USER MANUAL UM 42

COMPREHENSIVE DATA REQUIREMENT FOR NWS DAMBRK MODEL WITH SELECTED EXAMPLES

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PREFACE

Dam break study is a needed exercise to be carried out essentially for mitigating the catastrophic disasters, in the eventuality of dam failure. The National Weather Service's Dam break Flood Forecasting Model (DAMBRK) is a most widely used model all over the world. For carrying out a dam break study it needs a minimum level of expertise and skill for satisfactory implementation of the model. The earlier developed Technical Note (TN-22)at National Institute of Hydrology, Roorkee on Data Requirement for the DAMBRK Model presents the use of only one option of the model. A need for preparing a comprehensive data requirement for this model was felt in view of many control variables which significantly affect the results of a model run.

Present report explains in detail the each component of the data and its use in the model application. Selected examples of dam break studies carried out successfully at the NIH are presented so as to make the user cognizant how to use properly the field data for obtaining reliable results.

The report on the 'Comprehensive Data Requirement for NWS DAMBRK Model with Selected Examples' has been prepared by Sh. S.K. Mishra, Scientist C, Sh. B.P. Roy, Scientist E and Sh. Rajesh Agrawal, Research Asstt. under the guidance of Dr. S.M. Seth, Director, National Institute of Hydrology, Roorkee.

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ABSTRACT

Planning and design requirement for a wide range of projects, such as emergency preparedness and location of nuclear power plants, have generated widespread interest in dam break floods analysis. Although much academic research have been accomplished on this topic, a generalised analytic technique for calculating and routing of dam break floods in natural channels is rarely available. The U.S. National Weather Service DAMBRK programme is meant to serve this practical purpose. This note presents the data requirements for analysing the flood wave generated by dam failure using the DAMBRK programme, and also gives the details on how to prepare the data for executing the DAMBRK programme for a most practical case. The DAMBRK programme was developed so as to require data that is accessible to the forecaster. The input data can be categorised into two groups. The first data group pertains to the details of dam such as breach, spillways, and reservoir storage volume, etc. The second group pertains to the routing of the outflow through the downstream valley. The input data requirements are flexible in so far as much of the data may be ignored when a detailed analysis of a dam break flood inundation event is not feasible due to lack of data or insufficient data preparation time.

1.0 INTRODUCTION

1.1 Need for Dam break Studies

The total number of dams throughout the world and also in India are on steady increase. There have been continuous increase in the safety of dams by better site and material exploration, design procedures, construction methods and controls and improved surveillance of dam behaviour. Even after all these, experience shows that the number of dam failures throughout the world have not decreased over time. On the other hand, it is on the increase. Additionally, the potential of international destruction capability has increased in this age of sophisticated and highly destructive weaponry system. Even the sabotage type of destruction can not be ruled out. In addition to this scenario, the IS Code 11223-1985 on "Guidelines for Fixing Spillway Capacity" stipulates the Dambreak study as an aid to visualise the flood hazard downstream of a dam for deciding appropriate design criteria for inflow flood to a Dam. All these call for adopting a routine procedure for dam break studies.

1.2 Models available for dam break studies and DAMBRK program

Significant advances in the state of art of dam break flood wave modelling have been achieved during the past decade. A list of models in use is given below:

1. National Weather Service's (NWS) Dam-Break Flood Forecasting Model (DAMBRK)
2. U.S. Army Corps of Engineers South Western Division (SWD) Flow Simulation Models (FLOW SIM 1 and 2)
3. US Army Corps of Engineers Hydrologic Engineers Centre (HEC) Flood

Hydrograph Package (HEC-1)

4. Soil Conservation Service's (SCS) Simplified Dam Breach Routine Procedure (TR 66)
5. NWS simplified Dam-Break Flood Forecasting Model (SMPDBK) and HEC Dimensionless Graph Procedure.

A comparative evaluation of all these models indicates that a dynamic routing model as in DAMBRK may be used for obtaining maximum practical level of accuracy.

National Institute of Hydrology have published a Users' manual (Report TN-22) for DAMBRK program with an illustrative example. However, it lacks explanation of a number of control variables. The test example solved is a very simple one and is not of much help in solving complex problems in real world engineering. To overcome these deficiencies, elaborate explanation of input variables with number of typical test examples would be necessary. The main emphasis should be to acclimatize the user in any type of case study. Following is an attempt in that direction.

1.3 Capabilities and Options available in DAMBRK

The program can take up only one dimensional flood wave routing and has the following capabilities.

i) Simulate the dam breach of an earthen dam and

ii) Hydrologic storage routing or hydraulic storage routing through a dam breached or unbreached.

iii) Dynamic routing of flood wave (both subcritical and supercritical flows) through a channel.

iv) Downstream routing of flood wave through more than one dam or through bridges and weirs.

v) Routing inflow hydrograph through a channel.

For achieving these, the program has the following 12 options (For explanation of variables and arrangement of input cards reference to be made to Section 4).

Option 1: Storage routing in a reservoir of a breaching dam to compute outflow hydrograph from reservoir with subcritical dynamic routing outflow hydrograph through entire length of downstream valley: KUI=0, KKN=1, KSUPC=0, MULDAM=0. Input data cards : 1-4, 6-58.

Option 2: Storage routing in a reservoir of a breaching dam to compute outflow hydrograph from reservoir with supercritical dynamic routing of outflow hydrograph through entire length of downstream valley: KUI=0, KKN=1, KSUPC=1, MULDAM=0, Input data cards:1-4, 6-58.

Option 3: Storage routing in a reservoir of a breaching dam to compute outflow hydrograph from reservoir with super-critical dynamic routing of outflow hydrograph through upstream portion of downstream valley and subcritical dynamic routing through downstream portion of downstream valley: KUI=0, KKN=2, KSUPC=1, MULDAM=0. Input data cards: 1-4, 6-52, 16-58.

Option 4: Same as Option 1 except reservoir dynamic routing to compute outflow hydrograph from reservoir: KUI=1, KKN=2, KSUPC=0, MULDAM=0. Input data cards: 1-4, 8-58, 63, 16-52.

Option 5: Same as Option 2 except reservoir dynamic routing to compute outflow hydrograph from reservoir: KUI=1, KKN=2, KSUPC=1, MULDAM=0. Input data cards: 1-4, 8-58, 63, 16-52.

Option 6: Same as Option 3 except reservoir dynamic routing to compute outflow hydrograph from reservoir: KUI=1, KKN=3, KSUPC=1, MULDAM=0. Input data cards: 1-4, 8-58, 63, 16-52, 16-52.

Option 7: Subcritical dynamic routing of input hydrograph through a channel valley: KUI=0, KKN=9, KSUPC=0, MULDAM=0. Input data cards: 1-4, 12-52.

Option 8: Supercritical dynamic routing of input hydrograph through a channel-valley: KUI=0, KKN=9, KSUPC=1, MULDAM=0. Input data cards: 1-4, 12-52.

Option 9: "Sequential method" Reservoir storage routing to compute outflow hydrograph from reservoir with subcritical dynamic routing of outflow hydrograph through downstream channel-reservoir having a dam which may fail: KUI=0, KKN=2, KSUPC=0, MULDAM=1. Input data cards: 1-4, 6-63, 16-63, 16-52.

Option 10: "Sequential method" Reservoir dynamic routing to compute outflow hydrograph from reservoir with sub-critical dynamic routing of outflow hydrograph through downstream channel-reservoir having a dam which may fail: KUI=1, KKN=3, KSUPC=0, MULDAM=1. Input data cards: 1-4, 8-58, 63, 16-63, .. 16-52.

Option 11: "Sequential Method" Simultaneous computation method for single dam or bridge (structure) using dynamic routing in the reach upstream of the structure and downstream of the structure with special internal boundary conditions for flow through the structure: KUI=1, KKN=1, MULDAM=1, KSUPC=0. Input data cards: 1-5, 8-11, 12-58.

Option 12: "Simultaneous methods" Simultaneous computation method for multiple dams and/ or bridges (structures) using dynamic routing for all reaches with special internal boundary conditions for flow through each structure: KUI=1, KKN=1, MULDAM=no. of dams and/or bridges, KSUPC=0. Input data cards: 1-5, 8-11, 8-11, 8-11, 12-58.

1.4 Description of DAMBRK Program

The program is developed by U.S. National Weather Service (NWS). It is written in FORTRAN language. The program listing consists of 6304 lines including the comment cards.

2.0 THEORETICAL BACKGROUND

2.1 Dam Breach Simulation

Two types of breaching can be simulated using this program. These two types with their descriptions are given below:

2.1.1 Breach formation due to overtopping

Simulation is made as a rectangular, triangular or trapezoidal shape. The user has to input the failure time interval and the terminal size and shape of the breach. The size is described by the initial and final breach levels and the breach width reached finally. The shape is described by z defining the side slope of the breach i.e. 1 vertical to z horizontal. For rectangular breach z=0 and for triangular breach the bottom width equals zero. For a trapezoidal breach, the z and the final breach with are not equal to zero. The initial width of the breach is taken as zero and the terminal bottom width is as b. If the time of failure is less than 10 minutes, the initial breach width assumes a value b rather than a small one which otherwise assumed in gradual breaches. The simulation of the growth of the breach is shown in Fig.1.

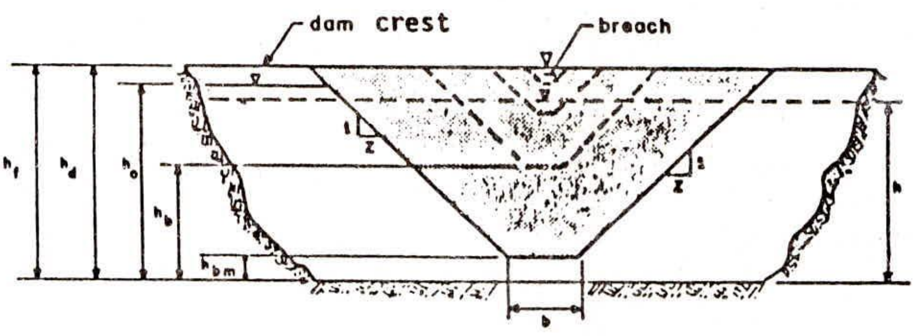

Figure. 1 FRONT VIEW OF DAM SHOWING FORMATION OF BREACH

2.1.2 Breach formation due to piping

If the elevation of water level that triggers the formation of the breach is below the crest level of the dam, piping failure is simulated. In this case, the breach is rectangular in shape and grows with time. The flow through such type of breach will be as orifice flow. The simulation of the growth of orifice breach is given in Fig.2.

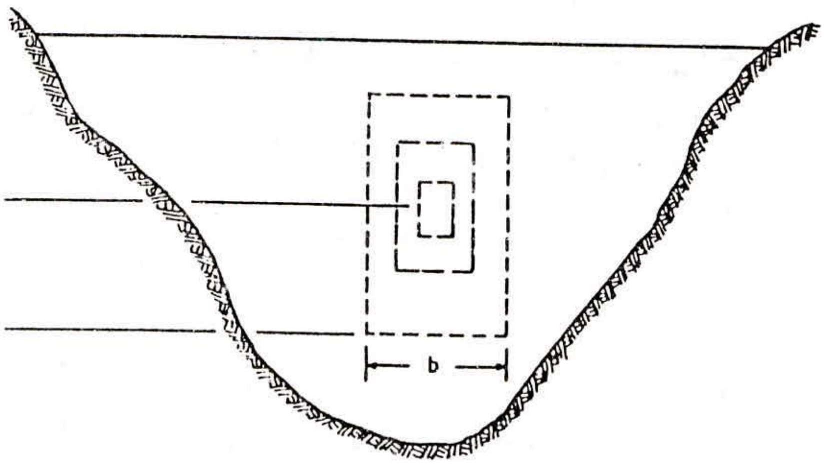

Figure 2 ORIFICE BREACH

If breach is formed by piping

$$Q_b = 4.8\ A_p (h-\bar{h})^{0.5}$$

$$A_p = \left[2b_i + 4z\ (h_f-h_b)\right] (h_f-h_b)$$

$$\bar{h} = h_f \text{ for } h_t \leq (2h_f-h_b)$$

$$= h_t \text{ for } h_t \leq (2h_f-h_b)$$

$$h_b = h_f - (h_f-h_{bm}) \frac{t_b}{\tau} \text{ for } t_b \leq \tau$$

where $h_f = h_t$ of water surface when piping begins

(if $\bar{h} = h_f$ and $(h-h_b) < 2.2\ (h_f-h_b)$ the flow become a broad crested flow)

2.2 Reservoir Outflow Hydrograph

The total reservoir outflow (Q) consists of flow through the breach (Qb) and flow through any spillway outlet (Qs), i.e.

$$Q = Qb + Qs \qquad (1)$$

On the basis of breach simulation explained in para 2.1.1 the outflow though the breach is considered as broad crested weir flow.

