NOAA Technical Memorandum ERL GLERL-24

UPPER ST. LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL

Alan J. Potok

Great Lakes Environmental Research Laboratory
Ann Arbor, Michigan
October 1978

UNITED STATES
DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Richard A. Frank, Administrator

Environmental Research
Laboratories
Wilmot N Hess, Director

NOTICE

The NOAA Environmental Research Laboratories do not approve, recommend, or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to the NOAA Environmental Research Laboratories, or to this publication furnished by the NOAA Environmental Research Laboratories, in any advertising or sales promotion which would indicate or imply that the NOAA Environmental Research Laboratories approve, recommend, or endorse any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this NOAA Environmental Research Laboratories publication.

CONTENTS

FIGURES

APPENDIX FIGURES

TABLES

UPPER ST. LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL

Alan J. Potok

The Great Lakes Environmental Research Laboratory (GLERL) has developed hydrologic response models for simulation studies on precipitation augmentation, ice retardation, system diversions, and connecting channel changes. For example, hydraulic transient models developed for use on the Detroit and St. Clair Rivers have been used to compute channel flow.

The most recent addition to this series of models, a hydraulic transient model of the upper St. Lawrence River, is designed to simulate river profiles and flows on the St. Lawrence River from Lake Ontario to the Moses-Saunders powerhouse near Massena, N.Y. It is capable of simulation on varying time increments and includes flow under ice-covered, as well as open-water conditions. This paper describes the mathematical model, its development, calibration, verification, and typical applications.

1. INTRODUCTION

As the outlet from Lake Ontario, the St. Lawrence River conveys water from the Great Lakes Basin to the Atlantic Ocean. It varies from 0.25 to 2 miles in width, averages near 30 feet in depth, and normally discharges between 180 and 320 thousand cubic feet of water per second. Approximately 90 miles downstream of Lake Ontario the river flow is regulated by the Moses-Saunders Power Dam, which was built during the development of the St. Lawrence Seaway in 1959.

Operation of the power dam is governed by the water level in Lake Ontario in accordance with Regulation Plan 1958-D. Regulation of the river is of vital concern to many interests of national and international power, navigation, recreation, industrial, and domestic users. Although regulation of the river occurs on a weekly basis, the river flows and water levels are monitored and adjusted on an hourly and daily basis to meet power demands or navigational requirements. During winter ice forms on the river, resulting in a suspension of navigation and reduced power generation for approximately 15 weeks of the year.

GLERL Contribution No. 181.

The international reach of the river between Lake Ontario and the Moses-Saunders Power Dam has been simulated by a hydraulic transient model. Development of the model, designed to simulate river profiles and flows during open-water and partially or totally ice-covered conditions, was undertaken at the request of the U.S. Army Corps of Engineers, Detroit District. The purpose was to provide a useful tool in water resources management. The Corps of Engineers needs such a model to evaluate water surface changes due to channel dredging, changing ice covers, and the effect of extending the navigation season on the St. Lawrence River.

2. COMPUTER REQUIREMENTS

The St. Lawrence River hydraulic transient model is a digital model relying on the simultaneous solution of the mass continuity and momentum equations to determine discharge and stage at various points along the river from Lake Ontario to the Moses-Saunders Power Dam. The program was developed on a CDC 6600 computer with a FORTRAN IV language compiler. An implicit solution procedure used in the program requires a banded matrix solution subroutine. Subroutine LEQT1B (1), developed by International Mathematical and Statistical Libraries, Inc., was used during development of the model. However, any subroutine capable of solving the linear equation

$$C\vec{X} = \vec{D}$$

may be used in its place.

The model requires a core storage of 58 k (octal) on a CDC 6600 machine. Central processing time is a function of the number of time increments used in the model run. Estimated computer costs are $3 for initialization of the model and $.20 for each time step of solution required. Manpower requirements are limited to defining the set of circumstances to be examined by the model.

3. MODEL DESCRIPTION

The area of the St. Lawrence River simulated by the model extends from Lake Ontario to the Moses-Saunders Power Dam near Massena, N.Y. The configuration in the model consists of 30 reaches interrelated by 21 intersection or "nodal" points as shown in Figure 1. Each reach is assumed prismatic with its own physical characteristics of length, width, wetted area, wetted perimeter, and bed roughness. The nodal points describe the river configuration by specifying the sequence of reaches and the logic of the flow pattern. For example, at a node

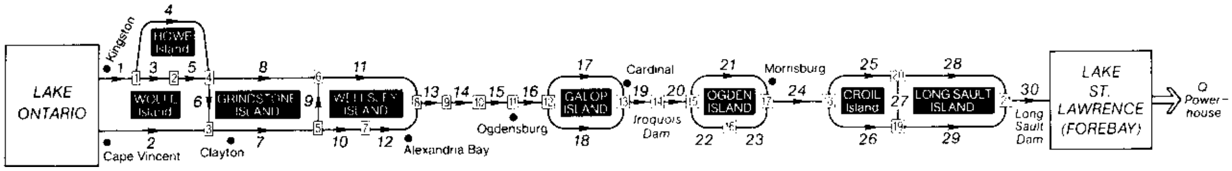

Figure 1. St. Lawrence River *conceptualized* transient model.

number 9, the flow leaving reach 13 is an incoming flow to the node. Likewise, the water flowing into reach 14 is an outgoing flow. The flow and stage at the downstream end of reach 13 can then be equated to the flow and stage at the upstream end of reach 14 from the equations of continuity and energy. Information describing the nodal points is maintained in a separate array. The technique of maintaining an array to describe the flow pattern was employed because of the need for a generalized model during development to allow a changing definition of the channels and a changing emphasis on points of information.

The model is capable of simulating a river profile under partial or total ice cover, as well as open water conditions. When ice is included on a reach of the river, the model decreases the hydraulic radius for that reach and the area is constricted by an amount 0.9 times the ice thickness (the specific gravity of ice is assumed to be 0.9). In addition, the Manning's roughness coefficient is adjusted by the composite roughness formula developed by Belokon-Sabaneev (Sabaneev, 1948). Any ice configuration may be input into the model by specifying the ice thickness and roughness coefficient of the ice cover. Each reach is considered either open or completely ice covered depending on whether or not the ice thickness is zero.

The history of the river has shown ice jams to form in the Galop and Ogden Island reaches of the river. These ice jams, called hanging dams, severely restrict river flows and power generation downstream. The model provides for simulation of hanging dams (up to a maximum of three), if desired, in addition to the ice cover on the river.

Input to the model consists of the initial stage and flow conditions along the river, the respective channel roughness coefficients, ice-cover roughness coefficients, and ice thickness for all the reaches. Generally, a complete set of initial stage and flow conditions is not available. In this case, initial conditions are set at zero discharge and a level pool at the elevation of Lake Ontario. An initial discharge is then simulated and a steady state profile is achieved corresponding to the desired discharge to be simulated. All input and output data are in the English system of units.

A net total supply (NTS) hydrograph or water level hydrograph is allowable input as upstream boundary conditions. Downstream boundary conditions include a discharge or water level hydrograph at the power house. Sample computer runs and a program listing are given in Appendices B and C.

4. MATHEMATICAL THEORY

The unsteady one-dimensional equations of continuity and momentum have been adapted by numerous authors (e.g., Wylie and Streeter, 1978). In the St. Lawrence model, the equations take the form

$$Q_x + A_t = 0 \qquad (1)$$

$$\frac{2\overline{Q}}{\overline{A}} Q_x - \frac{\overline{Q}^2}{\overline{A}^2} A_x + g\overline{A}H_x + \frac{gn^2\overline{Q}|\overline{Q}|\overline{A}}{2.208\ \overline{A}^2\overline{R}^{4/3}} + Q_t \quad \frac{T\ T}{\rho} \quad 0 \qquad (2)$$

where

Q = mean discharge in a reach,

$\overline{A}$ = mean area in a reach,

$\overline{R}$ = mean hydraulic radius, and

A, = the partial derivative of the area A with respect to distance x,

H_x = the partial derivative of the water surface elevation H with respect to distance x,

Q_x = the partial derivative of the flow Q with respect to distance x,

A_t = the partial derivative of A with respect to t (time),

Q_t = the partial derivative of Q with respect to t (time).

n = the Manning's roughness coefficient,

g = force of gravity,

T_x = wind stress $\left(T_x = Cd\rho_a V_w^{\ 2}\right)$,

T = channel top width,

ρ = density of water (assumed at 10°F),

C_d = drag coefficient ($C_d \cong 0.0013$),

ρ_a = density of air, and

V_w = wind speed along the channel.

Equations (1) and (2) are evaluated over the time-space domain to find the variation in unknown conditions of stage and flow at the upstream and downstream end points of each reach as shown in Figures 2 and 3.

Because each end of each reach is uniquely defined, equations (1) and (2) are expressed in terms of four unknown quantities of flow Q and stage H. That is, 30 reaches implies 60 points, each of which has an unknown H and Q. Using finite difference methods, one can evaluate equations (1) and (2) at point m as follows:

$$\frac{\Theta(Q_d^P - Q_u^P) + (1-\Theta)(Q_d - Q_u)}{AX}$$

$$\frac{\bar{T}\left[(H_d^P - H_d) + (H_u^P - H_u)\right]}{2\Delta t} = 0 \qquad (3)$$

$$\begin{aligned}
&\frac{2\bar{Q}}{\bar{A}}\left[\frac{\Theta(Q_d^P - Q_u^P) + (1-\Theta)(Q_d - Q_u)}{AX}\right] - \frac{\bar{Q}^2}{\bar{A}^2} \\
&+ \Big[\Theta\left[T_d(H_d^P - Z_d) - T_u(H_u^P - Z_u)\right] \\
&+ (1-\Theta)\left[T_d(H_d - Z_d) - T_u(H_u - Z_u)\right] + A_{bd} - A_{bu}\Big] \\
&\times \frac{1}{\Delta X} + g\bar{A}\left[\frac{\Theta(H_d^P - H_u^P) + (1-\Theta)(H_d - H_u)}{AX}\right] \\
&+ \frac{g^2 n^2 \bar{Q}|\bar{Q}|\bar{A}}{2.208\ \bar{A}^2\bar{R}^{4/3}} + \frac{Q_d^P + Q_u^P - (Q_d + Q_u)}{2At} \\
&- \frac{T_x T}{\rho} = 0
\end{aligned} \qquad (4)$$

where $\Theta = At_m/At$, H is the water surface elevation, and A_b is the area below a reference low water datum z_b. The subscripts u and d refer to the upstream and downstream ends of the reach, respectively. The superscript p refers to conditions at time t + At. The magnitude of A_b is

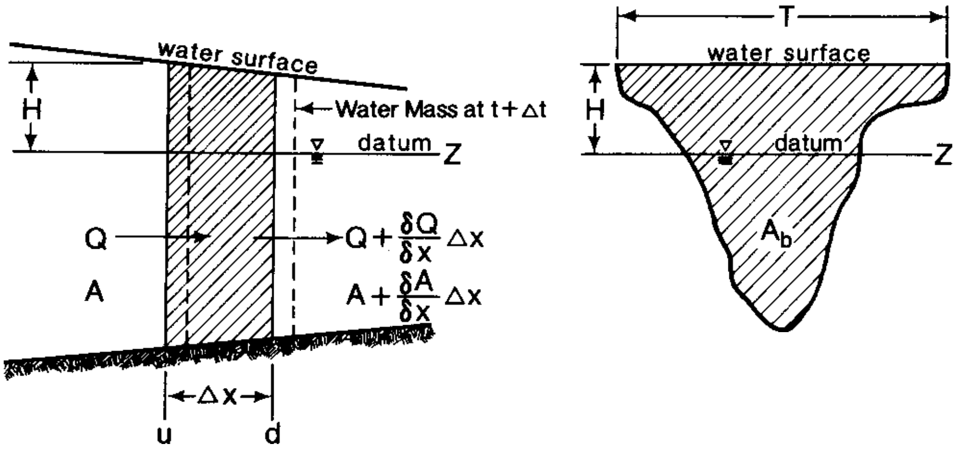

Figure 2. Definition sketch.

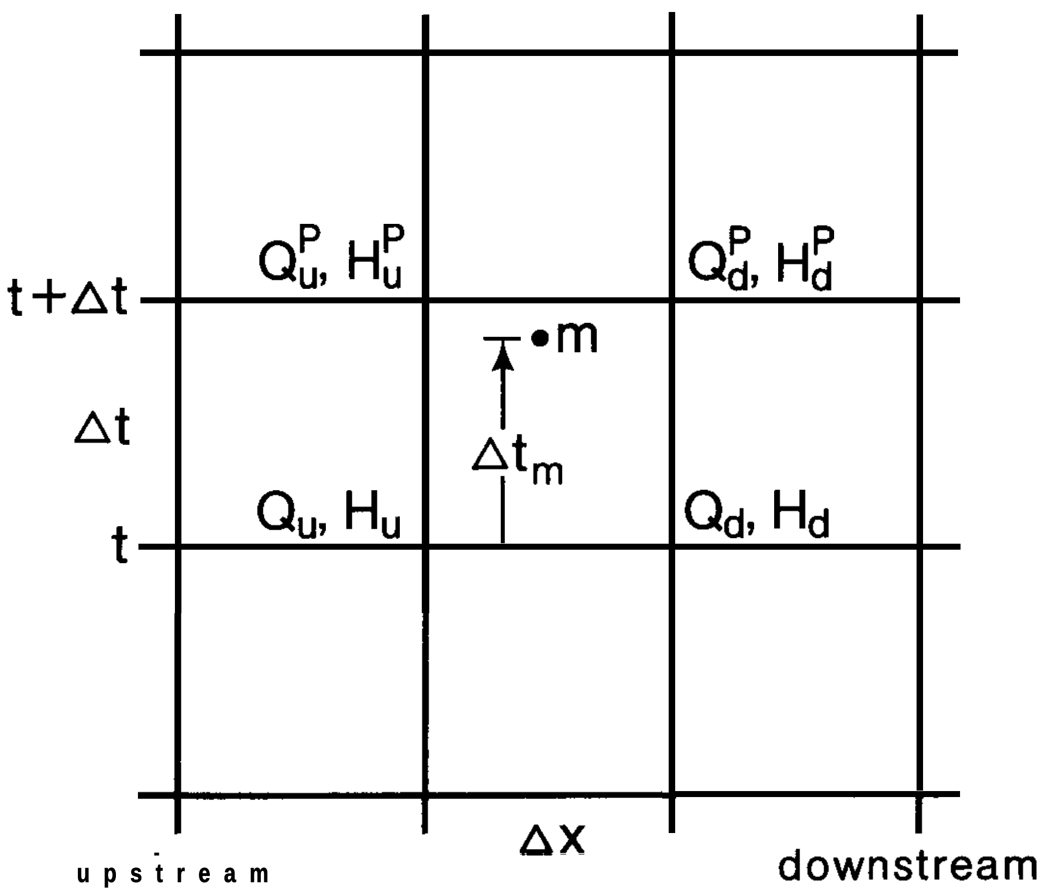

Figure 3. Time-space grid *for* implicit solution.

normally large with respect to the incremental area $T(H - Z)$. Therefore, substitution of a mean top width $\bar{T} = T_u = T_d$ can be made without affecting the A_x term in the momentum equation. Equation (4) can then be simplified to

$$\frac{2\bar{Q}}{\bar{A}}\left[\frac{\Theta(Q_d^P - Q_u^P) + (1 - \Theta)(Q_d - Q_u)}{\Delta X}\right] + \frac{\bar{Q}^2 T}{\bar{A}^2 \Delta X}$$

$$\times \left[\Theta\left[(H_d^P - Z_d) - (H_u^P - Z_d)\right] + (1 - \Theta)\left[(H_d - Z_d)\right.\right.$$

$$\left.\left. - (H_u - Z_u)\right] + A_{bd} - A_{bu}\right] + \frac{g\bar{A}}{\Delta X}\left[\Theta(H_d^P - H_u^P)\right.$$

$$\left. + (1 - \Theta)(H_d - H_u)\right] + \frac{g^2 n^2 \bar{Q}|\bar{Q}|\bar{A}}{2.208\ \bar{A}^2 \bar{R}^{4/3}}$$

$$+ \frac{Q_d^P + Q_u^P - (Q_d + Q_u)}{2\Delta t} - \frac{T_x T}{\rho} = 0 \qquad (5)$$

where

$$\bar{Q} = 0.5\left[\Theta(Q_d^P + Q_u^P) + (1 - \Theta)(Q_d + Q_u)\right],$$

$$\Theta = \Delta t_m / \Delta t, \text{ and}$$

$$\bar{A} = 0.5\left[\Theta(A_d^P + A_u^P) + (1 - \Theta)(Q_d + Q_u)\right].$$

Several values of Θ in the range of $0.5 < \Theta < 1.0$ were examined. It was determined that $\Theta = 0.75$ provided a rapid convergence to a stable solution. At each of the 21 junction points shown in Figure 1, the equations of steady continuity are applied, giving

$$\Sigma Q_u^P - \Sigma Q_d^P = 0 \qquad (6)$$

and,

$$H_u^P - H_d^P = 0 \tag{7}$$

where Q_u^P, H_u^P and Q_d^P, H_d^P correspond to the flow and stage at the entering (upstream) and leaving (downstream) reaches of each junction. Lake Ontario and the power dam reservoir pool are included in the model by the use of the reservoir storage routing equation.

$$\frac{\Delta S}{\Delta t} = (\bar{I} - \bar{O}) \tag{8}$$

where

$\frac{\Delta S}{\Delta t}$ = the time rate of change in storage,

$\bar{I}$ = the mean inflow over the time period, and

$\bar{O}$ = the mean outflow over the time period.

For a reservoir with a large surface area (A_s), such as Lake Ontario or the reservoir pool, the change in storage can be approximated by:

$$\frac{\Delta S}{\Delta t} = A_s \frac{\Delta H}{\Delta t} \ . \tag{9}$$

Substituting into equation (8) and rearranging yields

$$F_u = \frac{NTS_1 + NTS_2}{2} - \frac{Q^P + Q}{2} - \frac{A_o(H^P - H)}{\Delta t} = 0 \tag{10}$$

$$F_d = \frac{Q_{fb}^P + Q_{fb}}{2} - \frac{Q_{ph}^P + Q_{ph}}{2} - \frac{A_{fb}(H^P - H)}{\Delta t} = 0, \tag{11}$$

where

NTS = the net total supply of water to Lake Ontario (including precipitation, runoff, evaporation, and Niagara River and Welland Canal inflows;

Q = the flow from Lake Ontario;

A_o = the surface area of Lake Ontario, km^2;

H = the respective water surface elevation at Lake Ontario or the reservoir pool;
Q_{fb} = the river flow entering the reservoir pool;
Q_{ph} = the discharge through the powerhouse; and
A_{fb} = the surface area of the powerhouse reservoir pool, km^2.

The superscript p indicates the solution at time increment t + Δt. Equations (10) and (11) complete the equation set for the model. Equations (3), (5), (6), and (7) are applied to each of the 30 reaches and 21 nodal points in the model. These equations, along with equations (10) and (11), form a matrix of 120 equations and 122 unknowns. Either the net total supply (NTS) or the water level at Kingston, and either the discharge through the powerhouse (Q_{ph}), or the water level at the powerhouse are specified as functions of time, leaving 120 equations and 120 unknowns.

The non-linear nature of the equation matrix requires application of an iterative solution technique. A Newton-Raphson algorithm with projected approximations is used in the model. The Newton-Raphson procedure can be defined by equations of the form

$$F_i + \sum_{j=id}^{iu} \frac{\partial F_i}{\partial H_j} \Delta H_j + \sum_{j=id}^{iu} \frac{\partial F_i}{\partial Q_j} \Delta Q_j = 0 \ , \qquad (12)$$

where iu and id represent the upstream and downstream points, respectively, of each reach i (i = 1 to 30). The partial derivatives $\partial F_i/\partial H_j$ and $\partial F_i/\partial Q_j$ are evaluated with finite difference techniques and the partial derivatives of continuity for the i^{th} reach (i = 1 to 30) are expressed as

$$\frac{\partial F_{ci}}{\partial H_{iu}} = \frac{\partial F_{ci}}{\partial H_{id}} = T/2\Delta t \qquad (13)$$

$$\frac{\partial F_{ci}}{\partial Q_{iu}} = -\Theta/L \qquad (14)$$

$$\frac{\partial F_{ci}}{\partial Q_{id}} = \Theta/L \qquad (15)$$

The partial derivatives of the momentum equation are approximated as

$$\frac{\partial F_{mi}}{\partial H_{iu}} = \frac{-2\bar{Q}}{\bar{A}^2} Q_x \frac{\theta\bar{T}}{2} + \frac{2\bar{Q}^2}{\bar{A}} A_x \frac{\theta\bar{T}}{2} + \frac{\bar{Q}^2}{\bar{A}^2} \frac{\theta\bar{T}}{\Delta X}$$

$$- g\bar{A} \frac{\theta}{\Delta X} + g\, H_x \frac{\theta\bar{T}}{2} \quad \frac{(7/3)\bar{Q}^2 n^2\, \bar{P}^{4/3}}{\bar{A}^{10/3}} \quad \frac{\theta\bar{T}}{2}$$

$$+ \frac{4/3\bar{Q}^2 n^2 g P^{1/3}\theta}{A^{7/3}} \qquad (16)$$

$$\frac{\partial F_{mi}}{\partial H_{id}} = \frac{\partial F_{mi}}{\partial H_{iu}} + \frac{2g\bar{A}\theta}{\Delta X} \qquad (17)$$

$$\frac{\partial F_{mi}}{\partial Q_{iu}} = Q_x \frac{\theta}{\bar{A}} - \frac{2\bar{Q}}{\bar{A}} \frac{\theta}{\Delta X} - \frac{\bar{Q}}{\bar{A}^2} A_x \theta + \frac{g\bar{Q}n^2 P^{4/3}\theta}{\bar{A}^{7/3}} + 1/2\Delta t \qquad (18)$$

$$\frac{\partial F_{mi}}{\partial Q_{id}} \quad \frac{\partial F_{mi}}{\partial Q_{iu}} + \frac{4\bar{Q}}{\bar{A}} \frac{\theta}{\Delta X} \qquad (19)$$

For each nodal point j (j = 1 to 21) the partial derivatives of equations (6) and (7) are

$$\frac{\partial F_{cj}}{\partial H_{2K}} = 1 \qquad (20)$$

where

2k is the downstream point of the incoming reach k.

$$\frac{\partial F_{cj}}{\partial H_{2k-1}} = -1 \qquad (21)$$

where

2k-1 is the upstream point of the outgoing reach k.

$$\sum_{n=1}^{IN} \frac{\partial F_{cj}}{\partial Q_{2k}} = 1 \qquad (22)$$

where

IN = the number of reaches flowing into the node.

$$\sum_{n=1}^{IOUT} \frac{\partial F_{cj}}{\partial Q_{2k-1}} = -1 \qquad (23)$$

where

IOUT = the number of reaches flowing out of the node.

Partial derivatives of the boundary condition at Lake Ontario, equation (10), become

$$\frac{\partial F_u}{\partial H_1} = \frac{\partial F_d}{\partial H_2} = \frac{Ao}{At} \qquad (24)$$

$$\frac{\partial F_u}{\partial Q_1} = \frac{-1}{2} \qquad (25)$$

$$\frac{\partial F_u}{\partial Q_2} = \frac{-1}{2} \qquad (26)$$

Finally, the partial derivatives of the downstream boundary at the powerhouse are

$$\frac{\partial F_d}{\partial Q_{fb}} = \frac{1}{2} \tag{27}$$

$$\frac{\partial F_d}{\partial H_{fb}} = \frac{A_o}{A_t} \tag{28}$$

The partial derivatives equations (13) through (28) form the Jacobian matrix C in the model. Equations (3), (4), (5), (7), (8), (10), and (11) form the functional vector D in the model.

Although there are 120 equations to be solved simultaneously, each equation will be a function of no more than 4 unknowns (H_u^p, Q_u^p, H_d^p, Q_d^p). Assigning the proper row number to each of the equations involved results in a banded matrix with all the array elements outside the band equal to zero. Assignment of row numbers to the equations is accomplished by the nodal descriptive array B in the model. The number of incoming reaches to each node will determine the number of continuity and energy equations [(6) and (7)] to be evaluated before the reach equations of continuity and momentum [(4) and (5)] can be evaluated. The advantage to this technique is the savings in core storage (about 60 percent) and CPU time (about 80 percent) obtained by using a banded matrix solution routine as opposed to a standard Guassian elimination routine on a square matrix.

5. MODEL CALIBRATION

Model calibration consisted of determining the bed roughness coefficient in each reach. An estimate of the roughness coefficients between two water level gages can be obtained from the adaptation of the equation (2) to steady, uniform flow. Setting $Q_x = Q_t = 0$ yields

$$\frac{g n^2 \bar{Q}^2}{2.208\, \bar{A}^2 \bar{R}^{4/3}} + g\bar{A}H_x - \frac{\bar{Q}^2}{\bar{A}^2} A_x = 0 \tag{29}$$

Solving for n yields

$$n = \frac{1.486\, \bar{A}\bar{R}^{2/3}}{\bar{Q}} \left(H_x + \frac{\bar{Q}^2 A_x}{g\bar{A}^3} \right)^{1/2} \tag{30}$$

Initial estimates of bed roughness coefficients were made by applying equation (30) to recorded stage and discharge data as described by Quinn and Hagman (1977).

Recorded stage data at Cape Vincent, N.Y.; Clayton, N.Y.; Kingston, Ont.; Alexandria Bay, N.Y.; Ogdensburg, N.Y.; Canada, Iroquois Dam, Morrisburg, Ont.; and Long Sault Dam were used to calibrate the segments of river between each gage. Each segment contained more then one reach as conceptualized by the model. The A and R terms of equation (16) were estimated by weighted averaging of several representative cross sections for each reach within each segment. Cross sections were computed by the U.S. Army Corps of Engineers, Detroit District, from navigation charts at 1:30,000 and weighted according to the length of each equivalent reach. The time periods examined were selected such that a quasi-steady state existed along the river, allowing Q to be assumed equal to the recorded discharge at the powerhouse. Flows used ranged from 248 TCFS to 330 TCFS. Typical values of roughness coefficients obtained for each segment of the river are shown in Table 1. To complete calibration of the model, individual reach roughness coefficients were adjusted to reflect proper flow distribution around islands as determined by the U.S. Army Corps of Engineers (1976, 1977).

Table 1. Manning's Roughness *Values*

Segment of River	n
Kingston to Clayton	0.022
Clayton to Alexandria Bay	0.042
Alexandria Bay to Ogdensburg	0.033
Ogdensburg to Cardinal	0.035
Cardinal to Iroquois Dam	0.027
Iroquois Dam to Morrisburg	0.034
Morrisburg to Long Sault	0.039

Model calibration was verified by using the model to simulate recorded river profiles for flows ranging from 260 TCFS to 350 TCFS. Errors in river stage were less than 0.2 ft for the cases tested.

Stage-fall relationships were then computed from recorded data for the following sections of river: Kingston-Ogdensburg, Ogdensburg-Cardinal, Ont., Cardinal-Morrisburg, and Morrisburg-Long Sault Dam. Mean monthly values of fall (F), flow (Q), and the stage at the upstream gage were used to plot the relationship of stage versus the quantity $(Q/\sqrt{F})^{1/2}$ for each of the four sections. Regression lines and correlation coefficients for recorded data were also determined. Simulated model output was then plotted for a series of conditions of flow and stage. As shown by Figure 4, the model compared well with the regression line in all segments of the river, with the Kingston-Ogdensburg segment showing the largest variation. This is due to the low fall over this region. A difference of 0.01 ft in fall will result in a substantial shift in the $(Q/\sqrt{F})^{1/2}$ axis. This sensitivity is also reflected in the low correlation and the scatter about the regression line.

Final bed roughness coefficients used in the model are tabulated in Table 2.

6. HYDRAULIC EFFECT OF ICE COVER

The St. Lawrence River is at least partially ice covered 3 months of the year. Simulation of the river operation during these winter months requires compensation for the drag effect of ice cover on the wetted perimeter and roughness of the channel. A review by Nezhikhovskiy (1964) compared the assumptions and limitations of several formulae for computing a composite channel roughness. Three of the methods presented; Pavlovskiy's (1931), Belokon-Sabaneev's (Sabaneev, 1948), and a mean weighted formulae; were considered for use in the St. Lawrence model.

Equation (30) is applicable to ice covered channels provided the wetted perimeter is adjusted for ice cover and the restriction in flow area due to ice thickness is known. Since 1963, the St. Lawrence Seaway Authority has taken periodic ice thickness measurements in the reach between the Cardinal and Iroquois Dam water level gages. The channel roughness was computed using equation (30) assuming a 0.90 specific gravity for ice and using recorded river stage at the Cardinal and Iroquois Dam water level gages. Channel roughness was computed for 49 periods of ice measurement between 1963 and 1975.

