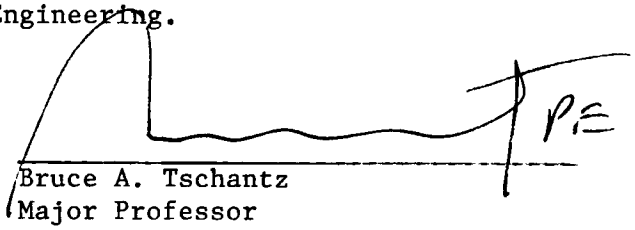
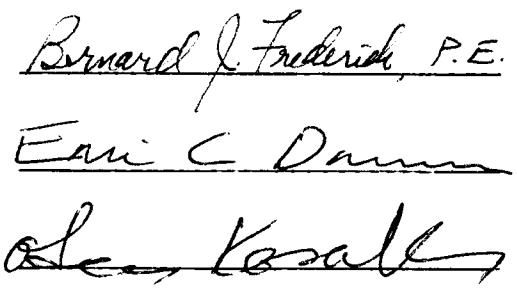
To the Graduate Council:

I am submitting herewith a dissertation written by Reza M. Mojib entitled "Development of a Computer Program for Gradual Failure of Earthen Dams Due to Overtopping." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Civil Engineering.

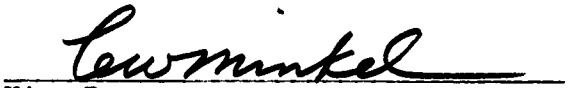


Bruce A. Tschantz
Major Professor

We have read this dissertation
and recommend its acceptance:



Accepted for the Council:



Vice Provost
and Dean of The Graduate School

DEVELOPMENT OF A COMPUTER PROGRAM FOR GRADUAL FAILURE OF EARTHEN DAMS DUE TO OVERTOPPING

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Reza M. Mojib

May 1990

DEDICATION

The author wishes to dedicate his thesis to his mother and father, Dr. and Mrs. Mojib, and his wife, Kay Mojib, whose constant support and encouragement made his education possible.

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ABSTRACT

A mathematical model for simulating the gradual failure of earthen dams due to overtopping was developed. The model was based on the water continuity, sediment continuity, sediment transportation equations (sandy soil and clayey soil), and a breach shape geometric descriptor.

The water continuity equation, elevation-storage relation, and discharge-elevation equations as a whole were utilized via the Newton-Raphson iteration scheme to compute the pool elevation, reservoir storage and discharge during each computational increment.

Commencement of erosion was based on the critical shear stress criterion. As the water overtopped the dam and surpassed the permissible shear stress of the dam protective cover, erosion of the dam began. The rate of erosion was considered according to two different approaches. For sandy soil mixtures, a sediment transport equation developed by Smart (65) was used, and for clayey soil mixtures, a modified Du Boy's type equation was used (75). Determination of the dimensions of the breach channel during each time increment is an iterative one. An algorithm also based on the Newton-Raphson iteration scheme was used to compute, for every iteration that is completed, the length of the breach channel, and the elevations of the upstream end and the downstream ends of the breach channel.

The assumed breach shape was trapezoidal. The side slope of the trapezoid was set equal to the angle of repose of the fill material and the breach channel slope is assumed to be equal to the internal friction angle of the fill material.

The validity of the model was successfully tested by simulating the failure of the Laurel Run Dam that occurred in July 1977, in Johnstown, Pennsylvania.

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CHAPTER I

INTRODUCTION

The study of catastrophic flooding following collapse of a dam is of interest because of the potential risk to downstream life and property. Recent disasters have focused the attention of Federal and state agencies on the areas of hazard mitigation, emergency preparedness, and on means for assessing public safety and predicting probable damage in the event of dam failure.

It has been estimated that over 2,000 dams have failed since the 12th century. There have been more than 200 major dam failures in the world resulting in more than 8,000 deaths in the 20th century alone. This is not merely a compilation of past mistakes that is unlikely to occur again. Table I-1 is a listing of major dam failures that occurred in the United States from 1963 to 1983. These 18 failures in 20 years resulted in the deaths of 307 persons (74).

Dr. Manual Rocha, Chairman of the Committee on Dam Deterioration, told the 1979 International Congress on Large Dams (ICOLD) in New Delhi that nearly 1 percent of all dams fail (5). The dimensions of the problem become apparent when the one percent failure statistic is coupled with the fact that there are more than 70,000[1] Federal and non-Federal dams in the United States and that new dams are being

---

[1]Combined April 1981 Corps of Engineers National Non-Federal Dam Inventory (66,804) and estimated number of inventoried Federal Dams (3,000).

TABLE I-1

LOSS OF LIFE AND PROPERTY DAMAGE FROM NOTABLE U.S. DAM FAILURES, 1963-1983

Name & Location of Dam	Date of Failure	Number of Lives Lost	Damages
Mohegan Park, CT	Mar. 1963	6	$3 million
Little Deer Creek, UT	June 1963	1	Summer cabins damaged
Baldwin Hills, CA	Dec. 1963	5	41 houses destroyed, 986 houses damaged. 100 apartment buildings damaged.
Swift, MT	June 1964	19	Unknown
Lower Two Medicine, MT	June 1968	9	Unknown
Lee Lake, Mass.	Mar. 1968	2	6 houses destroyed. 20 houses damaged , 1 manufacturing plant damaged or destroyed.
Buffalo Creek, WV	Feb. 1972	125	546 houses destroyed, 538 houses damaged.
Lake "O" Hills, AR	Apr. 1972	1	Unknown
Canyon Lake, SD	June 1972	33	Unable to assess damage because dam failure accompanied damage caused by natural flooding.
Bear Wallow, NC	Feb. 1976	4	1 house destroyed.
Teton, ID	June 1976	11	771 houses destroyed, 3,002 houses damaged, 246 business damaged or destroyed.
Laurel Run, PA	July 1977	39	6 houses destroyed, 19 houses damaged.
Sandy Run & 5 others, PA	July 1977	5	Unknown.

TABLE I-1 (continued)

Name & Location of Dam	Date of Failure	Number of Lives Lost	Damages
Kelly Barnes, GA	Nov. 1979	39	9 houses, 18 house trailers and 2 college buildings destroyed; 6 houses, 5 college buildings damaged.
Swimming Pool, NY	1979	4	Unknown
About 20 dams in CT	June 1982	0	Unknown
Lawn Lake, CO	July 1982	3	18 bridges destroyed, 117 businesses and 108 houses damaged. Campgrounds, fisheries, power plant damaged.
DMAD, UT	June 1983	1	Unknown

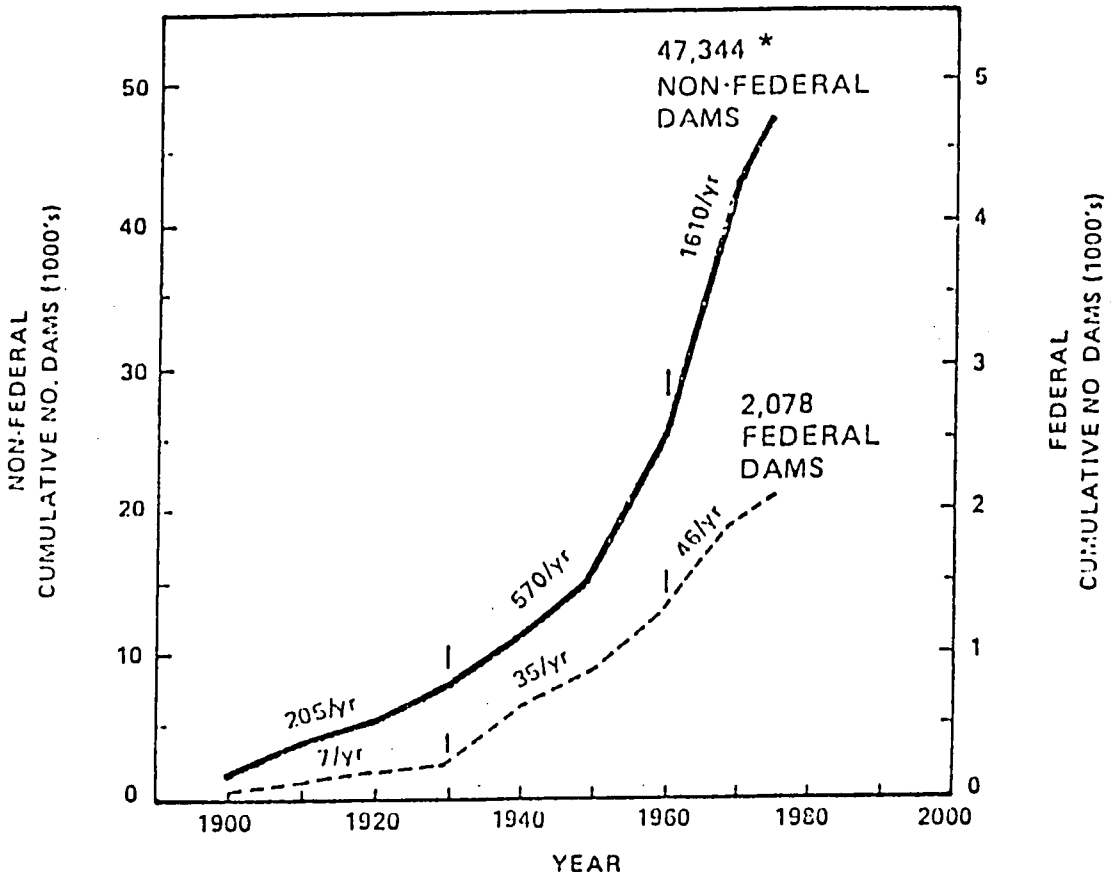
Source: Graham, 1983 (74).

constructed at the rate of approximately 1,610 per year (Figure I-1) (2).

A U.S. Committee on Large Dams (USCOLD) study of 4,918 Federal and non-Federal dams higher than 24 feet indicated 349 incidents (7 percent) of unsatisfactory and/or unsafe performance, including 74 failures (1.5 percent) (3). Data from the USCOLD report showed that about 16 percent of the dams constructed during the period between 1850 and 1930 experienced incidents of unsatisfactory performance. The primary causes of incidents occurring after 1900 and their incidence rates are given in Figure I-2 (74). Figure I-2 clearly illustrates that overtopping, foundation defects, piping and seepage are the main causes of failure, but it is interesting to note that failures are approximately equally distributed among these three causes.

Recent Concern in Dam Safety

Public concern for dam safety heightened following the 1972 collapse of the Buffalo Creek, West Virginia, coal tailings pond embankment, in which 125 people were killed. In 1972, Congress enacted Public Law 92-367, the "National Dam Inspection Act," under which the Army Corps of Engineers was authorized to inspect high-hazard non-Federal dams meeting certain size and storage limitations. In compliance with supplemental directives contained in the Act, the Corps prepared an inventory of dams, surveyed the activities and capabilities of each state with regard to non-Federal dam safety and developed



*Subsequently updated by Corps of Engineers to 66,804 on April 30, 1981.

Figure I-1. National Federal and non-Federal dam growth rate trends (from FCCSET Report, Improving Federal Dam Safety).

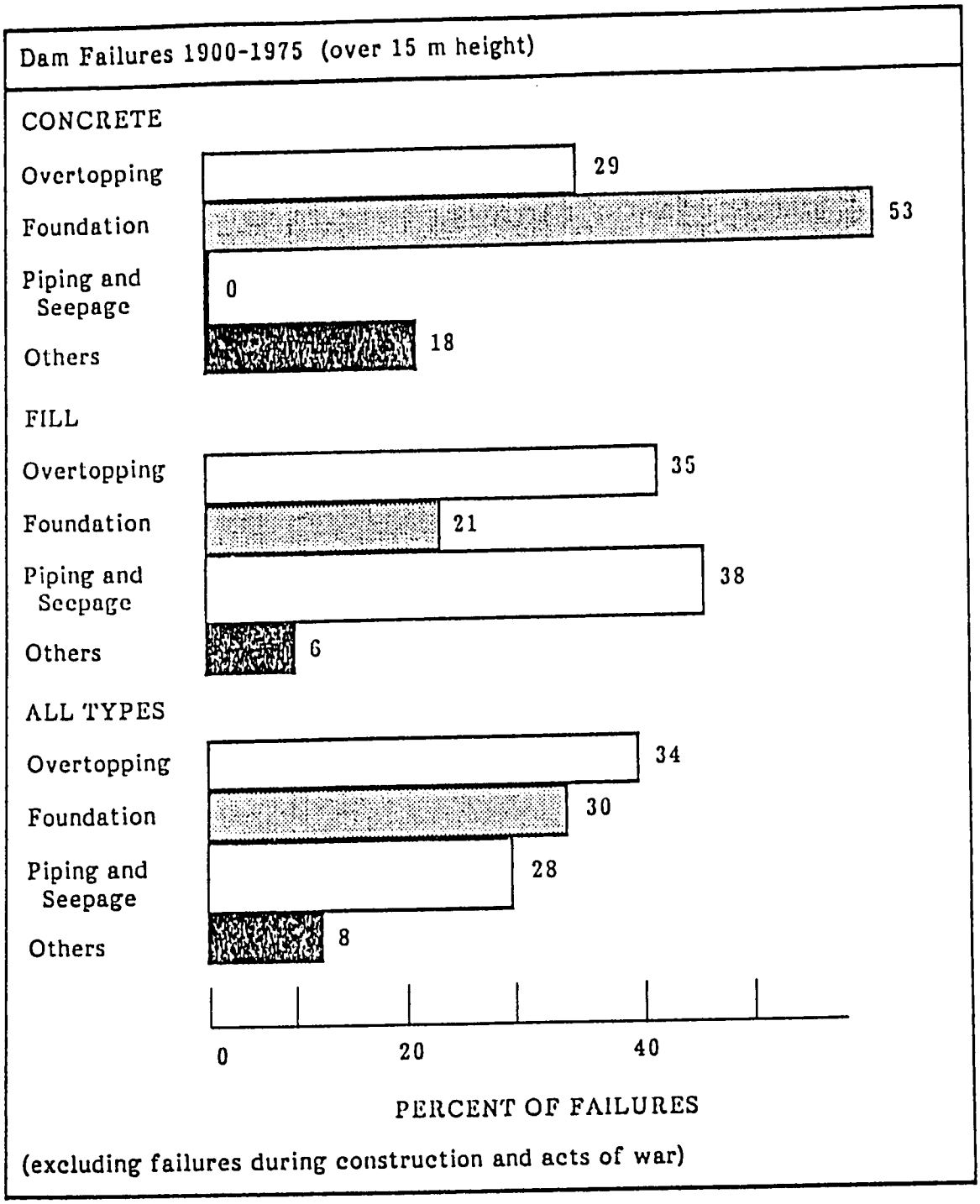


Figure I-2. Cause of failure.

Source: ICOLD (1973) (74).

inspection and safety guidelines (4). However, because of lack of funding, no dam inspections were made under the program until late 1977.

Federal interest in dam safety was revived after the sudden failure of Teton Dam on June 5, 1976, during first filling of the reservoir. During April of 1977, the President authorized the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) and the inter-agency committee to review Federal dam practices and to prepare Federal guidelines for management procedures to ensure Federal dam safety. FCCSET's report and proposed guidelines followed on the heels of the failure of the Kelly Barnes Lake Dam near Toccoa, Georgia, in November 1977 (2, 45). Although not charged with an evaluation of non-Federal dams, the 1977 FCCSET report expressed concern over the safety of the 47,300[2] non-Federal dams, of which only 3,400 were subject to any degree of Federal regulation. FCCSET recommended in its report that a pilot inspection program for non-Federal dams should be initiated by FY 1978. In November of 1977, following the Toccoa Dam failure, President Carter authorized the Corps of Engineers to begin a five-year inspection program of 9,000 high-hazard non-Federal dams that represent a "high" potential for loss of life and property if they fail. The importance of inspecting the non-Federal dams was reiterated a year later by an independent review panel of recognized experts convened for review of FCCSET's proposed Federal guidelines for dam safety, which were issued in final form on June 25, 1979.

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[2]Based on initial inventory required by PL 92-367 and reported by Corps in May 1975 (62).

The Non-Federal Dams

Among the major objectives of the Corps non-Federal Dam Safety Inspection is encouraging and preparing the states in initiate effective dam safety programs for the approximately 67,000 privately-owned dams in the U.S. Eventually, all states would be responsible for assessing the potential hydraulic impact of failure of all non-Federal dams under their jurisdiction in order to manage effective dam safety programs.

On December 1, 1978, the Chief of Engineers submitted to the President a report on the first year's progress in the inspection of non-Federal dams (7). The inspection program focused on performing initial technical inspections and safety evaluations (designated Phase I Investigations under the Corps' recommended guidelines) of dams which were limited to high-hazard dams that either were at least 25 feet high and retained a minimum of 15 acre-feet of water or stored at least 50 acre-feet of water and had a minimum height of 6 feet.

Inspections in each state were performed under the overall direction of the Corps, or where the states had the capability, by the states themselves. The actual inspections were accomplished by the Corps, the states, private consulting firms, or by cooperative arrangements among these three.

About 2,000 dams were inspected during the first year. Of the 1,400 or so reported at the close of the first year, nearly one-quarter were assessed as unsafe either because of emergency situations or because of potentially dangerous conditions. Nine out of ten unsafe assessments were attributed to hydrologic and hydraulic deficiencies (inadequate spillway capacity), either as the sole cause or in

conjunction with other deficiencies. Other causes to which unsafe assessments were attributed are seepage problems (4.3 percent of the dams reported), structural distress (2.5 percent), and embankment instability (2.5 percent).

The Corps' progress report for the month ending February 1980, indicated that since the inception of the program, nearly 5,687 inspections has been initiated and 4,906 completed. Of those dams inspected, about 29 percent were assessed as unsafe. The distribution of dams assessed as unsafe in each state is shown in Figure I-3 and expressed as a percent of the total number of dam inspections completed in that state. Although a breakdown of the causes for the unsafe assessments are not available for the February 1980 progress report, it is likely that it is similar to t hat reported to the President in the 1978 report (5).

General Discussion on dam Size and Hazard Classification

The Corps of Engineers has developed guidelines for classifying dams in accordance with size and downstream hazard potential, should failure occur, in order to formulate a priority basis for selecting dams to be included in the inspection program and also for providing consistency between guideline requirements and involved risks (4). The size categories are small, intermediate, and large. The classifications are as follows:

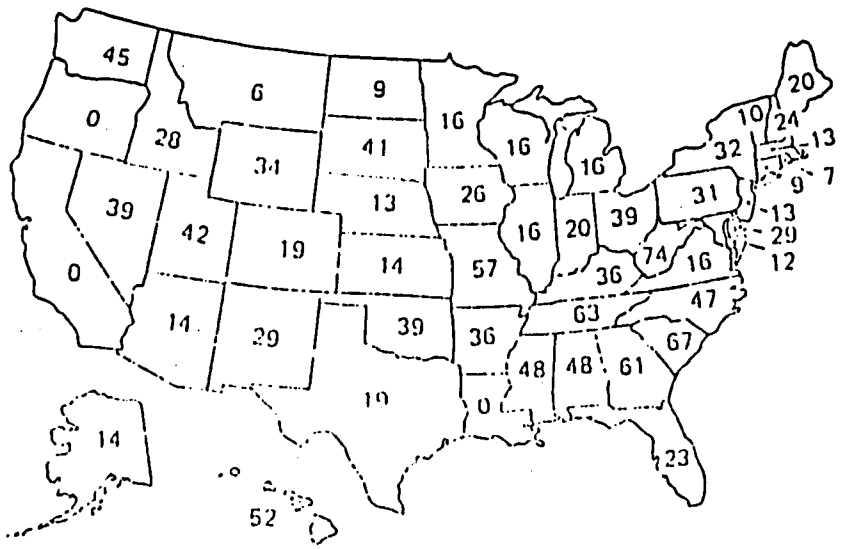


Figure I-3. Dams assessed as unsafe as a percentage of the total reported in each state as of February 29, 1980 (5).

Category	Storage (AC-FT)	Height (FT)
Small	30 to less than 1,000	20 to less than 41
Intermediate	1,000 to 5,000	41 to 100
Large	greater than 5,000	greater than 100

An existing dam's hazard rating (i.e., low, significant, or high) often becomes the basis for multiple-dam owners or regulating agencies, who have limited resources, for safety rehabilitation or re-evaluation purposes, to rank order their priorities. Planners and designers of new dams need to know probable impacts of hypothesized dam failures for siting, specifying design criteria and operating purposes. The Corps' classification for potential hazards is presented as follows:

Hazard Potential Classification

Category	Loss of Life (Extent of Development)	Economic Loss (Extent of Development)
Low	None expected (no permanent structures for human habitation)	Minimal (Underdeveloped to occasional structures or agriculture)
Significant	Few (No urban developments and no more than a small number of inhabitable structures)	Appreciable (Notable agriculture, industry or structures)
High	More than few	Excessive (Extensive community, industry or agriculture)

The hazard classification scheme is highly subjective and a dam's hazard classification is dependent upon the judgment of the engineer. In making his judgment, the engineer must assume different failure

scenarios, predict flood heights downstream and estimate the subsequent impacts on life and property.

In order to better assess the hazard potential of a dam in a systematic and equitable manner, one may employ an analytical approach called dam breach analysis. Dam breach analysis provides information to the engineer about the appropriate hazard classification for the dam. Estimation of downstream flooding times and identification of flood inundation areas permit rational development and implementation of emergency preparedness, warning, and evacuation plant. Such plans, coupled with frequent inspection and conscientious maintenance work, could minimize the loss of life resulting from a failure.

Many types of dam breach models exist. The objective of each is to model a simulated failure of a dam. Some procedures can be performed by hand, such as the Soil Conservation Service (SCS) TR #66 Simplified Dam-Breach Model (1) while others are very complex and require computer analysis. In general, the hand-worked methods represent simplified, time-consuming and conservative solutions to rigorous mathematical equations. Before the advent of digital computers, a hand-worked or graphical solution to the equations of motion using the method of characteristics was developed by Nosek and Dice in 1947 (61).

The main objective of a dam breach analysis is a realistic estimate of the outflow hydrograph from a breached dam. The outflow hydrograph development will be affected by numerous factors, such as height of the dam, impounded volume, type of dam, strength of materials, quality of construction, and other hydraulic and physical parameters. Engineering judgment plays a large part in quantifying each of the input

parameters and assessing their importance in an analysis. In this study it is attempted to minimize this judgment.

Relevance of Research

Ultimately, all states are responsible for assessing the potential hydraulic impact of failure for all non-Federal dams under their jurisdictions in order to manage effective dam safety programs. Specific reasons for a hydraulic assessment include the following:

1. Establishing dam inspection priorities. It is well known that state funds and manpower inspections are limited. Therefore, it is anticipated that those dams which represent the highest hazard to downstream lives and property in event of failure would receive the first inspection priority as state programs are conducted.

2. Some state civil defense and emergency planning offices are beginning to require the preparation of maps showing the area which would be inundated as a result of dam failure (11, 13). The map serves the purpose of defining those areas which would be flooded and permits warnings to be dispatched to the highest hazard areas if failure has occurred or is imminent. Estimated downstream flow velocities and depths would also serve to facilitate emergency planning. In some cases, it would be important to use such inundation maps, together with velocity, depth, and time of arrival information, to define areas for restricting or protecting certain land uses (14, 15). As public information, the maps would also serve as a planning tool and a constant reminder to a normally unsuspecting public of inherent floodplain dangers to unsold properties below dams.

3. A likely role for the Federal government in non-Federal dam safety is Federal reinsurance or guarantees to assure that owners of dams would be able to obtain liability insurance at reasonable rates and to protect persons located downriver from dams (9). However, liability insurance for dams either is not available or is excessively costly because of uncertainty and insufficient data for developing actuarial estimates of expected loses. Data generated from state hydraulic assessment studies would provide valuable information to insurance companies for determining actuarial rates. Availability of insurance to dam owners at reasonable rates would (a) shift to financial burden of disaster risk from government to those more closely responsible for failure; and (b) encourage continuous owner maintenance, upgrading, and surveillance of the structure in order to maintain the lowest insurance premium rates.

Objective of Study

The first objective of this study was to develop a trigonometric--geometric-descriptor in order to predict the dimensions of the breach channel in time and space via a Newton-Raphson iterative scheme. The second objective was to account for the volume of the eroded fill material and the ratio of the sediment discharge rate to the water discharge rate during every computational time increment. If this ratio exceeded unity the model user would be warned since sediment transport equations are not applicable to mud flow.

The third objective was to incorporate the most recent and effective equations to describe the erosion of the fill material. The

fourth objective was to incorporate all the above objectives into a dam-failure model and to test its validity by simulating the failure of a historical overtopping dam-failure.

CHAPTER II

LITERATURE REVIEW

Studies and dam breach models were reviewed in the literature and are described briefly in the following paragraphs.

The first model for simulation of breach erosion processes was developed by Cristofano (12). This was a manual-iterative model based on the assumption that the discharging water force was balanced by friction forces along the wetted perimeter. Erosion characteristics were lumped into a proportionality parameter, while lateral erosion of breach was neglected. The breach was assumed to maintain a constant top width and a trapezoidal shape throughout the failure process. In addition, side slopes of the breach channel were set equal to the angle of repose of the fill material, and the bottom slope of this channel was set to be the same as the angle of friction of the fill material (53).

Harris and Wagner suggested an erosion model for erosion of a parabolic breach by utilizing the Schoklitsch bed load formula (47). Grain size and critical value of discharge for erosion to begin were the characteristic parameters (66).

Brown and Rogers (67) developed a computational model based on earlier work by Harris and Wagner (47), in which the Schoklitsch formula was used to compute the rate of erosion. They considered the failure of an earth dam immediately upon overtopping, degradation of the breach, and erosion to datum level.

Brown and Rogers (67) point out the need for incorporating lateral erosion into the model simulation. They also address some of the difference in modes of failure for exceptionally high earth dams as opposed to long, low embankments. In addition, they point out that the bulk of the material eroded from the breach is deposited almost immediately downstream of the dam. Thus affecting tail-water depths and the out-flow hydrograph.

The HEC-1 Flood Hydrograph Package, Dam Safety Version computer model was developed by the Corps of Engineers Hydrologic Engineering Center in Davis, Californi (36). This model has been designed to enable the user to perform two basic types of analyses. The analyses consist of the evaluation of the overtopping potential of the dam, and the capability to estimate the downstream hydraulic-hydrologic consequences resulting from the assumed structural failure of the dam.

The Tennessee Valley Authority (TVA) Unsteady Flow Model (SOCH) was developed by Garrison, Granju, and Price (34). This hydraulic routing program uses the basic differential equations of continuity and momentum, which are solved by an explicit numerical scheme. SOCH computes the stage, discharge, and velocity at predetermined intervals of time and space throughout a reservoir or river channel. This model is used for instantaneous complete or partial failures.

The National Weather Service Dam-Break Flood Forecasting Model was developed by Fread (42). This model has two basic parts. The first part simulates the outflow hydrograph due to a time-dependent, erosion-type of dam breach using a hydraulic weir representation of the outflow through the breach, while simultaneously considering the effects

of the reservoir storage depletion and the inflow hydrograph via either a storage or hydraulic routing technique. The second part routes the generated outflow hydrograph through the downstream valley by an explicit finite difference solution of the complete one-dimensional equation of unsteady flow.

Balloffet (16) developed a dam breach and flood wave model consisting of an explicit finite difference solution of the St. Venant and continuity equations. This model represents the continuity equation by assuming that the storage capacity in the field of flow is decomposed into discrete reservoirs, each ascribed to a node of a network. Furthermore, the volume and surface area ascribed to each node are functions of water surface elevation and topography. The TAMS model includes a complete appraisal of the convective inertia term in the St. Venant equations of motion, except for links with multiple connections (tributary inlet into the main channel.) Balloffet showed that the mathematical approach has given a satisfactory description of the engineering and theoretical problems of the propagation of a dam collapse wave in a natural channel (5, 16, 44).

The Soil Conservation Service Simplified Dam-Break Routing Procedure was developed by the U.S. Department of Agriculture (1). This model represents a hand-worked dam breach routing procedure that utilizes a simplified version of a simultaneous storage routing-Kinematic routing method, the Attenuation-Kinematic model.

The TVA Dam Breaching Program was developed by the TVA Flood Control Branch (46). This program predicts if a flood overtopped earth

embankment will fail and, if so, the time and rate of failure. TVA's breaching program is based on a study by Cristofano.

Rajar (24, 25) experimentally studied the problem of dam breach hydrograph routing. He concluded that channel bend losses should be considered in hydraulic routing computations and that uniform velocity assumption over a channel cross section is not valid. He also showed that the Lax Wendroff numerical scheme seemed to be most suitable and accurate for very non-prismatic channels in solving the St. Venant equations to prevent numerical instability during computations and to achieve better flow simulation.

Martin and Zovne (49) performed a study on "Finite Difference Simulation of Bore Propagation." In this study, the solution to the dam-breach and bore-reflection problems was obtained by using a finite-difference approximation to the one-dimensional equations of motion. A fixed-rectangular grid in the form of a staggered array of points was specified in their report.

A study on "Open Channel Surge Simulation by Digital Computer" was conducted by DeFazio and Martin (48). The purpose in this study was to demonstrate the use of the digital computer for simulation of prismatic open-channel flow problems. The St. Venant equations of motion for gradually-varied flow are expressed in finite-difference form, resulting in algebraic equations that are readily programmed for use on a digital computer. In this study it was demonstrated that the simple finite-difference equations developed by Stoker can be adapted to many open-channel wave problems involving flow from gradually-varied to rapidly-varied form and to systems of channels.

Strelkoff (47) published a study on computing two-dimensional dam breach waves. The existing one-dimensional models for dam breach flood waves are unable to simulate the details of the flow resulting from a breached dam or total dam failure in an abruptly expanding valley. In his work, Strelkoff developed a two-dimensional model based on the method of characteristics and tested its capability for simulating the preceding situations. His results were correct to the second order, with respect to Δt, thus significantly improving the computational efficiency in two-dimensional situations.

Barnes (28), in his study on "Geometric and Frictional Effects of Sudden Releases" extended Dressler's theoretical study in order to include both the effects of resistance and channel cross section on the waves of sudden releases (dam breach outflow). Barnes showed that effects of channel cross-sectional shape and resistance on the waves are significant. He also demonstrated that the perturbation techniques given by Dressler can be extended to include the factor of channel cross-sectional geometry.

Keulegan developed the so-called "classic dam-break equations" (31). Garrison, Lowe, and Price showed that values of peak failure discharge and velocity determined by use of the St. Venant equations compare favorably with the corresponding values computed from the classical dam-break equations (34).

Dimensionless depth and distance curves developed by Sakkas, have been presented by the Corps of Engineers Hydrologic Engineering Center for estimating maximum flood depth at various points downstream from an instantaneous and completely failed dam (51). The dimensionless curves

were developed from numerical simulation of the St. Venant equations for a simple downstream prismatic channel.

Fread (42) presented a parametric model for simulation of rectangular, triangular or trapezoidal breaches. His model assumed a linear predetermined rate of erosion, so it was useful only for estimation of a spectrum of possible failure events, but not for prediction of the one most likely to occur.

Lou (68), and Ponce and Tsivoglou (63) described the flow dynamics by using the St. Venant system of equations and solving it by Priessmann's four-point finite differences scheme. Lou utilized a simplified sediment transport relation by assuming that dam erosion was proportional to the kinetic energy of flowing water. His formula however included two parameters: the erodibility index and failure duration time which are very difficult to estimate. Ponce and Tsivoglou treated the sedimentation problem by utilizing the Meyer-Peter and Mueller bed-load relation. Thus, their model required knowledge of the critical shear stress for erosion.

Fread (69) presented another iterative numerical model which included not only surface layer-by-layer erosion, but also sloughing, under dry soil conditions, of the breach slopes. In his model sediment transport was approached by the Meyer-Peter and Mueller formula.

A breach erosion model was developed by Singh and Scarlatos in 1985 (70). This was an iterative numerical model that considered both surface erosion and mass failure of the breach sides. Sediment transport was simulated by the Einstein-Brown method from a study performed by Senturk and Simons (71), while slope instability was

treated by the contour technique so that seepage forces were also included (72).

Fread (73) developed a breach erosion model (BREACH) based on principles of hydraulics, sediment transport, and soil mechanics. The model uses equations of weir or orifice flow to simulate the outflow entering a channel that is gradually eroded through an earthen man-made or landslide-formed dam. A sediment transport relation, the Meter-Peter and Muller equation modified for steep channels is used to predict the transport capacity of the breach flow whose depth is determined by a quasi-steady uniform flow relation. Breach enlargement is governed by the rate of erosion which is a function of the breach bottom slope and depth of flow and by the extent of collapse that occurs to the sides of the breach due to one or more sequential slope failures. The breach material properties (internal friction angle and cohesive strength) are critical in determining the extent of enlargement of the trapezoidal--shaped breach. The model has the potential to determine if a breach will develop sufficiently during an overtopping of the dam to cause a catastrophic release of the reservoir's stored water.

Scarlalos and Singh (64) performed a study on mud flows and sedimentation problems associated with a dam-break event. In this study, the volume rate depletion of the reservoir water is given by the continuity equation while the breach outflow discharge is obtained by the broad-crested weir formula. The rate of erosion is governed by a functional relationship of the Einstein-Brown bed-load formula. This model considers the failure of the breach side slopes when seepage and gravitational forces exceed the stabilizing effects of cohesion and

internal friction. The water phase is routed by using the Muskingum method, while for the sediment routing, a mass continuity Exner type equation is utilized.