The breach outflow (Q_b) is computed as:

$$Q_b = c_1(h-h_b)^{1.5} + c_2(h-h_b)^{2.5} \qquad (2)$$

where:

$$c_1 = 3.1\ b_i\ c_v\ k_s \qquad (3)$$

$$c_2 = 2.45\ zc_v\ k_s \qquad (4)$$

$$h_b = h_d - (h_d - h_{bm})^{t} b/t \quad \text{if } t_b < \tau \qquad (5)$$

$$h_b = h_{bm} \quad \text{if } t_b \geq \tau \qquad (6)$$

$$b_1 = bt_b/t \quad \text{if } t_b < \tau \qquad (7)$$

$$c_v = 1.0 + 0.023\ Q^2/(B_d^2\ (h-h_{bm})^2\ (h-h_b) \qquad (8)$$

$$k_s = 1.0 \text{ if } (h_t-h_b)/(h-h_b) < 0.67 \qquad (9)$$

otherwise :

$$k_s = 1.0 - 27.8[(h_t-h_b)/(h-h_b)-0.67] \qquad (10)$$

where,

Q = Total outflow from breached dam

Q_b = Breach outflow

Q_s = Outflow from spillway outlets

c_1 = Co-efficient of discharge for the rectangular portion of the trapezoidal section

c_2 = Co-efficient of discharge for the triangular portion of the trapezoidal section.

c_v = Correction for velocity of approach

k_s = Submergence correction for tail water effect

b = bottom width of trapezoidal breach

b_1 = instantaneous bottom width of trapezoidal breach

h = reservoir water surface elevation

h_b = bottom elevation of breach

h_d = Top elevation of dam

h_{bm} = bottom elevation of breach in its maximum development

B_d = Width of reservoir at dam

t_b = time interval since starting of breach formation

= Time of total breach formation

h_t = Tail water elevation

The tailwater elevation (h_t) is computed from Manning's equation, i.e.,

$$Q = \frac{1.49}{n} S^{1/2} A^{5/3}/B^{2/3} \quad (11)$$

where, n = the Manning roughness coefficient

A = the cross-sectional area of flow

B = the top width of the wetted cross-sectional area, and

S = the energy slope

Each term in Eq. 11 applies to a representative channel reach immediately downstream of the dam. The S parameter can be specified by the user and it does not change with time, if it is not specified, the model uses the channel bottom slope of the first third of the downstream valley reach. Since A and B are functions of h_t and Q is the total discharge given by Eqs. 1, and 11 provide a sufficiently accurate value h_t if there are no backwater effects immediately below the dam due to downstream constructions, dams, bridges, or significant tributary inflows. When these affect the tailwater, Eq. 11 is not used and another procedure the "simultaneous method", which is described separately later, is used.

2.2.1 Breach outflow due to failure by Piping

Refer to simulation of breach due to piping explained in para 2.1.2 and Fig. 2. Eq. 2 may be replaced by the following:

$$Q_b = 4.8\, A_p\, (h-\bar{h}\,)^{0.5} \quad (12)$$

where, $A_p = (b_i + (h-h_b)\, Z)\, (h-h_b)$ (13)

$$h_b = h_f - (h_f - h_{bm})\, t_b/\tau \qquad \text{if } t_b \le \tau$$

$$h_b = h_{bm} \qquad \text{if } t_b > \tau \qquad (14)$$

$$b_i = b\, t_b/\tau \qquad \text{if } t_b \le \tau$$

$$\bar{h} = (h_f + h_{bm})/2 \qquad \text{if } h_t \le h_{bm} \qquad (15)$$

$$\bar{h} = (h_f + h_t)/2 \qquad \text{if } h_t > h_{bm} \qquad (16)$$

As long as $(h-h_b) \ge 2.2\ (h_f-h_b)$, the breach outflow Q_b will be computed as orifice flow by Eq. 12. When $(h-h_b) < 2.2\ (h_f-h_b)$ the breach outflow is as computed by broad crested weirflow and will be governed by Eq. 2.

2.2.2 Flow through spillway outlets

The spillway outflow (Q_s) is computed as:

$$Q_s - Q_s\ L_s(h-h_s)^{1.5}\ C_g A_g (h-h_g)^{0.5}\ C_d L_d (h-h_d)^{1.5} Q_t \qquad (17)$$

where, c_s = the uncontrolled spillway discharge coefficient

h = uncontrolled spillway crest elevation

c_g = the gated spillway discharge coefficient

h_g = the centre-line elevation of the gated spillway

c_d = the discharge coefficient for flow over the crest of the dam

L_s = spillway length

A_g = the gate flow area

L_d = the length of the dam crest less L

and Q_t = is a constant outflow term which is head independent

The uncontrolled spillway flow or the gated spillway flow can also be represented as a table of head-discharge values. The gate flow may be specified as a function of time.

2.2.3 Flood Routing through the Reservoir

The outflow hydrograph from the breached dam is determined by routing through the reservoir. The DAMBRK can route the flood in the reservoir in two ways: (a) Hydrologic Storage routing and (b) Dynamic Storage routing. The Hydrologic storage routing implies that the water surface elevation within the reservoir is level. This assumption is quite adequate for gradually occurring break with no substantial reservoir inflow hydrograph. This routing technique is based on the law of conservation of mass as explained in the later part of this section. On the other hand, the dynamic storage routing procedure can take into account the unlevelled reservoir surface as a result of strong negative wave engendered due to instantaneous breach formation or as a result of a substantially strong positive wave due to a significant inflow flood hydrograph. The routing technique is based on solution of St Venant's equation which will be explained alongwith routing in the channels.

Storage Routing:

DAMBRK utilizes a hydrologic storage routing technique based on the law of conservation of mass, i.e.,

$$I - Q = dS/dt \qquad (18)$$

in which I is the reservoir inflow, Q is the total reservoir outflow, and dS/dt is the time rate of change of reservoir storage volume. Eq. 18 may be expressed in finite difference form as:

$$(I+I')/2 - (Q+Q')/2 = \Delta S/\Delta t \qquad (19)$$

In which the prime (') superscript denotes values at the time t-Δt and the Δ approximates the differential. The term ΔS may be expressed as:

$$S = (A_s+A'_s)\ (h-h')/2 \qquad (20)$$

in which A_s is the reservoir surface area coincident with the elevation (h).

Combining Eqs. 1, 2, 17, 19 and 20 result in the following expression:

$$(A_s+A'_s)(h-h')/\Delta t + c_1(h-h_b)^{1.5} + c_2(h-h_b)^{2.5} + c_s(h-h_b)^{1.5}$$

$$+ c_g(h-h_g)^{0.5} + c_d(h-h_d)^{1.5} + Q_t + Q'-I-I' = 0 \qquad (21)$$

Since A_s is a function of h and all other terms except h are known, Eq. 21 can be solved for the unknown h using Newton-Raphson iteration. Having obtained h, usually within two or three iterations, Eqs. 2 and 17 can be used to obtain the total outflow (Q) at time (t). In this way the outflow hydrograph Q(t) can be developed for each time (t) as t goes from zero to some terminating value (t_e) sufficiently large for the reservoir to be drained. In Eq. 21, the time step (Δt) is chosen sufficiently small to incur minimal numerical integration error. This is taken by the model as $\tau/50$.

2.3 Dynamic Routing in Channel/Reservoir

For routing dam break flood waves, the dynamic wave method is used. This choice is based on its ability to provide more accuracy in simulating the dam break flood wave than that provided by the hydrologic methods, as well as other hydraulic methods such as the kinematic wave and diffusion wave methods.

The Saint-Venant unsteady flow equations consist of a conservation of mass equation:

$$\frac{\partial Q}{\partial x} + \frac{\partial (A+A_o)}{\partial t} - q = 0 \qquad (22)$$

and a conservation of momentum equation:

$$\frac{\partial Q}{\partial t} + \frac{\partial (Q^2/A)}{\partial x} + gA\left(\frac{\partial h}{\partial x} + S_f + S_e\right) = 0 \qquad (23)$$

where, A = the active cross-sectional area of flow

A_o = the inactive (off-channel storage) cross-sectional area

x = the longitudinal distance along the channel (valley)

t = the time

q = the lateral inflow or outflow per linear distance along the channel (inflow is positive and outflow is negative in sign)

g = the acceleration due to gravity

S_f = the friction slope, and

S_e = the expansion-contraction slope.

The friction slope is evaluated from Manning's equation for uniform, steady flow:

$$S_f = \frac{n^2 Q^2}{2.21\ A^2 R^{4/3}} \qquad (24)$$

where, n = the Manning's coefficient of frictional resistance

R = the hydraulic radius defined as A/B where

B = the top width of the active cross-sectional area. The term(S_e) is defined as follows:

$$S_e = \frac{K\ \Delta(Q/A)^2}{2g\Delta x} \qquad (25)$$

where k = (the expansion-contraction coefficient varying from 0.0 to + 1.0 (+ if contraction, - if expansion), L is the momentum effect of lateral flow assumed herein to enter or exit perpendicular to the direction of the main flow. This term has the following form: 1) lateral inflow, L = 0: 2) seepage lateral outflow, L = -0.5q Q/A; and 3) bulk lateral outflow, L = -q Q/A.

Eqs. 22 and 23 are modified to better account for the differences in flood wave properties for flow occurring simultaneously in the river channel and the overbank flood plain of the downstream valley as given below:

$$\frac{\partial(K_c Q)}{\partial x_c} + \frac{\partial(K_l Q)}{\partial x_l} + \frac{\partial(K_r Q)}{\partial x_r} + \frac{\partial A}{\partial t} - q = 0 \qquad (26)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial(K_c^2 Q^2/A_c)}{\partial x_c} + \frac{\partial(K_l^2 Q^2/A_l)}{\partial x_l} + \frac{\partial(K_r^2 Q^2/A_r)}{\partial x_r}$$

$$+ gA_c\left[\frac{\partial h}{\partial x_c} + S_{fc} + S_e\right] + gA_l\left[\frac{\partial h}{\partial x_l} + S_{fl}\right] + gA_r\left[\frac{\partial h}{\partial x_r} + S_{fr}\right] = 0 \qquad (27)$$

where the subscripts (c), (l), and (r) represent the channel, left flood-plain, and right flood-plain sections, respectively. The parameters K_c, K_l and K_r proportion the total flow (Q) into channel flow, left flood-plain flow, and right flood-plain flow, respectively. These are defined as follows:

$$K_c = \frac{1}{1+k_l+k_r} \quad (28)$$

$$K_l = \frac{k_l}{1+k_l+k_r} \quad (29)$$

$$K_r = \frac{k_r}{1+k_l+k_r} \quad (30)$$

where

$$k_l = \frac{Q_l}{Q_c} \quad (31)$$

and

$$k_r = \frac{Q_r}{Q_c} \quad (32)$$

Eqs. 31 and 32 represent the ratio of flow in the channel section to flow in the left and right flood-plain (overbank) sections, where the flows are expressed in terms of the Manning's equation in which the energy slope is approximated by the water surface slope ($\Delta h/\Delta x$).

The friction slope terms in Eq. 27 are the following:

$$S_{fc} = \frac{n_c^2 (K_c Q)^2}{2.21\ A_c^2 R_c^2} \quad (33)$$

$$S_{fl} = \frac{n_l^2 (K_l Q)^2}{2.21 A_l^2 R_l^2} \quad (34)$$

$$S_{fr} = \frac{n_r^2 (K_r Q)^2}{2.21 A_r^2 R_r^2} \quad (35)$$

In Eq. 26 the term A is the total cross-sectional area, i.e.,

$$A = A_c + A_l + A_r + A_o \quad (36)$$

where A_o is the off-channel storage (inactive) area. Eqs. 22, 23 and 26 and 27 constitute a system of partial differential equations of the hyperbolic type. They contain two independent variables, x and t, and two dependent variables, h and Q; the remaining terms are either functions of x, t, h, and/or Q, or they are constants. These equations are not amenable to analytical solutions except in cases where the channel geometry and boundary conditions are uncomplicated and the non-linear properties of the equations are either neglected or made linear. The equations may be solved numerically by performing two basic steps. First, the partial differential equations are represented by a corresponding set of finite difference algebraic equations; and second, the system of algebraic equations is solved in conformity with prescribed initial and boundary conditions. In DAMBRK models the "weighted four-point" scheme has been utilised. In such a scheme the finite difference operators are defined below.