Using the Manning roughness coefficient of $n = 0.026$ calibrated for open water conditions, the ice-cover roughness was computed according to each of the three formulae. The ratio of composite roughness to Manning's roughness coefficient (n/n,) was plotted against the ratio of the ice roughness to the Manning's roughness coefficient (n_I/n_B) from each of the three formulae (Fig. 5) in turn. A distribution of all the computed

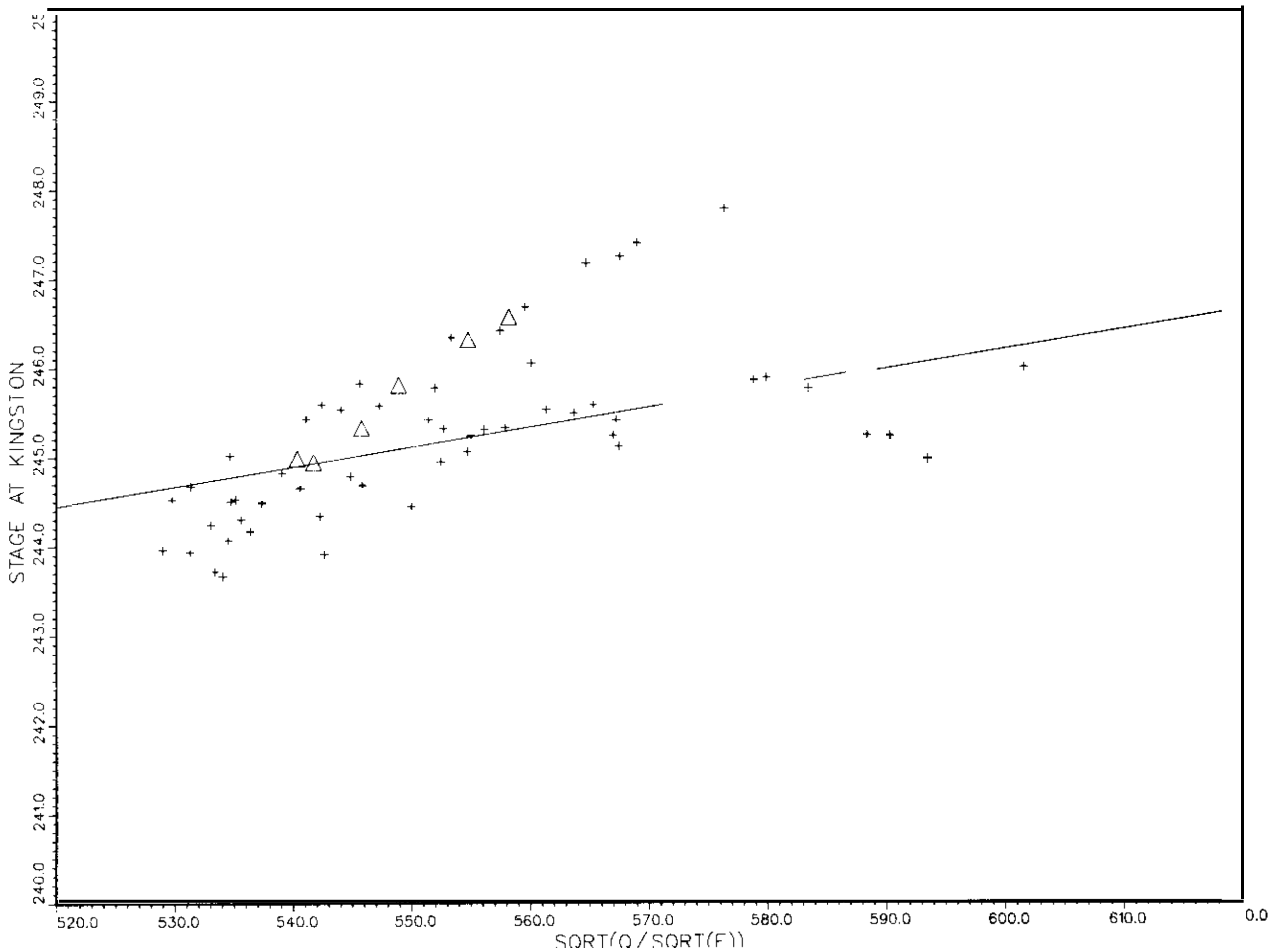

Figure *4a. Comparison of stage vs.* $(Q/\sqrt{F})^{\frac{1}{2}}$ **for prototype** *(+) and model* (Δ)
(Kingston, *Ont.,* **to** *Ogdensburg, N.Y.).*

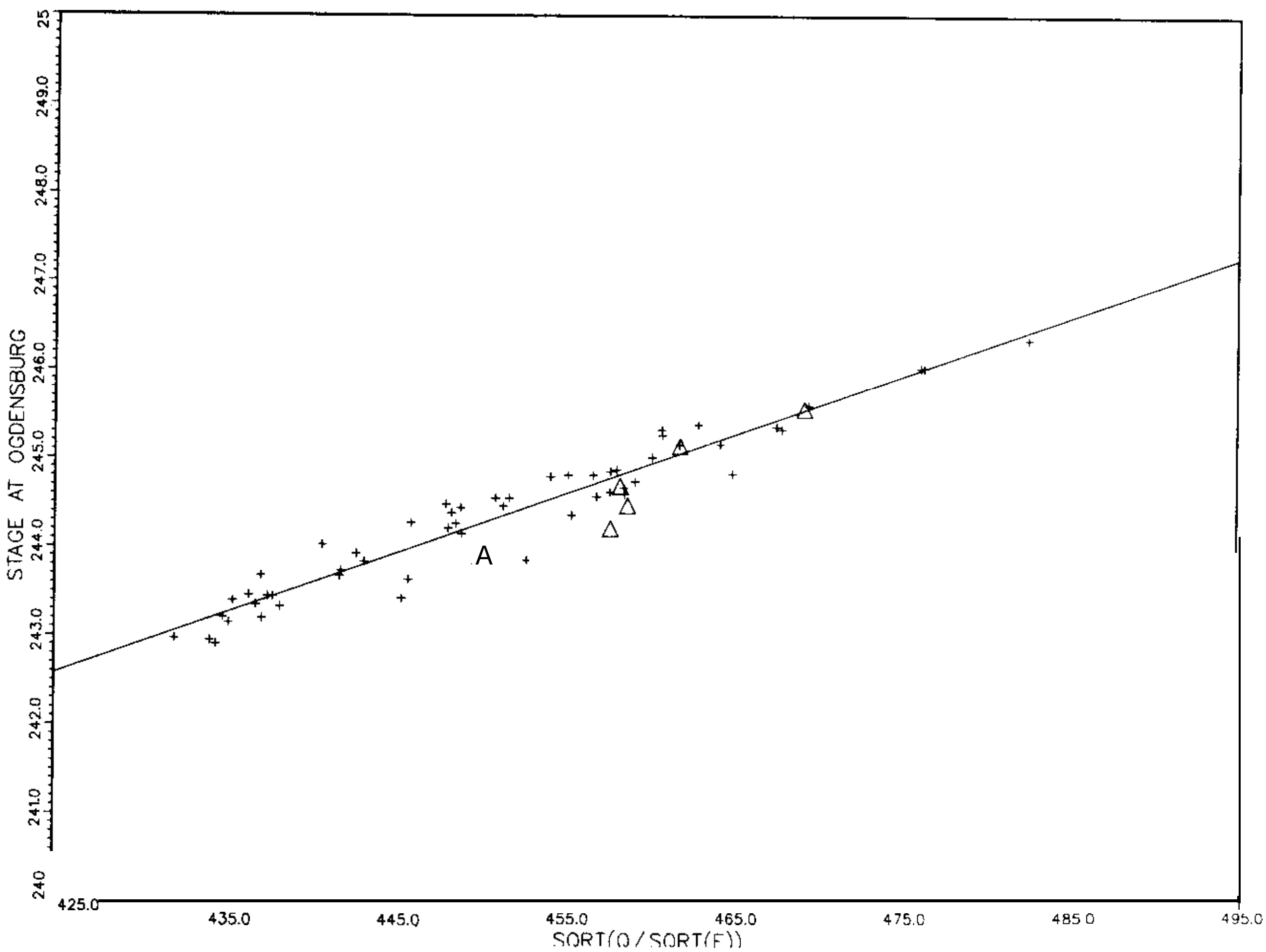

Figure *4b.* **Comparison of stage vs.** $(Q/\sqrt{F})^{\frac{1}{2}}$ **for prototype** *(+)* **and** *model* (Δ) *(Ogdensburg, N.Y.,* **to** *Cardinal, Ont.).*

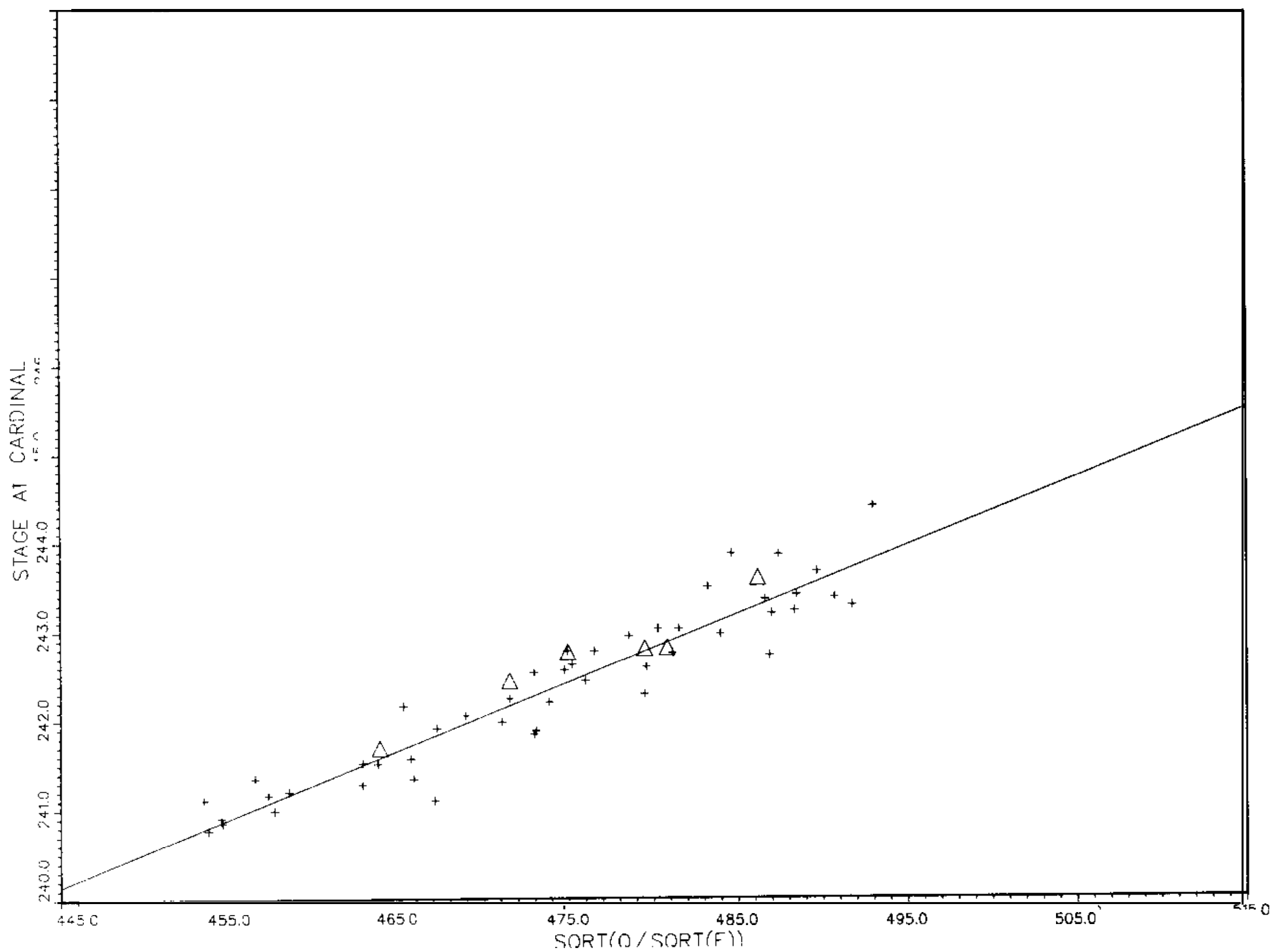

Figure *4c*. **Comparison of stage** vs. $(Q\sqrt{F})^{\frac{1}{2}}$ **for prototype** *(+)* **and model** *(Δ)* **(Cardinal to** *Morrisburg, Ont.).*

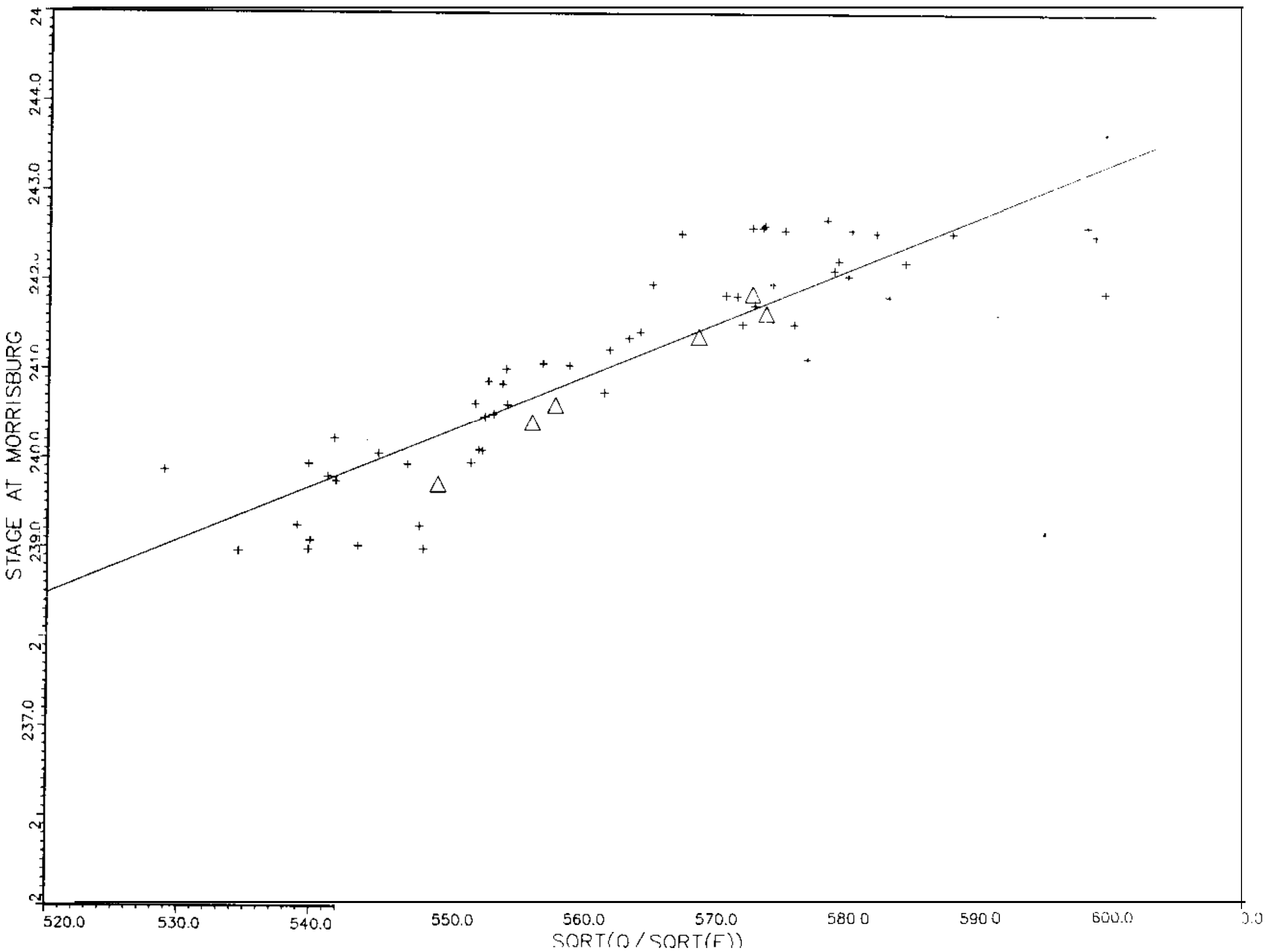

Figure 4d. Comparison of **stage vs.** $(Q/\sqrt{F})^{\frac{1}{2}}$ *for* **prototype** *(+)* **and model** *(Δ)* *(Morrisburg* **to Long** *Sault, Ont.)*.

Table 2. Calibrated Manning's Roughness Coefficients

Reach	n	Reach	n
1	0.028	16	0.033
2	0.023	17	0.033
3	0.028	18	0.038
4	0.037	19	0.026
5	0.025	20	0.031
6	0.032	21	0.026
7	0.040	22	0.033
8	0.038	23	0.033
9	0.033	24	0.040
10	0.035	25	0.040
11	0.035	26	0.040
12	0.036	27	0.040
13	0.030	28	0.040
14	0.029	29	0.040
15	0.026	30	0.046

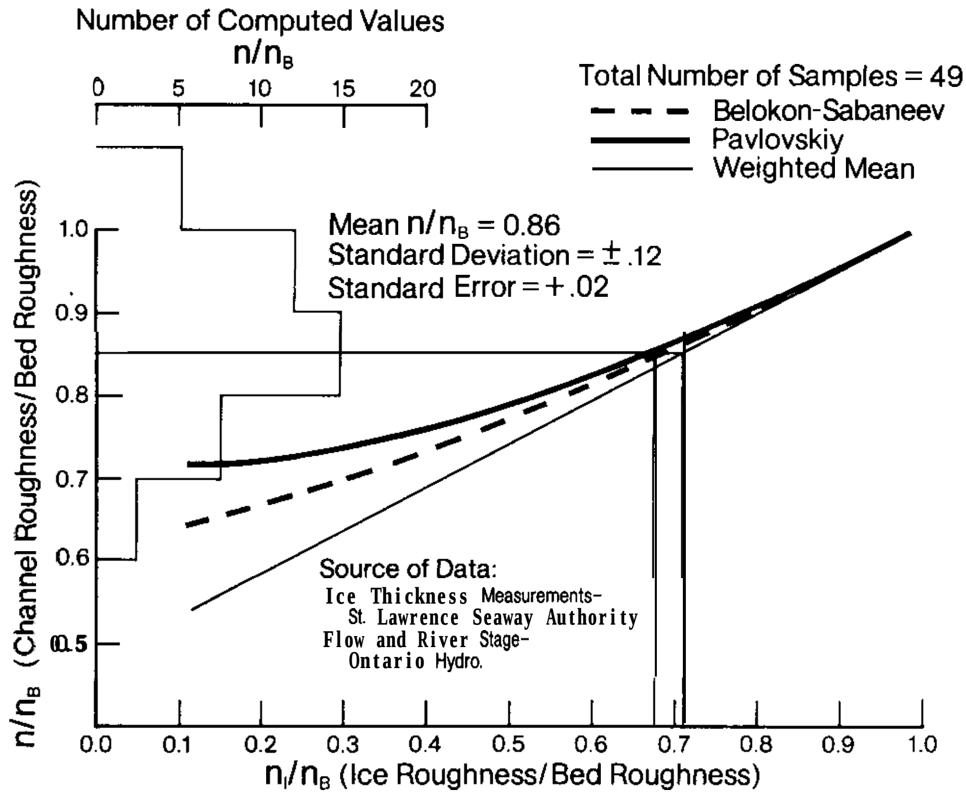

Figure 5. Determination of composite roughness in ice-covered channel.

values of n/n_B was also plotted. The mean computed ratio n/n_B for these 49 periods was 0.86 and all but four of the values are above 0.7. Entering Figure 6 with the mean values of n/n_B of 0.86 indicates that any of the three formulae being examined would result in virtually the same ice roughness coefficient. Of the three formulae, only that of Belokon-Sabaneev, equation (31), considers a non-linear velocity distribution in the ice-covered channel. For this reason, it was incorporated into the model in the form

$$n = 0.63\, n_B \left(1 + \left(\frac{n_I}{n_B}\right)^{1.5}\right)^{2/3} \tag{31}$$

where

n = composite channel roughness,
n_B = Manning's roughness coefficient, and
n_I = roughness of underside of ice cover.

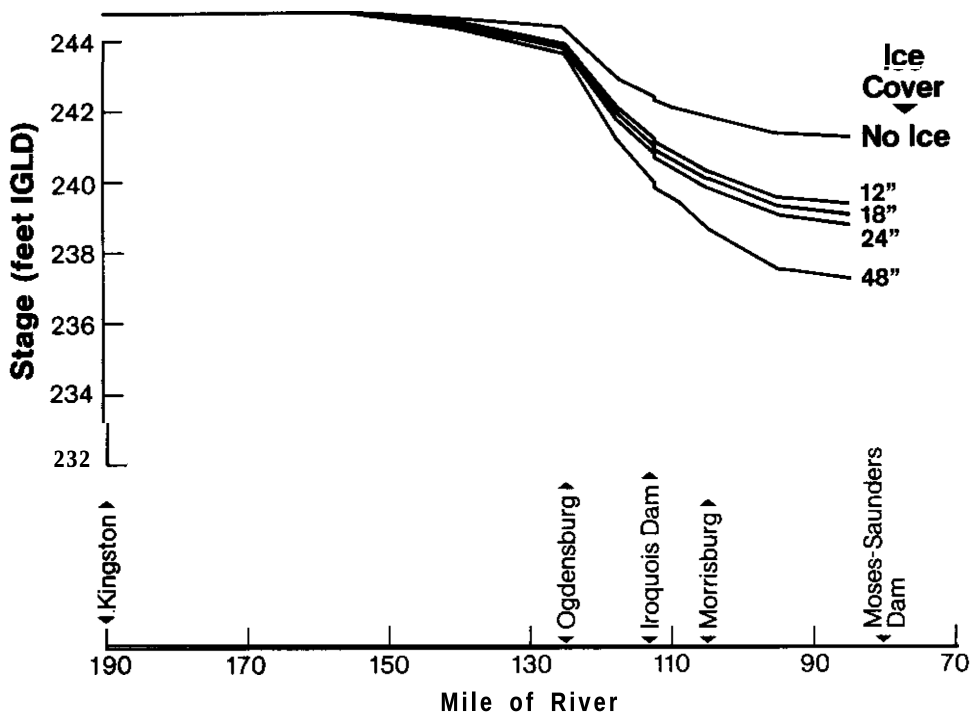

Figure 6a. *Sensitivity* of river profile to ice thickness. (Flow = 245 thousand cubic feet per second.)

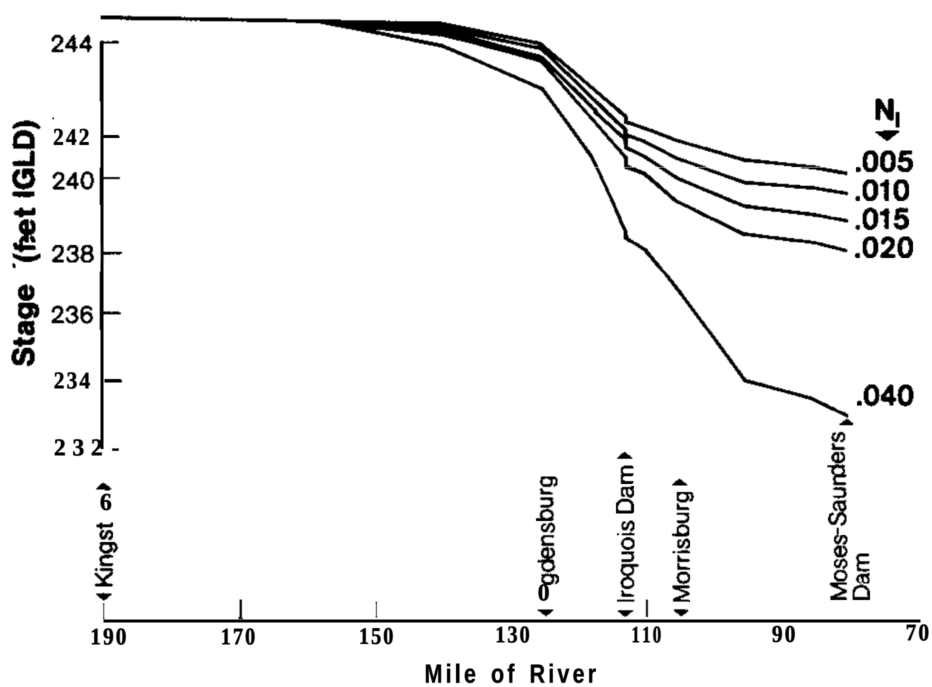

Figure 6b. *Sensitivity of river* profile to ice roughness. *(Flow* = 245 thousand cubic feet per second.!

Varying n_I in the range $0.005 < n_I < 0.03$ resulted in duplicating river profiles recorded on the St. Lawrence River.

Required input to the model for computation of river profiles under ice cover conditions includes the ice roughness coefficient and ice thickness. Although adequate data on the characteristics of the St. Lawrence River ice cover is not readily available, the limited data combined with aerial photographs allowed the following assumptions:

a. The roughness of the underside of the ice cover has a normal range of $0.005 < n_I < 0.03$, with a mean value of $n_I = 0.014$ as determined through the use of equations (13) and (14).

b. Sheet ice at least 12-inches thick is experienced along the entire river, except for the area immediately downstream of the Prescott ice boom and Iroquois Dam, which remain ice free.

The river profile is sensitive to both input parameters as exhibited in Figure 6. While ice thickness may be the easier parameter to estimate, it is the least sensitive of the two. Success in simulating river profiles was achieved by assuming a uniform 12-inch layer of ice on the river and adjusting the roughness coefficients to attain the required profile.

Figure 7 represents the sensitivity of river stage to ice roughness. The discharges selected are typical of those experienced during winter. Entering the curves in Figure 7 with recorded conditions of stage and flow, a related ice roughness coefficient was obtained. Using this coefficient, the river profile over a" entire winter could be simulated, until the ice cover changed during spring thawing. Table 3 lists the mean errors and error distribution obtained with a single ice roughness coefficient. A strong point of interest was that the ice roughness remains fairly stable over the winter (although it varies from season to season) and the changing fall is due primarily to fluctuating river flows.

7. THE HANGING DAM

Conditions of intermittent freezing and thawing of the ice cover and strong winds on the river have been know" to cause portions of the ice cover to break free and flow downstream, where they are stopped by a solid sheet of ice cover. Unconsolidated ice forced under the solid cover causes a" ice jam referred to as a hanging dam. Hanging dams occur most frequently around the areas of Ogden Island and Galop Island. Conditions under the dam include a severely restricted flow area and rougher Manning's coefficient. Simulation of a hanging dam (Fig. 8) is accomplished by considering the energy equation across the dam. If

$$Q_1 = Q_2 = Q_3 = Q_4$$

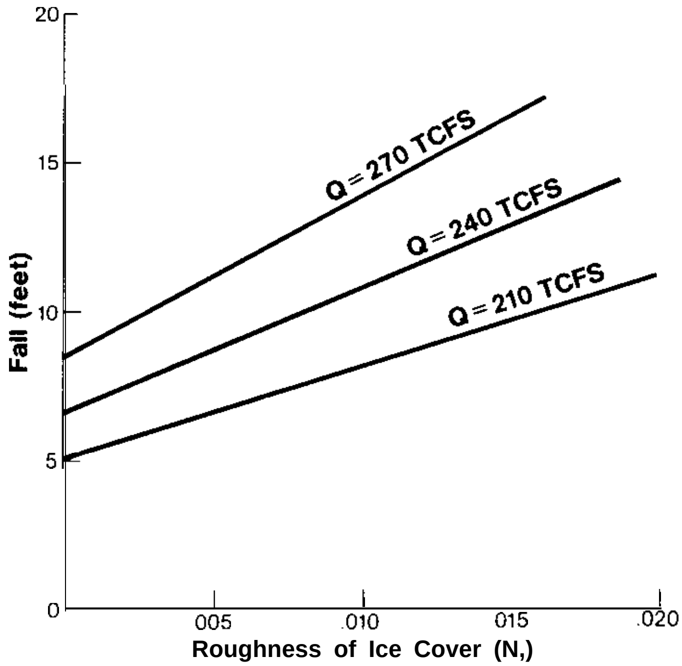

Figure *7a. Sensitivity* **of fall to ice-cover roughness with** *12-inch* **ice** *cover (Lake* **Ontario to** *Ogdensburg, N.Y.).*

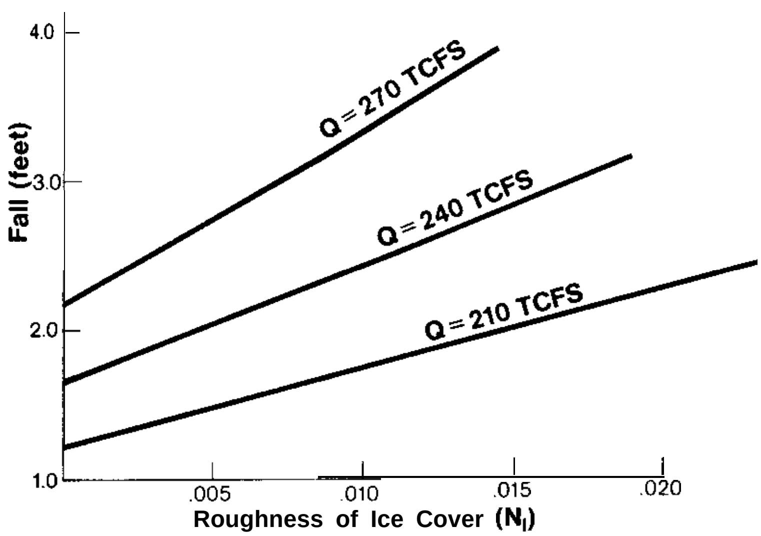

Figure 7b. *Sensitivity* **of** *fall to ice-cover* **roughness with** *12-inch ice* **cover** *(Ogdensburg,* **N.Y., to** *Cardinal,* **Ont.** *).*

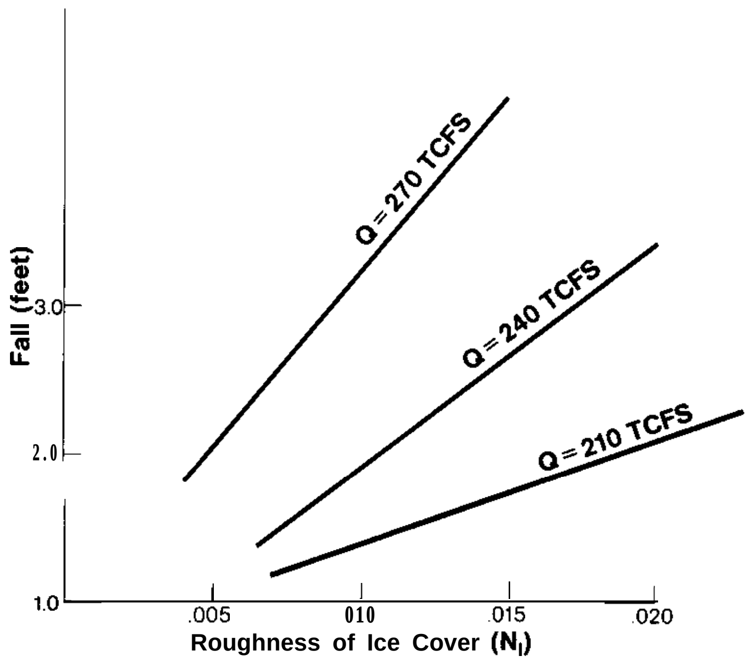

Figure 7c. Sensitivity of fall to ice-cover roughness with 12-inch ice cover (Cardinal to Morrisburg, Ont.).

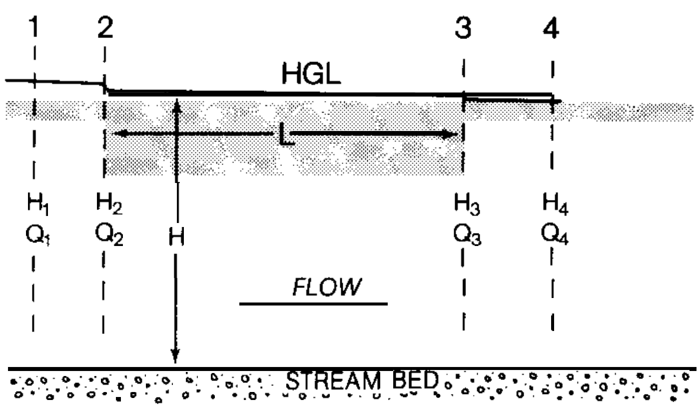

Figure 8. The hanging dam.

Table 3. **Water** Level **Simulation Error** During **Ice-cover** Conditions

Year	Number of Events	Mean Difference (Computed-Recorded), Feet	Maximum Difference (Computed-Recorded), Feet	Number of Events Whose Difference Was in the Range				
				o-o.1 ft	0.1-0.2 ft	0.2-0.3 ft	0.3-0.4 ft	>0.4 ft
1961	8	-0.00	-0.18	7	1	0	0	0
1962	10	-0.03	-0.16	8	2	0	0	0
1963	a	-0.00	-0.14	7	1	0	0	0
1964	14	-0.00	+0.27	10	2	2	0	0
1965	14	-0.01	-0.5	9	4	0	0	1
1968	1	-0.07	-0.0;	1	0	0	0	0
1969	2	0.00	-0.04	2	0	0	0	0
1970	8	+0.03	+0.15	7	1	0	0	0
1971	7	+0.03	+0.29	4	0	3	0	0
1972	4	+0.02	+0.32	2	0	1	1	0
1974	1	+0.03	+0.03	1	0	0	0	0
1976	5	+0.07	+0.29	3	1	1	0	0

and

$$V_2 = V_3,$$

then the energy equation between points (1) and (4) can be written as

$$h_1 + \frac{V_1|V_1|}{2g} = h_4 + \frac{V_4|V_4|}{2g} + f_L + h_e + h_d , \qquad (32)$$

where

h_1 = the hydraulic gradient at section 1,
h_4 = the hydraulic gradient at section 4,
f_L = the friction loss through the dam,
h_e = the entrance loss equal to 1.0 $\left(\frac{V_2^2 - V_1^2}{2g}\right)$, and
h_d = the exit loss equal to 0.5 $\left(\frac{V_3^2 - V_4^2}{2g}\right)$.