Chen (75) developed a computer model to determine hydraulic conditions and erosion of embankments due to flood overtopping. The embankment is considered to obtain four layers: pavement, gravel base, grass cover, and base soil (this model was developed in regard to roadway embankments). The critical shear stress, Manning's n, and thickness of these layers at each computation section are input. When one layer is eroded, the critical shear stress and Manning's n for the immediate lower layer are utilized. A DuBoy's type equation proposed by the Agricultural Research Laboratory is utilized to compute erosion rate. The coefficient and the exponent to this equation are determined empirically. The critical shear stress is determined from Shield's diagram for noncohesive soil and from the plasticity index for cohesive soil.

The major limitations of the dam failure models which are based on the hydraulics of sediment transport are summarized below.

Lou (68) utilized a simplified sediment transport relation by assuming that dam erosion was proportional to the kinetic energy of flowing water. His formula included two parameters: the erodibility index and failure duration time which are very difficult to estimate. Lou also used DuBoy's and Cristofano's equations in his modeling effort. These equations have not been tested for high shear stress and steep slope conditions. Another limitation of this model was that the initial

top width of the breach channel, which caused great variations in the peak outflow discharge predictions, had to be estimated based on engineering judgment.

Scarlatos and Singh (64, 70) developed two models that considered both surface erosion and mass failure of the breach sides. The main disadvantage of these models is that the erosion process was based on the Einstein-Brown bed-load formula. When rapid vertical erosion under high schear stress and steep slope conditions is simulated the Einstein-Brown formula almost always extrapolates the bed-laod rate. This equation is only applicable to sandy soils. Thus, when clayey cores are encountered in a dam the validity of the application of this equation is questionable. The breach channel's geometry was not discussed in this study.

Chen's (75) embankment erosion model was primarily developed for highway embankments. Thus, it does not address the mechanism that determines the width of the breach section. This model also assumes that erosion occurs in horizontal layers. Conservation of mass is not considered in calculation of the volume of the eroded soil.

Fread's (73) breach erosion model (BREACH) assumes that the slope of the breach channel is equal to the downstream slope of the dam. Historical dam failures (66) indicate that the breach channel slopes vary and are not equal to the slope of the downstream face of the dam. Setting the breach channel slope equal to the slope of the downstream face of the dam also tends to simulate a less conservative scenario than a flatter breach channel slope. This effect is due to the fact that the overtopping outflow of the dam is not affected by the later propagation

of the breach channel until the upstream face of the dam is encountered. Estimation of the erosion rate is based on Meyer-Peter and Muller equation which is applicable to sandy soils only.

Cristofano's (80) equation was examined by Chen (75) based on laboratory flume tests. Chen's finding indicated that Cristano's equation greatly overestimates the erosion rate for different types of soil mixtures. The analysis showed that the higher the observed erosion rate the greater the predicted and observed erosion rate difference would be.

The dam failure model developed in this study includes components that eliminate most of the weaknesses that the models discussed above possess. These components are briefly described below and are discussed in detail in the following chapter.

This model accomodates the user with the state-of-the-art sediment transport equations which have been laboratory tested, for clayey and sandy soil mixtures, under high shear stress and steep slope conditions. The estimation of the initial breach channel width is optional. It can be estimated by the user based on historical data or the model, baed on the optimum channel hydraulic efficiency, automatically selects the breach channel width. The breach channel slope is set equal to the angle of friction. Due to the development of a complex trigonometric-geometric-descriptor that is built into this model, all possible breach channel slopes can be simulated. Thus, the user is able to simulate different scenarios. A computational time increment (Dt) criterion is proposed in this study. This criterion essentially states that Dt is equal to half of the time it takes for a grain of soil to traverse the

length of the breach channel. This Dt is compared to that of the hydrologic reservoir routing and whichever has the lower value is used.

In short, this model minimizes the guesswork required in estimating the input parameters for dam failure analysis.

CHAPTER III

MODEL DESCRIPTION

The model utilizes the hydrologic routing method to account for the inflow into the reservoir, the outflow from the reservoir, and the consequent change in the reservoir water surface elevation.

As the water overtops the dam the shear stress exerted on the downstream face of the dam by the flowing water is computed. Once the computed shear stress exceeds the critical shear stress of the downstream face of the dam's cover, erosion of the dam commences through a breach channel as shown in Figure III-1.

The average depth of water in the breach channel is computed by Manning's equation. The use of Manning's equation is appropriate because the extremely short reach and very steep channel slopes contribute to produce very small variation in flow with distance along the breach channel.

The determination of the erosion rate is based on the hydraulics of sediment transport for clayey and sandy soil mixtures. The equations used to determine the failure erosion rate have been tested in the laboratory under high shear stress and steep slope conditions.

Trapezoidal, triangular, and rectangular breach channel cross sections can be simulated by this model. The side slopes of the cross section (trapezoidal or triangular) of the breach channel are set equal to the angle of repose of the dam fill material. The bottom width of

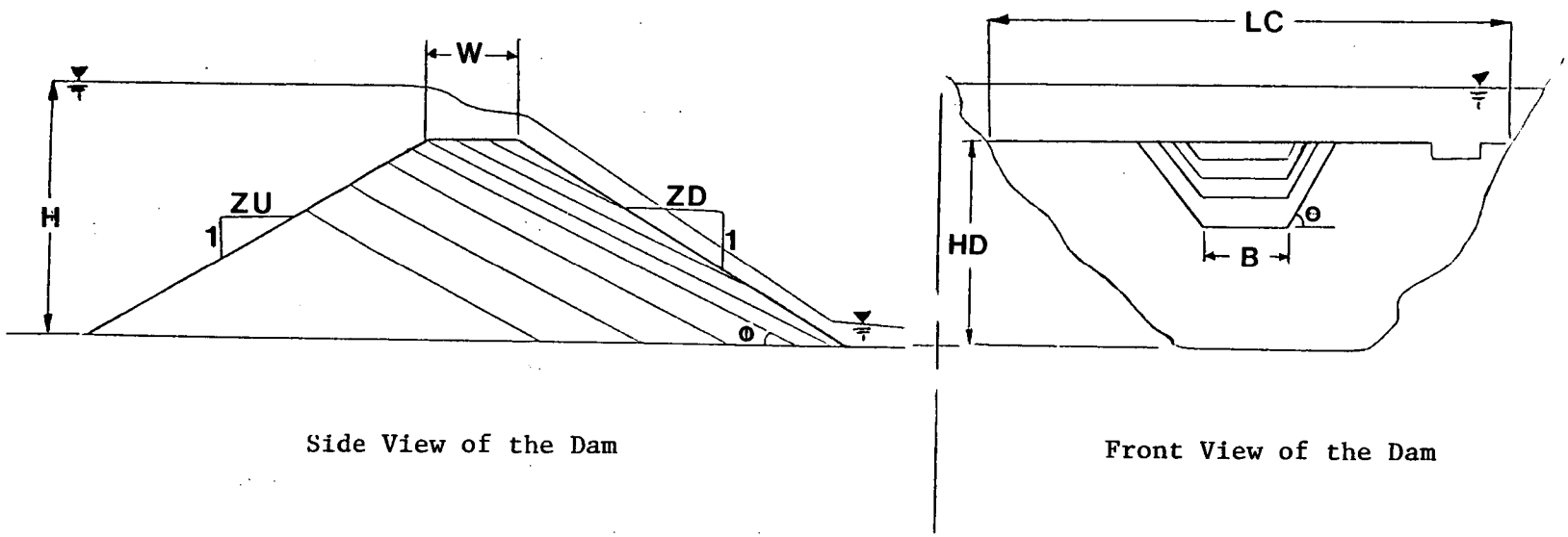


Figure III-1. Side view and front view of an overtopping failure.

the trapezoidal or rectangular breach channel is selected from historical dam failure data or is set equal to twice the depth of flow. The breach channel slope is set equal to the internal angle of friction of the soil mixture.

Once the breach channel shape is determined and the erosion rate computed, the volume of the eroded soil within the computational time increment is determined. Trigonometric geometric subroutines, depending on the slope of the breach channel, calculate the length, upstream elevation, downstream elevation, and other geometric parameters of the breach channel.

The model components mentioned above are discussed in the following sections.

General

The dam fill material has the following properties which are utilized in the model:

θ - angle of repose

φ - friction angle

d_{50} - average grain size diameter

γ_s - specific weight of the fill material

Pr - porosity of the fill material

The downstream face of the dam may be specified as having:

- grass cover with specified length of good or fair stand
- material identical to the dam fill material

- material with larger average d_{50} than the fill material (rip-rap)

The geometry of the dam is described as follows:

W - the width of the dam's crest

LC - the length of the dam's crest

ZU - the slope of the upstream face of the dam. This slope is given by the ratio of 1 (vertical) to ZU (horizontal)

ZD - the slope of the downstream face of the dam. This slope is given by the ratio of 1 (vertical) to ZD (horizontal)

HD - height of dam from downstream toe

The storage characteristics of the reservoir are described by a table that consists of surface area (SA-Acre-Ft) vs. pool elevation (HSA-feet MSL), the initial water surface elevation (Y_o-feet MSL) at the beginning of the simulation (when t = 0), and a table of the reservoir inflow hydrograph that presents the inflows (I-cfs) vs. their corresponding time (T-hours) of their occurrence. The water surface elevation in the reservoir is presented by (H-feet MSL).

When an overtopping is simulated, the water level (H) in the reservoir must exceed the top of the dam before erosion can occur. As the shear stress exerted by the flow exceeds the critical shear stress of the soil or the protective cover, erosion begins.

Table III-1 presents the critical shear stress values for different protective covers and soil types (75).

TABLE III-1

MAXIMUM PERMISSIBLE VELOCITIES RECOMMENDED BY FORTIER AND SCOBEY AND THE CORRESPONDING UNIT-TRACTIVE-FORCE VALUES CONVERTED BY THE U.S. BUREA OF RECLAMATION (FOR STRAIGHT CHANNELS OF SMALL SLOPE, AFTER AGING)

	Clear Water		Water Transporting colloidal silts	
Material	V_c ft/s	τ_c lb/ft^2	V_c ft/s	τ_c lb/ft^2
Fine sand, colloidal	1.50	0.027	2.50	0.075
Sandy loam, noncolloidal	1.75	0.037	2.50	0.075
Silt loam, noncolloidal	2.00	0.048	3.00	0.11
Alluvial silts, noncolloidal	2.00	0.048	3.50	0.15
Ordinary firm loam	2.50	0.075	3.50	0.15
Volcanic ash	2.50	0.075	3.50	0.15
Stiff clay, very colloidal	3.75	0.26	5.00	0.46
Alluvial silts, colloidal	3.75	0.26	5.00	0.46
Shales and hardpans	6.0	0.67	6.00	0.67
Fine gravel	2.50	0.075	5.00	0.32
Graded loam to cobbles when noncolloidal	3.75	0.38	5.00	0.66
Graded silts to cobbles when colloidal	4.00	0.43	5.50	0.80
Coarse gravel, noncolloidal	4.00	0.30	6.00	0.67
Cobbles and shingles	5.00	0.91	5.50	1.10

Source: Chen, Y. and Anderson, B. A. 1986 (75).

Derivation of Shear Stress Exerted by the Flow on the Downstream Face of the Dam

A short reach of length L between stations 1 and 2 of the downstream face of a dam in uniform flow with area A of the water section in Figure III-2 is considered. Static equilibrium and zero acceleration are assumed. Since the depth of flow between stations 1 and 2 is constant, the hydrostatic pressure forces (P_1A_1, and P_2A_2) balance each other. Therefore, the only force in the direction of motion is the gravity component, and this must be resisted by the boundary shear stress acting over the area P_oL. According to Newton's Second Law, if steady state flow is assumed

$$\Sigma Fx = 0 \tag{1}$$

$$A_1 = A_2 = A$$

$$W = AL\gamma$$

$$W_x = W \sin\varphi$$

$$\Sigma Fx = P_1A_1 - P_2A_2 + Wx - f = 0 \tag{2}$$

$$A_2 = A_1 \tag{3}$$

$$P_1 = P_2 = \gamma h \text{ and } P_1A_1 = P_2A_2 \tag{4}$$

Therefore

$$f = Wx = W \sin\varphi = AL\gamma \sin\varphi \tag{5}$$

$$\tau_o = \frac{f}{P_oL}, \text{ where } P_o = \text{wetted perimeter} \tag{6}$$

$$f \frac{(1)}{P_oL} = \frac{(1)}{P_oL} AL\ \gamma \sin\varphi \tag{7}$$

$$\tau_o = \frac{A}{P_o} \gamma \sin\varphi, \text{ if } R_h = \frac{A}{P_o} \text{ then:} \tag{8}$$

$$\tau_o = R_h \gamma \sin\varphi \tag{9}$$

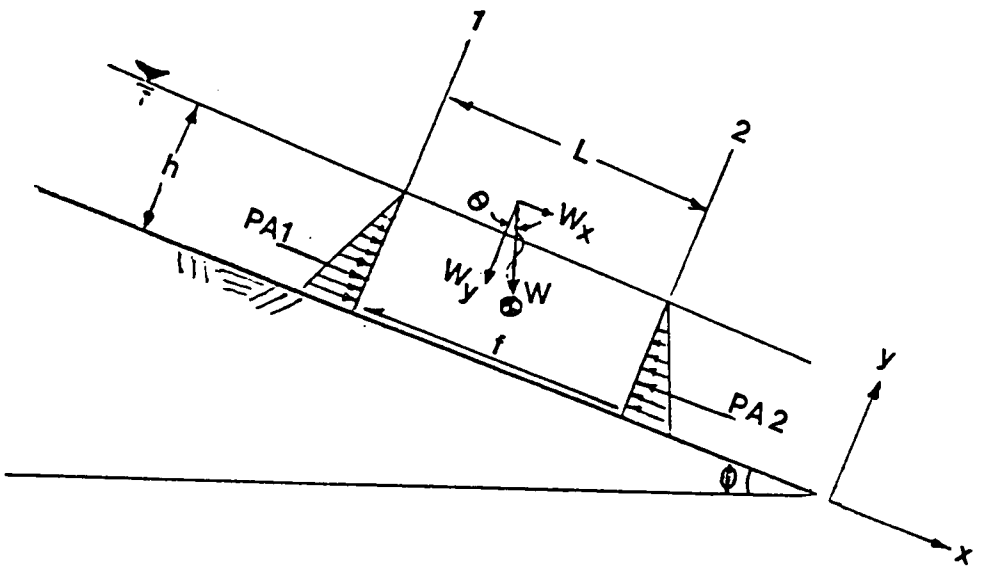


Figure III-2. Hypothetical cross section of the downstream of the dam.

A - cross sectional area of the element

L - length of the element

τ_o - shear stress exerted by the water on the exposed embankment surface

P - hydrostatic pressure

P_o - wetted perimeter

φ - angle of inclination

γ - specific weight of water

h - depth of water

f - shear force acting over the area P_oL

R_h - hydraulic radius

For wide open channels the following relationship (92) may be used:

$$\tau_o = \gamma D \, \mathrm{Sin}\varphi \qquad (10)$$

where D is the average depth of water in the channel and the model assumes that D is the critical depth at the top of the dam and is:

$$D = (2/3)(H-HD)$$

For H and HD definition see Figure III-1.

The shear stress exerted by the flow on the downstream face of the dam is, therefore, calculated by the above relationship during every time interval (Δt) until it exceeds the critical shear stress of the

protective cover of the downstream face of the dam. At this moment the protective cover is removed and erosion of the dam due to overtopping commences.

Reservoir Level Determination

The flow hydrograph through the reservoir and a breaching dam may be estimated by the method of flood routing through a reservoir. In practice, there are two methods of flood routing, these are frequently called the hydraulic method, and the hydrologic routing method (11).

The hydraulic method is based on the equation of continuity and the equation of motion for a channel. The development of the complex mathematical solution procedures of these equations can be found in several published articles (26-30), 44, 47). The hydrologic routing method is based on the conservation of mass equation:

$$I - Q = \frac{dS}{dt} \tag{11}$$

where

I - inflow

Q - outflow

S - storage

t - time

The equation above may be expressed in the finite difference form as:

$$\frac{I1 + I2}{2} - \frac{Q1 + Q2}{2} = \frac{S2 - S1}{t2 - t1} = \frac{\Delta S}{\Delta t} \qquad (12)$$

Subscripts 1 and 2 refer to parameter values at time $t_1 = t$, and

$t_2 = t_1 + \Delta t$.

The change in storage may be approximated by:

$$\Delta S = (1/2)(AS1 + AS2) \qquad (13)$$

where

AS = surface areas in acres

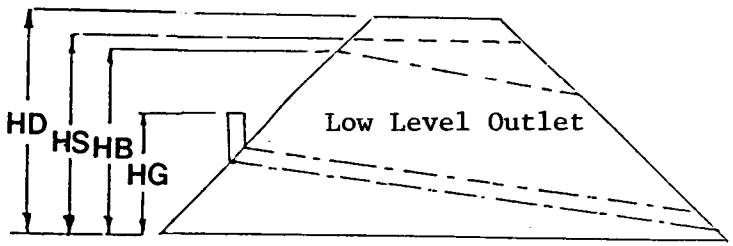
H = pool elevation in feet

Combining equations (12) and (13) results in the following expression:

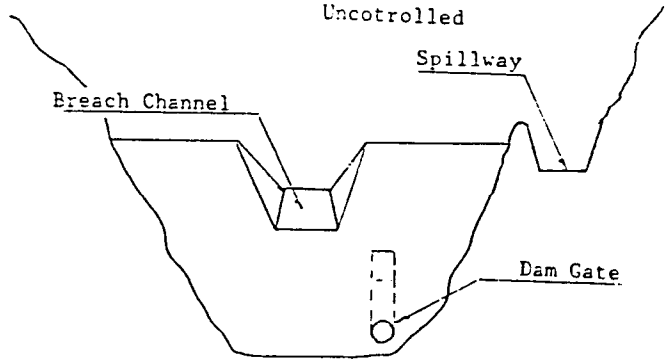
$$I1 + I2 - Q1 - Q2 = (AS1 + AS2)\ (H2 - H1)/\Delta t \qquad (14)$$

The total reservoir outflow as depicted in the schematic in Figure III-3 consists of the following outlets: an uncontrolled spillway, QS; a dam gate, QG; the dam overflow, QD; a constant outflow, QK; and the breach outflow, QB.

The uncontrolled spillway flow may be approximated by the rectangular wier flow equation (82).



Side View of the Dam



Front View of the Dam

Figure III-3. Side view and front view of the dam outlets.

$$QS = CS\ (H - HS)^{1.5} \tag{15}$$

where C is the coefficient of discharge (82) for broad crested wiers and CS is the product of C and the width of the wier.

The dam gate flow is controlled by a valve or it may be uncontrolled and it carries the water through a conduit that passes through the dam. The flow for a fully open or uncontrolled gate is approximated by the following equation (83).

$$QG = CG\ (H - HG)^{0.5} \tag{16}$$

where C is the coefficient of discharge (83) for uncontrolled gates and CG is the product of C and the area of the gate.

The dam essentially functions as an uncontrolled spillway once the dam is overtopped by a flood, therefore, its flow is calculated by a rectangular wier flow equation (92).

$$QD = CD\ (H - HD)^{1.5} \tag{17}$$

The approximation of the flow through the breached channel is based on the wier flow equation for a trapezoidal cross section (73).

$$QB = C1\ (H - HB)^{1.5} + C2\ (H - HB)^{2.5} \tag{18}$$

$$C1 = C\ B \tag{19}$$

where C is the coefficient of discharge for rectangular wiers.

$$C2 = C\ Z \tag{20}$$

where C is the coefficient of discharge for triangular wiers (82, 92).

The constant outflow (QK) may be defined as the flow through the dam which is known as seepage.

The definitions of variables used in equations (15) through (20) are as follows:

CS - spillway coefficient

HS - spillway elevation (ft-MSL)

CG - gate coefficient

HG - gate elevation (ft-MSL)

CD - dam coefficient

HD - dam elevation (ft-MSL)

C1 - breach coefficient

C2 - breach coefficient

HB - breach elevation (ft-MSL)

B - breach bottom width (ft)

Z - breach size slope, which is given by the ratio of 1 (vertical) to Z (horizontal)

The total reservoir outflow, Q, is computed according to equation (21):

$$Q_2 = QS + QG + QD + QK + QB \quad (cfs) \tag{21}$$

The resultant mass flow equation is reached by combining equations (14) and (21):

$$(AS1 + AS2)\ (H2 - H1)/DT + (QS + QG + QD + QK + QB) + Q1 - I2 - I1 = 0 \quad (cfs) \tag{22}$$

This equation is a function of H_2 since all other terms are known values. Newton-Raphson iteration may be used to solve for H2, as follows:

$$FUNCT = (AS1 + AS2) * (H2 - H1) * 12.1/\Delta t + Q2 + Q1 - I1 - I2 \quad (cfs) \tag{23}$$

and the derivative of the above expression with respect to H_2 is:

$$DERIV = (AS1 + AS2)\ 12.2/\Delta t + DS + DG + DD + DB\ (ft^2/sec) \tag{24}$$

where

$$DQ2 = DS + DB + DD + DB\ (ft^2/sec) \tag{25}$$

$$DS = 1.5\ CS\ (H2 - HS)^{0.5}\ (ft^2/sec) \tag{26}$$

and

$$DG = .5\ CG\ (H2 - HG)^{-0.5}\ (ft^2/sec) \tag{27}$$

$$DD = 1.5\ CD\ (H2 - HD)^{0.5}\ (ft^2/sec) \tag{28}$$

$$DB = 1.5\ B\ 3.1\ (H2 - HB)^{.5} + 2.5\ Z\ (H_2 - HB)^{1.5}\ (ft^2/sec)$$

and 12.2 is a conversion factor. (29)

$$NH2 = \text{New } H2\ (\text{ft-MSL}) \tag{30}$$

and

$$NH2 = H2 - \frac{FUNCT}{DERIV}\ (\text{ft-MSL}) \tag{31}$$

$$H2 = NH2\ (\text{ft/MSL}) \tag{32}$$

if

$$|NH2 - H2| < 0.001\ (\text{ft-MSL}) \tag{33}$$

Then stop and use new value (NH2) as H2.

Hydraulics of the Breach Channel

The use of quasi-steady uniform flow in contrast to the unsteady flow equations as used by Ponce and Tsivoglou (63) greatly simplifies the hydraulics and the computational algorithm.

Fread (73) states that the breach flow is assumed to adequately describe quasi-steady uniform flow as determined by applying the Manning equation for open channel flow at each time step (Δt).

The use of Manning equation is appropriate because the extremely short reach and very steep channel slopes contribute to produce very small variation in flow with distance along the breach channel.

The Manning equation can describe the breach flow as follows:

$$QB = \frac{1.49}{n} S^{0.5} \frac{A^{1.67}}{P^{0.67}} \tag{34}$$

where

QB - breach flow

A - the channel cross-section area

P - the channel wetted perimeter

n - Manning roughness coefficient of the channel material

S - slope of the channel

The breach flow QB-cfs is calculated by equation (18) which was presented in the previous section. Therefore, depth of flow is the unknown and is determined by the following algorithm based on Newton-Raphson iteration. For a trapezoidal breach channel.

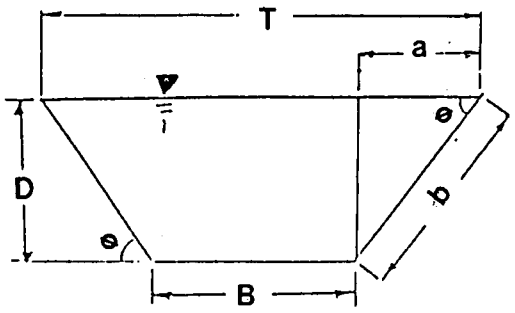
φ - angle of repose of the channel material

D - depth of water in the channel

T - the top width of the trapezoidal channel

B - the bottom width of the trapezoidal channel which is equal to 1/2 HD

$$A = \frac{T + B}{2} D \tag{35}$$



$$T = B + 2a \tag{36}$$

$$\frac{D}{a} = \tan\varphi \tag{37}$$

$$a = \frac{D}{\tan\varphi} \tag{38}$$

$$\frac{D}{b} = \sin\varphi \tag{39}$$

$$b = \frac{D}{\sin\varphi} \tag{40}$$

After substitution and simplification the area of the cross section (trapezoidal) is:

$$A = (B + \frac{D}{\tan\varphi}) D \tag{41}$$

and

$$P = B + 2b \tag{42}$$

$$P = B + \frac{2D}{\sin\varphi} \tag{43}$$

The derivative of A and P with respect to D are as follows:

$$\frac{dA}{dD} = A' \tag{44}$$

$$\frac{dP}{dD} = P' \tag{45}$$

$$A' = B + \frac{2D}{\tan\varphi} \tag{46}$$

$$P' = \frac{2}{\text{Sin}\varphi} \tag{47}$$

$$QB = \frac{1.49}{n} \frac{A^{1.67} S^{0.5}}{p.67} \quad \text{or} \quad Q_B P^{.67} - \frac{1.49}{n} A^{1.67} S^{0.5} = 0 \tag{48}$$

$$\text{Let FUNCT} = QB\ p^{0.67} - \frac{1.49}{n} A^{1.67} S^{0.5} \tag{49}$$

Then, the derivation of FUNCT is presented as DERIV and is as follows:

$$\text{DERIV} = .67\ Q_B \frac{P'}{p.33} - \frac{1.49}{n} S^{.5}\ 1.67(A^{.67})\ A' \tag{50}$$

To find the new depth (ND) the following is presented:

$$ND = D - \frac{\text{FUNCT}}{\text{DERIV}} \tag{51}$$

The convergence criterion is checked by the following relationship:

$$|ND - D| < E \tag{52}$$

where E is set to equal .001. The iteration is repeated until the above criterion is met, and ND will be the depth of the water in the breach channel.

Sediment Transportation Equations

The following equation that was developed by Peter Meyer using the data provided by Eidgenossische Technische Hochschule, called ETH in Switzerland, is the foundation of the equation used for sandy soils in this study (79):

$$S\ \gamma\ R_h/d - .047\ (\gamma_s - \gamma) = .25\ \rho^{.33}\ g_s{}'^{.66}/d$$

where

$g_s = g_{s'} \gamma_s/(\gamma_s - \gamma)$

S - tan θ = angle of friction of particle mixture)

R_h - hydraulic radius

d - d_{50} of mixture

g_s - bedload rate in weight per unit width and unit time

γ - specific weight of water

γ_s - specific weight of particle mixture

ρ - density of water

ETH experiments were extended to include data with particle mixture. Peter-Meyer et al., after some data fitting, supported with a certain amount of hydraulic backing, fitted all of the data surprisingly well, as can be seen in Figure III-4. This equation was applied to Gilbert's data that was collected for fine particles and moderately steep slopes successfully and has the following ranges for the diameter and specific gravity of the grain mixture:

$.785 < d < 28$ mm

$1.05 < Sg < 4.22$

Chien (78) has shown that this equation can be reduced to the form of a DuBoys-type equation, but he also showed its similarity to the bedload equation developed by Einstein (1950). Chien also has shown that this equation can be written in terms of φ (intensity of bedload transport) and ψ (intensity of shear on particle) and, the results are presented in Figure III-5.

$$\phi = [(4/\psi) - 0.188]^{1.5} \qquad (53)$$

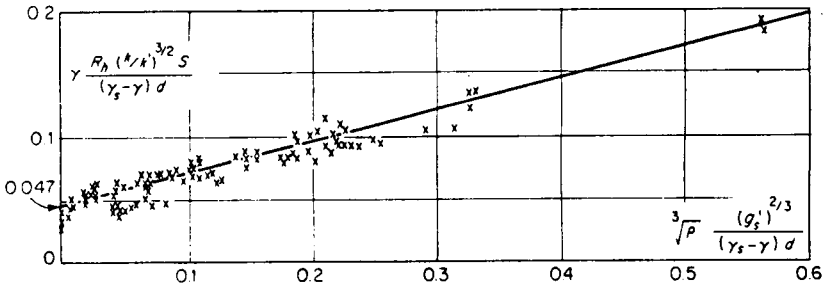


Figure III-4. The E.T.H. bedload equation (79).

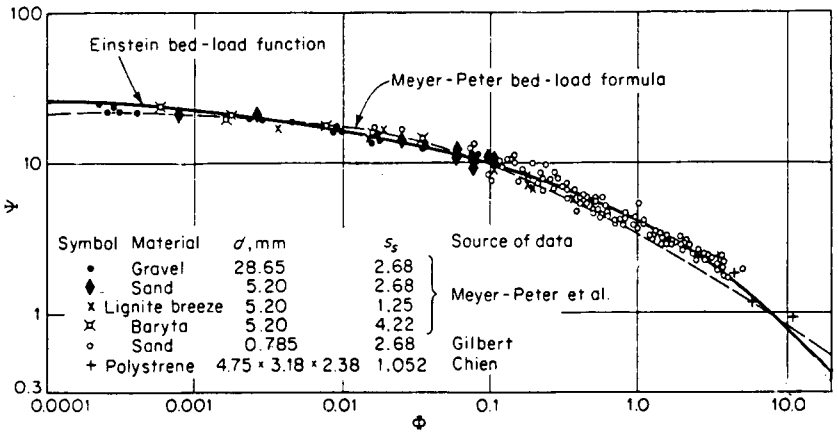


Figure III-5. Comparison of the bedload equations by Einstein and Peter-Meyer (79).

where

$$\psi = (\gamma_s - \gamma)\ d/y\ R_h \tag{54}$$

and

$$\phi = (gs/\gamma_s)\ [(1/S_g - 1)(gd^{3)})]^{0.5} \tag{55}$$

Sg - specific gravity of particle mixture

g - constant of gravity

ψ - intensity of shear on particle

ϕ - intensity of bedload transport

For sediment mixtures, by using d_{35} in the Einstein relation and d_{50} in the Peter-Meyer et al. relation, agreement was found to be equally good. Another advantage of this equation is that a critical value (critical shear) does not have to be calculated for the initiation of erosion. Graf (79) expresses that Peter-Meyer's and Einstein's (76) bedload relations are considered to represent the most complete equations of all, and are dimensionally homogeneous.

According to Smart (65) for breach slopes greater than 3% and less than 20%, this equation underestimates the sediment discharge rate. A modified form of the Peter-Meyer equation (equation 55) is used in this study which is dimensionally homogeneous and is presented in the following.

$$\phi = 4[d_{90}/d_{30})^{0.2}S^{0.6}C^{0.5}(\Theta-\Theta cr)] \quad (56)$$

$$C = V/(gDS)^{0.5} \quad (57)$$

$$V = 1.49\ R_h^{0.66}S^{0.5}/n \quad (58)$$

$$n = .013d^{0.167} \quad \text{where d is in millimeters} \quad (59)$$

where

d - grain size at which 50% of total weight is finer

d_{90} - grain size at which 90% of total weight is finer

D - depth of water (average)

d_{30} - grain size at which 30% of total weight is finer

$$\theta cr = \tau cr/(\gamma s - \gamma)d_{50} \quad (60)$$

$$\tau cr = \tau' cr \cos\varphi\ (1 - \tan\varphi/\tan\theta) \quad (61)$$

where

φ - angle of repose of mixture

θ - internal angle of friction of mixture

$\tau' cr$ - critical shear of mixture

$$= \tau_o/(\gamma_s - \gamma)d_{50} \quad (62)$$

$$\tau_o = \gamma R_h \text{Sin}\varphi \tag{63}$$

$$q_s = g(S_g - 1)(d_{50})^3 \phi \tag{64}$$

The equation above has the following ranges for the diameter, and specific gravity (Sg) of the grain mixture, and channel slope:

$$2\text{mm} < d_{50} < 10.5\text{mm}$$

$$2.67 < Sg \quad 2.68$$

$$3\% < S < 25\%$$

This equation is only applicable to gravelly and sandy soils.

Chen (75), for clayey soils, developed a modified form of the DuBoy's type equation:

$$q_s = a(\tau_o - \tau_c)^K \tag{65}$$

$$q_s = ft^3/sec - ft^2$$

$$\tau_o \text{ and } \tau_c = lb/ft^2$$

where a and K were experimentally determined and the critical shear stress (τ_c) is determined by:

$$\tau_c = 0.0034(PI)^{0.84} \tag{66}$$

where PI is the plasticity index. This relation was developed for silty loam soils with little cohesion to a highly cohesive clayey soils. For

well compacted clayey soils in the following relationship may be used (75):

$$\tau_c = .019(PI)^{0.58} \tag{67}$$

Parameter values for the modified DuBoy's equation are as follows for highly cohesive soil with PI ≥ 10:

$$a = .91 \text{ and } K = 8.6 \times 10^{-5}$$

and for low-cohesive soil with PI ≤ 5:

$$a = .43 \text{ and } K = 2.2 \times 10^{-4}$$

Bottom Width of the Trapezoidal Breach Channel

There is less information on determination of the bottom width of the breach channel than all the parameters discussed previously. Fread (69) states that this parameter can vary according to the following relationship.

$$0.5\ HD \leq B \leq 3\ HD$$

The relationship above was developed based on observation of failed dams and is only applicable to engineered earthen dams. The left side

of the relationship is applied to small dams and the right side to large dams.

