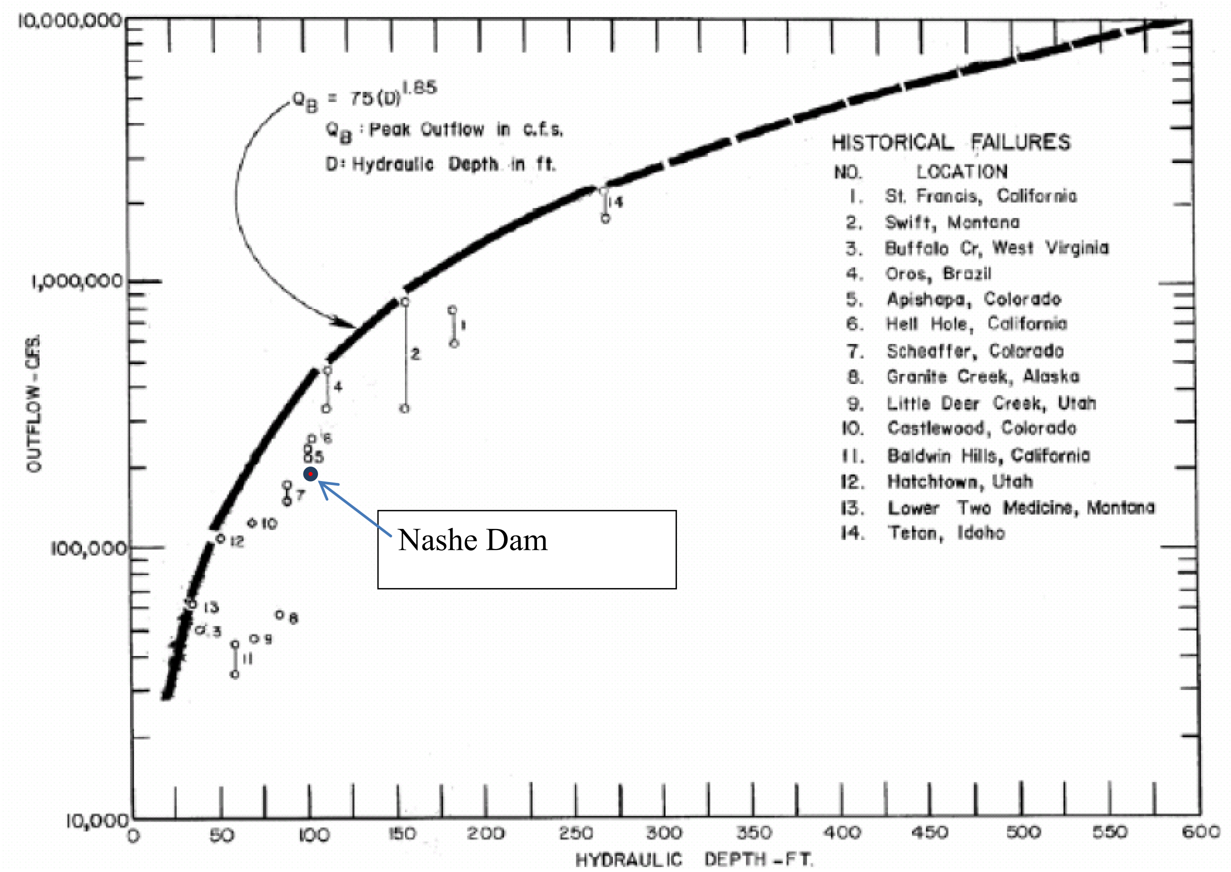

Figure 4-1 location of Nashe Dam on envelope of experienced outflow rates from breached dam by overtopping

Figure 4.2 and 4.3 which are taken from Table Appendix-1 shows routing of flood hydrograph by overtopping at dam and different points downstream of the dam.

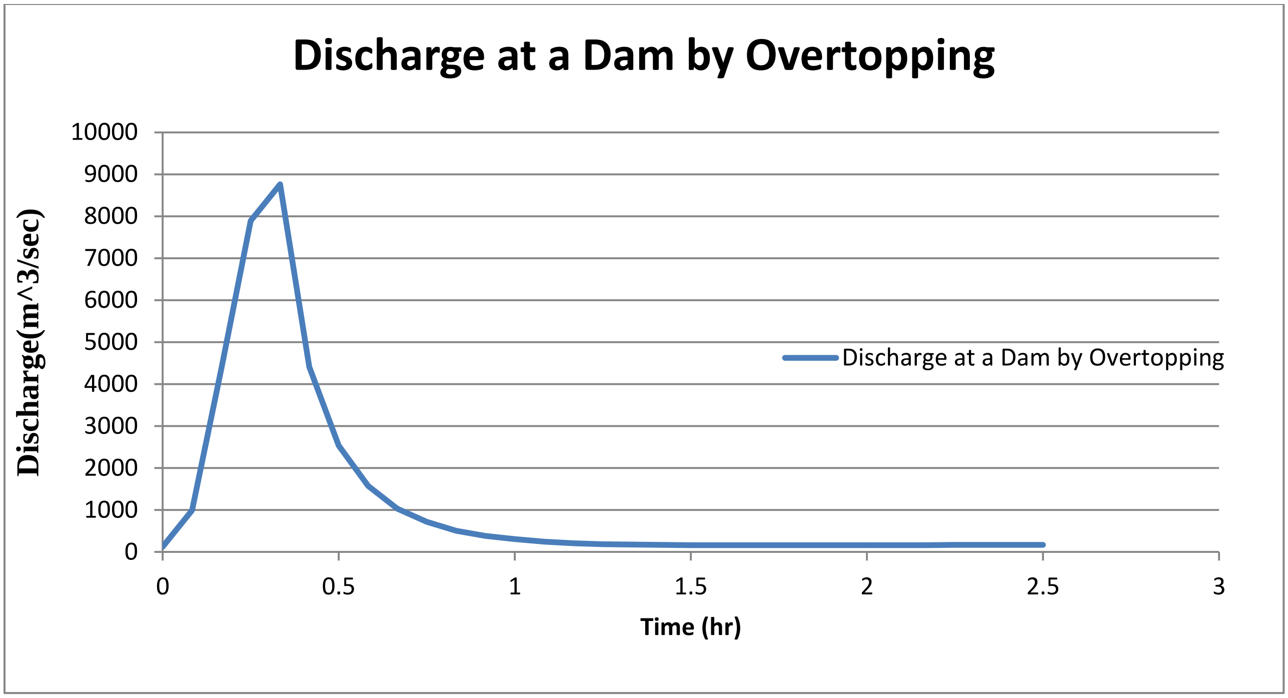

Figure 4-2 Flood routing at Dam site by Overtopping

4.2.2 Routing of flood hydrograph at different chainage by overtopping

Routing of flood hydrograph is analyzed at four chainage points, 5.09Km, 10.09Km, 20.49Km and 25.71Km downstream of the dam. Figure 4.2 shows the flood hydrographs for these chainage points. At dam site the peak discharge of 8761.23m^3/s is flows out at 20minutes from the starting time of dam break. At 5.09km downstream location, the peak flood discharge is about 8463.07 m^3/s which is 3.4% less than the peak discharge coming out from the breached dam and it reached at 25minutes. This flood reaches 10.09km at 30minutes and the peak discharge of about 8012.37 m^3/s. Now, if goes further downstream of the dam then we see that the arrival of peak discharge 6565.35m^3/s at 20.49km is 50minutes and at 25.71km downstream of the dam the peak discharge which is 5474.66m^3/s is 60minutes.

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 graphs and cross sections of the river and flood map.

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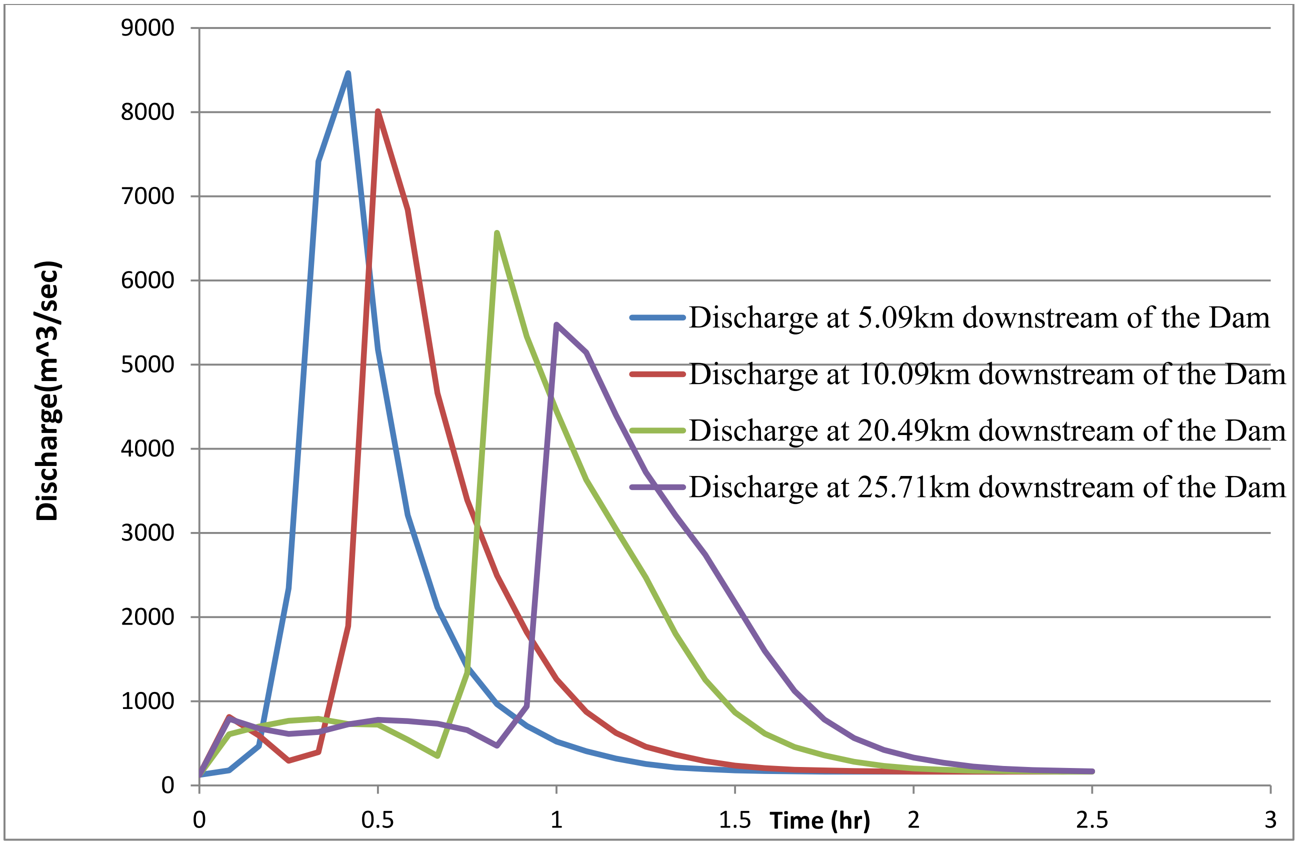

Figure 4-3 Flood hydrograph at different Chainage downstream of the dam by overtopping

4.2.3 Longitudinal Bed profile

Fig. 4-4 shows the longitudinal profile of Nashe River including bed level, minimum bank level, and maximum water level reached when dam break. As we analyzed from longitudinal profile and from the study of topography the flood that flows out from dam enter plains for 250m downstream of the dam. From 250m to 4.2km it runs through steepy longitudinal bed. At further downstream, the longitudinal bed slope become flat.

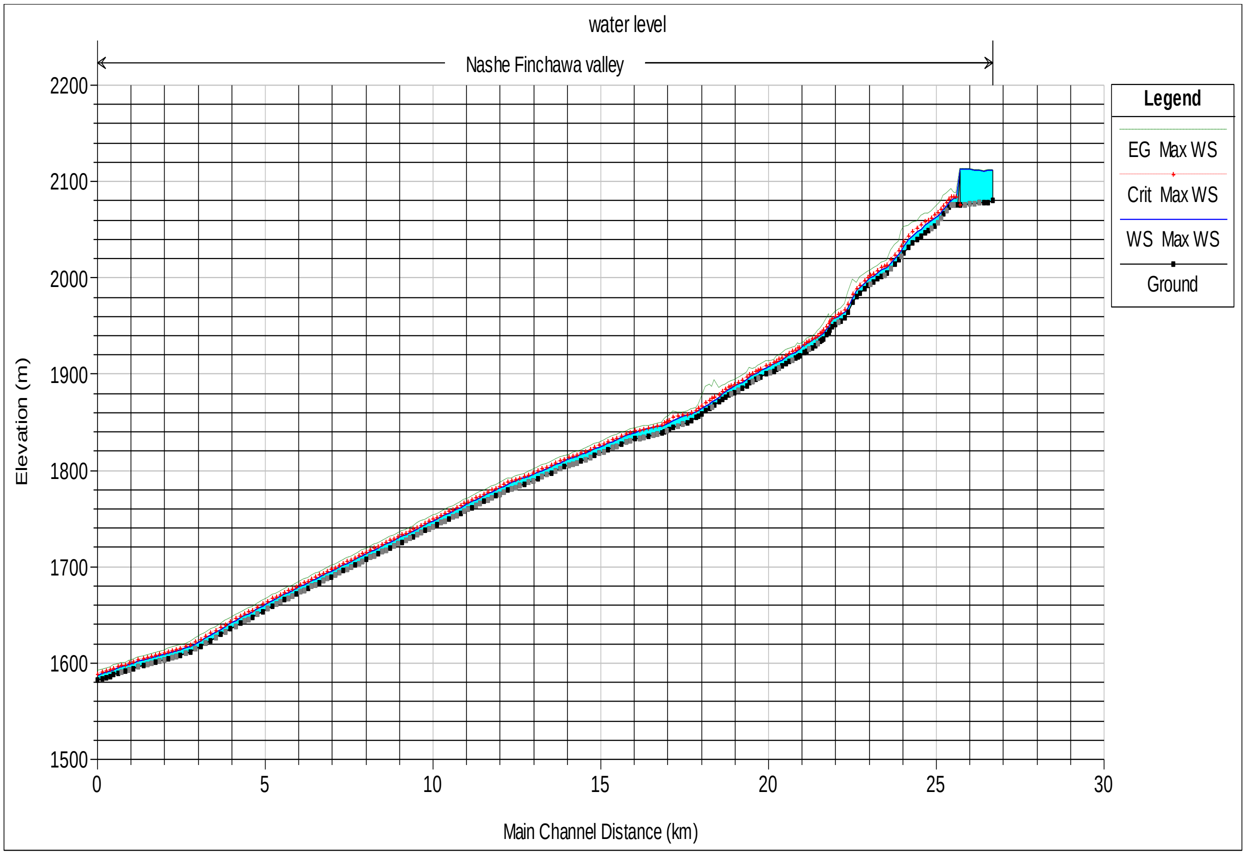

Figure 4-4: longitudinal bed profile of Nashe river showing MWL

Fig. 4-5 to 4-8 shows the cross section of river at 5.09km, 10.09km, 20.49km and 25.71km respectively with maximum water level. As we obsreved from these cross sections 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 the coresponding the top width are 205.00m, 211.97m, 199.81m and 193.90m respectively. Depending on these we can determine the area that is affected by flood due to dam break.