The friction loss term can be related to the Manning's roughness coefficient by

$$f_L = \frac{Q^2 n^2 L}{2.208\ A_2^2 R_2^{4/3}} .$$

Rewriting equation (32) yields

$$h_1 + \frac{V_1|V_1|}{2g} = h_4 + \frac{V_4|V_4|}{2g} + \frac{Q^2 n^2 L}{2.208\ A_2^2 R_2^{4/3}} + 1.0 \frac{\left(V_2^2 - V_1^2\right)}{2g}$$

$$+ 0.5 \frac{\left(V_3^2 - V_4^2\right)}{2g} \qquad (33)$$

Since $V_2 = V_3$ and $\frac{Q}{A} = V$, the equation reduces to

$$h_1 + \frac{1.5\ Q|Q|}{2gA_1^2} - h_4 - \frac{1.5\ Q|Q|}{2gA_2^2} - \frac{Q|Q|n^2 L}{2.208\ A_2^2 R_2^{4/3}} = 0. \qquad (34)$$

The model assumes that the hanging dam occurs at the upstream end of the reach selected for study. Equation (7) at the particular nodal point involving the reach is then modified to include the energy losses created by the hanging dam represented by equation (34). Input required to simulate the effects of a hanging dam include the length of the dam, the ice thickness, and the anticipated roughness of the channel under the dam. Because the dam may be of substantial length, the length of the dam is subtracted from the reach length when solving equations (3), (4), and (5). It is assumed that the hanging dam will not occupy an entire reach length.

8. MODEL STRUCTURE

The physical characteristics of the St. Lawrence River are described by two arrays in the model. Array R (30, 23) describes each of the 30 reaches in terms of length, top width, perimeter, bed roughness, and low water datum at each end of the reach. Elements R (N, 16-23) contain the computed discharge and stage at each end of each reach N (N = 1 to 30). Channel configuration is defined by array B (21, 9). This array provides the model with information required to define the sequence of flow from reach to reach. Array B is used to develop equations (6) and (7) in the model.

The use of arrays R and B provide a generalized model formulation. As a result, the user is not limited to examining the river in its existing state, but by appropriate substitution of the elements in R, can evaluate what will happen if changes are made. Modification of array B would allow the user to look at only a portion of the river or a different river configuration. While the model is generalized to allow the user to examine only a portion of the river, it requires a limited number of programming changes to accomplish this purpose. Figure 9 is the flow chart representing step by step logic in the model.

The model can be operated on hourly, daily, weekly, or monthly (assuming 1 month = 720 hr) time increments. Required input data include the initial stage and flow conditions in each reach, the initial stage at Lake Ontario, the NTS hydrograph into Lake Ontario, or the stage hydrograph at Kingston, and either the powerhouse discharge hydrograph or Long Sault Dam water level hydrograph. If conditions with ice are to be considered, the time variation of ice roughness and thickness must also be included. Sample input deck listings and corresponding output are given in Appendices A and B.

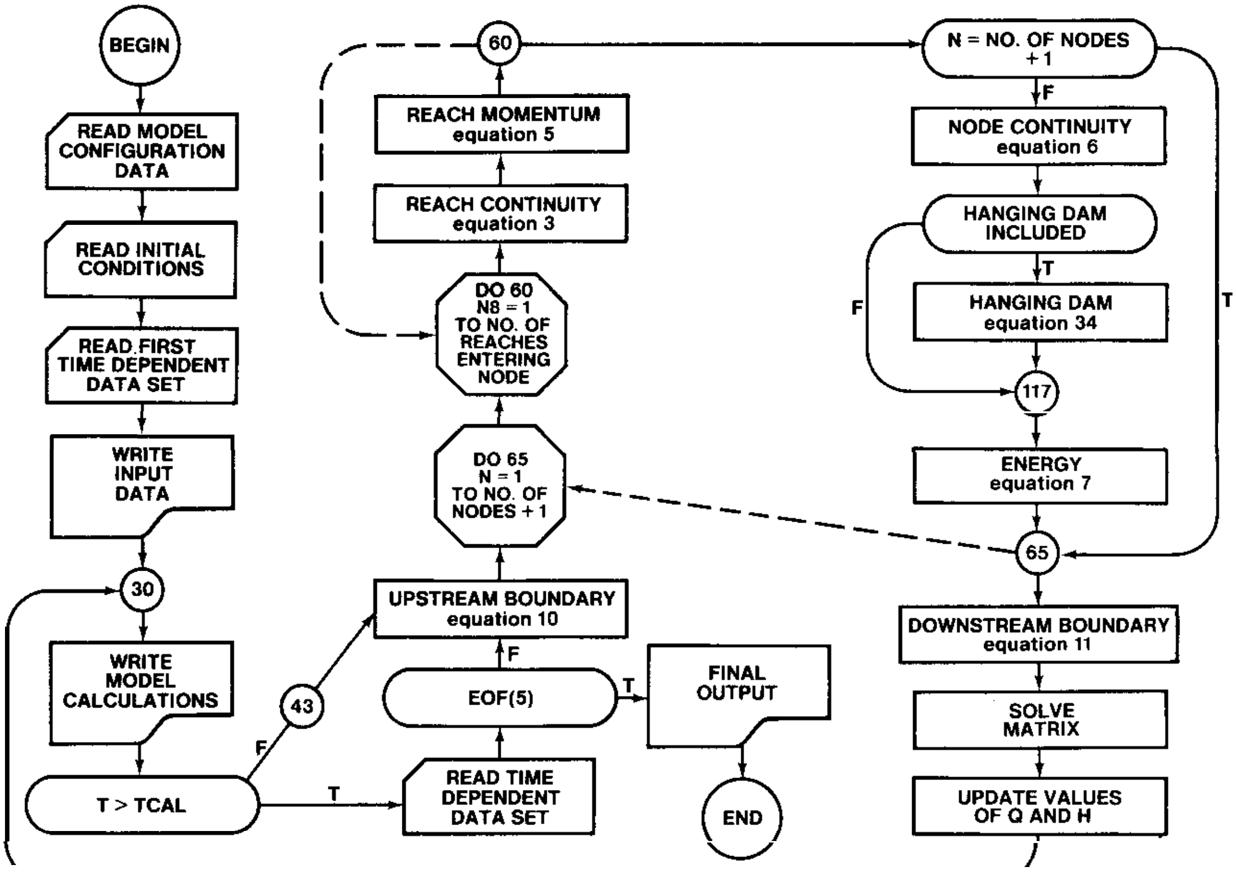

Figure 9. Flow chart.

9. MODEL INITIALIZATION

The complex configuration of the river, combined with the limited number of stage recorders, makes it difficult to estimate an initially accurate river profile with the model. Although this can be estimated if desired, the inaccuracies caused by the lack of recorded data cause the model to start with an inaccurate condition and thus to spend considerable time stabilizing to an accurate solution.

To overcome this drawback, the model can be initiated by assuming a level pool at the level of Lake Ontario along with entire length of the river and zero discharge at the powerhouse. A desired discharge then simulated with a monthly (720 hrs) time increment. The simulation continues until the simulated profile is steady. Ten iterations of monthly time increments are used in the model to reach the steady profile. After the steady profile has been achieved, the time increment is changed internally to that desired in operation of the model to examine its response to changing conditions at the boundaries.

RECOMMENDATIONS

It has been shown that the hydraulic transient model for the Upper St. Lawrence River provides an accurate simulation of water levels and flows. Because the model uses the full equations of mass continuity and momentum, the author believes the model to be a vast improvement over the stage-fall-discharge methods presently used.

There are many potential uses for the model relating to water resource studies, including analysis of both physical and operational changes in the river. The generalized nature of the model leaves room for future operational capabilities. Any improvements made to the model will be published in future reports.

10. REFERENCES

Belokon, P. N. (1938): Engineering hydraulics of the flow under an ice cover. *Meteorol.* **and** *Hydrol.*, **No. 11-12.**

Carey, K. L. (1967): Observed configuration and computed roughness of the underside of river ice, St. Croix River, Wisconsin, Geological Survey Prof. Paper 550-B, National Technical Information Service, Springfield, Va.

Chow, V. T. (1959): *Open* **Channel Hydraulics,** McGraw-Hill, pp. 136-138.

Coleman, G., and D. G. Decoursey. Sensitivity and model variance analysis applied to some evaporation and evapotranspiration models. **Water** *Resour.* **Res., 12(5):873-879.**

Larsen, P. (1973): Hydraulic roughness of ice covers. **J.** *Hydraul. Div.*, ASCE, **99(HY1):111-119.**

McCuen, R. H. (1974): A sensitivity analysis of procedures used for estimating evaporation. **Water** *Resour.* **Bull., 10(3):486-497.**

Muir, L. R. (1975): Unsteady flow in networks of open channels, Manuscript Report Series No. 1. Canadian Center for Inland Waters, Burlington, Ontario.

Nezhikhovskiy, R. A. (1964): Coefficients of roughness of bottom surface of slush ice cover. In **Soviet** *Hydrology*, Selected Paper No. 2, the American Geophysical Union.

Pavlovskiy, P. A. (1963): Computations and forecasts of the flows of slush and ice during the period of freezing of rivers. Trans. State Hydrologic Institute (Trudy G G I) Iss. p. 103.

Quinn, F. H., and E. B. Wylie (1972): Transient analysis of the Detroit River by the implicit method. **Water** *Resour.* **Res., 8(6):** 1461-1469.

Quinn, F. H., and J. C. Hagman (1977): Detroit and St. Clair River transient models. NOAA Tech. Memo. ERL GLERL-14, National Technical Information Service, Springfield, Va.

Regulation of Great Lakes Water Levels Report to the International Joint Commission (1973): Regulation Plan 1958-D, International Great Lakes Levels Board.

Sabaneev, A. A. (1948): On the computation of a uniform flow in a channel with non-uniform walls. Transactions, Leningrad Polytechnic Institute No. 5, Leningrad Polytechnic Institute, Leningrad, U.S.S.R.

U.S. Army Corps of Engineers, Detroit District (1976): St. Lawrence River Velocity and Flow Measurements, Galop Island, New York, Ogden Island, New York, Copeland Cut, New York.

Wylie, E. B., and V. L. Streeter (1978): Fluid transients. McGraw-Hill, p. 286-297.

Appendix A. MODEL INPUT SUMMARY

```
**********************************************************************
*            ST LAURENCE RIVER HYDRAULIC TRANSIENT MODEL INPUT SUMMARY          **
**********************************************************************


          PROGRAM INPUT IS  DIVIDED INTO THREE GROUPS:
                  RIVER CONFIGURATION
                  INITIAL CONDITIONS
                  TIME DEPENDENT DATA

**********************************************************************

   GROUP 1       MODEL CONFIGURATION

                             IDATER      - DATE OF RUN
                             IDATE(1)    - STARTING DATE
                                  (2)    - ENDING DATE
                             IPURP       - PURPOSE

       CARD 2                     FORMAT(2I5)
                             NR    -   NUMBER OF REACHES (USUALLY 30)
                             NB    -   NUMBER OF NODAL POINTS (USUALLY 21)
                         **NOTE:  A PORTION OF THE RIVER MAY BE EXAMINED BY
                             AFPROPRIATLY REDUCING NR AND NB.  LAKE ONTARIO
                             IS ALWAYS ASSUMED TO BE THE UPSTREAM BOUNDRY.

       CARD 3 (AND 4)             FORMAT(16F5.4)
                             R((N,13)  - MANNINGS ROUGHNESS COEFICIENTS FOR
                                         OPEN UATER FOR EACH REACH CALIBRATED
                                         RESPECTIVELY TO:
                                         .028,.023,.028,.037,.025,.032,.040
                                         .038,.033,.035,.035,.036,.030,.029
                                         .026,.033,.033,.038,.025,.031,.026
                                         .033,.033,.040,.040,.040,.040,.040
                                         .040,.040
                         **NOTE:  SECOND CARD IS  NOT NESSECARY FOR NR LESS
                             THAN 17. (TRUE FOR ALL SIMILAR CASES)
```

CARD 5(AND 6)
FORMAT(5X,15F5.0)
R(N,14) - ICE THICKNESS IN EACH REACH

CARD 7 (AND 8)
FORMAT(16F5.4)
RICE(N) - MANNINGS ICE ROUGHNESS IN EACH REACH

CARD 9
FORMAT(3F5.0,I5,2F6.2,F10.0,3I5)
DTT- TIME INCREMENT
TMAX- ENDING TIME
PSI- 0.75
KIT - NUMBER OF NEWTON RAPHSON ITERATIONS ALLOYED.
8 IS A SAFE MAXIMUM SINCE THE HODEL USUALLY
SUCCEEDS IN 4
HL - INITIAL STAGE AT LAKE ONTARIO
HLDN- INITIAL STAGE AT DOWSTREAM RESERVOIR
AR - ARE4 OF LAKE ONTARIO IN SQUARE MILES (7340.)
ITIMINT - UNITS OF DTT 1-HR, 2-DAY, 3-WEEK,
4-MONTH
IPRTYF = 0-PRINT ALL COMPUTATIONS INCLUDING
INITIALIZATION
1-DO NOT PRINT COMPUTATIONS DURING
INITIALIZATION
2-PRINT ONLY FINAL DATA
ISICE - =0 ICE IS NOT INCLUDED IN THIS RUN
=1 ICE Is INCLUDED

CARD 13
FORMAT(F10.0,I5)
ARES -AREA OF DOWNSTREAM FOREBAY IN SQUARE MILES
(USUALLY 15.)
NEXIT -REACH ENTERING FOREBAY(USUALLY 30)

CARD 11
FORMAT(2I5)
NUMUF- NUMBER CF REACHES FLOWING FROM UPSTREAM
RESERVOIR (USUALLY 2, ONE ON EACH SIDE OF
WOLFE ISLAND)
NHD -NUMBER OF HANGING DAMS, A MAXIMUM OF THREE
IS ALLOWED

CARD 12 FORMAT(6F10.4)

HANGING DAM DESCRIPTION

BOUND(I)- BOUNARY OR NODE AT WHICH THE DAM OCCURRS
RN1 (I)- REACH NUMBER CONTAINING THE DAM
THICK(I)- ICE THICKNESS IN FEET
RL (I)- LENGTH OF DAM IN FEET
RN(I) -MANNINGS ROUGHNESS UNDER DAM.

• * NOTE: ONE CARD FOR EACH DAM. OMIT IF NHD=0

****

GROUP 2 INITIAL CONDITIONS

CARD 1 FORMAT(5X,F10.0)
DISO-INITIAL DISCHARGE AT POWERHOUSE (USUALLY 0)

CARD 2 FORMAT(5X,F10.0)
NTSO-INITIAL NET TOTAL SUPPLY (USUALLY 0)

CARD 3 (AND 4) FORMAT(5X,15F5.2)
R(N,16)-INITIAL UPSTREAM STAGE FOR EACH REACH
(USUALLY = HL)

CARD 5 (AND 6) FORMAT(5X,15F5.2)
R(N,17)-INITIAL DOWNSTREAM STAGE AT EACH REACH
(USUALLY = HL)

CARD 7 (THRU 11) FORMAT(5X,7F10.0,5X)
R(N,18)-INITIAL FLOWS IN EACH REACH (USUALLY 0)

```
*****************************************************************************

GROUP 3                TIME DEPENDENT DATA

     CARD A (AND 2)              FORMAT(5X,15F5.0)
                            RICTHK(N)- ICE THICKNESS FOR EACH REACH
                    • * NOTE: ONLY   REQUIRED IF ISICE=1

     CARD 3(AND4)                FORMAT(16F5.4)
                            RICE(N)   - ICE ROUGHNESS IN EACH REACH
                    • * NOTE: ONLY   REQUIRED IF  ISICE=1

     CARD 5                      FORMAT(10X,2F10.0,3F5.2,I5)
                            DIS   -DISCHARGE AT POWERHOUSE
                            NTS   -NET TOTAL SUPPLY AT LAKE
                            STAGE- CONTROLLING STAGE AT DOWNSTREAM RESERVOIR.
                                   IF  STAGE DOES NOT EQUAL 0 . DIS IS  COMPUTED
                                   RATHER THAN INPUT. FIRST VALUE MUST =0.
                            HKING- CONTROLLING STAGE AT KINGSTON.  IF  HKING
                                   DOES NOT  EQUAL 0, THERE IS  NO  NEED, TO
                                   INCLUDE NTS.
                            WIND- WIND SPEED IN MPH. WIND  IS  +  IN
                                  DIRECTION OF FLOW AND - IF OPPOSITE
                                  OF DIRECTION OF FLOW

                              NHDC- CHANGE TO BE MADE IN HANGING DAM.
                                    IF NHDC .GT. 0, CARD 12 SHOULD BE
                                    REPEATED USING NEU INFORMATION.

  • ⊠  REPEAT GROUP 3 SEQUENCE FOR EACH TIME INTERVAL.      • ⊠⊠⊠⊠⊠⊠⊠⊠⊠

*****************************************************************************
```

Appendix B. EXAMPLE PROBLEMS

a. The Simple Drawdown

The most basic use of the model is to solve for a steady state profile given a level of Lake Ontario and a powerhouse discharge. The model initially starts as a level pool at the elevation specified (244.00 for this case). Using the initial discharge (280 TCFS) as a forcing function, the model iterates through 11 steps until a steady profile is achieved. In conditions of very high flow, a small fluctuation of 0.01 or 0.02 may be exhibited near Lake St. Lawrence. However, eleven time steps were found to provide ample time for convergence.

Input

```
AUGUST 1978                                                                                 SIMPLE CRAUDOUN
 30    21     9
0280 0230 0280 0370 0250 0323 0400 0380 0330 0350 0350 0360 0300 0290 0260 0330
8330 0380 0260 0310 0260 0330 0330 0400 0400 0400 0400 0400 0400 0400
   0    0    0    C    C    0    0    0    0    0    0    0    0    0    0    0
   0    c    0    0    0    0    0    0    0    a    0    0    0    0
   0    0    0    0    C    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    c    0    3    0    0    0    0    0
   1    1  0.75   8 24553 24500  7343.       1    0    0
   15.        30
   2    0
DISO          0
NTSO          0
U.S. 24500245002450024500245002450024500245002450024500245002450024500245002450024500
U.S. 24500245002450024500245002450024500245002450024500245002450024500245002450024500
D.S. 24500245002450024500245002450024500245002450024500245002450024500245002450024500
D.S. 24500245002450024500245002450024500245002450024500245002450024500245002450024500
              0         0         0         0         0         0         0
              0         0         0         0         a         0         0
              0         0         0                   0         0         0
                        u         0         0         0         0         0
              0
              280       280       0    0
```

Output

```
**************************************************************************************************************************************
**************************************************************************************************************************************
*************                   **********                                             **********                  *************
*************                   **********   ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL   **********                  *************
*************   PRINT OPTION 0  **********                                             **********                  *************
*************                   **********               DEVELOPED BY                  **********                  *************
*************  ALL INTERMEDIATE ********** GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY **********                  *************
************* CALCULATIONS ARE  **********            ANN ARBOR,MICHIGAN               **********     INCLUDES:    *************
*************   PRINTED OUT.    **********               JULY 1978                     **********                  *************
*************                   **********                                             **********   OPEN WATER ONLY *************
*************                   **********                                             **********                  *************
*************                   ********** PERIOD:       NONE         TO        NONE   **********                  *************
*************                   **********        PURPOSE:    SIMPLE DRAWDOWN          **********                  *************
*************                   **********                                             **********                  *************
**************************************************************************************************************************************
**************************************************************************************************************************************
```

GEOGRAPHICAL KEY TO REACH NUMBERS

```
 1.....KINGSTON
 2.....CAPE VINCENT
 3.....NORTH OF WOLFE ISLAND
 4.....NORTH OF HOWE ISLAND
 5.....SOUTH OF HOWE ISLAND
 6.....FLOW BETWEEN WOLFE IS. AND GRINDSTONE IS.
 7.....SOUTH OF GRINDSTONE ISLAND
 8.....NORTH OF GRINDSTONE ISLAND
 9.....FLOW BETWEEN GRINDSTONE IS. AND WELLSLEY IS.
10.....SOUTH OF WELLSLEY ISLAND
11.....NORTH OF WELLSLEY ISLAND
12.....SOUTH OF WELLSLEY ISLAND
13.....SOUTH OF GRENADIER ISLAND
14.....HILLCREST POINT
15.....BROCKVILLE
16.....OGDENSBURG
17.....NORTH OF GALOP ISLAND
18.....SOUTH OF GALOP ISLAND
19.....CARDINAL
20.....IROQUOIS
21.....NORTH OF OGDEN ISLAND
22.....WADDINGTON
23.....SOUTH OF OGDEN ISLAND
24.....MORRISBURG
25.....NORTH OF CROIL ISLAND
26.....SOUTH OF CROIL ISLAND
27.....FLOW BETWEEN CROIL IS. AND LONG SAULT IS.
28.....NORTH OF LONG SAULT ISLAND
29.....SOUTH OF LONG SAULT ISLAND
30.....LONG SAULT DAM
```

DATA FOR ST LAWRENCE MODEL
***   JULY 1978   ***

NUMBER OF REACHES........................... 30
NUMBER OF NODAL POINTS...................... 21
PSI... .75
AREA OF LAKE ONTARIO........................ .205E+12SQ.FT.
AREA OF DOWNSTREAM FOREBAY.................. .418E+09SQ.FT.
NUMBE R OF REACHES FLOWING FROM UPSTREAM...... 2
REACH ENTERING FOREBAY...................... 30

TIME INCREMENT.... 1.00 HRS
ENDING TIME....... 1.0 HRS

NUMBER OF NEWTON-RAPHSON ITERATIONS...... 8
OUTPUT OPTION............................ 0

INITIAL DISCHARGE............ 0.CFS
INITIAL NET TOTAL SUPPLY...... 0.CFS

NODAL POINT INFORMATION

NO.	NO. OF INCOMING REACHES	NO. OF OUTGOING REACHES	REACHES INVOLVED					
1	1	2	1	3	4	0	0	0
2	1	1	3	5	0	0	0	0
3	1	2	2	6	7	0	0	0
4	3	1	4	5	6	8	0	0
5	1	2	7	9	10	0	0	0
6	2	1	8	9	11	0	0	0
7	1	1	10	12	0	0	0	0
8	2	1	11	12	13	0	0	0
9	1	1	13	14	0	0	0	0
10	1	1	14	15	0	0	0	0
11	1	1	15	16	0	0	0	0
12	1	2	16	17	18	0	0	0
13	2	1	17	18	19	0	0	0
14	1	1	19	20	0	0	0	0
15	1	2	20	21	22	0	0	0
16	1	1	22	23	0	0	0	0
17	2	1	21	23	24	0	0	0
18	1	2	24	25	26	0	0	0
19	1	2	26	27	29	0	0	0
20	2	1	25	27	28	0	0	0
21	2	1	28	29	30	0	0	0

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 1 TO 10

REACH NO.	1.0000	2.0000	3.0000	4.0000	5.0000	6.0000	7.0000	8.0000	9.0000	10.0000
U.S. PT.	1.0000	3.0000	5.0000	7.0000	9.0000	11.0000	13.0000	15.0000	17.0000	19.0000
D.S. PT.	2.0000	4.0000	6.0000	8.0000	10.0000	12.0000	14.0000	16.0000	18.0000	20.0000
U.S. TOP	6422.0000	6520.0000	3977.0000	1520.0000	13400.0000	1860.0000	6905.0000	6450.0000	1510.0000	7290.0000
D.S. TOP	6422.0000	6520.0000	3977.0000	1520.0000	13400.0000	1860.0000	6905.0000	6450.0000	1510.0000	1620.0000
U.S. AREA	499000.0000	398700.0000	189500.0000	45100.0000	505000.0000	62000.0000	314300.0000	187100.0000	60400.0000	367600.0000
D.S. AREA	234600.0000	314300.0000	339000.0000	45100.0000	833200.0000	62000.0000	376700.0000	187100.0000	60400.0000	143300.0000
U.S. DATUM	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.7800	242.7800	242.7800
D.S. DATUM	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.7800	242.7400	242.7400	242.7200
U.S. PER	6577.4033	6642.3006	4072.2980	1579.3421	13475.3731	1926.6667	6996.0355	6508.0155	1590.0000	7390.8505
D.S. PER	6495.0614	6616.4110	4147.4803	1579.3421	13524.3582	1926.6667	7014.1093	6508.0155	1590.0000	1796.9136
LENGTH	35000.0000	68700.0000	28130.0000	62800.0000	27200.0000	10500.0000	22200.0000	28100.0000	16600.0000	15000.0000
MANNINGS R	.0280	.0230	.0280	.0370	.0250	.0320	.0400	.0380	.0330	.0350
ICE THK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MANNINGS R	.0280	.0230	.0280	.0370	.0250	.0320	.0400	.0380	.0330	.0350
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 11 TO 20

REACH NO.	11.0000	12.0000	13.0000	14.0000	15.0000	16.0000	17.0000	18.0000	19.0000	20.0000
U.S. PT.	21.0000	23.0000	25.0000	27.0000	29.0000	31.0000	33.0000	35.0000	37.0000	39.0000
D.S. PT.	22.0000	24.0000	26.0000	28.0000	30.0000	32.0000	34.0000	36.0000	38.0000	40.0000
U.S. TOP	3620.0000	1820.0000	7600.0000	3240.0000	4740.0000	3730.0000	1540.0000	1030.0000	2620.0000	2650.0000
D.S. TOP	3620.0000	1820.0000	7600.0000	3240.0000	4740.0000	3760.0000	1540.0000	1030.0000	2620.0000	2650.0000
U.S. AREA	166200.0000	143200.0000	379400.0000	142400.0000	105000.0000	140600.0000	46500.0000	32700.0000	92900.0000	87700.0000
D.S. AREA	225000.0000	154400.0000	142400.0000	105000.0000	259300.0000	80400.0000	70400.0000	22500.0000	82700.0000	108800.0000
U.S. DATUM	242.7400	242.7200	242.5600	242.3700	242.3300	242.2000	242.0000	242.0000	240.8000	239.7000
D.S. DATUM	242.5600	242.5600	242.3700	242.3300	242.2100	242.0000	240.8000	240.8000	239.9000	239.4000
U.S. PER	3711.8232	1977.3626	7699.8421	3327.9012	4784.3038	3805.3887	1600.3896	1093.4951	2690.9160	2716.1887
D.S. PER	3744.3094	1989.6703	7637.4737	3304.8148	4849.4093	3802.7660	1631.4286	1073.6893	2683.1298	2732.1132
LENGTH	50800.0000	49700.0000	75000.0000	15000.0000	65900.0000	17200.0000	28100.0000	30000.0000	23100.0000	16900.0000
MANNINGS R	.0350	.0360	.0300	.0290	.0260	.0330	.0330	.0380	.0260	.0310
ICE THK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MANNINGS R	.0350	.0360	.0300	.0290	.0260	.0330	.0330	.0380	.0260	.0310
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 21 TO 30

REACH NO.	21.0000	22.0000	23.0000	24.0000	25.0000	26.0000	27.0000	28.0000	29.0000	30.0000
U.S. PT.	41.0000	43.0000	45.0000	47.0000	49.0000	51.0000	53.0000	55.0000	57.0000	59.0000
D.S. PT.	42.0000	44.0000	46.0000	48.0000	50.0000	52.0000	54.0000	56.0000	58.0000	60.0000
U.S. TOP	1988.0000	1540.0000	1540.0000	4780.0000	1570.0000	2840.0000	1530.0000	3260.0000	1010.0000	6790.0000
D.S. TOP	1988.0000	1540.0000	1540.0000	4780.0000	1570.0000	2840.0000	1530.0000	3260.0000	1010.0000	6790.0000
U.S. AREA	65000.0000	43800.0000	43800.0000	158700.0000	86400.0000	150000.0000	76800.0000	169800.0000	57600.0000	232500.0000
D.S. AREA	50000.0000	43800.0000	108700.0000	200000.0000	86300.0000	150000.0000	76800.0000	168900.0000	63600.0000	232500.0000
U.S. DATUM	239.4100	239.4100	239.2600	239.1200	238.1700	238.1700	237.9900	237.9900	237.9900	237.7200
D.S. DATUM	239.1200	239.2600	239.1200	238.1700	237.9900	237.9900	237.9900	237.7200	237.7200	237.5000
U.S. PER	2053.3924	1596.8831	1596.8831	4846.4017	1680.0637	2945.6338	1630.3922	3364.1718	1124.0594	6858.4831
D.S. PER	2038.3018	1596.8831	1681.1688	4863.6820	1679.9363	2945.6338	1630.3922	3363.6196	1135.9406	6858.4831
LENGTH	17300.0000	9750.0000	9650.0000	52500.0000	20600.0000	11900.0000	5930.0000	13100.0000	19700.0000	15900.0000
MANNINGS R	.0260	.0330	.0330	.0400	.0400	.0400	.0400	.0400	.0400	.0400
ICE THK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MANNINGS R	.0260	.0330	.0330	.0400	.0400	.0400	.0400	.0400	.0400	.0400
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

0280.0230.0280.0370.0250.0320.0400.0380.0330.0350.0350.0360.0300.0290.0260.0330
0330.0380.0260.0310.0260.0330.0330.0400.0400.0400.0400.0400.0400.0400

------------------- TIME IN HRS = 0.00 LIKE ONTARIO = 245.00 LAKE ST LAWRENCE = 245.00-------------------

REACH	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
STAGE	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00
FLOW	0.	0.	I.	0.	I.	0.	0.	0.	0.	0.
REACH	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
STAGE	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00
FLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
STAGE	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00	245.00
FLOW	I.	0.	0.	0.	3.	0.	0.	0.	0.	0.

DISCHARGE AT P.H.= 0. NTS= -8400.

	COMPUTED HT
CAPE VINCENT	245.00
KINGSTON	245.00
OGDENSBURG	245.00
CARDINAL	245.00
IRIQUOIS H.W.	245.00
IRIQUOIS T.W.	245.00
WADDINGTON	245.00
MORRISBURG	245.00
LONGSAULT DAM	245.00

------------------- TIME IN HRS = 0.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 239.72-------------------

REACH	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
STAGE	244.98	244.97	244.97	244.97	244.96	244.96	244.96	244.96	244.94	244.94
FLOW	122304.	157712.	117246.	5058.	117247.	-20580.	178292.	101725.	41868.	137223.