Singh and Scarlatos (86) indicate that, within a certain degree of likelihood, the breach will be trapezoidal with T/B = 1.29 and T/D = 3. Dividing the last expression by the first expression the following relationship is obtained.

$$B/D = 2.325$$

This ratio (2.325) seems to be comparable to the ratio that Fread (73) states in BREACH to be equal to 2.0 which is based on optimum channel hydraulic efficiency. These criteria are examined in this study.

Shape and Slope of the Breach Channel

Lou (68) states that the mechanisms involved in breach formation during an earth dam failure are too complicated to be completely and accurately described. Initial flow may occur on the zone of largest settlement in case of overtopping or zones of bad compaction may generate formation of the initial breach. He also points out that highly turbulent flow in conjunction with the complex constitution of the dam lead to the impossibility to forecast exactly the breach shape.

Harris and Wagener (66) in their thesis mention that a trapezoidal shape seems to be the most popular. Newton and Cripe (46) based on Cristonfano's (80) work developed a model that assumed a trapezoidal shape for the breach channel. Other sources that have assumed a

trapezoidal breach shape are TVA (41), Price, Lowe and Garrison (34), U.S. Army Corps of Engineers (36), Balloffet (44), Fread (42, 69, 73).

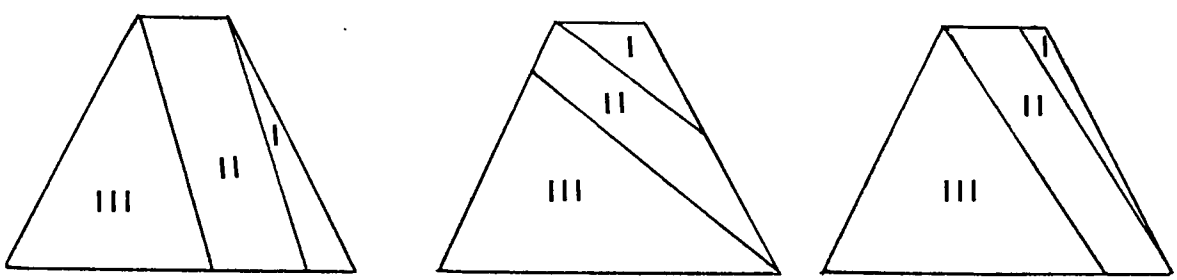
The breach channel slope was assumed by Cristofano (80), Harris and Wagener (66), Newton and Cripe (46), and Lou (1981) to be equal to the developed angle of friction of the fill material. This is the angle between the abscissa and the tangent of the curve representing the relationship of shear resistance to normal stress acting within a soil (53). According to Lou (68) "Newton and Cripe (46, 41) determined the maximum flood level for the Sequoyah Nuclear Plant being constructed by TVA, assuming that a PMP (Probable Maximum Precipitation) occurred above Watts Bar Dam resulting in overtopping and breaching of this dam upstream of the nuclear plant." Basically they followed Cristofano's (80) approach to compute the rate of erosion." In this study, the breach shape was assumed to be trapezoidal, the breach channel slope and the side slope of the trapezoid were set equal to the internal friction angle and the angle of repose of the fill material respectively. The angle of repose is the angle between the horizontal and the maximum slope that a soil assumes through natural processes (53). Other factors that may affect the slope of the breach channel are:

a. Zoning of different soils in the dam
b. The nature of the initial slippage
c. The location of the hydraulic jump at the downstream toe of the dam
d. The depth of tailwater

The Geometric Descriptor

As the water overtops the dam and surpasses the permissible velocity, the protective cover is removed and erosion of the fill material commences and within a given interval of time (computational) a certain amount of soil is eroded away. By using trigonometric relations, the geometric information that leads to the derivation of volumetric equations for Zones I, II, and III is acquired. An algorithm based on Newton-Raphson iteration will be used to compute the eroded volume of the fill material during Δt. For every iteration that is completed, the conservation of mass, the volume of the eroded soil, the length of the breach channel, and the elevations of the upstream end and the downstream end of the breach channel are determined.

The derivation of the geometric descriptor for one of the cases shown below that relates to the simulation data is presented in Appendix C.



Model Verification

Once the model is developed, its validity will be examined by simulating the historical earthen dam failure data (Johnston dam failure data).

Computational Algorithm

A flow chart is provided in Appendix A and variables definitions are exhibited in Appendix B. The major sequence of calculations in the model are described in the following steps.

1. Increment the time: $T_1 = T_o + \Delta t$
2. Use the initial condition (the known variables at time T_o, I_1, Q, AS_1, Δt, H1) in the conservation of mass: Equation (22)
3. Apply the Newton Raphson iteration to solve for the only unknown H_2 in equation (22) using equations (23) through (32)
4. Repeat step 3 until the convergence criterion, equation (33), is satisfied: New H = H_1
5. If Vs > 0 go to step 9
6. If H_1 < HD go to step 1 and continue
7. If H_1 > HD then calculate τ_o using equation (9)
8. If $\tau_o < \tau_c$ go to step 1 and continue
9. If $\tau_o > \tau_c$ go to step (9)
10. Compute the water depth (D) and the hydraulic radius (Rh) of the breach channel using Manning equation and Newton Raphson iteration: equations (46) through (52)
11. If HB = HM go to step 17

12. If d_{50} > .074 mm then use equation (64) to calculate Qs
13. If d_{50} < .074 mm then use equation (65) to calculate Qs
14. Find soil volume: $Vs = \frac{\Delta t\ Qs}{(1 - Pr)}$
15. Choose the proper geometric descriptor routine using the following criterion:

    Condition I: $\varphi > BR$

    Condition II: $\varphi = BR$

    Condition III: $\varphi < BR$

    where BR is the angle which the downstream face of the dam makes with bedrock.
16. After choosing the proper geometric descriptor routine calculate the new breach channel dimensions
17. Record total outflow from the dam, the breach channel dimensions, the volume of the eroded soil, the breach flow and the rate of erosion, and inflow
18. Go to step 1

CHAPTER IV

APPLICATION OF THE MODEL TO JOHNSTOWN DAM FAILURE DATA

Introduction

Laurel Run Dam was located 4-1/2 miles north of Johnstown City, Pennsylvania and was built in 1916. Laurel Run River has a drainage area of 14 square miles and it flows into Conemough River just downstream of Johnstown, Pennsylvania (Figure IV-1). Johnstown is located in southwest Pennsylvania (87).

On July 19-20, 1977, a severe rainstorm caused heavy flooding in areas near Johnstown. The flooding in the valley caused heavy property damage and claimed more than 70 lives. Many homes were severely damaged and some were totally destroyed. The flooding of Johnstown caused by high runoff was compounded by the failure of Laurel Run Reservoir Dam.

Watershed Characteristics

The area of the watershed is 7.56 square miles. The character of the watershed is fairly uniform with thin soil mantle on steep slopes having good vegetal cover. The highest point within the watershed is 2500 ft. and the average slope of the watershed is 11%. The minimum gradient of the stream upstream from the dam is 100 ft/mile (87).

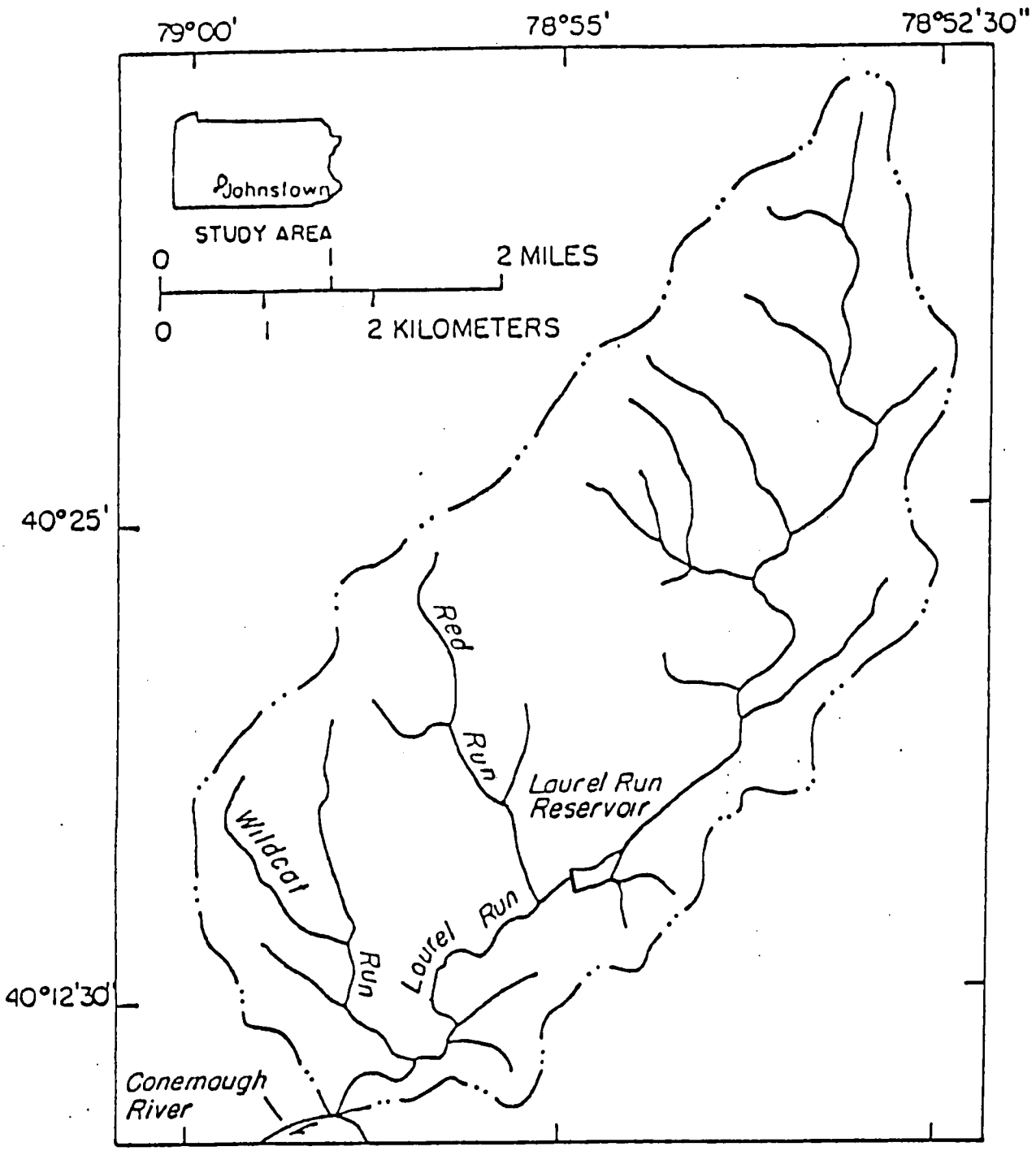


Figure IV-1. Laurel Run Dam location map.

Reservoir Characteristics

The reservoir has an impounding capacity of 360 acre-feet when the pool elevation is at the emergency spillway crest (1430). At zero free board, when the dam crest elevation is 1437 feet, the capacity of the reservoir is 570 acre-feet. The reservoir water surface area is 22.1 acres at normal pool elevation, 1430 feet, and has a pool length of 0.38 miles.

Figure IV-2 shows the area-volume-elevation curves for the Laurel Run Reservoir (87). The spillway was clogged with debris and the dam overtopping discharge varies with the progression of the breach channel, thus a rating curve is not presented.

Dam Characteristics

The principal feature and dimensions of the Laurel Run Dam (90, 91) are as follows:

Dam Geometry

a. Nonhomogeneous earth embankment

b. Trapezoidal cross-section with upstream and downstream slopes, 1V:3H and 1V:2H, respectively.

c. Maximum height above valley floor = 47 ft.

d. Crest length = 625 ft.

e. Crest elevation = 1437 ft. (MSL)

f. Crest width = 20 ft.

g. Normal pool elevation = 1430 ft. (MSL)

Figure IV-3 shows a cross-section of the dam at maximum height.

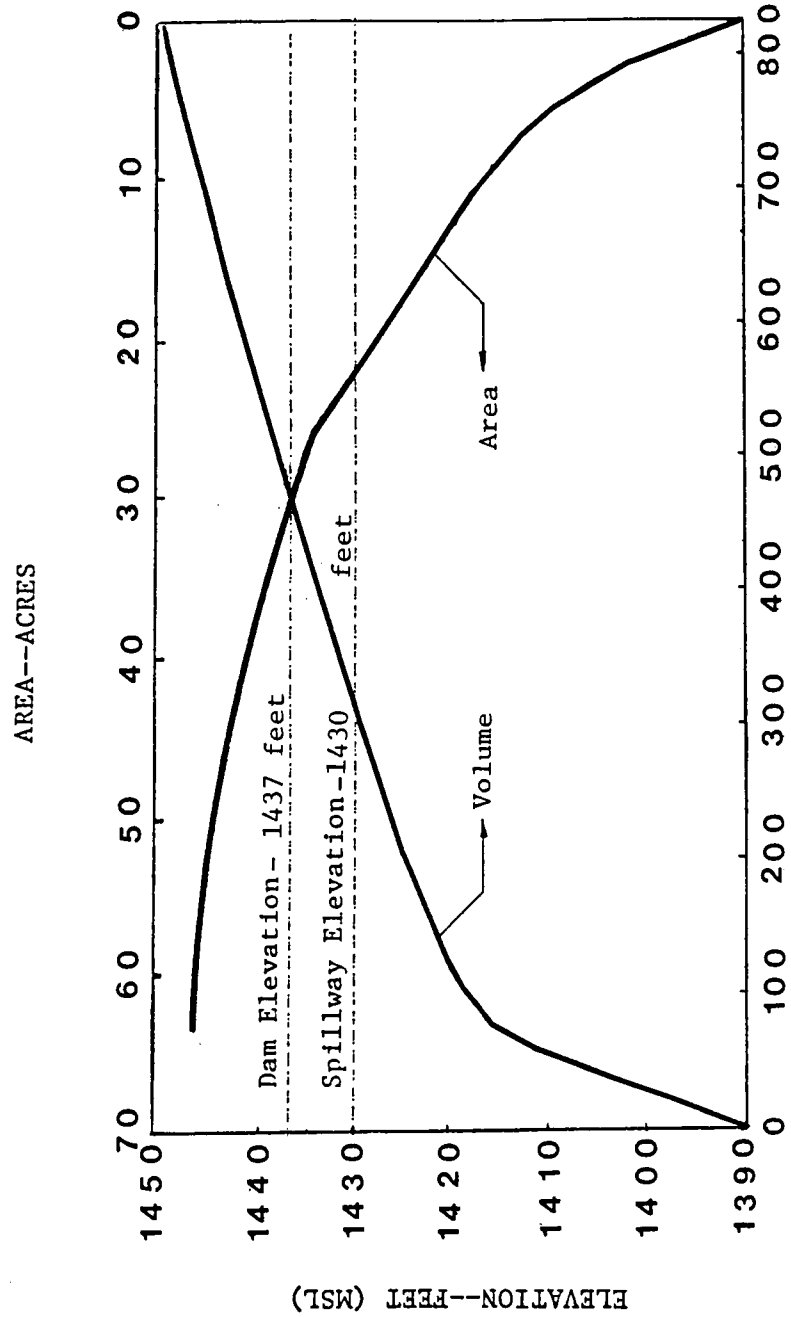


Figure IV-2. Area-volume-elevation curve (87).

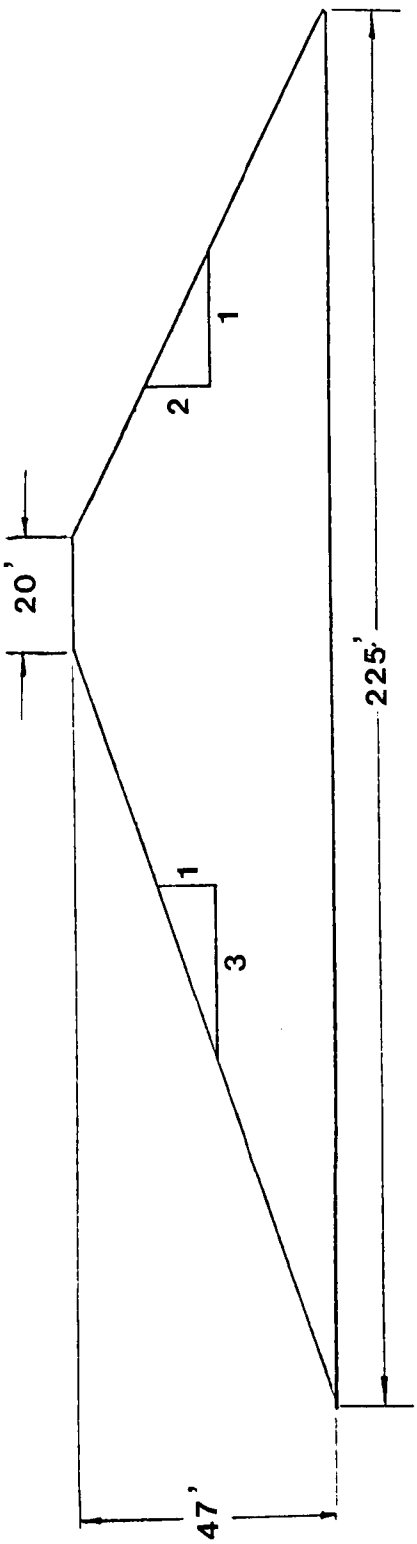


Figure IV-3. Cross-section of Laurel Run Dam at maximum section.

Dam Soil Characteristics

Twenty boring samples were taken, out of which six were located in the vicinity where the dam failure occurred. These borings were obtained from a soils analysis report that was published by Johnstown Water Authority (91).

The mean diameter (d_{50}), specific gravity, and the angle of friction of the soil were obtained from the six boring samples that were mentioned above. The average d_{50} was then used to determine the soil's porosity, angle of repose, and critical shear.

a. Angle of friction = 25 degrees (average of six boring samples)
b. Angle of repose = 24 degrees
c. Porosity = .25
d. Specific weight of water = 62.4 lbs/ft^3
e. Specific weight of sediment = 168.5 lbs/ft^3
f. Critical shear stress of sediment = .32 lbs/ft^2
g. d_{50} = .0163 ft (average of six boring samples)
h. d_{90}/d_{30} = 10

It should be noted that the coefficient of rolling friction (tengent of the angle of repose) of all soils is smaller than the coefficient of sliding friction (tangent of the angle of friction) (100).

Spillway Characteristics

The emergency spillway is trough-type and bathtub-shaped, with the sides acting as a broad crested wier. The length and the width of the spillway are 54 feet and 10 feet respectively. The crest contains

supporting columns for the gate house walkway. The total net spillway length is 86 feet. The spillway crest elevation is 1430 feet (MSL) which is 7 feet below the top of the dam. The discharge overflows into the bottom invert of the spillway structure located 35 feet below the crest of the dam. The overflow then discharges into a 15 feet diameter outlet pipe which passes through the dam and connects to a 15 feet high and 10 feet wide horseshoe-shaped tunnel structure at the downstream toe to Laurel Run River.

It was reported (87) that the spillway was filled with trash. But, the time and extent of cloggage was not known. Thus, four simulation runs were performed using zero, quarter, half, and full spillway capacities. The consequent peak outflow discharge (Qp) values were 26,852 cfs, 30,332 cfs, 32,851 cfs, and 28,917 cfs, respectively. The largest (Qp (32,851 cfs) was the closest to the estimated (87) Qp, the half spillway capacity was chosen for an applied to all the simulation runs in this study.

Reservoir Inflow Hydrograph

A flood hydrograph, describing the inflow of the Laurel Run River to the reservoir, has been obtained from a USGS report on this flood (87). The peak discharge at the upstream edge of the reservoir is 10,500 cfs and the inflow hydrograph to the reservoir is shown in Figure IV-4.

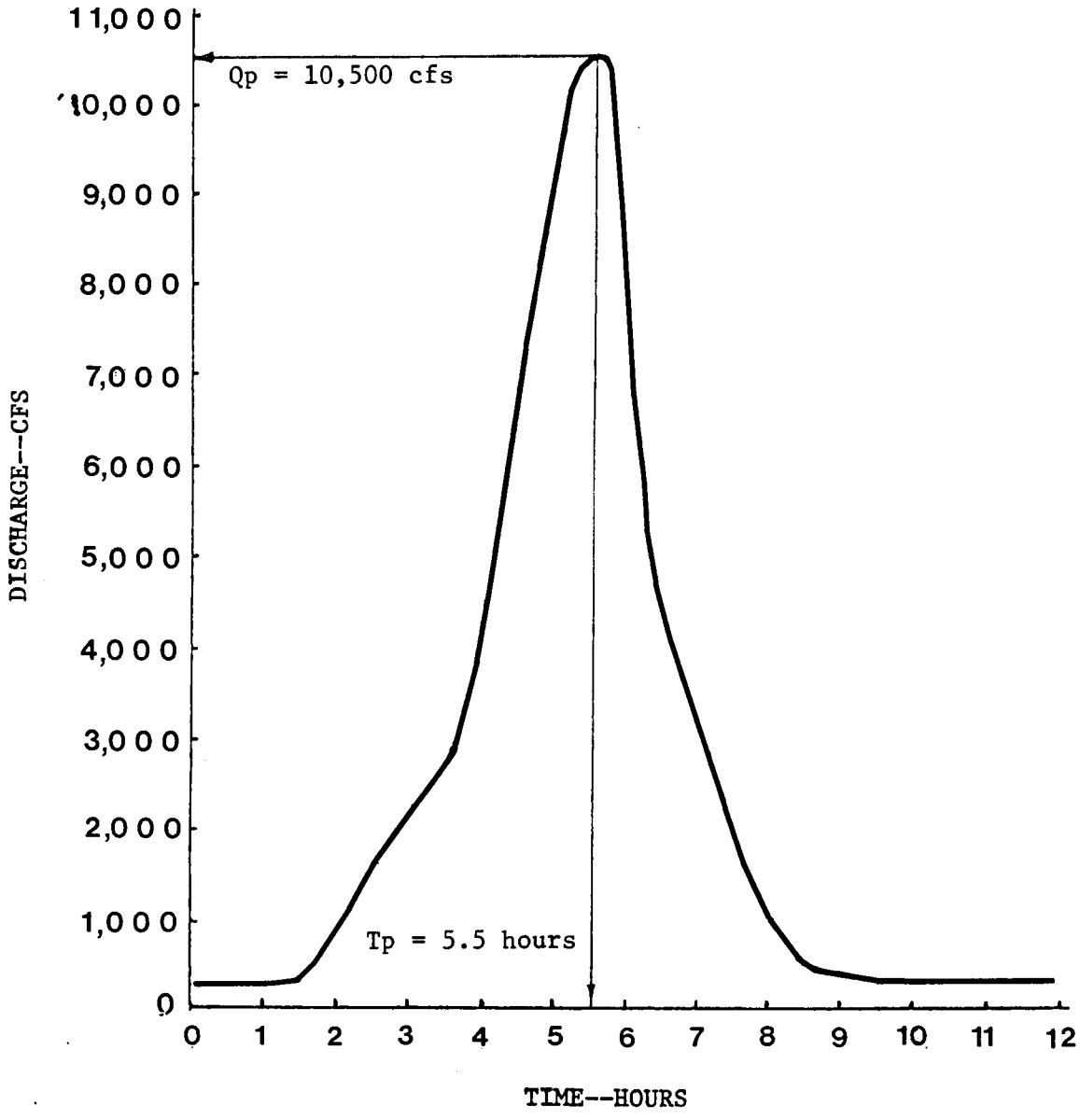


Figure IV-4. Laurel Run reservoir inflow hydrograph (87).

Downstream Channel Condition

A downstream reach extending 2.28 miles below the dam is considered for this study. This reach is represented by four cross-sections. The profile of the downstream valley has a vertical drop equal to 227.4 feet.

A USGS report (87) on the Johnstown flood used a range of Manning's n values from 0.04 to 0.06 depending on the downstream location. Manning's n values that ranged from 0.04 to 0.06 were used in the 2.28 mile downstream reach.

The Model Features and Limitations

The model features, limitations and related assumptions are summarized as follows:

1. Reservoir (hydrologic) routing to Produce Outflow Hydrograph.
   a. Storage type, assume level pool condition.
2. Breach Characteristics
   a. Breach channel slope based on angle of friction.
   b. Breach channel side slope based on angle of repose.
   c. Breach channel bottom width (B) based on the criteria presented in Chapter III, ($1/2HD \leq B \leq 3HD$) and ($B = 2D$).
   d. Erosion-formed breach opening based on hydraulics of sediment transport, conservation of mass, and trigonometric-geometric-descriptor.
   e. Triangular, rectangular, or trapezoidal shape.

3. Outflow From Reservoir

   a. Reservoir inflow hydrograph.

   b. Reservoir elevation-storage characteristics.

   c. Spillway flow rating and constant base outlet flow (broad-crested wier flow).

   d. Crest overflow rating (broad-crested wier flow).

   e. Breach outflow rating (broad-crested wier flow).

4. Model Limitations

   a. Breach outflow is not corrected for submergence.

   b. Due to geometric discontinuity, an average d_{50} must be used for nonhomogeneous dams.

   c. Does not include downstream routing.

   d. Does not account for erosion, due to sloughing of the breach channel sides, after the bedrock is encountered.

   e. The model is applicable to homogeneous earthen dams only.

5. Convergence Criteria

   a. In order to evaluate the convergence tolerance of the model's hydrologic (storage) routing subroutine four values (.1, .01, .001, .0001) were examined under nonfailure condition. The first three values resulted in comparable peak outflow (Qp) values, but the fourth value resulted in nonconvergence (NC). The results are summarized below.

Convergence Tolerance for H (feet)	Qp (cfs)
0.1	10,220
0.01	10,288
0.001	10,316
0.0001	NC

Although the variation in Qp for 0.01 and 0.001 convergence tolerance values was only 0.27%, it seemed appropriate to validate the performance and accuracy of the model with a widely accepted hydrologic model.

To validate the reservoir routing capability of the model, the input data were applied to the model and the Army Corps of Engineers (ACOE) HEC-1 under nonfailure condition. The results of ACOE HEC-1 compared very well with the model run that used the convergence tolerance value of .001 feet. These comparative runs are shown in Appendix D and their results are summarized below.

	Maximum Reservoir W. S. Elev. Feet	Maximum Depth Over Dam Feet	Maximum Outflow cfs	Duration Over Top Hours	Time of Max Outflow Hours
HEC-1	1438.53	1.53	10319	2.17	5.50
Model	1438.53	1.53	10316	2.10	5.53

Thus the 0.001 convergence tolerance was selected for further application in this study.

b. Convergence tolerance values of .1, .01, and .001 feet were applied to the geometric descriptor subroutines. The variation in the volume of eroded soil was examined for each tolerance value. The results of these runs are summarized below.

Convergence Tolerance for DC (feet)	Volume of Eroded Soil-V (Ft^3)
.1	1,528,164
.01	1,527,575
.001	1,527,574

(For variable definition see Appendix B)

Since there was no significant variation in V between the last two runs, .01 was selected and utilized in all the runs performed in this study.

The required input parameters' definition and their corresponding numerical values and the simulation run output are presented in Appendix A. A listing of the internal variables and their definition are presented in Appendix B. The derivation of the volumetric-geometric-descriptor (for the breach channel) is presented in Appendix C.

Results of Analysis

Simulated water inflow-outflow discharges and sediment discharge, depicted from the reservoir depletion table in Appendix A, are shown in Figure IV-5. From this figure, it can be seen that sediment and water discharge peaks occurred almost simultaneously. Scarlatos and Singh (64) observed the same phenomenon with Teton's dam failure simulation. There were two outflow hydrograph peaks to use for verification of the model. The first was the estimated peak outflow (86, 89) that was equal to 37,000 cfs. This peak outflow was measured one mile downstream from the Laurel Run dam (101). Therefore, this value does not depict the peak outflow from the dam failure since Red Run tributary is located between the point of measurement and the dam (Figure III-1). The peak flow of Red Run tributary hydrograph was 4,000 cfs (89). Based on the time that the passage of the peak outflow from the dam failure occurred at the Red Run tributary, the Red Run inflow was estimated to be approximately 3,000 cfs. Thus, the estimated peak outflow from the

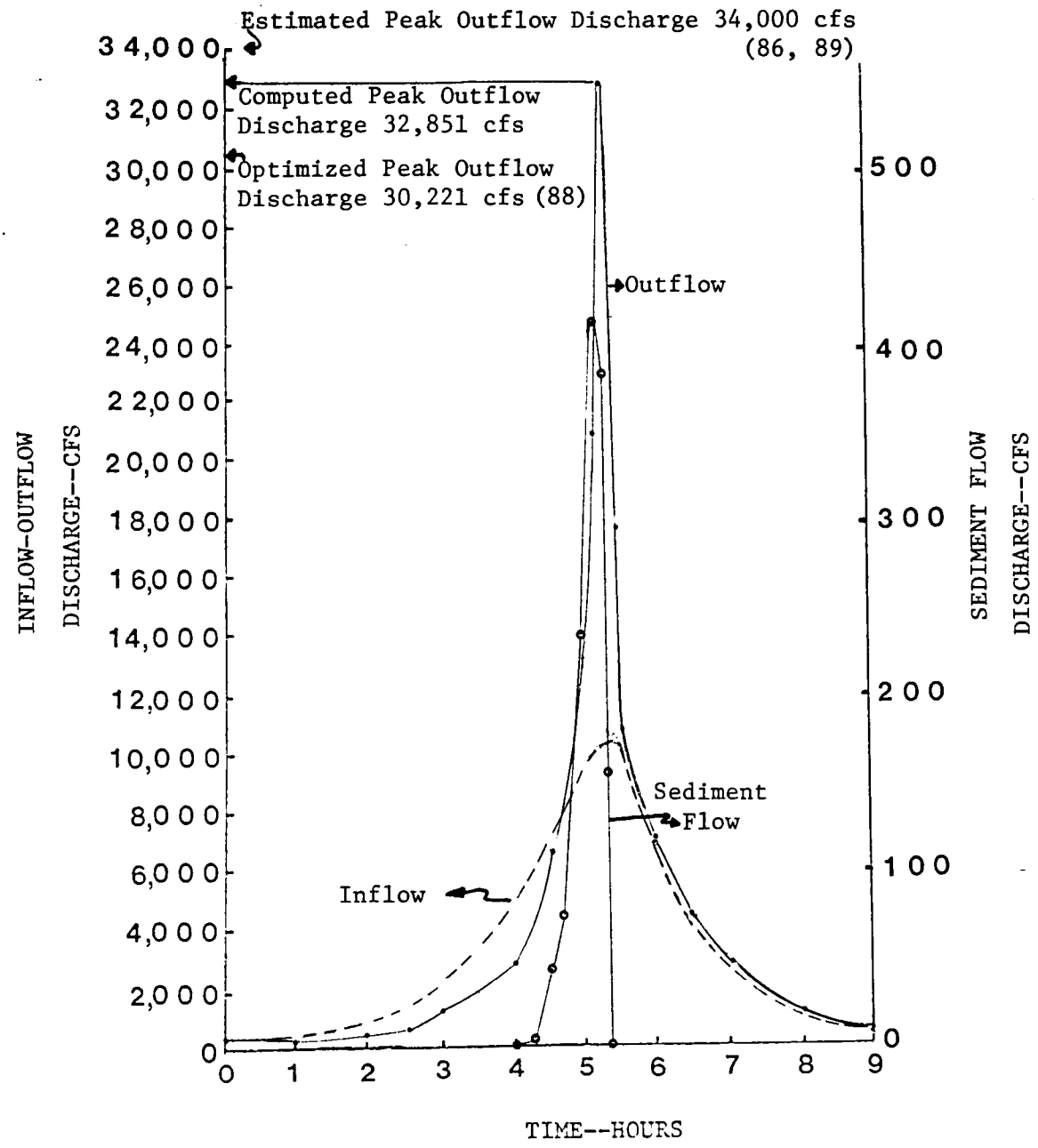


Figure IV-5. Inflow-computed outflow discharge hydrographs and computed sediment flow discharge hydrograph.

dam should be 34,000 cfs. The second was the optimized peak outflow (88) that was equal to 30,221 cfs. The model simulated a peak outflow equal to 32,851 cfs (see Appendix A). This peak outflow was routed for 2.2 miles downstream from the dam. This reach was described with four cross sections. Routing of the outflow hydrograph was performed by the NWS DAMBRK model (69). The simulated peak outflow discharge (32,851 cfs) is 3.38% lower than the estimated (86, 89) peak outflow discharge and 8% higher than the optimized peak outflow discharge (88). The results of routing the model's peak outflow discharge thru the 2.28 mile reach are compared with observed high water marks (87) in Table IV-1.

The duration of vertical erosion was 0.95 hours (hydrologic time: from hour 4.35 to hour 5.30). The total duration of failure was 1.24 hours. The estimated duration of failure (vertical erosion) was one hour (87).