$$\frac{\partial K}{\partial t} = \frac{K_i^{j+1} + K_{i+1}^{j+1} - K_i^j - K_{i+1}^j}{2\Delta t_j} \quad (37)$$

$$\frac{\partial K}{\partial x} = \theta\left[\frac{K_{i+1}^{j+1} - K_i^{j+1}}{\Delta x_i}\right] + (1-\theta)\left[\frac{K_{i+1}^j - K_i^j}{\Delta x_i}\right] \quad (38)$$

$$K = \theta\left[\frac{K_i^{j+1} + K_{i+1}^{j+1}}{2}\right] + (1-\theta)\left[\frac{K_i^j + K_{i+1}^j}{2}\right] \quad (39)$$

$$= \theta\bar{K}^{j+1} + (1-\theta)\bar{K}^j$$

where K represents any variable, subscripts, i stands for node in x-axis and superscripts j stands for node in t-axis and,

$$\Delta x_i = x_{i+1} - x_i$$

$$\Delta t_j = t_{j+1} - t_j$$

and $$\bar{K}^j = \frac{K_i^j + K_{i+1}^j}{2}$$

Using the operators defined in Eqs. 37 through 39, and in the Eqs. 22 and 23 can be written in the finite difference scheme as given below

$$\theta\left[\frac{Q_{i+1}^{j+1} - Q_i^{j+1}}{\Delta x_i}\right] + (1-\theta)\left[\frac{Q_{i+1}^j - Q_i^j}{\Delta x_i}\right] - \theta\bar{q}^{j+1} - (1-\theta)\bar{q}^j$$

$$+\left[\frac{(A+A_o)_i^{j+1} + (A+A_o)_{i+1}^{j+1} - (A+A_o)_i^j - (A+A_o)_{i+1}^j}{2\Delta t_j}\right] \quad (40)$$

and,

$$\left[\frac{Q_i^{j+1} + Q_{i+1}^{j+1} - Q_i^j - Q_{i+1}^j}{2\Delta t_j}\right] + \theta\left[\frac{(Q^2/A)_{i+1}^{j+1} - (Q^2/A)_i^{j+1}}{\Delta x_i}\right.$$

$$\left.+ g\bar{A}^{j+1}\left(\frac{h_{i+1}^{j+1} - h_i^{j+1}}{\Delta x_i} + \bar{S}_f^{j+1} + S_e^{j+1}\right)\right] + (1-\theta)\left[\frac{(Q^2/A)_{i+1}^j - (Q^2/A)_i^j}{\Delta x_i}\right.$$

$$\left.+ g\bar{A}^j\left(\frac{h_{i+1}^j - h_i^j}{\Delta x_i} + \bar{S}_f^j + S_e^j\right)\right] = 0 \quad (41)$$

where, $$\bar{S}_f = h^2\,(\bar{Q})^2/(2.2\bar{A}^2\,\bar{R}^{4/3}) \quad (42)$$

$$\bar{R} = \bar{A}/\bar{B} \quad (43)$$

From Eqs. 40 and 41 the unknowns h and Q are to be evaluated. It will be seen that there are eight variables concerning h and Q. These are h_i^j, h_{i+1}^j, h_i^{j+1}, h_{i+1}^{j+1}, Q_i^j, Q_{i+1}^j, Q_i^{j+1} and Q_{i+1}^{j+1}. Out of these the jth time line are known either from the initial boundary conditions or from previous computation. This leaves four unknown in (j +1) the line to be evaluated for which there are only two equations. Hence, explicitly or directly no solution can be found. However, if Eqs. 40 and 41 are applied to each of the (N-1) rectangular grids between the upstream and downstream boundaries, a total of (2N-2) equations with 2N unknowns can be formulated. (N denotes the total number of nodes). Then prescribed boundary conditions, one at the upstream boundary and one at the downstream boundary, provide the necessary two additional equations required for the system to be determinate. The resulting system of 2N non-linear equations with 2N unknowns is solved by a functional iterative procedure, the Newton-Raphson method.

3.0 DATA REQUIREMENT

3.1 Data Requirement

3.1.1 Simulation of Dam breach

a) Length of reservoir

b) Elevation of water surface in reservoir when computation starts

c) Side slope of the breach

d) Lowest elevation of the bottom of breach

e) Width of base of breach

f) Time taken from start of the breach formation till it attains maximum size.

g) Elevation of the bottom of Dam

h) Elevation of water when failure commences

i) Top of dam

3.1.2 Inflow flood hydrograph

(a) Flood hydrograph ordinates with corresponding time (It can take flood hydrograph ordinates at regular or irregular intervals of time).

(b) It can also be constructed with the help of the following information:

i) Initial steady discharge

ii) Ratio of peak flow to initial flow

iii) Time from initial time to centroid of hydrograph.

iv) Time from initial flow to peak flow.

3.1.3 Storage routing through breached Dam

a) Area Capacity Curve of the reservoir

b) Elevation of uncontrolled spillway area

c) Elevation of centre of gate opening

d) Discharge coefficient of uncontrolled spillway

e) Discharge coefficient for gate flow or spillway or gate rating curve

3.1.4 Reservoir dynamic routing through breached Dam

Area Capacity curve of the reservoir is not required for this option. However, croos-sectional details of the reservoir bed relatively at shorter interval are required. The data requirement given at (b) to (e) of 2.1.3 will also be valid in this case.

3.1.5 Dynamic Routing in downstream valley of the dam

The information required is

a) No. of cross-sections to describe the channel;

b) Geometrical details i.e. top width-elevation table, at each cross-sections;

c) distance of the cross-section from the dam;

d) From the cross-sections at (b) above, if it is seen that the top width is too large at some sections, these may have to be divided judiciously into active flow portion and inactive flow portion. Sometimes from topography of the channel the active-inactive portion are easily identified.

e) In some sections, the off channel storage portion which could absorb some flow may be identified and their sectional

f) Manning's n at each section at different elevation.

g) Flood plain compartment (FPC) details:- Location, elevation at which water flows into the FPC or out of FPC into the channel.

h) Pump discharges into or out of FPC

i) Lateral inflow/outflow hydrograph details

j) Initial water elevation in channel

k) Landslide details

4.0 INPUT VARIABLES

The input variables for the DAMBRK program in standard computer formats are given below:

Card Block	Card No.	Variable	Format	Columns	Brief Description
A. NAME, ADDRESS & MESSAGE					
	1a	MDAM	20 A 4	1 - 20	Name of dam
		MRVR		21- 40	Name of river
		MNAME		41- 60	Agency Name
	1b	MESSAGE	20 A 4	1 - 40	Street,Room,City, State of the Agency.
B. CONTROL PARAMETERS FOR CHOICE OF OPTION & PRINTOUTS					
	2	KKN	8 I 10	1 - 10	Control parameter to decide if the down stream channel below failed dam is sub critical or supercritical regime
		KUI		11-20	Control parameter to select dynamic or storage routing in reservoir
		MULDAM		21-30	Indicates number of dams
		KDMP		31-40	Control parameter to select various print options
		ITEH		41-50	Denotes number of hydrograph

	NPRT		51-60	Control parameter to select number of cross-sections at which hydraulic informations are printed
	KFLP		61-70	Control parameter to select if special flood plain routing is derived.
	KSL		71-80	Control parameter to select if Landslide features are desired.
3	NPT(K)	8 I 10	depends on NPRT value	Sequential number of cross-sections at which hydraulic information is printed.
4	IOPUT(K)	10 I 1 2 I 2		Twelve nos. optional print parameters. First ten options are printed in one column each starting from Col.No.1 and end in Col.No.10. Eleventh parameter is at Col.No.11-12 and Twelth at Col.No.13-14.

C. REQUIREMENT OF SIMULTANEOUS COMPUTATION

5	IDAM(K)	8 I 10	Depends upon MULDAM	No. of cross-section coincident with u/s face of each dam surface area or vol. of reservoir at different elevation.

D. REQUIREMENT FOR STORAGE ROUTING

6	SA(K)	8 F 10.0		Reservoir elevations at which
7	HSA(K)	8 F 10.0		SA(K) are desired.

E. RESERVOIR SPECIFICATIONS & BREACHING PARAMETERS

8	RLM	8 F 10.0	1 - 10	Length of reservoir
	YO		11 - 20	Reservoir Level when computation commences
	Z		21 - 30	Side Slope
	YBMIN		31 - 40	Elevation of bottom of breach
	BB		41 - 50	Width of base of breach
	TFH		51 - 60	Time from beginning of breach formation until it reaches maximum size
	DATUM		61 - 70	Bottom elevation of dam
	VOL		71 - 80	Control parameter to select if vol. or surface area are used in storage routing.
9	HF	8 F 10.0	1 - 10	Elevation of water when failure of dam commences
	HD		11 - 20	Elevation of top of dam
	HSP		21 - 30	Elevation of uncontrolled spillway crest
	HGT		31 - 40	Elevation of centre of gate openings
	CS		41 - 50	Discharge coefficient of uncontrolled spillway
	CG		51 - 60	Discharge coefficient of gateflow
	CDO		61 - 70	Discharge coefficient of uncontro-lled weirflow over top of dam.
	QT		71 - 80	Discharge through turbines
10	QSPILL(K,L)	8 F 10.0		Flow of spillway rating curve
11	HEAD (K,L)	8 F 10.0		Head above spillway crest corresponding to QSPILL(K).

F. INFLOW HYDROGRAPH

12	DHF	2 F 10.0	1 - 10	Interval between hydrograph ordinates
	TEH		11 - 20	Time from beginning of routing till the end.
13	QO	4 F 10.0	1 - 10	Initial steady discharge
	RHO		11 - 20	Ratio of peack flow to initial flow
	GAMA		21 - 30	Ratio of time from initial steady flow to CG of flood hydrograph
	TPG		31 - 40	Time of initial flow to peak flow
14	QI(K)	8 F 10.0		Inflow ordinates at the upstream end of reservoir/channel.
15	TI(K)	8 F 10.0		Time associated with QI(K)

G. CROSS-SECTION SPECIFICATIONS - CONTROL PARAMETERS

16	NS	8 I 10	1 - 10	Number of cross-sections to describe channel
	NCS		11 - 20	Maximum number of top widths
	NTT		21 - 30	Total number of cross-sections at which discharge hydrographs will be plotted.
	JNK		31 - 40	Parameter to specify type of output. valley specification and/or smoothening
	KSUPC		51 - 60	Parameter to specify if subcritical or supercritical
	LQ		61 - 70	Parameter to denote number of

				lateral inflow/outflow
	KCG		71 - 80	Number of ordinates for time variable gate coefficient or number to indicate number of flood plain compartments
17	NT(K)	6 I 10	1 - 10	No. of cross-sections at which hydrograph plots desired.
			11 - 20	
			21 - 30	
			31 - 40	
			41 - 50	
			51 - 60	

H. CROSS-SECTIONS - SMOOTHENING

18	SMF	F 10.2	1 - 10	Smoothening factor
	NTSM	2 I 10	11 - 20	Parameter indicating smoothening type
	NSMR		21 - 30	Number of separate smoothening reaches
19	NUSM (K)	2 I 10	1 - 10	Upstream cross-section number of Kth smoothening reach
	NDSM(K)		11 - 20	Downstream (cross-section number of Kth smoothening reach.

I. CROSS-SECTIONS - DETAILED SPECIFICATIONS

20	XS(I)	4 F 10.0	1 - 10	Location of cross-section used for describing channel valley
	FSTG(I)	.	11 - 20	Level at which flooding commences

	XSL (I)	21 - 30	Location of left(looking upstream) flood plain
	XSR(I)	31 - 40	Location of right flood plain.
21	HS (K,I) 8F 10.0		Elevation corresponding to each top width BS(K,I)
22	BS(K,I) 8F 10.0		Top width of active flow of main channel corresponding to HS(K,I)
23	BSL(K,I)8F 10.0		Top width of active flow of left flood plain corresponding to HS (K,I)
24	BSR(K,I)8F 10.0		Top width of active flow of right flood plain corresponding to HS(K,I)
25	BSS(K,I) 8F 10.0		Top width of off channel storage portion of channel valley corresponding to HS(K,I)
26	DSA (K,I) 8D 10.0		Surface area of active flow portion corresponding to HS(K,I)
27	SSA(K,I) 8F 10.0		Surface area of off channel storage portion corresponding to HS(K,I)

J. ROUGHNESS COEFFICIENTS

28	CM(K,I) 8 F 10.0		Manning's n for main channel corresponding to HS(K,I)

29	CML(K,I)8 F 10.0	Manning's n for left flood plain channel corresponding to HS(K,I)
30	CMR(K,I)8 F 10.0	Manning's n for Right flood plain channel corresponding to HS(K,I)

K. MINIMUM REACH LENGTH & CONTRACTION-EXPANSION COEFFICIENTS

31	DXM(I) 8F 10.0	Minimum Δx distance between two successive cross-sections.
32	FKC(I) 8F 10.0	

L. CONTROL PARAMETERS FOR CHOICE OF TIMESTEP & INITIAL BOUNDARY CONDITIONS

33	QMAXD 8F 10.0	Estimated maximum discharge at downstream extremity
	QLL	Maximum lateral outflow
	DTHM	Initial time step size
	YDN	Indicator for initial water surface elevation
	SOM	Slope of down stream channel
	FII	Theta(θ) weighting factor in finite difference solution
	EPSY	convergence criterion for stage in Newton Raphson solution

	TFI		Time when change of time step takes place

M. FLOOD PLAIN COMPARTMENTS - INFORMATIONS & SPECIFICATIONS

34	NPLD I 10		No. of last flood plain compartment on the same side as the first FPC.
35	NPXI(K) 2 I 10	1 - 10	No. of cross-sections upstream of Δx reach where inflow to Kth FPC occurs.
	NQLP(K) 4 F 10.0	11 - 20	Parameter indicating pump discharge in Kth FPC
	PWELV(K)	21 - 30	Average elevation of crest weir (levee) in Kth FPC
	PCWR(K)	31 - 40	Coefficient of discharge of weirflow in Kth FPC.
	PEO(K)	41 - 50	Initial water surface elevation in Kth FPC.
	QMINP(K)	51 - 60	Minimum discharge of total number of pumps in Kth FPC.
36	PSA(I,K) 8 F 10.0		Volume of Kth FPC corresponding to elevation PEL(J,K)
37	PEL (I,K) 8 F 10.0		Elevation corresponding to PSA (I,K)

38	QPU(I,K)	8 F 10.0		Inflow into Kth FPC other than that from river through weir
39	QLP(I,K)	8 F 10.0		Specified total pump discharge for Kth FPC.
40	COFF(I,K)	8 F 10.0		Coefficient of discharge for flow over levee separating two FPCs.
41	HCFF(I,K)	8 F 10.0		Elevation associated with discharge coefficient COFF(I,K)
42	NPM	I 10	1 - 10	Total number of pumps in all the FPC.
43	IPMP(L)	2 I 10	1 - 10	Number of Kth FPC where Lth pump is located.
	NXPO(L)	2 I 10	11 - 20	Number of cross-section upstream of Δx reach where Lth pump is located
	PEMN(L)	2 F 10.0	21 - 30	Elevation of water in Kth FPC when Lth pump starts pumping
	PEXM(L)		31 -40	Elevation of water in Kth FPC when Lth pump stops pumping
44	DHP(I,L)	8 F 10.0		Head associated with Lth pump rating curve.
45	OP(I.L)	8 F 10.0		Pump discharge associated with Lth pump rating

N. LATERAL FLOW HYDROGRAPH

46	LQX(L,K) 8 F 10.0		Number of cross-section immediately upstream of lateral inflow/outflow
47	QL(L,K) 8 F 10.0		Lateral inflow/outflow

O. INITIAL BOUNDARY CONDITION

48	YD (I) 8 F 10.0		Initial water surface elevation along the routing reach
49	RH (K) 8 F 10.0		Elevation points on single value rating curve for downstream boundary
50	RQ (K) 8 F 10.0		Discharge associated with elevation RH(K)
51	STN(K) 8 F 10.0		Specified water surface elevation
52	TTN(K) 8 F 10.0		Time associated with STN(K)

P. LANDSLIDE PARAMETERS

53	NSLI I 10	1 - 10	Total number of cross-section where land slide occurs.
54	NXSLI(K) I 10	1 - 10	Sequential number of cross-section where land slide occurs.
	TSL 7 F 10.2	11 - 20	Time of duration of landslide.