REACH	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
STAGE	244.92	244.92	244.85	244.57	244.33	244.06	243.46	243.46	242.22	241.44
FLOW	142793.	137223.	280016.	280013.	280012.	280007.	215860.	64145.	280082.	279997.

REACH	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
STAGE	241.06	241.06	240.64	240.64	240.01	240.01	239.95	239.89	239.95	239.85
FLOW	153064.	126929.	126927.	279986.	101054.	178902.	100322.	201370.	78575.	279937.

DISCHARGE AT P.H.= 280000. NTS= 280000.

	COMPUTED HT
CAPE VINCENT	244.97
KINGSTON	244.98
OGDENSBURG	244.06
CARDINAL	242.22
IRIQUOIS H.W.	241.60
IRIQUOIS T.W.	241 .44
WADDINGTON	241.06
MORRISBURG	240.64
LONGSAULT DAM	239.85

------------------- TIME IN HRS = 0.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 239.15-------------------

REACH	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
STAGE	244.98	244.98	244.97	244.97	244.97	244.96	244.96	244.96	244.94	244.94
FLOW	122150.	151962.	11,133.	5014.	117131.	-20469.	178424.	101670.	41112.	137310.

REACH	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
STAGE	244.91	244.92	244.84	244.53	244.27	243.98	243.32	243.32	241.95	241.09
FLOW	142779.	137310.	280086.	280085.	280086.	280095.	216174.	63926.	280111.	280127.

REACH	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
STAGE	240.66	240.66	240.19	240.19	239.47	239.47	239.40	239.36	239.40	239.29
FLOW	153220.	126921.	126927.	280166.	101222.	119062.	100203.	201446.	78877.	280357.

DISCHARGE AT P.H.= 280000. NTS= 280000.

	COMPUTED H1
CAPE VINCENT	244.98
KINGSTON	244.98
OGDENSBURG	243.98
CARDINAL	241.95
IRIQUOIS H.W.	241.25
IRIQUOIS T.W.	241.09
WADDINGTON	240.66
MORRISBURG	240.19
LONGSAULT DAM	239.29

------------------ TIME IN HRS = 0.00 LAKE ONTARIO = 244.96 LAKE ST LAWRENCE = 241.43--------------------

REACH	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
STAGE	244.96	244.96	244.96	244.96	244.95	244.95	244.95	244.95	244.93	244.93
FLOW	121767.	155679.	116624.	5147.	116627.	-20748.	176438.	101037.	40601.	135842.

REACH	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
STAGE	244.92	244.92	244.87	244.66	244.49	244.29	243.87	243.87	243.04	242.50
FLOW	141645.	135844.	277504.	277573.	277584.	277682.	213393.	64319.	277771.	277839.

REACH	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
STAGE	242.25	242.25	242.00	242.00	241.61	241.61	241.57	241.55	241.57	241.50
FLOW	151683.	126217.	126239.	277995.	100344.	178064.	100542.	200959.	77581.	278652.

DISCHARGE AT P.H.= 280000. NTS= 280000.

	COMPUTED HT
CAPE VINCENT	244.96
KINGSTON	244.96
OGDENSBURG	244.29
CARDINAL	243.04
IRIQUOIS H.W.	242.63
IRIQUOIS T.W.	242.50
WADDINGTON	242.25
MORRISBURG	242.00
LONGSAULT DAM	241.50

------------------ TIME IN HRS = 0.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 239.64--------------------

REACH	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
STAGE	244.98	244.97	244.97	244.97	244.96	244.96	244.96	[illegible]	[illegible]	[illegible]
FLOW	122229.	157675.	117179.	5049.	117179.	-20557.	178232.	101671.	[illegible]	137176.

REACH	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
STAGE	244.91	244.92	244.85	244.56	244.32	244.05	243.44	243.44	[illegible]	[illegible]
FLOW	142727.	137176.	279903.	279909.	279910.	279920.	215831.	64092.	279931.	279941.

REACH	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
STAGE	241.00	241.00	240.58	240.58	239.93	239.93	239.87	239.83	[illegible]	239.77
FLOW	153050.	126900.	126904.	279965.	101087.	178944.	100323.	201422.	78631.	280071.

DISCHARGE AT P.H.= 280000. NTS= 280000.

	COMPUTED HT
CAPE VINCENT	244.97
KINGSTON	244.98
OGDENSBURG	244.05
CARDINAL	242.18
IRIQUOIS H.W.	241.55
IRIQUOIS T.W.	241.39
WADDINGTON	241.00
MORRISBURG	240.58
LONGSAULT DAM	239.77

```
------------------- TIME IN HRS =   0.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 239.70-------------------
REACH     1.       2.       3.       4.       5.       6.       7.       8.       9.      10.
STAGE  244.98   244.97   244.97   244.97   244.96   244.96   244.96   244.96   244.94   244.94
FLOW  122267.  157679.  117212.    5055.  117212.  -20571.  178250.  101696.  41059.  137191.

REACH    11.      12.      13.      14.      15.      16.      17.      18.      19.      20.
STAGE  244.91   244.92   244.85   244.57   244.33   244.06   243.46   243.46   242.21   241.43
FLOW    142755.  137191.  279946.  279946.  2799.6.  2199.6.  215823.  64124.  279946.  279946.

REACH    21.      22.      23.      24.      25.      26.      27.      28.      29.      30.
STAGE 241.05   241.05   240.63   240.63   239.99   239.99   239.93   239.89   239.93   239.83
FLOW    153040.  126905.  126905.  279945.  101051.  178893.  100313.  201364.   78580.  279944.

DISCHARGE AT P.H.=     280000. NTS=     280000.

                       COMPUTED HT
    CAPE VINCENT         244.97
    KINGSTON             244.98
    OGDENSBURG           244.06
    CARDINAL             242.21
    IRIQUOIS H.W.        241.59
    IRIQUOIS T.W.          241.43
    WADDINGTON               241.05
    MORRISBURG               240.63
    LONGSAULT DAM            239.83


REACH:      1            2            3            4            5            6            7            8            9           10
      ------------+------------+------------+------------+------------+------------+------------+------------+------------+------------+
  HRS   Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H
  0.   122. 244.98 158. 244.97 117. 244.97   5. 244.97 117. 244.96 -21. 244.96 178. 244.96 102. 244.96  41. 244.94 137. 244.94
REACH:     11           12           13           14           15           16           17           18           19           20
      ------------+------------+------------+------------+------------+------------+------------+------------+------------+------------+
  HRS   Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H
  0.   143. 244.91 137. 244.92 280. 244.85 280. 244.57 280. 244.33 280. 244.06 216. 243.46  64. 243.46 280. 242.21 280. 241.43
REACH:     21           22           23           24           25           26           27           28           29           30
      ------------+------------+------------+------------+------------+------------+------------+------------+------------+------------+
  HRS   Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H      Q      H
  0.   153. 241.05 127. 241.05 127. 240.63 280. 240.63 101. 239.99 179. 239.99 180. 239.93 281. 239.89  79. 239.93 280. 239.83
```

```
------------------- TIME IN   HRS =   0.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 239.71---------
REACH    1.      2.      3.      4.      5.      6.      7.      8.      9.     10.
STAGE 244.98  244.97  244.97  244.97  244.96  244.96  244.96  244.96  244.94  244.94
FLOW   122271. 157683. 117216.   5055. 117216. -20572. 178255. 101699.  41060. 137195.

REACH   11.     12.     13.     14.     15.     16.     17.     18.     19.     20.
STAGE 244.91  244.92  244.85  244.57  244.33  244.06  243.46  243.46  242.21  241.43
FLOW   142759. 137195. 279954. 279953. 279953. 279952. 215826.  64126. 279951. 279950.

REACH   21.     22.     23.     24.     25.     26.     27.     28.     29.     30.
STAGE 241.05  241.05  240.63  240.63  239.99  239.99  239.93  239.89  239.93  239.83
FLOW   153042. 126907. 126907. 279948. 101050. 178892. 100312. 201361.  78579. 279938.

DISCHARGE AT P.H.=    280000. NTS=    280000.

                      COMPUTED HT
    CAPE VINCENT        244.97
    KINGSTON            244.98
    OGDENSBURG          244.06
    CARDINAL            242.21
    IRIQUOIS H.W.       241.59
    IRIQUOIS T.W.         241.43
    WADDINGTON             241.05
    MORRISBURG             240.63
    LONGSAULT DAM          239.83


------------------- TIME IN   HRS =   0.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 239.70-------------------
REACH    1.      2.      3.      4.      5.      6.      7.      8.      9.     10.
STAGE 244.98  244.97  244.97  244.97  244.96  244.96  244.96  244.96  244.94  244.94
FLOW   122314. 157739. 117257.   5057. 117257. -20579. 178318. 101735.  41075. 137244.

REACH   11.     12.     13.     14.     15.     16.     17.     18.     19.     20.
STAGE 244.91  244.92  244.85  244.57  244.33  244.06  243.46  243.46  242.21  241.43
FLOW   142810. 137244. 280053. 280054. 280054. 280054. 215908.  64147. 280055. 280055.

REACH   21.     22.     23.     24.     25.     26.     27.     28.     29.     30.
STAGE 241.04  241.04  240.63  240.62  239.98  239.98  239.93  239.89  239.93  239.82
FLOW   153101. 126955. 126955. 280056. 101093. 178966. 100352. 201446.  78614. 280061.

DISCHARGE AT P.H.=    280000. NTS=    280000.

                      COMPUTED HT
    CAPE VINCENT        244.97
    KINGSTON            244.98
    LONGSAULT DAM          239.82
```

------------------- TIME IN HRS = 0.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 239.88-------------------

REACH	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
STAGE	244.98	244.97	244.97	244.97	244.96	244.96	244.96	244.96	244.94	244.94
FLOW	122426.	157745.	117355.	5073.	117355.	-20624.	178371.	101807.	41883.	137288.

REACH	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
STAGE	244.92	244.92	244.86	244.58	244.34	244.09	243.50	243.50	242.29	241.54
FLOW	142891.	137289.	280179.	280172.	280170.	280153.	215902.	64246.	280133.	280116.

REACH	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
STAGE	241.17	241.17	240.77	240.76	240.15	240.15	240.10	240.16	240.20	240.00
FLOW	153102.	126997.	126991.	280073.	101039.	178913.	100383.	201400.	78513.	279879.

DISCHARGE AT P.H.= 280000. NTS= 280000.

	COMPUTED HT
CAPE VINCENT	244.97
KINGSTON	244.98
OGDENSBURG	244.09
CARDINAL	242.29
IRIQUOIS H.W.	241.69
IRIQUOIS T.W.	241.54
WADDINGTON	241.17
MORRISBURG	240.76
LONGSAULT DAM	240.00

------------------- TIME IN HRS = 0.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 239.69-------------------

REACH	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
STAGE	244.98	244.97	244.97	244.97	244.96	244.96	244.96	244.96	244.94	244.94
FLOW	122300.	157727.	117245.	5056.	117245.	-20576.	178303.	101724.	41071.	137232.

REACH	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
STAGE	244.91	244.92	244.85	244.57	244.33	244.06	243.45	243.45	242.21	241.42
FLOW	142796.	137232.	280028.	280029.	280029.	280031.	215893.	64139.	280034.	280036.

REACH	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
STAGE	241.04	241.04	240.62	240.62	239.98	239.98	239.92	239.88	239.92	239.82
FLOW	153092.	126946.	126947.	280041.	101092.	178963.	100349.	201443.	78616.	280062.

DISCHARGE AT P.H.= 280000. NTS= 280000.

	COMPUTED HT
CAPE VINCENT	244.97
KINGSTON	244.98
OGDENSBURG	244.06
CARDINAL	242.21
IRIQUOIS H.W.	241.58
IRIQUOIS T.W.	241.42
WADDINGTON	241.04
MORRISBURG	240.62
LONGSAULT DAM	239.82

b. The Simple Drawdown Under Ice Conditions

The next basic problem to be solved with the model is similar to problem 1 with the addition of an ice cover. In the example problem, a 12-inch uniform ice cover with a Manning's roughness coefficient of N = 0.02 is used. The difference in input can be noted on cards 5, 6, 7, and 8 of the input deck listing. Intermediate results are not shown.

Input

```
   AUGUST  1978                                                              SIMPLE DRAWDOWN ICE
  30    21     9
0280 0230 0280 0370 0250 0320 0400 0380 0330 0350 0350 0360 0300 0291 0260 0330
0330 0380 0260 0310 0260 0330 0330 0400 0400 0400 0400 0400 0400 0400
  12   12   12   12   12   i2   12   12   12   12   12   12   12   12   12   00
  12   12   12   00   12   12   12   12   12   12   12   12   12   12
0200 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200    0
0200 0200 0200    0 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200
   1    1 0.75    8 245"' 24500  7340.         1    0    1
   15.    30
   2    3
DISO           0
NTSO           0
U.S.24500245002450024500245002450024500245002450024500245002450024500245002450024500
U.S. 24500245002450024500245002450024500245002450024500245002450024500245002450024500
D.S. 24500245002450024500245002450024500245002450024500245002450024500245002450024500
D.S. 24500245002450024500245002450024500245002450024500245002450024500245002450024500
               5         0         0         0         0         0         0
               6         0         0         0         0         0         0
                                   0                   0         0         0
               0         0         0         0         0         0         0

  12   12   12   12   12   12   12   12   12   12   12   12   12   12   12   00
0200 0200 0200 0200   12   12   12   12   12   12   12   12   12   12
                    0200 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200    0
0200 0200 0200    0 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200
              2 8       280      0    0
```

Output

```
PRINT OPTION 0          ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL

                                      DEVELOPED BY
ALL INTERMEDIATE        GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY
CALCULATIONS ARE                 ANN ARBOR,MICHIGAN                       INCLUDES:
PRINTED OUT.                        JULY 1978
                                                                          ICE CONDITIONS

                        PERIOD:       NONE         TO        NONE
                              PURPOSE:    SIMPLE DRAWDOWN
```

GEOGRAPHICAL KEY TO REACH NUMBERS

```
 1.....KINGSTON
 2.....CAPE VINCENT
 3.....NORTH OF WOLFE ISLAND
 4.....NORTH OF HOWE ISLAND
 5.....SOUTH OF HOWE ISLAND
 6.....FLOW BETWEEN WOLFE IS. AND GRINDSTONE IS.
 7.....SOUTH OF GRINDSTONE ISLAND
 8.....NORTH OF GRINDSTONE ISLAND
 9.....FLOW BETWEEN GRINDSTONE IS. AND WELLSLEY IS.
10.....SOUTH OF WELLSLEY ISLAND
11.....NORTH OF WELLSLEY ISLAND
12.....SOUTH OF WELLSLEY ISLAND
13.....SOUTH OF GRENADIER ISLAND
14.....HILLCREST POINT
15.....BROCKVILLE
16.....OGDENSBURG
17.....NORTH OF GALOP ISLAND
18.....SOUTH OF GALOP ISLAND
19.....CARDINAL
20.....IROQUOIS
21.....NORTH OF OGDEN ISLAND
22.....WADDINGTON
23.....SOUTH OF OGDEN ISLAND
24.....MORRISBURG
25.....NORTH OF CROIL ISLAND
26.....SOUTH OF CROIL ISLAND
27.....FLOW BETWEEN CROIL IS. AND LONG SAULT IS.
28.....NORTH OF LONG SAULT ISLAND
29.....SOUTH OF LONG SAULT ISLAND
30.....LONG SAULT DAM
```

DATA FOR ST LAWRENCE MODEL
***   JULY 1978   ***

NUMBER OF REACHES........................... 30
NUMBER OF NODAL POINTS...................... 21
PSI... .75
AREA OF LAKE ONTARIO........................ .205E+12SQ.FT.
AREA OF DOWNSTREAM FOREBAY.................. .418E+09SQ.FT.
NUMBER OF REACHES FLOWING FROM UPSTREAM...... 2
REACH ENTERING FOREBAY...................... 30

TIME INCREMENT.... 1.00 HRS
ENDING TIME....... 1.0 HRS

NUMBER OF NEWTON-RAPHSON ITERATIONS...... 8
OUTPUT OPTION........................... 0

ICE IS INCLUDED

HANGING DAM IS INCLUDED

NUMBER OF HANGING DAMS.....	1		
BOUNDRY OR NODE...........	12.	-R	-R
REACH.....................	17.	-R	-R
THICKNESS.................	8.50	-R	-R
LENGTH....................	300.	-R	-R
MANNINGS ROUGHNESS........	.100	-R	-R

INITIAL DISCHARGE............. 0.CFS
INITIAL NET TOTAL SUPPLY...... 0.CFS

NODAL POINT INFORMATION

NO.	NO. OF INCOMING REACHES	NO. OF OUTGOING REACHES	REACHES INVOLVED					
				3				
1	1		1	5	4	0	0	0
2	1	11	3		0	0	0	0
3	1		2	6	7	0	0	0
5	3	1	4	5		8	0	0
6	1	2	7	9	6	C	0	0
	2		8	9	10 ||	0	0	0
7	1	1	10	12	0	0	0	0
8	2	11	11	14	13	0	0	0
9	1	1	13	15	0	0	0	0
10	1	1	14	16	0	0	0	0
11	1	1	15	17	0	0	0	0
12	1	2	16	18	18	0	0	0
13	2	1	17	20	19	0	0	0
15	1	1	19	21	0	0	0	0
16	1	2	20	23	22	0	0	0
17	2	1	22		0	0	0	0
18	1	1	21	23	24	0	0	0
19	1	2	24	25	26	0	0	0
20	2	2	26	27	29	0	0	0
		1	25	27	28	0	0	0
21	2	1	28	29	30	0	0	0

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 1 TO 10

REACH NO.	1.0000	2.0000	3.0000	4.0000	5.0000	6.0000	7.0000	8.0000	9.0000	10.0000
U.S. PT.	1.0000	3.0000	5.0000	7.0000	9.0000	11.0000	13.0000	15.0000	17.0000	19.0000
D.S. PT.	2.0000	4.0000	6.0000	8.0000	10.0000	12.0000	14.0000	16.0000	18.0000	20.0000
U.S. TOP	6422.0000	6520.0000	3977.0000	1520.0000	13400.0000	1860.0000	6905.0000	6450.0000	1510.0000	7290.0000
D.S. TOP	6422.0000	6520.0000	3977.0000	1520.0000	13400.0000	1860.0000	6905.0000	6450.0000	1510.0000	1620.0000
U.S. AREA	499000.0000	398700.0000	189500.0000	45100.0000	585000.0000	62000.0000	314300.0000	187100.0000	60400.0000	367600.0000
D.S. AREA	234600.0000	314300.0000	339000.0000	45100.0000	833200.0000	62000.0000	376700.0000	187100.0000	60400.0000	143300.0000
U.S. DATUM	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.7800	242.7800	242.7800
D.S. DATUM	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.7800	242.7400	242.7400	242.7200
U.S. PER	12999.4033	13162.3006	8049.2980	3099.3421	26875.3731	3786.6667	13901.0355	12958.0155	3100.0000	14680.8505
D.S. PER	12917.0614	13136.4110	8124.4803	3099.3421	26924.3582	3786.6667	13919.1093	12958.0155	3100.0000	3416.9136
LENGTH	35000.0000	68750.0000	28130.0000	62800.0000	27200.0000	10500.0000	22200.0000	28100.0000	16600.0000	15000.0000
MANNINGS R	.0280	.0230	.0280	.0370	.0250	.0320	.0400	.0380	.0330	.0350
ICE THK	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000
MANNINGS R	.0280	.0230	.0280	.0370	.0250	.0320	.0400	.0380	.0330	.0350
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 11 TO 20

REACH NO.	11.0000	12.0000	13.0000	14.0000	15.0000	16.0000	17.0000	18.0000	19.0000	20.0000
U.S. PT.	21.0000	23.0000	25.0000	27.0000	29.0000	31.0000	33.0000	35.0000	37.0000	39.0000
D.S. PT.	22.0000	24.0000	26.0000	28.0000	30.0000	32.0000	34.0000	36.0000	38.0000	40.0000
U.S. TOP	3620.0000	1820.0000	7600.0000	3240.0000	4740.0000	3730.0000	1540.0000	1030.0000	2620.0000	2650.0000
D.S. TOP	3620.0000	1820.0000	7600.0000	3240.0000	4740.0000	3760.0000	1540.0000	1030.0000	2620.0000	2650.0000
U.S. AREA	166200.0000	143200.0000	379400.0000	142400.0000	105000.0000	140600.0000	46500.0000	32700.0000	92900.0000	87700.0000
D.S. AREA	225000.0000	154400.0000	142400.0000	105000.0000	259300.0000	80400.0000	70400.0000	22500.0000	82700.0000	108800.0000
U.S. DATUM	242.7400	242.7200	242.5600	242.3700	242.3300	242.2000	242.0000	242.0000	240.8000	239.7000
D.S. DATUM	242.5600	242.5600	242.3700	242.3300	242.2100	242.0000	240.8000	240.8000	239.9000	239.4000
U.S. PER	7331.8232	3797.3626	15299.8421	6567.9012	9524.3038	3805.3887	3140.3896	2123.4951	5310.9160	2716.1887
D.S. PER	7384.3094	3809.6703	15237.4737	6544.8148	9589.4093	3802.7660	3171.4286	2103.6893	5303.1298	2732.1132
LENGTH	50800.0000	49700.0000	75000.0000	15000.0000	65900.0000	17200.0000	28100.0000	30000.0000	23100.0000	16900.0000
MANNINGS R	.0350	.0360	.0300	.0290	.0260	.0330	.0330	.0380	.0260	.0310
ICE THK	12.0000	12.0000	12.0000	12.0000	12.0000	0.0000	12.0000	12.0000	12.0000	0.0000
MANNINGS R	.0350	.0360	.0300	.0290	.0260	.0330	.0330	.0380	.0260	.0310
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	-245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 21 TO 30

REACH NO.	21.0000	22.0000	23.0000	24.0000	25.0000	26.0000	27.0000	28.0000	29.0000	30.0000
U.S. PT.	41.0000	43.0000	45.0000	47.0000	49.0000	51.0000	53.0000	55.0000	57.0000	59.0000
D.S. PT.	42.0000	44.0000	46.0000	48.0000	50.0000	52.0000	54.0000	56.0000	58.0000	60.0000
U.S. TOP	1988.0000	1540.0000	1540.0000	4780.0000	1570.0000	2840.0000	1530.0000	3260.0000	1010.0000	6790.0000
D.S. TOP	1988.0000	1540.0000	1540.0000	4780.0000	1570.0000	2840.0000	1530.0000	3260.0000	1010.0000	6790.0000
U.S. AREA	65000.0000	43800.0000	43800.0000	158700.0000	86400.0000	150000.0000	76800.0000	169800.0000	57600.0000	232500.0000
D.S. AREA	50000.0000	43800.0000	108700.0000	200000.0000	86300.0000	150000.0000	76800.0000	168900.0000	63600.0000	232500.0000
U.S. DATUM	239.4100	239.4100	239.2600	239.1200	238.1700	238.1700	237.9900	237.9900	237.9900	237.7200
D.S. DATUM	239.1200	239.2600	239.1200	238.1700	237.9900	237.9900	237.9900	237.7200	237.7200	237.5000
U.S. PER	4041.3924	3136.8831	3136.8831	9626.4017	3250.0637	5785.6338	3160.3922	6624.1718	2134.0594	13648.4831
D.S. PER	4026.3018	3136.8831	3221.1688	9643.6820	3249.9363	5785.6338	3160.3922	6623.6196	2145.9406	13648.4831
LENGTH	17300.0000	9750.0000	9650.0000	52500.0000	20600.0000	11900.0000	5930.0000	13100.0000	19700.0000	15900.0000
MANNINGS R	.0260	.0330	.0330	.0400	.0400	.0400	.0400	.0400	.0400	.0400
ICE THK	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000
MANNINGS R	.0260	.0330	.0330	.0400	.0400	.0400	.0400	.0400	.0400	.0400
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0060	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LONGSAULT DAM 234.03

------------------- TIME IN HRS = 0.00 LAKE ONTARIO = 245.01 LAKE ST LAWRENCE = 233.55--------------------

REACH	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
STAGE	245.01	245.01	244.99	244.99	244.98	244.97	244.97	[illegible]	244.94	244.94
FLOW	123048.	157285.	116675.	6372.	116675.	-22553.	179838.	100494.	38964.	140874.

REACH	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
STAGE	244.90	244.92	244.80	244.26	243.82	243.15	242.48	242.48	239.85	237.88
FLOW	139458.	140874.	280333.	280334.	280334.	280336.	214647.	65689.	280338.	280340.

REACH	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
STAGE	237.34	237.34	236.03	235.96	234.28	234.28	234.15	234.07	234.15	233.92
FLOW	151122.	129220.	129220.	280345.	101837.	178526.	97308.	199149.	81221.	280375.

DISCHARGE AT P.H.= 280000. NTS= 280000.

	COMPUTED HT
CAPE VINCENT	245.01
KINGSTON	245.01
OGDENSBURG	243.15
CARDINAL	239.85
IRIQUOIS H.W.	238.08
IRIQUOIS T.W.	237.88
WADDINGTON	237.34
MORRISBURG	235.96
LONGSAULT DAM	233.92

55

```
REACH:      1              2              3              4
 HRS -- H  ---- Q ---- H  .+--- Q ---- H  ----------+-----------------+-----------------Q . H                      8              -----------------+
 0.   245.01 H  157.0   245.01   117.  244.99   Q    H    Q   H    Q    H    Q . 244.97    H   --------- Q                    H
      123.                                    6. 244.99  117. 244.98  -23. 244.97           244.94.         141.                244.94

 HRS   Q ------------+--------------+--------------+--------------+--------------+--------------+--------------+--------------+
REACH:     Q  H  H    Q    H  Q  Q    H         Q              H        Q          17        18        H     Q    H     Q    H
 0.   139.  244.90  141.  244.92 280. 280. 244.80  280. 244.26      243.82     215.       242.48   66. 242.48  280. 239.85  280. 237.88
REACH:     21       Q  22 Q      H        Q        H        Q        H
 0.   -------------+-129.---129.--+-236.03---280.--235.96---102.--234.28  Q  ----------+--------------+--------------+--------------+ 30
 HRS   Q     H            H                                                     H      Q     H      H   H    Q    Q           H
      151. 237.34       237.34                                          179. 234.28   97. 234.15  1234.154.07   280.           233.92
```

c. The Hanging Dam

The situation from problem 2 is modified by including an ice dam with a length of 320 ft and a depth of 8.5 ft in the reach on the north side of Galop Island (reach 17). The difference in data sets is noted in cards 11 and 12 of the input deck.

Figure B.l is a pictorial representation of the river profiles obtained from example problems a, b, and c.

Input

```
AUGUST 1978                                                                                    SIMPLE DRAWDOWN H.D.
  30    21     9
0280 023n 0283 0370 0250 0320 0400 0380 0330 0350 0350 0360 0300 0291 0260 0330
3333 0380 0260 0310 0260 0330 0330 0400 0400 0400 0400 0400 0400 0400
  12   12   12   12   12   12   12   12   12   12   12   12   12   12   12   00
  12   12   12   30   12   12   12   12   12   12   12   12   12   12
0200 0200 0200 7200 0200 0200 0200 0200 0200 3200 0200 0200 0200 0200 0200    0
0200 0200 0200    0 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200
   1    1 0.75    8 24500 24500 7340.      1    0    1
  15.       30
   2    1
  12.       17.       8.5       300.   .100
DISO        0
NTSO        0
U.S. 245002450024500245002450024500245002450024500245002450024500245002450024500245002450024500
U.S. 245002450024500245002450024500245002450024500245002450024500245002450024500245002450024500
D.S. 245002450024500245002450024500245002450024500245002450024500245002450024500245002450024500
C.S. 24500245002450024500245 024500245002450024500245002450024500245002450024500245002450024500
                         0         3                   0         0         3
            0                      0         0         0         0         0
                                   0                   0         0         0
            3            0         0         0         0         0         0

 '12   12   12   12   12   12   12   12   12   12   12   12   12   12   12   00
  12   12   12   00   12   12   12   12   12   12   12   12   12   12
'200 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200 020: 0200 0200 0200    a
0200 0200 0200    0 0200 0200 0200 0200 0200 0200 0200 0200 0200 0200
            280          280       0    0
```

Output

```
PRINT OPTION 0

ALL INTERMEDIATE
CALCULATIONS ARE
PRINTED OUT.

ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL

DEVELOPED BY
GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY
ANN ARBOR,MICHIGAN
JULY 1978

PERIOD:        NONE        TO        NONE
PURPOSE:    SIMPLE DRAWDOWN

INCLUDES:

ICE CONDITIONS
HANGING DAM
```

```
GEOGRAPHICAL KEY TO REACH NUMBERS
---------------------------------

 1.....KINGSTON
 2.....CAPE VINCENT
 3.....NORTH OF WOLFE ISLAND
 4.....NORTH OF HOWE ISLAND
 5.....SOUTH OF HOWE ISLAND
 6.....FLOW BETWEEN WOLFE IS. AND GRINDSTONE IS.
 7.....SOUTH OF GRINDSTONE ISLAND
 8.....NORTH OF GRINDSTONE ISLAND
 9.....FLOW BETWEEN GRINDSTONE IS. AND WELLSLEY IS.
10.....SOUTH OF WELLSLEY ISLAND
11.....NORTH OF WELLSLEY ISLAND
12.....SOUTH OF WELLSLEY ISLAND
13.....SOUTH OF GRENADIER ISLAND
14.....HILLCREST POINT
15.....BROCKVILLE
16.....OGDENSBURG
17.....NORTH OF GALOP ISLAND
18.....SOUTH OF GALOP ISLAND
19.....CARDINAL
20.....IROQUOIS
21.....NORTH OF OGDEN ISLAND
22.....WADDINGTON
23.....SOUTH OF OGDEN ISLAND
24.....MORRISBURG
25.....NORTH OF CROIL ISLAND
26.....SOUTH OF CROIL ISLAND
27.....FLOW BETWEEN CROIL IS. AND LONG SAULT IS.
28.....NORTH OF LONG SAULT ISLAND
29.....SOUTH OF LONG SAULT ISLAND
30.....LONG SAULT DAM
```

DATA FOR ST LAWRENCE MODEL
JULY 1978

NUMBER OF REACHES.......................... 30
NUMBER OF NODAL POINTS..................... 21
PSI.. .75
AREA OF LAKE ONTARIO....................... .205E+12SQ.FT.
AREA OF DOWNSTREAM FOREBAY................. .418E+09SQ.FT.
NUMBER OF REACHES FLOWING FROM UPSTREAM.... 2
REACH ENTERING FOREBAY..................... 30

TIME INCREME NT.... 1.00 HRS
ENDING TIME........ 1.0 HRS

NUMBER OF NEWTON-RAPHSON ITERATIONS...... 6
OUTPUT OPTION............................ 0

ICE IS INCLUDED

INITIAL DISCHARGE............ 0.CFS
INITIAL NET TOTAL SUPPLY...... 0.CFS

NODAL POINT INFORMATION

NO.	NO. OF INCOMING REACHES	NO. OF OUTGOING REACHES	REACHES INVOLVED					
1	1	2	1	3	4	0	0	0
2	1	1	3	5	0	0	0	0
3	1	2	2	6	7	0	0	0
4	3	1	4	5	6	8	0	0
5	1	2	7	9	10	0	0	0
6	2	1	8	9	11	0	0	0
7	1	1	10	12	0	0	0	0
8	2	1	11	12	13	0	0	0
9	1	1	13	14	0	0	0	0
10	1	1	14	15	0	0	0	0
11	1	1	15	16	0	0	0	0
12	1	2	16	17	18	0	0	0
13	2	1	17	18	19	0	0	0
14	1	1	19	20	0	0	0	0
15	1	2	20	21	22	0	0	0
16	1	1	22	23	0	0	0	0
17	2	1	21	23	24	0	0	0
18	1	2	24	25	26	0	0	0
19	1	2	26	27	29	0	0	0
20	2	1	25	27	28	0	0	0
21	2	1	28	29	30	0	0	0