Computational time increment (Dt) requirement until erosion commenced was based on the hydrologic (storage) routing criterion. Thus, Dt was set equal to half the time it takes for the incremental reservoir inflow to traverse the length of the reservoir. A sensitivity analysis was performed on Dt during vertical erosion. It was realized that as Dt was decreased the outflow hydrograph peak discharge (Qp) also decreased. This process was repeated until Qp stayed constant. From all the runs made as is shown in Figure IV-6, it became evident that .001 hr was the proper Dt and lower Dt values resulted in comparable Qp values. The actual breach channel bottom width (B = 17 feet) was used in producing the curve in Figure IV-6.

TABLE IV-1

OBSERVED MAXIMUM STAGES (87) AND PREDICTED MAXIMUM STAGES (BY MOJIB)
OF LAUREL RUN DAM VALLEY CROSS SECTIONS

Distance from Dam (miles)	Predicted Peak Flow (cfs)	Channel Invert feet (MSL)	Observed Max. Stage feet (MSL)	Predicted Max. Stage feet (MSL)	% Difference Between Predicted and Observed Depths
0.21	32,444	1376.2	1390.38	1390.05	2.33
0.83	35,299	1315.4	1332.45	1332.17	1.64
1.73	33,412	1224.0	1238.00	1237.70	2.14
2.28	33,415	1162.6	1179.00	1178.64	2.20

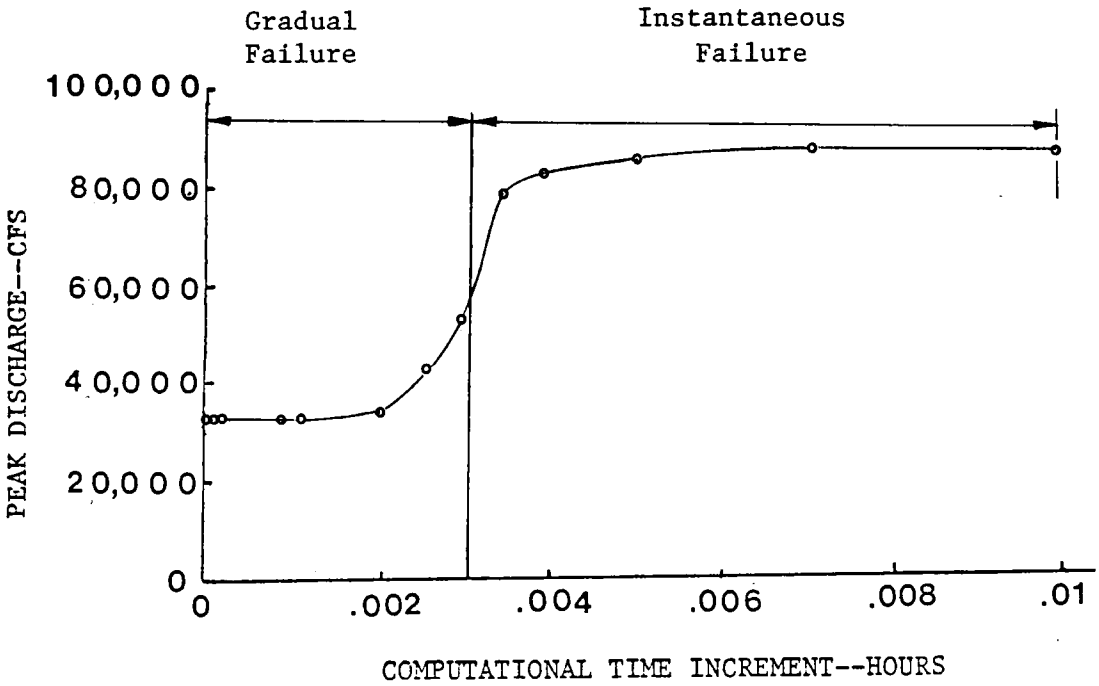


Figure IV-6. Peak outflow-computational time increment sensitivity curve.

All the input parameter values had a very small range that could not change the outflow hydrograph significantly. But as mentioned earlier the breach bottom width seemed to be the parameter with the highest degree of variability.

Several runs were made using breach channel bottom widths within the range presented earlier. The results are graphically presented in Figure IV-7. The actual breach width was estimated to be 17 feet (90). The simulation results based on breach bottom widths equal to 2D, HD/2, and 17 feet (observed) are summarized in Table IV-2.

With regard to great variations in Qp, caused by varying Dt and B values, the following criteria were examined. Based on the hydrologic storage routing computational time (Dt) incrementation criterion, a criterion for Dt incrementation during erosion was incorporated into the model. This Dt criterion was based on half the time it took a soil particle to traverse the length of the breach channel. Furthermore, the breach channel bottom width (B) was set at twice the depth of flow in the breach channel (73, 86). The simulation results under the above criteria are summarized below.

$Qp = 30,595$ cfs

$Dt_{minimum} = 0.000002$ hours

This simulation took 14 hours to complete on an IBM AT.

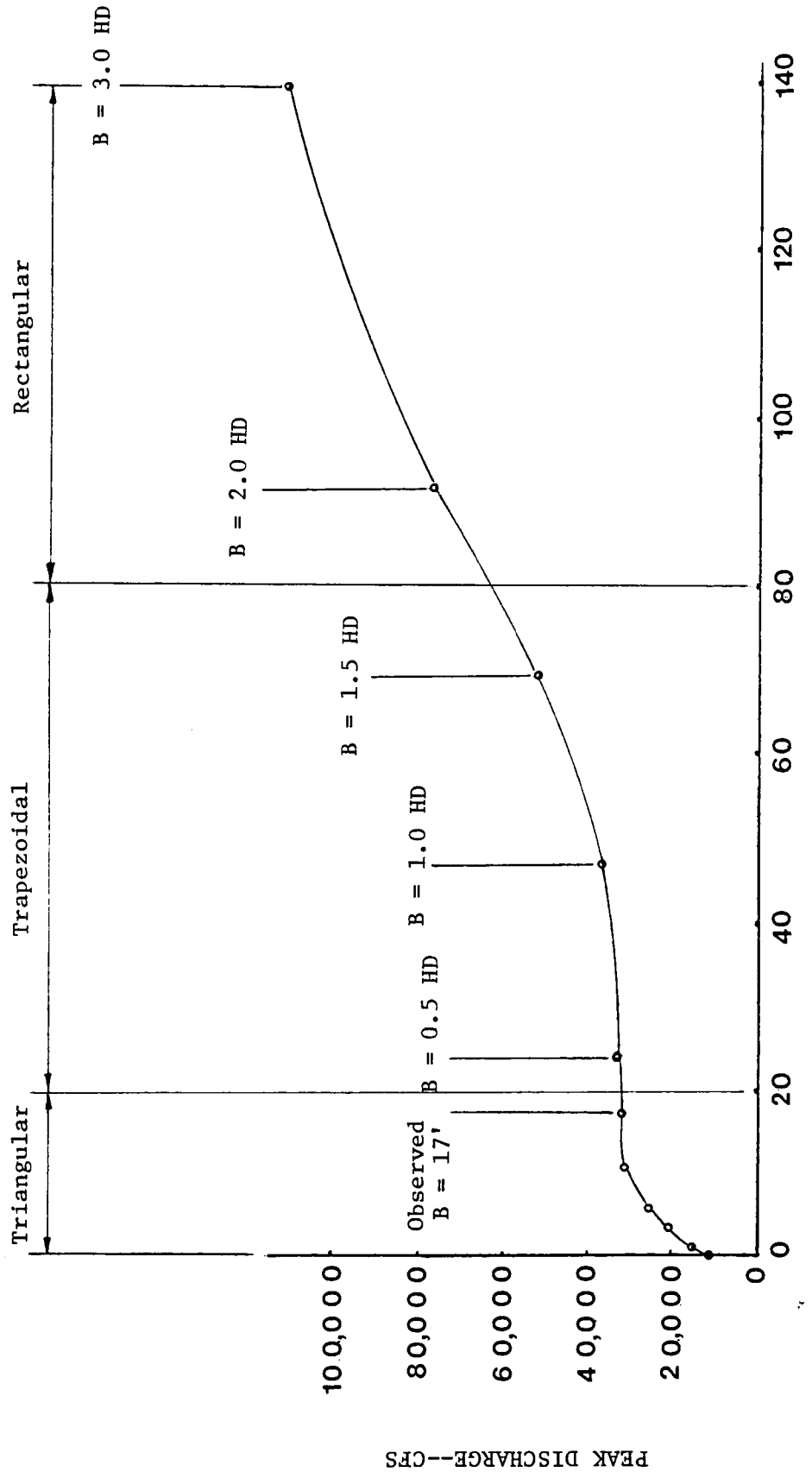


Figure IV-7. Peak outflow-breach channel bottom width sensitivity curve.

TABLE IV-2

BREACH BOTTOM WIDTH CRITERIA SIMULATION RESULTS

Breach Bottom Width - B	B = HD/2	B = 2D	B = 17'
Qp (cfs)	33,183	34,950	32,851

CHAPTER V

DISCUSSION OF RESULTS, CONCLUSION, AND RECOMMENDATIONS

The simulated outflow peak (Qp = 32,851 cfs) shown in Figure IV-6 compares favorably with the optimized Qp that was proposed by Ganta (88) and with the estimated Qp that was proposed by the U.S. Geological Survey (87). The simulated maximum stage and the observed maximum stage (87) are very close. Comparison of the observed and simulated stages (Table IV-1) shows that the model produces a stage that deviates by no more than 2.26% from the observed stage.

The water outflow and sediment discharge hydrographs (Figure IV-5) possess the same general shape. This indicates that sediment discharge and water discharge promote one another. In other words, an increase in water discharge causes an increase in sediment discharge and a higher sediment discharge enlarges the breach size which in turn increases the water discharge. This effect is intensified for larger reservoirs. Both water and sediment discharge peaks occur almost at the same time. This is consistent with Singh's and Scarlatos' observation about Teton's dam failure simulation (64).

The simulation of vertical erosion lasted 0.95 hours, but according to Johnstown Water Authority (91) the vertical erosion lasted about one hour. Thus, the duration of failure (vertical erosion) simulated by the model is only 5% lower than the observed duration (91). This is indicative that the simulation of the erosion process has been successful.

The average side slope used in the simulation was equal to 2.24 horizontal to 1 vertical and the average observed side slope was equal to 1.86 horizontal to 1 vertical. Thus, it appears that setting the side slopes of the breach channel equal to the angle of repose of the mean grain diameter is a fair assumption.

Smart's equation (65) was used in the simulation. The maximum channel slope for Smart's equation was 20 percent, but the breach channel slope that was used in the simulation was equal to 46.6 percent. It appears that Smart's equation performed very well, but further analysis for channel slopes greater than 20 percent is required and simulation of other dam failures can help to determine its applicability. It must be realized that this is the only equation found in the literature for application to erodible channels having slopes greater than 2 percent.

In Figure IV-6, peak flow seems to behave asymptotically as minimum and maximum values of Dt are experienced. This curve has an inflection point where Qp is equal to 51,414 cfs. This curve also experiences the steepest gradient around its inflection point. Figure IV-6 shows that a Dt range of 0.00001 hrs to 0.001 hrs produced similar results, but the disadvantage of these small time incrementations is that the smaller the Dt the longer it takes to complete the simulation. For example, the simulation run shown in Appendix A took approximately 0.5 hours using an IBM AT personal computer. The curve in Figure IV-6 consists of two distinct regions which are separated by an inflection point. This point is approximately located where the computational time increment (Dt) is equal to 0.003 hours. As Dt value becomes larger than 0.003 hours the

dam failure is approaching instantaneous failure. As Dt value is approaching zero from the inflection point the dam failure is approaching gradual failure.

In Figure IV-7 there are three distinct zones which are separated by two inflection points. The first inflection point occurs where the bottom width of the trapezoidal breach channel is 80 feet. This indicates that the geometric property of the channel is changing from rectangular to trapezoidal. In other words, the wider the bottom width of a trapezoid the more it geometrically behaves like a rectangle. The second inflection point occurs where the bottom width of the breach channel is 20 feet. In this reach which lies between 20' and 80' the channel cross section is behaving like a trapezoid. As the breach channel width decreases from 20' to 0' the trapezoidal channel is approaching a triangular shape.

The observed breach bottom width (87) was used to examine the model's predictive capability. The simulated peak outflow discharge was 3.38% lower and 8.7% higher than the estimated (87) and optimized (88) peak discharge values, respectively. The simulated duration of vertical erosion was only 5% lower than the observed duration of failure (87). From Table IV-1, it is evident that the maximum variation between the observed high water marks and the simulated stage did not vary by more than 2.26%. Since the results of the simulation run, based on the actual breach bottom width, were satisfactory the breach channel width criteria that were proposed in Chapter III were incorporated into the model and simulation runs were performed. From Table IV-2, it is

evident that the breach channel width criteria (B = 2D and B = HD/2) produced peak outflow discharge (Qp) values comparable to the peak outflow discharge value that was based on the observed breach channel width. The B = HD/2 criterion simulation resulted in a Qp value which was 2.4% lower than the USGS's (87) Qp and 9.8% higher than the optimized (88) Qp. The application of the B = 2D criterion resulted in a Qp value that was 2.79% higher than the USGS's (87) Qp and 15.6% higher than the optimized (88) Qp. These simulation results appear to be closer to the estimated Qp (87) than the optimized (88) Qp.

The application of the criterion presented by Fread (73) and Brown and Rogers (86), which states that the width of the breach channel is equal to twice the depth of flow based on optimum hydraulic efficiency, in combination with the Dt criterion presented at the end of Chapter IV resulted in a Qp equal to 30,595 cfs. This flow is 1.24% higher than the optimized value reported by Ganta (88), and 11.3% lower than the estimated Qp reported by USGS (87).

As a whole the model within its limitations appeared to have performed exceptionally well and the results seem to vary between the results of Ganta (88) and USGS (87).

Recommendations for further study include:

a. Further investigation or experimentation of sediment erosion under high shear stresses.

b. Modification or validation of Smart's sediment transport equation for slopes greater than 20 percent.

c. Investigation of suspended load, its significance, and separation from bedload, under high shear stresses.

d. Development of a general computational time incrementation criterion.

e. A scientific investigation about the ratio of the width of the breach channel to the depth of flow.

f. Consideration of dynamic interaction between water and soil (sediment).

g. Application of this model to other dam failures to further validate its performance and applicability to earthen dams.

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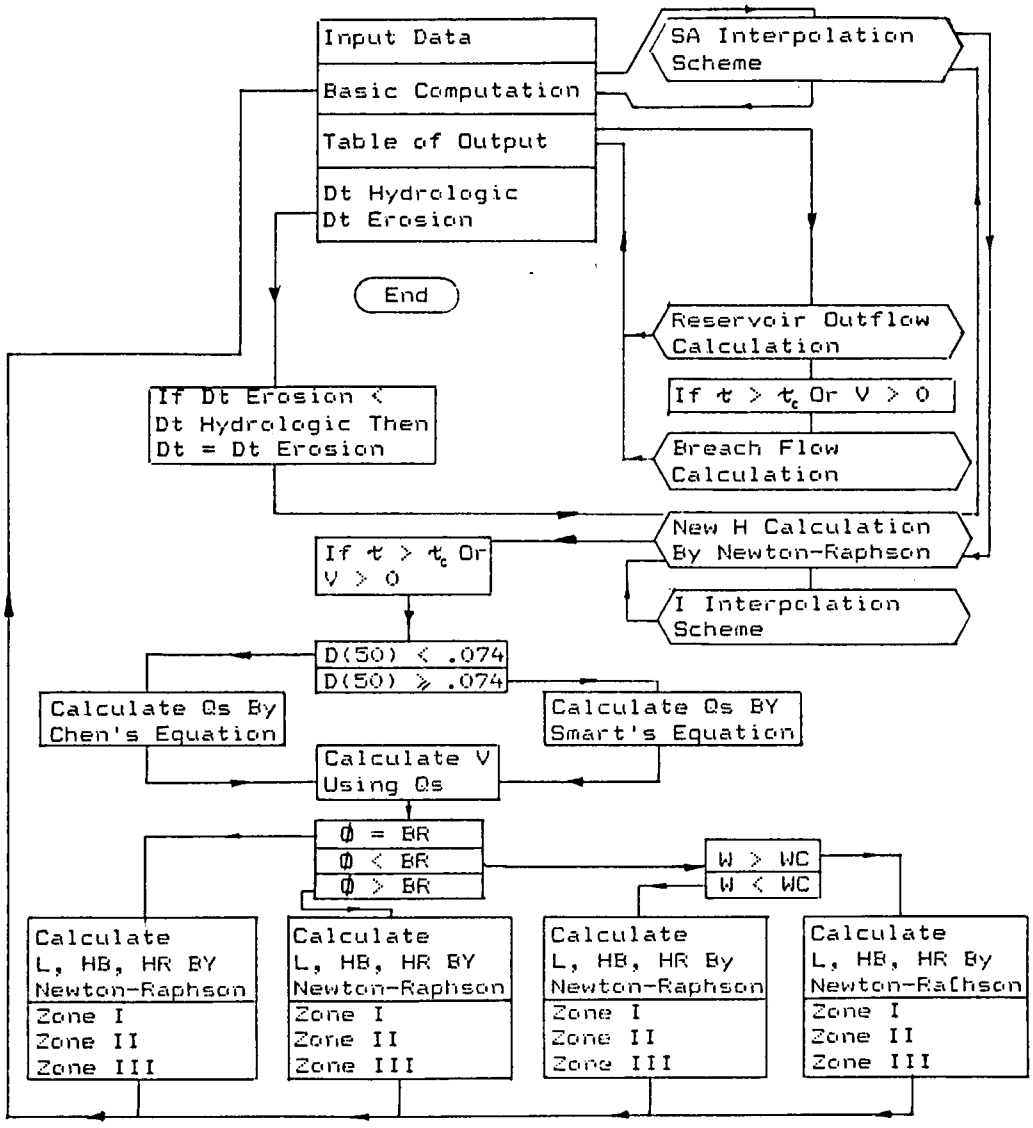
APPENDICES

APPENDIX A

APPENDIX A

THE PROGRAM FLOW CHART

(For definition of variables see Appendix B)



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|                                                    |
|     DAM BREAK PROGRAM - MODEL #1                   |
|     BY: REZA M. MOJIB - OCTOBER 89                 |
|                                                    |
------------------------------------------------------
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ANALYSIS OF 1977 JOHNSTOWN DAM FAILURE

RUN BY REZA M. MOJIB

ELEVATION (FT)	SURFACE AREA (ACRES)
1445	63.8
1435	25.5
1430	22.1
1425	18.5
1415	9.3
1410	6.2
1390	0
0	0

INITIAL WATER SURFACE ELEVATION (YO) =..... 1430 FT
SPILLWAY ELEVATION (HS) =..... 1430 FEET MSL
SPILLWAY COEFFICIENT OF DISCHARGE (CS) = ... 133.3
GATE ELEVATION (HG) = ... 0 FEET MSL
GATE COEFFICIENT OF DISHARGE (CG) = ... 0
DAM ELEVATION (HD) = ... 1437 FEET MSL

THE INVERSE OF THE BREACH CHANNEL SIDE SLOPE (Z) =. 2.46
MINIMUM ELEVATION OF THE DAM (HM) = ... 1390 FEET MSL
THE BREACH CHANNEL BOTTOM WIDTH (B) = ... 17 FEET
BASE FLOW OF HTE DAM (QK) = ... 300 CFS

SOIL ANGLE OF FRICTION (SI1) = ... 25 DEGREES
SOIL ANGLE OF REPOSE (TH1) = ... 24 DEGREES
POROSITY OF THE SOIL (PR) = ... .25
SPECIFIC WEIGHT OF THE SOIL (GS) = ... 168.5 LBS/FT^3
SPECIFIC WEIGHT OF WATER (GA) = ... 62.4 LBS/FT^3
PLASTICITY INDEX OF THE SOIL (PI) = ... 23
CRITICAL SHEAR STERSS OF THE SOIL (TOC) = ... .32 LBS/FT^2

GRAIN SIZE AT WHICH 30% OF TOTAL WEIGHT IS FINER (D3) = ... .0033 FEET
GRAIN SIZE AT WHICH 50% OF TOTAL WEIGHT IS FINER (D5) = ... .0163 FEET
GRAIN SIZE AT WHICH 90% OF TOTAL WEIGHT IS FINER (D9) = ... .033 FEET

TOP WIDTH OF THE DAM (W) = ... 20 FEET
LENGTH OF THE CREST OF THE DAM (CL) = ... 625 FEET
THE INVERSE OF THE SLOPE OF THE UPSTREAM FACE OF DAM (ZU) = ... 3
THE INVERSE OF THE SLOPE OF THE DOWNSTREAM FACE OF DAM (ZR) = .. 2
THE ANGLE WHICH DOWNSTREAM FACE OF DAM MAKES WITH HORIZON (BR1)= 26.56 DEGREES
THE ANGLE WHICH UPSTREAM FACE OF DAM MAKES WITH HORIZON (BL1) =. 18.26 DEGREES
THE SLOPE OF THE BREACH CHANNEL (S) =..... .466

INFLOW HYDROGRAPH

TIME (HRS)	INFLOW (CFS)
0	300
.5	300
1	300
1.5	410
2	900
2.5	1600
3	2250
3.5	2750
4	4500
4.5	6800
5	9600
5.5	10500
6	6900
6.5	4200
7	2550
7.5	1600
8	1050
8.5	530
9	310

TABLE OF POOL DEPLETION AND DAM FAILURE

LISTING OF THE OF THE PARAMETERS' ABREVIATIONS

ELEV. = ELEVATION
BR = BREACH
UP = UPSTREAM
DS = DOWNSTREAM

TIME	POOL ELEV.	UP BR ELEV.	DS BR ELEV.	BREACH LENGTH	SOIL VOLUME	IN-FLOW	BREACH FLOW	BED-LOAD	TOTAL OUTFLOW
HOUR	FEET	FEET	FEET	FEET	FEET^3	CFS	CFS	CFS	CFS
0.00	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.25	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.32	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.39	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.46	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.53	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.60	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.67	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.74	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.81	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.88	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
0.95	1430.00	1437.0	1437.0	0	0	300	0	0.00	300
1.02	1430.00	1437.0	1437.0	0	0	305	0	0.00	300
1.09	1430.00	1437.0	1437.0	0	0	320	0	0.00	300
1.16	1430.01	1437.0	1437.0	0	0	335	0	0.00	300
1.23	1430.02	1437.0	1437.0	0	0	350	0	0.00	300
1.29	1430.04	1437.0	1437.0	0	0	364	0	0.00	300
1.36	1430.05	1437.0	1437.0	0	0	378	0	0.00	301
1.42	1430.07	1437.0	1437.0	0	0	392	0	0.00	302
1.48	1430.09	1437.0	1437.0	0	0	405	0	0.00	303
1.54	1430.12	1437.0	1437.0	0	0	450	0	0.00	305
1.60	1430.16	1437.0	1437.0	0	0	507	0	0.00	308
1.65	1430.20	1437.0	1437.0	0	0	560	0	0.00	312
1.71	1430.25	1437.0	1437.0	0	0	611	0	0.00	317
1.76	1430.31	1437.0	1437.0	0	0	660	0	0.00	323
1.80	1430.37	1437.0	1437.0	0	0	706	0	0.00	330
1.85	1430.44	1437.0	1437.0	0	0	752	0	0.00	339
1.89	1430.51	1437.0	1437.0	0	0	796	0	0.00	348
1.94	1430.59	1437.0	1437.0	0	0	839	0	0.00	359
1.98	1430.66	1437.0	1437.0	0	0	881	0	0.00	371
2.02	1430.74	1437.0	1437.0	0	0	931	0	0.00	385
2.06	1430.83	1437.0	1437.0	0	0	989	0	0.00	400
2.10	1430.91	1437.0	1437.0	0	0	1044	0	0.00	416
2.14	1431.00	1437.0	1437.0	0	0	1098	0	0.00	434
2.18	1431.10	1437.0	1437.0	0	0	1151	0	0.00	453
2.22	1431.19	1437.0	1437.0	0	0	1203	0	0.00	473
2.25	1431.29	1437.0	1437.0	0	0	1254	0	0.00	495
2.29	1431.39	1437.0	1437.0	0	0	1304	0	0.00	517
2.32	1431.49	1437.0	1437.0	0	0	1354	0	0.00	541
2.36	1431.59	1437.0	1437.0	0	0	1402	0	0.00	566
2.39	1431.69	1437.0	1437.0	0	0	1450	0	0.00	592
2.43	1431.79	1437.0	1437.0	0	0	1497	0	0.00	620
2.46	1431.90	1437.0	1437.0	0	0	1543	0	0.00	648
2.49	1432.00	1437.0	1437.0	0	0	1589	0	0.00	677
2.59	1432.32	1437.0	1437.0	0	0	1720	0	0.00	772
2.64	1432.49	1437.0	1437.0	0	0	1785	0	0.00	823
2.69	1432.65	1437.0	1437.0	0	0	1849	0	0.00	875
2.74	1432.81	1437.0	1437.0	0	0	1912	0	0.00	929
2.79	1432.97	1437.0	1437.0	0	0	1974	0	0.00	983
2.84	1433.13	1437.0	1437.0	0	0	2035	0	0.00	1039
2.88	1433.29	1437.0	1437.0	0	0	2096	0	0.00	1095
2.93	1433.45	1437.0	1437.0	0	0	2156	0	0.00	1153
2.97	1433.60	1437.0	1437.0	0	0	2216	0	0.00	1211
3.02	1433.75	1437.0	1437.0	0	0	2269	0	0.00	1269

3.06	1433.90	1437.0	1437.0	0	0	2314	0	0.00	1327
3.11	1434.05	1437.0	1437.0	0	0	2359	0	0.00	1385
3.15	1434.19	1437.0	1437.0	0	0	2404	0	0.00	1442
3.20	1434.33	1437.0	1437.0	0	0	2448	0	0.00	1500
3.24	1434.46	1437.0	1437.0	0	0	2492	0	0.00	1557
3.29	1434.60	1437.0	1437.0	0	0	2536	0	0.00	1613
3.33	1434.73	1437.0	1437.0	0	0	2580	0	0.00	1669
3.37	1434.85	1437.0	1437.0	0	0	2623	0	0.00	1725
3.42	1434.98	1437.0	1437.0	0	0	2666	0	0.00	1780
3.46	1435.10	1437.0	1437.0	0	0	2709	0	0.00	1834
3.51	1435.24	1437.0	1437.0	0	0	2784	0	0.00	1897
3.56	1435.38	1437.0	1437.0	0	0	2959	0	0.00	1963
3.61	1435.54	1437.0	1437.0	0	0	3134	0	0.00	2037
3.66	1435.71	1437.0	1437.0	0	0	3309	0	0.00	2117
3.71	1435.88	1437.0	1437.0	0	0	3484	0	0.00	2202
3.76	1436.07	1437.0	1437.0	0	0	3659	0	0.00	2293
3.81	1436.26	1437.0	1437.0	0	0	3834	0	0.00	2388
3.86	1436.46	1437.0	1437.0	0	0	4009	0	0.00	2488
3.91	1436.66	1437.0	1437.0	0	0	4184	0	0.00	2592
3.96	1436.87	1437.0	1437.0	0	0	4359	0	0.00	2699
4.01	1437.08	1437.0	1425.1	28	182	4544	1	0.76	2850
4.02	1437.12	1437.0	1422.4	34	276	4590	2	1.20	2910
4.03	1437.16	1437.0	1419.3	41	411	4636	4	1.62	2975
4.04	1437.20	1437.0	1416.0	49	586	4682	5	2.03	3046
4.05	1437.24	1437.0	1412.6	57	800	4728	7	2.44	3119
4.06	1437.28	1437.0	1409.2	65	1054	4774	9	2.84	3196
4.07	1437.31	1437.0	1405.8	73	1344	4820	11	3.22	3274
4.08	1437.35	1437.0	1402.4	81	1672	4866	13	3.60	3354
4.09	1437.39	1437.0	1399.1	89	2035	4912	16	3.97	3435
4.10	1437.42	1437.0	1395.8	97	2434	4958	18	4.33	3516
4.11	1437.45	1437.0	1392.5	105	2867	5004	20	4.68	3598
4.12	1437.49	1437.0	1390.0	111	3332	5050	22	5.02	3679
4.13	1437.52	1437.0	1390.0	111	3830	5096	25	5.35	3760
4.14	1437.55	1437.0	1390.0	111	4360	5142	27	5.68	3840
4.15	1437.58	1437.0	1390.0	111	4919	5188	29	5.99	3920
4.16	1437.61	1437.0	1390.0	111	5509	5234	32	6.29	3999
4.17	1437.63	1437.0	1390.0	111	6127	5280	34	6.59	4077
4.18	1437.66	1437.0	1390.0	111	6773	5326	36	6.87	4154
4.19	1437.69	1437.0	1390.0	111	7446	5372	39	7.16	4229
4.20	1437.71	1437.0	1390.0	111	8146	5418	41	7.43	4304
4.21	1437.74	1437.0	1390.0	111	8872	5464	43	7.69	4377
4.22	1437.76	1437.0	1390.0	111	9622	5510	46	7.95	4450
4.23	1437.79	1437.0	1390.0	111	10397	5556	48	8.20	4521
4.24	1437.81	1437.0	1390.0	111	11196	5602	50	8.44	4591
4.25	1437.83	1437.0	1390.0	111	12018	5648	52	8.68	4660
4.26	1437.85	1437.0	1390.0	111	12862	5694	54	8.92	4727
4.27	1437.88	1437.0	1390.0	111	13729	5740	57	9.14	4794
4.28	1437.90	1437.0	1390.0	111	14617	5786	59	9.37	4860
4.29	1437.92	1437.0	1390.0	111	15527	5832	61	9.58	4924
4.30	1437.94	1437.0	1390.0	111	16457	5878	63	9.80	4988
4.31	1437.96	1437.0	1390.0	111	17408	5924	65	10.01	5051
4.32	1437.98	1437.0	1390.0	111	18378	5970	67	10.21	5113
4.33	1438.00	1437.0	1390.0	111	19368	6016	69	10.41	5173
4.34	1438.01	1437.0	1390.0	111	20377	6062	71	10.61	5234
4.35	1438.03	1437.0	1390.0	111	21404	6108	73	10.80	5293
4.36	1438.05	1437.0	1390.0	111	22451	6154	75	10.99	5351
4.37	1438.07	1436.7	1390.0	110	23621	6200	110	13.38	5436
4.37	1438.07	1436.7	1390.0	110	23756	6205	112	14.12	5443
4.37	1438.07	1436.7	1390.0	110	23892	6210	114	14.28	5451
4.37	1438.07	1436.7	1390.0	110	24030	6214	116	14.43	5458
4.37	1438.07	1436.7	1390.0	110	24170	6219	118	14.59	5465
4.37	1438.08	1436.7	1390.0	110	24311	6223	120	14.75	5473
4.38	1438.08	1436.7	1390.0	110	24454	6228	122	14.91	5480
4.38	1438.08	1436.6	1390.0	110	24598	6232	124	15.07	5487
4.38	1438.08	1436.6	1390.0	110	24744	6237	126	15.23	5494
4.38	1438.08	1436.6	1390.0	110	24891	6242	128	15.40	5501