HSL(K)	21 - 30	Lowest elevation of land-slide mass
HSM(K)	31 - 40	Middle elevation of landslide mass
HSU(K)	41 - 50	Highest elevation of landslide mass
THKSL(K)	51 - 60	Greatest thickness of landslide mass
ALPHA	61 - 70	Angle of repose of deposited material in reservoir bed.
POR	71 - 80	Porosity of landslide material

Q. ADDITIONAL DATA FOR TIME DEPENDENT GATE FLOW

55	ICG(K) 8 I 10	Parameter indicating if there is time dependent gateflow
56	CGCG(L,K) 8 F 10.0	Spillway gate coefficient
57	GBL(L,K) 8 F 10.0	Distance from bottom of gate to gate sill
58	TCG(L,K) 8 F 10.0	Time associated with CGCG(L,K)

R. RESERVOIR SPECIFICATIONS AND BREACHING PARAMETERS OF LOWER DAM

Card	Variable	Format	Columns	Description
59	Z	4 F 10.0	1 - 10	Slide slope
	YBMIN		11 - 20	Elevation of bottom of breach
	BB		21 - 30	Width of base of breach
	TFH		31 - 40	Time from beginning of breach formation until it reaches maximum size.
60	HF	8 F 10.0	1 - 10	Elevation of water when failure of dam commences
	HD		11 - 20	Elevation of top of dam
	HSP		21 - 30	Elevation of uncontrolled spillway gate
	HGT		31 - 40	Elevation of centre of gate opening
	CS		41 - 50	Discharge coefficient of uncontroll-ed spillway
	CG		51 - 60	Discharge coefficient of gateflow
	CDO		61 - 70	Discharge coefficient of uncontroll-ed weirflow over top of dam
	QT		71 - 80	Discharge through turbines.
61	QSPILL(K,I)	8F 10.0		Flow as per spillway rating curve

62	HEAD (K,I)	8D 10.0		Head above spillway crest corresponding to QSPILL(K,I)

S. DUMMY GROUP

63	UPSH	3F 10.0	1 - 10	Dummy variable
	SOM		11 - 20	Slope of downstream channel
	CMN		21 - 30	Average Manning's for downstream channel

It is seen that there are broadly 19 groups of cards from Group A to group S. Although the name of each of the groups are given at the beginning indicating broadly the type of general specification of variables in the cards of the group, this nomenclature is not complete in some cases. The user is advised to go into the variables in these groups and their detailed explanations being given later .

4.1 Detailed Explanation of Variables

4.1.1 Input Data File Structure

The section 4.0 gives in brief all the input variables with brief description. The following instructions may be gone through systematically and carefully alongwith cross references for constructing the input data files. Various options in dealing with different types of problems have been explained in section 1.3 alongwith use of certain control variables. These are referred in several places in the instructions given below. The detailed descriptions of variables and their usages are given below. These are arranged card wise.

Card No. 1 (a) & 1(b)

MDAM, MRVR, MNAME The brief description of these variables given in section 4.0 is sufficient.

Card No.2

KKN - A control variable to indicate mainly if supercritical or subcritical flow in channel considered. This is associated with KSUPC (Card 16).

a) For KSUPC=0, flow through entire downstream channel is subcritical. Keep KKN=1 in this case.

b) For KSUPC=1 flow is supercritical in the channel or in the upstream channel depending upon KKN=1 OR KKN=2

That is,

(i) KSUPC=1 and KKN=1, flow is supercritical throughout

(ii) KSUPC=1, KKN=2, flow is supercritical in upstream reach and subcritical in downstream reach

c) KKN=9 indicates that only a hydrograph is routed through channel (Note that routing of a flood hydrograph in a channel normally assumes a subcritical flow and hence KSUPC=0).

KUI is a control variable to select type of reservoir routing for determining outflow hydrograph.

KUI=0, storage routing is used.

KUI=1, dynamic routing is used

Remember KUI=0 for options 1,2,3,7,8 and 9.

and KUI=1 options 4,5,6,10,11 and 12

MULDAM is a control variable to select option for routing through multiple reservoirs.

a) If there are no dams downstream of first dam (breached dam), MULDAM=0

b) If there is one dam downstream of the first dam(breached dam), MULDAM=1

c) If there are more than one Dam and/or bridges downstream of first dam(breached Dam), MULDAM=Number of Dams and/or bridges.

d) If a flood hydrograph is routed in a channel, MULDAM=0

Note: Multiple dams downstream of the breach dams can be treated in two ways

(A) Sequential Method - In this method the properties of the downstream dam are taken as the boundary condition. This can be used when the tail water below a dam is not affected by the back water produced by the downstream Dam. For this,

KKN=1+No. of downstream Dam and
MULDAM = No. of Dams

In this case, the number of dams is restricted to 7.

(B) Multiple Dams as Internal boundaries:

In this the effect of the backwater of the downstream dam on the tailwater of u/s dam can be taken into account.

For this KKN=1, MULDAM = No. of dams downstream

KDMP is a control parameter for printing

KDMP =0, Print only title page

KDMP =1, Title page, abstract, variable descriptions

KDMP =2, title page, abstract, variable descriptions and input data.

KDMP =3, Title page plus input Data

KDMP =4, same as KDMP=2

KDMP =5, IOPUT on card (4) allows selective point out.

Note: The user is advised to use KDMP=3 and appropriate value of JNK(card 16) initially to get all possible input and output data alongwith explanation to help him either for debugging or for analyzing his results. However, in the final results, the KDMP=5 with selective print out for IOPUT (card 4) is advised.

ITEH is a variable denoting number of inflow flood hydrograph ordinates (Maximum of 50 ordinates allowed).

If ITEH = 0 an inflow hydrograph is generated via a mathematical function. The requirement is as indicated in Card Group No.13.

NPRT is a parameter to control print output for JNK=9 (card 16) NPRT is the total number of cross-sections at which hydraulic information is printed-out during dynamic routing; if NPRT=0, the program uses a variable NPRT computed by the program and prints-out hydraulic information at NPRT intervals of cross sections along the routing reach.

KFLP is a parameter denoting the use of the special flood-plain routing feature; if KFLP=0, the special flood-plain feature is not used; if KFLP=1, the special flood-plain routing is used.

KSL is a parameter denoting simulation of landslide;if

KSL=0, no landslide;

KSL=1, a landslide occurring along one bank of the reservoir is simulated;

KSL=2, the landslide occurs along both banks of reservoir.

Card 3

NPT(K) Omit this card if NPRT=0

It indicates sequential number of cross-section at which hydraulic information is printed out K index goes from 1 to NPRT.

Card 4

IOPUT(K) is a optional point parameter that may override the JNK parameter, (card 16). K index goes from 1 to 12. If IOPUT(K)=0, allow the output to be printed; if IOPUT(K)=1, suppress the output. The following output can be controlled;

Col

1. Slope profile plot

2. Summary tables of input cross-sections and reaches

3. Initial conditions table - flow and "L" tables (reversed)

4. Initial conditions table - backwater elevation table (forward)

5. Dynamic routing - at upstream and downstream boundaries

6. Dynamic routing - at each multiple dam site (similar to depletion table)

7. Summary plots - peak elevation, discharge, time to peak, and time to flood elevation.

8. Arrays for selected hydrograph plots

9. List of input cross-sectional information

10.Reservoir depletion table

11-12 This value represents the time at which printing of output will commence. All output will be suppressed until this time is reached.

13-14 The interval at which the output will be pointed.

Note: This information can only be controlled if the JNK parameter allowed it to be printed originally.

5. IDAM(K) - 8 I 10 Format

IDAM(K) is the number of cross-section coincident with the upstream face of read-in when the simultaneous computation of the complete system is desired (see note under variable MULDAM in card 2 for explanation) further information on the use of this computational option).

6. SA(K) - 8 F 10.0 Format

SA(K) is the surface area (acres) or volume (acre-ft.) of reservoir at elevation HSA (K) IN CARD 7. If KUI=1 and KKN=1 or KKN=9, omit card (6). Maximum of 8 values allowed.

7. HSA (K) - 8 F 10.0 Format

HSA(K) is the elevation (ft) at which reservoir surface area SA(K) in card 6 is defined; elevation is referenced to a datum plane corresponding to mean sea level (m.s.l.). If KUI=1 AND KKN=1 or KKN=9, omit card (7). Elevation start at highest and proceed to lowest. Maximum of 8 values allowed. Lowest elevation must be YBMIN as defined on card (8).

Note:

I. In reservoir storage routing of the breached Dams, i.e. for KUI=0 (Option No.1,2,3, and 9) Omit card (5) and use card (6) and (7).

2. In reservoir dynamic routing, i.e. for KUI=1 (option number 4,5,6,10, 11 and 12) use card 5 and omit cards 6 and 7.

3. In the dynamic routing of input hydrograph through a channel, i.e. for KUI=0 and KKN=9, (for option 7 and 8) omit cards 5, 6 and 7.

(8) RLM, YO, Z, YBMIN, BB, TFH, DATUM, VOL - 8 F 10.0 Format.

RLM is the length (ml) of reservoir. Elevation (ft) of water surface in reservoir when computation commences; elevation is referenced to m.s.l. datum.

Z is the side slope (1:vertical to z:horizontal) of breach. For rectangular breach z = 0

YBMIN is the lowest elevation (ft) that bottom of breach reaches; elevation is referenced to m.s.l. datum.

BB is the width (ft) of base of breach. For a triangular breach BB = 0

TPH is the time(hr) from beginning of breach formation until it reached its maximum size.

DATUM is the elevation (m.s.l.) of bottom of dam.

VOL is the parameter indicating if SA (K) is surface area (areas) or volume (acre-ft); if VOL=0.0, SA (K) is acres; if VOL=1.0, SA(K) is acre-ft.

(9) HF, HD, HSP, HGT, CS, CG, CDO, QT - 8 F 10.0 Format

HF Elevation (ft) of water when failure of dam commences; elevation is referenced to m.s.l datum; if HF is less than HD, the breach is formed by "piping".

HD Elevation (ft) of top of dam; elevation is reference to m.s.l. datum.

HSP Elevation (ft) of uncontrolled spillway crest; elevation is reference to m.s.l. datum.

HGT Elevation (ft) of center of gate openings; elevation is reference to m.s.l. datum.

CS Discharge coefficient of discharge (2.6-3.2) times the length (ft) of the spillway.

CG Discharge coefficient for gate flow; it is equal to the coefficient of discharge (o.60-0.80) times the area of gates.

CDO Discharge coefficient for uncontrolled weir flow over the top of the dam; it is equal to the coefficient of discharge (2.6-3.2) times the length of the dam crest (ft) less the length of the uncontrolled spillway and gates.

QT Discharge (cfs) through turbines; this flow is assumed constant from start of computations until the dam is completely breached; thereafter, QT is assumed to be zero. QT may also be considered leaking or constant spillway flow.

Note: 1) Omit cards (8) and (9) if KKN=9

2) The cards (8) and (9) give specifications of the breach formation

and connected control variables. The model gives two types of breach formation as explained vide section 2.1. The descriptions of these breach formations with respect to figures 1 and 2 of sections 2.1.1 and 2.1.2 are as given below:

a) Breach formation due to overtopping. The explanations of relevant variables in cards (8) and (9) with respect to Fig.1 of section 2.1.1 are given below:

YO = h

YBMIN = h_{bm}

BB = b

Z = z

DATUM = msl elevation of the bottom of dam or deepest bed level

HF = h_f

HD = h_d

Such a formation of breach is caused when HF ≥ HD or $h_f \geq h_d$ as fig. 1. The temporal growth of the breach from initial time to final time (represented as TFH in card 8) is as explained in section 2.1.1.

b) Breach formation due to piping -

The explanations of relevant variables in cards (8) and (9) with respect to fig.2 of section 2.1.2 are as given below:

YO = h_o

YBMIN = h_b

BB = b

Z = z (normally z is put a zero, i.e., the breach formation is rectangular)

DATUM = msl elevation of the bottom of dam or deepest bed level

HF = h_f

HD = H_d

Such a formation of breach is caused when HF < HD or $h_f < h_d$ as of breach formation is as explained in section 2.1.2.