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 1 TO 10

REACH NO.	1.0000	2.0000	3.0000	4.0000	5.0000	6.0000	7.0000	8.0000	9.0000	10.0000
U.S. PT.	1.0000	3.0000	5.0000	7.0000	9.0000	11.0000	13.0000	15.0000	17.0000	19.0000
D.S. PT.	2.0000	4.0000	6.0000	8.0000	10.0000	12.0000	14.0000	16.0000	18.0000	20.0000
U.S. TOP	6422.0000	6520.0000	3977.0000	1520.0000	13400.0000	1860.0000	6905.0000	6450.0000	1510.0000	7290.0000
D.S. TOP	6422.0000	6520.0000	3977.0000	1520.0000	13400.0000	1860.0000	6905.0000	6450.0000	1510.0000	1620.0000
U.S. AREA	499000.0000	398700.0000	189500.0000	45100.0000	505000.0000	62000.0000	314300.0000	187100.0000	60400.0000	367600.0000
D.S. AREA	234600.0000	314300.0000	339000.0000	45100.0000	833200.0000	62000.0000	376700.0000	187100.0000	60400.0000	143300.0000
U.S. DATUM	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.7800	242.7800	242.7800
D.S. DATUM	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.7800	242.7400	242.7400	242.7200
U.S. PER	6577.4033	6642.3006	4072.2980	1579.3421	13475.3731	1926.6667	6996.0355	6508.0155	1590.0000	7390.8505
D.S. PER	6495.0614	6616.4110	4147.4803	1579.3421	13524.3582	1926.6667	7014.1093	6508.0155	1590.0000	1796.9136
LENGTH	35000.0000	68700.0000	28130.0000	62800.0000	27200.0000	10500.0000	22200.0000	28100.0000	16600.0000	15000.0000
MANNINGS R	.0280	.0230	.0280	.0370	.02[illegible]	.0320	.0400	.0380	.0330	.0350
ICE THK	0.0000	0.0000	0.0000	0.0000	0.00[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000
MANNINGS R	.0280	.0230	.0280	.0370	.02[illegible]	.0320	.0400	.0380	.0330	.0350
U.S. H	245.0700	245.0700	245.0700	245.0700	245.07[illegible]	245.0700	245.0700	245.0700	245.0700	245.0700
D.S. H	245.0700	245.0700	245.0700		245.07[illegible]	245.0700	245.0700	245.0700	245.0700	245.0700
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.00[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.00[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0700	245.0700	245.0700	245.0700	245.07[illegible]	245.0700	245.0700	245.0700	245.0700	245.0700
D.S. HP	245.0700	245.0700	245.0700	245.0700	245.07[illegible]	245.0700	245.0700	245.0700	245.0700	245.0700
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.00[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.00[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 11 TO 20

REACH NO.	11.0000	12.0000	13.0000	14.0000	15.0000	16.0000	17.0000	18.0000	19.0000	20.0000
U.S. PT.	21.0000	23.0000	25.0000	27.0000	29.0000	31.0000	33.0000	35.0000	37.0000	39.0000
D.S. PT.	22.0000	24.0000	26.0000	28.0000	30.0000	32.0000	34.0000	36.0000	38.0000	40.0000
U.S. TOP	3620.0000	1820.0000	7600.0000	3240.0000	4740.0000	3730.0000	1540.0000	1030.0000	2620.0000	2650.0000
D.S. TOP	3620.0000	1820.0000	7600.0000	3240.0000	4740.0000	3760.0000	1540.0000	1030.0000	2620.0000	2650.0000
U.S. AREA	166200.0000	143200.0000	379400.0000	142400.0000	105000.0000	140600.0000	46500.0000	32700.0000	92900.0000	87700.0000
D.S. AREA	225000.0000	154400.0000	142400.0000	105000.0000	259300.0000	80400.0000	70400.0000	22500.0000	82700.0000	108800.0000
U.S. DATUM	242.7400	242.7200	242.5600	242.3700	242.3300	242.2000	242.0000	242.0000	240.8000	239.7000
D.S. DATUM	242.5600	242.5600	242.3700	242.3300	242.2100	242.0000	240.8000	240.8000	239.9000	239.4000
U.S. PER	3711.8232	1977.3626	7699.8421	3327.9012	4784.3038	3805.3887	1600.3896	1093.4951	2690.9160	2716.1887
D.S. PER	3744.3094	1989.6703	7637.4737	3304.8148	4849.4093	3802.7660	1631.4286	1073.6893	2683.1298	2732.1132
LENGTH	50800.0000	49700.0000	75000.0000	15000.0000	65900.0000	17200.0000	28100.0000	30000.0000	23100.0000	16900.0000
MANNINGS R	.0350	.0360	.0300	.0290	.0260	.0330	.0330	.0380	.0260	.0310
ICE THK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MANNINGS R	.0350	.0360	.0300	.0290	.0260	.0330	.0330	.0380	.0260	.0310
U.S. H	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700
D.S. H	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700
D.S. HP	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 21 TO 30

REACH NO.	21.0000	22.0000	23.0000	24.0000	25.0000	26.0000	27.0000	28.0000	29.0000	30.0000
U.S. PT.	41.0000	43.0000	45.0000	47.0000	49.0000	51.0000	53.0000	55.0000	57.0000	59.0000
D.S. PT.	42.0000	44.0000	46.0000	48.0000	50.0000	52.0000	54.0000	56.0000	58.0000	60.0000
U.S. TOP	1988.0000	1540.0000	1540.0000	4780.0000	1570.0000	2840.0000	1530.0000	3260.0000	1010.0000	6790.0000
D.S. TOP	1988.0000	1540.0000	1540.0000	4780.0000	1570.0000	2840.0000	1530.0000	3260.0000	1010.0000	6790.0000
U.S. AREA	65000.0000	43800.0000	43800.0000	158700.0000	86400.0000	150000.0000	76800.0000	169800.0000	57600.0000	232500.0000
D.S. AREA	50000.0000	43800.0090	108700.0000	200000.0000	86300.0000	150000.0000	76800.0000	168900.0000	63600.0000	232500.0000
U.S. DATUM	239.4100	239.4100	239.2600	239.1200	238.1700	238.1700	237.9900	237.9900	237.9900	237.7200
D.S. DATUM	239.1200	239.2600	239.1200	238.1700	237.9900	237.9900	237.9900	237.7200	237.7200	237.5000
U.S. PER	[illegible]	3136.8831	3136.8831	9626.4017	3250.0637	5785.6338	3160.3922	6624.1718	2134.0594	13648.4831
D.S. PER	4026.3018	3136.8831	3221.1688	9643.6820	3249.9363	5785.6338	3160.3922	6623.6196	2145.9406	13648.4831
LENGTH	17300.0000	9750.0000	9650.0000	52500.0000	20600.0000	11900.0000	5930.0000	13100.0000	19700.0000	15900.0000
MANNINGS R	.0260	.0330	.0330	.0400	.0400	.0400	.0400	.0400	.0400	.0400
ICE THK	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000
MANNINGS R	.0260	.0330	.0330	.0400	.0400	.0400	.0400	.0400	.0400	.0400
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

IRIQUOIS H.W.	235.14
IRIQUOIS T.W.	234.89
WADDINGTON	234.16
MORRISBURG	231.84
LONGSAULT DAM	228.54

REACH:	1		2		3		4		5		6		7		8		9		10	
HRS	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
0.	123.	245.03	157.	245.03	117.	245.02	6.	245.02	117.	245.01	-23.	245.00	180.	245.00	100.	245.01	39.	244.97	A.	244.97

REACH:	11		12		13		14		15		16		17		18		19		20	
HRS	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
0.	139.	244.93	141.	244.94	280.	244.83	280.	244.29	280.	243.85	280.	243.19	197.	240.22	84.	242.52	280.	237.51	280.	234.89

REACH:	21		22		23		24		25		26		27		28		29		30	
HRS	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
0.	151.	234.16	129.	234.16	129.	231.95	280.	231.84	102.	229.05	178.	229.05	95.	228.86	197.	228.75	83.	228.86	280.	228.54

******************************DATA FOR ST LAWRENCE MODEL******************************
****************************** JULY 1978 ******************************

NUMBER OF REACHES.......................... 30
NUMBER OF NODAL POINTS..................... 21
PSI.. .75
AREA OF LAKE ONTARIO....................... .205E+12 SQ.FT.
AREA OF DOWNSTREAM FOREBAY................. .418E+09 SQ.FT.
NUMBER OF REACHES FLOWING FROM UPSTREAM...... 2
REACH ENTERING FOREBAY..................... 30

TIME INCREMENT.... 1.00 HRS
TIME ENDING....... 97.0 HRS

NUMBER OF NEWTON-RAPHSON ITERATIONS...... 8
OUTPUT OPTION............................ 2

INITIAL DISCHARGE............ 0.CFS
INITIAL NET TOTAL SUPPLY...... 0.CFS

NODAL POINT INFORMATION

NO.	NO. OF INCOMING REACHES	NO. OF OUTGOING REACHES	REACHES INVOLVED					
1	1	2	1	3	4	a	0	0
2	1	1	3	5	0	0	0	0
3	1	2	2	6	7	0	0	0
4	3	1	4	5	6	8	0	0
5	1	2	7	9	10	0	0	0
6	2	1	8	9	11	0	0	0
7	1	1	10	12	0	0	0	0
8	2	1	11	12	13	0	0	0
9	1	1	13	14	0	0	0	0
10	1	1	14	15	0	0	0	0
11	1	1	15	16	0	0	0	0
12	1	2	16	17	18	0	0	0
13	2	1	17	18	19	3	0	0
14	1	1	19	20	0		0	0
15	1	2	20	21	22	a	0	0
16	1	1	22	23	0	0	0	0
17	2	1	21	23	24	0	0	0
18	1	2	24	25	26	0	0	0
19	1	2	26	27	29	0	0	0
20	2	1	25	27	28	0	0	0
21	2	1	28	29	30	0	0	0

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 1 TO 10

REACH NO.	1.0000	2.0000	3.0000	4.0000	5.0000	6.0000	7.0000	8.0000	9.0000	10.0000
U.S. PT.	1.0000	3.0000	5.0000	7.0000	9.0000	11.0000	13.0000	15.0000	17.0000	19.0000
D.S. PT.	2.0000	4.0000	6.0000	8.0000	10.0000	12.0000	14.0000	16.0000	18.0000	20.0000
U.S. TOP	6422.0000	6520.0000	3977.0000	1520.0000	13400.0000	1860.0000	6905.0000	6450.0000	1510.0000	7290.0000
D.S. TOP	6422.0000	6520.0000	3977.0000	1520.0000	13400.0000	1860.0000	6905.0000	6450.0000	1510.0000	1620.0000
U.S. AREA	499000.0000	398700.0000	189500.0000	45100.0000	505000.0000	62000.0000	314300.0000	187100.0000	60400.0000	367600.0000
D.S. AREA	234600.0000	314300.0000	339000.0000	45100.0000	833200.0000	62000.0000	376700.0000	187100.0000	60400.0000	143300.0000
U.S. DATUM	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.7800	242.7800	242.7800
D.S. DATUM	242.8000	242.8000	242.8000	242.8000	242.8000	242.8000	242.7800	242.7400	242.7400	242.7200
U.S. PER	12999.4033	13162.3006	8049.2980	3099.3421	26875.3731	3786.6667	13901.0355	12958.0155	3100.0000	14680.8505
D.S. PER	12917.0614	13136.4110	8124.4803	3099.3421	26924.3582	3786.6667	13919.1093	12958.0155	3100.0000	3416.9136
LENGTH	35000.0000	68700.0000	28130.0000	62800.0000	27200.0000	10500.0000	22200.0000	28100.0000	16600.0000	15000.0000
MANNINGS R	.0280	.0230	.0280	.0370	.0250	.0320	.0400	.0380	.0330	.0350
ICE THK	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000	12.0000
MANNINGS R	.0280	.0230	.0280	.0370	.0250	.0320	.0400	.0380	.0330	.0350
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 11 TO 20

REACH NO.	11.0000	12.0000	13.0000	14.0000	15.0000	16.0000	17.0000	18.0000	19.0000	20.0000
U.S. PT.	21.0000	23.0000	25.0000	27.0000	29.0000	31.0000	33.0000	35.0000	37.0000	39.0000
D.S. PT.	22.0000	24.0000	26.0000	28.0000	30.0000	32.0000	34.0000	36.0000	38.0000	40.0000
U.S. TOP	3620.0000	1820.0000	7600.0000	3240.0000	4740.0000	3730.0000	1540.0000	1030.0000	2620.0000	2650.0000
D.S. TOP	3620.0000	1820.0000	7600.0000	3240.0000	4740.0000	3760.0000	1540.0000	1030.0000	2620.0000	2650.0000
U.S. AREA	166200.0000	143200.0000	379400.0000	142400.0000	105000.0000	140600.0000	46500.0000	32700.0000	92900.0000	87700.0000
D.S. AREA	225000.0000	154400.0000	142400.0000	105000.0000	259300.0000	80400.0000	70400.0000	22500.0000	82700.0000	108800.0000
U.S. DATUM	242.7400	242.7200	242.5600	242.3700	242.3300	242.2000	242.0000	242.0000	240.8000	239.7000
D.S. DATUM	242.5600	242.5600	242.3700	242.3300	242.2100	242.0000	240.8000	240.8000	239.9000	239.4000
U.S. PER	7331.8232	3797.3626	15299.8421	6567.9012	9524.3038	3805.3887	3140.3896	2123.4951	5310.9160	2716.1887
D.S. PER	7364.3094	3809.6703	15237.4737	6544.8148	9589.4093	3802.7660	3171.4286	2103.6893	5303.1298	2732.1132
LENGTH	50800.0000	49750.0000	75000.0000	15000.0000	65900.0000	17200.0000	27800.0000	30000.0000	23100.0000	16900.0000
MANNINGS R	.0350	.0360	.0300	.0290	.0260	.0330	.0330	.0380	.0260	.0310
ICE THK	12.0000	12.0000	12.0000	12.0000	12.0000	0.0000	12.0000	12.0000	12.0000	0.0000
MANNINGS R	.0350	.0360	.0300	.0290	.0260	.0330	.0330	.0380	.0260	.0310
U.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. H	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
D.S. HP	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000	245.0000
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR REACHES 21 TO 30

REACH NO.	21.0000	22.0000	23.0000	24.0000	25.0000	26.0000	27.0000	28.0000	29.0000	30.0000
U.S. PT.	41.0000	43.0000	45.0000	47.0000	49.0000	51.0000	53.0000	55.0000	57.0000	59.0000
D.S. PT.	42.0000	44.0000	46.0000	48.0000	50.0000	52.0000	54.0000	56.0000	58.0000	60.0000
U.S. TOP	1988.0000	1540.0000	1540.0000	4780.0000	1570.0000	2840.0000	1530.0000	3260.0000	1010.0000	6790.0000
D.S. TOP	1988.0000	1540.0000	1540.0000	4780.0000	1570.0000	2840.0000	1530.0000	3260.0000	1010.0000	6790.0000
U.S. AREA	65000.0000	43800.0000	43800.0000	158700.0000	86400.0000	150000.0000	76800.0000	169800.0000	57600.0000	232500.0000
D.S. AREA	50000.0000	43800.0000	108700.0000	200000.0000	86300.0000	150000.0000	76800.0000	168900.0000	63600.0000	232500.0000
U.S. DATUM	239.4100	239.4100	239.2600	239.1200	238.1700	238.1700	237.9900	237.9900	237.9900	237.7200
D.S. DATUM	239.1200	239.2600	239.1200	238.1700	237.9900	237.9900	237.9900	237.7200	237.7200	237.5000
U.S. PER	2053.3924	1596.8831	1596.8831	4846.4017	1680.0637	2945.6338	1630.3922	3364.1718	1124.0594	6858.4831
D.S. PER	2038.3018	1596.8831	1681.1688	4863.6820	1679.9363	2945.6338	1630.3922	3363.6196	1135.9406	6858.4831
LENGTH	17300.0000	9750.0000	9650.0000	52500.0000	20600.0000	11900.0000	5930.0000	13100.0000	19700.0000	15900.0000
MANNINGS R	.0260	.0330	.0330	.0400	.0400	.0400	.0400	.0400	.0400	.0400
ICE THK	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MANNINGS R	.0260	.0330	.0330	.0400	.0400	.0400	.0400	.0400	.0400	.0400
U.S. H	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700
D.S. H	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700
U.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
U.S. HP	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700
D.S. HP	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700	245.0700
U.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D.S. QP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

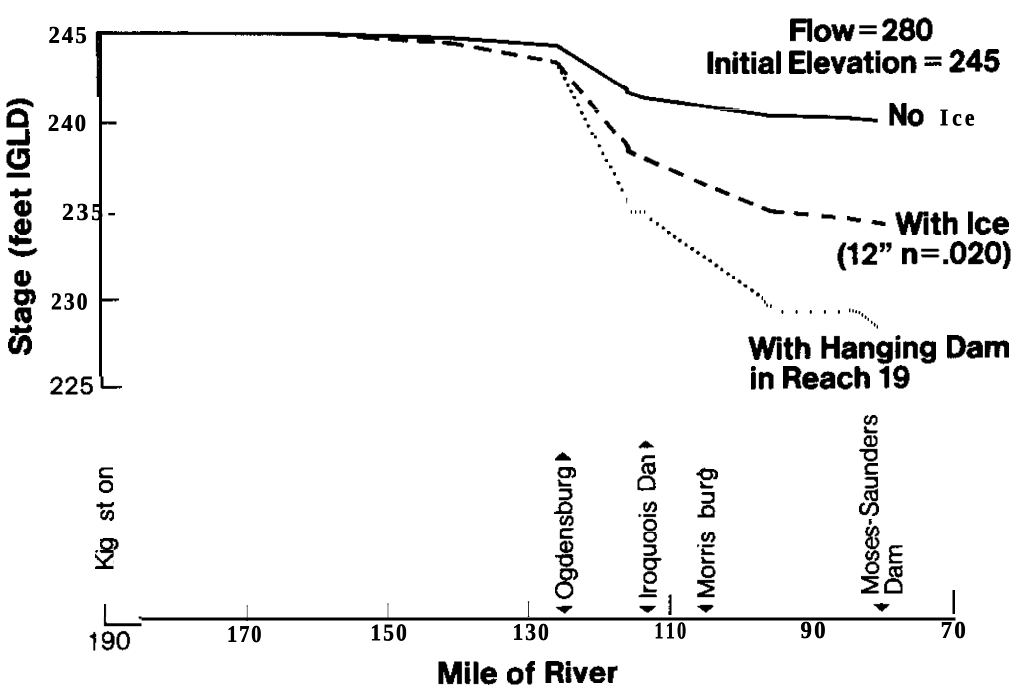

Figure B. 1. River profiles for example problems a, b, and c.

d. The Unsteady Condition

The advantage to using a flood routing model or transient model over a backwater model is its capability to examine a time varying condition on the river. The period 7 through 10 August 1977 is examined using recorded hourly values of the stage at Kingston and the powerhouse discharge.

The primary difference between problem d. and problem a. is the addition of a flow hydrograph and water level hydrograph for each of 96 hourly periods.

Two cases are examined. The first uses the flow hydrograph at the power dam as a downstream control to determine river profiles. The second uses the stage at the Moses-Saunders Power Dam as a downstream control to derive a flow hydrograph (Fig. B.2).

Input

```
  JULY  1978        AUGUST 7,1977        AUGUST 10,1977        96 HOUR RUN
  30   21     9
0280 0230 0280 0370 0250 0320 0400 0380 0333 0350 0350 0360 0300 0290 0260 0350
0350 0400 0260 0313 0260 0330 0330 0400 0400 0400 0400 0400 0400 0400



  1    1  0.75     8 24500 24500   734c.         1     2     0
   15.      30
  2
IS0      0
TSO
450024500245002450024500245002450024500245002450024500245002450024500245002450024500
450024500245002450024500245002450024500245002450024500245002450024500245002450024500
450024500245002450024500245002450024500245002450024500245002450024500245002450024500
450024500245002450024500245002450024500245002450024500245002450024500245002450024500
        0         0         0         0         0         0
        0         0         0         0         0         0
         0        0         0         0         0         0
         0        3         0         0         3         0
         0        0
```

67

254214	24507	238350	24507
227330	24508	224800	24510
225120	24508	223260	24508
223880	24511	223410	24555
221990	24503	222925	24514
223930	245'7	223313	24537
223790	24500	223820	24500
223660	24500	224840	24499
228710	24504	229300	24494
246070	24506	245260	24499
261400	24507	263480	24501
26741"	24501	268230	245 03
274170	24501	277800	24536
277510	24504	276240	24504
276553	24506	274270	24504
275900	245-4	273850	24507
275130	24502	276860	24508
276830	24501	275830	24508
274810	24505	277390	24537
27522')	24501	275830	24507
277599	24514	277050	24500
278221	24500	277170	24500
268270	24505	268670	24501
254141	24502	255950	24499
239380	24507	239350	24490
225790	24506	223270	24490
222400	24508	224800	24479
223380	24505	223533	24495
223780	24504	222910	24438
223080	24512	224750	24493
223280	24514	224250	24496
224000	24508	224360	24499
229550	24506	227893	24508
248120	24507	249980	24518
263860	24508	262860	24526
2663911	24506	266510	24521
274910	24504	275420	24519
277200	24502	274930	24511
277020	24513	273900	24505
255850	24511	275410	24506
278370	24515	276220	24506
278340	24512	276830	245 04
278020	24516	274690	24506
278360	24513	274220	24500
279656	24512	277300	24504
279800	24514	277720	24510
269560	2451:	270250	24513
256910	24509	257870	24510

Output

```
PRINT OPTION 2            ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL

                                         DEVELOPED BY
 NO INTERMEDIATE          GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY
CALCULATIONS ARE                      ANN ARBOR,MICHIGAN                      INCLUDES:
  PRINTED OUT.                           JULY  1978
                                                                           OPEN WATER ONLY

                        PERIOD: AUGUST 7,1977      TO AUGUST 10,1977
                               PURPOSE:      96 HOUR RUN
```

GEOGRAPHICAL KEY TO REACH NUMBERS

```
 1.....KINGSTON
 2.....CAPE VINCENT
 3.....NORTH OF WOLFE ISLAND
 4.....NORTH OF HOWE ISLAND
 5.....SOUTH OF HOWE ISLAND
 6.....FLOW BETWEEN WOLFE IS. AND GRINDSTONE IS.
 7.....SOUTH OF GRINDSTONE ISLAND
 8.....NORTH OF GRINDSTONE ISLAND
 9.....FLOW BETWEEN GRINDSTONE IS. AND WELLSLEY IS.
10.....SOUTH OF WELLSLEY ISLAND
11.....NORTH OF WELLSLEY ISLAND
12.....SOUTH OF WELLSLEY ISLAND
13.....SOUTH OF GRENADIER ISLAND
14.....HILLCREST POINT
15.....BROCKVILLE
16.....OGDENSBURG
17.....NORTH OF GALOP ISLAND
18.....SOUTH OF GALOP ISLAND
19.....CARDINAL
20.....IROQUOIS
21.....NORTH OF OGDEN ISLAND
22.....WADDINGTON
23.....SOUTH OF OGDEN ISLAND
24.....MORRISBURG
25.....NORTH OF CROIL ISLAND
26.....SOUTH OF CROIL ISLAND
27.....FLOW BETWEEN CROIL IS. AND LONG SAULT IS.
28.....NORTH OF LONG SAULT ISLAND
29.....SOUTH OF LONG SAULT ISLAND
30.....LONG SAULT DAM
```

```
NUMBER OF ITERATIONS=    BSDH,SDQ=      .20 *** *****
------------------- TIME IN   HRS =   0.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 241.17-------------------
------------------- TIME IN   HRS =   0.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 240.78-------------------
------------------- TIME IN   HRS =   1.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 240.87-------------------
------------------- TIME IN   HRS =   2.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 241.00-------------------
------------------- TIME IN   HRS =   3.00 LAKE ONTARIO = 245.11 LAKE ST LAWRENCE = 241.10-------------------
------------------- TIME IN   HRS =   4.00 LAKE ONTARIO = 245.03 LAKE ST LAWRENCE = 241.20-------------------
------------------- TIME IN   HRS =   5.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 241.30-------------------
------------------- TIME IN   HRS =   6.00 LAKE ONTARIO = 245.00 LAKE ST LAWRENCE = 241.38-------------------
------------------- TIME IN   HRS =   7.00 LAKE ONTARIO = 245.00 LAKE ST LAWRENCE = 241.45-------------------
------------------- TIME IN   HRS =   8.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 241.50-------------------
------------------- TIME IN   HRS =   9.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 241.49-------------------
------------------- TIME IN   HRS =  10.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 241.41-------------------
------------------- TIME IN   HRS =  11.00 LAKE ONTARIO = 245.01 LAKE ST LAWRENCE = 241.31-------------------
------------------- TIME IN   HRS =  12.00 LAKE ONTARIO = 245.01 LAKE ST LAWRENCE = 241.21-------------------
------------------- TIME IN   HRS =  13.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 241.10-------------------
------------------- TIME IN   HRS =  14.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 241.00-------------------
------------------- TIME IN   HRS =  15.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 240.91-------------------
------------------- TIME IN   HRS =  16.00 LAKE ONTARIO = 245.02 LAKE ST LAWRENCE = 240.83-------------------
------------------- TIME IN   HRS =  17.00 LAKE ONTARIO = 245.01 LAKE ST LAWRENCE = 240.76-------------------
------------------- TIME IN   HRS =  18.00 LAKE ONTARIO = 245.05 LAKE ST LAWRENCE = 240.69-------------------
------------------- TIME IN   HRS =  19.00 LAKE ONTARIO = 245.01 LAKE ST LAWRENCE = 240.64-------------------
------------------- TIME IN   HRS =  20.00 LAKE ONTARIO = 245.14 LAKE ST LAWRENCE = 240.57-------------------
------------------- TIME IN   HRS =  21.00 LAKE ONTARIO = 245.00 LAKE ST LAWRENCE = 240.51-------------------
------------------- TIME IN   HRS =  22.00 LAKE ONTARIO = 245.05 LAKE ST LAWRENCE = 240.49-------------------
------------------- TIME IN   HRS =  23.00 LAKE ONTARIO = 245.02 LAKE ST LAWRENCE = 240.53-------------------
------------------- TIME IN   HRS =  24.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 240.61-------------------
------------------- TIME IN   HRS =  25.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 240.74-------------------
------------------- TIME IN   HRS =  26.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 240.87-------------------
------------------- TIME IN   HRS =  27.00 LAKE ONTARIO = 245.05 LAKE ST LAWRENCE = 240.99-------------------
------------------- TIME IN   HRS = 28.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 241.09-------------------
```

```
------------------- TIME IN   HRS =  29.00 LAKE ONTARIO = 245.12 LAKE ST LAWRENCE = 241.20--------------------
------------------- TIME IN   HRS =  30.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 241.29--------------------
------------------- TIME IN   HRS =  31.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 241.38--------------------
------------------- TIME IN   HRS =  32.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 241.43--------------------
------------------- TIME IN   HRS =  33.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 241.43--------------------
------------------- TIME IN   HRS =  34.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 241.36--------------------
------------------- TIME IN   HRS =  35.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 241.27--------------------
------------------- TIME IN   HRS =  36.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 241.18--------------------
------------------- TIME IN   HRS =  37.00 LAKE ONTARIO = 245.02 LAKE ST LAWRENCE = 241.07--------------------
------------------- TIME IN   HRS =  38.00 LAKE ONTARIO = 245.13 LAKE ST LAWRENCE = 240.98--------------------
------------------- TIME IN   HRS =  39.00 LAKE ONTARIO = 245.11 LAKE ST LAWRENCE = 240.95--------------------
------------------- TIME IN   HRS =  40.00 LAKE ONTARIO = 245.15 LAKE ST LAWRENCE = 240.89--------------------
------------------- TIME IN   HRS =  41.00 LAKE ONTARIO = 245.12 LAKE ST LAWRENCE = 240.79--------------------
------------------- TIME IN   HRS =  42.00 LAKE ONTARIO = 245.16 LAKE ST LAWRENCE = 240.73--------------------
------------------- TIME IN   HRS =  43.00 LAKE ONTARIO = 245.13 LAKE ST LAWRENCE = 240.68--------------------
------------------- TIME IN   HRS =  44.00 LAKE ONTARIO = 245.12 LAKE ST LAWRENCE = 240.62--------------------
------------------- TIME IN   HRS =  45.00 LAKE ONTARIO = 245.14 LAKE ST LAWRENCE = 240.57--------------------
------------------- TIME IN   HRS =  46.00 LAKE ONTARIO = 245.10 LAKE ST LAWRENCE = 240.55--------------------
------------------- TIME IN   HRS =  47.00 LAKE ONTARIO = 245.09 LAKE ST LAWRENCE = 240.58--------------------
------------------- TIME IN   HRS =  48.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 240.66--------------------
------------------- TIME IN   HRS =  49.00 LAKE ONTARIO = 245.10 LAKE ST LAWRENCE = 240.80--------------------
------------------- TIME IN   HRS =  50.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 240.93--------------------
------------------- TIME IN   HRS =  51.00 LAKE ONTARIO = 245.05 LAKE ST LAWRENCE = 241.04--------------------
------------------- TIME IN   HRS =  52.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 241.15--------------------
------------------- TIME IN   HRS =  53.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 241.25--------------------
------------------- TIME IN   HRS =  54.00 LAKE ONTARIO = 245.00 LAKE ST LAWRENCE = 241.33--------------------
------------------- TIME IN   HRS =  55.00 LAKE ONTARIO = 244.99 LAKE ST LAWRENCE = 241.41--------------------
------------------- TIME IN   HRS =  56.00 LAKE ONTARIO = 244.94 LAKE ST LAWRENCE = 241.45--------------------
------------------- TIME IN   HRS =  57.00 LAKE ONTARIO = 244.99 LAKE ST LAWRENCE = 241.44--------------------
------------------- TIME IN   HRS =  58.00 LAKE ONTARIO = 245.01 LAKE ST LAWRENCE = 241.36--------------------
------------------- TIME IN   HRS =  59.00 LAKE ONTARIO = 245.03 LAKE ST LAWRENCE = 241.26--------------------
------------------- TIME IN   HRS =  60.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 241.14--------------------
------------------- TIME IN   HRS =  61.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 241.03--------------------
```

------------------- TIME IN HRS = 62.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 240.95--------------------

------------------- TIME IN HRS = 63.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 240.87--------------------

------------------- TIME IN HRS = 64.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 240.80--------------------