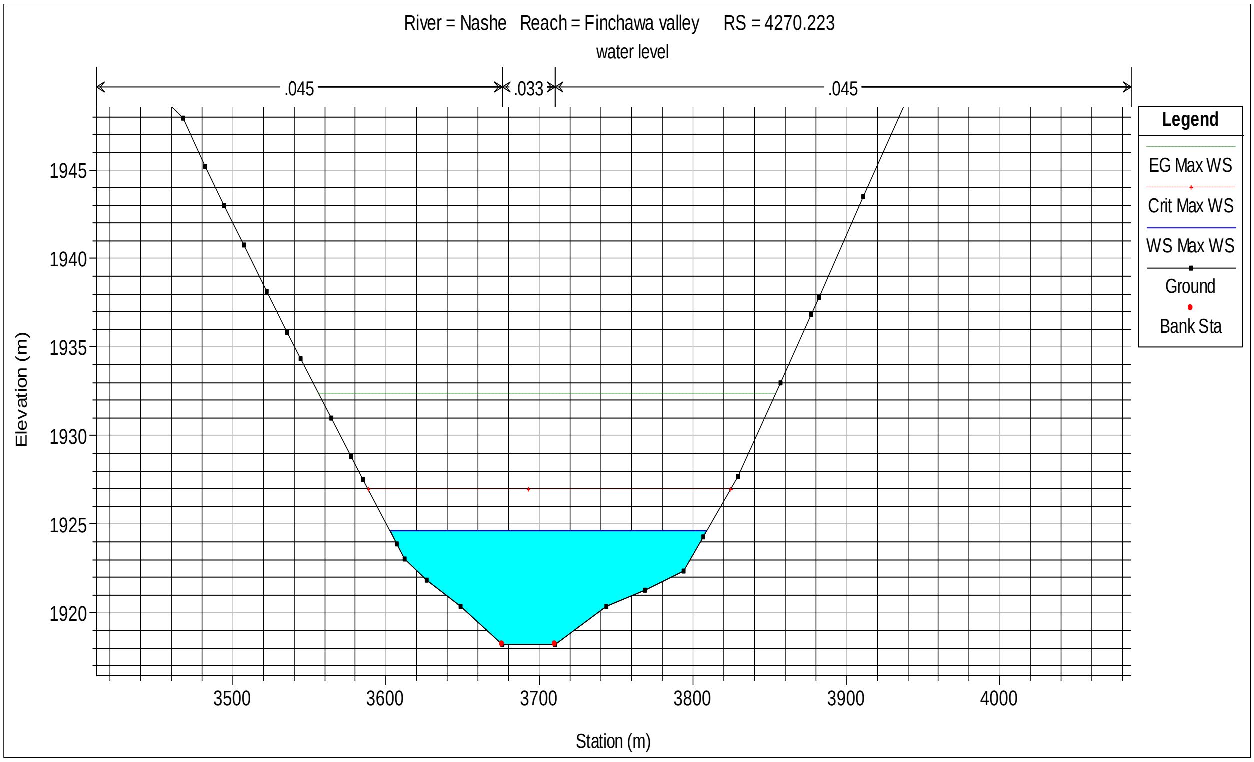

Figure 4-5: River cross-section at 5.09km from the Nashe River

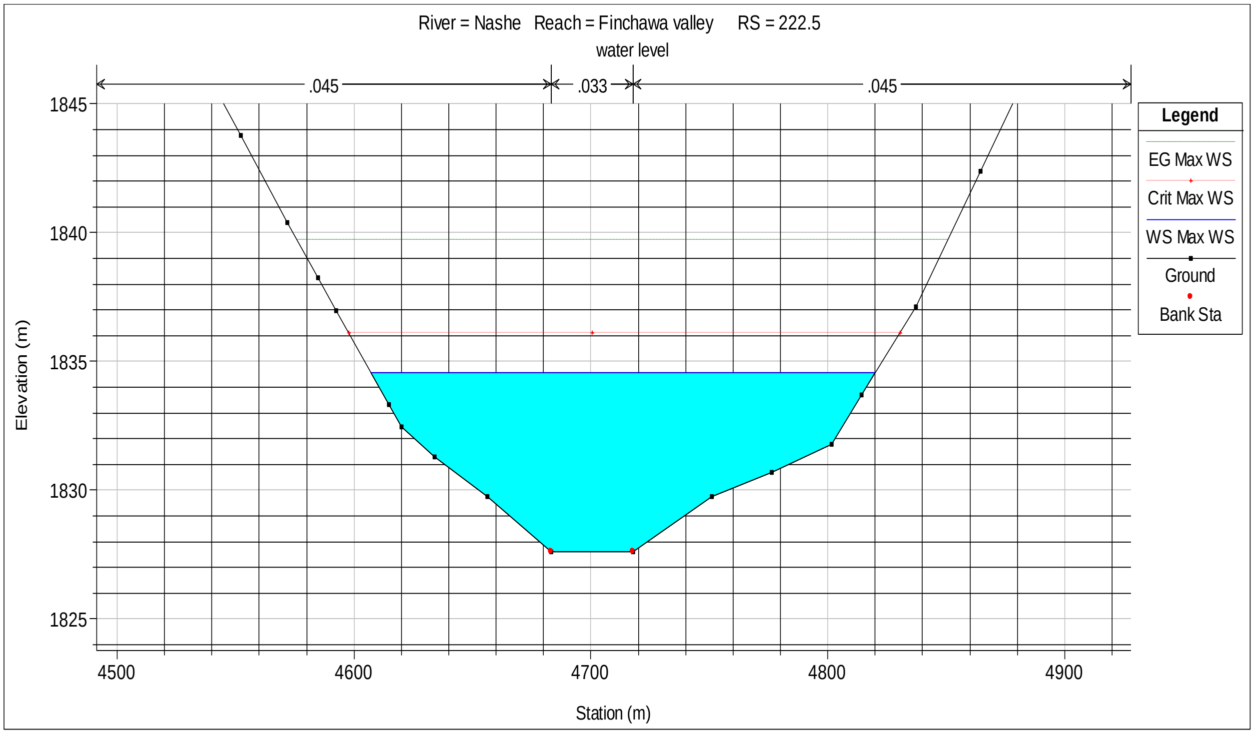

Figure 4-6: River cross-section at 10.09km from the Nashe River

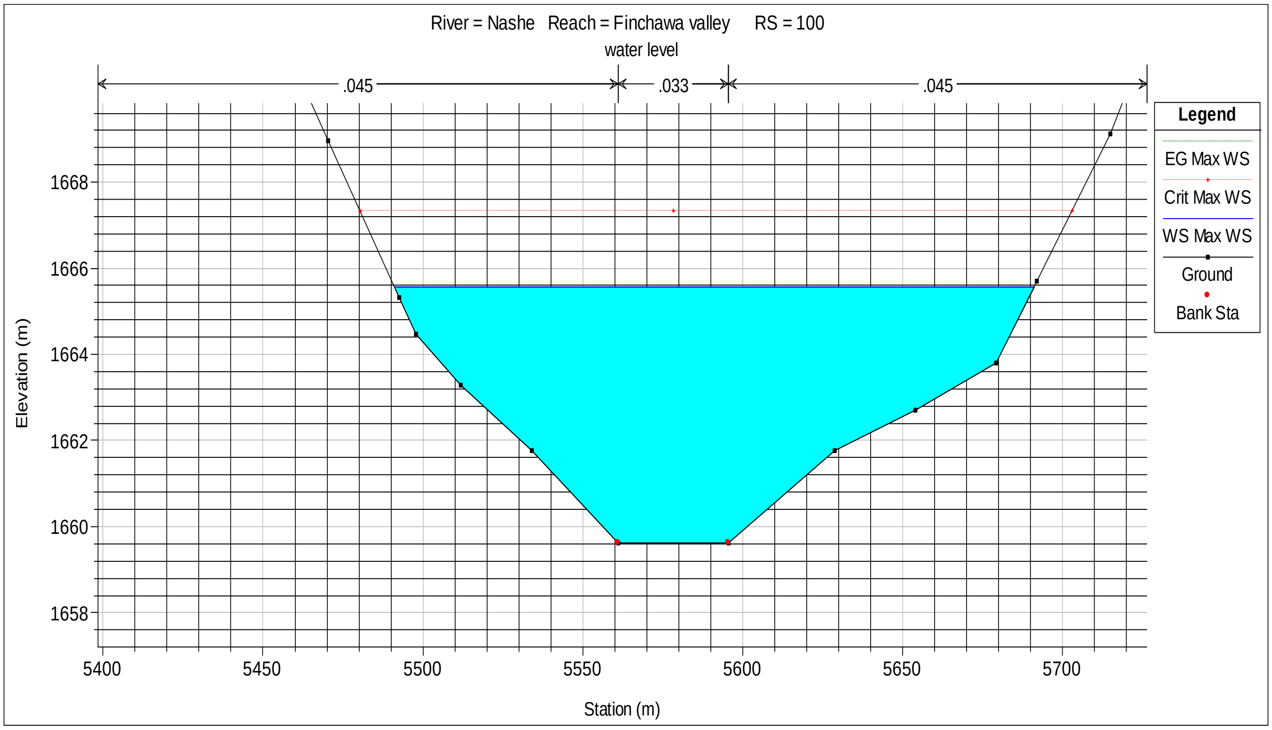

Figure 4-7: River cross-section at 20.49km from the Nashe River

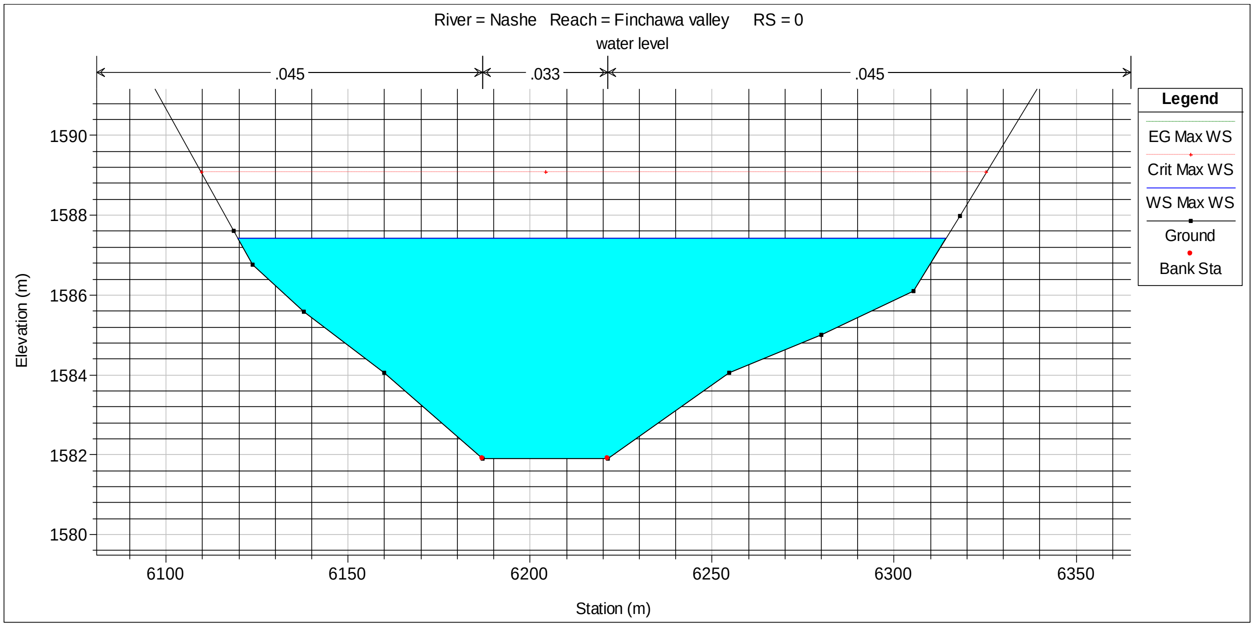

Figure 4-8: River cross-section at 25.71km from the Nashe River

Figure 4-9, 4-10, 4-11, 4-12 and 4-13 shows 3-dimensional water surface profile of peak discharge at 5.09km, 10.09km, 20.49km, 25.71km and the maximum water surface in all cross sections respectively

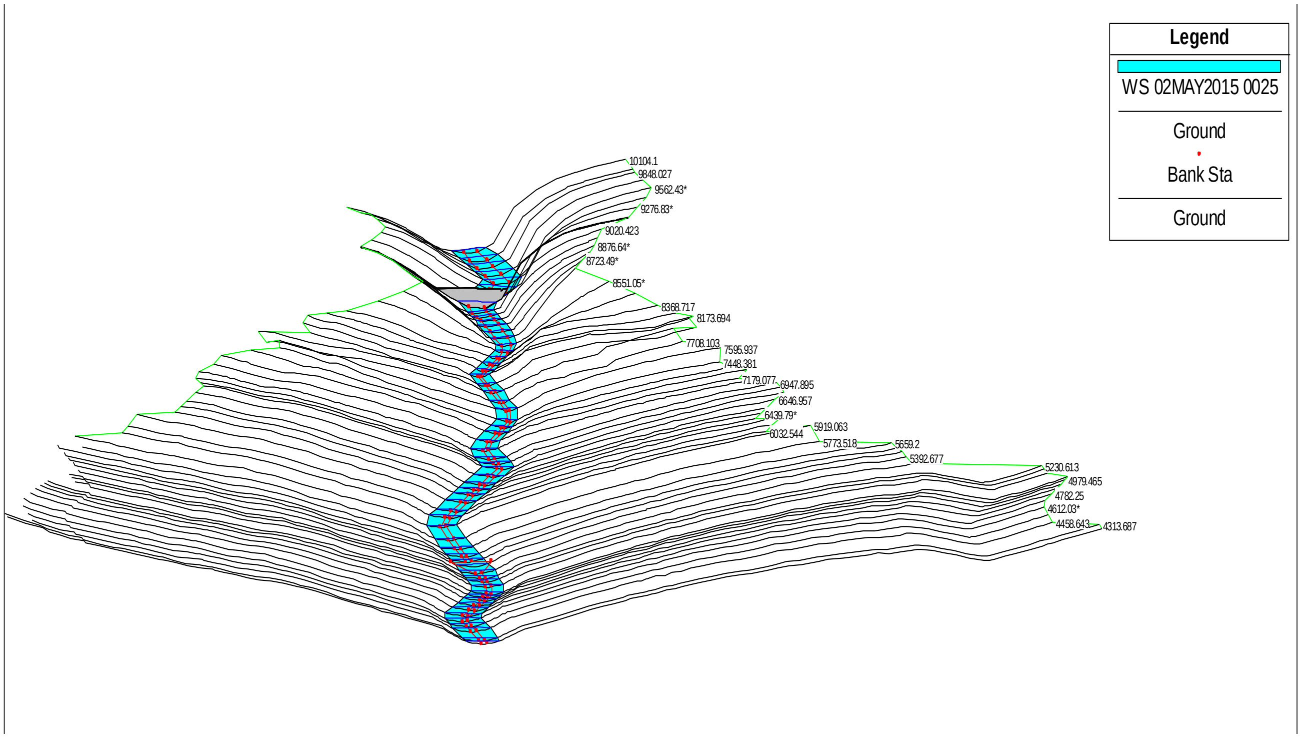

Figure 4-9 3-D WSP of peak discharge at 5.09km downstream (between Dam and 5.09km)