(10) QSPILL (K,L) - 8 f 10.0 Format

QSPILL(K,L) Flow (cfs) of spillway or gate rating curve; K goes from 1 to maximum of 8; L goes from 1 to MULDAM (card 21) which may be a maximum of 10; if MULDAM=0, L goes from 1 to 1.

(11) HEAD (K,L) - 8 F 10.0 Format

HEAD (K,L) Head (ft) above spillway crest or gate center; head is associated with spillway flow or gate flow in rating curve; K goes from 1 to maximum of 8; L goes from 1 to MULDAM.

Note: 1) Repeat cards 10-11 as L index goes from 1 to MULDAM.

If MULDAM=0, L index goes from 1 to 1.

2) Cards (10) and (11) are used when the spillway rating is supplied by

the user. These are read-in only if either HSP is non-zero and CS is zero, or HGT is non-zero and CG is zero.

(12) DHF, TEH - 2 F 10.0 Format

DHF Interval (hr) between QI(K) input hydrograph ordinates; enter 0.0 if intervals are not equal.

TEH Time (hrs) from beginning of routing until routing is terminated.

(13) QO, RHO, GAMA, TPG - - 4 F 10.0 Format

QO Initial steady discharge (cfs).

RHO Ratio of peak flow to initial flow of inflow hydrograph.

GAMA Ratio of time from initial steady flow to center of gravity of inflow hydrograph to time to peak of inflow hydrograph.

TPG Time from initial flow to peak flow of inflow (hr).

Note: Omit card 13 if ITEH (card 2) is nonzero. If card 13 is included, then omit cards (14) and (15).

(14) QI (K) - 8 f 10.0 Format

QI (K) Inflow (cfs) at upstream end of reservoir for each interval of time during the failure and until time TEH is reached; K goes from 1 to ITEH which can assume a maximum value of 50; if ITEH=0, omit this card.

(15) TI (K) - 8 F 10.0 Format

TI (K) Time associated with QI(K) inflows; if DHF (card 12) is non-zero, or if ITEH (card 2) is equal to zero, omit this card, K goes from 1 to ITEH.

(16) NS, NCS, NTT, JNK, KSA, KSUPC, LQ, KCG - 8 I 10 Format

NS Number of cross-sections used to describe the channel and valley downstream of dam; first cross-section should be immediately downstream of dam; last cross-section should be at farthest point downstream of dam where flood information is desired; other cross-sections can be located as desired by user; maximum of 90 and minimum of 2 cross-sections can be used to describe the downstream channel valley.

NCS Maximum number of top widths used to describe a cross-section.

NTT Total number of cross-sections at which discharge hydrographs will be plotted; maximum number is limited to 6. The location of the cross-sections at which plots are provided is specified by the parameter NT(K), which is on card (17). If NTT=0, no plots are provided. If NTT=a negative value between 1 and 6, the profile plots are suppressed.

JNK Parameter to specify the type of output other than plots which will be provided; if JNK=0, a minimum of output is provided - this includes all input data and hydrograph plots; if JNK=1, reservoir depletion table printed, profile of downstream crests and times, and designated hydrographs; if JNK=4, additional information is printed at each time step for debugging; if JNK=9, information is printed for debugging.

KSA This is a control variable to decide (a) whether downstream channel valley will be described by cross-sections or (b) whether downstream channel valley will be described by surface area vs. elevation curve or (c) whether downstream channel valley will be described by cross-sections with proper smoothening factors. For this purpose three sets of values of KSA are used as given below:

i) KSA =0, the downstream channel valley is described by NS number of cross-sections without smoothening.

ii) KSA =1, the downstream channel valley is described by input data consisting of a single table of surface area vs. elevation. For this purpose NS =2.

iii) KSA = any negative integer like - 1, -2, -3, etc., this enables effecting proper smoothening factor when the downstream channel valley is described by NS number of cross-sections. The absolute integer value of KSA decides smoothening of widths in vertical direction as explained in variable NTSM of card 18.

Note: Further use of KSA = 0 and KSA = 1 are explained in the note after card 27.

KSUPC Parameter to indicate if flow is supercritical. If KSUPC=0 , flow through entire downstream channel-valley reach is subcritical and no special treatment is required; if KSUPC=1, the flow is known to be supercritical in either an upstream portion of the downstream channel-valley or throughout the entire downstream reach. When flow is supercritical,. special computational procedures are used within the program. If only the upstream portion of the reach has supercritical flow, two sets of downstream channel-valley inputs commencing with card no.(16) are read in.

LQ Parameter denoting the total number of lateral inflow hydrographs along the downstream channel-valley; a maximum of 10 hydrographs, each with 50 ordinates, are allowed.

KCG Number of ordinates in spillway gate control curve of gate coefficient (CGCG) vs. time (TCG) described on cards (56) and (58). If KCG is negative, it is the total number of floodplain compartments. Maximum of 16 allowed.

Note: For debugging, JNK=4 or 9 is preferred.

(17) NT(K) - 6 I 10 Format

NT (K) Number of cross-section (1 through NS in card 16) at which hydrograph plots are desired; K goes from 1 to NTT in card 16: if NTT=0, card no.(17) is omitted.

(18) SMF, NTSM, NSMR - F 10.2, 2 I 10

SMF Smoothing factor, 0.5 < SMF < 0.9.

NTSM Parameter indicating type of smoothing. If NTSM=1, smoothing of widths along x = axis; if NTSM=2, smoothing of widths in vertical where maximum width/ft change is /KSA/ *50; if NTSM=3, smoothing of widths in vertical where maximum width/ft change is/KSA/ *50; if NTSM=3, smoothing of elevations along x-axis; NTSM=4, type 1 and type 2 smoothing; if NTSM=5, type 1,2, and 3 smoothing.

NSMR Number of separate smoothing reaches within the total routing reach.

(19) NUSM(K), NDSM(K) - 2 I 10

NUSM(K) Upstream cross section number of Kth smoothing reach.

NDSM(K) Downstream cross section number of Kth smoothing reach.

Note: Card (19) is read-in for each Kth smoothing reach as K goes from 1 to NSMR.

Note: Omit cards 18 and 19 if KSA ≥ 0 (card 16).

(20) XS(I), FSTG(I), XSL(I) , XSR(I) - 4 F 10.0 Format

XS(I) Location (mi) of cross-sections used to describe downstream channel-valley; mileage must increase in the downstream direction from dam. If KFLP=1 (CARD (2)), XS (I) is mileage measured along centre of channel.

FSTG(I) Elevation (m.s.l.) at which flooding commences; may be left blank.

XSL(I) If KFLP=0, leave blank; if KFLP=1, XSL(I) is the mileage (location) of the Ith cross-section along cross-section along the left (looking upstream) flood plain.

XSR(I) If KFLP=0, leave blank; if KFLP=1, XSR(I) is the mileage (location) of the Ith cross-section along the right flood-plain.

(21) HS (K,I) - 8 F 10.0 Format

HS(K,I) Elevation (ft), referenced to ms.1. datum. corresponding to each top width (BS (K,I) on card (22) used to describe cross-sections; K goes from 1 to NCS; NCS values of HS (K,I) are punched on a single card. NCS is limited to a maximum of 8. Start with lowest HS and proceed to highest values of HS.

(22) BS (K,I) - 8 F 10.0 Format

BS (K,I) Top width (ft) of active flow portion of channel-valley cross-section corresponding to each elevation HS(K,I); K goes from 1 to NCS in card (16); NCS values of BS (K,I) are punched on a single card; NCS is limited to maximum of 8. This card is omitted if KSA=1.

(23) BSL (K,I) - 8 F 10.0 Format

BSL (K,I) Top width (ft) of active flow portion of left flood-plain corresponding to each elevation HS (K,I); K goes from 1 to NCS; NCS values of BSL(K,I) are punched on a single card; NCS is limited to a maximum of 8. This card is omitted if KFLP=O (card (2)).

(24) BSR (K,I) - 8 F 10.0 Format

BSR (K,I) Top width (ft) of active flow portion of right flood-plain corresponding to each elevation HS (K,I). This card is omitted if KFLP=0.

(25) BSS (K,I) - 8 F 10.0 Format

BSS (K,I) Top width (ft) of off-channel storage portion of channel-valley cross-section corresponding to each elevation HS (K,I); K goes from 1 to NCS; NCS values of BSS (K,I) are punched on a single card; NCS is limited to maximum of 8; this card is omitted if KSA=1 (card 16)).

(26) DSA (K,I) - 8 F 10.0 Format

DSA (K,I) Surface area (acres) of active flow portion of downstream channel-valley cross-section corresponding to each elevation HS(K,I); K goes from 1 to NCS; NCS values of DSA (K,I) are punched on a single card; NCS is limited to maximum of 8; this card is omitted if KSA < 0.

(27) SSA (K,I) - 8 F 10.0 Format

SSA (K,I) Surface area (acres) of off-channel storage portion of channel valley cross-section corresponding to each elevation HS (K,I); K goes from 1 to NCS; NCS values of SSA (K,I) are punched on a single card; NCS is limited to maximum of 8; this card is omitted if KSA=0.

Note: The arrangement of cards from 20 to 27 is given below:

a) For KSA = 0 or KSA = negative integer as explained at (i) and (iii) under the explanation for variable KSA in card 16, the arrangement of cards will be from card 20 to card 25 serially. This arrangement is repeated as index I goes from 1 to NS.

b) For KSA =1 (for which NS =2), the cards are arranged as 20, 21, 26, 27, 20, 21.

(28) CM (K,I) - 8 F 10.0 Format

CM (K,I) - Manning n for channel corresponding to each elevation HS (K,I); K goes from 1 to NCS; NCS values of CM(K,I) are punched on a single card; NCS is limited to maximum of 8; the Manning n represents the roughness encountered by the flow through the reach bounded by cross-sections at locations I and I+1.

(29) CML (K,I) - 8 F 10.0 Format

CML (K,I) Manning n for left flood-plain corresponding to each elevation HS (K,I); K goes from 1 to NCS; NCS values of CM (K,I) are punched on a single card; NCS is limited to a maximum of 8. This card is omitted if KFLP=0 (card 2).

(30) CMR (K,I) - 8 F 10.0 Format

CMR (K,I) Manning n for right flood-plain corresponding to each elevation HS (K,I). This card is omitted if KFLP=0.

Note: CARDS (28, 29, 30) are repeated for (NS-1) reaches.

(31) DXM (I) - 8 F 10.0 Format

DXM (I) Minimum Δx distance (mi) between cross-sections used in the computations. If DXM (I) is less than the distance between two adjacent cross-sections among the NS cross-sections read in, then intermediate cross-sections are created within the program via an interpolation procedure. (NS-1) values of DXM (I) are punched on one or more cards (8 values to a card); maximum no.

of DXM (I) values is limited to 89; values assigned to DXM (I) should not result in more than 200 cross-sections produced by the interpolation procedure. (DXM) values should be determined by the relationship C times Δt, where C is the approximate speed of the flood wave.)

(32) FKC (I) - 8 F 10.0 Format

FKC (I) Contraction-expansion coefficient; contraction values vary from 0.1 to 0.3 , expansion values vary from -0.5 to -1.0 ; if contraction-expansion effects are negligible, enter 0.0 for FKC (I); (NS-1) values of FKC (I) are punched on one or more cards (8 values to a card); maximum no. of FKC (I) values is limited to 89.

(33) QMAXD, QLL, DTHM, YDN, SCM, F1I, EPSY, TFI -8 F 10.0 Format

QMAXD Estimated maximum discharge (cfs) at downstream extremity of channel-valley reach; can be read in as 0.0 for initial run, subsequent runs can have a value of QMAXD as determined by the routing computations during the initial run. Only required when QLL is non-zero.

QLL Maximum lateral outflow (cfs/ft) producing the volume losses experienced by the passage of the dam-break flood wave through the downstream valley; QLL has a negative sign. DTHM Initial t time step DTHM size (hr); if 0.0 is read in, the value of DTHM is computed by the program; if DTHM<0.0. DTHM represents the divisor MDT for determining the time step (DTH=TFH/MDT) and DTHM is reset to zero.

YDN Initial elevation of water surface at downstream end of routing reach; if channel control exists at this location, enter 0.0; YDN is non-zero if a dam or other control structure exists at the downstream end of the routing reach; if YDN=0.25 , A single value rating curve of water surface elevation (m.s.l.) vs. discharge exists at downstream end; if YDN = 0.5, critical flow such as waterfall exists at downstream end; if YDN=0.75, a specified water surface elevation (m.s.l.) such as a tide exists at the downstream end; if

YDN=1.0, channel control exists at downstream end, but this signals the program that initial water surface elevations will be read-in at the NS cross-sections via card (48).

SOM Slope of downstream channel (ft/ml) for first mile below dam.

FlI Theta (θ) weighting factor in finite difference solution; if left blank, a value of 0.60 is used in program; if 0.5 is used. θ is set internally to 0.60 and the model is capable of allowing negative flows to occur; if 0.51 is used. θ is set internally to 0.60 and the model routing is done by the diffusion method instead of dynamic routing.