------------------- TIME IN HRS = 65.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 240.73--------------------

------------------- TIME IN HRS = 66.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 240.67--------------------

------------------- TIME IN HRS = 67.00 LAKE ONTARIO = 245.07 LAKE ST LAWRENCE = 240.61--------------------

------------------- TIME IN HRS = 68.00 LAKE ONTARIO = 245.00 LAKE ST LAWRENCE = 240.56--------------------

------------------- TIME IN HRS = 69.00 LAKE ONTARIO = 245.00 LAKE ST LAWRENCE = 240.51--------------------

------------------- TIME IN HRS = 70.00 LAKE ONTARIO = 245.01 LAKE ST LAWRENCE = 240.49--------------------

------------------- TIME IN HRS = 71.00 LAKE ONTARIO = 244.99 LAKE ST LAWRENCE = 240.51--------------------

------------------- TIME IN HRS = 72.00 LAKE ONTARIO = 244.90 LAKE ST LAWRENCE = 240.59--------------------

------------------- TIME IN HRS = 73.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 240.72--------------------

------------------- TIME IN HRS = 74.00 LAKE ONTARIO = 244.99 LAKE ST LAWRENCE = 240.84--------------------

------------------- TIME IN HRS = 75.00 LAKE ONTARIO = 244.95 LAKE ST LAWRENCE = 240.94--------------------

------------------- TIME IN HRS = 76.00 LAKE ONTARIO = 244.98 LAKE ST LAWRENCE = 241.04--------------------

------------------- TIME IN HRS = 77.00 LAKE ONTARIO = 244.93 LAKE ST LAWRENCE = 241.13--------------------

------------------- TIME IN HRS = 78.00 LAKE ONTARIO = 244.96 LAKE ST LAWRENCE = 241.21--------------------

------------------- TIME IN HRS = 79.00 LAKE ONTARIO = 244.99 LAKE ST LAWRENCE = 241.29--------------------

------------------- TIME IN HRS = 80.00 LAKE ONTARIO = 245.08 LAKE ST LAWRENCE = 241.34--------------------

------------------- TIME IN HRS = 81.00 LAKE ONTARIO = 245.18 LAKE ST LAWRENCE = 241.33--------------------

------------------- TIME IN HRS = 82.00 LAKE ONTARIO = 245.26 LAKE ST LAWRENCE = 241.25--------------------

------------------- TIME IN HRS = 83.00 LAKE ONTARIO = 245.21 LAKE ST LAWRENCE = 241.19--------------------

------------------- TIME IN HRS = 84.00 LAKE ONTARIO = 245.19 LAKE ST LAWRENCE = 241.12--------------------

------------------- TIME IN HRS = 85.00 LAKE ONTARIO = 245.11 LAKE ST LAWRENCE = 241.05--------------------

------------------- TIME IN HRS = 86.00 LAKE ONTARIO = 245.05 LAKE ST LAWRENCE = 241.00--------------------

------------------- TIME IN HRS = 87.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 240.94--------------------

------------------- TIME IN HRS = 88.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 240.87--------------------

------------------- TIME IN HRS = 89.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 240.79--------------------

------------------- TIME IN HRS = 90.00 LAKE ONTARIO = 245.06 LAKE ST LAWRENCE = 240.72--------------------

------------------- TIME IN HRS = 91.00 LAKE ONTARIO = 245.00 LAKE ST LAWRENCE = 240.66--------------------

------------------- TIME IN HRS = 92.00 LAKE ONTARIO = 245.04 LAKE ST LAWRENCE = 240.60--------------------

------------------- TIME IN HRS = 93.00 LAKE ONTARIO = 245.10 LAKE ST LAWRENCE = 240.54--------------------

------------------- TIME IN HRS = 94.00 LAKE ONTARIO = 245.13 LAKE ST LAWRENCE = 240.51--------------------

------------------- TIME IN HRS = 95.00 LAKE ONTARIO = 245.10 LAKE ST LAWRENCE = 240.53-------------------

------------------- TIME IN HRS = 96.00 LAKE ONTARIO = 245.03 LAKE ST LAWRENCE = 240.60-------------------

REACH:	1		2		3		4		5		6		7		8		9		10	
HRS	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
0.	113.	245.07	146.	245.07	109.	245.06	5.	245.06	109.	245.06	-19.	245.06	165	[illegible]	94.	245.06	38.	245.04	127.	245.04
1.	116.	245.08	148.	245.08	110.	245.07	5.	245.07	110.	245.07	-19 95	245.06	166.	245.06		245.06	38.	245.04	127.	245.04
2.	115.	245.08	147.	245.08	110.	245.07	5.	245.07	110.	245.07	-19 95	245.07	166.	245.07		245.07	38.	245.05	128.	245.05
3.	121.	245.11	154.	245.11	113.	245.10	3.	245.10	113.	245.09	-19.	245.09	168.	245.09	96.	245.09	39.	245.07	129.	245.07
4.	97.	245.03	130.	245.03	100.	245.05		245.05	102.	245.06	-20.	245.06	160.	245.06	91.	245.06	37.	245.05	124.	245.05
5.	110.	245.07	141.	245.07	102.	245.05	3.	245.05	102.	245.04	-20 88	245.04	156.	245.04		245.04	36.	245.02	121.	245.02
6.	94.	245.00	125.	245.00	96.	245.01		245.01	98.	245.02	-19.	245.02	153.	245.02	86.	245.02	35.	245.00	118.	245.00
7.	98.	245.00	129.	245.00	94.	244.99	5.	244.99	95.	244.99	-19.	244.98	147.	244.98	83.	244.99	34.	244.97	115.	244.97
8.	113.	245.04	143.	245.04	105.	245.02		245.02	104.	245.01	-17.	245.00	155.	245.00	87.	245.00	35.	244.98	118.	244.98
9.	117.	245.06	147.	245.06	110.	245.05	5.	245.05	109.	245.05	-16.	245.04	161.	245.04	92.	245.05	37.	245.02	122.	245.02
10.	113.	245.07	144.	245.07	107.	245.07	6.		107.	245.07	-18.	245.06	160.	245.06	92.	245.07	37.	245.05	123.	245.05
11.	92.	245.01	123.	245.01	94.	245.02	3.	[illegible]	96.	245.03	-19.	245.03	150.	245.03	86.	245.04	35.	245.02	117.	245.02
12.	95.	245.01	125.	245.01	92.	245.00		245.00	92.	245.00	-19.	244.99	144.	244.99	81.	245.00	33.	244.98	113.	244.98
13.	109.	245.04	139.	245.04	102.	245.02	5.	245.02	101.	245.01	-17 86	245.01	152.	245.01		245.00	35.	244.99	116.	244.99
14.	116.	245.06	146.	245.06	109.	245.05		245.05	108.	245.04	-16.	245.04	160.	245.04	92.	245.04	37.	245.02	122.	245.02
15.	108.	245.04	140.	245.04	105.	245.04	4.	245.04	105.	245.04	-18.	245.04	160.	245.04	93.	245.04	37.	245.02	124.	245.02
16.	103.	245.02	135.	245.02	100.	245.02	4.	245.02	101.	245.02	-19.	245.01	157.	245.01	90.	245.02	36.	245.00	122.	245.00
17.	105.	245.01	136.	245.01	101.	245.00		245.00	102.	245.00	-19.	244.99	156.	244.99	89.	245.00	36.	244.98	121.	244.98
18.	119.	245.05	151.	245.05	111.	245.03	6.	245.03	110.	245.02	-17.	245.01	163.	245.01	94.	245.01	37.	244.99	125.	244.99
19.	108.	245.01	141.	245.01	107.	245.02	5.	245.02	108.	245.02	-1[illegible] 95	245.01	164.	245.01		245.02	38.	245.00	126.	245.00
20.	142.	245.14	174.	245.14	124.	245.10	7.	245.10	121.	245.07	-17 01	245.07	175.	245.07		245.07	40.	245.04	132.	245.04
21.	98.	245.00	132.	245.00	106.	245.04	4.	245.04	108.	245.06	-19.	245.06	169.	245.06	98.	245.07	39.	245.05	131.	245.05
22.	111.	245.05	145.	245.05	102.	245.02	4.	245.02	103.	245.02	-21.	245.01	160.	245.01	91.	245.02	37.	245.00	125.	245.00
23.	109.	245.02	141.	245.02	107.	245.02	5.	245.02	107.	245.01	-19.	245.01	164.	245.01	93.	245.01	38.	244.99	126.	244.99
24.	125.	245.07	158.	245.07	115.	245.05		245.05	114.	245.04	-1[illegible] 97	245.03	169.	245.03		245.03	39.	245.01	129.	245.01
25.	120.	245.06	154.	245.06	116.	245.06	6.	245.06	115.	245.06	-19 [illegible]	245.05	173.	245.05		245.06	40.	245.03	133.	245.03
26.	122.	245.08	155.	245.08	114.	245.07	5.	245.07	114.	245.07	-19.	245.06	172.	245.06	99.	245.07	40.	245.04	132.	245.04
27.	110.	245.05	144.	245.05	108.	245.05	4.	245.05	109.	245.06	-20.	245.05	168.	245.05	96.	245.06	39.	245.04	129.	245.04
28.	107.	245.04	140.	245.04	104.	245.03	4.	245.03	104.	245.04	-20.	245.03	161.	245.03	91.	245.04	37.	245.02	125.	245.02
29.	128.	245.12	160.	245.12	116.	245.09	4.	245.09	114.	245.07	-18.	245.07	168.	245.07	95.	245.07	38.	245.05	127.	245.05
30.	102.	245.04	134.	245.04	104.	245.06		245.06	106.	245.08	-19.	245.07	163.	245.07	93.	245.08	38.	245.06	126.	245.06
31.	110.	245.08	141.	245.08	102.	245.06	4.	245.06	102.	245.06	-20.	245.05	156.	245.05	88.	245.06	36.	245.04	121.	245.04
32.	105.	245.06	136.	245.06	103.	245.06	4.	245.06	103.	245.06	-18.	245.06		157.	88.	245.06.06	6.	245.04	120.	245.04
33.	108.	245.07	138.	245.07	102.	245.06	4.	245.06	102.	245.06	-18.	245.05	155.	245.05	88.	245.06	6.	245.04	119.	245.04
34.	109.	245.08	140.	245.08	104.	245.07	4.	245.07	104.	245.07	-18.	245.07	156.	245.07	89.	245.07	36.	245.05	120.	245.05
35.	102.	245.06	133.	245.06	100.	245.06	4.	245.06	100.	245.06	-18.	245.06	154.	245.06	88.	245.06	36.	245.05	119.	245.05
36.	98.	245.04	128.	245.04	96.	245.04	3.	245.04	97.	245.04	-19.	245.03	150.	245.03	85.	245.04	35.	245.02	116.	245.02
37.	97.	245.02	127.	245.02	95.	245.01	7.	245.01	96.	245.01	-18.	245.01	148.	245.01	84.	245.01	34.	245.00	115.	245.00
38.	131.	245.13	161.	245.13	116.	245.09		245.09	113.	245.07	-16.	245.06	163.	245.06	94.	245.06	37.	245.04	123.	245.04
39.	121.	245.11	153.	245.11	117.	245.12	6.	245.12	117.	245.12	-1[illegible]	245.[illegible]11	171.	245.11	100.	245.12	39.	245.09	130.	245.09
40.	123.	245.15	156.	245.15	114.	245.14	5.		114.	245.14	-19.	245.13	170.	245.13	99.	245.14	39.	245.11	131.	245.11
41.	110.	245.12	143.	245.12	108.	245.13		245.13	109.	245.13	-19.	245.13	167.	245.13	96.	245.13	38.	245.11	128.	245.11
42.	120.	245.16	152.	245.16	111.	245.14	5.	245.14	110.	245.13	-19.	245.13	166.	245.13	95.	245.13	38.	245.11	127.	245.11
43.	110.	245.13	143.	245.13	108.	245.13	4.	245.13	109.	245.13	-19.	245.13	165.	245.13	95.	245.14	38.	245.12	127.	245.12
44.	108.	245.12	140.	245.12	104.	245.11		245.11	105.	245.11	-20.	245.11	162.	245.11	93.	245.11	37.	245.10	125.	245.10
45.	116.	245.14	149.	245.14	110.	245.12	5.	245.12	109.	245.11	-19.	245.11	165.	245.11	94.	245.11	38.	245.09	127.	245.09
46.	108.	245.10	141.	245.10	107.	245.10	4.	245.10	108.	245.10	-19.	245.10	165.	245.10	95.	245.10	38.	245.08	128.	245.08
47.	109.	245.09	142.	245.09	105.	245.08		245.08	105.	245.08	-20.	245.07	163.	245.07	93.	245.08	38.	245.06	127.	245.06
48.	108.	245.07	141.	245.07	106.	245.06	4.	245.06	106.	245.06	-19.	245.06	163.	245.06	93.	245.06	38.	245.04	126.	245.04
49.	121.	245.10	154.	245.10	113.	245.08	5.	245.08	112.	245.07	-19 96	245.07	168.	245.07		245.07	39.	245.05	129.	245.05
50.	115.	245.08	149.	245.08	112.	245.08		245.08	112.	245.08	-19.	245.08	170.	245.08	98.	245.08	39.	245.06	130.	245.06
51.	106.	245.05	139.	245.05	104.	245.05	4.	245.05	105.	245.06	-20.	245.05	163.	245.05	93.	245.06	38.	245.04	127.	245.04
52.	105.	245.04	138.	245.04	102.	245.03	4.	245.03	103.	245.03	-20.	245.03	159.	245.03	90.	245.03	37.	245.01	123.	245.01

53.	116.	245.07	147.	245.07	108.	245.05	5.	245.05	108.	245.04	-18.	245.04	161.	245.04	91.	245.04	37.	245.02	123.	245.02
54.	96.	245.00	128.	245.00	98.	245.01	3.	245.01	100.	245.02	-19.	245.02	156.	245.02	88.	245.03	36.	245.01	121.	245.01
55.	96.	244.99	127.	244.99	93.	244.98	3.	244.98	94.	244.98	-20.	244.98	148.	244.98	83.	244.98	34.	244.97	116.	244.97
56.	89.	244.94	119.	244.94	90.	244.94	3.	244.94	91.	244.94	-19.	244.94	144.	244.94	80.	244.94	33.	244.93	112.	244.93
57.	109.	244.99	139.	244.99	101.	244.96	4.	244.96	100.	244.95	-17.	244.95	149.	244.95	84.	244.95	34.	244.93	114.	244.93
58.	115.	245.01	146.	245.01	109.	245.00	5.	245.00	108.	244.99	-16.	244.99	159.	244.99	91.	244.99	36.	244.97	120.	244.97
59.	115.	245.03	146.	245.03	109.	245.02	5.	245.02	108.	245.02	-17.	245.02	161.	245.02	93.	245.02	37.	245.00	123.	245.00
60.	117.	245.06	148.	245.06	109.	245.05	5.	245.05	109.	245.05	-17.	245.04	162.	245.04	93.	245.05	37.	245.03	124.	245.03
61.	106.	245.04	138.	245.04	104.	245.04	4.	245.04	104.	245.05	-18.	245.04	159.	245.04	91.	245.05	37.	245.03	122.	245.03
62.	105.	245.04	136.	245.04	101.	245.03	4.	245.03	101.	245.03	-19.	245.03	155.	245.03	89.	245.03	36.	245.01	120.	245.01
63.	115.	245.07	146.	245.07	107.	245.05	5.	245.05	107.	245.04	-18.	245.04	160.	245.04	91.	245.04	37.	245.02	122.	245.02
64.	117.	245.08	149.	245.08	111.	245.07	5.	245.07	110.	245.07	-18.	245.06	165.	245.06	95.	245.07	38.	245.04	126.	245.04
65.	115.	245.08	147.	245.08	110.	245.08	5.	245.08	110.	245.07	-19.	245.07	166.	245.07	96.	245.07	38.	245.05	127.	245.05
66.	111.	245.07	143.	245.07	107.	245.07	5.	245.07	107.	245.07	-19.	245.06	164.	245.06	94.	245.07	38.	245.05	127.	245.05
67.	112.	245.07	144.	245.07	107.	245.06	5.	245.06	107.	245.06	-19.	245.05	164.	245.05	94.	245.06	38.	245.04	126.	245.04
68.	96.	245.00	128.	245.00	98.	245.01	3.	245.01	100.	245.02	-20.	245.01	158.	245.01	90.	245.02	37.	245.00	123.	245.00
69.	103.	245.00	135.	245.00	99.	244.98	4.	244.98	100.	244.98	-20.	244.97	155.	244.97	88.	244.98	36.	244.96	121.	244.96
70.	114.	245.01	146.	245.01	108.	245.00	5.	245.00	108.	244.98	-18.	244.98	163.	244.98	93.	244.98	37.	244.96	125.	244.96
71.	112.	244.99	145.	244.99	109.	244.99	5.	244.99	109.	244.99	-19.	244.98	166.	244.98	95.	244.99	38.	244.96	128.	244.96
72.	91.	244.90	124.	244.90	95.	244.91	3.	244.91	97.	244.93	-21.	244.92	157.	244.92	90.	244.93	36.	244.91	123.	244.91
73.	121.	244.98	153.	244.98	109.	244.94	5.	244.94	107.	244.92	-19.	244.92	162.	244.92	92.	244.92	37.	244.90	124.	244.90
74.	126.	244.99	159.	244.99	120.	244.98	7.	244.98	118.	244.97	-17.	244.97	174.	244.97	100.	244.97	40.	244.95	131.	244.95
75.	110.	244.95	144.	244.95	108.	244.96	4.	244.96	109.	244.97	-20.	244.96	168.	244.96	97.	244.97	39.	244.95	130.	244.95
76.	114.	244.98	148.	244.98	107.	244.97	5.	244.97	107.	244.96	-20.	244.96	164.	244.96	93.	244.96	38.	244.94	126.	244.94
77.	101.	244.93	133.	244.93	101.	244.94	4.	244.94	102.	244.94	-19.	244.94	158.	244.94	89.	244.94	37.	244.93	122.	244.93
78.	110.	244.96	141.	244.96	103.	244.94	4.	244.94	102.	244.94	-19.	244.93	156.	244.93	88.	244.94	36.	244.92	120.	244.92
79.	117.	244.99	148.	244.99	110.	244.98	5.	244.98	109.	244.97	-17.	244.97	162.	244.97	91.	244.97	37.	244.95	123.	244.95
80.	135.	245.08	167.	245.08	122.	245.06	7.	245.06	119.	245.04	-16.	245.04	171.	245.04	98.	245.04	39.	245.01	129.	245.01
81.	147.	245.18	180.	245.18	132.	245.16	8.	245.16	129.	245.15	-16.	245.14	183.	245.14	106.	245.15	42.	245.12	136.	245.12
82.	146.	245.26	180.	245.26	133.	245.25	8.	245.25	131.	245.25	-17.	245.24	187.	245.24	109.	245.25	43.	245.22	140.	245.22
83.	111.	245.21	145.	245.21	111.	245.23	4.	245.23	112.	245.25	-20.	245.25	172.	245.25	99.	245.26	40.	245.24	133.	245.24
84.	97.	245.19	129.	245.19	95.	245.19	2.	245.19	97.	245.20	-22.	245.20	154.	245.20	87.	245.20	36.	245.19	121.	245.19
85.	80.	245.11	111.	245.11	85.	245.12	1.	245.12	88.	245.12	-21.	245.12	143.	245.12	78.	245.13	33.	245.12	113.	245.12
86.	78.	245.05	108.	245.05	81.	245.05	1.	245.05	83.	245.05	-20.	245.04	136.	245.04	75.	245.05	32.	245.03	108.	245.03
87.	99.	245.06	128.	245.06	94.	245.04	3.	245.04	94.	245.02	-18.	245.02	145.	245.02	81.	245.02	33.	245.00	112.	245.00
88.	111.	245.06	142.	245.06	106.	245.05	5.	245.05	106.	245.03	-17.	245.03	157.	245.03	91.	245.03	36.	245.01	120.	245.01
89.	110.	245.04	142.	245.04	106.	245.04	5.	245.04	107.	245.04	-18.	245.03	162.	245.03	94.	245.03	37.	245.01	125.	245.01
90.	117.	245.06	149.	245.06	110.	245.05	5.	245.05	110.	245.04	-18.	245.03	165.	245.03	96.	245.04	38.	245.02	127.	245.02
91.	102.	245.00	134.	245.00	103.	245.01	4.	245.01	104.	245.02	-19.	245.01	161.	245.01	93.	245.02	37.	245.00	125.	245.00
92.	115.	245.04	148.	245.04	107.	245.02	5.	245.02	107.	245.01	-19.	245.00	162.	245.00	92.	245.01	37.	244.99	125.	244.99
93.	132.	245.10	165.	245.10	122.	245.08	7.	245.08	119.	245.06	-17.	245.06	174.	245.06	100.	245.06	40.	245.03	131.	245.03
94.	133.	245.13	167.	245.13	124.	245.12	7.	245.12	123.	245.12	-18.	245.11	180.	245.11	105.	245.12	41.	245.09	137.	245.09
95.	115.	245.10	150.	245.10	113.	245.11	5.	245.11	114.	245.12	-20.	245.11	174.	245.11	101.	245.12	40.	245.10	135.	245.10
96.	95.	245.03	129.	245.03	97.	245.04	3.	245.04	100.	245.05	-22.	245.05	160.	245.05	91.	245.05	37.	245.04	126.	245.04

REACH:	11		12		13		14		15		16		17		18		19		20	
HRS	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
0.	132.	245.02	127.	245.02	259.	244.96	259.	244.72	259.	244.52	259.	244.30	199.	243.80	60.	243.80	259.	242.77	259.	242.15
1.	133.	245.02	127.	245.03	260.	244.97	259.	244.72	259.	244.52	259.	244.30	199.	243.80	60.	243.80	259.	242.78	258.	242.16
2.	133.	245.03	128.	245.04	260.	244.97	259.	244.73	259.	244.53	258.	244.31	198.	243.82	59.	243.82	257.	242.82	256.	242.22
3.	134.	245.04	128.	245.05	261.	244.99	258.	244.75	258.	244.55	256.	244.34	196.	243.85	59.	243.85	254.	242.88	253.	242.30
4.	130.	245.03	125.	245.03	256.	244.99	256.	244.76	255.	244.57	253.	244.37	194.	243.90	58.	243.90	251.	242.95	250.	242.38
5.	125.	245.00	121.	245.01	248.	244.97	251.	244.76	251.	244.58	250.	244.38	192.	243.93	58.	243.93	249.	243.00	248.	242.45
6.	122.	244.99	118.	244.99	242.	244.95	245.	244.74	245.	244.57	246.	244.38	190.	243.94	57.	243.94	246.	243.04	245.	242.50
7.	119.	244.96	115.	244.96	237.	244.92	241.	244.72	241.	244.55	243.	244.37	187.	243.94	56.	243.94	243.	243.07	242.	242.55
8.	121.	244.96	117.	244.97	238.	244.91	238.	244.71	239.	244.54	240.	244.35	184.	243.93	55.	243.93	240.	243.09	239.	242.58
9.	127.	245.00	121.	245.01	245.	244.94	240.	244.72	239.	244.55	238.	244.36	183.	243.94	55.	243.94	238.	243.10	238.	242.59
10.	128.	245.03	122.	245.03	248.	244.98	243.	244.76	242.	244.58	239.	244.38	184.	243.95	55.	243.95	239.	243.10	239.	242.58
11.	123.	245.01	118.	245.01	243.	244.98	243.	244.77	243.	244.60	242.	244.40	186.	243.96	56.	243.96	242.	243.08	243.	242.54
12.	117.	244.97	113.	244.97	234.	244.94	241.	244.75	241.	244.57	244.	244.38	188.	243.94	56.	243.94	245.	243.03	246.	242.48
13.	120.	244.96	115.	244.97	235.	244.91	240.	244.70	240.	244.53	245.	244.33	189.	243.89	57.	243.89	247.	242.97	248.	242.40
14.	127.	244.99	121.	245.00	246.	244.93	244.	244.69	244.	244.51	247.	244.29	190.	243.83	57.	243.83	249.	242.90	250.	242.32
15.	130.	245.00	124.	245.01	253.	244.95	251.	244.70	251.	244.51	250.	244.28	193.	243.81	58.	243.81	251.	242.84	252.	242.25
16.	128.	244.98	123.	244.99	252.	244.94	254.	244.71	254.	244.51	254.	244.29	195.	243.80	58.	243.80	254.	242.81	255.	242.20
17.	126.	244.96	121.	244.97	250.	244.91	254.	244.69	254.	244.49	256.	244.28	197.	243.78	59.	243.78	256.	242.78	257.	242.16
18.	130.	244.97	124.	244.98	253.	244.91	254.	244.67	254.	244.47	256.	244.25	198.	243.76	59.	243.76	258.	242.74	259.	242.11
19.	132.	244.98	126.	244.98	258.	244.92	257.	244.67	257.	244.46	258.	244.23	199.	243.73	59.	243.73	259.	242.70	260.	242.06
20.	138.	245.02	131.	245.02	266.	244.95	261.	244.68	261.	244.47	260.	244.23	200.	243.72	60.	243.72	261.	242.67	261.	242.02
21.	138.	245.03	131.	245.03	269.	244.97	265.	244.71	265.	244.49	263.	244.25	202.	243.73	61.	243.73	263.	242.66	263.	242.00
22.	131.	244.98	126.	244.99	261.	244.94	265.	244.71	265.	244.50	265.	244.26	204.	243.73	61.	243.73	265.	242.65	265.	241.97
23.	130.	244.97	126.	244.98	257.	244.92	262.	244.68	262.	244.47	265.	244.25	204.	243.72	61.	243.72	265.	242.63	266.	241.96
24.	135.	244.99	129.	244.99	262.	244.92	262.	244.66	262.	244.45	263.	244.22	203.	243.70	61.	243.70	264.	242.64	264.	241.98
25.	138.	245.01	132.	245.02	268.	244.94	264.	244.68	264.	244.47	262.	244.23	202.	243.72	60.	243.72	261.	242.67	261.	242.03
26.	138.	245.02	132.	245.03	269.	244.97	265.	244.71	265.	244.50	261.	244.27	200.	243.76	60.	243.76	259.	242.74	258.	242.12
27.	135.	245.02	130.	245.03	265.	244.97	263.	244.73	262.	244.53	259.	244.31	199.	243.82	60.	243.82	257.	242.82	255.	242.22
28.	130.	245.00	125.	245.01	256.	244.96	257.	244.74	257.	244.55	256.	244.34	196.	243.86	59.	243.86	254.	242.89	253.	242.31
29.	131.	245.03	126.	245.03	255.	244.97	253.	244.74	253.	244.56	252.	244.36	194.	243.89	58.	243.89	251.	242.95	250.	242.38
30.	131.	245.04	126.	245.05	255.	244.99	252.	244.76	251.	244.57	250.	244.37	192.	243.91	57.	243.91	249.	242.99	248.	242.44
31.	126.	245.02	122.	245.03	249.	244.99	250.	244.77	249.	244.59	248.	244.39	190.	243.94	57.	243.94	246.	243.04	245.	242.50
32.	124.	245.02	120.	245.03	244.	244.98	246.	244.77	246.	244.60	245.	244.41	188.	243.97	57.	243.97	244.	243.08	244.	242.55
33.	124.	245.02	119.	245.03	243.	244.98	243.	244.77	243.	244.60	243.	244.41	187.	243.98	56.	243.98	243.	243.10	242.	242.58
34.	124.	245.03	119.	245.04	243.	244.98	242.	244.77	242.	244.60	242.	244.40	186.	243.97	56.	243.97	242.	243.10	243.	242.56
35.	123.	245.03	119.	245.03	243.	244.98	243.	244.77	243.	244.59	243.	244.39	187.	243.96	56.	243.96	244.	243.06	245.	242.52
36.	121.	245.01	117.	245.01	240.	244.97	243.	244.76	244.	244.58	245.	244.38	189.	243.93	57.	243.93	246.	243.02	247.	242.45
37.	120.	244.98	116.	244.98	238.	244.94	243.	244.73	244.	244.55	247.	244.35	190.	243.89	57.	243.89	248.	242.96	250.	242.39
38.	127.	245.01	122.	245.02	246.	244.94	246.	244.71	246.	244.52	249.	244.31	192.	243.85	57.	243.85	250.	242.90	251.	242.31
39.	136.	245.07	129.	245.07	261.	244.99	253.	244.73	253.	244.53	252.	244.30	194.	243.83	58.	243.83	252.	242.85	253.	242.26
40.	138.	245.09	131.	245.10	267.	245.03	260.	244.78	260.	244.57	256.	244.33	196.	243.84	59.	243.84	255.	242.85	255.	242.24
41.	135.	245.09	129.	245.10	263.	245.04	262.	244.80	262.	244.60	259.	244.37	199.	243.87	60.	243.87	258.	242.85	258.	242.22
42.	133.	245.09	127.	245.10	260.	245.04	261.	244.80	261.	244.60	261.	244.38	201.	243.87	60.	243.87	261.	242.83	262.	242.18
43.	133.	245.09	127.	245.10	260.	245.04	261.	244.80	261.	244.59	262.	244.36	202.	243.85	60.	243.85	263.	242.79	264.	242.14
44.	131.	245.08	126.	245.08	259.	245.03	262.	244.78	262.	244.58	263.	244.34	203.	243.83	61.	243.83	264.	242.76	265.	242.10
45.	132.	245.07	127.	245.08	260.	245.01	262.	244.77	262.	244.56	264.	244.33	204.	243.80	61.	243.80	265.	242.73	266.	242.06
46.	134.	245.06	128.	245.07	262.	245.01	263.	244.75	264.	244.54	265.	244.31	204.	243.78	61.	243.78	266.	242.70	266.	242.03
47.	133.	245.04	127.	245.05	262.	244.99	264.	244.74	264.	244.53	265.	244.29	204.	243.77	61.	243.77	266.	242.68	266.	242.01
48.	132.	245.02	127.	245.03	260.	244.97	263.	244.72	264.	244.51	265.	244.28	204.	243.76	61.	243.76	265.	242.69	264.	242.03
49.	134.	245.02	128.	245.03	262.	244.96	262.	244.71	262.	244.51	263.	244.28	202.	243.77	60.	243.77	262.	242.72	261.	242.09
50.	136.	245.03	130.	245.04	265.	244.98	262.	244.72	262.	244.52	260.	244.30	200.	243.80	60.	243.80	259.	242.78	257.	242.17
51.	133.	245.02	127.	245.03	261.	244.98	260.	244.74	260.	244.54	257.	244.33	198.	243.84	59.	243.84	256.	242.85	254.	242.26
52.	128.	245.00	123.	245.00	253.	244.96	255.	244.74	255.	244.55	254.	244.35	195.	243.88	58.	243.88	253.	242.92	252.	242.34
53.	127.	245.00	123.	245.01	250.	244.95	250.	244.73	250.	244.55	250.	244.35	193.	243.90	58.	243.90	250.	242.97	249.	242.41
54.	126.	244.99	121.	245.00	248.	244.95	248.	244.73	247.	244.55	247.	244.36	190.	243.91	57.	243.91	246.	243.01	246.	242.46
55.	120.	244.95	117.	244.96	240.	244.92	244.	244.72	244.	244.55	244.	244.36	188.	243.92	56.	243.92	244.	243.04	243.	242.51
56.	116.	244.91	113.	244.92	232.	244.88	239.	244.69	239.	244.53	241.	244.35	185.	243.92	56.	243.92	241.	243.06	241.	242.55
57.	118.	244.91	114.	244.92	232.	244.86	235.	244.66	235.	244.50	238.	244.32	183.	243.91	55.	243.91	238.	243.06	238.	242.56
58.	124.	244.95	119.	244.95	240.	244.89	236.	244.67	236.	244.50	237.	244.30	183.	243.89	55.	243.89	238.	243.04	238.	242.53