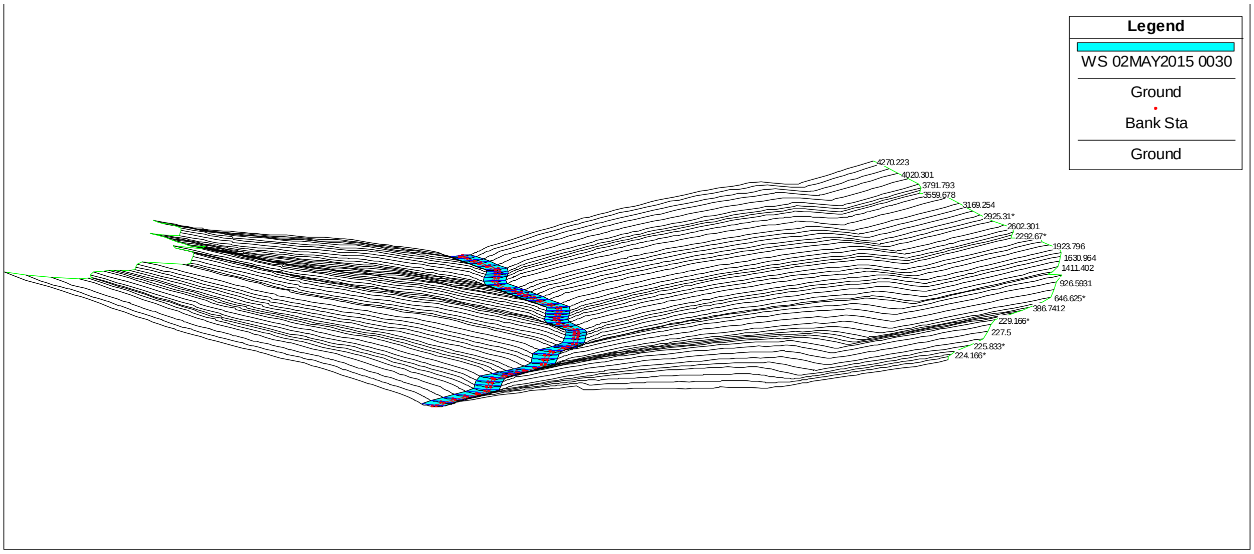

Figure 4-10 3-D WSP of peak discharge at 10.09km downstream (between 5.09km and 10.09km)

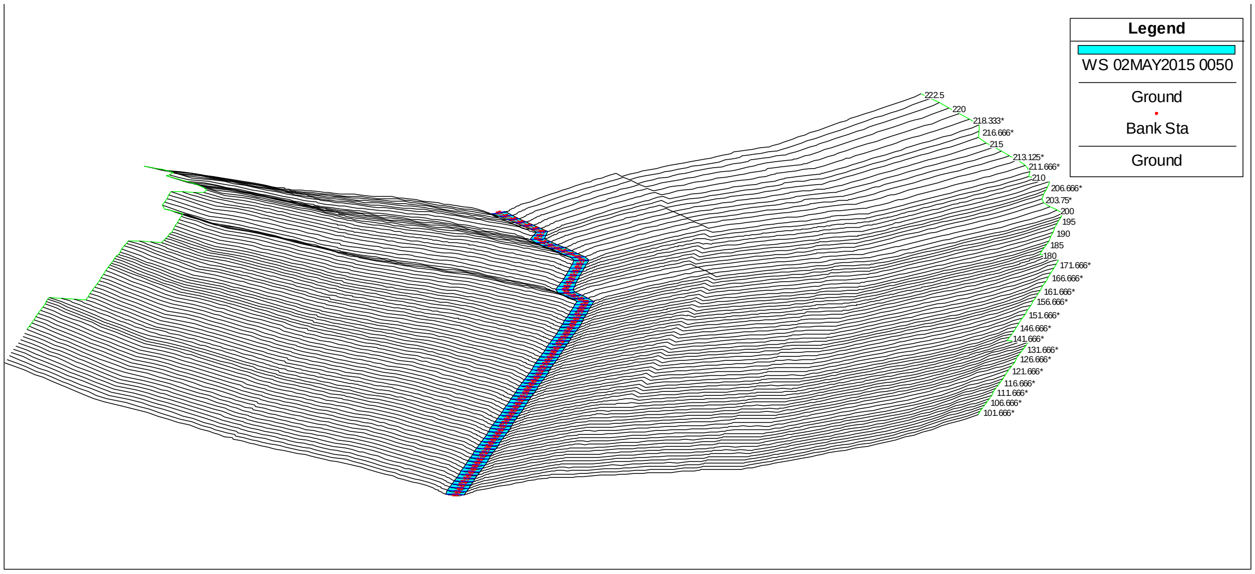

Figure 4-11 3-D Water surface profile of peak discharge at 20.49km downstream (between 10.09km and 20.49km)

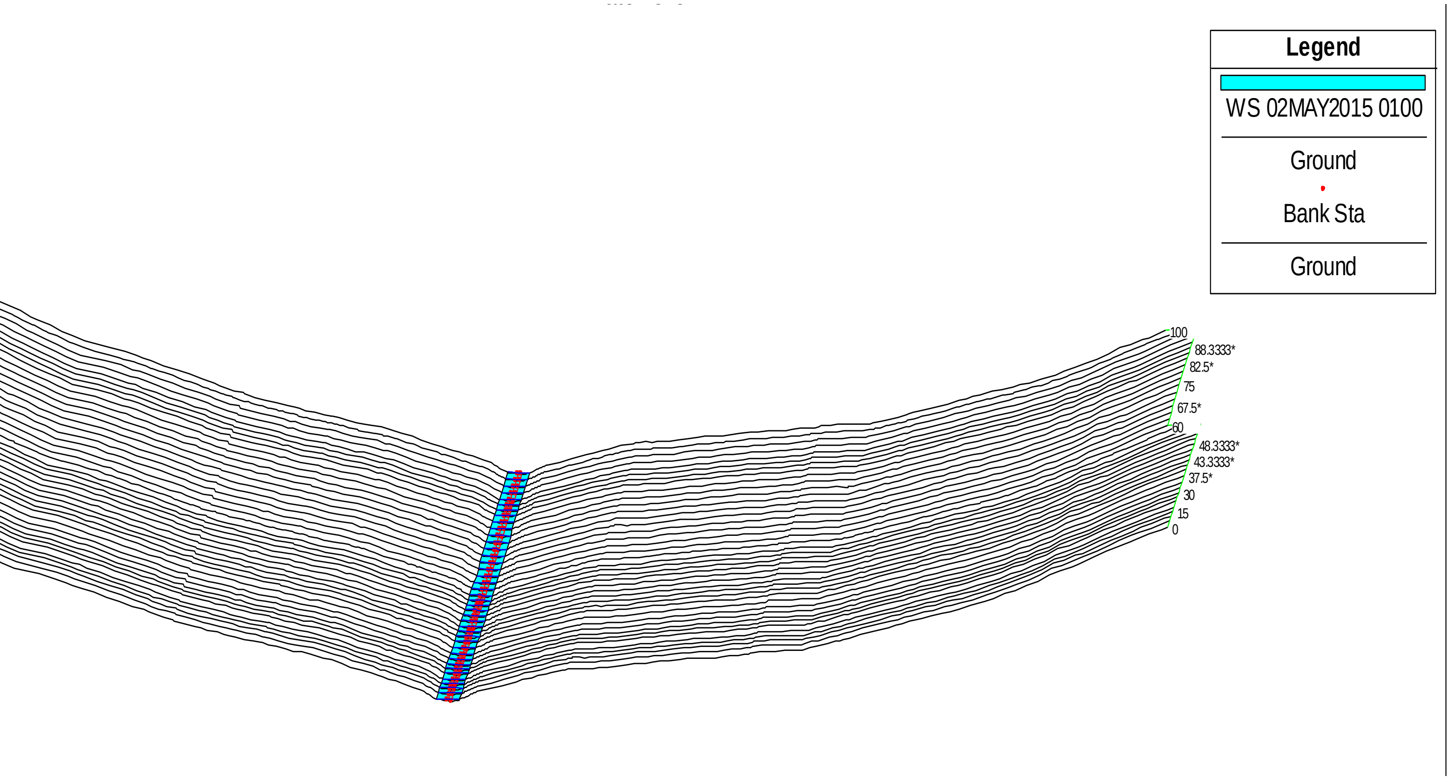

Figure 4-12 3-D water surface profile of peak discharge at 25.71km Downstream (between 20.49km and 25.71km)

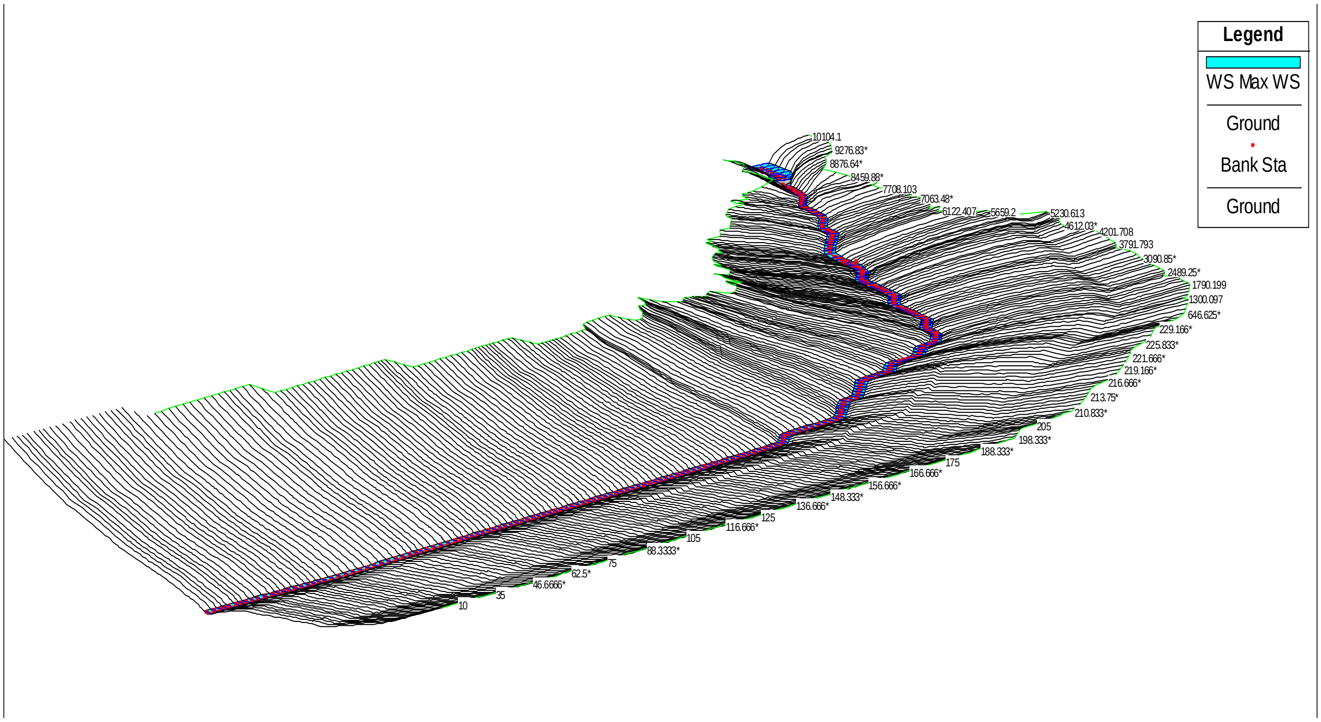

Figure 4-13 3-D maximum water surface profile of peak discharge in the whole cross section

4.3 Piping Failure Method

In this method the most critical situation is at normal condition. The breach by this method depends on the sunny day condition rather than rainy day condition. As we stated before dam breach parameters used for input in (the HEC-RAS model) are calculated by Von Thun and Gillette. The water level of reservoir when dam breach started is 2106m and breach will continue up bed level.

4.3.1 Dam Breach statistics and flood hydrograph by piping method

When peak discharge 8620.85m^3/s which is 7.21 times the PMF flows out from dam breach by piping method the water level attain 2102.82m.The maximum discharge flows out at 15min from the starting of dam breach and the water is coming out with maximum velocity 13.54m/s. In this method the peak discharge is 1.6% less than the amount of peak discharge flow out by overtopping method. This shows that the dam breached by overtopping is more devastating than that breached by piping method. Figure 4-14 shows routing of flood hydrograph of the dam breach at dam site.

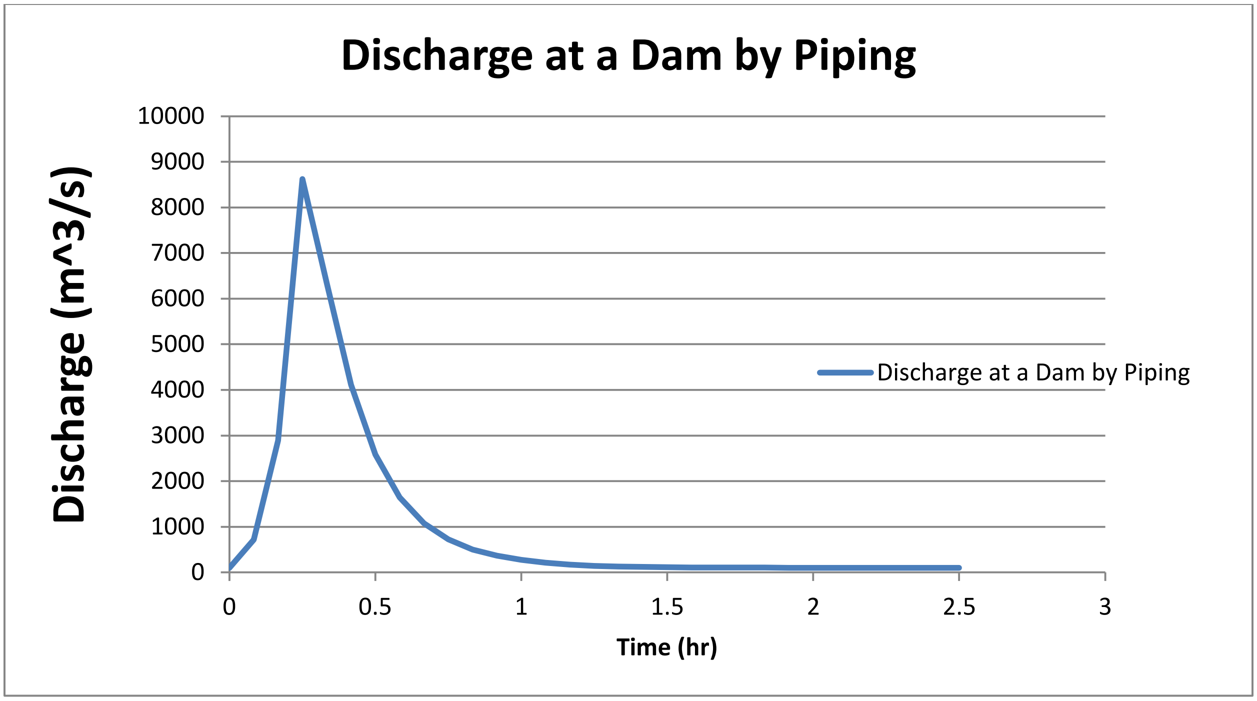

Figure 4-14: Flood routing at Dam site by piping

4.3.2 Routing of flood hydrograph at different chainage by piping method

Similar to routing of flood hydrograph under overtopping 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 discharge 8620.85m^3/s, flows out at 15minute from the starting time of the dam breach. At 5.09km the peak discharge 7148.99m^3/s which is 17.07% less than the peak discharge flows out at the dam is at 20minute from the starting time of dam breach. As we go further to 10.09km, 20.49km and 25.71km downstream of the dam, the corresponding peak discharges are: 6591.09m^3/s, 5021.39m^3/s and 4729.99m^3/s and flows out at 30minute, 55minute and 65minute respectively. Figure 4-15 shows flood hydrograph at 5.09km, 10.09km, 20.49km and 25.71km downstream of the dam. At these downstream locations the depth of water and top width are known. Figure 4-16 to 4-19 shows the cross sections of each location with their water level and top width. The water depth at the stated locations are 6.08m, 6.40m, 5.44m and 5.14m respectively and the corresponding top width are 198.06m, 204.35m, 191.41m and 189.58m.

Generally when we analyze the dam breach for Nashe Dam by both failure mode i.e. overtopping and piping method, by overtopping has greater water depth and top width. 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.