4.38	1438.08	1436.6	1390.0	110	25040	6246	130	15.56	5508
4.38	1438.09	1436.6	1390.0	110	25191	6251	132	15.73	5515
4.38	1438.09	1436.6	1390.0	110	25343	6255	135	15.89	5522
4.38	1438.09	1436.6	1390.0	110	25497	6260	137	16.06	5529
4.38	1438.09	1436.5	1390.0	110	25652	6265	139	16.23	5537
4.38	1438.09	1436.5	1390.0	110	25809	6269	141	16.40	5544
4.39	1438.09	1436.5	1390.0	110	25968	6274	144	16.57	5551
4.39	1438.10	1436.5	1390.0	110	26128	6278	146	16.75	5558
4.39	1438.10	1436.5	1390.0	109	26290	6283	148	16.92	5566
4.39	1438.10	1436.5	1390.0	109	26454	6288	151	17.10	5573
4.39	1438.10	1436.5	1390.0	109	26619	6292	153	17.27	5581
4.39	1438.10	1436.4	1390.0	109	26786	6297	156	17.45	5588
4.39	1438.10	1436.4	1390.0	109	26955	6301	158	17.63	5595
4.39	1438.10	1436.4	1390.0	109	27126	6306	161	17.81	5603
4.39	1438.11	1436.4	1390.0	109	27298	6311	163	18.00	5611
4.39	1438.11	1436.4	1390.0	109	27472	6315	166	18.18	5618
4.40	1438.11	1436.4	1390.0	109	27648	6320	169	18.37	5625
4.40	1438.11	1436.3	1390.0	109	27825	6324	171	18.55	5632
4.40	1438.11	1436.3	1390.0	109	28005	6329	174	18.74	5640
4.40	1438.11	1436.3	1390.0	109	28186	6334	177	18.92	5647
4.40	1438.12	1436.3	1390.0	109	28369	6338	180	19.11	5654
4.40	1438.12	1436.3	1390.0	109	28554	6343	183	19.30	5662
4.40	1438.12	1436.3	1390.0	109	28740	6347	185	19.50	5669
4.40	1438.12	1436.3	1390.0	109	28929	6352	188	19.69	5676
4.40	1438.12	1436.2	1390.0	109	29119	6357	191	19.88	5684
4.40	1438.12	1436.2	1390.0	109	29311	6361	194	20.08	5691
4.41	1438.12	1436.2	1390.0	109	29506	6366	197	20.28	5699
4.41	1438.13	1436.2	1390.0	109	29702	6370	200	20.47	5706
4.41	1438.13	1436.2	1390.0	109	29900	6375	203	20.67	5714
4.41	1438.13	1436.2	1390.0	109	30099	6380	206	20.88	5722
4.41	1438.13	1436.1	1390.0	109	30301	6384	210	21.08	5729
4.41	1438.13	1436.1	1390.0	109	30505	6389	213	21.28	5737
4.41	1438.13	1436.1	1390.0	109	30711	6393	216	21.49	5745
4.41	1438.13	1436.1	1390.0	109	30919	6398	219	21.70	5752
4.41	1438.14	1436.1	1390.0	108	31128	6403	223	21.90	5760
4.41	1438.14	1436.0	1390.0	108	31340	6407	226	22.11	5768
4.42	1438.14	1436.0	1390.0	108	31554	6412	229	22.32	5775
4.42	1438.14	1436.0	1390.0	108	31770	6416	233	22.53	5783
4.42	1438.14	1436.0	1390.0	108	31988	6421	236	22.75	5790
4.42	1438.14	1436.0	1390.0	108	32207	6426	240	22.96	5798
4.42	1438.14	1436.0	1390.0	108	32429	6430	243	23.18	5805
4.42	1438.14	1435.9	1390.0	108	32653	6435	247	23.39	5813
4.42	1438.15	1435.9	1390.0	108	32879	6439	251	23.61	5821
4.42	1438.15	1435.9	1390.0	108	33108	6444	254	23.83	5828
4.42	1438.15	1435.9	1390.0	108	33338	6449	258	24.05	5836
4.42	1438.15	1435.9	1390.0	108	33571	6453	262	24.28	5844
4.43	1438.15	1435.8	1390.0	108	33805	6458	266	24.50	5852
4.43	1438.15	1435.8	1390.0	108	34042	6462	270	24.73	5860
4.43	1438.15	1435.8	1390.0	108	34281	6467	273	24.95	5868
4.43	1438.16	1435.8	1390.0	108	34522	6472	277	25.18	5876
4.43	1438.16	1435.8	1390.0	108	34765	6476	281	25.41	5884
4.43	1438.16	1435.7	1390.0	108	35011	6481	285	25.64	5892
4.43	1438.16	1435.7	1390.0	108	35259	6485	290	25.88	5900
4.43	1438.16	1435.7	1390.0	108	35509	6490	294	26.11	5907
4.43	1438.16	1435.7	1390.0	108	35761	6495	298	26.34	5915
4.43	1438.16	1435.7	1390.0	108	36016	6499	302	26.58	5923
4.44	1438.16	1435.6	1390.0	107	36273	6504	306	26.82	5931
4.44	1438.17	1435.6	1390.0	107	36532	6508	311	27.06	5939
4.44	1438.17	1435.6	1390.0	107	36793	6513	315	27.30	5947
4.44	1438.17	1435.6	1390.0	107	37057	6518	320	27.54	5955
4.44	1438.17	1435.6	1390.0	107	37323	6522	324	27.78	5963
4.44	1438.17	1435.5	1390.0	107	37591	6527	329	28.03	5971
4.44	1438.17	1435.5	1390.0	107	37862	6531	333	28.27	5979
4.44	1438.17	1435.5	1390.0	107	38135	6536	338	28.52	5987
4.44	1438.17	1435.5	1390.0	107	38411	6541	342	28.77	5995
4.44	1438.18	1435.5	1390.0	107	38689	6545	347	29.02	6004

4.45	1438.18	1435.4	1390.0	107	38969	6550	352	29.27	6012
4.45	1438.18	1435.4	1390.0	107	39252	6554	357	29.53	6020
4.45	1438.18	1435.4	1390.0	107	39537	6559	362	29.78	6028
4.45	1438.18	1435.4	1390.0	107	39825	6564	367	30.04	6036
4.45	1438.18	1435.3	1390.0	107	40115	6568	372	30.29	6045
4.45	1438.18	1435.3	1390.0	107	40408	6573	377	30.55	6053
4.45	1438.18	1435.3	1390.0	107	40703	6577	382	30.81	6061
4.45	1438.18	1435.3	1390.0	107	41001	6582	387	31.08	6069
4.45	1438.19	1435.3	1390.0	107	41301	6587	392	31.34	6077
4.45	1438.19	1435.2	1390.0	107	41604	6591	397	31.60	6086
4.46	1438.19	1435.2	1390.0	106	41909	6596	403	31.87	6094
4.46	1438.19	1435.2	1390.0	106	42217	6600	408	32.14	6103
4.46	1438.19	1435.2	1390.0	106	42527	6605	414	32.41	6111
4.46	1438.19	1435.1	1390.0	106	42840	6610	419	32.68	6120
4.46	1438.19	1435.1	1390.0	106	43156	6614	425	32.95	6128
4.46	1438.19	1435.1	1390.0	106	43474	6619	430	33.23	6137
4.46	1438.19	1435.1	1390.0	106	43795	6623	436	33.50	6146
4.46	1438.20	1435.1	1390.0	106	44119	6628	442	33.78	6154
4.46	1438.20	1435.0	1390.0	106	44282	6633	445	33.91	6160
4.46	1438.20	1435.0	1390.0	106	44445	6637	448	34.06	6166
4.47	1438.20	1435.0	1390.0	106	44609	6642	451	34.20	6172
4.47	1438.20	1435.0	1390.0	106	44774	6646	454	34.35	6178
4.47	1438.20	1435.0	1390.0	106	44940	6651	457	34.50	6184
4.47	1438.20	1435.0	1390.0	106	45106	6656	460	34.64	6191
4.47	1438.20	1435.0	1390.0	106	45273	6660	463	34.79	6197
4.47	1438.20	1435.0	1390.0	106	45441	6665	466	34.94	6203
4.47	1438.20	1434.9	1390.0	106	45609	6669	469	35.09	6209
4.47	1438.21	1434.9	1390.0	106	45778	6674	472	35.23	6215
4.47	1438.21	1434.9	1390.0	106	45948	6679	475	35.38	6221
4.47	1438.21	1434.9	1390.0	106	46119	6683	479	35.53	6227
4.48	1438.21	1434.9	1390.0	106	46290	6688	482	35.68	6233
4.48	1438.21	1434.9	1390.0	106	46462	6692	485	35.83	6240
4.48	1438.21	1434.9	1390.0	106	46635	6697	488	35.98	6246
4.48	1438.21	1434.9	1390.0	106	46808	6702	492	36.13	6252
4.48	1438.21	1434.8	1390.0	106	46982	6706	495	36.28	6258
4.48	1438.21	1434.8	1390.0	106	47157	6711	498	36.44	6265
4.48	1438.21	1434.8	1390.0	106	47333	6715	501	36.59	6271
4.48	1438.21	1434.8	1390.0	106	47509	6720	505	36.74	6277
4.48	1438.22	1434.8	1390.0	105	47686	6725	508	36.89	6284
4.48	1438.22	1434.8	1390.0	105	47864	6729	511	37.05	6290
4.49	1438.22	1434.8	1390.0	105	48043	6734	515	37.20	6296
4.49	1438.22	1434.8	1390.0	105	48222	6738	518	37.36	6303
4.49	1438.22	1434.7	1390.0	105	48402	6743	522	37.51	6309
4.49	1438.22	1434.7	1390.0	105	48583	6748	525	37.67	6315
4.49	1438.22	1434.7	1390.0	105	48764	6752	528	37.82	6322
4.49	1438.22	1434.7	1390.0	105	48947	6757	532	37.98	6328
4.49	1438.22	1434.7	1390.0	105	49130	6761	535	38.14	6335
4.49	1438.22	1434.7	1390.0	105	49314	6766	539	38.29	6341
4.49	1438.23	1434.7	1390.0	105	49498	6771	542	38.45	6348
4.49	1438.23	1434.7	1390.0	105	49683	6775	546	38.61	6354
4.50	1438.23	1434.6	1390.0	105	49869	6780	549	38.77	6361
4.50	1438.23	1434.6	1390.0	105	50056	6784	553	38.93	6367
4.50	1438.23	1434.6	1390.0	105	50244	6789	557	39.08	6373
4.50	1438.23	1434.6	1390.0	105	50432	6794	560	39.24	6379
4.50	1438.23	1434.6	1390.0	105	50621	6798	564	39.40	6385
4.50	1438.23	1434.6	1390.0	105	50811	6804	567	39.56	6392
4.50	1438.23	1434.6	1390.0	105	51002	6809	571	39.72	6398
4.50	1438.23	1434.6	1390.0	105	51193	6815	575	39.88	6404
4.50	1438.23	1434.5	1390.0	105	51386	6820	578	40.04	6410
4.50	1438.24	1434.5	1390.0	105	51579	6826	582	40.20	6416
4.51	1438.24	1434.5	1390.0	105	51772	6832	586	40.36	6423
4.51	1438.24	1434.5	1390.0	105	51967	6837	589	40.52	6429
4.51	1438.24	1434.5	1390.0	105	52162	6843	593	40.69	6435
4.51	1438.24	1434.5	1390.0	105	52358	6848	597	40.85	6442
4.51	1438.24	1434.5	1390.0	105	52555	6854	601	41.01	6448
4.51	1438.24	1434.5	1390.0	105	52753	6860	605	41.18	6454

4.51	1438.24	1434.4	1390.0	105	52951	6865	608	41.34	6461
4.51	1438.24	1434.4	1390.0	105	53150	6871	612	41.51	6467
4.51	1438.24	1434.4	1390.0	105	53350	6876	616	41.67	6473
4.51	1438.24	1434.4	1390.0	105	53551	6882	620	41.84	6480
4.52	1438.24	1434.4	1390.0	105	53753	6888	624	42.00	6486
4.52	1438.25	1434.4	1390.0	104	53955	6893	628	42.17	6493
4.52	1438.25	1434.4	1390.0	104	54158	6899	632	42.34	6499
4.52	1438.25	1434.3	1390.0	104	54362	6904	636	42.50	6506
4.52	1438.25	1434.3	1390.0	104	54567	6910	640	42.67	6512
4.52	1438.25	1434.3	1390.0	104	54773	6916	644	42.84	6519
4.52	1438.25	1434.3	1390.0	104	54979	6921	648	43.01	6525
4.52	1438.25	1434.3	1390.0	104	55187	6927	652	43.18	6532
4.52	1438.25	1434.3	1390.0	104	55395	6932	656	43.35	6538
4.52	1438.25	1434.3	1390.0	104	55604	6938	660	43.52	6545
4.53	1438.25	1434.2	1390.0	104	55813	6944	664	43.69	6552
4.53	1438.25	1434.2	1390.0	104	56024	6949	668	43.86	6558
4.53	1438.25	1434.2	1390.0	104	56235	6955	672	44.03	6565
4.53	1438.26	1434.2	1390.0	104	56447	6960	677	44.20	6572
4.53	1438.26	1434.2	1390.0	104	56660	6966	681	44.38	6578
4.53	1438.26	1434.2	1390.0	104	56874	6972	685	44.55	6585
4.53	1438.26	1434.2	1390.0	104	57089	6977	689	44.72	6592
4.53	1438.26	1434.2	1390.0	104	57304	6983	693	44.90	6599
4.53	1438.26	1434.1	1390.0	104	57521	6988	698	45.07	6606
4.53	1438.26	1434.1	1390.0	104	57738	6994	702	45.25	6612
4.54	1438.26	1434.1	1390.0	104	57956	7000	706	45.42	6619
4.54	1438.26	1434.1	1390.0	104	58175	7005	711	45.60	6626
4.54	1438.26	1434.1	1390.0	104	58395	7011	715	45.78	6633
4.54	1438.26	1434.1	1390.0	104	58615	7016	719	45.95	6640
4.54	1438.27	1434.1	1390.0	104	58837	7022	724	46.13	6647
4.54	1438.27	1434.0	1390.0	104	59059	7028	728	46.31	6654
4.54	1438.27	1434.0	1390.0	104	59282	7033	733	46.49	6661
4.54	1438.27	1434.0	1390.0	104	59506	7039	737	46.66	6668
4.54	1438.27	1434.0	1390.0	104	59731	7044	742	46.84	6675
4.54	1438.27	1434.0	1390.0	104	59956	7050	746	47.02	6682
4.55	1438.27	1434.0	1390.0	104	60183	7056	751	47.20	6689
4.55	1438.27	1434.0	1390.0	103	60411	7061	755	47.38	6696
4.55	1438.27	1433.9	1390.0	103	60639	7067	760	47.57	6702
4.55	1438.27	1433.9	1390.0	103	60868	7072	765	47.75	6709
4.55	1438.27	1433.9	1390.0	103	61098	7078	769	47.93	6716
4.55	1438.27	1433.9	1390.0	103	61329	7084	774	48.11	6722
4.55	1438.27	1433.9	1390.0	103	61561	7089	778	48.29	6729
4.55	1438.28	1433.9	1390.0	103	61793	7095	783	48.47	6736
4.55	1438.28	1433.9	1390.0	103	62027	7100	788	48.65	6743
4.55	1438.28	1433.8	1390.0	103	62261	7106	792	48.84	6749
4.56	1438.28	1433.8	1390.0	103	62497	7112	797	49.02	6756
4.56	1438.28	1433.8	1390.0	103	62733	7117	802	49.21	6763
4.56	1438.28	1433.8	1390.0	103	62970	7123	807	49.39	6770
4.56	1438.28	1433.8	1390.0	103	63208	7128	811	49.58	6777
4.56	1438.28	1433.8	1390.0	103	63447	7134	816	49.76	6784
4.56	1438.28	1433.7	1390.0	103	63687	7140	821	49.95	6790
4.56	1438.28	1433.7	1390.0	103	63927	7145	826	50.13	6797
4.56	1438.28	1433.7	1390.0	103	64169	7151	831	50.32	6804
4.56	1438.28	1433.7	1390.0	103	64411	7156	836	50.51	6811
4.56	1438.28	1433.7	1390.0	103	64655	7162	841	50.70	6818
4.57	1438.29	1433.7	1390.0	103	64899	7168	846	50.89	6825
4.57	1438.29	1433.7	1390.0	103	65144	7173	851	51.07	6832
4.57	1438.29	1433.6	1390.0	103	65390	7179	856	51.26	6839
4.57	1438.29	1433.6	1390.0	103	65637	7184	861	51.45	6847
4.57	1438.29	1433.6	1390.0	103	65885	7190	866	51.64	6854
4.57	1438.29	1433.6	1390.0	103	66134	7196	871	51.83	6861
4.57	1438.29	1433.6	1390.0	103	66383	7201	876	52.03	6868
4.57	1438.29	1433.6	1390.0	103	66634	7207	881	52.22	6875
4.57	1438.29	1433.6	1390.0	103	66886	7212	886	52.41	6882
4.57	1438.29	1433.5	1390.0	103	67138	7218	892	52.60	6890
4.58	1438.29	1433.5	1390.0	102	67392	7224	897	52.80	6897
4.58	1438.29	1433.5	1390.0	102	67646	7229	902	52.99	6904

4.58	1438.29	1433.5	1390.0	102	67901	7235	907	53.19	6911
4.58	1438.29	1433.5	1390.0	102	68157	7240	912	53.38	6919
4.58	1438.30	1433.5	1390.0	102	68415	7246	918	53.58	6926
4.58	1438.30	1433.4	1390.0	102	68673	7252	923	53.77	6933
4.58	1438.30	1433.4	1390.0	102	68932	7257	928	53.97	6941
4.58	1438.30	1433.4	1390.0	102	69192	7263	934	54.17	6948
4.58	1438.30	1433.4	1390.0	102	69453	7268	939	54.36	6956
4.58	1438.30	1433.4	1390.0	102	69715	7274	945	54.56	6963
4.59	1438.30	1433.4	1390.0	102	69977	7280	950	54.76	6971
4.59	1438.30	1433.4	1390.0	102	70241	7285	956	54.96	6978
4.59	1438.30	1433.3	1390.0	102	70506	7291	961	55.16	6985
4.59	1438.30	1433.3	1390.0	102	70772	7296	967	55.36	6992
4.59	1438.30	1433.3	1390.0	102	71038	7302	972	55.56	6999
4.59	1438.30	1433.3	1390.0	102	71306	7308	978	55.76	7006
4.59	1438.30	1433.3	1390.0	102	71575	7313	983	55.96	7013
4.59	1438.30	1433.3	1390.0	102	71844	7319	989	56.16	7020
4.59	1438.30	1433.2	1390.0	102	72115	7324	994	56.36	7028
4.59	1438.31	1433.2	1390.0	102	72386	7330	1000	56.56	7035
4.60	1438.31	1433.2	1390.0	102	72659	7336	1006	56.76	7042
4.60	1438.31	1433.2	1390.0	102	72932	7341	1011	56.97	7049
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4.60	1438.31	1433.2	1390.0	102	73482	7352	1023	57.37	7064
4.60	1438.31	1433.1	1390.0	102	73758	7358	1029	57.58	7071
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4.60	1438.31	1433.1	1390.0	102	74314	7369	1040	57.99	7086
4.60	1438.31	1433.1	1390.0	101	74593	7375	1046	58.19	7094
4.60	1438.31	1433.1	1390.0	101	74874	7380	1052	58.40	7101
4.60	1438.31	1433.1	1390.0	101	75155	7386	1058	58.61	7109
4.61	1438.31	1433.1	1390.0	101	75437	7392	1064	58.81	7116
4.61	1438.31	1433.0	1390.0	101	75721	7397	1070	59.02	7124
4.61	1438.31	1433.0	1390.0	101	76005	7403	1076	59.23	7131
4.61	1438.31	1433.0	1390.0	101	76290	7408	1082	59.44	7139
4.61	1438.31	1433.0	1390.0	101	76577	7414	1088	59.65	7146
4.61	1439.32	1433.0	1390.0	101	76864	7420	1094	59.86	7154
4.61	1438.32	1433.0	1390.0	101	77152	7425	1100	60.07	7162
4.61	1438.32	1432.9	1390.0	101	77442	7431	1106	60.28	7169
4.61	1438.32	1432.9	1390.0	101	77732	7436	1112	60.49	7177
4.61	1438.32	1432.9	1390.0	101	78023	7442	1119	60.71	7185
4.62	1438.32	1432.9	1390.0	101	78316	7448	1125	60.92	7193
4.62	1438.32	1432.9	1390.0	101	78609	7453	1131	61.13	7200
4.62	1438.32	1432.9	1390.0	101	78904	7459	1137	61.34	7207
4.62	1438.32	1432.8	1390.0	101	79199	7464	1144	61.56	7215
4.62	1438.32	1432.8	1390.0	101	79496	7470	1150	61.77	7222
4.62	1438.32	1432.8	1390.0	101	79793	7476	1156	61.98	7230
4.62	1438.32	1432.8	1390.0	101	80092	7481	1162	62.20	7237
4.62	1438.32	1432.8	1390.0	101	80391	7487	1169	62.41	7245
4.62	1438.32	1432.8	1390.0	101	80692	7492	1175	62.63	7252
4.62	1438.32	1432.7	1390.0	101	80994	7498	1182	62.85	7260
4.63	1438.32	1432.7	1390.0	101	81296	7504	1188	63.06	7267
4.63	1438.32	1432.7	1390.0	101	81600	7509	1195	63.28	7275
4.63	1438.32	1432.7	1390.0	100	81905	7515	1201	63.50	7282
4.63	1438.32	1432.7	1390.0	100	82211	7520	1208	63.72	7290
4.63	1438.32	1432.7	1390.0	100	82517	7526	1214	63.93	7298
4.63	1438.33	1432.6	1390.0	100	82825	7532	1221	64.15	7305
4.63	1438.33	1432.6	1390.0	100	83134	7537	1228	64.37	7313
4.63	1438.33	1432.6	1390.0	100	83444	7543	1234	64.59	7321
4.63	1438.33	1432.6	1390.0	100	83756	7548	1241	64.81	7329
4.63	1438.33	1432.6	1390.0	100	84068	7554	1248	65.04	7337
4.64	1438.33	1432.6	1390.0	100	84381	7560	1254	65.26	7344
4.64	1438.33	1432.5	1390.0	100	84695	7565	1261	65.48	7352
4.64	1438.33	1432.5	1390.0	100	85011	7571	1268	65.70	7360
4.64	1438.33	1432.5	1390.0	100	85327	7576	1275	65.93	7368
4.64	1438.33	1432.5	1390.0	100	85645	7582	1282	66.15	7376
4.64	1438.33	1432.5	1390.0	100	85963	7588	1289	66.38	7384
4.64	1438.33	1432.4	1390.0	100	86283	7593	1295	66.60	7392
4.64	1438.33	1432.4	1390.0	100	86604	7599	1302	66.83	7400

4.64	1438.33	1432.4	1390.0	100	86926	7604	1309	67.06	7408
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4.65	1438.33	1432.4	1390.0	100	87573	7616	1323	67.51	7423
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4.65	1438.33	1432.3	1390.0	100	88551	7632	1345	68.19	7446
4.65	1438.33	1432.3	1390.0	100	88880	7638	1352	68.42	7454
4.65	1438.33	1432.3	1390.0	100	89209	7644	1359	68.65	7462
4.65	1438.33	1432.3	1390.0	100	89540	7649	1366	68.88	7470
4.65	1438.33	1432.3	1390.0	99	89871	7655	1373	69.11	7478
4.65	1438.34	1432.2	1390.0	99	90204	7660	1381	69.34	7485
4.65	1438.34	1432.2	1390.0	99	90538	7666	1388	69.57	7493
4.66	1438.34	1432.2	1390.0	99	90873	7672	1395	69.80	7501
4.66	1438.34	1432.2	1390.0	99	91209	7677	1403	70.03	7509
4.66	1438.34	1432.2	1390.0	99	91547	7683	1410	70.26	7517
4.66	1438.34	1432.2	1390.0	99	91885	7688	1417	70.50	7525
4.66	1438.34	1432.1	1390.0	99	92225	7694	1425	70.73	7534
4.66	1438.34	1432.1	1390.0	99	92565	7700	1432	70.97	7542
4.66	1438.34	1432.1	1390.0	99	92907	7705	1440	71.20	7550
4.66	1438.34	1432.1	1390.0	99	93250	7711	1447	71.44	7558
4.66	1438.34	1432.1	1390.0	99	93594	7716	1455	71.67	7566
4.66	1438.34	1432.0	1390.0	99	93939	7722	1462	71.91	7574
4.67	1438.34	1432.0	1390.0	99	94285	7728	1470	72.15	7583
4.67	1438.34	1432.0	1390.0	99	94633	7733	1478	72.38	7591
4.67	1438.34	1432.0	1390.0	99	94981	7739	1486	72.62	7599
4.67	1438.34	1432.0	1390.0	99	95331	7744	1493	72.86	7607
4.67	1438.34	1432.0	1390.0	99	95682	7750	1501	73.10	7615
4.67	1438.34	1431.9	1390.0	99	96034	7756	1509	73.34	7623
4.67	1438.34	1431.9	1390.0	99	96387	7761	1516	73.58	7631
4.67	1438.34	1431.9	1390.0	99	96741	7767	1524	73.82	7639
4.67	1438.34	1431.9	1390.0	99	97097	7772	1532	74.06	7647
4.67	1438.34	1431.9	1390.0	99	97454	7778	1540	74.30	7655
4.68	1438.34	1431.8	1390.0	98	97811	7784	1548	74.54	7663
4.68	1438.34	1431.8	1390.0	98	98170	7789	1556	74.78	7671
4.68	1438.34	1431.8	1390.0	98	98530	7795	1564	75.02	7679
4.68	1438.34	1431.8	1390.0	98	98892	7800	1572	75.27	7687
4.68	1438.34	1431.8	1390.0	98	99254	7806	1580	75.51	7696
4.68	1438.34	1431.8	1390.0	98	99618	7812	1588	75.76	7704
4.68	1438.34	1431.7	1390.0	98	99983	7817	1596	76.00	7712
4.68	1438.34	1431.7	1390.0	98	100349	7823	1604	76.25	7721
4.68	1438.34	1431.7	1390.0	98	100716	7828	1613	76.49	7729
4.68	1438.34	1431.7	1390.0	98	101084	7834	1621	76.74	7737
4.69	1438.34	1431.7	1390.0	98	101454	7840	1629	76.99	7746
4.69	1438.34	1431.6	1390.0	98	101824	7845	1637	77.23	7754
4.69	1438.35	1431.6	1390.0	98	102196	7851	1646	77.48	7763
4.69	1438.35	1431.6	1390.0	98	102569	7856	1654	77.73	7771
4.69	1438.35	1431.6	1390.0	98	102944	7862	1662	77.98	7780
4.69	1438.35	1431.6	1390.0	98	103319	7868	1671	78.23	7788
4.69	1438.35	1431.5	1390.0	98	103696	7873	1679	78.48	7796
4.69	1438.35	1431.5	1390.0	98	104074	7879	1688	78.73	7804
4.69	1438.35	1431.5	1390.0	98	104453	7884	1696	78.98	7812
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4.70	1438.35	1431.5	1390.0	98	105598	7901	1722	79.74	7837
4.70	1438.35	1431.4	1390.0	98	105981	7907	1731	79.99	7846
4.70	1438.35	1431.4	1390.0	97	106367	7912	1739	80.24	7854
4.70	1438.35	1431.4	1390.0	97	106753	7918	1748	80.50	7862
4.70	1438.35	1431.4	1390.0	97	107141	7924	1757	80.75	7871
4.70	1438.35	1431.4	1390.0	97	107529	7929	1765	81.01	7879
4.70	1438.35	1431.3	1390.0	97	107920	7935	1774	81.26	7888
4.70	1438.35	1431.3	1390.0	97	108311	7940	1783	81.52	7897
4.70	1438.35	1431.3	1390.0	97	108703	7946	1792	81.78	7905
4.71	1438.35	1431.3	1390.0	97	109097	7952	1801	82.03	7914
4.71	1438.35	1431.3	1390.0	97	109492	7957	1810	82.29	7922
4.71	1438.35	1431.2	1390.0	97	109888	7963	1819	82.55	7931
4.71	1438.35	1431.2	1390.0	97	110286	7968	1828	82.81	7940

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4.71	1438.35	1431.2	1390.0	97	111486	7985	1855	83.59	7965
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4.71	1438.35	1431.1	1390.0	97	112292	7996	1873	84.11	7982
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4.72	1438.35	1431.1	1390.0	97	113511	8013	1901	84.90	8007
4.72	1438.35	1431.0	1390.0	97	113920	8019	1911	85.16	8016
4.72	1438.35	1431.0	1390.0	97	114330	8024	1920	85.43	8025
4.72	1438.35	1431.0	1390.0	97	114741	8030	1929	85.69	8033
4.72	1438.35	1431.0	1390.0	96	115154	8035	1939	85.96	8042
4.72	1438.35	1431.0	1390.0	96	115567	8041	1948	86.22	8051
4.72	1438.35	1430.9	1390.0	96	115983	8047	1958	86.49	8060
4.72	1438.35	1430.9	1390.0	96	116399	8052	1967	86.76	8069
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4.73	1438.35	1430.9	1390.0	96	117236	8063	1986	87.29	8086
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4.73	1438.35	1430.8	1390.0	96	118078	8075	2006	87.83	8104
4.73	1438.35	1430.8	1390.0	96	118500	8080	2016	88.10	8113
4.73	1438.35	1430.8	1390.0	96	118925	8086	2025	88.37	8121
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4.73	1438.35	1430.7	1390.0	96	120205	8103	2055	89.18	8147
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4.74	1438.35	1430.6	1390.0	96	122365	8131	2105	90.55	8191
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4.74	1438.35	1430.6	1390.0	96	123238	8142	2125	91.10	8209
4.74	1438.35	1430.6	1390.0	96	123677	8147	2135	91.37	8218
4.74	1438.35	1430.6	1390.0	95	124117	8153	2145	91.65	8227
4.74	1438.35	1430.5	1390.0	95	124558	8159	2155	91.93	8236
4.74	1438.35	1430.5	1390.0	95	125000	8164	2166	92.20	8244
4.74	1438.35	1430.5	1390.0	95	125444	8170	2176	92.48	8253
4.75	1438.35	1430.5	1390.0	95	125890	8175	2186	92.76	8262
4.75	1438.34	1430.5	1390.0	95	126336	8181	2197	93.04	8270
4.75	1438.34	1430.4	1390.0	95	126784	8187	2207	93.31	8279
4.75	1438.34	1430.4	1390.0	95	127233	8192	2217	93.59	8288
4.75	1438.34	1430.4	1390.0	95	127684	8198	2228	93.87	8297
4.75	1438.34	1430.4	1390.0	95	128136	8203	2238	94.15	8306
4.75	1438.34	1430.4	1390.0	95	128589	8209	2249	94.44	8315
4.75	1438.34	1430.3	1390.0	95	129044	8215	2260	94.72	8324
4.75	1438.34	1430.3	1390.0	95	129500	8220	2270	95.00	8333
4.75	1438.34	1430.3	1390.0	95	129957	8226	2281	95.28	8342
4.76	1438.34	1430.3	1390.0	95	130416	8231	2292	95.57	8351
4.76	1438.34	1430.3	1390.0	95	130876	8237	2302	95.85	8360
4.76	1438.34	1430.2	1390.0	95	131337	8243	2313	96.14	8370
4.76	1438.34	1430.2	1390.0	95	131800	8248	2324	96.43	8379
4.76	1438.34	1430.2	1390.0	95	132264	8254	2335	96.71	8388
4.76	1438.34	1430.2	1390.0	95	132730	8259	2346	97.00	8398
4.76	1438.34	1430.2	1390.0	94	133197	8265	2357	97.29	8407
4.76	1438.34	1430.1	1390.0	94	133665	8271	2368	97.58	8416
4.76	1438.34	1430.1	1390.0	94	134135	8276	2379	97.86	8425
4.76	1438.34	1430.1	1390.0	94	134606	8282	2390	98.15	8434
4.77	1438.34	1430.1	1390.0	94	135079	8287	2401	98.44	8443
4.77	1438.34	1430.0	1390.0	94	135553	8293	2412	98.73	8452
4.77	1438.34	1430.0	1390.0	94	136028	8299	2423	99.02	8461
4.77	1438.34	1430.0	1390.0	94	136505	8304	2435	99.31	8471
4.77	1438.34	1430.0	1390.0	94	136983	8310	2446	99.60	8480
4.77	1438.34	1430.0	1390.0	94	137462	8315	2457	99.90	8489
4.77	1438.34	1429.9	1390.0	94	137943	8321	2469	100.19	8499
4.77	1438.34	1429.9	1390.0	94	138425	8327	2480	100.48	8508
4.77	1438.34	1429.9	1390.0	94	138909	8332	2491	100.78	8517
4.77	1438.34	1429.9	1390.0	94	139394	8338	2503	101.07	8526