REACH:	11		12		13		14		15		16		17		18		19		20	
HRS	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
59.	128.	244.98	122.	244.99	248.	244.93	242.	244.70	241.	244.52	240.	244.31	184.	243.88	55.	243.88	240.	243.01	241.	242.48
60.	129.	245.01	123.	245.01	250.	244.95	246.	244.73	246.	244.54	244.	244.33	188.	243.88	56.	243.88	244.	242.97	245.	242.41
61.	128.	245.01	122.	245.02	250.	244.96	249.	244.74	249.	244.55	248.	244.34	191.	243.88	57.	243.88	249.	242.93	249.	242.35
62.	126.	245.00	121.	245.00	248.	244.95	250.	244.73	250.	244.54	251.	244.33	193.	243.86	58.	243.86	252.	242.89	253.	242.29
63.	127.	245.00	122.	245.01	249.	244.95	251.	244.72	251.	244.53	253.	244.31	195.	243.83	58.	243.83	254.	242.84	255.	242.24
64.	131.	245.02	126.	245.03	255.	244.96	254.	244.71	254.	244.51	255.	244.29	196.	243.80	59.	243.80	256.	242.80	257.	242.19
65.	134.	245.03	127.	245.04	260.	244.97	258.	244.72	258.	244.52	257.	244.29	198.	243.79	59.	243.79	258.	242.77	258.	242.14
66.	133.	245.03	127.	245.03	260.	244.97	260.	244.73	260.	244.52	260.	244.29	200.	243.78	60.	243.78	260.	242.75	261.	242.10
67.	132.	245.02	126.	245.02	259.	244.96	261.	244.72	261.	244.52	261.	244.29	201.	243.77	60.	243.77	262.	242.72	262.	242.07
68.	129.	244.98	124.	244.99	256.	244.94	260.	244.70	260.	244.50	262.	244.27	202.	243.75	60.	243.75	263.	242.69	264.	242.03
69.	126.	244.94	122.	244.95	251.	244.90	258.	244.67	259.	244.47	262.	244.24	202.	243.72	60.	243.72	263.	242.66	264.	241.99
70.	129.	244.93	124.	244.94	254.	244.88	258.	244.63	258.	244.43	262.	244.20	202.	243.68	60.	243.68	263.	242.62	264.	241.95
71.	133.	244.94	128.	244.95	261.	244.88	260.	244.62	260.	244.41	262.	244.18	202.	243.65	60.	243.65	263.	242.59	263.	241.93
72.	130.	244.90	125.	244.90	258.	244.85	262.	244.61	262.	244.40	262.	244.17	202.	243.65	60.	243.65	262.	242.59	261.	241.94
73.	129.	244.87	124.	244.88	255.	244.82	259.	244.59	259.	244.39	260.	244.17	200.	243.66	60.	243.66	260.	242.63	259.	242.00
74.	136.	244.92	130.	244.93	262.	244.85	258.	244.59	258.	244.39	257.	244.17	198.	243.68	59.	243.68	256.	242.68	255.	242.07
75.	136.	244.93	130.	244.94	265.	244.88	259.	244.63	259.	244.42	255.	244.20	196.	243.72	59.	243.72	253.	242.74	252.	242.15
76.	131.	244.92	126.	244.93	258.	244.88	257.	244.65	257.	244.46	253.	244.25	194.	243.77	58.	243.77	251.	242.81	250.	242.23
77.	127.	244.91	123.	244.92	251.	244.87	252.	244.66	252.	244.47	251.	244.27	193.	243.81	58.	243.81	249.	242.87	248.	242.30
78.	124.	244.90	120.	244.91	245.	244.86	247.	244.65	247.	244.47	247.	244.28	190.	243.82	57.	243.82	247.	242.91	246.	242.36
79.	126.	244.92	122.	244.93	246.	244.87	245.	244.65	245.	244.47	244.	244.28	188.	243.83	56.	243.83	244.	242.94	243.	242.41
80.	133.	244.99	127.	245.00	255.	244.92	246.	244.68	246.	244.50	243.	244.30	187.	243.86	56.	243.86	242.	242.98	241.	242.45
81.	141.	245.09	134.	245.10	267.	245.02	252.	244.76	251.	244.56	245.	244.35	187.	243.91	56.	243.91	242.	243.02	242.	242.49
82.	146.	245.19	138.	245.20	276.	245.13	258.	244.86	257.	244.66	249.	244.43	190.	243.98	57.	243.98	246.	243.06	246.	242.51
83.	139.	245.23	133.	245.23	271.	245.18	262.	244.94	260.	244.74	254.	244.52	194.	244.04	58.	244.04	252.	243.09	251.	242.50
84.	126.	245.18	122.	245.18	253.	245.16	258.	244.96	258.	244.76	257.	244.55	197.	244.07	59.	244.07	256.	243.09	256.	242.48
85.	116.	245.10	114.	245.11	237.	245.08	250.	244.89	251.	244.72	256.	244.52	198.	244.04	59.	244.04	258.	243.05	259.	242.44
86.	112.	245.02	110.	245.02	228.	244.99	243.	244.80	245.	244.63	253.	244.43	196.	243.96	59.	243.96	257.	242.97	258.	242.37
87.	116.	244.98	112.	244.98	231.	244.92	242.	244.71	243.	244.54	251.	244.33	195.	243.86	58.	243.86	255.	242.89	256.	242.29
88.	125.	244.98	120.	244.99	245.	244.91	246.	244.67	247.	244.48	251.	244.26	194.	243.79	58.	243.79	253.	242.82	255.	242.22
89.	131.	244.99	125.	245.00	256.	244.93	253.	244.67	253.	244.47	253.	244.24	195.	243.76	58.	243.76	254.	242.77	255.	242.16
90.	133.	244.99	127.	245.00	260.	244.94	258.	244.69	258.	244.48	257.	244.25	197.	243.76	59.	243.76	257.	242.74	257.	242.11
91.	131.	244.98	126.	244.99	258.	244.93	259.	244.69	259.	244.49	259.	244.26	199.	243.75	60.	243.75	259.	242.72	260.	242.08
92.	130.	244.97	125.	244.97	256.	244.92	259.	244.68	259.	244.48	260.	244.25	200.	243.74	60.	243.74	261.	242.69	261.	242.05
93.	136.	245.00	130.	245.01	263.	244.94	260.	244.67	260.	244.47	261.	244.24	201.	243.72	60.	243.72	262.	242.66	263.	242.01
94.	143.	245.06	136.	245.07	274.	244.99	266.	244.71	265.	244.49	264.	244.24	203.	243.72	61.	243.72	264.	242.64	264.	241.98
95.	142.	245.08	135.	245.08	276.	245.02	271.	244.75	270.	244.53	267.	244.28	205.	243.74	61.	243.74	266.	242.65	265.	241.97
96.	133.	245.03	128.	245.03	265.	244.99	269.	244.75	269.	244.54	268.	244.31	206.	243.77	62.	243.77	267.	242.68	266.	242.01

REACH:	21		22		23		24		25		26		27		28		29		30	
HRS	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H	Q	H
0.	142.	241.84	118.	241.84	118.	241.51	259.	241.51	93.	241.01	166.	241.01	93.	240.96	187.	240.93	73.	240.96	259.	240.88
1.	141.	241.86	117.	241.86	117.	241.54	257.	241.54	92.	241.06	162.	241.06	91.	241.02	181.	240.99	71.	241.02	251.	240.95
2.	139.	241.92	116.	241.92	115.	241.62	253.	241.62	89.	241.17	157.	241.17	87.	241.14	174.	241.11	68.	241.14	240.	241.07
3.	138.	242.02	114.	242.02	114.	241.72	250.	241.72	87.	241.29	155.	241.29	86.	241.25	173.	241.22	67.	241.25	238.	241.18
4.	136.	242.10	113.	242.10	113.	241.82	248.	241.82	87.	241.38	154.	241.38	86.	241.35	172.	241.32	67.	241.35	238.	241.28
5.	135.	242.18	112.	242.18	112.	241.90	246.	241.90	87.	241.48	153.	241.48	86.	241.44	171.	241.41	67.	241.44	236.	241.37
6.	134.	242.24	111.	242.24	111.	241.97	243.	241.97	86.	241.56	152.	241.56	85.	241.52	170.	241.49	66.	241.52	235.	241.45
7.	132.	242.29	110.	242.29	109.	242.03	241.	242.03	85.	241.63	151.	241.63	85.	241.59	169.	241.57	66.	241.59	234.	241.53
8.	130.	242.33	108.	242.33	108.	242.07	238.	242.07	85.	241.68	150.	241.68	84.	241.64	169.	241.62	65.	241.64	233.	241.58
9.	130.	242.35	108.	242.35	108.	242.09	237.	242.09	86.	241.68	152.	241.68	86.	241.64	172.	241.61	66.	241.64	238.	241.57
10.	131.	242.33	109.	242.33	109.	242.06	240.	242.06	88.	241.62	156.	241.62	88.	241.58	177.	241.55	68.	241.58	247.	241.50
11.	133.	242.27	111.	242.27	111.	241.99	245.	241.99	90.	241.53	160.	241.53	91.	241.49	182.	241.46	70.	241.49	254.	241.41
12.	135.	242.20	112.	242.20	113.	241.91	248.	241.91	92.	241.44	163.	241.44	92.	241.39	185.	241.36	71.	241.39	258.	241.31
13.	136.	242.12	113.	242.12	114.	241.82	251.	241.82	93.	241.34	165.	241.34	93.	241.29	188.	241.26	72.	241.29	262.	241.20
14.	137.	242.03	114.	242.03	114.	241.73	253.	241.72	93.	241.24	166.	241.24	94.	241.19	188.	241.16	73.	241.19	263.	241.10
15.	138.	241.95	115.	241.95	115.	241.65	254.	241.64	94.	241.15	166.	241.15	94.	241.10	189.	241.07	73.	241.10	263.	241.01
16.	139.	241.90	116.	241.90	116.	241.58	256.	241.58	94.	241.07	167.	241.07	94.	241.02	189.	240.99	73.	241.02	264.	240.94
17.	141.	241.85	117.	241.85	117.	241.52	259.	241.52	95.	241.00	168.	241.00	95.	240.95	191.	240.92	74.	240.95	266.	240.86
18.	142.	241.79	118.	241.79	118.	241.46	260.	241.46	95.	240.94	169.	240.94	95.	240.89	191.	240.85	74.	240.89	267.	240.80
19.	142.	241.74	118.	241.74	118.	241.41	261.	241.41	96.	240.88	169.	240.88	95.	240.83	192.	240.80	74.	240.83	267.	240.74
20.	143.	241.70	119.	241.70	119.	241.36	262.	241.36	96.	240.82	170.	240.82	96.	240.77	192.	240.74	75.	240.77	268.	240.68
21.	144.	241.67	120.	241.67	120.	241.32	264.	241.32	97.	240.77	171.	240.77	97.	240.72	194.	240.68	75.	240.72	270.	240.62
22.	145.	241.64	121.	241.64	121.	241.29	266.	241.28	97.	240.74	171.	240.74	96.	240.68	193.	240.65	75.	240.68	269.	240.60
23.	145.	241.63	120.	241.63	120.	241.28	266.	241.28	95.	240.75	169.	240.75	95.	240.70	190.	240.67	74.	240.70	263.	240.62
24.	144.	241.66	119.	241.66	119.	241.32	262.	241.32	93.	240.82	165.	240.82	92.	240.78	184.	240.75	72.	240.78	255.	240.70
25.	142.	241.72	118.	241.72	117.	241.40	258.	241.40	91.	240.93	160.	240.93	89.	240.89	179.	240.86	70.	240.89	246.	240.82
26.	140.	241.82	116.	241.82	116.	241.51	254.	241.51	89.	241.05	157.	241.05	87.	241.02	175.	240.99	68.	241.02	241.	240.95
27.	139.	241.93	115.	241.93	115.	241.63	252.	241.62	88.	241.18	156.	241.18	87.	241.14	174.	241.11	68.	241.14	239.	241.07
28.	138.	242.02	114.	242.02	114.	241.73	250.	241.72	88.	241.28	155.	241.28	87.	241.24	174.	241.22	68.	241.24	239.	241.17
29.	136.	242.10	113.	242.10	113.	241.81	248.	241.81	87.	241.38	155.	241.38	86.	241.34	173.	241.32	67.	241.34	238.	241.27
30.	135.	242.17	112.	242.17	112.	241.89	245.	241.89	87.	241.47	153.	241.47	86.	241.43	171.	241.41	67.	241.43	236.	241.37
31.	134.	242.24	111.	242.24	111.	241.96	243.	241.96	86.	241.55	152.	241.55	85.	241.51	170.	241.49	66.	241.51	235.	241.45
32.	133.	242.29	110.	242.29	110.	242.03	242.	242.02	86.	241.61	152.	241.61	85.	241.58	171.	241.55	66.	241.58	236.	241.51
33.	132.	242.32	110.	242.32	110.	242.05	242.	242.05	87.	241.63	154.	241.63	87.	241.59	174.	241.56	67.	241.59	242.	241.51
34.	133.	242.30	110.	242.30	111.	242.03	244.	242.02	89.	241.57	159.	241.57	90.	241.53	180.	241.50	69.	241.53	251.	241.45
35.	134.	242.24	112.	242.24	112.	241.96	247.	241.95	91.	241.49	162.	241.49	92.	241.45	183.	241.42	71.	241.45	256.	241.37
36.	135.	242.17	113.	242.17	113.	241.88	250.	241.88	92.	241.41	163.	241.41	92.	241.36	185.	241.33	72.	241.36	259.	241.28
37.	137.	242.10	114.	242.10	114.	241.80	252.	241.80	93.	241.31	165.	241.31	94.	241.26	188.	241.23	73.	241.26	262.	241.18
38.	138.	242.02	115.	242.02	115.	241.71	254.	241.71	94.	241.21	166.	241.21	94.	241.17	189.	241.13	73.	241.17	264.	241.08
39.	139.	241.96	115.	241.96	115.	241.65	255.	241.65	93.	241.16	165.	241.16	93.	241.12	186.	241.09	72.	241.12	259.	241.04
40.	139.	241.93	116.	241.93	116.	241.62	256.	241.62	93.	241.12	165.	241.12	93.	241.08	186.	241.05	72.	241.08	260.	240.99
41.	141.	241.91	117.	241.91	118.	241.58	259.	241.58	95.	241.05	169.	241.05	96.	240.99	192.	240.96	74.	240.99	268.	240.90
42.	143.	241.86	119.	241.86	119.	241.52	264.	241.52	97.	240.98	171.	240.98	97.	240.93	194.	240.89	75.	240.93	270.	240.84
43.	144.	241.81	120.	241.81	120.	241.47	265.	241.47	97.	240.93	172.	240.93	97.	240.87	194.	240.84	75.	240.87	270.	240.78
44.	145.	241.77	120.	241.77	121.	241.43	266.	241.42	97.	240.87	172.	240.87	97.	240.82	195.	240.79	76.	240.82	271.	240.73
45.	145.	241.73	121.	241.73	121.	241.38	267.	241.38	98.	240.82	173.	240.82	97.	240.77	196.	240.74	76.	240.77	272.	240.68
46.	146.	241.69	121.	241.69	121.	241.34	267.	241.34	97.	240.79	172.	240.79	97.	240.74	194.	240.71	76.	240.74	270.	240.65
47.	145.	241.68	121.	241.68	121.	241.34	266.	241.33	96.	240.80	169.	240.80	95.	240.76	190.	240.73	74.	240.76	264.	240.67
48.	144.	241.71	120.	241.71	120.	241.37	263.	241.37	93.	240.87	165.	240.87	92.	240.83	185.	240.80	72.	240.83	255.	240.75
49.	142.	241.78	118.	241.78	118.	241.46	259.	241.46	91.	240.98	160.	240.98	89.	240.94	179.	240.92	70.	240.94	246.	240.88
50.	140.	241.88	116.	241.88	116.	241.57	254.	241.57	89.	241.11	157.	241.11	87.	241.08	175.	241.05	68.	241.08	241.	241.01
51.	138.	241.97	115.	241.97	114.	241.68	251.	241.67	88.	241.23	156.	241.23	87.	241.19	174.	241.16	68.	241.19	239.	241.12
52.	137.	242.06	114.	242.06	113.	241.77	249.	241.77	87.	241.33	155.	241.33	87.	241.29	173.	241.27	67.	241.29	238.	241.23
53.	136.	242.14	112.	242.14	112.	241.85	247.	241.85	87.	241.43	154.	241.43	86.	241.39	172.	241.37	67.	241.39	237.	241.32
54.	134.	242.20	111.	242.20	111.	241.93	244.	241.92	86.	241.51	152.	241.51	85.	241.47	171.	241.45	66.	241.47	236.	241.41
55.	132.	242.25	110.	242.25	110.	241.99	241.	241.99	86.	241.58	151.	241.58	85.	241.54	170.	241.52	66.	241.54	234.	241.48
56.	131.	242.30	109.	242.30	109.	242.03	239.	242.03	85.	241.63	151.	241.63	85.	241.59	170.	241.57	66.	241.59	235.	241.53
57.	130.	242.31	108.	242.31	108.	242.05	238.	242.05	86.	241.64	152.	241.64	86.	241.60	172.	241.57	67.	241.60	239.	241.53
58.	130.	242.28	108.	242.28	109.	242.01	240.	242.01	88.	241.58	156.	241.58	88.	241.53	177.	241.50	68.	241.53	247.	241.45

59.	132.	242.21	110.	242.21	110.	241.93	243.	241.93	90.	241.48	160.	241.48	91.	241.43	182.	241.40	70.	241.43	254.	241.35
60.	134.	242.13	112.	242.13	112.	241.85	247.	241.84	92.	241.37	163.	241.37	92.	241.32	185.	241.29	71.	241.32	258.	241.24
61.	137.	242.06	114.	242.06	114.	241.76	252.	241.75	93.	241.26	165.	241.26	94.	241.21	188.	241.18	73.	241.21	262.	241.13
62.	139.	241.99	115.	241.99	116.	241.68	255.	241.68	94.	241.18	167.	241.18	94.	241.13	189.	241.10	73.	241.13	263.	241.05
63.	140.	241.93	116.	241.93	116.	241.62	257.	241.61	94.	241.11	167.	241.11	94.	241.06	189.	241.03	73.	241.06	264.	240.98
64.	140.	241.88	117.	241.88	117.	241.56	258.	241.55	95.	241.04	168.	241.04	95.	240.99	190.	240.96	74.	240.99	265.	240.90
65.	141.	241.83	118.	241.83	118.	241.50	260.	241.50	95.	240.97	169.	240.97	95.	240.92	191.	240.89	74.	240.92	267.	240.84
66.	143.	241.78	118.	241.78	119.	241.45	262.	241.44	96.	240.91	170.	240.91	96.	240.86	192.	240.83	75.	240.86	268.	240.77
67.	144.	241.74	119.	241.74	119.	241.40	264.	241.40	96.	240.86	171.	240.86	96.	240.81	193.	240.78	75.	240.81	269.	240.72
68.	144.	241.71	120.	241.71	120.	241.36	265.	241.36	97.	240.81	171.	240.81	97.	240.76	194.	240.73	75.	240.76	270.	240.67
69.	145.	241.66	120.	241.66	120.	241.32	265.	241.31	97.	240.77	172.	240.77	97.	240.71	194.	240.68	75.	240.71	270.	240.62
70.	144.	241.63	120.	241.63	120.	241.28	265.	241.28	96.	240.73	171.	240.73	96.	240.68	193.	240.65	75.	240.68	268.	240.60
71.	144.	241.61	119.	241.61	119.	241.26	263.	241.26	95.	240.74	168.	240.74	94.	240.69	189.	240.66	74.	240.69	262.	240.61
72.	143.	241.63	118.	241.63	118.	241.29	260.	241.29	93.	240.79	164.	240.79	92.	240.75	183.	240.72	72.	240.75	254.	240.68
73.	141.	241.69	117.	241.69	117.	241.37	256.	241.37	90.	240.90	159.	240.90	89.	240.86	177.	240.84	69.	240.86	244.	240.79
74.	139.	241.78	115.	241.78	115.	241.47	252.	241.47	88.	241.02	156.	241.02	87.	240.98	174.	240.96	68.	240.98	239.	240.92
75.	137.	241.87	114.	241.87	113.	241.57	249.	241.57	88.	241.13	155.	241.13	86.	241.09	173.	241.06	67.	241.09	239.	241.02
76.	136.	241.95	113.	241.95	112.	241.66	247.	241.66	87.	241.22	154.	241.22	86.	241.18	172.	241.16	67.	241.18	237.	241.12
77.	135.	242.03	112.	242.03	112.	241.74	246.	241.74	87.	241.31	153.	241.31	86.	241.27	172.	241.25	67.	241.27	237.	241.21
78.	134.	242.09	111.	242.09	111.	241.81	244.	241.81	86.	241.39	153.	241.39	86.	241.35	171.	241.33	67.	241.35	236.	241.29
79.	133.	242.15	110.	242.15	110.	241.87	242.	241.87	86.	241.46	152.	241.46	85.	241.43	170.	241.40	66.	241.43	235.	241.36
80.	132.	242.19	109.	242.19	109.	241.93	240.	241.93	85.	241.52	151.	241.52	85.	241.48	169.	241.46	66.	241.48	234.	241.42
81.	132.	242.23	109.	242.23	109.	241.96	241.	241.96	87.	241.53	154.	241.53	87.	241.49	173.	241.46	67.	241.49	241.	241.41
82.	134.	242.23	111.	242.23	111.	241.95	246.	241.94	90.	241.48	159.	241.48	90.	241.43	181.	241.40	70.	241.43	252.	241.35
83.	137.	242.21	114.	242.21	114.	241.91	252.	241.90	92.	241.42	164.	241.42	93.	241.37	186.	241.34	72.	241.37	258.	241.29
84.	140.	242.18	117.	242.18	117.	241.87	258.	241.86	94.	241.36	167.	241.36	94.	241.31	189.	241.28	73.	241.31	263.	241.22
85.	142.	242.13	118.	242.13	118.	241.81	260.	241.81	95.	241.29	169.	241.29	96.	241.24	192.	241.21	74.	241.24	267.	241.16
86.	141.	242.06	118.	242.06	118.	241.75	260.	241.74	95.	241.24	169.	241.24	96.	241.19	192.	241.16	74.	241.19	267.	241.10
87.	140.	241.99	117.	241.99	117.	241.68	258.	241.67	95.	241.17	168.	241.17	95.	241.13	190.	241.10	74.	241.13	265.	241.04
88.	139.	241.92	116.	241.92	116.	241.61	257.	241.60	94.	241.10	167.	241.10	95.	241.05	190.	241.02	74.	241.05	265.	240.97
89.	140.	241.86	116.	241.86	116.	241.54	257.	241.53	94.	241.03	168.	241.03	95.	240.98	190.	240.94	74.	240.98	265.	240.89
90.	141.	241.80	117.	241.80	117.	241.48	259.	241.47	95.	240.96	168.	240.96	95.	240.91	190.	240.87	74.	240.91	265.	240.82
91.	142.	241.76	118.	241.76	118.	241.43	261.	241.43	95.	240.90	169.	240.90	95.	240.85	191.	240.82	74.	240.85	266.	240.76
92.	143.	241.73	119.	241.73	119.	241.39	263.	241.38	96.	240.85	170.	240.85	96.	240.80	192.	240.76	75.	240.80	268.	240.71
93.	144.	241.68	119.	241.68	120.	241.34	264.	241.34	97.	240.79	171.	240.79	96.	240.74	194.	240.71	75.	240.74	270.	240.65
94.	144.	241.65	120.	241.65	120.	241.30	265.	241.30	96.	240.75	171.	240.75	96.	240.70	193.	240.67	75.	240.70	269.	240.61
95.	145.	241.64	120.	241.64	120.	241.29	265.	241.29	96.	240.76	169.	240.76	95.	240.71	190.	240.68	74.	240.71	264.	240.62
96.	145.	241.68	120.	241.68	120.	241.33	264.	241.33	94.	240.82	166.	240.82	93.	240.77	186.	240.74	72.	240.77	257.	240.70

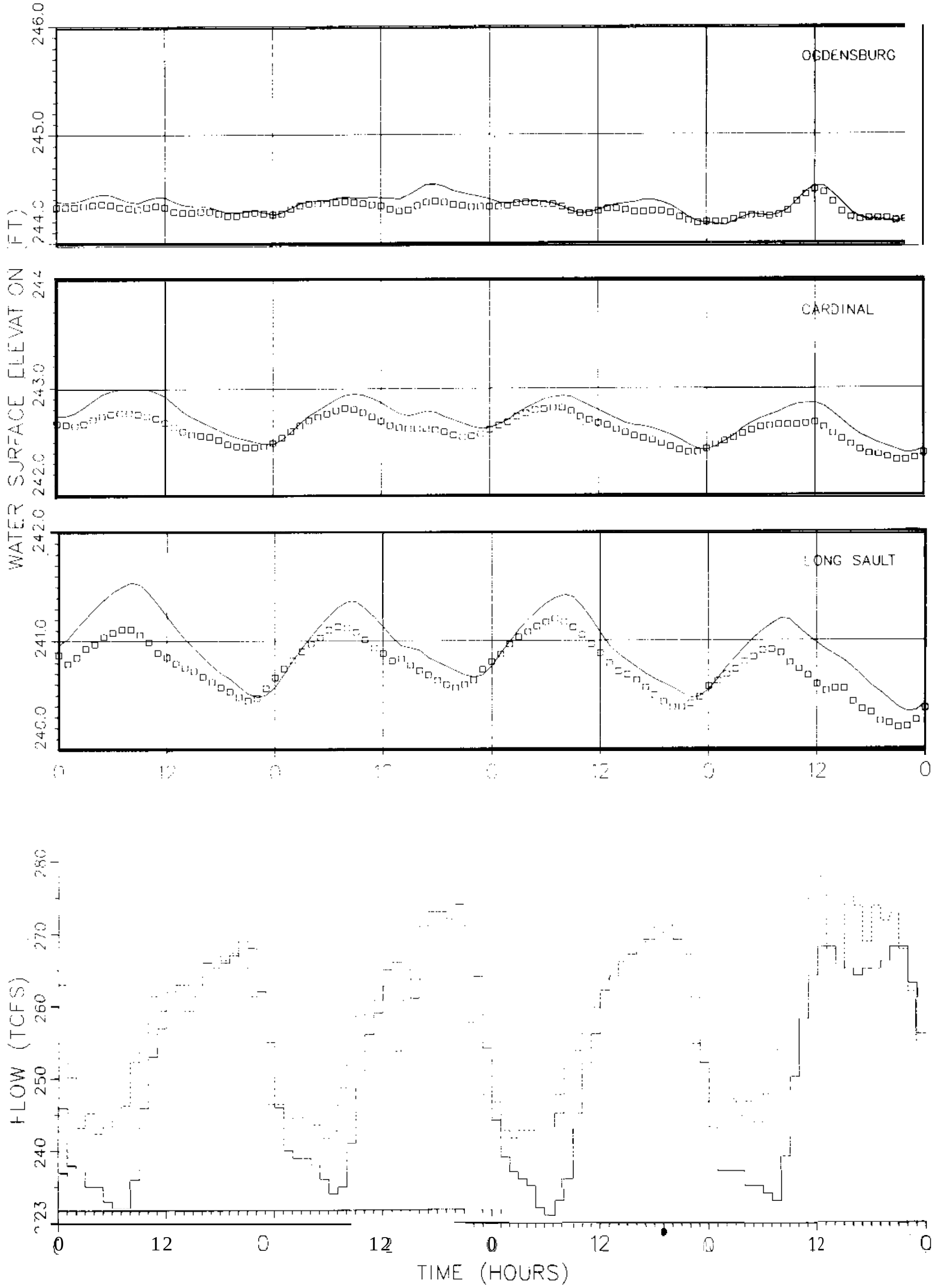

Figure B.2. Simulation of river profile for the period 7-10 August 1977.