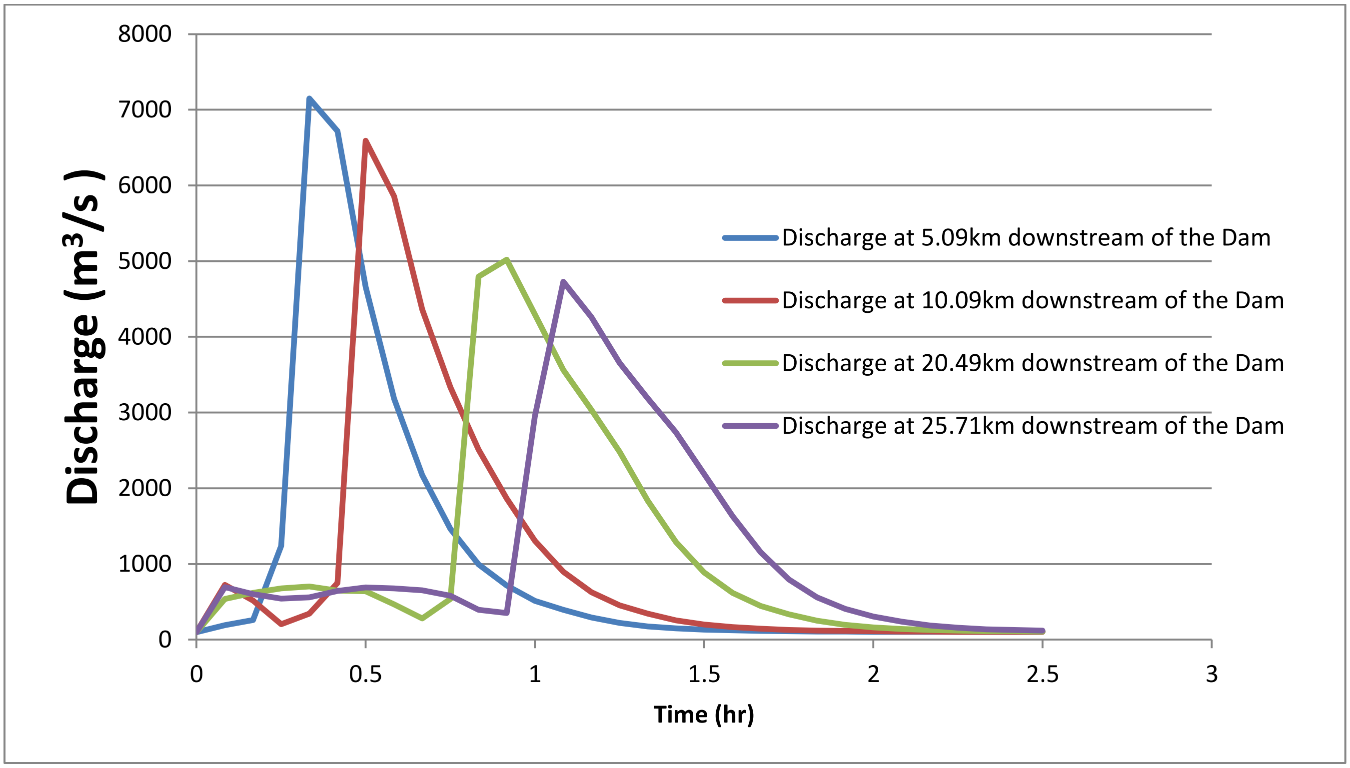

Figure 4-15 Flood hydrograph at different Chainage downstream of the dam by piping

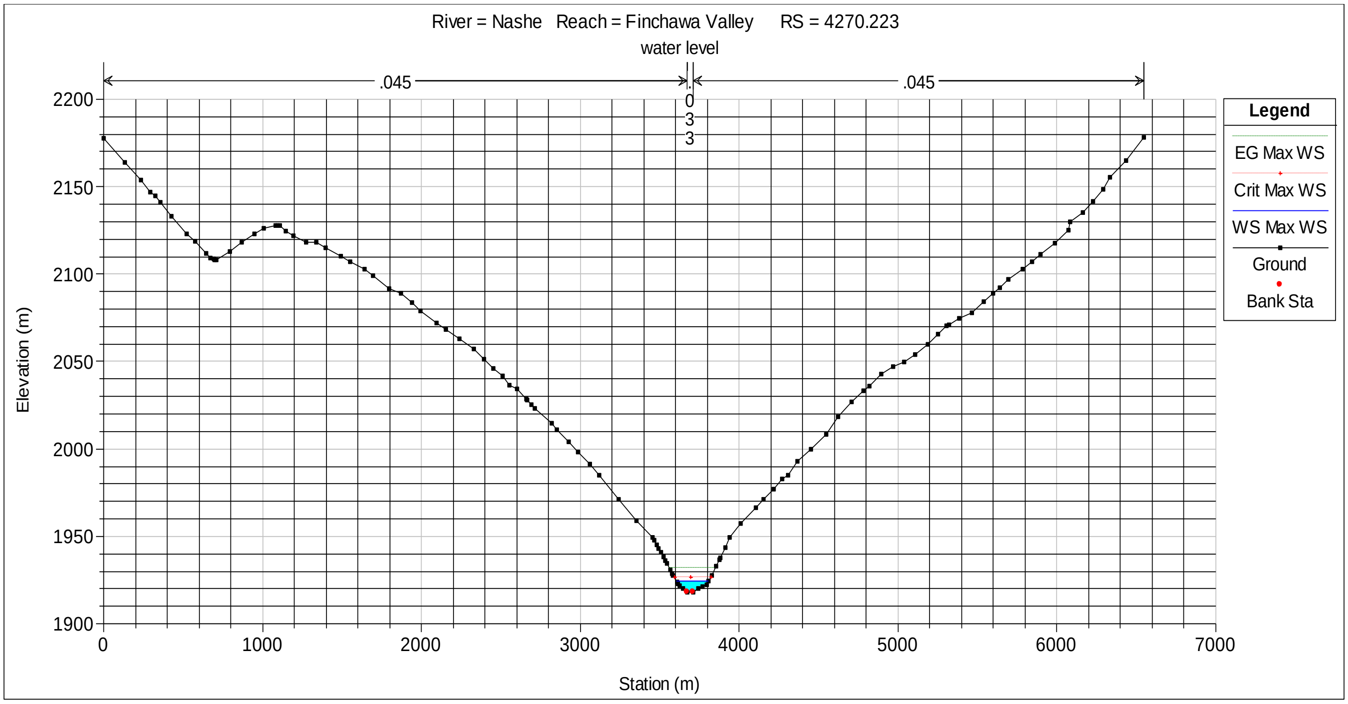

Figure 4-16 River cross-section at 5.09km from the Nashe River

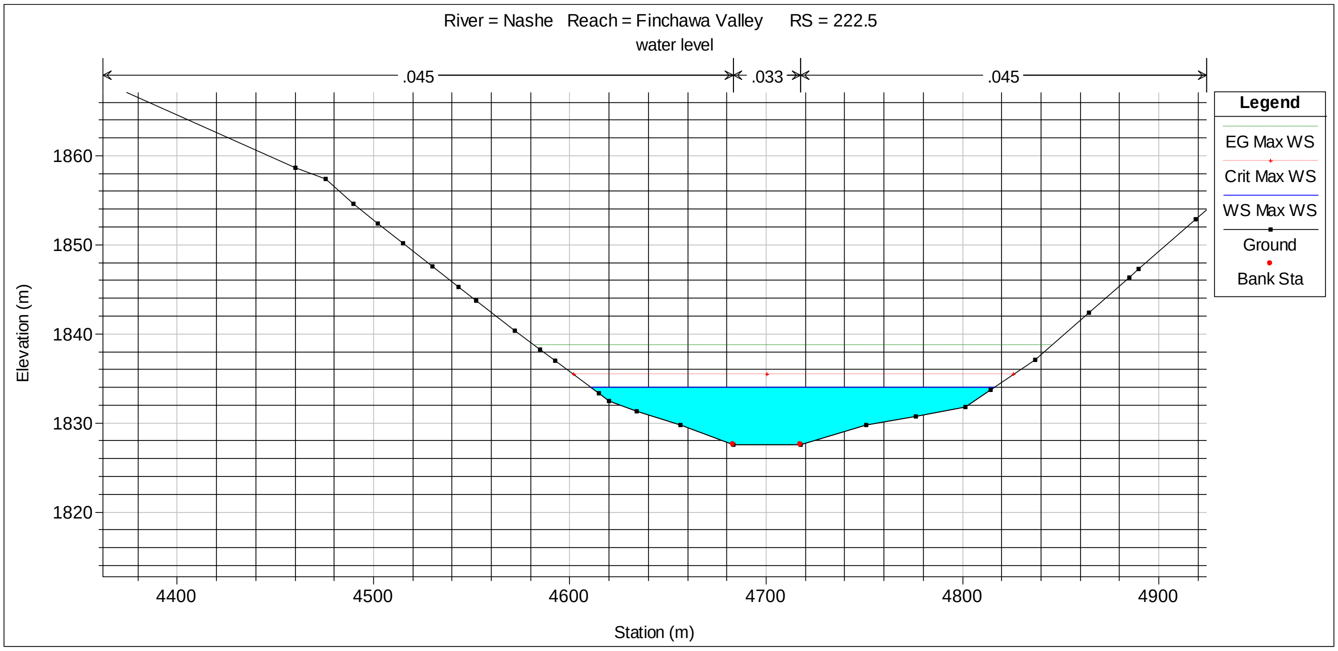

Figure 4-17 River cross-section at 10.09km from the Nashe River

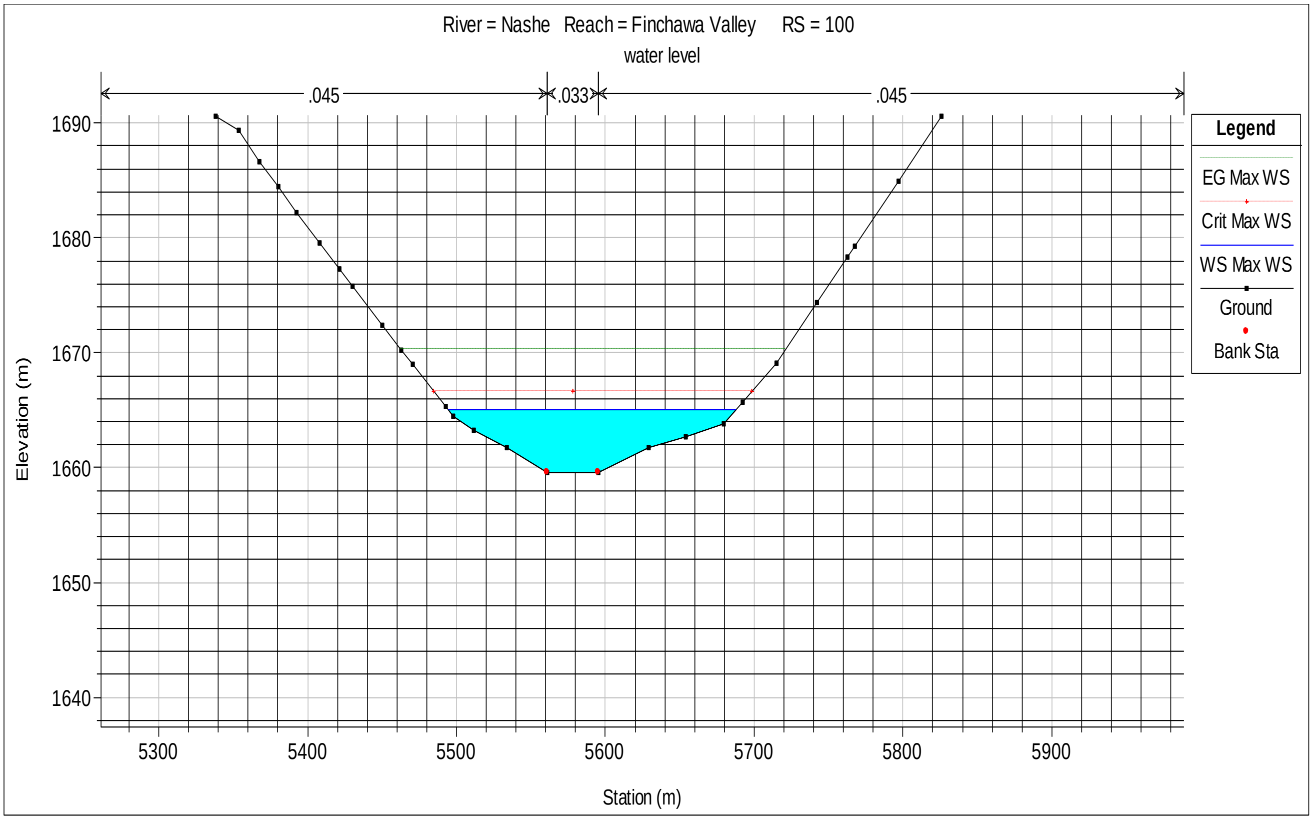

Figure 4-18 River cross-section at 20.49km from the Nashe River

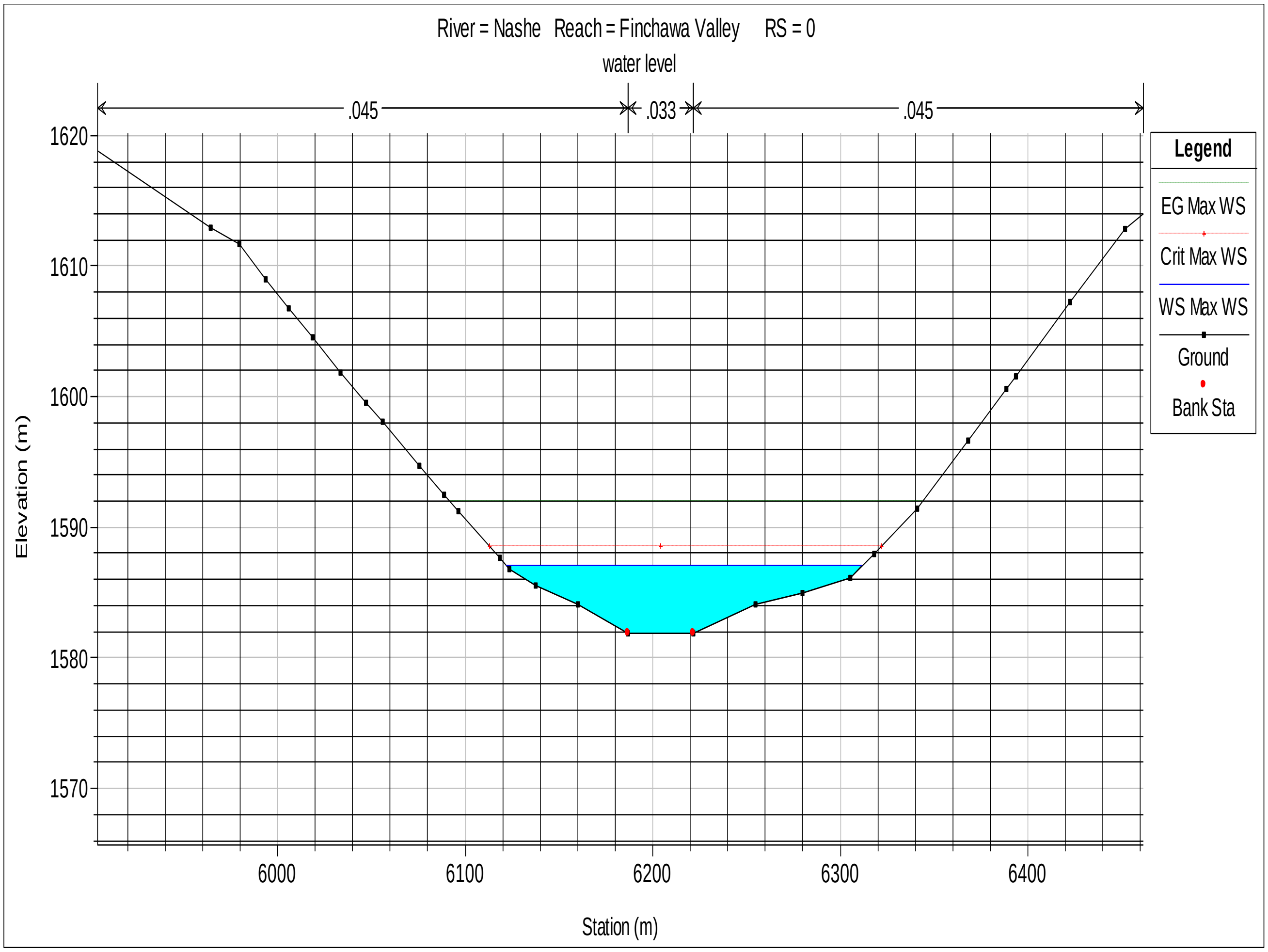

Figure 4-19 River cross-section at 25.71km from the Nashe River

4.4 Sensitive parameters for input parameters in terms of peak discharge and water level

As we know the selection of input parameters for the dam break model are very important to do the analysis. If we change the values of these input parameters to the model setup then what is the effect on discharge values and water levels is analyzed and this analysis part is known as sensitivity analysis. So Input parameters which are considered for the sensitivity analysis are:

a. Breach time
b. Breach width
c. Side slope

d. Manning's roughness

For the full study of Nashe Dam break the results are obtained, analysed and compared with different dam break scenarios as explained in Table 4-1. 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.