EPSY Convergence criterion for state (ft) in Newton-Raphson interactive solution of finite difference unsteady flow equations; varies from .01 to .1 ft; if left blank, program us 0.01 ft. TFI Time (hr) when TFI time step changes from DTHM to TFH/MDT.

(34) NPLD - I 10

NPLD Number of last flood plain compartment on same side of river where first flood plain compartment (FPC) is located; if no flow is transferred from one FPC to an adjacent FPC, let NFLD=0. Omit this card if KCG $\geq$ 0.

(35) NPXI (K), NQLP (K), PWELV (K), PCWR (K), PEO (K), QMINP (K) - 2 I 10, 4 F 10.0

NPXI (K) Number of cross section immediately upstream of Δx reach share inflow to Kth FPC occurs.

NQLP (K) Parameter indicating if pump discharge within the Kth FPC will be specified by a discharge hydrograph; 0 if no, 1 if yes.

PWELV (K) Average elevation (ft. msl) of crest of weir (levee) along Δx reach where inflow to Kth FPC occurs.

PCWR(K) Coefficient of discharge for weir flow along Δx reach where inflow to

PEO (K) Initial elevation (ft. msl) of water surface in Kth FPC at time = 0.

QMINP (K) Minimum discharge (cfs) of total number of pumps in Kth FPC at all times.

(36) PSA (I,K) - 8 F 10.0

PSA(I,K) Total volume (acre-ft) of Kth FPC below each elevation (PEL (I,K); I index goes from 1 to 8.

(37) PEL (I,K) - 8 F 10.0

PEF (I,K) Elevation (ft. msl) associated with each volume PSA (I,K); elevations start at the lowest and proceed to the highest; I index goes from 1 to 8; last specified elevation should be greater than any expected water elevation within the FPC.

(38) QPU (I,K) - 8 F 10.0

QPU (I,K) Inflow (cfs) to Kth FPC other than that transmitted over the weir (levee) from the main river; I index goes from 1 to ITEH (card no.2).

(39) QLP (I,K) - 8 F 10.0

QLP (I,K) Specified total pump discharge (cfs) for Kth FPC; I index goes from 1 to ITEH (card no.2); omit this card if NQLP (K)=0.

(40) COFF (I,K) - 8 F 10.0

COFF (I,K) Coefficient of discharge for flow over levee separating the Kth and Kth+1 FPC; coefficient is product of the broad- crested weir coefficient (2.6 to 3.2) and the length (ft) of the weir crest; the coefficient varies with elevation (HCFF (I,K); I index goes from 1 to 8; omit this card if NPFD =0.

(41) COFF (I,K) - 8 F 10.0

COFF (I,K) Elevation (ft. msl) associated with the discharge coefficients COFF (I,K); elevations start at the lowest point along the levee crest and proceed upward; I index goes from 1 to 8; omit this card if NPLD=0.

(42) NPM - I 10

NPM Total number of pumps in all the FPC.

Note: 1) For KCG $\geq$ 0 (card 16) omit card 34 to 45

2) For KCG $<$ 0 repeat card no.35 to 41 as K goes from 1 to absolute value of KCG.

3) If NPM = 0, omit card No.43 to 45.

(43) IPMPL (L), NXPO (L), PEMN (L), PEMX (L) - 2 I 10, 2F 10.0

IPMPL (L) Number of the Kth FPC in which the Lth pump is located.

NXPO (L) Number of the cross section immediately upstream of Δx reach where the Lth pump discharges into main river.

PEMN (L) Elevation (ft. msl) of water in Kth FPC when Lth pump starts pumping.

PEMX(L) Elevation (ft. msl) of water in Kth FPC when Lth pump stops pumping.

(44) DHP (I,L) - 8 F 10.0

DHP (I,L) Head (ft) associated with Lth pump rating curve; 1 index goes from 1 to 8; head starts at smallest and proceeds to greatest; negative head may be specified. Omit this card if NQLP (K) = 0 (card 35).

(45) OP (I,L) - 8 F 10.0

OP (I,L) Pump discharge (cfs) associated with Lth pump rating curve; I index goes from 1 to 8; each value is associated with its corresponding DHP(I,L) value. Omit this card if NQLP (K) = 0. (card 35)

Note: Repeat card no.43 to 45 as L index goes from 1 to NPM.

(46) LQX(K) - 8I 10 Format

LQX(K) Number of cross-section immediately upstream of lateral inflow/outflow; K goes from 1 to LQ (card (16). If LQX (K) is specified as a negative number, this indicates that the reach may have outflow via broad-crested weir flow.

(47) QL (L,K) - 8 F 10.0 Format

QL(L,K) Lateral inflow (cfs) for Kth lateral inflow point; L index goes from 1 to ITEH (card (2)); ordinates of lateral inflow hydrograph have same time as those of reservoir inflow hydrograph QI(L) on card (14)); K index goes from 1 to LQ. If LQX (K) is negative, two values only are specified on card (47) according to a 2 F 10.2 format. The first (WELV (K)) is the crest elevation (msl) at which overflow occurs (this represents the average crest elevation along the reach). The second (CWR (K) is the discharge coefficient ranging in value from 2.6 to 3.2 with 3.0 a most common value.

Note: Omit cards (46) and (47) if LQ=0 (on card no.16).

(48) YD (I) - 8 F 10.0 Format

YD (I) Initial water surface elevations (m.s.l.) along routing reach; this is used only if YDN=1.0; if YDN $\neq$ 1.0, omit this card and program computes the initial water surface elevations.

(49) RH (K) - 8 F 10.0 Format

RH (K) Elevation (m.s.l.) points on single value rating curve for downstream boundary, read in only if YDN (card no.33) = 0.25; K index goes from 1 to maximum of 8.

(50) RQ (K) - 8 F 10.0 Format

RQ (K) Discharge (cfs) associated with elevation points on single value rating curve for downstream boundary, read in only if YDN = 0.25

(51) STN(K) - 8 F 10.0 Format

STN (K) Specified water surface elevation (m.s.l.) at downstream boundary such as a tide; K goes from 1 to ITEH, read in only if YDN=0.75.

(52) TTN (K) - 8 F 10.0 Format

TTN (K) Time (hrs) associated with STN (K); K goes from 1 to ITEH, read in only if YDN = 0.75.

(53) NSLI - I 10 Format

NSLI Total no. of cross-sections (read-in) where landslide occurs; maximum no. allowed is 6; also maximum total cross-sections (including interpolated ones created by DXM values on card (31) is limited to 31; omit if KSL = 0

(54).NXSLI (K), TSL, HSL (K), HSM (K), HSU (K), THKSL (K), ALPHA, POR - I 10, 7 F 10.2 Format

NXSLI (K) Sequential number of cross-section where landslide occurs; K index ones from 1 to NSLI

TSL Time of duration for landslide (usually in the range of 15 seconds to a few minutes); unit must be in hrs.

HSL (K) Elevation (ft above msl) of lowest portion of landslide mass; K goes from 1 to NSLI,

HSM (K) Elevation (ft above msl.) of middle portion of landslide mass-at this elevation, the landslide mass has the greatest thickness into the bank; K goes from 1 to NSLI.

HSU(K) Elevation (ft above m.s.l.) of highest portion of landslide mass, K goes from 1 to NSLI.

THKSL(K) Greatest thickness (depth into the bank) in ft of the landslide mass at elevation HSM(K); K goes from 1 to NSLI.

ALPHA Angle of repose that deposited material from the landslide assumes in the bottom of the reservoir, in degrees.

POR Porosity of landslide material, decimal fraction.

Note: Omit cards (53) and (54) if KSL=0.

Note: Card (54) is repeated for each K as it goes from 1 to NSLI.

(55) ICG (K) - 8 I 10 Format

ICG (K) Parameter indicating if a dam has time- dependent gate flow; if yes ICG (K)-1; if no, ICS (K) = 0; K goes from 1 to M, where M = MULDAM if MULDAM >1 and M = 1 if MULDAM = 0

(56) CGCG (L,K) - 8 F 10.0 Format

CGCG (L,K). Spillway gate coefficient equal to area of gates (opened at time TCG (L,K)) x coefficient of discharge; L goes from 1 to KCG (see card 16); and K goes from 1 to the total number of dams having time-dependent gate control.

(57) GBL (L,K) - 8 F 10.0 Format

GBL (L,K) Distance (ft) from bottom of gate to gate sill (HGT-card (9)); This distance is time dependent and is associated with the time array TCG (L,K); L and K index are same as described on card (56).

(58) TCG (L,K) - 8 F 10.0 Format

TCG (L,K) Time (hrs) associated with CGCG (L,K); L goes from 1 to KCG; and K goes from 1 to the total number of dams having time-dependent gate control.

Note: Omit cards (55), (56), (57) and (58) if KCG=0 (on card no.16).

(59) Z, YBMIN, BB, TFH - 4 F 10.0 Format

Z Side slope (1: vertical to z: horizontal) of breach of downstream dam.

YBMIN Lowest elevation (ft) that bottom of breach reaches; elevation is reference to m.s.l. datum.

BB Width (ft) of base of breach of downstream dam.

TFH Time (hr) from beginning of breach formation of downstream dam until it reaches its maximum size.

(60) HF, HD, HSP, HGT, CS, CG, CDO, QT - 8 F 10.0 Format

HF Elevation (ft) of water when failure of downstream dam commences; elevation is reference to m.s.l. datum.

HD Elevation (ft) of top of downstream dam; elevation is referenced to m.s.l.datum.

HSP Elevation (ft) of uncontrolled spillway crest; elevation is referenced to m.s.l. datum.

HGT Elevation (ft) of center of gate openings; elevation is referenced to m.s.l. datum.

CS Discharge coefficient for uncontrolled spillway; it is equal to the coefficient of discharge (2.6 - 3.2) times the length (ft) of the spillway.

CG Discharge coefficient for gate flow; it is equal to the coefficient of discharge (0.10-0.80) times the area of gates.

CDO Discharge coefficient for uncontrolled weir flow over the top of the downstream dam; it is equal to the coefficient of discharge (2.6 - 3.2) times the length of the downstream dam crest (ft) less the length of the uncontrolled spillway and gates.

QT Discharge (cfs) through turbines; this flow is assumed constant from start of computations until the downstream dam is completely breached; thereafter QT is assumed to be zero.

(61) QSPILL (K,1)- 8 F 10.0 Format

QSPILL(K,1) Flow (cfs) of spillway or gate rating curve; k goes from 1 to maximum of 8.

(62) HEAD (K,1) - 8 F 10.0 Format

HEAD(K,1) Head (ft) above spillway crest or gate center; head is associated with spillway flow or gate flow in rating curve.

Note: Cards (61) and (62) are read-in only if either HSP is non-zero and CS is zero or HGT is non-zero and CG is zero. This option allows a rating curve to be used for either the uncontrolled spillway or submerged gate rather than an equation for each using a constant discharge coefficient.

(63) UPSH, SOM, CMN - 3 F 10.0 Format

UPSH Dummy variable, leave blank.

SOM Slope of downstream channel (ft/mi) for first few miles below dam.

CMN Average Manning's n for downstream channel for first few miles below dam.

Note: Cards (59-63) are omitted if KUI=0 and MULDAM=0 or if KKN=9.

Note: If KUI=1 and dynamic routing is used for the reservoir routing procedure, cards (6) and (7) are omitted and cards (98) - (58) and (51) apply to the reservoir characteristics. Then, cards (16) - (58) are read in again; this time they apply to the downstream channel and valley.

Note: If KKN=9, only a downstream routing is used to route a read- in hydrograph (cards (12) - (15)). Also, cards (16) - (25) and (28) - (58) are required.

5.0 APPLICATION OF DAMBRK PROGRAM

DAMBRK is a dynamic flood routing program. It has wide application besides simulating movement of dam-breach flood wave. Some of the typical flood wave routing applications of this program are:

5.1 Category I - Dam break flood wave routing:-

A. Single dam breach with dynamic reservoir routing of breached dam.

B. Single dam breach with storage routing of the reservoir of the breached dam.

C. Multiple dam breach with dynamic reservoir routing of the upstream-most of the breached dams.

D. Multiple dam breach with storage routing of the upstream most of the breached dams.

For these applications the relevant options to be used are given below:

Type of application	Options to be used	Conditions necessary for deciding the relevant option
A.	4	Subcritical flow in entire downstream reach of the breached dam.
	5	Supercritical flow in entire downstream reach of the breached dam.
	6	Supercritical flow in the upstream portion

		and subcritical flow in the downstream portion of the reach below the breached dam.
	11	Flood routing through bridges and/or with special internal boundary condition
B	1	Subcritical flow in entire downstream reach of the breached dam.
	2	Supercritical flow in entire downstream reach of the breached dam.
	3	Super critical flow in the upstream portion and subcritical flow in the downstream portion of the reach below the breached dam.
C.	10	When two dams are involved.
	12	Two or more dams and/or bridges are involved.
D.	9	Reservoir Routing having one dam with sub-critical down stream flow below the breached dam.

5.2 Category II - Channel routing

Different types or application of channel routing with relevant options to be used are given below:

Type of applications in channel	Option to be use routing	Conditions necessary for deciding the relevant options.

1. Channel routing of flood hydrograph	7	a. Subcritical flow throughout.
		b. Subcritical flow throughout with definite boundary condition like presence of tide at the downstream end of the reach.
	8	Supercritical flow throughout.
	12	a. routing through bridges.
		b. routing through bridges and with definite boundary condition like presence of tide at the downstream end of the reach.