4.78	1438.34	1429.9	1390.0	94	139881	8343	2514	101.37	8535
4.78	1438.34	1429.8	1390.0	94	140369	8349	2526	101.66	8545
4.78	1438.33	1429.8	1390.0	94	140858	8355	2537	101.95	8554
4.78	1438.33	1429.8	1390.0	94	141349	8360	2549	102.25	8563
4.78	1438.33	1429.8	1390.0	94	141841	8366	2561	102.55	8572
4.78	1438.33	1429.7	1390.0	94	142335	8371	2572	102.84	8581
4.78	1438.33	1429.7	1390.0	93	142830	8377	2584	103.14	8591
4.78	1438.33	1429.7	1390.0	93	143326	8383	2596	103.44	8600
4.78	1438.33	1429.7	1390.0	93	143824	8388	2608	103.74	8610
4.78	1438.33	1429.7	1390.0	93	144324	8394	2620	104.04	8619
4.79	1438.33	1429.6	1390.0	93	144825	8399	2632	104.34	8628
4.79	1438.33	1429.6	1390.0	93	145327	8405	2644	104.64	8638
4.79	1438.33	1429.6	1390.0	93	145831	8411	2656	104.94	8648
4.79	1438.33	1429.6	1390.0	93	146336	8416	2668	105.25	8657
4.79	1438.33	1429.6	1390.0	93	146842	8422	2680	105.55	8667
4.79	1438.33	1429.5	1390.0	93	147351	8427	2692	105.85	8677
4.79	1438.33	1429.5	1390.0	93	147860	8433	2704	106.16	8686
4.79	1438.33	1429.5	1390.0	93	148371	8439	2716	106.46	8696
4.79	1438.33	1429.5	1390.0	93	148884	8444	2729	106.77	8705
4.79	1438.33	1429.4	1390.0	93	149398	8450	2741	107.07	8715
4.80	1438.33	1429.4	1390.0	93	149913	8455	2753	107.38	8724
4.80	1438.32	1429.4	1390.0	93	150430	8461	2766	107.68	8734
4.80	1438.32	1429.4	1390.0	93	150948	8467	2778	107.99	8743
4.80	1438.32	1429.4	1390.0	93	151468	8472	2791	108.30	8753
4.80	1438.32	1429.3	1390.0	93	151989	8478	2803	108.61	8763
4.80	1438.32	1429.3	1390.0	93	152512	8483	2816	108.92	8772
4.80	1438.32	1429.3	1390.0	92	153036	8489	2828	109.23	8782
4.80	1438.32	1429.3	1390.0	92	153562	8495	2841	109.54	8792
4.80	1438.32	1429.2	1390.0	92	154090	8500	2854	109.85	8802
4.80	1438.32	1429.2	1390.0	92	154618	8506	2866	110.16	8811
4.81	1438.32	1429.2	1390.0	92	155149	8511	2879	110.47	8821
4.81	1438.32	1429.2	1390.0	92	155680	8517	2892	110.78	8830
4.81	1438.32	1429.2	1390.0	92	156214	8523	2905	111.09	8840
4.81	1438.32	1429.1	1390.0	92	156748	8528	2918	111.41	8850
4.81	1438.32	1429.1	1390.0	92	157285	8534	2931	111.72	8859
4.81	1438.32	1429.1	1390.0	92	157822	8539	2944	112.03	8869
4.81	1438.31	1429.1	1390.0	92	158362	8545	2957	112.35	8879
4.81	1438.31	1429.0	1390.0	92	158902	8551	2970	112.66	8889
4.81	1438.31	1429.0	1390.0	92	159445	8556	2983	112.98	8899
4.81	1438.31	1429.0	1390.0	92	159988	8562	2996	113.30	8909
4.82	1438.31	1429.0	1390.0	92	160534	8567	3009	113.62	8919
4.82	1438.31	1429.0	1390.0	92	161081	8573	3023	113.93	8929
4.82	1438.31	1428.9	1390.0	92	161629	8579	3036	114.25	8939
4.82	1438.31	1428.9	1390.0	92	162179	8584	3049	114.57	8949
4.82	1438.31	1428.9	1390.0	91	162731	8590	3063	114.89	8959
4.82	1438.31	1428.9	1390.0	91	163284	8595	3076	115.21	8968
4.82	1438.31	1428.8	1390.0	91	163838	8601	3090	115.53	8978
4.82	1438.31	1428.8	1390.0	91	164394	8607	3103	115.85	8988
4.82	1438.31	1428.8	1390.0	91	164952	8612	3117	116.18	8998
4.82	1438.30	1428.8	1390.0	91	165511	8618	3130	116.50	9008
4.83	1438.30	1428.7	1390.0	91	166072	8623	3144	116.82	9018
4.83	1438.30	1428.7	1390.0	91	166634	8629	3158	117.14	9028
4.83	1438.30	1428.7	1390.0	91	167198	8635	3171	117.47	9038
4.83	1438.30	1428.7	1390.0	91	167763	8640	3185	117.79	9049
4.83	1438.30	1428.7	1390.0	91	168330	8646	3199	118.12	9058
4.83	1438.30	1428.6	1390.0	91	168899	8651	3213	118.44	9068
4.83	1438.30	1428.6	1390.0	91	169469	8657	3227	118.77	9078
4.83	1438.30	1428.6	1390.0	91	170041	8663	3241	119.10	9088
4.83	1438.30	1428.6	1390.0	91	170614	8668	3255	119.42	9098
4.83	1438.30	1428.5	1390.0	91	171189	8674	3269	119.75	9108
4.84	1438.29	1428.5	1390.0	91	171765	8679	3283	120.08	9118
4.84	1438.29	1428.5	1390.0	91	172343	8685	3297	120.41	9128
4.84	1438.29	1428.5	1390.0	91	172922	8691	3311	120.74	9138
4.84	1438.29	1428.4	1390.0	90	173504	8696	3326	121.07	9149
4.84	1438.29	1428.4	1390.0	90	174086	8702	3340	121.40	9159
4.84	1438.29	1428.4	1390.0	90	174671	8707	3354	121.73	9169

4.84	1438.29	1428.4	1390.0	90	175257	8713	3369	122.06	9180
4.84	1438.29	1428.3	1390.0	90	175844	8719	3383	122.40	9190
4.84	1438.29	1428.3	1390.0	90	176433	8724	3398	122.73	9201
4.84	1438.29	1428.3	1390.0	90	177616	8730	3428	123.40	9225
4.85	1438.28	1428.2	1390.0	90	178806	8735	3458	124.09	9250
4.85	1438.28	1428.2	1390.0	90	180002	8741	3488	124.78	9275
4.85	1438.28	1428.1	1390.0	90	181205	8747	3518	125.47	9300
4.85	1438.28	1428.1	1390.0	90	182415	8752	3549	126.17	9325
4.85	1438.28	1428.0	1390.0	90	183631	8758	3580	126.86	9351
4.85	1438.28	1428.0	1390.0	89	184854	8763	3611	127.56	9376
4.85	1438.28	1427.9	1390.0	89	186083	8769	3642	128.27	9401
4.85	1438.28	1427.9	1390.0	89	187320	8775	3674	128.97	9426
4.85	1438.27	1427.8	1390.0	89	188563	8780	3706	129.68	9452
4.85	1438.27	1427.8	1390.0	89	189813	8786	3737	130.39	9477
4.86	1438.27	1427.8	1390.0	89	191070	8791	3770	131.10	9503
4.86	1438.27	1427.7	1390.0	89	192334	8797	3802	131.82	9528
4.86	1438.27	1427.7	1390.0	89	193605	8803	3835	132.54	9554
4.86	1438.27	1427.6	1390.0	88	194882	8808	3867	133.25	9580
4.86	1438.26	1427.6	1390.0	88	196167	8814	3900	133.98	9606
4.86	1438.26	1427.5	1390.0	88	197458	8819	3933	134.70	9632
4.86	1438.26	1427.5	1390.0	88	198757	8825	3967	135.43	9658
4.86	1438.26	1427.4	1390.0	88	200062	8831	4000	136.16	9684
4.86	1438.26	1427.4	1390.0	88	201375	8836	4034	136.89	9711
4.86	1438.26	1427.3	1390.0	88	202694	8842	4068	137.63	9737
4.87	1438.25	1427.3	1390.0	88	204021	8847	4103	138.37	9763
4.87	1438.25	1427.2	1390.0	88	205355	8853	4137	139.11	9790
4.87	1438.25	1427.2	1390.0	87	206695	8859	4172	139.85	9816
4.87	1438.25	1427.1	1390.0	87	208044	8864	4207	140.60	9843
4.87	1438.25	1427.1	1390.0	87	209399	8870	4242	141.34	9869
4.87	1438.24	1427.0	1390.0	87	210761	8875	4278	142.09	9896
4.87	1438.24	1427.0	1390.0	87	212131	8881	4313	142.85	9923
4.87	1438.24	1426.9	1390.0	87	213508	8887	4349	143.60	9950
4.87	1438.24	1426.8	1390.0	87	214892	8892	4385	144.36	9977
4.87	1438.23	1426.8	1390.0	87	216283	8898	4422	145.12	10005
4.88	1438.23	1426.7	1390.0	86	217682	8903	4458	145.89	10032
4.88	1438.23	1426.7	1390.0	86	219088	8909	4495	146.65	10059
4.88	1438.23	1426.6	1390.0	86	220502	8915	4532	147.42	10087
4.88	1438.22	1426.6	1390.0	86	221922	8920	4569	148.19	10114
4.88	1438.22	1426.5	1390.0	86	223351	8926	4607	148.97	10142
4.88	1438.22	1426.5	1390.0	86	224787	8931	4645	149.74	10170
4.88	1438.22	1426.4	1390.0	86	226230	8937	4683	150.52	10198
4.88	1438.21	1426.4	1390.0	86	227681	8943	4721	151.30	10225
4.88	1438.21	1426.3	1390.0	85	229139	8948	4759	152.09	10254
4.88	1438.21	1426.3	1390.0	85	230605	8954	4798	152.87	10282
4.89	1438.20	1426.2	1390.0	85	232078	8959	4837	153.67	10310
4.89	1438.20	1426.2	1390.0	85	233559	8965	4876	154.46	10339
4.89	1438.20	1426.1	1390.0	85	235048	8971	4916	155.25	10367
4.89	1438.20	1426.1	1390.0	85	236544	8976	4956	156.05	10396
4.89	1438.19	1426.0	1390.0	85	238048	8982	4996	156.85	10425
4.89	1438.19	1426.0	1390.0	85	239560	8987	5036	157.65	10453
4.89	1438.19	1425.9	1390.0	84	241079	8993	5076	158.46	10482
4.89	1438.18	1425.8	1390.0	84	242606	8999	5117	159.26	10511
4.89	1438.18	1425.8	1390.0	84	244141	9004	5158	160.08	10541
4.89	1438.18	1425.7	1390.0	84	245684	9010	5199	160.89	10570
4.90	1438.17	1425.7	1390.0	84	247234	9015	5241	161.71	10599
4.90	1438.17	1425.6	1390.0	84	248793	9021	5282	162.52	10629
4.90	1438.17	1425.6	1390.0	84	250359	9027	5325	163.35	10659
4.90	1438.16	1425.5	1390.0	84	251933	9032	5367	164.17	10689
4.90	1438.16	1425.5	1390.0	83	253516	9038	5409	165.00	10718
4.90	1438.15	1425.4	1390.0	83	255106	9043	5452	165.82	10748
4.90	1438.15	1425.4	1390.0	83	256704	9049	5495	166.66	10778
4.90	1438.15	1425.3	1390.0	83	258310	9055	5538	167.49	10809
4.90	1438.14	1425.2	1390.0	83	259924	9060	5582	168.33	10839
4.90	1438.14	1425.2	1390.0	83	261546	9066	5626	169.17	10869
4.91	1438.14	1425.1	1390.0	83	263176	9071	5670	170.01	10900
4.91	1438.13	1425.1	1390.0	82	264815	9077	5714	170.85	10931

4.91	1438.13	1425.0	1390.0	82	266461	9083	5759	171.70	10962
4.91	1438.12	1425.0	1390.0	82	268116	9088	5804	172.55	10993
4.91	1438.12	1424.9	1390.0	82	269778	9094	5849	173.40	11024
4.91	1438.11	1424.9	1390.0	82	271450	9099	5895	174.26	11055
4.91	1438.11	1424.8	1390.0	82	273129	9105	5940	175.12	11087
4.91	1438.11	1424.7	1390.0	82	274816	9111	5987	175.98	11118
4.91	1438.10	1424.7	1390.0	82	276512	9116	6033	176.84	11150
4.91	1438.10	1424.6	1390.0	81	278216	9122	6079	177.71	11182
4.92	1438.09	1424.6	1390.0	81	279929	9127	6126	178.57	11214
4.92	1438.09	1424.5	1390.0	81	281649	9133	6173	179.45	11246
4.92	1438.08	1424.5	1390.0	81	283379	9139	6221	180.32	11279
4.92	1438.08	1424.4	1390.0	81	285116	9144	6269	181.20	11311
4.92	1438.07	1424.3	1390.0	81	286862	9150	6317	182.08	11343
4.92	1438.07	1424.3	1390.0	81	288617	9155	6365	182.96	11376
4.92	1438.06	1424.2	1390.0	80	290380	9161	6413	183.84	11409
4.92	1438.06	1424.2	1390.0	80	292151	9167	6462	184.73	11442
4.92	1438.05	1424.1	1390.0	80	293931	9172	6511	185.62	11475
4.92	1438.05	1424.0	1390.0	80	295720	9178	6561	186.52	11509
4.93	1438.04	1424.0	1390.0	80	297517	9183	6611	187.41	11542
4.93	1438.04	1423.9	1390.0	80	299323	9189	6661	188.31	11576
4.93	1438.03	1423.9	1390.0	80	301138	9195	6711	189.21	11610
4.93	1438.03	1423.8	1390.0	79	302961	9200	6762	190.11	11644
4.93	1438.02	1423.8	1390.0	79	304793	9206	6813	191.02	11678
4.93	1438.02	1423.7	1390.0	79	306633	9211	6864	191.93	11712
4.93	1438.01	1423.6	1390.0	79	308483	9217	6915	192.84	11747
4.93	1438.01	1423.6	1390.0	79	310341	9223	6967	193.75	11781
4.93	1438.00	1423.5	1390.0	79	312208	9228	7019	194.67	11816
4.93	1437.99	1423.5	1390.0	79	314083	9234	7071	195.59	11851
4.94	1437.99	1423.4	1390.0	78	315968	9239	7124	196.51	11886
4.94	1437.98	1423.3	1390.0	78	317861	9245	7177	197.43	11922
4.94	1437.98	1423.3	1390.0	78	319764	9251	7230	198.36	11957
4.94	1437.97	1423.2	1390.0	78	321675	9256	7284	199.29	11993
4.94	1437.96	1423.1	1390.0	78	323595	9262	7338	200.22	12028
4.94	1437.96	1423.1	1390.0	78	325524	9267	7392	201.15	12064
4.94	1437.95	1423.0	1390.0	78	327462	9273	7447	202.09	12100
4.94	1437.95	1423.0	1390.0	77	329409	9279	7501	203.03	12137
4.94	1437.94	1422.9	1390.0	77	331366	9284	7557	203.97	12174
4.94	1437.93	1422.8	1390.0	77	333331	9290	7612	204.92	12210
4.95	1437.93	1422.8	1390.0	77	335305	9295	7668	205.87	12247
4.95	1437.92	1422.7	1390.0	77	337289	9301	7724	206.82	12284
4.95	1437.91	1422.7	1390.0	77	339281	9307	7780	207.77	12322
4.95	1437.91	1422.6	1390.0	77	341283	9312	7837	208.72	12359
4.95	1437.90	1422.5	1390.0	76	343294	9318	7894	209.68	12397
4.95	1437.89	1422.5	1390.0	76	345314	9323	7951	210.64	12434
4.95	1437.89	1422.4	1390.0	76	347344	9329	8009	211.60	12473
4.95	1437.88	1422.3	1390.0	76	349382	9335	8067	212.57	12511
4.95	1437.87	1422.3	1390.0	76	351430	9340	8125	213.54	12549
4.95	1437.86	1422.2	1390.0	76	353488	9346	8184	214.51	12588
4.96	1437.86	1422.2	1390.0	76	355554	9351	8243	215.48	12627
4.96	1437.85	1422.1	1390.0	75	357630	9357	8302	216.46	12666
4.96	1437.84	1422.0	1390.0	75	359716	9363	8362	217.43	12706
4.96	1437.83	1422.0	1390.0	75	361810	9368	8422	218.41	12745
4.96	1437.83	1421.9	1390.0	75	363915	9374	8482	219.40	12785
4.96	1437.82	1421.8	1390.0	75	366028	9379	8543	220.38	12825
4.96	1437.81	1421.8	1390.0	75	368152	9385	8604	221.37	12865
4.96	1437.80	1421.7	1390.0	75	370284	9391	8665	222.36	.2905
4.96	1437.80	1421.6	1390.0	74	372426	9396	8727	223.35	12946
4.96	1437.79	1421.6	1390.0	74	374578	9402	8789	224.35	12987
4.97	1437.78	1421.5	1390.0	74	376739	9407	8851	225.34	13028
4.97	1437.77	1421.4	1390.0	74	378910	9413	8913	226.34	13070
4.97	1437.76	1421.4	1390.0	74	381091	9419	8976	227.34	13111
4.97	1437.75	1421.3	1390.0	74	383281	9424	9040	228.35	13153
4.97	1437.75	1421.2	1390.0	73	385481	9430	9103	229.36	13195
4.97	1437.74	1421.2	1390.0	73	387690	9435	9167	230.36	13237
4.97	1437.73	1421.1	1390.0	73	389909	9441	9231	231.37	13280
4.97	1437.72	1421.0	1390.0	73	392138	9447	9296	232.39	13323

4.97	1437.71	1421.0	1390.0	73	394377	9452	9361	233.40	13366
4.97	1437.70	1420.9	1390.0	73	396626	9458	9426	234.42	13409
4.98	1437.69	1420.8	1390.0	72	398884	9463	9492	235.44	13452
4.98	1437.68	1420.8	1390.0	72	401152	9469	9558	236.46	13496
4.98	1437.67	1420.7	1390.0	72	403430	9475	9624	237.49	13540
4.98	1437.66	1420.6	1390.0	72	405718	9480	9691	238.52	13585
4.98	1437.65	1420.6	1390.0	72	408015	9486	9758	239.55	13629
4.98	1437.65	1420.5	1390.0	72	410323	9491	9825	240.58	13674
4.98	1437.64	1420.4	1390.0	72	412640	9497	9893	241.61	13719
4.98	1437.63	1420.4	1390.0	71	414968	9503	9961	242.65	13765
4.98	1437.62	1420.3	1390.0	71	417305	9508	10029	243.69	13810
4.98	1437.61	1420.2	1390.0	71	419652	9514	10098	244.73	13856
4.99	1437.60	1420.2	1390.0	71	422010	9519	10167	245.77	13902
4.99	1437.59	1420.1	1390.0	71	424377	9525	10236	246.81	13949
4.99	1437.58	1420.0	1390.0	71	426755	9531	10306	247.86	13996
4.99	1437.57	1420.0	1390.0	70	429142	9536	10376	248.91	14044
4.99	1437.55	1419.9	1390.0	70	431540	9542	10447	249.96	14091
4.99	1437.54	1419.8	1390.0	70	433948	9547	10517	251.01	14139
4.99	1437.53	1419.8	1390.0	70	436366	9553	10588	252.07	14187
4.99	1437.52	1419.7	1390.0	70	438794	9559	10660	253.12	14235
4.99	1437.51	1419.6	1390.0	70	441232	9564	10732	254.18	14284
4.99	1437.50	1419.5	1390.0	69	443680	9570	10804	255.24	14333
5.00	1437.49	1419.5	1390.0	69	446139	9575	10876	256.30	14383
5.00	1437.48	1419.4	1390.0	69	448607	9581	10949	257.36	14432
5.00	1437.47	1419.3	1390.0	69	451086	9587	11022	258.43	14482
5.00	1437.45	1419.3	1390.0	69	453575	9592	11096	259.49	14532
5.00	1437.44	1419.2	1390.0	69	456075	9598	11170	260.56	14583
5.00	1437.43	1419.1	1390.0	68	458584	9601	11244	261.63	14634
5.00	1437.42	1419.0	1390.0	68	461104	9603	11319	262.70	14686
5.00	1437.41	1419.0	1390.0	68	463635	9604	11393	263.77	14738
5.00	1437.39	1418.9	1390.0	68	466175	9606	11469	264.85	14790
5.00	1437.38	1418.8	1390.0	68	468726	9608	11544	265.92	14843
5.01	1437.37	1418.8	1390.0	68	471288	9610	11620	267.00	14896
5.01	1437.36	1418.7	1390.0	67	473859	9612	11697	268.08	14949
5.01	1437.34	1418.6	1390.0	67	476441	9613	11773	269.16	15003
5.01	1437.33	1418.5	1390.0	67	479034	9615	11850	270.24	15057
5.01	1437.32	1418.5	1390.0	67	481636	9617	11927	271.32	15112
5.01	1437.31	1418.4	1390.0	67	484250	9619	12005	272.40	15167
5.01	1437.29	1418.3	1390.0	67	486873	9621	12083	273.49	15223
5.01	1437.28	1418.3	1390.0	66	489507	9622	12161	274.57	15279
5.01	1437.27	1418.2	1390.0	66	492152	9624	12240	275.66	15335
5.01	1437.25	1418.1	1390.0	66	494807	9626	12319	276.75	15392
5.02	1437.24	1418.0	1390.0	66	497472	9628	12398	277.84	15450
5.02	1437.22	1418.0	1390.0	66	500148	9630	12478	278.93	15508
5.02	1437.21	1417.9	1390.0	65	502834	9631	12558	280.02	15567
5.02	1437.19	1417.8	1390.0	65	505531	9633	12638	281.11	15626
5.02	1437.18	1417.7	1390.0	65	508238	9635	12718	282.20	15686
5.02	1437.17	1417.7	1390.0	65	510956	9637	12799	283.29	15746
5.02	1437.15	1417.6	1390.0	65	513685	9639	12880	284.38	15807
5.02	1437.14	1417.5	1390.0	65	516423	9640	12962	285.48	15869
5.02	1437.12	1417.4	1390.0	64	519173	9642	13043	286.57	15932
5.02	1437.10	1417.4	1390.0	64	521932	9644	13126	287.67	15995
5.03	1437.09	1417.3	1390.0	64	524703	9646	13208	288.76	16060
5.03	1437.07	1417.2	1390.0	64	527484	9648	13291	289.85	16125
5.03	1437.06	1417.1	1390.0	64	530275	9649	13374	290.95	16191
5.03	1437.04	1417.1	1390.0	64	533077	9651	13457	292.04	16259
5.03	1437.03	1417.0	1390.0	63	535889	9653	13540	293.14	16328
5.03	1437.01	1416.9	1390.0	63	538712	9655	13624	294.23	16398
5.03	1436.99	1416.8	1390.0	63	541546	9657	13708	295.32	16473
5.03	1436.97	1416.7	1390.0	63	544390	9658	13793	296.41	16548
5.03	1436.96	1416.7	1390.0	63	547244	9660	13877	297.51	16623
5.03	1436.94	1416.6	1390.0	62	550109	9662	13962	298.60	16699
5.04	1436.92	1416.5	1390.0	62	552984	9664	14047	299.68	16775
5.04	1436.90	1416.4	1390.0	62	555870	9666	14132	300.77	16851
5.04	1436.89	1416.4	1390.0	62	558766	9667	14218	301.86	16927
5.04	1436.87	1416.3	1390.0	62	561673	9669	14303	302.95	17003

5.04	1436.85	1416.2	1390.0	61	564590	9671	14390	304.04	17079
5.04	1436.83	1416.1	1390.0	61	567518	9673	14476	305.12	17155
5.04	1436.81	1416.0	1390.0	61	570456	9675	14562	306.20	17232
5.04	1436.79	1416.0	1390.0	61	573404	9676	14649	307.28	17309
5.04	1436.77	1415.9	1390.0	61	576363	9678	14736	308.36	17386
5.04	1436.75	1415.8	1390.0	61	579332	9680	14823	309.44	17462
5.05	1436.73	1415.7	1390.0	60	582312	9682	14910	310.52	17540
5.05	1436.71	1415.7	1390.0	60	585302	9684	14998	311.59	17617
5.05	1436.69	1415.6	1390.0	60	588302	9685	15085	312.67	17694
5.05	1436.67	1415.5	1390.0	60	591313	9687	15173	313.74	17771
5.05	1436.65	1415.4	1390.0	60	594333	9689	15262	314.81	17848
5.05	1436.63	1415.3	1390.0	59	597364	9691	15350	315.88	17926
5.05	1436.61	1415.2	1390.0	59	600406	9693	15438	316.94	18004
5.05	1436.59	1415.2	1390.0	59	603457	9694	15527	318.01	18081
5.05	1436.57	1415.1	1390.0	59	606519	9696	15616	319.07	18159
5.05	1436.54	1415.0	1390.0	59	609591	9698	15705	320.13	18237
5.06	1436.52	1414.9	1390.0	58	612673	9700	15794	321.19	18314
5.06	1436.50	1414.8	1390.0	58	615766	9702	15884	322.24	18392
5.06	1436.48	1414.8	1390.0	58	618868	9703	15973	323.29	18470
5.06	1436.45	1414.7	1390.0	58	621981	9705	16063	324.34	18548
5.06	1436.43	1414.6	1390.0	58	625103	9707	16153	325.39	18626
5.06	1436.41	1414.5	1390.0	58	628236	9709	16243	326.43	18704
5.06	1436.38	1414.4	1390.0	57	631378	9711	16333	327.47	18782
5.06	1436.36	1414.4	1390.0	57	634531	9712	16423	328.51	18860
5.06	1436.33	1414.3	1390.0	57	637694	9714	16514	329.54	18938
5.06	1436.31	1414.2	1390.0	57	640866	9716	16604	330.57	19016
5.07	1436.28	1414.1	1390.0	57	644048	9718	16694	331.60	19094
5.07	1436.26	1414.0	1390.0	56	647241	9720	16785	332.62	19172
5.07	1436.23	1413.9	1390.0	56	650443	9721	16876	333.65	19250
5.07	1436.21	1413.9	1390.0	56	653655	9723	16967	334.66	19328
5.07	1436.18	1413.8	1390.0	56	656876	9725	17058	335.67	19406
5.07	1436.15	1413.7	1390.0	56	660108	9727	17149	336.68	19484
5.07	1436.13	1413.6	1390.0	55	663349	9729	17240	337.69	19561
5.07	1436.10	1413.5	1390.0	55	666599	9730	17332	338.69	19639
5.07	1436.07	1413.4	1390.0	55	669859	9732	17423	339.69	19717
5.07	1436.04	1413.4	1390.0	55	673129	9734	17515	340.68	19795
5.08	1436.02	1413.3	1390.0	55	676409	9736	17606	341.67	19872
5.08	1435.99	1413.2	1390.0	54	679697	9738	17697	342.65	19950
5.08	1435.96	1413.1	1390.0	54	682996	9739	17789	343.63	20027
5.08	1435.93	1413.0	1390.0	54	686303	9741	17880	344.60	20105
5.08	1435.90	1412.9	1390.0	54	689620	9743	17972	345.57	20182
5.08	1435.87	1412.8	1390.0	54	692946	9745	18063	346.54	20259
5.08	1435.84	1412.8	1390.0	53	696282	9747	18155	347.50	20336
5.08	1435.81	1412.7	1390.0	53	699627	9748	18246	348.45	20413
5.08	1435.78	1412.6	1390.0	53	702980	9750	18338	349.40	20490
5.08	1435.75	1412.5	1390.0	53	706343	9752	18430	350.34	20566
5.09	1435.72	1412.4	1390.0	53	709715	9754	18521	351.28	20643
5.09	1435.68	1412.3	1390.0	52	713096	9756	18613	352.21	20719
5.09	1435.65	1412.2	1390.0	52	716486	9757	18704	353.13	20795
5.09	1435.62	1412.2	1390.0	52	719885	9759	18795	354.05	20871
5.09	1435.59	1412.1	1390.0	52	723292	9761	18887	354.96	20947
5.09	1435.55	1412.0	1390.0	51	726708	9763	18978	355.87	21022
5.09	1435.52	1411.9	1390.0	51	730133	9765	19069	356.77	21098
5.09	1435.49	1411.8	1390.0	51	733567	9766	19160	357.66	21173
5.09	1435.45	1411.7	1390.0	51	737009	9768	19251	358.55	21247
5.09	1435.42	1411.6	1390.0	51	740459	9770	19341	359.43	21322
5.10	1435.38	1411.5	1390.0	50	743918	9772	19432	360.30	21396
5.10	1435.35	1411.5	1390.0	50	747386	9774	19522	361.16	21470
5.10	1435.31	1411.4	1390.0	50	750861	9775	19612	362.02	21543
5.10	1435.27	1411.3	1390.0	50	754345	9777	19702	362.87	21616
5.10	1435.24	1411.2	1390.0	50	757837	9779	19792	363.70	21689
5.10	1435.20	1411.1	1390.0	49	761336	9781	19881	364.53	21762
5.10	1435.16	1411.0	1390.0	49	764844	9783	19971	365.35	21834
5.10	1435.12	1410.9	1390.0	49	768360	9784	20059	366.17	21906
5.10	1435.09	1410.8	1390.0	49	771883	9786	20148	366.97	21977
5.10	1435.05	1410.7	1390.0	49	775414	9788	20237	367.77	22048

5.11	1435.01	1410.7	1390.0	48	778953	9790	20325	368.55	22119
5.11	1434.97	1410.6	1390.0	48	782499	9792	20413	369.33	22189
5.11	1434.93	1410.5	1390.0	48	786052	9793	20501	370.10	22259
5.11	1434.89	1410.4	1390.0	48	789613	9795	20589	370.87	22329
5.11	1434.85	1410.3	1390.0	48	793182	9797	20677	371.63	22399
5.11	1434.81	1410.2	1390.0	47	796757	9799	20765	372.39	22469
5.11	1434.77	1410.1	1390.0	47	800340	9801	20853	373.14	22539
5.11	1434.72	1410.0	1390.0	47	803930	9802	20941	373.89	22609
5.11	1434.68	1409.9	1390.0	47	807528	9804	21029	374.63	22679
5.11	1434.64	1409.8	1390.0	46	811132	9806	21117	375.37	22749
5.12	1434.60	1409.7	1390.0	46	814744	9808	21205	376.10	22819
5.12	1434.56	1409.7	1390.0	46	818362	9810	21293	376.83	22889
5.12	1434.51	1409.6	1390.0	46	821987	9811	21381	377.55	22959
5.12	1434.47	1409.5	1390.0	46	825620	9813	21469	378.26	23028
5.12	1434.43	1409.4	1390.0	45	829259	9815	21557	378.98	23098
5.12	1434.38	1409.3	1390.0	45	832905	9817	21644	379.68	23168
5.12	1434.34	1409.2	1390.0	45	836558	9819	21732	380.38	23237
5.12	1434.30	1409.1	1390.0	45	840217	9820	21820	381.07	23307
5.12	1434.25	1409.0	1390.0	44	843883	9822	21908	381.76	23376
5.12	1434.21	1408.9	1390.0	44	847556	9824	21996	382.45	23446
5.13	1434.16	1408.8	1390.0	44	851235	9826	22083	383.13	23515
5.13	1434.12	1408.7	1390.0	44	854921	9828	22171	383.80	23584
5.13	1434.07	1408.6	1390.0	44	858613	9829	22258	384.46	23653
5.13	1434.03	1408.6	1390.0	43	862311	9831	22346	385.12	23723
5.13	1433.98	1408.5	1390.0	43	866016	9833	22434	385.78	23792
5.13	1433.93	1408.4	1390.0	43	869727	9835	22521	386.43	23861
5.13	1433.89	1408.3	1390.0	43	873445	9837	22608	387.07	23930
5.13	1433.84	1408.2	1390.0	43	877168	9838	22696	387.71	23999
5.13	1433.79	1408.1	1390.0	42	880897	9840	22783	388.34	24068
5.13	1433.75	1408.0	1390.0	42	884633	9842	22870	388.96	24136
5.14	1433.70	1407.9	1390.0	42	888374	9844	22957	389.58	24205
5.14	1433.65	1407.8	1390.0	42	892122	9846	23044	390.19	24274
5.14	1433.60	1407.7	1390.0	41	895875	9847	23131	390.80	24342
5.14	1433.55	1407.6	1390.0	41	899634	9849	23218	391.39	24411
5.14	1433.50	1407.5	1390.0	41	903399	9851	23305	391.99	24479
5.14	1433.46	1407.4	1390.0	41	907169	9853	23392	392.57	24548
5.14	1433.41	1407.3	1390.0	41	910945	9855	23478	393.15	24616
5.14	1433.36	1407.2	1390.0	40	914727	9856	23565	393.73	24684
5.14	1433.31	1407.1	1390.0	40	918514	9858	23651	394.29	24752
5.14	1433.26	1407.0	1390.0	40	922307	9860	23737	394.85	24820
5.15	1433.21	1407.0	1390.0	40	926104	9862	23824	395.41	24889
5.15	1433.15	1406.9	1390.0	39	929907	9864	23910	395.95	24956
5.15	1433.10	1406.8	1390.0	39	933716	9865	23996	396.49	25024
5.15	1433.05	1406.7	1390.0	39	937529	9867	24082	397.02	25092
5.15	1433.00	1406.6	1390.0	39	941348	9869	24167	397.55	25160
5.15	1432.95	1406.5	1390.0	38	945171	9871	24253	398.07	25227
5.15	1432.90	1406.4	1390.0	38	949000	9873	24338	398.58	25295
5.15	1432.84	1406.3	1390.0	38	952833	9874	24424	399.08	25362
5.15	1432.79	1406.2	1390.0	38	956671	9876	24509	399.58	25430
5.15	1432.74	1406.1	1390.0	38	960514	9878	24594	400.07	25497
5.16	1432.68	1406.0	1390.0	37	964362	9880	24679	400.56	25565
5.16	1432.63	1405.9	1390.0	37	968214	9882	24764	401.03	25632
5.16	1432.57	1405.8	1390.0	37	972071	9883	24848	401.50	25699
5.16	1432.52	1405.7	1390.0	37	975932	9885	24933	401.96	25766
5.16	1432.47	1405.6	1390.0	36	979797	9887	25017	402.41	25833
5.16	1432.41	1405.5	1390.0	36	983667	9889	25101	402.86	25899
5.16	1432.35	1405.4	1390.0	36	987541	9891	25185	403.29	25966
5.16	1432.30	1405.3	1390.0	36	991420	9892	25268	403.72	26033
5.16	1432.24	1405.2	1390.0	35	995302	9894	25352	404.14	26100
5.16	1432.19	1405.1	1390.0	35	999188	9896	25435	404.56	26166
5.17	1432.13	1405.0	1390.0	35	1003079	9898	25518	404.96	26233
5.17	1432.07	1404.9	1390.0	35	1006973	9900	25601	405.37	26299
5.17	1432.02	1404.8	1390.0	35	1010871	9901	25684	405.76	26365
5.17	1431.96	1404.7	1390.0	34	1014773	9903	25766	406.14	26432
5.17	1431.90	1404.6	1390.0	34	1018678	9905	25849	406.51	26498
5.17	1431.84	1404.5	1390.0	34	1022587	9907	25931	406.88	26564