4.4.1 Effect of Breach time

In this section setup1 and setup3 are compared with setup2. Setup1, setup2 and setup3 represents when the time breach is 0.9hr, 1hr and 1.1hr respectively.

Sensitivity of discharge is analysed by changing time parameters which are explained in table5-1 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%.

Breach time is the time of development of breach fully in the dam structure and we know that earthen dams are assumed to be breached gradually. When the breach time is increased or decreased almost the same peak water level along the downstream location is observed. Fig 4.20 and fig 4.21 shows the effect of breach time on discharge and water level.

Table 4-1 DB modeling for different breach parameters for Nashe River

Scenario	Breach time (hr.)	Bottom breach width (m)	Breach slope
Setup1	0.9	107.4	1H:1V
Setup2	1	107.4	1H:1V
Setup3	1.1	107.4	1H:1V
Setup4	1	96.66	1H:1V
Setup5	1	118.14	1H:1V

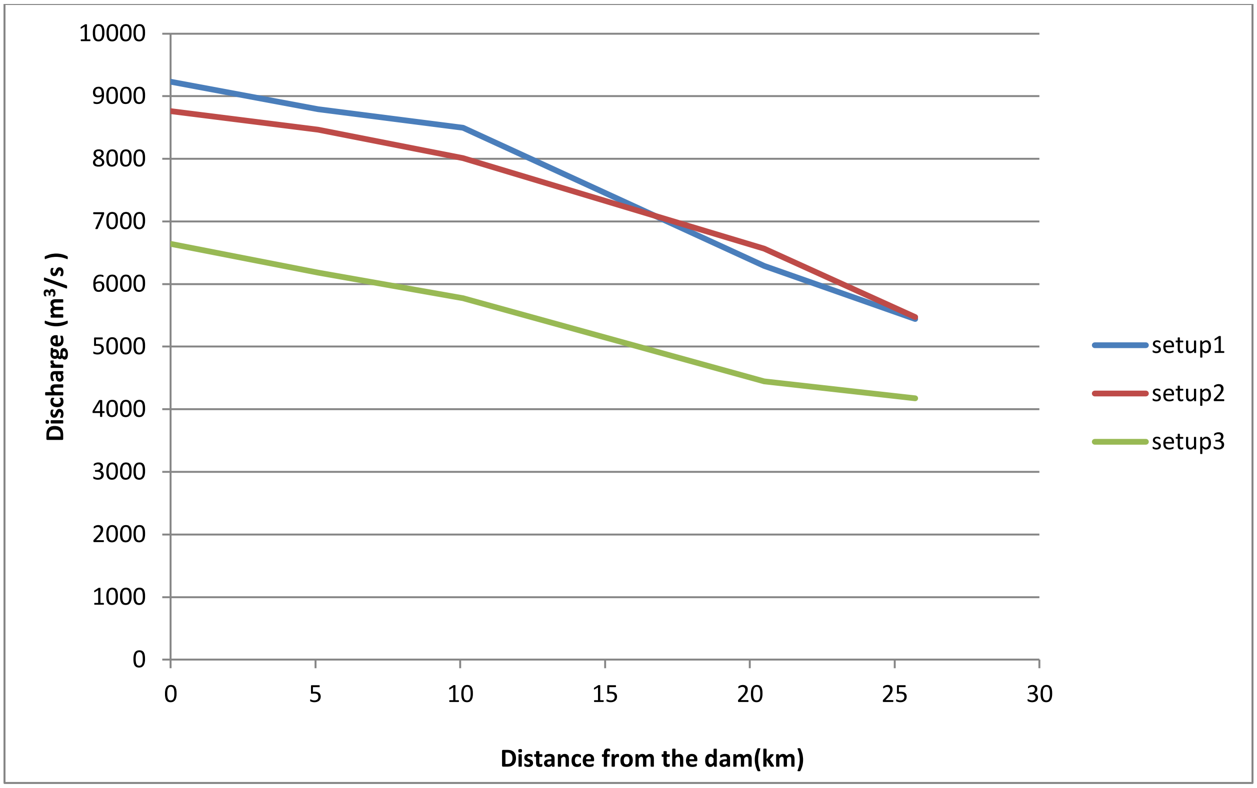

Figure 4-20 Sensitivity of breach time on Max. Peak Discharge of Nashe Dam

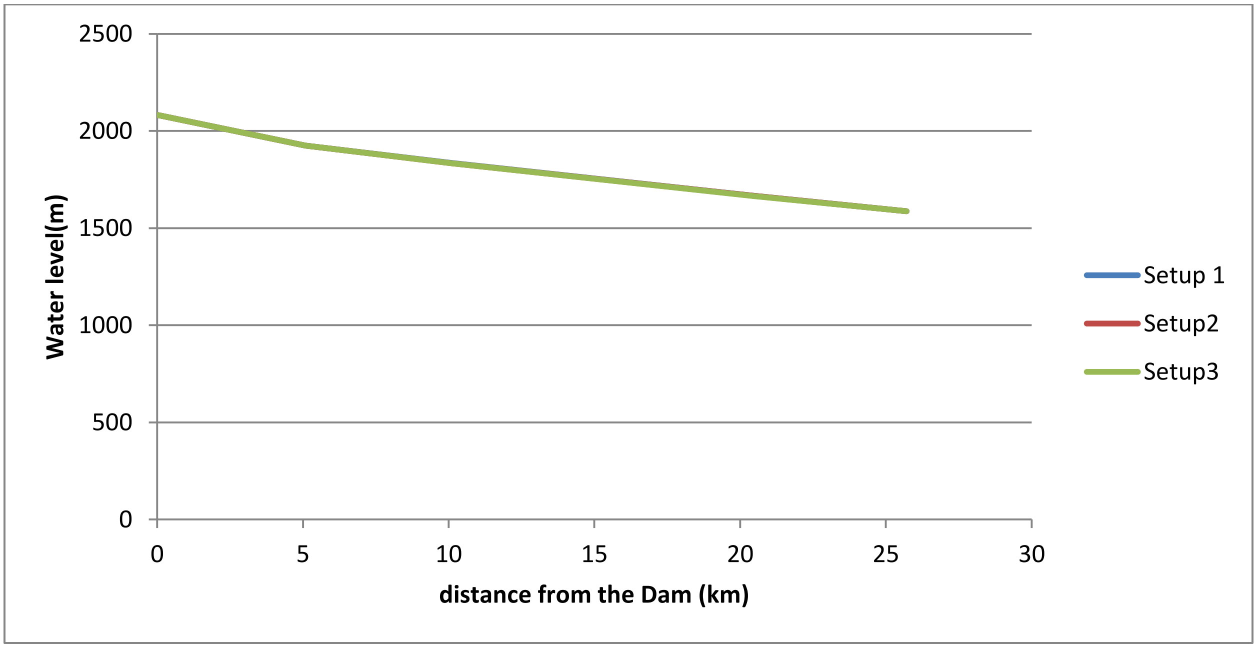

Figure 4-21 Sensitivity of Breach Time on Max. WL of Nashe dam

4.4.2 Effect of bottom breach width

It is analysed by changing breach bottom width and keeping the other parameters constant. The setup4 and setup5 shows the change of bottom breach width by keeping breach time constant and the results obtained from these setups is analysed as how much the bottom breach width will affect the peak discharge and water level downstream of the valley comparing with setup2. These setups represent the decrement and increment of bottom breach width by 10% respectively. When it is increased from 107.4m to 118.14m means by 10% there is 4% increment in the peak discharge is noticed at dam and when 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 and almost same peak water level along the downstream location is observed. Fig. 4- 22 and fig. 4-23 shows the effect of breach width on discharge and water level

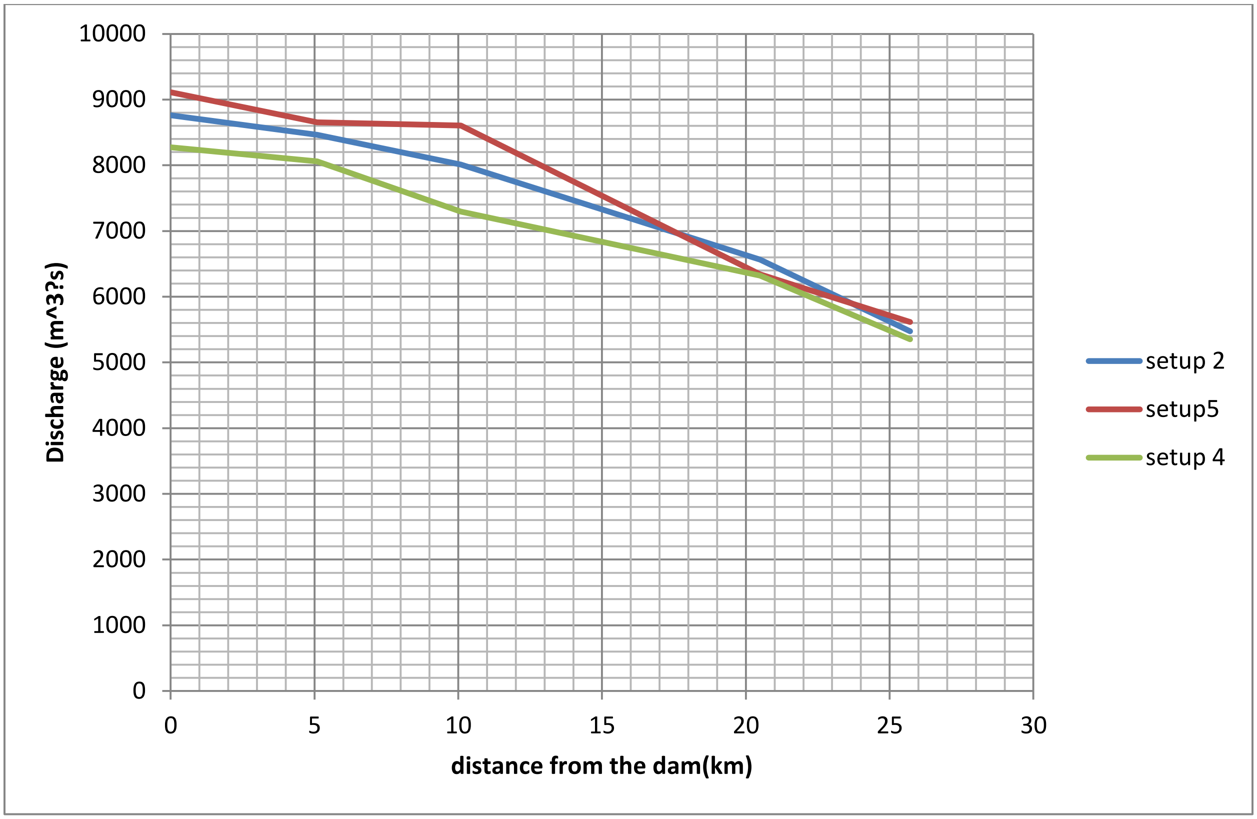

Figure 4-22 Sensitivity of bottom Breach Width on Peak Discharge of Nashe Dam

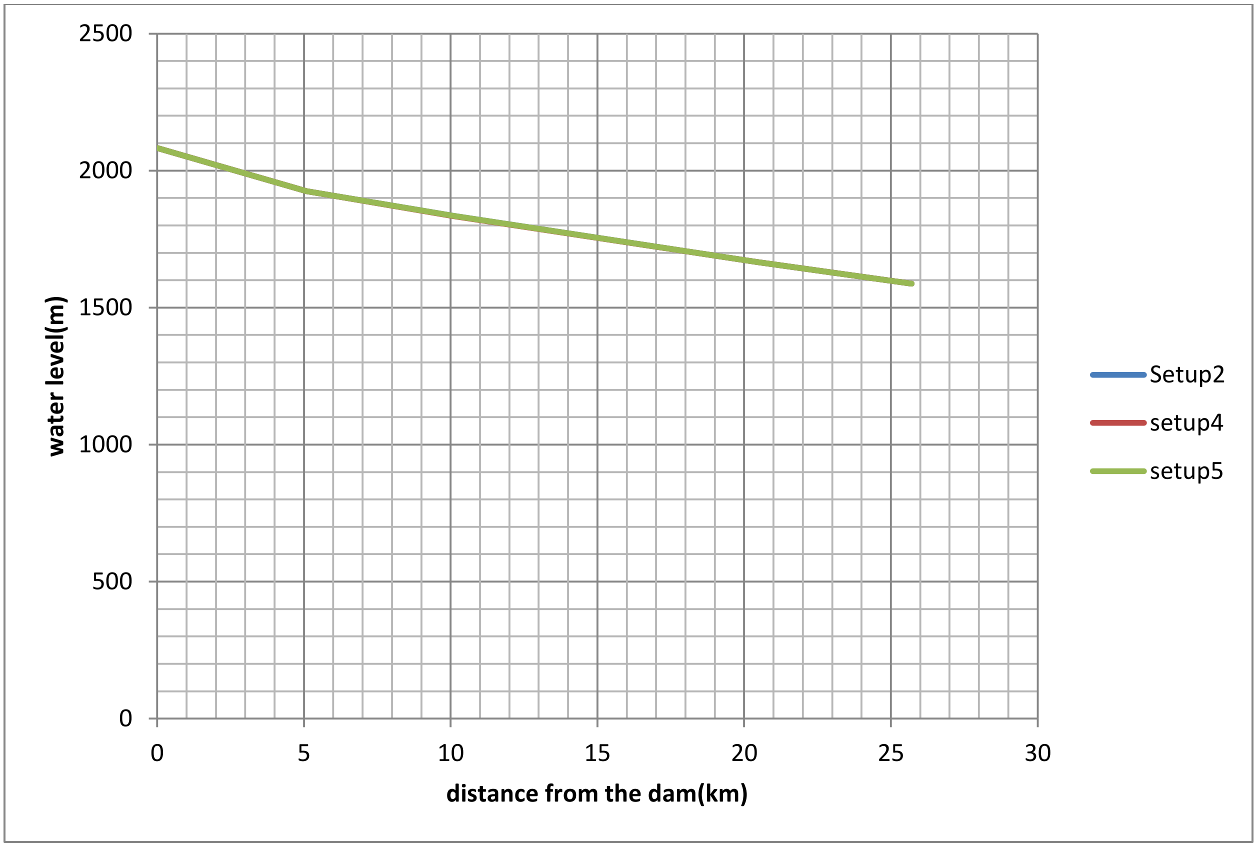

Figure 4-23 Sensitivity of bottom breach width on Max. WL of Nashe dam

4.4.3 Effect of side slope

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

So, we conclude that sensitivity of this parameter has insignificant effect on the peak values of water level and discharge.