5.3 Category III - Reservoir Routing

(a) Simple reservoir storage routing can be done by using Option 1 by forcing no-breach condition of the dam. This is achieved by giving a very high value to the variable HF in Card No.9. Besides the breach parameters are sufficiently reduced e.g. YBMIN in Card 8 is given a value almost equal to HD in Card 9 and BB in card 8 is given a value near to zero. The shortcoming in this routing is that it starts from the beginning of the hydrograph period instead of at a discharge corresponding to the discharge at FRL. Besides, the users are not advised to use this big program in simple storage routing.

(b) Reservoir dynamic routing can be done by using Option 4. In this case also no-breach condition is forced on the program as done in case of storage routing described in 5.3 (a) by putting appropriate values to variables HF in card 9 and YBMIN and BB in card 8. This is a very useful routing exercise especially in the backwater curve analysis in a reservoir.

5.4 Printing Options Available with DAMBRK.

Various options for printing the outputs are available. For exercising these options, the relevant variables are KDMP in Card 2, IOPUT(K) in Card 4 and JNK in card 16. The users are advised to understand these variables clearly as explained in section 4. Most of the printing options give lot of outputs requiring more stationery. If the user is interested in some selected outputs only, he is advised to use KDMP = 5 in card 2 and required outputs as per instructions given for IOPUT (K) in card 4.

For example, for backwater curve analysis, the requirement is to know the levels of reservoir at different cross-sections at different times. Since the program has capability to give prints of hydrograph at maximum of six cross-sections as given in NT(K) of card 17, it may be required to get further outputs for other sections by repeatedly changing the values of NT(K) as per requirement. To avoid wastage of stationery in these repeated outputs, the following values are suggested.

KDMP = 5

IOPUT = 1111111 0 111111

C1(a)	MACCHU DAM-II		MACHHU RIVER (OPTION-1)					
C1(b)	NATIONAL INSTITUTE OF HYDROLOGY				ROORKEE-247 667 (U.P.)			
C2	1	0	0	3	27			
C6	177915	158402	128318	60026	38092	21359	7926	0
C7	198.5	197	194	184	178	170	155	130
C8	4.3	198.5	.027	130.	1036.	1.0	130.	1.
C9	198.5	197.0	168.	0.	0.	0.	27055.	0.
C10	0.	17190.	63751.	103149.	160690.	184780.	205069.	229217.
C11	0.	4.0	10.	14.	21.	24.	27.	30.5
C12	2.	52.						
C14	464000.	420000	350000	276000	194000	134000	92000	74500
C14	58000.	42000	30000	20000	10000	4000	2000	2000
C14	2000.	2000	2000	2000	2000	2000	2000	2000
C14	2000.	2000	2000					
C16	6	8	6	4	0	0	0	0
C16	1	2	3	4	5	6		
C20	0.							
C21	121.15	122.11	123.98	148.18	158.63	160.65	166.98	168.41
C22	0.	459.32	615.16	1099.08	1476.40	3280.80	5905.50	6561.70
	0.	0.	0.	0.	1066.30	3445.00	2132.50	1804.50
C20	5.813							
C21	86.81	94.78	105.07	110.27	123.85	125.87	127.18	131.00
C22	0.	738.19	1269.69	1443.60	1919.30	2263.80	2657.50	2706.70
	0.	0.	0.	0.	0.	0.	0.	9842.5
C20	10.81							
C21	44.59	47.08	66.72	88.11	88.78	90.94	93.34	101.12
C22	0.	429.13	853.02	1837.27	2575.50	2625.00	4265.10	4921.30
	0.	0.	98.4	574.15	531.5	623.40	1148.3	7053.8
C20	15.81							
C21	27.73	34.32	37.57	56.78	68.36	71.92	72.92	77.00
C22	0.	354.33	534.78	918.64	2378.60	3608.90	6889.80	9843.00
	0.	0.	0.	0.	0.	3412.	5413.	9022.
C20	20.69							
C21	17.69	17.88	22.89	32.48	40.78	45.15	48.35	52.97
C22	0.	170.60	354.30	659.40	1141.70	2625.00	7874.00	19685.0
	0.	0.	0.	0.	0.	610.	1509.	2625.
C20	24.63							
C21	2.91	15.59	26.05	30.73	32.48	32.81	34.45	36.09
C22	0.	262.47	278.90	820.20	11811.00	22966.0	26247.0	29528.0
	0.	0.	0.	0.	0.	0.	0.	0.
C28	.035	.035	.035	.035	.035	.035	.035	.035
C28	.035	.035	.035	.035	.035	.035	.035	.035
C28	.035	.035	.035	.035	.035	.035	.035	.035
C28	.03	.03	.03	.03	.03	.03	.03	.03
C28	.03	.03	.03	.03	.03	.03	.03	.03
C31	0.5	0.5	0.5	0.5	0.5			
C32	0.0	0.0	-0.5	-0.5	-0.5			
C33	0.0	0.0	0.0	0.0	7.87	0.0	0.0	0.0

Note: C1, C2, ... etc. represent the card numbers described in Chapter 4, page Nos. 23-61. These card numbers are NOT the part of data requirement.

C1(a)	GANDHI SAGAR DAM		CHAMBAL RIVER	(OPTION - 4)				
C1(b)	NATIONAL INSTITUTE OF HYDROLOGY			ROORKEE-247 667 (U.P.)				
C2	2	1	0	3	31			
C8	69.	1328.	.03	1120.	800.	1.0	1120.	
C9	1328.	1324.	1284.	0.	0.	0.	3000.	151220.
C10	0.	27793.	78621.	151197.	230199.	330829.	406054.	495269.
C11	0.	6.0	12.	18.	24.	30.	36.	42.
C12	4.	120.						
C14	27511	27511	29523	40811	78431	151739	251106	365509
C14	489253	631277	815815	1072413	1412609	1683168	1735597	1588275
C14	1322813	998641	689440	427322	247643	132657	72713	46517
C14	34432	30048	28395	27760	15023	14966	14949	
C16	28	8	1	1	0	0	0	0
C17	28							
C20	0.							
C21	1305.	1308.	1312.	1328.	1335.	1345.	1389.	1400.
C22	500.	1000.	1120.	1550.	1775.	1968.	3100.	3700.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	4.							
C21	1298.	1300.	1305.	1312.	1330.	1350.	1380.	1400.
C22	500.	1000.	1080.	1700.	2000.	2400.	3000.	3300.
C23	200.	208.	227.	255.	225.	404.	421.	500.
C20	9.							
C21	1286.	1292.	1305.	1312.	1328.	1350.	1375.	1400.
C22	500.	1000.	1080.	1120.	6145.	12500.	19200.	29000.
C23	180.	199.	240.	260.	312.	382.	461.	540.
C20	15.							
C21	1274.	1290.	1290.	1300.	1312.	1350.	1375.	1400.
C22	500.	1600.	2100.	3100.	4000.	8000.	11200.	12500.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	19.							
C21	1266.	1286.	1296.	1300.	1312.	1350.	1375.	1400.
C22	500.	2800.	4200.	4900.	6200.	16800.	23600.	30000.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	25.75							
C21	1251.	1276.	1286.	1290.	1295.	1300.	1312.	1340.
C22	300.	800.	3600.	5100.	5700.	8600.	12500.	24400.
C23	8000.	12200.	13909.	14584.	15729.	16273.	18299.	22970.
C20	28.5							
C21	1250.	1272.	1287.	1294.	1301.	1307.	1312.	1340.
C22	300.	600.	1400.	3000.	8000.	14200.	18500.	33020.
C23	8000.	11785.	14253.	15405.	16457.	17544.	18367.	22970.
C20	29.25							
C21	1249.	1272.	1286.	1292.	1300.	1305.	1312.	1340.
C22	300.	1100.	2000.	3000.	11100.	14000.	17400.	26820.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	30.							
C21	1248.	1277.	1289.	1295.	1302.	1306.	1312.	1340.
C22	310.	1300.	1400.	6300.	11000.	14200.	17000.	24570.
C23	10000.	17250.	18250.	19750.	21000.	22500.	22500.	33000.
C20	33.							
C21	1247.	1267.	1272.	1280.	1288.	1297.	1312.	1340.
C22	310.	1570.	2200.	5300.	13000.	14200.	15100.	29520.
C23	10000.	14938.	16173.	18148.	20123.	22346.	26049.	32960.
C20	38.5							
C21	1246.	1265.	1270.	1279.	1286.	1295.	1312.	1340.
C22	320.	1600.	2200.	5400.	13100.	14300.	25200.	23300.
C23	0.	0.	2230.	5800.	9280.	13400.	22900.	22750.
C20	40.5							
C21	1245.	1259.	1265.	1274.6	1282.	1289.	1312.	1340.
C22	1200.	3700.	4300.	8200.	8900.	27600.	31500.	43400.
C23	0.	0.	0.	4700.	6500.	11000.	21000.	22750.

Note: C1, C2, ... etc. represent the card numbers described in Chapter 4, page Nos. 23-61. These card numbers are NOT the part of data requirement.

C20	42.0							
C21	1244.	1254.	1260.	1269.	1277.	1284.	1312.	1340.
C22	1150.	3700.	4300.	3200.	9900.	27600.	31500.	43400.
C23	0.	0.	0.	3000.	6600.	11000.	21000.	22750.
C20	42.75							
C21	1241.	1256.	1270.	1280.	1290.	1300.	1312.	1340.
C22	1100.	5900.	10300.	13500.	16700.	19800.	23700.	50730.
C23	1100.	1479.	1833.	2086.	2339.	2592.	2895.	3606.
C20	45.75							
C21	1232.	1240.	1260.	1280.	1290.	1300.	1312.	1340.
C22	950.	3700.	10700.	17700.	21100.	24700.	29000.	42940.
C23	1000.	1167.	1583.	2000.	2108.	2416.	2666.	3250.
C20	46.5							
C21	1229.	1240.	1260.	1280.	1290.	1300.	1312.	1340.
C22	900.	4900.	12400.	19800.	23400.	27200.	31700.	38380.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	47.75							
C21	1225.	1240.	1260.	1280.	1290.	1300.	1312.	1340.
C22	800.	4700.	10000.	15200.	17800.	20500.	23700.	27900.
C23	6600.	8522.	11085.	13648.	14830.	16211.	17749.	21349.
C20	50.							
C21	1217.	1224.	1249.	1263.	1273.	1286.	1295.	1340.
C22	660.	1640.	3610.	15600.	23000.	29800.	33100.	36100.
C23	6100.	6876.	9646.	11197.	12305.	13746.	14743.	20050.
C20	52.5							
C21	1210.	1230.	1250.	1270.	1290.	1300.	1312.	1340.
C22	600.	9200.	17900.	26600.	35200.	39600.	44800.	51700.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	55.							
C21	1200.	1220.	1240.	1260.	1280.	1300.	1312.	1340.
C22	600.	6100.	12000.	17300.	23300.	28400.	31700.	36200.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	56.5							
C21	1194.	1214.	1223.	1254.	1274.	1292.	1312.	1340.
C22	600.	6000.	11500.	17000.	22400.	28000.	33000.	37710.
C23	0.	2900.	5000.	7000.	9200.	11200.	11550.	12699.
C20	58.75							
C21	1182.	1200.	1230.	1250.	1290.	1293.	1305.	1340.
C22	600.	4880.	12000.	16800.	26300.	26325.	26350.	26420.
C23	0.	2900.	5000.	7000.	9200.	11200.	11600.	12560.
C20	59.5							
C21	1179.	1200.	1220.	1240.	1280.	1290.	1305.	1340.
C22	600.	6000.	8660.	16000.	25600.	28500.	28600.	29210.
C23	0.	1800.	3500.	5000.	3300.	9200.	9350.	9580.
C20	60.25							
C21	1177.	1200.	1230.	1260.	1291.	1297.	1312.	1340.
C22	600.	6300.	13800.	21300.	29100.	30300.	30400.	30750.
C23	0.	750.	1700.	2700.	3800.	3750.	3900.	4950.
C20	61.25							
C21	1172.	1220.	1260.	1291.	1296.	1305.	1312.	1340.
C22	600.	11200.	20000.	33670.	33600.	33900.	34000.	35750.
C23	10.	68.	114.	153.	159.	170.	173.	220.
C20	64.25							
C21	1168.	1180.	1200.	1220.	1240.	1260.	1280.	1340.
C22	400.	760.	1115.	1120.	1123.	1125.	1130.	1160.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	66.							
C21	1166.	1178.	1198.	1218.	1238.	1258.	1278.	1340.
C22	400.	760.	1115.	1120.	1123.	1125.	1130.	1160.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	69.							
C21	1162.	1180.	1200.	1220.	1240.	1260.	1280.	1340.

Note: C1, C2, ... etc. represent the card numbers described in Chapter 4, page Nos. 23-61. These card numbers are NOT the part of data requirement.