5.17	1431.78	1404.4	1390.0	34	1026499	9909	26013	407.23	26630
5.17	1431.72	1404.3	1390.0	33	1030415	9910	26094	407.58	26696
5.17	1431.66	1404.2	1390.0	33	1034334	9912	26176	407.92	26762
5.17	1431.61	1404.1	1390.0	33	1038256	9914	26257	408.26	26828
5.18	1431.55	1404.0	1390.0	33	1042182	9916	26338	408.58	26894
5.18	1431.49	1403.9	1390.0	32	1046110	9918	26419	408.89	26960
5.18	1431.42	1403.8	1390.0	32	1050042	9919	26499	409.20	27026
5.18	1431.36	1403.7	1390.0	32	1053976	9921	26579	409.49	27091
5.18	1431.30	1403.6	1390.0	32	1057913	9923	26659	409.78	27157
5.18	1431.24	1403.5	1390.0	32	1061853	9925	26739	410.06	27223
5.18	1431.18	1403.4	1390.0	31	1065796	9927	26818	410.33	27288
5.18	1431.12	1403.3	1390.0	31	1069741	9928	26897	410.59	27354
5.18	1431.05	1403.2	1390.0	31	1073689	9930	26976	410.84	27420
5.18	1430.99	1403.1	1390.0	31	1077639	9932	27054	411.09	27486
5.19	1430.93	1403.0	1390.0	30	1081591	9934	27132	411.32	27551
5.19	1430.86	1402.9	1390.0	30	1085545	9936	27210	411.55	27617
5.19	1430.80	1402.8	1390.0	30	1089502	9937	27288	411.76	27683
5.19	1430.74	1402.7	1390.0	30	1093460	9939	27365	411.96	27749
5.19	1430.67	1402.6	1390.0	29	1097421	9941	27442	412.16	27815
5.19	1430.61	1402.5	1390.0	29	1101383	9943	27518	412.34	27881
5.19	1430.54	1402.4	1390.0	29	1105347	9945	27594	412.52	27947
5.19	1430.47	1402.3	1390.0	29	1109313	9946	27670	412.68	28013
5.19	1430.41	1402.2	1390.0	28	1113280	9948	27745	412.83	28080
5.19	1430.34	1402.1	1390.0	28	1117248	9950	27820	412.98	28146
5.20	1430.27	1402.0	1390.0	28	1121218	9952	27895	413.11	28214
5.20	1430.21	1401.9	1390.0	28	1125189	9954	27969	413.23	28281
5.20	1430.14	1401.8	1390.0	27	1129161	9955	28042	413.35	28349
5.20	1430.07	1401.7	1390.0	27	1133135	9957	28116	413.45	28419
5.20	1430.00	1401.6	1390.0	27	1137109	9959	28189	413.54	28489
5.20	1429.93	1401.5	1390.0	27	1141084	9961	28261	413.62	28561
5.20	1429.86	1401.4	1390.0	26	1145060	9963	28333	413.69	28633
5.20	1429.79	1401.3	1390.0	26	1149036	9964	28405	413.74	28705
5.20	1429.72	1401.2	1390.0	26	1153013	9966	28476	413.78	28776
5.20	1429.65	1401.1	1390.0	26	1156990	9968	28546	413.82	28846
5.21	1429.58	1401.0	1390.0	25	1160967	9970	28616	413.84	28916
5.21	1429.51	1400.9	1390.0	25	1164945	9972	28686	413.85	28986
5.21	1429.44	1400.8	1390.0	25	1168922	9973	28755	413.85	29055
5.21	1429.37	1400.7	1390.0	25	1172900	9975	28823	413.83	29123
5.21	1429.29	1400.6	1390.0	24	1176877	9977	28891	413.81	29191
5.21	1429.22	1400.5	1390.0	24	1180854	9979	28958	413.77	29258
5.21	1429.15	1400.4	1390.0	24	1184831	9981	29025	413.71	29325
5.21	1429.07	1400.3	1390.0	24	1188807	9982	29091	413.65	29391
5.21	1429.00	1400.1	1390.0	23	1192782	9984	29157	413.57	29457
5.21	1428.92	1400.0	1390.0	23	1196756	9986	29222	413.49	29522
5.22	1428.85	1399.9	1390.0	23	1200730	9988	29286	413.39	29586
5.22	1428.77	1399.8	1390.0	23	1204703	9990	29351	413.27	29651
5.22	1428.70	1399.7	1390.0	23	1208674	9991	29414	413.14	29714
5.22	1428.62	1399.6	1390.0	22	1212644	9993	29476	413.01	29776
5.22	1428.54	1399.5	1390.0	22	1216613	9995	29538	412.86	29838
5.22	1428.47	1399.4	1390.0	22	1220580	9997	29600	412.69	29900
5.22	1428.39	1399.3	1390.0	22	1224546	9999	29661	412.51	29961
5.22	1428.31	1399.2	1390.0	21	1228509	10000	29721	412.32	30021
5.22	1428.23	1399.1	1390.0	21	1232471	10002	29781	412.12	30081
5.22	1428.15	1399.0	1390.0	21	1236431	10004	29839	411.90	30139
5.23	1428.07	1398.9	1390.0	21	1240389	10006	29898	411.67	30198
5.23	1427.99	1398.8	1390.0	20	1244344	10008	29955	411.43	30255
5.23	1427.91	1398.7	1390.0	20	1248297	10009	30013	411.18	30313
5.23	1427.83	1398.6	1390.0	20	1252248	10011	30069	410.91	30369
5.23	1427.75	1398.5	1390.0	19	1256196	10013	30125	410.63	30425
5.23	1427.67	1398.3	1390.0	19	1260141	10015	30180	410.33	30480
5.23	1427.58	1398.2	1390.0	19	1264083	10017	30234	410.02	30534
5.23	1427.50	1398.1	1390.0	19	1268022	10018	30288	409.70	30588
5.23	1427.42	1398.0	1390.0	18	1271958	10020	30341	409.36	30641
5.23	1427.33	1397.9	1390.0	18	1275891	10022	30393	409.01	30693
5.24	1427.25	1397.8	1390.0	18	1279820	10024	30445	408.66	30745
5.24	1427.17	1397.7	1390.0	18	1283746	10026	30496	408.28	30796

5.24	1427.08	1397.6	1390.0	17	1287668	10027	30546	407.89	30846
5.24	1426.99	1397.5	1390.0	17	1291586	10029	30595	407.48	30895
5.24	1426.91	1397.4	1390.0	17	1295500	10031	30644	407.07	30944
5.24	1426.82	1397.3	1390.0	17	1299411	10033	30692	406.63	30992
5.24	1426.74	1397.2	1390.0	16	1303317	10035	30739	406.19	31039
5.24	1426.65	1397.1	1390.0	16	1307218	10036	30786	405.73	31086
5.24	1426.56	1397.0	1390.0	16	1311115	10038	30832	405.25	31132
5.24	1426.47	1396.8	1390.0	16	1315008	10040	30877	404.77	31177
5.25	1426.38	1396.7	1390.0	15	1318896	10042	30921	404.26	31221
5.25	1426.29	1396.6	1390.0	15	1322778	10044	30964	403.75	31264
5.25	1426.20	1396.5	1390.0	15	1326656	10045	31007	403.22	31307
5.25	1426.11	1396.4	1390.0	15	1330529	10047	31049	402.67	31349
5.25	1426.02	1396.3	1390.0	14	1334396	10049	31090	402.11	31390
5.25	1425.93	1396.2	1390.0	14	1338258	10051	31130	401.54	31430
5.25	1425.84	1396.1	1390.0	14	1342115	10053	31170	400.95	31470
5.25	1425.75	1396.0	1390.0	14	1345965	10054	31209	400.35	31509
5.25	1425.66	1395.9	1390.0	13	1349810	10056	31247	399.73	31547
5.25	1425.56	1395.8	1390.0	13	1353648	10058	31283	399.10	31583
5.26	1425.47	1395.6	1390.0	13	1357481	10060	31320	398.45	31620
5.26	1425.37	1395.5	1390.0	13	1361307	10062	31355	397.79	31655
5.26	1425.28	1395.4	1390.0	12	1365127	10063	31390	397.11	31690
5.26	1425.18	1395.3	1390.0	12	1368940	10065	31424	396.42	31724
5.26	1425.09	1395.2	1390.0	12	1372747	10067	31457	395.72	31757
5.26	1424.99	1395.1	1390.0	12	1376547	10069	31488	395.00	31788
5.26	1424.90	1395.0	1390.0	11	1380339	10071	31520	394.26	31820
5.26	1424.80	1394.9	1390.0	11	1384125	10072	31549	393.51	31849
5.26	1424.70	1394.8	1390.0	11	1387903	10074	31578	392.74	31878
5.26	1424.60	1394.7	1390.0	10	1391674	10076	31606	391.94	31906
5.27	1424.50	1394.5	1390.0	10	1395437	10078	31632	391.13	31932
5.27	1424.40	1394.4	1390.0	10	1399192	10080	31657	390.31	31957
5.27	1424.30	1394.3	1390.0	10	1402939	10081	31681	389.46	31981
5.27	1424.20	1394.2	1390.0	9	1406678	10083	31704	388.60	32004
5.27	1424.10	1394.1	1390.0	9	1410408	10085	31726	387.72	32026
5.27	1424.00	1394.0	1390.0	9	1414130	10087	31746	386.82	32046
5.27	1423.90	1393.9	1390.0	9	1417843	10089	31766	385.90	32066
5.27	1423.79	1393.8	1390.0	8	1421547	10090	31784	384.96	32084
5.27	1423.69	1393.7	1390.0	8	1425242	10092	31800	384.00	32100
5.27	1423.59	1393.5	1390.0	8	1428928	10094	31816	383.02	32116
5.28	1423.48	1393.4	1390.0	8	1432604	10096	31830	382.03	32130
5.28	1423.37	1393.3	1390.0	7	1436271	10098	31843	381.02	32143
5.28	1423.27	1393.2	1390.0	7	1439927	10099	31854	379.98	32154
5.28	1423.16	1393.1	1390.0	7	1443574	10101	31864	378.93	32164
5.28	1423.05	1393.0	1390.0	7	1447211	10103	31873	377.85	32173
5.28	1422.94	1392.9	1390.0	6	1450837	10105	31880	376.76	32180
5.28	1422.83	1392.8	1390.0	6	1454452	10107	31886	375.65	32186
5.28	1422.72	1392.6	1390.0	6	1458057	10108	31891	374.52	32191
5.28	1422.61	1392.5	1390.0	5	1461651	10110	31894	373.36	32194
5.28	1422.50	1392.4	1390.0	5	1465233	10112	31896	372.19	32196
5.29	1422.39	1392.3	1390.0	5	1468804	10114	31896	371.00	32196
5.29	1422.28	1392.2	1390.0	5	1472364	10116	31894	369.78	32194
5.29	1422.16	1392.1	1390.0	4	1475912	10117	31891	368.54	32191
5.29	1422.05	1392.0	1390.0	4	1479447	10119	31887	367.29	32187
5.29	1421.94	1391.9	1390.0	4	1482971	10121	31880	366.01	32180
5.29	1421.82	1391.8	1390.0	4	1486482	10123	31873	364.71	32173
5.29	1421.70	1391.6	1390.0	3	1489981	10125	31864	363.39	32164
5.29	1421.59	1391.5	1390.0	3	1493466	10126	31853	362.05	32153
5.29	1421.47	1391.4	1390.0	3	1496939	10128	31840	360.68	32140
5.29	1421.35	1391.3	1390.0	3	1500399	10130	31826	359.30	32126
5.30	1421.23	1391.2	1390.0	2	1503845	10132	31810	357.90	32110
5.30	1421.11	1391.1	1390.0	2	1507277	10134	31793	356.46	32093
5.30	1420.99	1391.0	1390.0	2	1510696	10135	31774	355.01	32074
5.30	1420.87	1390.9	1390.0	1	1514101	10137	31753	353.54	32053
5.30	1420.74	1390.7	1390.0	1	1517491	10139	31730	352.05	32030
5.30	1420.62	1390.6	1390.0	1	1520867	10141	31705	350.53	32005
5.30	1420.50	1390.5	1390.0	1	1524228	10143	31679	348.99	31979
5.30	1420.37	1390.0	1390.0	0	1527574	10144	32551	0.00	32851

5.30	1420.24	1390.0	1390.0	0	1527574	10146	32250	0.00	32550
5.30	1420.11	1390.0	1390.0	0	1527574	10148	31951	0.00	32251
5.31	1419.98	1390.0	1390.0	0	1527574	10150	31656	0.00	31956
5.31	1419.85	1390.0	1390.0	0	1527574	10152	31364	0.00	31664
5.31	1419.72	1390.0	1390.0	0	1527574	10153	31075	0.00	31375
5.31	1419.60	1390.0	1390.0	0	1527574	10155	30789	0.00	31089
5.31	1419.47	1390.0	1390.0	0	1527574	10157	30506	0.00	30806
5.31	1419.34	1390.0	1390.0	0	1527574	10159	30226	0.00	30526
5.31	1419.22	1390.0	1390.0	0	1527574	10161	29949	0.00	30249
5.31	1419.09	1390.0	1390.0	0	1527574	10162	29675	0.00	29975
5.31	1418.97	1390.0	1390.0	0	1527574	10164	29403	0.00	29703
5.31	1418.85	1390.0	1390.0	0	1527574	10166	29135	0.00	29435
5.32	1418.72	1390.0	1390.0	0	1527574	10168	28869	0.00	29169
5.32	1418.60	1390.0	1390.0	0	1527574	10170	28606	0.00	28906
5.32	1418.48	1390.0	1390.0	0	1527574	10171	28346	0.00	28646
5.32	1418.36	1390.0	1390.0	0	1527574	10173	28088	0.00	28388
5.32	1418.24	1390.0	1390.0	0	1527574	10175	27833	0.00	28133
5.32	1418.12	1390.0	1390.0	0	1527574	10177	27581	0.00	27881
5.32	1418.00	1390.0	1390.0	0	1527574	10179	27332	0.00	27632
5.32	1417.88	1390.0	1390.0	0	1527574	10180	27085	0.00	27385
5.32	1417.76	1390.0	1390.0	0	1527574	10182	26841	0.00	27141
5.32	1417.65	1390.0	1390.0	0	1527574	10184	26599	0.00	26899
5.33	1417.53	1390.0	1390.0	0	1527574	10186	26360	0.00	26660
5.33	1417.42	1390.0	1390.0	0	1527574	10188	26123	0.00	26423
5.33	1417.30	1390.0	1390.0	0	1527574	10189	25889	0.00	26189
5.33	1417.19	1390.0	1390.0	0	1527574	10191	25657	0.00	25957
5.33	1417.07	1390.0	1390.0	0	1527574	10193	25428	0.00	25728
5.33	1416.96	1390.0	1390.0	0	1527574	10195	25202	0.00	25502
5.33	1416.85	1390.0	1390.0	0	1527574	10197	24977	0.00	25277
5.33	1416.73	1390.0	1390.0	0	1527574	10198	24755	0.00	25055
5.33	1416.62	1390.0	1390.0	0	1527574	10200	24536	0.00	24836
5.33	1416.51	1390.0	1390.0	0	1527574	10202	24319	0.00	24619
5.34	1416.40	1390.0	1390.0	0	1527574	10204	24104	0.00	24404
5.34	1416.29	1390.0	1390.0	0	1527574	10206	23891	0.00	24191
5.34	1416.18	1390.0	1390.0	0	1527574	10207	23681	0.00	23981
5.34	1416.07	1390.0	1390.0	0	1527574	10209	23473	0.00	23773
5.34	1415.97	1390.0	1390.0	0	1527574	10211	23267	0.00	23567
5.34	1415.86	1390.0	1390.0	0	1527574	10213	23063	0.00	23363
5.34	1415.75	1390.0	1390.0	0	1527574	10215	22862	0.00	23162
5.34	1415.65	1390.0	1390.0	0	1527574	10216	22663	0.00	22963
5.34	1415.54	1390.0	1390.0	0	1527574	10218	22466	0.00	22766
5.34	1415.44	1390.0	1390.0	0	1527574	10220	22271	0.00	22571
5.35	1415.33	1390.0	1390.0	0	1527574	10222	22078	0.00	22378
5.35	1415.23	1390.0	1390.0	0	1527574	10224	21888	0.00	22188
5.35	1415.13	1390.0	1390.0	0	1527574	10225	21699	0.00	21999
5.35	1415.02	1390.0	1390.0	0	1527574	10227	21513	0.00	21813
5.35	1414.92	1390.0	1390.0	0	1527574	10229	21329	0.00	21629
5.36	1413.96	1390.0	1390.0	0	1527574	10247	19623	0.00	19923
5.37	1413.09	1390.0	1390.0	0	1527574	10265	18149	0.00	18449
5.38	1412.30	1390.0	1390.0	0	1527574	10283	16880	0.00	17180
5.39	1411.60	1390.0	1390.0	0	1527574	10301	15791	0.00	16091
5.40	1410.98	1390.0	1390.0	0	1527574	10319	14860	0.00	15160
5.41	1410.43	1390.0	1390.0	0	1527574	10337	14067	0.00	14367
5.42	1409.95	1390.0	1390.0	0	1527574	10355	13396	0.00	13696
5.43	1409.54	1390.0	1390.0	0	1527574	10373	12837	0.00	13137
5.44	1409.20	1390.0	1390.0	0	1527574	10391	12376	0.00	12676
5.45	1408.91	1390.0	1390.0	0	1527574	10409	11996	0.00	12296
5.46	1408.66	1390.0	1390.0	0	1527574	10427	11683	0.00	11983
5.47	1408.46	1390.0	1390.0	0	1527574	10445	11426	0.00	11726
5.48	1408.29	1390.0	1390.0	0	1527574	10463	11215	0.00	11515
5.49	1408.16	1390.0	1390.0	0	1527574	10481	11042	0.00	11342
5.50	1408.04	1390.0	1390.0	0	1527574	10499	10901	0.00	11201
5.51	1407.94	1390.0	1390.0	0	1527574	10430	10779	0.00	11079
5.52	1407.85	1390.0	1390.0	0	1527574	10358	10666	0.00	10966
5.53	1407.76	1390.0	1390.0	0	1527574	10286	10559	0.00	10859
5.54	1407.68	1390.0	1390.0	0	1527574	10214	10459	0.00	10759

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8000 DATA 1445, 63.8, 1435, 25.5, 1430, 22.1, 1425, 18.5, 1415, 9.3, 1410,6.2,13
90.0, 0, 0
8001 DATA 1430,19
8002 DATA 0.300,.5,300,1.300,1.5,410,2,900,2.5,1600,3,2250,3.5,2750,4,4500,4.5,6
800,5,9600,5.5,10500,6,6900,6.5,4200,7,2550,7.5,1600,8,1050,8.5,530,9,310
8003 DATA .25
8004 DATA 1430,133.30,0,0,1437
8005 DATA 2.46, 1390,17.0, 300
8006 DATA 25.0, 24, .25, 168.5, 62.4, 23,.32
8007 DATA .00330, .0163, .0660, .025
8008 DATA 20, 625, 3, 2
8009 DATA 26.56, 18.26, 0.466
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APPENDIX B

TABLE B-1

DESCRIPTION OF THE INPUT PARAMETERS AND VARIABLES
FOR THE DAM BREAK MODEL #1

Variable	Description
HSA(I)	elevation in Feet corresponding to a surface area with the same subscript*
SA(I)	surface area in Acres corresponding to an elevation with the same subscript*
YO	initial water surface elevation
ITEH	number of inflow hydrograph data points
T(I)	time in Hours corresponding to an inflow with the same subscript
I(I)	an inflow in cubic feet per second corresponding to a time with the same subscript
DT	the initial time interval in Hours
Z	breach side slope inverse
HM	minimum elevation of the dam
HS	spillway elevation
CS	spillway coefficient
HG	gate elevation
CG	gate coefficient
HD	dam elevation
B	maximum (terminal) breach width in feet
QK	constant outflow in CFS
S1	internal angle of friction of mixture in degrees
TH	angle of repose of mixture in degrees
N	Maning's coefficient of friction of mixture

TABLE B-1 (continued)

Variable	Description
PR	porosity of mixture
GS	specific weight of mixture
GA	specific weight of water
PI	placticity index of mixture
TC	Shield's critical shear stress in pound per cubic feet
D3	grain size at which 30% of a total weight is finer
D5	grain size at which 50% of a total weight is finer
D9	grain size at which 90% of a total weight is finer
W	the width of the dam's crest in feet
CL	the length of the dam's crest in feet
ZL	the upstream embankment slope inverse
ZR	the downstream embankment slope inverse
BR	the angle which the downstream face of the dam makes with the horizon
BL	the angle which the upstream face of the dame makes with the horizon

*Eight SA and HSA values are required--subscript of 0 must be the maximum value decreasing to 7 which is the minimum value.

Data is entered in the program in lines 8000 to 8009, using the Data statement. The following demonstrates the necessary input information:

```
8000        DATA HSA(0), SA(0), HSA(10, SA(1), ... HSA(7), SA(7)

80001       DATA YO, HF, ITEH

8002        DATA T(0), I(0), T(1), I(1), ... T(ITEH-1), I(ITEH-1)

8003        DATA DT

8004        DATA HS, CS, HG, CG, HD

8005        DATA Z, HM, B, QK

8006        DATA AS1, TH, N, PR, GS, CA, PI, TOC

8007        DATA D3, DS, D9

8008        DATA 2, CL, ZL, ZR

8009        DATA BR, BL
```

TABLE B-2

INTERNAL VARIABLES LISTING--DAM BREAK PROGRAM #1

Variable	Description
I	a general loop counter
YI	depth in Feet corresponding to the maximum reservoir storage--YI is equal to the greater of YO or HF
VOL	reservoir volume in Acre-Feet
M	slope value used for interpolation
AS	an interpolated surface area in Acres
H1	water surface elevation at T1 in Feet
I1	inflow in CFS at time T1
H	equal to either H1 or H2--used to send a depth to a subroutine to compute surface area or flow-in Feet
AS1	surface area in Acrea at time T1
QS	spillway outflow in CFS
QG	gate outflow in CFS
QD	dam overflow in CFS
QK	constant outflow in CFS
QB	breach outflow in CFS
Q1	total outflow in CFS at time T1
T1	time in Hours
T2	time at T1 + DT in Hours
W	breach width in Feet
H2	water surface elevation in Feet at time T2
AS2	surface area in Acres at time T2

TABLE B-2 (continued)

Variable	Description
I2	inflow in CFS at time T2
QMAX	peak outflow in CFS
HEAD	used to calculate outflows--head is equal to the difference between H (water elevation) and the bottom of the outflow channel--in Feet
C1	breach outflow coefficient (triangular wier)
C2	breach outflow coefficient (rectangular wier)
R	used in the iteration process for convergence
Q2	total outflow corresponding to H2 in CFS
FUNCT	hydrologic storage equation used in the iteration process
DERIV	derivative of the hydrologic storage equation--used in the iteration process
DS	derivative of the QS equation
DG	derivative of the QG equation
DD	derivative of the QD equation
DB	derivative of the QB equation
NH2	newly iterated value for H2 in Feet
DC	the maximum depth encountered in the breach channel in feet
NDC	newly iterated value for DC in feet
K1, K2, K3	used as loop counters
DT	computational time interval in hours
TC	the top width corresponding to the greatest depth encountered in the breach channel

TABLE B-2 (continued)

Variable	Description
HB	bottom elevation of the highest point of breach channel in feet
HR	bottom elevation of the lowest point of breach channel in feet
L	length of the breach channel in feet
SQ	volume flow rate of the eroded soil (bed load) in CFS
V	volume of embankment soil and voids in cubic feet
FU	the Geometric volumetric equation used in the iteration
DR	the derivative of the geometric volumetric equation used in the iteration
OT	overland shear of the breach channel in pounds per square foot
D	depth of water in the breach channel in feet

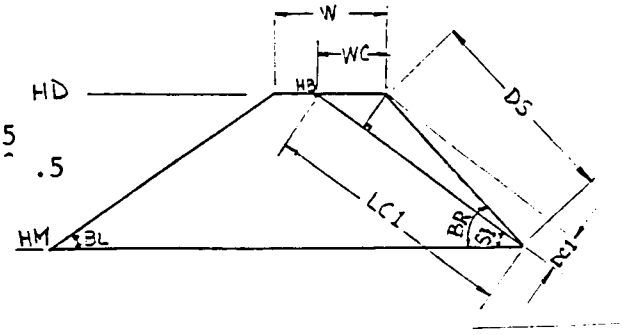
APPENDIX C

Geometric Volumetric Derivation

Condition : SI < BR and WC < W

Zone I

DC = Unknown

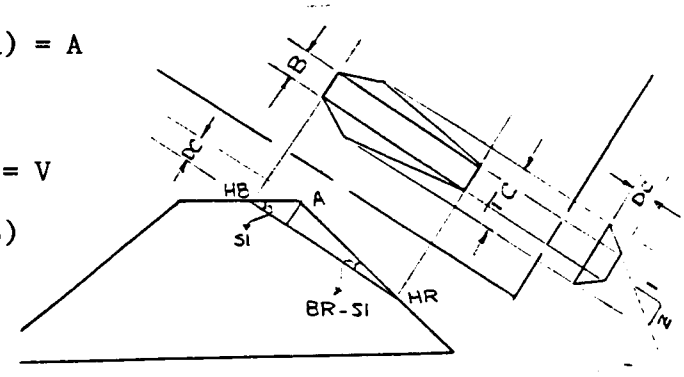


1. DS = ((DH^2) + (ZR*DH)^2) ^ .5
2. WC = (DS * SIN(BR - SI)) ^2) ^ .5
3. b = TAN(SI)
4. a = TAN(BR - SI)
5. L = a + b

Substituting for a and b in equation 5:

6. L = DC * (1/TAN(SI) + 1/TAN(BR - SI)

Area of the triangle (A,HB,HR) = A



7. A = 0.5 * L * DC

Volume of the breach channel = V

8. V = A * ((B + B + TC)/3)

where:

9. TC = B + 2 * Z * DC

Substituting for A and TC in equation 8:

10. V = (1/2) * ((1/TAN(SI) + (1/TAN(BR - SI)) * (B * dc ^ 2 + 0.66 * DC ^ 3)

FUNCTION = EQUATION 10 SET TO ZERO

DERIVATIVE = -2 * B * DC + 2 * Z * DC ^ 2

11. NDC = DC - FUNCTION / DERIVATIVE

where NDC is the new depth.

Supplementry Information:

12. LC1 = (HD = HM) / SIN(SI)

13. HB = HD & HR = HD - L * SIN(SI)

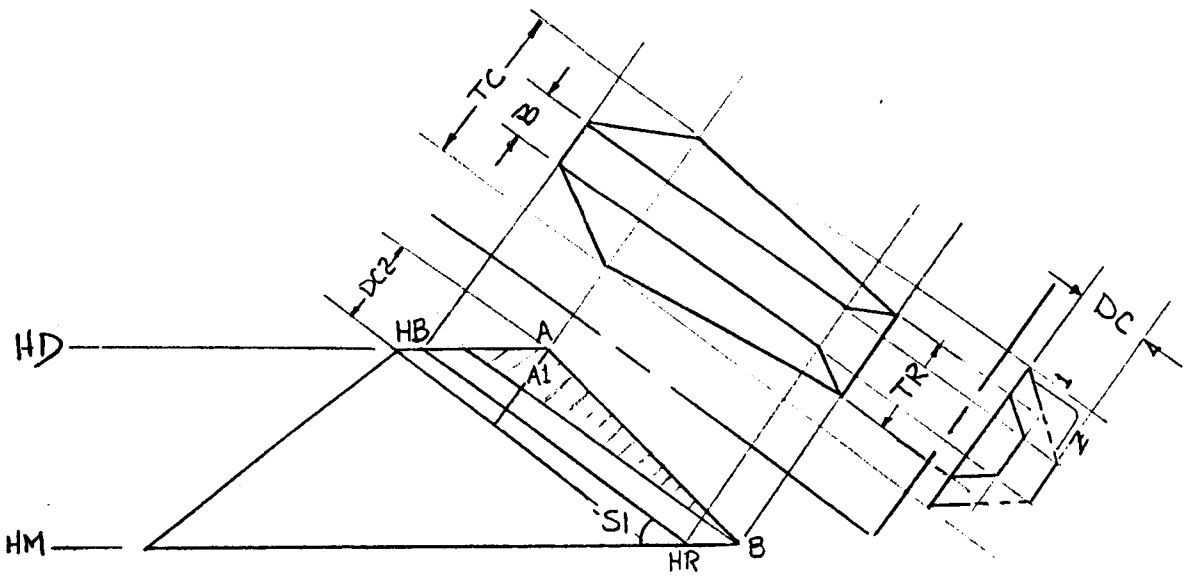
IF DC = > DC1 OR L = > LC1 GO TO ZONE II

ZONE II

1. A1 = 0.5 * DC1 * LC1
2. L = LC1 = (HD - HM) / SIN(SI)
3. HR = HM AND HB = HD
4. A = A1 + AREA OF (HB,A,B,HR)
5. A = A1 + (DC = CD1) * LC1
6. V = A * (B + B + TB + TC)
7. TR = B + 2 * Z * (DC - DC1)
8. TC = B + 2 * Z * DC
9. FUNCTION = V - A * (B + B + TR + TC)
10. DERIVATIVE = -LC1 * (B + 2 * Z * (DC - 0.5 * DC1)
11. NDC = DC - FUNCTION / DERIVATIVE

Supplementary Information:

12. DC2 = W * SIN(SI)
13. IF DC = > DC2 OR L = > LC1 GO TO ZONE III



ZONE III

AT = TOTAL AREA OF THE TRAPEZOID (DAM CROSS SECTION)

HR = HM

1. AT = 0.5 * (W + BD) * (HD = HM)

WHERE

2. BD = W + HD * (ZR + ZL)

3. TC = B + 2 * Z * DC

4. TB = B + 2 * Z * (DC - DC2)

5. TR = B + 2 * Z * (DC - DC1)

6. A = AT - AREA OF TRIANBLE (A,HB,HR)

7. A = AT - A * (BD - LB) * 0.5

WHERE

8. LB = (DC - DC1) / SIN(SI)

9. A = (BD - LB) / (1 / TAN(BL) + 1 / TAN(SI)

THEREFDORE

10. A = AT - ((BD - LB) ^ 2 / (1 / TAN(SI) + 1 / TAN(BL)0

11. V = A * (B + B + TC + TB + TR) / 5

12. FUNCTION = V - A * (B + B + TR + TB) / 5

13. DERIVATIVE = 1.2 * AT * Z - (0.5 * (SIN(SI)) ^ 2) + CON * (1.2 * (BD * SIN(SI) + DC1) * Z - DC * (2 * B + 0.8 * Z * (DC2 + DC1)) + 3.6 * Z * (DC ^ 2))

WHERE

CON = 1 / TAN(SI) + 1 / TAN(BL)

14. NDC = DC - FUNCTION / DERIVATIVE

Supplementary Information:

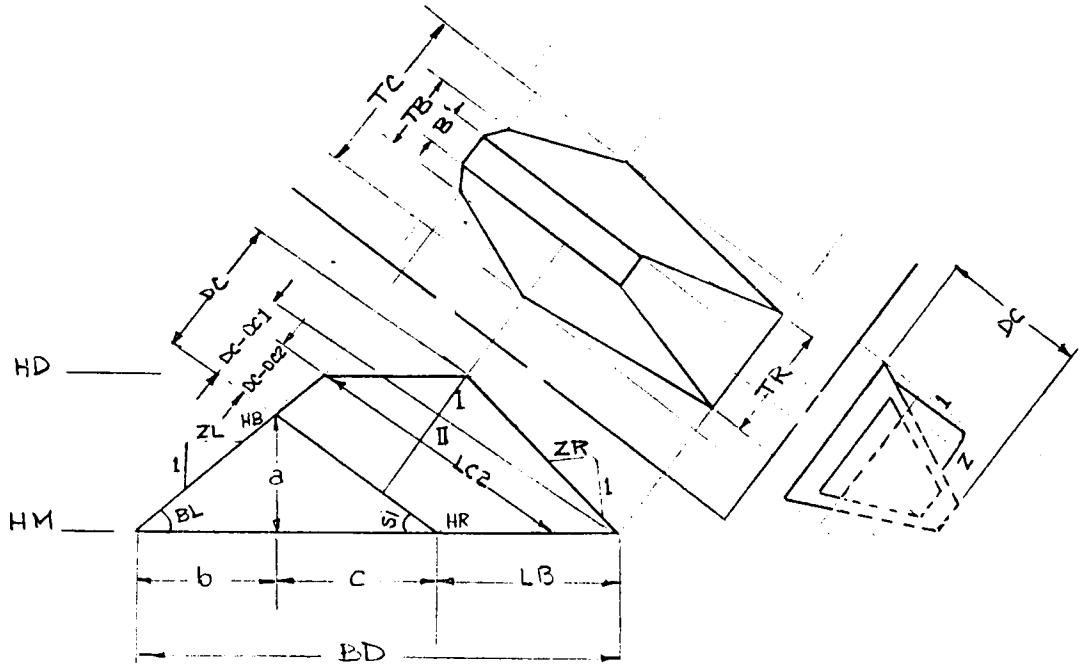
15. HB = HM + (MD - DR) / SIN(SI)) / CON

WHERE

16. DR = DC - DC1

17. L = (HB - HM) / SIN(SI)

IF L = < 1 THEN RETURN TO ...