4.4.4 Effects manning roughness value

As we Know, when the Manning's Roughness Coefficient (N) increases there is loss of energy which will 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 us the value of Manning's 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 as discussed earlier. As expected the velocities reduce with increase in Manning's N, and vice versa. This will affect the maximum water level and discharge value also.

Table 4-2 effects of Manning Values on Discharge

	Discharge		
Location from Dam (Km)	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

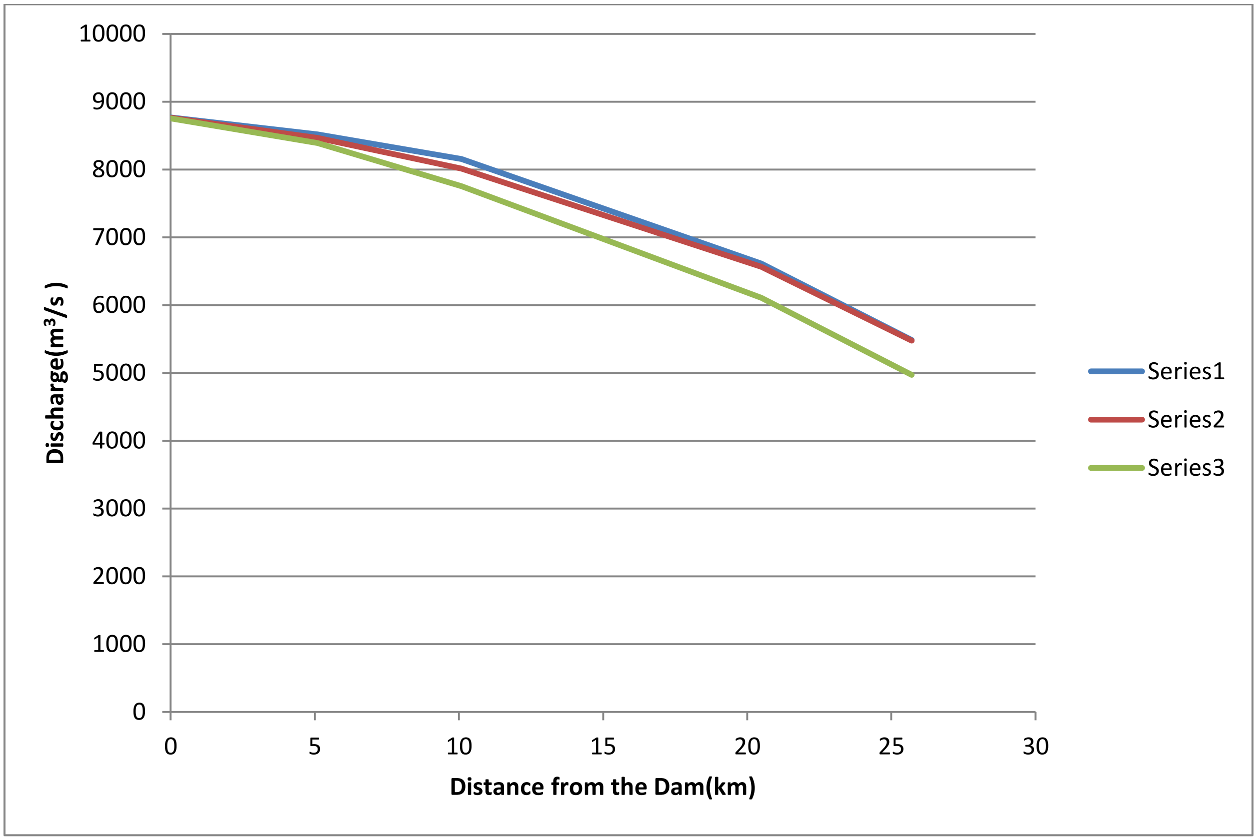

Figure 4-24 Sensitivity of manning roughness on Peak discharge of Nashe dam

4.5 Emergency action plan

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 4-3 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 4-3 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

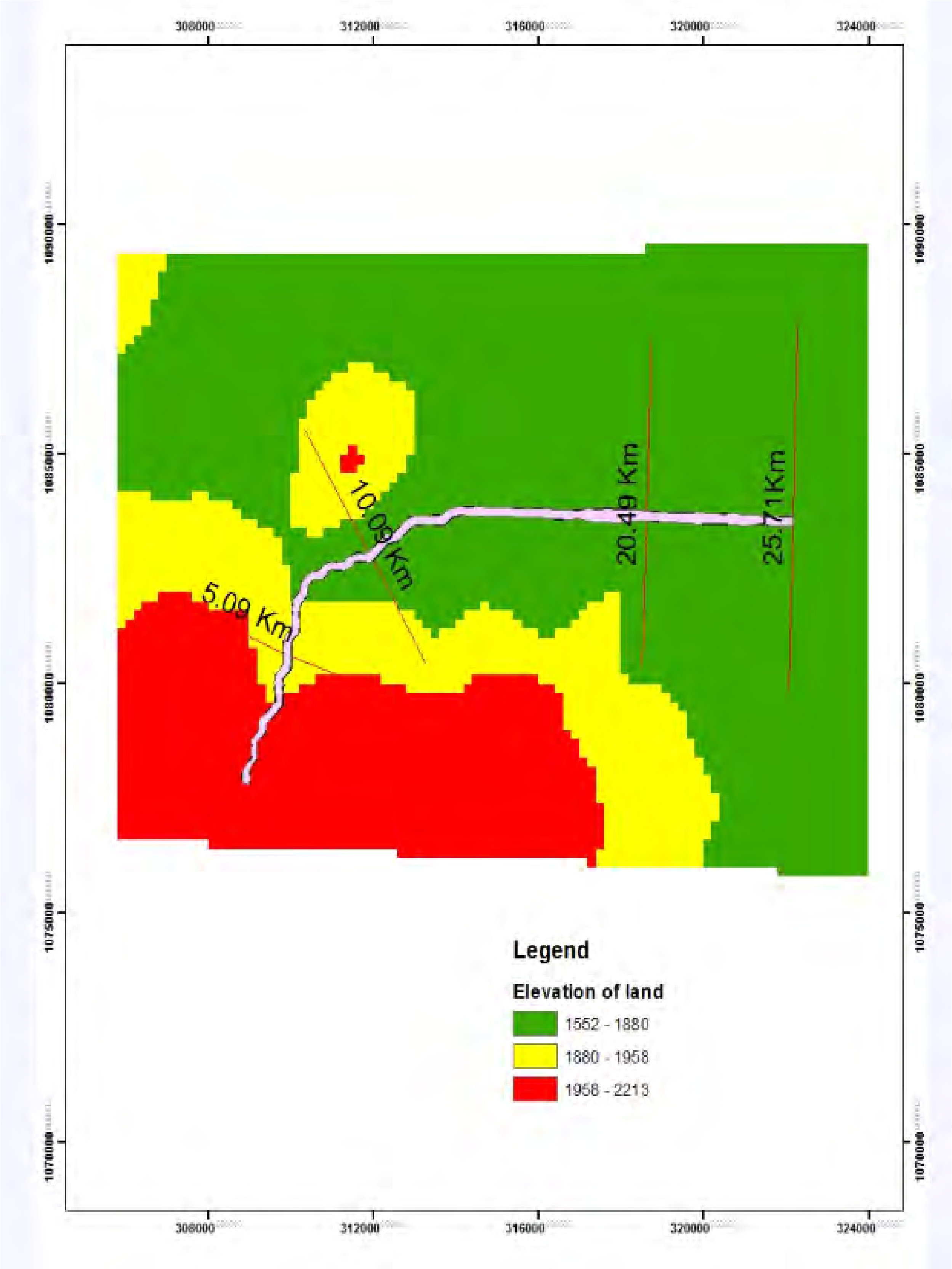

Figure 4-25 Inundation map b/n dam and 5.09km downstream of the dam

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this simulation of failure of Nashe dam is carried out on earth fill dam having height of 34m. The impact of dam break in the downstream area by both failure modes is observed in terms of flood hydrograph, flood duration, water level and flood map. 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. As input parameter data are different therefore the results obtained are different. So, conclusions are drawn by comparing the results as written below.

- In case of Nashe the peak discharge by overtopping mode is 8761.23m^3/sec which is 7.33 times greater than the probable maximum flood and by piping mode of peak discharge 8620.85 which is 7.21 times greater than probable maximum food at the location of the dam.
- The population those resettled downstream of the dam can be affected if the dam break.
- The Fincha'a sugar factory which is located at 15km downstream of the dam cannot be affected if the dam breaks.
- The Irrigated area around river bank throughout the River can be affected.
- We observe the difference in the peak discharge values as the dams has the same storage capacity. The reason behind that is since the breach parameter is the same; the inflow design flood (IDF) which is used as upper boundary condition plays the crucial role in the development of peak out flow difference. So we can conclude that dam break by overtopping mode will develop high peak out flow and risk to downstream compare to dam break by piping mode.
- From the sensitivity analysis we conclude that the effect of breach time on discharge is much pronounced than the water level. This is because of that the increment of water level is insignificant since the surface is flat and it flows to both side and the top width is increased.
- Even if the degree of sensitivity analysis of other parameter is less than breach time, their effect on discharge is more pronounced than the water level.

- Our Dam Break modeling results can be used as flood hazard maps and can assist communities in planning future developments in areas that are prone to flooding.

5.2 Recommendation

- For obtaining best results the accuracy of data is of very much important. So, with the data obtained from tool available in remote sensing (DEM) few surveyed data are required to get the real time condition for dam break analysis.
- Since the water pass over main channel the free space up to 100m from both side should be reserved along this channel.
- The population those live downstream of the dam should be again resettled far apart from a River bank to prevent the risk.
- The power house which is located downstream of the dam will be affected if the dam is failed either by overtopping or piping mode of failure.
- Since the Nashe dam is sensitive for break the further study is needed concerning Dam break analysis.

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APPENDIX

Table appendix-0-1 flood hydrograph at different chainage points D/s of the dam by Overtopping

Time		Discharge at different location from the Dam				
Time in (min)	time(hr.)	At dam	5.09km	10.09km	20.49km	25.71km
0	0	125	125	125	125	125
5	0.08	998.27	177.79	811.8	606.55	790.43
10	0.17	4391.47	469.34	593.33	698.3	678.57
15	0.25	7889.29	2343.09	292.63	767.49	612.92
20	0.33	8761.23	7413.5	393.63	792.59	633.41
25	0.42	4415.47	8463.07	1892.67	731.77	727.41
30	0.5	2537.88	5178.3	8012.37	721.5	780.62
35	0.58	1575.71	3212.96	6842.76	545.43	764.23
40	0.67	1035.75	2112.43	4662.59	348.85	733.88
45	0.75	717.27	1405.03	3392.87	1337.55	658.14
50	0.83	508.88	964.38	2493.24	6565.35	470.37
55	0.92	382.72	707.6	1821.59	5334.2	939.31
60	1	306.35	519.26	1263.65	4447.55	5474.66
65	1.08	244.62	406.18	874.12	3630.68	5146.21
70	1.17	209.6	320.54	624.26	3047.03	4398.53
75	1.25	189.49	253.74	461.82	2471.68	3722.29
80	1.33	177.74	214.42	364.32	1802.11	3208.9
85	1.42	170.74	192.89	287.55	1254.6	2742.41
90	1.5	166.62	179.67	234.33	866.27	2170.1
95	1.58	164.22	171.91	204	614.5	1598.8
100	1.67	164.16	167.48	187.67	456.38	1122.96
105	1.75	163.86	164.75	176.65	355.8	783.26
110	1.83	164.05	163.91	170.15	282.4	561.03
115	1.92	164.33	163.87	166.36	232.24	422.11
120	2	164.64	164.06	164.3	202.99	330.62
125	2.08	165.13	164.25	163.9	186.55	268.55
130	2.17	165.91	164.57	163.94	176.16	223.16
135	2.25	166.93	165.01	164.13	169.85	197.57
140	2.33	168.08	165.78	164.43	166.21	183.33
145	2.42	169.3	166.71	164.74	164.41	174.22
150	2.5	170.63	167.86	165.31	163.98	168.78
155	2.58	172.04	169.02	166.15	163.98	165.66
160	2.67	173.52	170.38	167.13	164.19	164.29
165	2.75	175.01	171.76	168.35	164.41	163.99
170	2.83	176.53	173.26	169.56	164.83	164.03

175	2.92	178.14	174.75	170.96	165.42	164.24
180	3	179.75	176.23	172.37	166.31	164.54
185	3.08	181.57	177.85	173.81	167.27	165
190	3.17	183.72	179.46	175.36	168.48	165.66
195	3.25	186.15	181.23	176.89	169.78	166.58
200	3.33	188.77	183.32	178.47	171.15	167.64
205	3.42	191.84	185.69	180.1	172.54	168.85
210	3.5	195.19	188.28	182.06	174.04	170.15
215	3.58	198.74	191.33	184.25	175.52	171.53
220	3.67	202.33	194.6	186.65	177.1	173.01
225	3.75	206	198.09	189.45	178.72	174.45
230	3.83	209.76	201.75	192.54	180.41	175.97
235	3.92	213.51	205.4	196	182.41	177.54
240	4	217.25	209.2	199.83	184.54	179.21
245	4.08	221.58	213	203.47	187.11	180.99
250	4.17	226.63	216.74	207.23	189.85	183.01
255	4.25	232.25	220.92	210.95	193.02	185.35
260	4.33	238.1	225.92	214.72	196.6	187.91
265	4.42	244.2	231.48	218.68	200.25	190.88
270	4.5	250.34	237.31	223.25	204.02	194.13
275	4.58	256.61	243.4	228.48	207.77	197.77
280	4.67	262.93	249.53	234.18	211.48	201.49
285	4.75	269.2	255.78	240.12	215.32	205.17
290	4.83	275.57	261.99	246.29	219.4	208.9
295	4.92	281.91	268.32	252.43	223.99	212.66
300	5	288.21	274.63	258.67	229.29	216.53
305	5.08	295.01	280.97	265	235.06	220.79
310	5.17	302.53	287.24	271.29	240.98	225.63
315	5.25	310.45	293.96	277.59	247.12	231.05
320	5.33	318.6	301.33	283.93	253.27	236.85
325	5.42	326.87	309.11	290.32	259.6	242.84
330	5.5	335.26	317.14	297.52	265.86	248.95
335	5.58	343.63	325.34	305.17	272.17	255.16
340	5.67	352.04	333.6	313.05	278.52	261.4
345	5.75	360.48	341.92	321.14	284.8	267.65
350	5.83	368.91	350.31	329.45	291.47	273.94
355	5.92	377.35	358.8	337.67	298.63	280.27
360	6	385.81	367.16	346.03	306.28	287.1
365	6.08	394.23	375.54	354.48	314.23	293.89
370	6.17	402.67	383.92	362.89	322.32	301.29
375	6.25	411.08	392.33	371.21	330.58	309.08