C22	380.	760.	1115.	1120.	1123.	1125.	1125.	1155.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C28	.035	.035	.035	.035	.035	.035	.030	.030
C28	.035	.035	.035	.035	.035	.035	.035	.040
C28	.035	.035	.035	.035	.035	.040	.045	.050
C28	.035	.035	.035	.035	.035	.040	.045	.045
C28	.035	.035	.035	.035	.035	.045	.045	.050
C28	.050	.050	.045	.045	.045	.045	.050	.050
C28	.045	.045	.045	.045	.045	.045	.050	.050
C28	.035	.035	.035	.035	.030	.030	.030	.030
C28	.035	.035	.040	.040	.045	.045	.045	.045
C28	.035	.035	.035	.040	.045	.045	.045	.045
C28	.035	.035	.040	.040	.040	.043	.045	.045
C28	.035	.035	.035	.035	.035	.035	.035	.040
C28	.035	.035	.040	.045	.045	.045	.045	.045
C28	.035	.030	.030	.030	.030	.030	.030	.030
C28	.035	.030	.030	.030	.030	.030	.030	.030
C28	.035	.035	.035	.030	.030	.030	.030	.030
C28	.050	.050	.045	.045	.040	.040	.035	.035
C28	.050	.050	.045	.045	.040	.040	.035	.035
C28	.035	.035	.030	.030	.030	.030	.030	.030
C28	.035	.035	.030	.030	.030	.030	.030	.030
C28	.035	.040	.038	.038	.037	.032	.032	.032
C28	.035	.040	.038	.038	.037	.032	.032	.032
C28	.035	.040	.038	.038	.037	.032	.032	.032
C28	.035	.040	.038	.038	.037	.032	.032	.032
C28	.035	.040	.038	.038	.037	.032	.032	.032
C28	.035	.035	.035	.035	.035	.035	.035	.045
C28	.035	.035	.035	.035	.032	.032	.032	.042
C31	.25	.5	.5	.5	.5	.5	.5	.5
C31	.5	.5	.5	.75	.75	.5	.75	1.25
C31	.75	1.25	1.25	1.5	1.125	.75	.75	.5
C31	1.5	1.75	.25					
C32	0.	-1.0	0.3	0.3	0.2	-0.6	0.3	-1.0
C32	-0.6	0.2	-0.8	0.	0.1	-0.5	0.1	-0.5
C32	-0.5	0.1	0.2	-0.7	0.2	0.	0.1	0.
C32	0.3	0.	0.					
C33	0.	0.	0.	1328.	1.75	0.	0.	0.1
C63		9.	0.035					
C16	4	8	4	1	0	0	0	0
C17	1	2	3	4				
C20	0.							
C21	1162.	1180.	1200.	1220.	1240.	1260.	1280.	1340.
C22	380.	760.	1115.	1120.	1123.	1125.	1125.	1155.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	3.							
C21	1138.	1150.	1165.	1180.	1200.	1220.	1260.	1300.
C22	507.	836.	1140.	1267.	1267.	1293.	1293.	1318.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	4.							
C21	1112.	1120.	1140.	1160.	1162.	1180.	1200.	1260.
C22	1014.	1647.	1901.	2181.	2534.	5069.	15236.	30415.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	34.							
C21	1112.	1120.	1140.	1160.	1162.	1180.	1200.	1260.
C22	1014.	1647.	1901.	2181.	2534.	5069.	15236.	30415.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C28	.035	.035	.035	.035	.030	.030	.030	.030
C28	.035	.035	.035	.035	.035	.038	.040	.040
C28	.035	.035	.035	.035	.035	.038	.040	.040
C31	0.5	0.5	3.					
C32	0.	-1.0	0.					
C33	0.	0.	1.	0.	8.	0.	0.	0.1

Note: Ci, C2, ... etc. represent the card numbers described in Chapter 4, page Nos. 23-61. These card numbers are NOT the part of data requirement.

Card								
C1(a)	GANDHI SAGAR DAM ASAN RIVER (OPTION-7)							
C1(b)	NATIONAL INSTITUTE OF HYDROLOGY ROORKEE-247 667 (U.P.)							
C2	9	0	0	3	26	0	0	0
C12	3	75						
C14	2825	3178	3885	4944	7769	12713	19423	30012
C14	47322	72392	119181	160618	208004	217539	184343	140553
C14	102413	71336	47675	30724	19070	11654	7063	5297
C14	4591	3885						
C16	11	8	3	4	0	0	0	0
C17	1	5	11					
C20	0							
C21	581	597	604	607	612	617	626	630.5
C22	105	230	305	450	700	850	1210	1350
C23								
C20	3.12							
C21	575	590	597	600	605	610	619	623.5
C22	105	230	305	450	700	850	1210	1350
C23								
C20	6.24							
C21	573	583	591	596.5	602.0	610	620	630
C22	60	210	500	760	830	920	1020	1170
C23								
C20	9.36							
C21	570	577	585	588	591	597	602	605
C22	100	230	370	430	510	950	1080	1180
C23								
C20	12.48							
C21	557	560	566	571	575	581	584	585
C22	400	620	760	880	980	1210	1320	1400
C23								
C20	15.6							
C21	556	560	563	565	571	575	580	586
C22	150	210	420	510	670	1140	1210	1300
C23								
C20	18.72							
C21	554	559	565	571	580	583	587	593
C22	100	130	170	300	640	840	1330	1580
C23								
C20	21.84							
C21	547	549	552	555	558	560	562	564
C22	200	450	540	670	850	1510	1600	1700
C23								
C20	24.96							
C21	542	548	550	552	557	560	563	570
C22	70	100	550	750	1420	1600	1700	1900
C23								
C20	28.08							
C21	537	538	541	542	543	545	547	550
C22	60	70	250	650	840	1000	1100	1580
C23								
C20	31.20							
C21	531	540	543	546	549	552	554	558
C22	60	370	1310	1430	1540	1660	1750	1990
C23								
C28	.030	.030	.030	.040	.040	.040	.045	.045
C28	.030	.030	.030	.040	.040	.040	.045	.045
C28	.030	.030	.030	.040	.040	.040	.045	.045
C28	.030	.030	.030	.040	.040	.040	.045	.045
C28	.035	.035	.035	.045	.045	.045	.050	.050
C28	.035	.035	.035	.045	.045	.045	.050	.050
C28	.035	.035	.035	.045	.045	.045	.050	.050
C28	.035	.035	.035	.045	.045	.045	.050	.050
C28	.035	.035	.035	.045	.045	.045	.050	.050
C28	.035	.035	.035	.045	.045	.045	.050	.050
C31	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
C31	0.78	0.78						
C32	0	0	0	0	0	0	0	0
C32	0	0						
C33	0	0	0	0	1.92	0	0	

Note: C1, C2, ... etc. represent the card numbers described in Chapter 4, page Nos. 23-61. These card numbers are NOT the part of data requirement.

C1(a)	RIVER- PAGLADIYA (OPTION-12)							
C1(b)	NATIONAL INSTITUTE OF HYDROLOGY, ROORKEE(U.P.),INDIA.							
C2	1	1	6	3	50	0	0	0
C5	3	9	10	11	12	16		
C8			1.	206.	50.	1.		
C9	235.	230.	626.			20	0.8	0.2
C8			1.	171.	50.	1.		
C9	216.	210.	603.			30.	0.8	0.2
C8			1.	166.	50.	1.		
C9	205.	200.	600.			15.	0.8	0.2
C8			1.	165.	50.	1.		
C9	214.	209.	681.			15.	0.8	0.2
C8			1.	164.	50.	1.		
C9	205.	200.	653.			20.	0.8	0.2
C8			1.	139.	50.	1.		
C9	185.	180.	519.			15.	0.8	0.2
C12	3.	147.						
C14	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.
C14	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.
C14	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.
C14	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.
C14	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.
C14	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.
C14	21000.	21000.						
C16	20	8	6	0	0	0	2	0
C17	1	3	9	10	11	17		
C20	0.							
C21	225.	226.	227.	227.4	230.	230.5	234.5	234.6
C22	1.	105.	230.	610.	807.	1129.	1385.	1457.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	1.25							
C21	220.	220.7	221.4	222.9	226.9	229.6	230.4	230.8
C22	1.	98.	151.	479.	604.	932.	2480.	2612.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	3.41							
C21	206.	207.	207.4	208.2	212.7	214.	214.3	214.8
C22	1.	40.	52.	210.	400.	768.	961.	1000.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	4.73							
C21	201.3	202.9	203.6	208.4	208.5	209.7	211.8	230.
C22	1.	148.	394.	755.	801.	1030.	3209.	3425.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	6.6							
C21	195.	196.	198.	203.	203.4	204.4	207.9	208.5
C22	1.	13.	328.	597.	951.	997.	3320.	3468.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	8.16							
C21	189.	194.	194.6	196.7	200.1	201.5	204.1	209.0
C22	1.	197.	387.	466.	1634.	1680.	2054.	2132.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	10.0							
C21	184.2	185.6	186.2	193.2	193.4	194.	194.6	202.
C22	1.	105.	262.	420.	669.	768.	1325.	1673.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	12.66							
C21	176.5	178.	178.7	179.3	181.8	186.	188.1	196.
C22	1.	86.	341.	423.	684.	726.	1890.	2152.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	14.6							
C21	171.	171.6	172.	181.6	182.3	184.5	185.4	188.
C22	1.	183.	285.	814.	974.	1089.	1417.	1575.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	16.56							
C21	166.	169.	171.	180.	181.	182.	183.	187.
C22	1.	65.	200.	260.	295.	550.	885.	930.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	17.38							
C21	165.	168.	171.5	175.	178.	179.	180.	183.
C22	1.	20.	175.	185.	230.	480.	900.	1000.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	17.73							
C21	164.	167.	170.	173.	174.	176.	178.	200.
C22	1.	72.	230.	274.	390.	579.	874.	1200.
C23	0.	0.	0.	0.	0.	0.	0.	0.

Note: C1, C2, ... etc. represent the card numbers described in Chapter 4, page Nos. 23-61. These card numbers are NOT the part of data requirement.

C20	22.31							
C21	156.	157.6	158.6	159.7	160.	166.	171.	177.
C22	1.	13.	171.	177.	216.	459.	1060.	1096.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	24.10							
C21	153.	153.6	156.	160.	165.	165.7	170.	173.
C22	1.	85.	153.	236.	328.	853.	1083.	1106.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	27.06							
C21	145.	146.	147.	152.	156.	157.	160.	164.
C22	1.	28.	197.	333.	517.	689.	1345.	1368.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	28.31							
C21	140.	141.	143.	146.	154.	156.	158.	163.
C22	1.	69.	82.	116.	162.	313.	1193.	1211.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	30.19							
C21	139.	143.	144.	149.	150.	159.	160.	165.
C22	1.	28.	46.	151.	249.	454.	833.	1720.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	32.06							
C21	138.	140.	143.	143.2	145.	148.	151.	158.
C22	1.	111.	164.	236.	307.	381.	955.	1014.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	37.74							
C21	132.	133.	134.	135.	136.	136.3	143.7	144.4
C22	1.	85.	112.	141.	176.	197.	440.	489.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C20	40.22							
C21	131.5	132.5	133.3	134.5	134.7	135.3	136.	145.
C22	1.	75.	98.	126.	177.	189.	285.	377.
C23	0.	0.	0.	0.	0.	0.	0.	0.
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C28	0.023	0.024	0.025	0.026	0.027	0.028	0.029	0.030
C31	0.125	0.108	0.088	0.187	0.156	0.184	0.266	0.194
C31	0.196	0.164	0.070	0.229	0.358	0.296	0.250	0.376
C31	0.374	0.284	0.248					
C32	0.	0.	0.	0.	0.	0.	0.	0.
C32	0.	0.	0.	0.	0.	0.	0.	0.
C32	0.	0.	0.					
C33	0.	0.	-100.	0.75	5.78	0.	0.1	147.
C46	3	15						
C47	113.	113.	191.	580.	1431.	2108.	2430.	2563.
C47	2646.	2703.	2695.	2824.	2821.	2754.	2722.	2743.
C47	2762.	2642.	2586.	2591.	2545.	2439.	2392.	2320.
C47	2226.	2043.	1803.	1801.	1536.	1321.	1165.	1033.
C47	793.	585.	368.	233.	161.	128.	115.	113.
C47	113.	113.	113.	113.	113.	113.	113.	113.
C47	113.	113.						
C47	2825.	2825.	2825.	2825.	2825.	2825.	2825.	2825.
C47	2825.	2825.	2825.	2825.	2825.	2825.	2825.	2825.
C47	2825.	2825.	2825.	2825.	2825.	2825.	2825.	2825.
C47	2825.	2825.	2825.	2825.	2825.	2825.	2825.	2825.
C47	2825.	2825.	2825.	2825.	2825.	2825.	2825.	2825.
C47	2825.	2825.	2825.	2825.	2825.	2825.	2825.	2825.
C47	2825.	2825.						
C51	153.	153.	153.	153.	153.	153.	153.	153.
C51	153.	153.	153.	153.	153.	153.	153.	153.
C51	153.	153.	153.	153.	153.	153.	153.	153.
C51	153.	153.	153.	153.	153.	153.	153.	153.
C51	153.	153.	153.	153.	153.	153.	153.	153.
C51	153.	153.	153.	153.	153.	153.	153.	153.
C51	153.	153.						
C52	0.	3.	6.	9.	12.	15.	18.	21.
C52	24.	27.	30.	33.	36.	39.	42.	45.
C52	48.	51.	54.	57.	60.	63.	66.	69.
C52	72.	75.	78.	81.	84.	87.	90.	93.
C52	96.	99.	102.	105.	108.	111.	114.	117.
C52	120.	123.	126.	129.	132.	135.	138.	141.
C52	144.	147.						

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