APPENDIX D

```
C:\GWAN.REZ>CD  \REZA
The IBM Personal Computer Basic
Version A3.30 Copyright IBM Corp. 1981, 1982, 1983, 1984, 1985, 1986, 1987
60225 Bytes free

Ok
LOAD"REZ310
Ok
LIST 8000-
8000 DATA 1445, 63.8, 1435, 25.5, 1430, 22.1, 1425, 18.5, 1415, 9.3, 1410,6.2,13
90,0, 0, 0
8001 DATA 1430,19
8002 DATA 0,300,.5,300,1,300,1.5,410,2,900,2.5,1600,3,2250,3.5,2750,4,4500,4.5,6
800,5,9600,5.5,10500,6,6900,6.5,4200,7,2550,7.5,1600,8,1050,8.5,530,9,310
8003 DATA .25
8004 DATA 1430,266.80,0,0,1437
8005 DATA 1.73, 1390,17.0,0
8006 DATA 25.0, 30, .25, 168.5, 62.4, 23,200
8007 DATA .00330, .0163, .0660, .025
8008 DATA 20, 625, 3, 2
8009 DATA 26.56, 18.26, 0.466
Ok
RUN
Input your output filename:?

1LIST   2RUN  3LOAD"  4SAVE"  5CONT 6,"LPT1 7TRON 8TROFF9KEY    OSCREEN
T

 ---------------------------------------------------------
|                                                         |
|    DAM BREAK PROGRAM - MODEL #1                         |
|    BY: REZA M. MOJIB - JUNE 1989                        |
|                                                         |
 ---------------------------------------------------------


ANALYSIS OF 1977 JOHNSTOWN DAM FAILURE

RUN BY REZA M. MOJIB


ELEVATION (FT)    SURFACE AREA (ACRES)

 1445                    63.8
 1435                    25.5
 1430                    22.1
 1425                    18.5
 1415                    9.3
 1410                    6.2
 1390                    0
 0                       0
```

INITIAL WATER SURFACE ELEVATION (YO) =.....	1430 FT
SPILLWAY ELEVATION (HS) =.....	1430 FEET MSL
SPILLWAY COEFFICIENT OF DISCHARGE (CS) = ...	266.6
GATE ELEVATION (HG) = ...	0 FEET MSL
GATE COEFFICIENT OF DISCHARGE (CG) = ...	0
DAM ELEVATION (HD) = ...	1437 FEET MSL

THE INVERSE OF THE BREACH CHANNEL SIDE SLOPE (Z) =.	1.73
MINIMUM ELEVATION OF THE DAM (HM) = ...	1390 FEET MSL
THE BREACH CHANNEL BOTTOM WIDTH (B) = ...	17 FEET
BASE FLOW OF HTE DAM (QK) = ...	0 CFS

SOIL ANGLE OF FRICTION (SI1) = ...	25 DEGREES
SOIL ANGLE OF REPOSE (TH1) = ...	30 DEGREES
POROSITY OF THE SOIL (PR) = ...	.25
SPECIFIC WEIGHT OF THE SOIL (GS) = ...	160.5 LBS/FT^3
SPECIFIC WEIGHT OF WATER (GA) = ...	62.4 LBS/FT^3
PLASTICITY INDEX OF THE SOIL (PI) = ...	23
CRITICAL SHEAR STERSS OF THE SOIL (TOC) = ...	200 LBS/FT^2

GRAIN SIZE AT WHICH 30% OF TOTAL WEIGHT IS FINER (D3) = ...	.0033 FEET
GRAIN SIZE AT WHICH 50% OF TOTAL WEIGHT IS FINER (D5) = ...	.0163 FEET
GRAIN SIZE AT WHICH 90% OF TOTAL WEIGHT IS FINER (D9) = ...	.066 FEET
MANNING'S COEFFICIENT OF FRICTION (N) =.....	.025

TOP WIDTH OF THE DAM (W) = ...	20 FEET
LENGTH OF THE CREST OF THE DAM (CL) = ...	625 FEET
THE INVERSE OF THE SLOPE OF THE UPSTREAM FACE OF DAM (ZL) = ...	3
THE INVERSE OF THE SLOPE OF THE DOWNSTREAM FACE OF DAM (ZR) = ..	2
THE ANGLE WHICH DOWNSTREAM FACE OF DAM MAKES WITH HORIZON (BR1) =	26.56 DEGREES
THE ANGLE WHICH UPSTREAM FACE OF DAM MAKES WITH HORIZON (BL1) =.	18.26 DEGREES
THE SLOPE OF THE BREACH CHANNEL (S) =.....	.466

INFLOW HYDROGRAPH

TIME (HRS)	INFLOW (CFS)
0	300
.5	300
1	300
1.5	410
2	900
2.5	1600
3	2250
3.5	2750
4	4500
4.5	6800
5	9600
5.5	10500
6	6900
6.5	4200
7	2550
7.5	1600
8	1050
8.5	530
9	310

TABLE OF POOL DEPLETION AND DAM FAILURE

ELEV. = ELEVATION
BR = BREACH
UP = UPSTREAM
DS = DOWNSTREAM

TIME	POOL ELEV.	UP BR ELEV.	DS BR ELEV.	BREACH LENGTH	SOIL VOLUME	IN-FLOW	BREACH FLOW	BED-LOAD	TOTAL OUTFLW
0.00	1430.00	1437.0	1437.0	0	0	300	0	0.00	0
0.25	1430.26	1437.0	1437.0	0	0	300	0	0.00	35
0.32	1430.33	1437.0	1437.0	0	0	300	0	0.00	49
0.39	1430.39	1437.0	1437.0	0	0	300	0	0.00	65
0.46	1430.45	1437.0	1437.0	0	0	300	0	0.00	80
0.53	1430.51	1437.0	1437.0	0	0	300	0	0.00	95
0.61	1430.56	1437.0	1437.0	0	0	300	0	0.00	110
0.68	1430.60	1437.0	1437.0	0	0	300	0	0.00	125
0.75	1430.65	1437.0	1437.0	0	0	300	0	0.00	138
0.82	1430.69	1437.0	1437.0	0	0	300	0	0.00	152
0.89	1430.72	1437.0	1437.0	0	0	300	0	0.00	164
0.96	1430.76	1437.0	1437.0	0	0	300	0	0.00	176
1.04	1430.79	1437.0	1437.0	0	0	307	0	0.00	187
1.11	1430.82	1437.0	1437.0	0	0	323	0	0.00	198
1.18	1430.85	1437.0	1437.0	0	0	338	0	0.00	210
1.24	1430.89	1437.0	1437.0	0	0	353	0	0.00	222
1.31	1430.92	1437.0	1437.0	0	0	368	0	0.00	234
1.38	1430.95	1437.0	1437.0	0	0	382	0	0.00	246
1.44	1430.98	1437.0	1437.0	0	0	396	0	0.00	258
1.50	1431.01	1437.0	1437.0	0	0	413	0	0.00	271
1.57	1431.05	1437.0	1437.0	0	0	474	0	0.00	286
1.62	1431.09	1437.0	1437.0	0	0	530	0	0.00	304
1.68	1431.14	1437.0	1437.0	0	0	584	0	0.00	324
1.73	1431.19	1437.0	1437.0	0	0	635	0	0.00	346
1.78	1431.24	1437.0	1437.0	0	0	684	0	0.00	370
1.83	1431.30	1437.0	1437.0	0	0	731	0	0.00	395
1.88	1431.36	1437.0	1437.0	0	0	777	0	0.00	422
1.92	1431.42	1437.0	1437.0	0	0	822	0	0.00	449
1.96	1431.48	1437.0	1437.0	0	0	865	0	0.00	478
2.01	1431.54	1437.0	1437.0	0	0	911	0	0.00	508
2.05	1431.60	1437.0	1437.0	0	0	970	0	0.00	539
2.09	1431.66	1437.0	1437.0	0	0	1028	0	0.00	572
2.13	1431.73	1437.0	1437.0	0	0	1084	0	0.00	606
2.17	1431.80	1437.0	1437.0	0	0	1138	0	0.00	642
2.21	1431.86	1437.0	1437.0	0	0	1191	0	0.00	678
2.25	1431.93	1437.0	1437.0	0	0	1244	0	0.00	716
2.28	1432.00	1437.0	1437.0	0	0	1295	0	0.00	754
2.38	1432.19	1437.0	1437.0	0	0	1435	0	0.00	866
2.48	1432.39	1437.0	1437.0	0	0	1575	0	0.00	987
2.58	1432.60	1437.0	1437.0	0	0	1707	0	0.00	1116
2.68	1432.80	1437.0	1437.0	0	0	1837	0	0.00	1248
2.73	1432.90	1437.0	1437.0	0	0	1900	0	0.00	1314
2.78	1432.99	1437.0	1437.0	0	0	1963	0	0.00	1380
2.83	1433.09	1437.0	1437.0	0	0	2024	0	0.00	1445
2.87	1433.18	1437.0	1437.0	0	0	2085	0	0.00	1510
2.92	1433.27	1437.0	1437.0	0	0	2145	0	0.00	1574
2.97	1433.36	1437.0	1437.0	0	0	2205	0	0.00	1638
3.01	1433.44	1437.0	1437.0	0	0	2260	0	0.00	1701
3.06	1433.52	1437.0	1437.0	0	0	2305	0	0.00	1763
3.10	1433.60	1437.0	1437.0	0	0	2350	0	0.00	1823
3.14	1433.68	1437.0	1437.0	0	0	2394	0	0.00	1881
3.19	1433.75	1437.0	1437.0	0	0	2438	0	0.00	1938
3.23	1433.82	1437.0	1437.0	0	0	2481	0	0.00	1993
3.27	1433.89	1437.0	1437.0	0	0	2524	0	0.00	2048
3.32	1433.96	1437.0	1437.0	0	0	2567	0	0.00	2101
3.36	1434.03	1437.0	1437.0	0	0	2610	0	0.00	2153
3.40	1434.09	1437.0	1437.0	0	0	2652	0	0.00	2204
3.44	1434.15	1437.0	1437.0	0	0	2694	0	0.00	2254
3.49	1434.21	1437.0	1437.0	0	0	2736	0	0.00	2303
3.53	1434.27	1437.0	1437.0	0	0	2849	0	0.00	2355
3.57	1434.35	1437.0	1437.0	0	0	2991	0	0.00	2414
3.61	1434.43	1437.0	1437.0	0	0	3131	0	0.00	2481
3.65	1434.51	1437.0	1437.0	0	0	3268	0	0.00	2555
3.69	1434.60	1437.0	1437.0	0	0	3402	0	0.00	2634
3.72	1434.70	1437.0	1437.0	0	0	3534	0	0.00	2717
3.76	1434.80	1437.0	1437.0	0	0	3664	0	0.00	2805
3.80	1434.91	1437.0	1437.0	0	0	3792	0	0.00	2896
3.83	1435.01	1437.0	1437.0	0	0	3918	0	0.00	2990
3.88	1435.16	1437.0	1437.0	0	0	4093	0	0.00	3126

3.93	1435.31	1437.0	1437.0	0	0	4068	0	0.00	3263
3.98	1435.47	1437.0	1437.0	0	0	4443	0	0.00	3409
4.03	1435.63	1437.0	1437.0	0	0	4655	0	0.00	3558
4.08	1435.79	1437.0	1437.0	0	0	4865	0	0.00	3715
4.13	1435.96	1437.0	1437.0	0	0	5115	0	0.00	3881
4.18	1436.14	1437.0	1437.0	0	0	5345	0	0.00	4053
4.23	1436.32	1437.0	1437.0	0	0	5575	0	0.00	4232
4.28	1436.50	1437.0	1437.0	0	0	5805	0	0.00	4415
4.33	1436.68	1437.0	1437.0	0	0	6035	0	0.00	4603
4.38	1436.86	1437.0	1437.0	0	0	6265	0	0.00	4795
4.43	1437.05	1437.0	0.0	0	0	6495	0	0.00	5009
4.48	1437.22	1437.0	0.0	0	0	6725	0	0.00	5374
4.53	1437.37	1437.0	0.0	0	0	6907	0	0.00	5781
4.58	1437.51	1437.0	0.0	0	0	7269	0	0.00	6187
4.63	1437.63	1437.0	0.0	0	0	7549	0	0.00	6579
4.68	1437.73	1437.0	0.0	0	0	7829	0	0.00	6950
4.73	1437.83	1437.0	0.0	0	0	8109	0	0.00	7308
4.78	1437.92	1437.0	0.0	0	0	8389	0	0.00	7637
4.83	1438.00	1437.0	0.0	0	0	8669	0	0.00	7960
4.88	1438.07	1437.0	0.0	0	0	8949	0	0.00	8273
4.93	1438.15	1437.0	0.0	0	0	9229	0	0.00	8578
4.98	1438.22	1437.0	0.0	0	0	9509	0	0.00	8878
5.03	1438.28	1437.0	0.0	0	0	9660	0	0.00	9149
5.08	1438.33	1437.0	0.0	0	0	9750	0	0.00	9364
5.13	1438.38	1437.0	0.0	0	0	9840	0	0.00	9532
5.18	1438.39	1437.0	0.0	0	0	9930	0	0.00	9670
5.23	1438.42	1437.0	0.0	0	0	10020	0	0.00	9790
5.28	1438.44	1437.0	0.0	0	0	10110	0	0.00	9899
5.33	1438.46	1437.0	0.0	0	0	10200	0	0.00	10000
5.38	1438.49	1437.0	0.0	0	0	10290	0	0.00	10098
5.43	1438.51	1437.0	0.0	0	0	10380	0	0.00	10192
5.48	1438.53	1437.0	0.0	0	0	10470	0	0.00	10285
5.53	1438.53	1437.0	0.0	0	0	10256	0	0.00	10316
5.58	1438.51	1437.0	0.0	0	0	9896	0	0.00	10221
5.63	1438.47	1437.0	0.0	0	0	9536	0	0.00	10020
5.68	1438.41	1437.0	0.0	0	0	9176	0	0.00	9758
5.73	1438.35	1437.0	0.0	0	0	8816	0	0.00	9459
5.78	1438.28	1437.0	0.0	0	0	8456	0	0.00	9140
5.83	1438.20	1437.0	0.0	0	0	8096	0	0.00	8809
5.88	1438.12	1437.0	0.0	0	0	7736	0	0.00	8472
5.93	1438.04	1437.0	0.0	0	0	7376	0	0.00	8131
5.98	1437.96	1437.0	0.0	0	0	7016	0	0.00	7790
6.03	1437.87	1437.0	0.0	0	0	6717	0	0.00	7459
6.08	1437.79	1437.0	0.0	0	0	6447	0	0.00	7152
6.13	1437.71	1437.0	0.0	0	0	6177	0	0.00	6865
6.18	1437.63	1437.0	0.0	0	0	5907	0	0.00	6591
6.23	1437.55	1437.0	0.0	0	0	5637	0	0.00	6326
6.28	1437.47	1437.0	0.0	0	0	5367	0	0.00	6068
6.33	1437.39	1437.0	0.0	0	0	5097	0	0.00	5818
6.38	1437.30	1437.0	0.0	0	0	4827	0	0.00	5575
6.43	1437.21	1437.0	0.0	0	0	4557	0	0.00	5341
6.48	1437.11	1437.0	0.0	0	0	4287	0	0.00	5123
6.53	1437.01	1437.0	0.0	0	0	4088	0	0.00	4943
6.58	1436.90	1437.0	1437.0	0	0	3923	0	0.00	4827
6.63	1436.78	1437.0	1437.0	0	0	3758	0	0.00	4705
6.68	1436.66	1437.0	1437.0	0	0	3593	0	0.00	4578
6.73	1436.53	1437.0	1437.0	0	0	3428	0	0.00	4444
6.78	1436.39	1437.0	1437.0	0	0	3263	0	0.00	4306
6.83	1436.25	1437.0	1437.0	0	0	3098	0	0.00	4164
6.88	1436.10	1437.0	1437.0	0	0	2933	0	0.00	4018
6.93	1435.95	1437.0	1437.0	0	0	2768	0	0.00	3869
6.98	1435.79	1437.0	1437.0	0	0	2603	0	0.00	3716
7.03	1435.63	1437.0	1437.0	0	0	2485	0	0.00	3564
7.08	1435.48	1437.0	1437.0	0	0	2390	0	0.00	3417
7.13	1435.33	1437.0	1437.0	0	0	2295	0	0.00	3276
7.18	1435.18	1437.0	1437.0	0	0	2200	0	0.00	3139
7.23	1435.03	1437.0	1437.0	0	0	2105	0	0.00	3008
7.28	1434.89	1437.0	1437.0	0	0	2010	0	0.00	2881
7.33	1434.75	1437.0	1437.0	0	0	1916	0	0.00	2761
7.43	1434.48	1437.0	1437.0	0	0	1726	0	0.00	2531
7.53	1434.23	1437.0	1437.0	0	0	1563	0	0.00	2318
7.63	1433.99	1437.0	1437.0	0	0	1453	0	0.00	2127
7.73	1433.78	1437.0	1437.0	0	0	1343	0	0.00	1959
7.83	1433.58	1437.0	1437.0	0	0	1233	0	0.00	1807
7.93	1433.39	1437.0	1437.0	0	0	1123	0	0.00	1667
8.03	1433.22	1437.0	1437.0	0	0	1015	0	0.00	1537
8.13	1433.04	1437.0	1437.0	0	0	911	0	0.00	1414
8.23	1432.87	1437.0	1437.0	0	0	807	0	0.00	1298
8.33	1432.71	1437.0	1437.0	0	0	703	0	0.00	1187
8.43	1432.54	1437.0	1437.0	0	0	599	0	0.00	1080
8.53	1432.38	1437.0	1437.0	0	0	515	0	0.00	979
8.63	1432.23	1437.0	1437.0	0	0	471	0	0.00	885
8.73	1432.09	1437.0	1437.0	0	0	427	0	0.00	805
8.83	1431.96	1437.0	1437.0	0	0	383	0	0.00	732
8.90	1431.88	1437.0	1437.0	0	0	354	0	0.00	683
8.97	1431.80	1437.0	1437.0	0	0	324	0	0.00	646

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C:\GWAN.REZ>EDLIN  TYPE TIAL   RIAL22
1                                                    ****
                  FLOOD HYDROGRAPH PACKAGE (HEC-1)  (IBM XT 512K VERSION)  -FEB 1,1985
            U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                                     ****

          THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

1                                                                                                        PAGE   1
                                                    HEC-1 INPUT
          LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10
  *** FREE ***
              1      ID      LAUREL RUN DAM RESERVOIR
              2      IT      5       0       0       200
              3      IO      0
              4      IN      30
              5      KK   INFLOWHYDROGRAPH
              6      BA      5
              7      QI      300     300     300     410     900     1600    2250    2750    4500    6800
              8      QI      9600    10500   6900    4200    2550    1600    1050    530     310
              9      KK   ROUTEINFLOW HYDROGRAPH THRU RESERVOIR
             10      RS      1       ELEV    1430
             11      SA      0       6.2     9.3     18.5    22.1    25.5    63.8
             12      SE      1390    1410    1415    1425    1430    1435    1445
             13      SS      1430    86      3.1     1.5
             14      ST      1437    625     3.1     1.5
             15      ZZ
                                                     ****
1                 FLOOD HYDROGRAPH PACKAGE (HEC-1)  (IBM XT 512K VERSION)  -FEB 1,1985
            U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                                     ****

                                  LAUREL RUN DAM RESERVOIR

    3 IO          OUTPUT CONTROL VARIABLES
                        IPRNT          0  PRINT CONTROL
                        IPLOT          0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
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HYDROGRAPH AT STATION INFLOW

DA	MON	HRMN	ORD	FLOW	DA	MON	HRMN	ORD	FLOW	DA	MON	HRMN	ORD	FLOW
1		0000	1	300.	1		0410	51	5267.	1		0820	101	703.
1		0005	2	300.	1		0415	52	5650.	1		0825	102	617.
1		0010	3	300.	1		0420	53	6033.	1		0830	103	530.
1		0015	4	300.	1		0425	54	6417.	1		0835	104	493.
1		0020	5	300.	1		0430	55	6800.	1		0840	105	457.
1		0025	6	300.	1		0435	56	7267.	1		0845	106	420.
1		0030	7	300.	1		0440	57	7733.	1		0850	107	383.
1		0035	8	300.	1		0445	58	8200.	1		0855	108	347.
1		0040	9	300.	1		0450	59	8667.	1		0900	109	310.
1		0045	10	300.	1		0455	60	9133.					
1		0050	11	300.	1		0500	61	9600.					
1		0055	12	300.	1		0505	62	9750.					
1		0100	13	300.	1		0510	63	9900.					
1		0105	14	318.	1		0515	64	10050.					
1		0110	15	337.	1		0520	65	10200.					
1		0115	16	355.	1		0525	66	10350.					
1		0120	17	373.	1		0530	67	10500.					
1		0125	18	392.	1		0535	68	9900.					
1		0130	19	410.	1		0540	69	9300.					
1		0135	20	492.	1		0545	70	8700.					
1		0140	21	573.	1		0550	71	8100.					
1		0145	22	655.	1		0555	72	7500.					
1		0150	23	737.	1		0600	73	6900.					
1		0155	24	818.	1		0605	74	6450.					
1		0200	25	900.	1		0610	75	6000.					
1		0205	26	1017.	1		0615	76	5550.					
1		0210	27	1133.	1		0620	77	5100.					
1		0215	28	1250.	1		0625	78	4650.					
1		0220	29	1367.	1		0630	79	4200.					
1		0225	30	1483.	1		0635	80	3925.					
1		0230	31	1600.	1		0640	81	3650.					
1		0235	32	1708.	1		0645	82	3375.					
1		0240	33	1817.	1		0650	83	3100.					
1		0245	34	1925.	1		0655	84	2825.					
1		0250	35	2033.	1		0700	85	2550.					
1		0255	36	2142.	1		0705	86	2392.					
1		0300	37	2250.	1		0710	87	2233.					
1		0305	38	2333.	1		0715	88	2075.					
1		0310	39	2417.	1		0720	89	1917.					
1		0315	40	2500.	1		0725	90	1758.					
1		0320	41	2583.	1		0730	91	1600.					
1		0325	42	2667.	1		0735	92	1508.					
1		0330	43	2750.	1		0740	93	1417.					
1		0335	44	3042.	1		0745	94	1325.					
1		0340	45	3333.	1		0750	95	1233.					
1		0345	46	3625.	1		0755	96	1142.					
1		0350	47	3917.	1		0800	97	1050.					
1		0355	48	4208.	1		0805	98	963.					
1		0400	49	4500.	1		0810	99	877.					
1		0405	50	4883.	1		0815	100	790.					

PEAK FLOW	TIME	MAXIMUM AVERAGE FLOW			
		6-HR	24-HR	72-HR	16.58-HR
(CFS)	(HR)	(CFS)			
10500.	5.50	4519.	1062.	1062.	1062.
		(INCHES) 8.404	9.568	9.568	9.568
		(AC-FT) 2241.	2552.	2552.	2552.

CUMULATIVE AREA = 5.00 SQ MI

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          **************
          *            *
 9 KK     *   ROUTE    *     INFLOW HYDROGRAPH THRU RESERVOIR
          *            *
          **************

          HYDROGRAPH ROUTING DATA

10 RS     STORAGE ROUTING
               NSTPS          1  NUMBER OF SUBREACHES
               ITYP       ELEV  TYPE OF INITIAL CONDITION
              RSVRIC    1430.00  INITIAL CONDITION
                   X        .00  WORKING R AND D COEFFICIENT

11 SA          AREA          .0        6.2        9.3       18.5       22.1       25.5       63.8

12 SE          ELEVATION  1390.00    1410.00    1415.00    1425.00    1430.00    1435.00    1445.00

13 SS          SPILLWAY
               CREL       1430.00  SPILLWAY CREST ELEVATION
               SPWID        86.00  SPILLWAY WIDTH
               COAW          3.10  WEIR COEFFICIENT
               EXPW          1.50  EXPONENT OF HEAD

14 ST          TOP OF DAM
               TOPEL      1437.00  ELEVATION AT TOP OF DAM
              DAMWID       625.00  DAM WIDTH
               COAD          3.10  WEIR COEFFICIENT
               EXPD          1.50  EXPONENT OF HEAD

                                                ***
                                COMPUTED STORAGE-ELEVATION DATA

     STORAGE        .00      41.33      79.82     216.21     317.58     436.48     868.59
   ELEVATION    1390.00    1410.00    1415.00    1425.00    1430.00    1435.00    1445.00

                                COMPUTED OUTFLOW-ELEVATION DATA

                                (EXCLUDING FLOW OVER DAM)

     OUTFLOW        .00        .00       2.65      21.24      71.69     169.96     331.94     573.61     910.93    1359.75
   ELEVATION    1390.00    1430.00    1430.05    1430.19    1430.42    1430.74    1431.16    1431.67    1432.27    1432.96

     OUTFLOW    1936.01    2655.71    3534.70    4589.01    5834.61    7287.28    8962.95   10877.70   13047.48   15488.06
   ELEVATION    1433.75    1434.63    1435.60    1436.67    1437.82    1439.07    1440.42    1441.85    1443.38    1445.00

                          COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

                                (INCLUDING FLOW OVER DAM)

     STORAGE        .00      41.33      79.82     216.21     317.58     318.60     321.68     326.84     334.13     343.60
     OUTFLOW        .00        .00        .00        .00        .00       2.65      21.24      71.69     169.96     331.94
   ELEVATION    1390.00    1410.00    1415.00    1425.00    1430.00    1430.05    1430.19    1430.42    1430.74    1431.16

     STORAGE     355.33     369.42     385.98     405.15     427.08     436.48     452.37     483.23     520.97     566.94
     OUTFLOW     573.61     910.93    1359.75    1936.01    2655.71    2980.68    3534.70    4589.01    7284.07   13074.70
   ELEVATION    1431.67    1432.27    1432.96    1433.75    1434.63    1435.00    1435.60    1436.67    1437.82    1439.07

     STORAGE     622.70     690.10     771.25     868.59
     OUTFLOW   21198.90   31583.73   44267.70   59328.68
   ELEVATION    1440.42    1441.85    1443.38    1445.00
```

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	0.	317.6	1430.0	1		0535	68	10249.	545.8	1438.5
1		0005	2	7.	319.6	1430.1	1		0540	69	9869.	542.8	1438.4
1		0010	3	21.	321.6	1430.2	1		0545	70	9369.	538.8	1438.3
1		0015	4	36.	323.5	1430.3	1		0550	71	8795.	534.1	1438.2
1		0020	5	54.	325.2	1430.3	1		0555	72	8218.	529.2	1438.1
1		0025	6	72.	326.8	1430.4	1		0600	73	7643.	524.2	1437.9
1		0030	7	90.	328.4	1430.5	1		0605	74	7113.	519.4	1437.8
1		0035	8	108.	329.7	1430.5	1		0610	75	6644.	514.9	1437.6
1		0040	9	125.	331.0	1430.6	1		0615	76	6205.	510.4	1437.5
1		0045	10	141.	332.2	1430.7	1		0620	77	5786.	505.8	1437.4
1		0050	11	156.	333.2	1430.7	1		0625	78	5387.	500.9	1437.2
1		0055	12	170.	334.1	1430.7	1		0630	79	5029.	495.5	1437.1
1		0100	13	183.	335.0	1430.8	1		0635	80	4806.	489.7	1436.9
1		0105	14	196.	335.8	1430.8	1		0640	81	4595.	483.4	1436.7
1		0110	15	210.	336.7	1430.9	1		0645	82	4370.	476.7	1436.5
1		0115	16	224.	337.5	1430.9	1		0650	83	4133.	469.8	1436.2
1		0120	17	240.	338.4	1430.9	1		0655	84	3886.	462.6	1436.0
1		0125	18	255.	339.4	1431.0	1		0700	85	3632.	455.2	1435.7
1		0130	19	272.	340.3	1431.0	1		0705	86	3384.	448.0	1435.4
1		0135	20	292.	341.4	1431.1	1		0710	87	3155.	441.5	1435.2
1		0140	21	321.	343.0	1431.1	1		0715	88	2940.	435.3	1435.0
1		0145	22	357.	344.9	1431.2	1		0720	89	2738.	429.5	1434.7
1		0150	23	399.	347.1	1431.3	1		0725	90	2549.	423.9	1434.5
1		0155	24	448.	349.5	1431.4	1		0730	91	2370.	418.6	1434.3
1		0200	25	503.	352.1	1431.5	1		0735	92	2204.	413.5	1434.1
1		0205	26	566.	355.0	1431.7	1		0740	93	2056.	408.9	1433.9
1		0210	27	639.	358.2	1431.8	1		0745	94	1921.	404.7	1433.7
1		0215	28	721.	361.7	1431.9	1		0750	95	1797.	400.7	1433.6
1		0220	29	810.	365.4	1432.1	1		0755	96	1681.	396.9	1433.4
1		0225	30	907.	369.3	1432.3	1		0800	97	1571.	393.2	1433.3
1		0230	31	1010.	373.3	1432.4	1		0805	98	1467.	389.7	1433.1
1		0235	32	1118.	377.3	1432.6	1		0810	99	1368.	386.3	1433.0
1		0240	33	1228.	381.3	1432.8	1		0815	100	1273.	383.0	1432.8
1		0245	34	1341.	385.3	1432.9	1		0820	101	1181.	379.6	1432.7
1		0250	35	1455.	389.3	1433.1	1		0825	102	1092.	376.3	1432.6
1		0255	36	1571.	393.2	1433.3	1		0830	103	1005.	373.1	1432.4
1		0300	37	1687.	397.1	1433.4	1		0835	104	924.	369.9	1432.3
1		0305	38	1802.	400.8	1433.6	1		0840	105	850.	367.1	1432.2
1		0310	39	1912.	404.4	1433.7	1		0845	106	787.	364.5	1432.1
1		0315	40	2018.	407.8	1433.9	1		0850	107	729.	362.0	1432.0
1		0320	41	2121.	411.0	1434.0	1		0855	108	673.	359.7	1431.9
1		0325	42	2220.	414.1	1434.1	1		0900	109	623.	357.5	1431.8
1		0330	43	2320.	417.1	1434.2	1		0905	110	578.	355.5	1431.7
1		0335	44	2437.	420.6	1434.4	1						
1		0340	45	2592.	425.2	1434.6	1						
1		0345	46	2778.	430.6	1434.8	1						
1		0350	47	2988.	436.7	1435.0	1						
1		0355	48	3216.	443.2	1435.3	1						
1		0400	49	3456.	450.1	1435.5	1						
1		0405	50	3716.	457.6	1435.8	1						
1		0410	51	4001.	465.9	1436.1	1						
1		0415	52	4304.	474.8	1436.4	1						
1		0420	53	4621.	484.2	1436.7	1						
1		0425	54	4954.	494.0	1437.0	1						
1		0430	55	5574.	503.3	1437.3	1						
1		0435	56	6259.	511.0	1437.5	1						
1		0440	57	6896.	517.3	1437.7	1						
1		0445	58	7456.	522.5	1437.9	1						
1		0450	59	7985.	527.2	1438.0	1						
1		0455	60	8494.	531.6	1438.1	1						
1		0500	61	8990.	535.7	1438.2	1						
1		0505	62	9385.	539.0	1438.3	1						
1		0510	63	9641.	541.0	1438.4	1						
1		0515	64	9836.	542.5	1438.4	1						
1		0520	65	10006.	543.9	1438.5	1						
1		0525	66	10165.	545.1	1438.5	1						
1		0530	67	10319.	546.3	1438.5	1						

PEAK OUTFLOW IS 10319. AT TIME 5.50 HOURS

CUMULATIVE AREA = 5.00 SQ MI

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	INFLOW	10500.	5.50	4519.	1862.	1862.	5.00		
ROUTED TO	ROUTE	10319.	5.50	4477.	1842.	1842.	5.00	1438.53	5.50

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION ROUTE

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	1430.00	1430.00	1437.00
STORAGE	318.	318.	494.
OUTFLOW	0.	0.	4938.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	1438.53	1.53	546.	10319.	2.17	5.50	.00
MOJIB's →	1438.53	1.53		10316	2.10	5.53	

*** NORMAL END OF HEC-1 ***

VITA

Reza M. Mojib was born in Mashad, Iran, on March 30, 1950. He attended elementary school in Mashad, Iran and graduated from Young High School in Knoxville, Tennessee, 1968. He enrolled in the University of Tennessee following his graduation from high school. He received his Bachelor of Science degree in Mechanical Engineering in August of 1973. He received his Master's degree in Environmental Engineering in March of 1977. Following his graduation from the University of Tennessee he started working for Hensley Schmidt, Inc., in Chattanooga, Tennessee. In June 1979, he began to study toward a Ph.D. degree at the University of Tennessee. During his pursuit of his degree, he worked as a Teaching/Research Assistant in the Civil Engineering Department at the University of Tennessee (1979-1983), as a consulting hydrologist for environmental Planning Engineers (1980-1981), as a visiting instructor for University of Ferdousi in Mashad, Iran (1985-1986), as a Research Associate for the Department of Energy at Oak Ridge National Laboratory, Oak Ridge, Tennessee (1977-1978), as a Flood Control Planning Engineer for the City of Las Vegas in Las Vegas, Nevada (1988-1989), and as a Civil Design Engineer for the Las Vegas Valley Water District, Las Vegas, Nevada (1989-present). Mr. Mojib received his Ph.D. degree in Civil engineering in March 1990.