380	6.33	419.52	400.73	379.59	338.84	317.05
385	6.42	427.93	409.14	387.99	347.27	325.25
390	6.5	436.37	417.54	396.39	355.7	333.49
395	6.58	444.85	425.93	404.82	364.09	341.79
400	6.67	453.25	435.69	413.36	372.44	350.16
405	6.75	461.66	444.12	421.75	380.84	358.55
410	6.83	470.07	452.57	431.13	389.19	366.97
415	6.92	478.48	461.03	439.86	397.61	375.3
420	7	486.91	469.49	448.27	406.03	383.71
425	7.08	495.33	477.93	456.7	414.55	392.06
430	7.17	503.71	486.55	465.16	423.27	400.59
435	7.25	512.14	495.12	473.57	432.34	409.06
440	7.33	520.51	503.57	482.11	441.04	417.6
445	7.42	528.94	511.99	490.68	449.49	426.43
450	7.5	537.35	520.4	499.18	457.94	435.37
455	7.58	545.73	528.76	507.6	466.39	444.09
460	7.67	554.16	537.26	516	474.86	452.54
465	7.75	562.56	545.72	524.41	483.38	460.99
470	7.83	570.93	554.13	532.94	491.92	469.43
475	7.92	579.35	562.54	541.38	500.37	477.91
480	8	587.73	570.99	549.76	508.81	486.44
485	8.08	596.71	579.37	558.19	517.24	494.93
490	8.17	606.44	587.77	566.56	525.64	503.42
495	8.25	616.51	596.8	574.98	534.18	511.8
500	8.33	626.84	606.56	583.35	542.67	520.2
505	8.42	637.25	616.76	591.98	551.03	528.67
510	8.5	647.74	626.98	601.34	559.43	537.23
515	8.58	658.16	637.43	611.33	567.82	545.64
520	8.67	668.64	647.91	621.49	576.19	554.04
525	8.75	679.14	658.31	631.82	584.65	562.42
530	8.83	689.66	668.8	642.2	593.42	570.81
535	8.92	700.06	679.3	652.69	602.88	579.21
540	9	710.6	689.83	663.16	612.85	587.81
545	9.08	721.09	700.43	673.61	623.02	596.81
550	9.17	731.58	711.25	684.13	633.35	606.43
555	9.25	742.07	722.01	694.63	643.77	616.54
560	9.33	752.6	732.42	705.39	654.23	626.78
565	9.42	763.02	742.98	716.07	664.7	637.13
570	9.5	773.5	753.41	726.65	675.19	647.57
575	9.58	783.96	763.92	737.08	685.69	658.05
580	9.67	794.48	774.66	747.52	696.28	668.54

585	9.75	804.94	785.15	757.98	706.98	678.99
590	9.83	815.42	795.65	768.55	717.64	689.59
595	9.92	825.87	806.13	779.22	728.17	700.23
600	10	836.37	816.65	789.67	738.63	710.93
605	10.1	846.12	827.12	800.18	749.12	721.5
610	10.2	855.35	837.57	810.61	759.57	731.98
615	10.3	864.12	847.43	821.07	770.16	742.47
620	10.3	872.62	856.55	831.48	780.75	752.92
625	10.4	881.07	865.23	841.66	791.24	763.46
630	10.5	889.51	873.81	851.2	801.73	774.01
635	10.6	897.85	882.56	860.07	812.15	784.53
640	10.7	905.67	891.01	868.74	822.58	795.08
645	10.8	914.27	899.33	877.35	832.97	805.6
650	10.8	922.83	907.54	886.05	843.01	816.02
655	10.9	931.24	916	894.48	852.43	826.45
660	11	939.57	924.52	902.56	861.4	836.73
665	11.1	946.64	932.89	911.03	870.04	846.48
670	11.2	952.1	941.16	919.45	878.72	855.69
675	11.3	956.84	947.69	927.87	887.3	864.56
680	11.3	961.39	953	936.17	895.62	873.29
685	11.4	965.76	957.74	943.74	903.93	881.89
690	11.5	970.02	962.3	949.82	912.28	890.43
695	11.6	973.48	966.55	954.92	920.78	898.77
700	11.7	978.21	970.78	959.54	929.08	907.06
705	11.8	982.48	975.17	964	937.23	915.47
710	11.8	986.58	979.25	968.28	944.44	923.9
715	11.9	990.76	983.34	972.5	950.46	932.14
720	12	994.95	987.48	976.78	955.49	939.89
725	12.1	996.33	991.64	980.9	960.19	946.64
730	12.2	994.72	995.53	985.05	964.62	952.31
735	12.3	991.65	996.02	989.15	968.93	957.24
740	12.3	988.05	994.06	993.21	973.15	961.83
745	12.4	984.06	990.88	995.67	977.35	966.21
750	12.5	979.98	987.14	995.21	981.5	970.45
755	12.6	975.84	983.19	992.74	985.62	974.71
760	12.7	971.73	979.14	989.36	989.72	978.92
765	12.8	967.63	975	985.54	993.36	983.03
770	12.8	963.35	970.85	981.53	995.17	987.15
775	12.9	959.2	966.55	977.42	994.53	991.14
780	13	955.09	962.45	973.32	992.11	993.96
785	13.1	949.58	958.3	969.13	988.76	994.89

790	13.2	942.52	954.04	964.94	984.9	993.59
795	13.3	934.8	948.15	960.8	980.92	990.85
800	13.3	926.77	941.02	956.64	976.85	987.31
805	13.4	918.61	933.21	951.65	972.74	983.41
810	13.5	910.43	925.16	945.24	968.59	979.4
815	13.6	902.12	916.94	937.86	964.38	975.29
820	13.7	893.79	908.69	929.99	960.16	971.13
825	13.8	885.56	900.5	921.84	955.75	966.98
830	13.8	877.31	892.27	913.66	950.53	962.83
835	13.9	868.94	884.4	905.36	943.98	958.52
840	14	860.56	876.2	897.14	936.62	953.81
845	14.1	851.65	867.82	889	928.71	948.06
850	14.2	841.88	859.5	880.93	920.65	941.25
855	14.3	831.79	850.27	872.75	912.36	933.67
860	14.3	821.69	840.58	864.41	904.13	925.7
865	14.4	811.43	830.55	855.73	895.92	917.57
870	14.5	801.08	820.4	846.28	887.84	909.3
875	14.6	790.84	810.26	836.43	879.71	901.08
880	14.7	780.49	799.94	826.34	871.47	892.92
885	14.8	770.12	789.67	816.19	863.07	884.76
890	14.8	759.77	779.25	805.91	854.2	876.59
895	14.9	749.34	769.16	795.57	844.81	868.31
900	15	739.06	758.83	785.2	834.94	859.79
905	15.1	728.72	748.52	774.9	824.82	850.76
910	15.2	718.37	738.19	764.72	814.63	841.13
915	15.3	707.99	727.84	754.38	804.39	831.14
920	15.3	697.66	717.54	744.04	794.03	821.09
925	15.4	687.26	707.32	733.65	783.68	810.85
930	15.5	676.96	697.37	723.27	773.44	800.54
935	15.6	666.62	687.1	712.98	763.2	790.27
940	15.7	656.24	676.8	702.85	752.81	779.98
945	15.8	645.89	666.45	692.7	742.47	769.69
950	15.8	635.56	656.15	682.36	732.08	759.43
955	15.9	625.22	645.71	672.05	721.75	749.11
960	16	614.85	635.41	661.67	711.49	738.69
965	16.1	605.17	625.08	651.36	701.34	728.33
970	16.2	596.14	614.79	641.02	691.17	718.01
975	16.3	587.48	605.04	630.65	680.87	707.81
980	16.3	579.02	596.13	620.34	670.57	697.61
985	16.4	570.61	587.48	610.24	660.16	687.39
990	16.5	562.31	578.95	600.9	649.82	677.11

995	16.6	554.05	570.62	592.06	639.47	666.8
1000	16.7	545.73	562.37	583.47	629.19	656.46
1005	16.8	537.43	554.03	575	618.85	646.11
1010	16.8	529.22	545.77	566.71	608.96	635.77
1015	16.9	520.97	537.49	558.36	599.66	625.43
1020	17	512.62	529.31	550.05	590.86	615.28
1025	17.1	504.41	521.1	541.78	582.24	605.65
1030	17.2	496.11	512.79	533.52	573.82	596.58
1035	17.3	487.88	504.54	525.42	565.44	587.77
1040	17.3	479.59	496.26	517.14	557.13	579.24
1045	17.4	471.3	488.11	508.87	548.85	570.86
1050	17.5	463.03	480.11	500.6	540.56	562.51
1055	17.6	454.83	471.91	492.41	532.38	554.21
1060	17.7	446.55	463.65	484.25	524.16	545.92
1065	17.8	438.34	455.51	476.12	515.9	537.6
1070	17.8	430.09	447.25	467.88	507.67	529.48
1075	17.9	421.84	438.99	459.69	499.41	521.27
1080	18	413.51	430.74	451.46	491.17	513
1085	18.1	405.32	423.55	443.21	483.07	504.74
1090	18.2	397.04	415.53	434.92	474.93	496.49
1095	18.3	388.8	407.25	427.05	466.73	488.29
1100	18.3	380.58	399	419.58	458.49	480.16
1105	18.4	372.35	390.71	411.38	450.29	471.98
1110	18.5	364.14	382.46	403.31	442.02	463.78
1115	18.6	355.91	374.17	395.01	433.86	455.54
1120	18.7	347.69	365.85	386.73	426.04	447.32
1125	18.8	339.46	357.54	378.4	418.34	439.09
1130	18.8	331.23	349.4	370.14	410.26	431.1
1135	18.9	323	341.14	361.84	402.11	423.34
1140	19	314.83	332.85	353.55	393.84	415.51
1145	19.1	307.06	324.56	345.4	385.52	407.34
1150	19.2	300.06	316.29	337.09	377.24	399.14
1155	19.3	293.35	308.4	328.78	368.95	390.98
1160	19.3	286.92	301.2	320.5	360.66	382.72
1165	19.4	280.58	294.43	312.4	352.43	374.42
1170	19.5	274.36	287.91	304.81	344.2	366.12
1175	19.6	268.08	281.52	297.82	335.9	357.83
1180	19.7	261.91	275.2	291.37	327.64	349.55
1185	19.8	255.73	269.02	284.89	319.37	341.34
1190	19.8	249.56	262.77	278.55	311.32	333.02
1195	19.9	243.41	256.57	272.33	303.9	324.74

1200	20	237.25	250.42	266.09	296.98	316.56
1205	20.1	231.65	244.24	259.91	290.46	308.7
1210	20.2	226.75	238.11	253.7	284.03	301.44
1215	20.3	222.41	232.41	247.49	277.68	294.77
1220	20.3	218.24	227.45	241.3	271.41	288.27
1225	20.4	214.32	223	235.41	265.22	282.23
1230	20.5	210.45	218.8	230.03	259.03	275.96
1235	20.6	206.6	214.85	225.36	252.84	269.71
1240	20.7	202.87	211	221.1	246.65	263.47
1245	20.8	199.15	207.15	216.93	240.56	257.25
1250	20.8	195.41	203.51	213.07	234.65	251.02
1255	20.9	192.17	199.82	209.18	229.45	244.87
1260	21	189.14	196.08	205.47	224.77	238.78
1265	21.1	186.45	192.71	201.72	220.49	233.09
1270	21.2	184.12	189.67	198.03	216.43	228.04
1275	21.3	182.13	186.89	194.74	212.5	223.49
1280	21.3	180.28	184.59	191.59	208.73	219.24
1285	21.4	178.51	182.48	188.6	204.95	215.23
1290	21.5	176.84	180.57	186	201.19	211.34
1295	21.6	175.25	178.81	183.75	197.6	207.53
1300	21.7	173.69	177.11	181.79	194.33	203.76
1305	21.8	172.16	175.53	179.9	191.18	200.08
1310	21.8	170.72	173.98	178.16	188.27	196.55
1315	21.9	169.34	172.44	176.52	185.72	193.33
1320	22	167.99	170.99	174.9	183.48	190.22
1325	22.1	166.9	169.62	173.35	181.52	187.51
1330	22.2	166.05	168.3	171.87	179.65	185.08
1335	22.3	165.37	167.09	170.43	177.91	182.91
1340	22.3	164.82	166.23	169.07	176.28	180.98
1345	22.4	164.35	165.53	167.79	174.7	179.18
1350	22.5	163.89	164.98	166.76	173.19	177.46
1355	22.6	163.47	164.42	165.94	171.65	175.83
1360	22.7	163.07	163.97	165.29	170.24	174.25
1365	22.8	162.71	163.56	164.72	168.98	172.77
1370	22.8	162.33	163.2	164.23	167.72	171.27
1375	22.9	161.99	162.77	163.82	166.67	169.89
1380	23	161.64	162.45	163.37	165.85	168.55
1385	23.1	161.4	162.07	162.99	165.22	167.4
1390	23.2	161.2	161.72	162.65	164.69	166.42
1395	23.3	161.11	161.41	162.26	164.22	165.7
1400	23.3	161.05	161.25	161.96	163.8	165.04

1405	23.4	161.03	161.16	161.63	163.38	164.55
1410	23.5	161	161.05	161.36	162.97	164.08
1415	23.6	161	161.04	161.21	162.6	163.66
1420	23.7	160.97	161	161.07	162.19	163.25
1425	23.8	160.97	160.96	160.99	161.92	162.86
1430	23.8	160.92	160.96	161.05	161.54	162.49
1435	23.9	160.95	160.96	161.05	161.35	162.13
1440	24	160.95	160.96	161.01	161.19	161.8

Table Appendix-0-2 flood hydrograph at different chainage points D/s of the dam by piping

Time		Discharge at different location from the Dam				
Time (min)	Time (hr.)	At dam	5.09km	10.09km	20.49km	25.71km
0	0	100	100	100	100	100
5	0.08	716.63	191.53	723.52	535.78	692
10	0.17	2889.47	260.4	518.14	616.76	601.35
15	0.25	8620.85	1240.14	202.36	676.51	541.36
20	0.33	6340.44	7148.99	341.58	702.3	558.47
25	0.42	4111.79	6717.02	749.95	647.93	642.1
30	0.5	2584.49	4659.16	6591.09	640.64	689.99
35	0.58	1642.46	3182.16	5855.59	465.72	677.04
40	0.67	1073.22	2170.57	4360.64	279.4	651.15
45	0.75	727.35	1461.85	3335.92	537.21	579.51
50	0.83	501.08	992.04	2510.72	4795.79	394.06
55	0.92	363.63	715.6	1863.69	5021.39	351.77
60	1	277.15	514.2	1306.21	4297.1	2950.74
65	1.08	208.84	391.91	896.25	3561.66	4729.99
70	1.17	168.8	291.36	627.69	3034.09	4257.38
75	1.25	144.65	218.93	452.14	2479.75	3656.09
80	1.33	129.54	175.54	342.49	1836.38	3186.42
85	1.42	119.94	149.54	256.16	1291.52	2739.21
90	1.5	113.64	132.69	198.92	887.17	2187.61
95	1.58	109.43	122.13	165.5	617.19	1631.87
100	1.67	106.65	115.11	142.62	445.56	1153.24
105	1.75	104.77	110.42	128.36	333.07	796.77
110	1.83	103.49	107.29	119.13	250.79	559.37
115	1.92	102.66	105.22	113.13	196.63	407.39
120	2	102.07	103.77	109.04	163.3	304.43
125	2.08	101.64	102.82	106.38	141.41	235.65
130	2.17	101.39	102.18	104.58	127.51	185.88
135	2.25	101.21	101.77	103.38	118.55	157.08
140	2.33	101.09	101.44	102.55	112.73	138.2
145	2.42	101	101.22	102.03	108.79	125.84
150	2.5	100.91	101.11	101.61	106.23	117.65
155	2.58	100.89	100.99	101.36	104.48	112.19
160	2.67	100.88	100.96	101.2	103.33	108.49
165	2.75	100.84	100.91	101.09	102.46	106.04
170	2.83	100.86	100.84	100.98	102.03	104.34
175	2.92	100.82	100.86	100.94	101.57	103.21
180	3	100.82	100.83	100.87	101.36	102.44

185	3.08	100.82	100.84	100.86	101.16	101.94
190	3.17	100.8	100.84	100.86	101.05	101.59
195	3.25	100.8	100.84	100.86	100.99	101.34
200	3.33	100.82	100.8	100.83	100.94	101.18
205	3.42	100.8	100.84	100.83	100.94	101.06
210	3.5	100.8	100.83	100.79	100.88	100.97
215	3.58	100.8	100.81	100.86	100.84	100.94
220	3.67	100.8	100.8	100.79	100.84	100.88
225	3.75	100.82	100.83	100.83	100.84	100.87
230	3.83	100.82	100.79	100.83	100.84	100.85
235	3.92	100.8	100.81	100.82	100.84	100.83
240	4	100.8	100.79	100.79	100.8	100.83
245	4.08	100.8	100.77	100.79	100.79	100.82
250	4.17	100.8	100.78	100.79	100.75	100.8
255	4.25	100.82	100.79	100.83	100.84	100.79
260	4.33	100.82	100.84	100.79	100.84	100.83
265	4.42	100.82	100.78	100.79	100.8	100.81
270	4.5	100.8	100.84	100.83	100.79	100.8
275	4.58	100.79	100.83	100.79	100.83	100.8
280	4.67	100.82	100.81	100.83	100.79	100.8
285	4.75	100.8	100.81	100.83	100.8	100.82
290	4.83	100.8	100.83	100.79	100.79	100.8
295	4.92	100.82	100.81	100.79	100.84	100.79
300	5	100.79	100.81	100.79	100.8	100.82
305	5.08	100.82	100.81	100.82	100.79	100.82
310	5.17	100.8	100.78	100.79	100.8	100.8
315	5.25	100.8	100.8	100.79	100.84	100.81
320	5.33	100.82	100.77	100.83	100.79	100.8
325	5.42	100.8	100.78	100.83	100.8	100.81
330	5.5	100.82	100.83	100.82	100.78	100.8
335	5.58	100.8	100.81	100.79	100.84	100.79
340	5.67	100.82	100.83	100.83	100.82	100.8
345	5.75	100.78	100.75	100.79	100.82	100.8
350	5.83	100.82	100.82	100.79	100.8	100.8
355	5.92	100.8	100.83	100.83	100.84	100.82
360	6	100.8	100.83	100.86	100.79	100.77
365	6.08	100.82	100.83	100.79	100.79	100.79
370	6.17	100.82	100.83	100.86	100.8	100.79
375	6.25	100.82	100.8	100.79	100.84	100.8
380	6.33	100.82	100.81	100.79	100.82	100.82
385	6.42	100.82	100.8	100.83	100.75	100.8

390	6.5	100.8	100.79	100.83	100.84	100.81
395	6.58	100.82	100.78	100.79	100.8	100.82
400	6.67	100.8	100.78	100.79	100.8	100.8
405	6.75	100.81	100.79	100.83	100.82	100.8
410	6.83	100.8	100.78	100.83	100.84	100.79
415	6.92	100.8	100.78	100.83	100.8	100.79
420	7	100.81	100.79	100.83	100.8	100.82
425	7.08	100.82	100.83	100.86	100.85	100.81
430	7.17	100.8	100.81	100.83	100.83	100.82
435	7.25	100.8	100.79	100.83	100.82	100.8
440	7.33	100.8	100.8	100.83	100.79	100.8
445	7.42	100.8	100.83	100.82	100.84	100.8
450	7.5	100.82	100.8	100.79	100.79	100.8
455	7.58	100.82	100.8	100.83	100.8	100.8
460	7.67	100.8	100.79	100.79	100.8	100.8
465	7.75	100.8	100.79	100.79	100.75	100.82
470	7.83	100.8	100.78	100.82	100.84	100.8
475	7.92	100.82	100.78	100.79	100.84	100.82
480	8	100.82	100.79	100.79	100.8	100.79
485	8.08	100.8	100.78	100.79	100.75	100.79
490	8.17	100.8	100.78	100.79	100.8	100.8
495	8.25	100.8	100.83	100.79	100.82	100.8
500	8.33	100.82	100.83	100.83	100.79	100.82
505	8.42	100.8	100.85	100.79	100.79	100.8
510	8.5	100.8	100.81	100.79	100.84	100.82
515	8.58	100.82	100.81	100.79	100.8	100.8
520	8.67	100.8	100.83	100.79	100.79	100.81
525	8.75	100.81	100.83	100.83	100.79	100.8
530	8.83	100.8	100.8	100.83	100.84	100.8
535	8.92	100.82	100.8	100.83	100.79	100.79
540	9	100.82	100.78	100.82	100.8	100.8
545	9.08	100.8	100.77	100.83	100.79	100.8
550	9.17	100.82	100.79	100.83	100.83	100.82
555	9.25	100.8	100.79	100.79	100.84	100.8
560	9.33	100.82	100.78	100.79	100.8	100.82
565	9.42	100.8	100.78	100.79	100.79	100.8
570	9.5	100.78	100.78	100.79	100.83	100.82
575	9.58	100.82	100.83	100.83	100.8	100.79
580	9.67	100.8	100.83	100.79	100.79	100.8
585	9.75	100.82	100.81	100.83	100.79	100.82
590	9.83	100.82	100.82	100.79	100.83	100.82

595	9.92	100.82	100.82	100.79	100.8	100.8
600	10	100.82	100.81	100.79	100.79	100.82
605	10.1	100.81	100.81	100.83	100.79	100.79
610	10.2	100.82	100.8	100.79	100.83	100.8
615	10.3	100.8	100.81	100.79	100.8	100.8
620	10.3	100.8	100.78	100.83	100.84	100.8
625	10.4	100.8	100.79	100.83	100.79	100.81
630	10.5	100.82	100.81	100.83	100.83	100.82
635	10.6	100.82	100.78	100.79	100.79	100.81
640	10.7	100.82	100.78	100.79	100.79	100.8
645	10.8	100.8	100.79	100.79	100.79	100.82
650	10.8	100.8	100.84	100.83	100.84	100.79
655	10.9	100.82	100.83	100.79	100.84	100.8
660	11	100.79	100.84	100.83	100.79	100.8
665	11.1	100.82	100.83	100.83	100.78	100.8
670	11.2	100.82	100.83	100.79	100.75	100.83
675	11.3	100.8	100.8	100.82	100.83	100.8
680	11.3	100.82	100.81	100.83	100.82	100.8
685	11.4	100.8	100.81	100.79	100.84	100.79
690	11.5	100.8	100.8	100.79	100.84	100.8
695	11.6	100.8	100.8	100.79	100.79	100.79
700	11.7	100.82	100.79	100.82	100.83	100.82
705	11.8	100.8	100.79	100.86	100.84	100.8
710	11.8	100.82	100.8	100.79	100.84	100.8
715	11.9	100.82	100.78	100.79	100.84	100.8
720	12	100.82	100.77	100.79	100.79	100.8
725	12.1	100.82	100.84	100.79	100.79	100.79
730	12.2	100.8	100.81	100.83	100.75	100.82
735	12.3	100.8	100.83	100.83	100.8	100.82
740	12.3	100.8	100.83	100.79	100.83	100.8
745	12.4	100.8	100.83	100.79	100.8	100.79
750	12.5	100.82	100.8	100.79	100.84	100.8
755	12.6	100.8	100.84	100.79	100.79	100.8
760	12.7	100.82	100.83	100.86	100.84	100.79
765	12.8	100.8	100.83	100.79	100.79	100.8
770	12.8	100.8	100.81	100.79	100.84	100.79
775	12.9	100.8	100.79	100.79	100.79	100.83
780	13	100.79	100.77	100.86	100.78	100.79
785	13.1	100.79	100.81	100.83	100.84	100.82
790	13.2	100.82	100.79	100.83	100.84	100.8
795	13.3	100.8	100.79	100.79	100.8	100.82

800	13.3	100.81	100.78	100.79	100.84	100.79
805	13.4	100.82	100.78	100.79	100.84	100.8
810	13.5	100.8	100.81	100.83	100.8	100.8
815	13.6	100.8	100.83	100.79	100.85	100.8
820	13.7	100.81	100.8	100.79	100.79	100.8
825	13.8	100.8	100.81	100.79	100.8	100.8
830	13.8	100.82	100.82	100.79	100.79	100.8
835	13.9	100.8	100.8	100.79	100.79	100.79
840	14	100.8	100.8	100.79	100.84	100.79
845	14.1	100.8	100.78	100.83	100.84	100.8
850	14.2	100.82	100.79	100.79	100.84	100.8
855	14.3	100.8	100.79	100.79	100.8	100.8
860	14.3	100.82	100.77	100.79	100.84	100.82
865	14.4	100.8	100.78	100.82	100.83	100.8
870	14.5	100.82	100.79	100.79	100.84	100.79
875	14.6	100.82	100.78	100.79	100.8	100.82
880	14.7	100.82	100.77	100.79	100.79	100.8
885	14.8	100.81	100.83	100.79	100.84	100.82
890	14.8	100.82	100.83	100.79	100.83	100.8
895	14.9	100.82	100.81	100.86	100.84	100.8
900	15	100.8	100.83	100.83	100.84	100.8
905	15.1	100.82	100.83	100.79	100.84	100.8
910	15.2	100.8	100.83	100.79	100.75	100.8
915	15.3	100.8	100.81	100.79	100.79	100.82
920	15.3	100.8	100.8	100.83	100.84	100.79
925	15.4	100.82	100.81	100.83	100.84	100.82
930	15.5	100.78	100.8	100.83	100.8	100.82
935	15.6	100.82	100.81	100.86	100.79	100.79
940	15.7	100.8	100.79	100.82	100.79	100.82
945	15.8	100.8	100.78	100.83	100.83	100.8
950	15.8	100.8	100.77	100.86	100.75	100.8
955	15.9	100.82	100.78	100.79	100.85	100.82
960	16	100.82	100.83	100.79	100.84	100.79
965	16.1	100.8	100.83	100.86	100.83	100.79
970	16.2	100.8	100.81	100.83	100.8	100.82
975	16.3	100.82	100.83	100.79	100.79	100.8
980	16.3	100.78	100.81	100.83	100.79	100.8
985	16.4	100.8	100.82	100.79	100.75	100.8
990	16.5	100.8	100.82	100.83	100.8	100.82
995	16.6	100.8	100.81	100.83	100.84	100.8
1000	16.7	100.8	100.8	100.79	100.77	100.8

1005	16.8	100.8	100.81	100.82	100.84	100.79
1010	16.8	100.79	100.77	100.79	100.8	100.8
1015	16.9	100.8	100.77	100.83	100.79	100.82
1020	17	100.8	100.79	100.83	100.83	100.82
1025	17.1	100.82	100.77	100.79	100.8	100.81
1030	17.2	100.8	100.78	100.79	100.8	100.8
1035	17.3	100.82	100.77	100.83	100.85	100.82
1040	17.3	100.82	100.78	100.79	100.84	100.79
1045	17.4	100.8	100.78	100.83	100.8	100.8
1050	17.5	100.8	100.83	100.79	100.75	100.8
1055	17.6	100.82	100.84	100.79	100.75	100.8
1060	17.7	100.8	100.83	100.86	100.83	100.79
1065	17.8	100.8	100.83	100.79	100.8	100.82
1070	17.8	100.8	100.8	100.79	100.78	100.8
1075	17.9	100.8	100.8	100.79	100.75	100.8
1080	18	100.82	100.79	100.83	100.84	100.8
1085	18.1	100.82	100.81	100.83	100.79	100.8
1090	18.2	100.8	100.81	100.79	100.78	100.8
1095	18.3	100.8	100.78	100.79	100.84	100.82
1100	18.3	100.8	100.79	100.79	100.79	100.81
1105	18.4	100.82	100.79	100.86	100.8	100.79
1110	18.5	100.82	100.79	100.79	100.84	100.8
1115	18.6	100.8	100.83	100.79	100.79	100.79
1120	18.7	100.8	100.83	100.79	100.79	100.82
1125	18.8	100.8	100.84	100.86	100.79	100.79
1130	18.8	100.78	100.83	100.83	100.75	100.8
1135	18.9	100.8	100.79	100.79	100.79	100.82
1140	19	100.82	100.83	100.79	100.84	100.82
1145	19.1	100.82	100.8	100.79	100.84	100.8
1150	19.2	100.8	100.81	100.79	100.8	100.79
1155	19.3	100.78	100.77	100.79	100.79	100.82
1160	19.3	100.82	100.81	100.79	100.8	100.79
1165	19.4	100.8	100.8	100.79	100.79	100.8
1170	19.5	100.8	100.77	100.79	100.75	100.82
1175	19.6	100.8	100.78	100.83	100.74	100.8
1180	19.7	100.81	100.83	100.83	100.84	100.79
1185	19.8	100.82	100.77	100.79	100.83	100.82
1190	19.8	100.82	100.78	100.79	100.79	100.79
1195	19.9	100.82	100.83	100.83	100.84	100.8
1200	20	100.8	100.83	100.79	100.83	100.8
1205	20.1	100.8	100.81	100.79	100.79	100.8

1210	20.2	100.8	100.82	100.83	100.79	100.79
1215	20.3	100.82	100.82	100.79	100.84	100.8
1220	20.3	100.82	100.84	100.83	100.8	100.8
1225	20.4	100.8	100.83	100.79	100.75	100.79
1230	20.5	100.8	100.79	100.79	100.84	100.8
1235	20.6	100.82	100.8	100.79	100.75	100.79
1240	20.7	100.8	100.79	100.83	100.84	100.8
1245	20.8	100.82	100.77	100.83	100.8	100.81
1250	20.8	100.8	100.79	100.79	100.79	100.8
1255	20.9	100.8	100.79	100.83	100.8	100.81
1260	21	100.78	100.78	100.79	100.84	100.8
1265	21.1	100.8	100.84	100.79	100.84	100.79
1270	21.2	100.8	100.81	100.79	100.79	100.82
1275	21.3	100.82	100.83	100.79	100.85	100.79
1280	21.3	100.82	100.83	100.79	100.83	100.82
1285	21.4	100.82	100.83	100.79	100.83	100.82
1290	21.5	100.8	100.83	100.83	100.8	100.8
1295	21.6	100.82	100.83	100.79	100.84	100.81
1300	21.7	100.82	100.8	100.79	100.8	100.8
1305	21.8	100.8	100.79	100.79	100.84	100.8
1310	21.8	100.82	100.81	100.79	100.78	100.8
1315	21.9	100.8	100.78	100.79	100.83	100.8
1320	22	100.8	100.81	100.83	100.78	100.8
1325	22.1	100.8	100.78	100.83	100.84	100.8
1330	22.2	100.82	100.79	100.79	100.83	100.8
1335	22.3	100.8	100.79	100.79	100.84	100.8
1340	22.3	100.8	100.83	100.83	100.8	100.79
1345	22.4	100.8	100.78	100.83	100.82	100.8
1350	22.5	100.8	100.83	100.83	100.8	100.8
1355	22.6	100.82	100.83	100.79	100.8	100.82
1360	22.7	100.8	100.83	100.79	100.84	100.79
1365	22.8	100.8	100.8	100.79	100.79	100.8
1370	22.8	100.8	100.81	100.83	100.84	100.8
1375	22.9	100.8	100.83	100.83	100.79	100.82
1380	23	100.8	100.81	100.83	100.81	100.8
1385	23.1	100.82	100.8	100.79	100.75	100.82
1390	23.2	100.82	100.78	100.79	100.84	100.8
1395	23.3	100.8	100.77	100.83	100.84	100.82
1400	23.3	100.8	100.79	100.79	100.8	100.8
1405	23.4	100.8	100.79	100.79	100.79	100.8
1410	23.5	100.8	100.78	100.83	100.84	100.8

1415	23.6	100.82	100.79	100.79	100.8	100.8
1420	23.7	100.82	100.77	100.79	100.79	100.82
1425	23.8	100.8	100.77	100.79	100.79	100.79
1430	23.8	100.8	100.83	100.79	100.84	100.82
1435	23.9	100.82	100.81	100.79	100.8	100.8
1440	24	100.82	100.83	100.83	100.8	100.8