Appendix C. PROGRAM LISTING

```
 PROGRAM LAWRENC(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
1 TAPE7=/630)

**************************************************************
         ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL
**************************************************************

 DIMENSION R(30,23),B(29,9),C(122,31),D(122),BB(2000),E(189)
 DIMENSION AAP(2),U(299),V(230),U2(161),
1 RICE(30),RICTHK(30),RICTHK1(30)
 DIMENSION IDATE(4),ICHAR(23)
 DIMENSION IDATER(2),IPURP(2),IPRIT(3),INCCON(6)
 DIMENSION BOUND(3),THICK(3),RL(3),RN1(3),RN(3)
 DIMENSION TMULT(4),TWORD(4),OUT(63)
 DIMENSION CR1(30),CPERU(30),CPERD(30)
 INTEGER TWORD
 REAL NTSO
 REAL NTS,NTS1,NTS2
 INTEGER B    ,E
 INTEGER P
 DATA ICHAR/≠REACH NO.≠,≠U.S. PT.≠,≠D.S. PT.≠,≠U.S. TOP≠,≠D.S. TOP≠
1,≠U.S. AREA≠,≠D.S. AREA≠,≠U.S. DATUM≠,≠D.S. DATUM≠,≠U.S. PER≠,
2≠D.S. PER≠,≠LENGTH≠,≠MANNINGS R≠,≠ICE THK≠,≠MANNINGS R≠,≠U.S. H≠,
3≠D.S. H≠,≠U.S. Q≠,≠D.S. Q≠,≠U.S. HP≠,≠D.S. HP≠,≠U.S. QP≠,≠D.S. QP≠
4/
 DATA TWORD/≠  HRS≠,≠ DAYS≠,≠WEEKS≠,≠MONTH≠/
 DATA IPRIT/≠   ALL≠,≠ FINAL≠,≠    NO≠/
 DATA INCCON/≠   ICE CON≠,≠DITIONS   ≠,≠    HANGIN≠,≠G DAM
1,≠  OPEN WAT≠,≠ER ONLY   ≠/
 DATA TMULT/3600.,86400.,604800.,2628000./
 DATA U/1.,1.,2.,6422.,6422.,499.,234.6,42.8,42.8,7483.,5582.,3500.
1,.030,.0000,1.,0,0,0,0,0,0,0,2.,3.,4.,6520.,6520.,398.7,314.3,42
2.8,42.8,6642.,6616.,6870.,.030,.0000,1.,0,0,0,0,0,0,0,3.,5.,6.,3
3977.,3977.,189.5,339.0,42.8,42.8,4047.,4147.,2813.,.030,.0000,1.,0
4,0,0,0,0,0,0,0,4.,7.,8.,1520.,1520.,45.1,45.1,42.8,42.8,1579.,1579
4.,6280.,.030,.0000,1.,0,0,0,0,0,0,0,5.,9.,10.,13400.,13400.,505.
5,833.2,42.8,42.8,13475.,13524.,2720.,.030 ,.0000,1.,0,0,0,0,0,0,
60,6.,11.,12.,1860.,1860.,62.0,62.0,42.8,42.8,1926.,1926.,1050.,.03
70,.0000,1.,0,0,0,0,0,0,0,7.,13.,14.,6905.,6905.,314.3,376.7,42.8
8,42.78,4555.,4555.,2220.,.030,.0000,1.,0,0,0,0,0,0,0,8.,15.,16.,
96450.,6450.,187.1,187.1,42.78,42.74,6450.,6450.,2810.,.030,.0000,1
1.,0,0,0,0,0,0,0,0,9.,17.,18.,1510.,1510.,60.4,60.4,42.78,42.74,151
20.,1510.,1660.,.030,.0000,1.,0,0,0,0,0,0,0,10.,19.,20.,7290.,162
30.,367.6,143.3,42.78,42.72,1290.,1620.,1500.,.030,.0000,1.,0,0,0,0
4,0,0,0,0,11.,21.,22.,3620.,3620.,166.2,225.0,42.74,42.56,3620.,362
50.,5080.,.030,.0000,1.,0,0,0,0,0,0,0,12.,23.,24.,1820.,1820.,143
6.2,154.4,42.72,42.56,1820.,1820.,4970.,.030,.0000,1.,0,0,0,0,0,0,0,
7,0,13.,25.,26.,7600.,7600.,379.4,142.4,42.56,42.37,7600.,7600.,750
80.,.030,.0000,1.,0,0,0,0,0,0,0/
 DATA U2/14.,27.,28.,3240.,3240.,142.4,105.0,42.37,42.33,32.40,3240
1.,1500.,.030,.0000,1.,0,0,0,0,0,0,0,15.,29.,30.,4740.,4740.,105.
20,259.3,42.33,42.21,4740.,4740.,6590.,.030,.0000,1.,0,0,0,0,0,0,0
```

```
30,16.,31.,32.,3730.,3760.,140.6,80.4,42.2,42.0,3730.,3730.,1720.,.
4030,.0000,1.,0,0,0,0,0,0,0,0,17.,33.,34.,1540.,1540.,46.5,70.4,42.
60,40.8,1540.,1540.,2810.,.030,.0000,1.,0,0,0,0,0,0,0,0,18.,35.,36.
5,1030.,1030.,32.7,22.5,42.0,40.8,1030.,1030.,3000.,.030,.0000,1.,0
6,0,0,0,0,0,0,0,19.,37.,38.,2620.,2620.,92.9,82.7,40.8,39.9,2620.,2
7620.,2310.,.030,.0000,1.,0,0,0,0,0,0,0,20.,39.,40.,2650.,2650.,8
87.7,108.8,39.7,39.4,2650.,2650.,1690.,.030,.0000,1.,0,0,0,0,0,0,0,
90/
 DATA V/21.,41.,42.,1988.,1988.,65.0,50.,39.41,39.12,1988.,1988.,
11730.,.030,.0000,1.,0,0,0,0,0,0,0,0,22.,43.,44.,1540.,1540.,43.8,
2 43.8,39.41,39.26,1540.,1540., 975.,.030,.0000,1.,0,0,0,0,0,0,0,0
2,23.,45.,46.,1540.,1540.,43.8,108.7,39.26,39.12,1540.,1540.,965.,
3.030,.0000,1.,0,0,0,0,0,0,0,0
3,24.,47.,48.,4780.,4780.,158.7,200.0,39.12,38.17,4780.,4780.,5250.
4,.030,.0000,1.,0,0,0,0,0,0,0,0,25.,49.,50.,1570.,1570.,86.4, 86.3,
538.17,37.99,1570.,1570.,2060.,.030,.0000,1.,0,0,0,0,0,0,0,0,26.,51
6.,52.,2840.,2840.,150.0,150.0,38.17,37.99,2840.,2840.,1190.,.030,
1.0000,1.,0,0,0,0,0,0,0,0,27.,53.,54.,1530.,1530.,76.8,76.8,37.99,
837.99,2530.,2530.,593.,.030,.0000,1.,0,0,0,0,0,0,0,0,28.,55.,56.,
93260.,3260.,169.8,168.9,37.99,37.72,3260.,3260.,1310.,      .030,
1.0000,1.,0,0,0,0,0,0,0,0,29.,57.,58.,1010.,1010.,57.6,63.6,37.99,3
27.72,1010.,1010.,1970.,.030,.0000,1.,0,0,0,0,0,0,0,0,30.,59.,60.,
26790.,6790.,232.5,232.5,37.72,37.50,6970.,6970.,1590.,.030,.0000,
31.,0,0,0,0,0,0,0,0/
 DATA E/1,1,2,1,3,4,0,0,0,
1        2,1,1,3,5,0,0,0,0,
2        3,1,2,2,6,7,0,0,0,
3        4,3,1,4,5,6,8,0,0,
4        5,1,2,7,9,10,0,0,0,
5        6,2,1,8,9,11,0,0,0,
6        7,1,1,10,12,0,0,0,0,
7        8,2,1,11,12,13,0,0,0,
8        9,1,1,13,14,0,0,0,0,10,1,1,14,15,0,0,0,0,
9       11,1,1,15,16,0,0,0,0,12,1,2,16,17,18,0,0,0,
3       13,2,1,17,18,19,0,0,0,14,1,1,19,20,0,0,0,0,
5       15,1,2,20,21,22,0,0,0,
6        16,1,1,22,23,0,0,0,0,17,2,1,21,23,24,0,0,0,
7        18,1,2,24,25,26,0,0,0,
8        19,1,2,26,27,29,0,0,0,20,2,1,25,27,28,0,0,0,
9        21,2,1,28,29,30,0,0,0/

AREA FUNCTIONINCLUDING ICE COVER(.075*R(N,14) IS SUBTRACTED)

  AREA(N)=(R(N,6)+R(N,7)+PSI*(R(N,20)*R(N,4)+R(N,21)*R(N,5))+PSI1*
 1(R(N,16)*R(N,4)+R(N,17)*R(N,5))-((R(N,8)+R(N,14)*.075)*R(N,4)+
 1(R(N,9)+.075*R(N,14))*R(N,5)))*0.5
  PER(N)=(PSI*(R(N,10)+R(N,11))+PSI1*(CPERU(N)+CPERD(N))+2.*PSI*
 1(R(N,20)+R(N,21))+2.*PSI1*(R(N,16)
 1+R(N,17))-(R(N,8)+R(N,9))*2)*0.5
  QDIS(N)=(PSI*(R(N,22)+R(N,23))+PSI1*(R(N,18)+R(N,19)))/2
  READ IN DATE, DATES OF DATA, AND PURPOSE

   READ(5,202) IDATER,IDATE,IPURP
```

```
 LOAD 'BOUNDARY NODES INTO ARRAY B

     DO 9 I=1,NB
     DO 9 J=1,9
     M=(I-1)*9+J
   9 B(I,J)=E(M)

DOUNSTREAM BOUNDARY AND REACH NUMBER

     READ(5,907) ARES,NEXIT
     ARES=ARES*2.78784E7

READ NUMBER OF REACHES AT UPSTREAM BOUNDARY
A MAXIMUM OF TUO IS ALLOWED
 AND NUMBEROF HANGING DAMS

     IC=1
     READ(5,902) NUMUP,NHD

READ IN HANGING DAM. INFORMATION, BOUNDARY,REACH,THICKNESS O F ICE,
     LENGTH AND ICE ROUGHNESS

     IF(NHD-0) 112,112,113
113  DO 114 I=1,NHD
     READ(5,910) BOUND(I),RN1(I),THICK(I),RL(I),RN(I)
     N3=RN1(I)
114  R(N3 ,12)=R(N3,12)-RL(I)
     GO TO(112,482),IC
112  CONTINUE
     IC=2
     READ(5,905) DISO
     READ(5,905) NTSO.

   READ IN. INITIAL STAGES FOR UPSTREAM AND DOWNSTREAM ENDS OF EACH
     REACH.
     READ(5,904) (R(N,16),N=1,NR)
     READ(5,904) (R(N,17),N=1,NR)

   READ IN INITIAL DISCHARGE' IN EACH REACH (USUALLY 0)

     READ(5,905) (R(N,18),N=1,NR)

   READ IN FIRST TIME DEPENDENT DATA

     IF(ISICE.EQ.0) GO TO 148
     READ(5,906) (RICTHK(I),I=1,NR)
     READ(5,908) (RICE(I),I=1,NR)
148  READ(5,939)DIS,NTS,STAGE,HKING,WIND
```

```
      DO 15 N=1,NR
      R(N,20)=R(N,16)
      R(N,21)=R(N,17)
      R(N,19)=R(N,18)
      R(N,22)=R(N,19)
      R(N,23)=R(N,19)
   15 CONTINUE

    WRITE OUT INPUT DATA

      WRITE(6,7601) IDATER
      WRITE(6,7602) NR,DTT,TWORD(ITIMINT),NB,TMAX,TWORD(ITIMINT)
     1,PSI,AR,ARES,KIT,NUMUP,IPRTYP,NEXIT
      IF(ISICE.EQ.0) GO TO 6340
      WRITE(6,7603)
      IF(NHD.EQ.6) GO TO 6340
      WRITE(6,7604) NHD,BOUND,RN1,THICK,RL,RN
 6340 WRITE(6,7605) DISO,NTSO
      WRITE(6,7606)
      DO 11 I=1,NB
   11 WRITE(6,7607) (B(I,J),J=1,9)
      WRITE(6,7600)
      DO 779 N1=1,21,10
      N2=N1+9
      WRITE(6,780)  N1,N2
      DO 777 I=1,23
  777 WRITE(6,776)ICHAR(I), (R(N,I),N=N1,N2)
  779 CONTINUE
      TOLH =.J0008*32.2*NR

  INITIAL Q≠S ALL SET

  NOU SET TOLERANCES

      TOLQ=1000.
      K=1
      T=0

    WRITE TITLE PAGE

      WRITE(6,7600)
      WRITE(6,7620)
      WRITE(6,7621)
      IYGX=IPRTYP+1
      WRITE(6,7622) IPRTYP,IPRIT(IYGX),IDATER
      IF(ISICE.EQ.0) GO TO 6290
      WRITE(6,7610) (INCCON(I),I=1,2)
      IF(NHD.EQ.0) GO TO 6291
      WRITE(6,7610) (INCCON(I),I=3,4)
      GO TO 6231
 6290 WRITE(6,7610) (INCCON(I),I=5,6)
 6291 WRITE(6,7623) IDATE,IPURP
```

```
READ IN NUMBER OF REACHES AND BOUNDRIES

      READ(5,902) NR,NB

READ IN PERMANENT CHANNEL CHARACTERISTICS. BASE PERIMETERS
(R(I,10) AND R(I,11) MAY BE LEFT BLANK AS THEY ARE COMPUTED
BY PROGRAM..
      DO 5 N=1,13
      DO 5 J=1,23
      M=(N-1)*23+J
    5 R(N,J)=U(M)
      DO 7 N=14,20
      DO 7 J=1,23
      M=(N-14)*23+J
    7 R(N,J)=U2(M)
      DO 6 N=21,30
      DO 6 J=1,23
      M=(N-21)*23+J
    6 R(N,J)=V(M)
      READ(5,908) (R(N,13),N=1,NR)
      READ(5,906) (R(N,14),N=1,NR)
      READ(5,908) (RICE(J),J=1,NR)

READ PROGRAM DATA (TIME INTERVAL,MAXTIME,PSI,ITERATIONS
UPSTRAM RESERVOIR ELEV AND DOUNSTREAM ELEV
  AREA OF UPSTEAM RESERVOIR , TIME INTERVAL(1=HR, 2=DAY,
  3=WEEK,4=MONTH)    PRINT FORMATAND  ISICE)

      READ(5,903) DTT,TMAX,PSI,KIT,HL,HLDN,AR,ITIMINT,IPRTYP,ISICE
      FACTOR=3600.
      NCOND=TMAX/DTT+.99999
      DT=720*FACTOR
      TCAL=2592000O.
      AR=AR*2.78784E7
      PSI1=1-PSI

 COMPUTE CHANNEL PERIMETER, TOP WIDTH,AND  LENGTH

      DO 10 I=1,NR
      R(I,15)=R(I,13)
      ZETA=0.
      IF(R(I,14).GT.0.) ZETA=1.
      R(I,6)=R(I,6)*1000.
      R(I,7)=R(I,7)*1000.
      R(I,12)=R(I,12)*10.
      R(I,8)=R(I,8)+200.
      R(I,9)=R(I,9)+200.
      R(I,10)=2*R(I,6)/R(I,4)+R(I,4)*(1.+ZETA)
      R(I,11)=2*R(I,7)/R(I,5)+R(I,5)*(1.+ZETA)
      CPERU(I)=R(I,10)
      CPERD(I)=R(I,11)
   10 CONTINUE
```

```
      WRITE(6,7621)
      WRITE(6,7625)
      WRITE(6,7626)
      WRITE(6,7600)
      DIS2=DISO
      NTS2=NTSO-.03*NTS
      DELH=(HLDN-STAGE)/11.
      DO 4 J=1,NR
      IF(R(J,14).GT.0.)R(J,13)=R(J,15)*0.63*(1.+(RICE(  J)/R(J,15))
     **1.5   1)**.667
    4 CR1(J)=R(J,13)
      IF (IPRTYP.EQ.2) GOT O30
      WRITE(6,912) (R(J,13),J=1,NR)
      IF(ISICE.EQ.0)GOT O 30
      WRITE(6,914) (RICE(J),J=1,NR)
   30 TH=T/FACTOR
      IF(IPRTYP.NE.0.AND.T.LT.TCAL) GOT   O40
C     WRITE INTERMEDIATE CALCULATIONS

      N2=0
      IF(TH.GT.TMAX)  TH=0.
      WRITE(6,918) TWORD(ITIMINT),TH,HL,HLDN
      IF(IPRTYP.EQ.2)GO TO 45
       DO 31 I=1,3
      N1=N2+1
       N2=N1+9
      WRITE(6,919) (R(N,1),N=N1,N2),(R(N,16),N=N1,N2),(R(N,18),N=N1,
     .N2)
   31 CONTINUE
       WRITE(6,561) DIS2,NTS2
       WRITE(6,560) R(2,16),R(1,16),R(16,16),R(19,16),R(19,17),
     R(20,16), 1R(22,16),R(24,16),R(30,16)
   33 CONTINUE'
   35 CONTINUE
C BEGIN SETTING COEFF MATRICES FOR SOLUTION

   40 CONTINUE
       IF(T.GT.TCAL)GO TO 41
       T=T+DT
       TC1=0.5
       DIS1=DIS2
       NTS1=NTS2
       NTS2=NTS
       IF(STAGE.NE.0.)GO TO39
       DIS2=DIS
       GO TO 43
   39  HLDN=HLDN-DELH
       GO TO 43
   41  CONTINUE
       NR2=2*NR
       OUT(1)=TH
       DO 417IOA=2,NR2,2
```

```
      IOB=IOA/2
      OUT(IOA)=R(IOB,18)/1000.
      OUT(IOA+1)=R(IOB,16)
  417 CONTINUE
      NR2=NR2+3
      OUT(NR2-1)=DIS /1000.
      OUT(NR2)=HLDN

C   WRITE OUTPUT TO FILE TAPE7

      WRITE(7,418) (OUT(I),I=1,NR2)
      DIS1=DIS2
      FACTOR=TMULT(ITIMINT)
      DT=DTT*FACTOR
      T=T-TCAL*1.1+DT
      TCAL=0.
      K=K+1

C   READ IN TIME DEPENDENT DATA

      IF(ISICE.EQ.0)GO TO 487
      DO 484 IRIC=1,NR
  484 RICTHK1(IRIC)=RICTHK(IRIC)
      READ(5,906)(RICTHK(I),I=1,NR)
      IF(EOF(5)) 120,486
  486 READ(5,908)(RICE(I),I=1,NR)
  487 READ(5,939) DIS,NTS,STAGE,HKING,WIND,NHDC
      IF(EOF(5))   120,481
  481 IF(NHDC .GT. 0)GO TO 113
  482 IF(ISICE.EQ.0)GO TO 49
      DO 48 J=1,NR
      CR2=R(J,15)
      R(J,14)=RICTHK(J)
      IF(R(J,14).GT.0.) CR2=R(J,15)*0.63*(1.+(RICE(J)/R(J,15))**1.5
     1)**.667
      R(J,13)=PSI*CR2+PSI1*CR1(J)
      CR1(J)=CR2
      ZETA=0.
      IF(R(J,14).GT.0..AND.RICTHK1(J).LE.0.)GO TO 52
      IF(R(J,14).LE.0..AND.RICTHK1(J).GT.0.)GO TO 53
      GO TO 54
   52 ZETA=1.
      IF(IPRTYP.EQ.2) GO TO 54
      WRITE(6,56) J
      GO TO 54
   53 ZETA=-1.0
      IF(IPRTYP.EQ.2)GO TO 54
      WRITE(6,57) J
   54 CPERU(J)=R(J,10)
      CPERD(J)=R(J,11)
      R(J,10)=R(J,10)+ZETA*R(J,4)
      R(J,11)=R(J,11)+ZETA*R(J,5)
      IF(IPRTYP.EQ.2) GO TO 48
```

```
      IF(ZETA.NE.0.) WRITE(6,58) R(J,10),R(J,11)
 *48 CONTINUE
      IF(IPRTYP.EQ.2)GO TO 49
      WRITE(6,912)  (R(J,13),J=1,NR)
      WRITE(6,913)  (R(J,14),J=1,NR)
      WRITE(6,914)  (RICE(J),J=1,NR)
      WRITE(6,915)  (PER(J),J=1,NR)
 .49 CONTINUE
      NTS1=NTS2
      NTS2=NTS
      IF(STAGE.NE.0)GO TO 42
      DIS2=DIS
      GOT O43
  4 2HLDN=STAGE
  43 CONTINUE
      TAUX=6.77 E-6*WIND*ABS(WIND)
      DO 100K6=1,KIT
      DO 45I=1,122
      DO 45J=1,31
  45 C(I,J)=0.0
     DO 46 I-11122
  4 6D(I)=0.
. UPSTREAM BOUNDARY CDND AT KINGSTON AND.PSEUDOREACHABOVE CAFE
  VINCENT.  REACH=1=KINGSTON,REACH F.2 IS PSEUDO REACH
      QOUT=0.0
      QPOUT=0.0
      DO 44N=1,NUMUP
      QOUT=QOUT+R(N,18)
      QPOUT=QPOUT+R(N,22)
  4   7AP=(R(N,20)-R(N,8))*R(N,4)+R(N,6)-0.075*R(N,14)*R(N,4)
      AAP(N)=AP
  44 CONTINUE
      N1=1
      N-l
      N2H=2*R(N,2)-1
      N2H=N2H+16-N1
      N2Q=N2H+1
      AP=R(N,22)*R(N,22)*R(N,4)/(32.2*AAP(1)*AAP(1)*AAP(1))
      C1=1.
      IFtRtlr22l.LT.G.l C1=0.
      THETA=AR/DT
      IF(HKING.NE.0)G OTO252
      C(1,N2H)=(1-AP*C1)*THETA
  5 0C(1,N2Q)=THETA*R(N,22)/(32.2*AAP(1)*AAP(1))+0.5
      D(1)=THETA*(R(N,20)+R(N,22)*R(N,22)/(64.4*AAP(1)*AAP(1))
     *C1-HL)- 1((NTS1+NTS2)*TC1-(QPOUT+QOUT) *0.5 )
      GO TO 249
 252C(1,N2H)=1.
      C(1,N2Q)=0.
      D(1)=R(N,20)-HKING
 249 CONTINUE
```

```
      NP=0
      IF(NUMUP.EQ.1) GO TO 51
      C2=1.
      N1=N1+1
      IF(R(2,22).LT.0.) C2=0.
      L=R(1,2)
      M=R(2,2)
      L=2*L-1
      L=L+16-N1
      M=2*M-1
      M=M+16-N1
      C(1,M+1)=0.0
      C(2,L)=1.0 -R(1,22)*R(1,22)*R(1,4)/(32.2*AAP(1)*AAP(1)*AAP(1))
     .*1
      C(2,M)=-1.0+R(2,22)*R(2,22)*R(2,4)/(32.2*AAP(2)*AAP(2)*AAP(2))
     *C2
      L=L+1
      M=M+1
      IF(HKING.NE.0.) GO TO 253
      C(1,M+1)=0.5
  253 CONTINUE
      C(2,L)=R(1,22)/(32.2*AAP(1)*AAP(1))*C1
      C(2,M)=-R(2,22)/(32.2*AAP(2)*AAP(2))*C2
      D(2)=R(1,20)+R(1,22)*R(1,22)/(64.4*AAP(1)*AAP(1))*C1-(R(2,20)
     +R(2, 122)*R(2,22)/(64.4*AAP(2)*AAP(2))*C2)
      NP=1
   51 CONTINUE
C UPSTREAM BOUNDARY COMPLETE
      P=0
      N4=NB+1
      DO 65 N=1,N4
      IF(N.EQ.N4)GO TO a4
      N7=B(N,2)
      GO TO 86
   a4 N7=1
   86 CONTINUE
      DO6 0 N8=1,N7
      P=P+1
      PERR=PER(P)
      AREAR=AREA(P)
      DAP=PSI*(R(P,5)*(R(P,21)-R(P,9))-R(P,4)*(R(P,20)-R(P,8))+
     (R(P,7)-1R(P,6))-0.075*R(P,14)*(R(P,5)-R(P,4)))
      DA=PSI1*(R(P,5)*(R(P,17)-R(P,9))-R(P,4)*(R(P,16)-R(P,8))+
     (R(P,7)-1R(P,6))-0.075*R(P,14)*(R(P,5)-R(P,4)))
      DQP=PSI*(R(P,23)-R(P,22))
      DQ=PSI1*(R(P,19)-R(P,18))
      DHP=PSI*(R(P,21)-R(P,20))
      DH=PSI1*(R(P,17)-R(P,16))

C CONTINUITY EQUATION

      N1=N1+1
      N2H=R(P,2)*2-1
```

```
      N2H=N2H+16-N1
      N3H=R(P,3)*2-1
      N3H=N3H+16-N1
      N2Q=N2H+1
      N3Q=N3H+1
      C(N1,N2H)=R(P,4)/(2*DT)
      C(N1,N3H)=R(P,5)/(2*DT)
      C(N1,N2Q)=-PSI/R(P,12)
      C(N1,N3Q)=PSI/R(P,12)
      D(N1)=(DQP+DQ)/R(P,12)+(R(P,5)*(R(P,21)-R(P,17))+R(P,4)*(R(P,
     20)- 1R(P,16)))/(2*DT)
'MOMENTUM EQUATION
      N1=N1+1
      N2H=N2H-1
      N3H=N3H-1
      N2Q=N2Q-1
      N3Q=N3Q-1
      TWOQA=2*QDIS(P)/AREAR
      SF2=32.2*R(P,13)*R(P,13)/(2.208*(   AREAR**2.333))*
     PERR**1.333
      SF=QDIS(P)*ABS(QDIS(P))*SF2
      DQX=(DQP+DQ)/R(P,12)
      DAX=(DAP+DA)/R(P,12)
      C(N1,N2H)=-TWOQA/(AREAR)*DQX*PSI*R(P,4)*.5
     1+TWOQA**2/(2*   AREAR)*DAX*PSI*R(P,4)/2
     2+TWOQA*TWOQA/4*PSI*R(P,4)/R(P,12)
     3-32.2 •   AREAR*PSI/R(P,12)+32.2*(DHP+DH)/R(P,12)
     4*PSI*R(P,4)/2-2.333*SF/(   AREAR)*PSI*R(P,4)/2
     5+1.333*SF/(PERR)*PSI
      DN=PSI*R(P,5)/2
      C(N1,N3H)=-TWOQA/(AREAR)*DQX*DN+TWOQA**2/(2*   AREAR)*DAX
     1*DN-TWOQA*TWOQA*DN/(2*R(P,12))+32.2*   AREAR*PSI/R(P,12)
     +32.2*(DHP+ 2DH)/R(P,12)*DN-2.333*SF*DN/(AREAR)
     +1.333*SF*PSI/(PERR)
      C(N1,N3Q)=DQX*PSI/(AREAR)+TWOQA*PSI/R(P,12)-TWOQA*DAX*PSI
     1*.5/(AREAR)+SF2*ABS(QDIS(P))*PSI   • ll(DT+2)
      C(N1,N2Q)=C(N1,N3Q)-2*TWOQA*PSI/R(P,12)
      D(N1)=TWOQA*DQX-TWOQA*TWOQA*DAX/4+32.2*AREA(P)*(DHP
     +DH)/R(P,12)+ 1SF+(R(P,23)+R(P,22)-(R(P,19)+R(P,18)))/(2*DT)
     1-TAUX*R(P,4)/1.94
   60 CONTINUE

REACH EQUATIONS OF MOMENTUM AND CONTINUITY COMPLETED. NOU NEED
NODAL CONDITIONS OF STEADY STATE CONTINUITY AND ENERGY

      IF (N.EQ.N4) GO TO 65
      IF(NHD.EQ.0)GO TO 116
      IFLAG=0
      DO 115 J=1,NHD
      NBOUN=BOUND(J)
  115 IF(N.EQ.NBOUN) IFLAG=J
 ,116 CONTINUE
```

```
      N1=N1+1
      IN=B(N,2)
      IOUT=B(N,3)
```

CONTINUITY'

```
      FLOWOUT=0.0
      FLOWIN=0.0
      DO 61 I=1,IN
      IPT=B(N,3+I)
      FLOWIN=FLOWIN+R(IPT,23)
      IPT=R(IPT,3)
      IQIN=2*IPT
      IQIN=IQIN+16-N1
   61 C(N1,IQIN)=1.0
      DO 62 I=1,IOUT
      IP=B(N,3+IN+I)
      FLOWOUT=FLOWOUT+R(IP,22)
      IP=R(IP,2)
      IQOUT=2*IP
      IQOUT=IQOUT+16-N1
   62 C(N1,IQOUT)=-1.0
      D(N1)=FLOWIN-FLOWOUT
```

ENERGY EQUATION

```
      IPT=B(N,4)
      IFIN=R(IPT,3)*2-1
      ITOT=IN+IOUT-1
      DO 63 IJC=1,ITOT
      N1=N1+1
      IHIN=IFIN+16-N1
      LN=4+IJC
      IP=B(N,LN)
      IF(IJC.GE.IN) GO TO 64
      IHOUT=R(IP,3)*2-1
      IHOUT=IHOUT+16-N1
      C(N1,IHIN)=1.
      C(N1,IHOUT)=-1.
      D(N1)=R(IPT,21)-R(IP,21)
      GO TO 63
   64 CONTINUE
      IHOUT=R(IP,2)*2-1
      IHOUT=IHOUT+16-N1
      C(N1,IHIN)=1.
      C(N1,IHOUT)=-1.
      D(N1)=R(IPT,21)-R(IP,20)
      J=IFLAG
      IF(J.EQ.0) GO TO. 117
      N3=RN1(J)
      IF(IP.NE.N3) GO TO 117
      DIA=R(IPT,21)+R(IP,6)/R(IP,4)-(R(IP,8)+THICK(J))
      A=DIA*R(IP,4)
```

```
      A1=(R(IPT,21)-R(IPT,9))*R(IPT,5)+R(IPT,7)
      COEF=.023+RN(J)*RN(J)*RL(J)/(0.876*DIA**1.333)
      DH=COEF*R(IP,22)*ABS(R(IP,22))/(A*A)-R(IPT,23)*ABS(R(IPT,23))/
     1(42.93*A1*A1)
      IF(IPRTYP.NE.0)GOTO 6301
      WRITE(6,4002)
      WRITE(6,4003) DIA,A,COEF,DH
 6301 C(N1,IHIN)=1.+1.333*((COEF-0.023)/DIA)*R(IP,22)*
     1ABS(R(IP,22))/(A*A)+2.*COEF*R(IP,22)*ABS(R(IP,22))/(A*A*DIA)
     2-R(IPT,23)*ABS(R(IPT,23))*R(IPT,5)/(21.47*A1**3)
      IHOUT=IHOUT+1
      C(N1,IHOUT)=-2.*COEF*ABS(R(IP,22))/(A*A)
      IHIN=IHIN+1
      C(N1,IHIN)=C(N1,IHIN)-ABS(R(IPT,23))/(21.47*A1*A1)
      IHIN=IHIN-1
      D(N1)=D(N1)-DH
  117 CONTINUE
      IF(N.NE.14)GO TO 63
      FALL=.014*(R(20,20)-239.)-(R(20,22)-280000)*
     1.000001-.19
      IF(FALL.GE.0.)GO TO 63
      C(N1,IHOUT)=C(N1,IHOUT)+.014
      D(N1)=D(N1)+FALL
   63 CONTINUE
   65 CONTINUE
C
C  CONDITIONS AT NODES COMPLETED. NOU DODOWNSTREAM BOUNDARY
C
      N1=N1+1
      LN=R(NEXIT,3)
      N3H=2*LN-1
      N3H=N3H+16-N1
      N3Q=N3H+1
      LN=NEXIT
      IF(STAGE.EQ.0.)GO TO 67
      C(N1,N3H)=1.
      C(N1,N3Q)=0.
      D(N1)=R(LN,21)-HLDN
      N1=N1+1
      C(N1,N3Q)=.5
      N3Q=N3Q-1.
   67 CONTINUE
      THETA=ARES/DT
      C(N1,N3H)=THETA
      C(N1,N3Q)=-0.5
      D(N1)=THETA*(R(LN,21)-R(LN,17))+ ((DIS1+DIS2)*TC1-(R(LN,23)+
     1R(LN,19))*0.5)
C
C  REVERSE SIGN OF EQUATION MATRIX
C
      DO 66 N=1,N1
   66 D(N)=-D(N)
```

EQUATIONS ALL DONE

SOLVE MATRIX

```
      IER=0
      CALL LEQT1B(C,N1,15,15,122,D,1,122,0,BB,IER)
      IF(IER.EQ.0) GO TO 70
      WRITE(6,909) IER,K6
   70 SDH=0
      SDQ=0
      N3=4.*NR
      CNR=1.0
      IF(K6.LT.3) CNR=0.5
```

UPDATE VALUES OF HP AND QP EASED ON DELTA SOLUTION VECTOR

```
      DO 72 I=1,NR
      L=2*R(I,2)-1
      M=2*R(I,3)-1
      R(I,21)=R(I,21)+D(M)*CNR
      R(I,20)=R(I,20)+D(L)*CNR
      SDH=SDH+ABS(D(L))
      L=L+1
      M=M+1
      R(I,22)=R(I,22)+D(L)*CNR
      R(I,23)=R(I,23)+D(M)*CNR
      IF(STAGE.NE.0.) M=M+1
      IF(STAGE.NE.0.) DIS2=DIS2+D(M)
   72 SDQ=SDQ+ABS(D(L))
```

ALL DOWNSTREAM QP AND HP REPLACE"

```
      IF(K6.EQ.KIT) WRITE(6,911) K6,SDH,SDQ
      IF(SDH.LE.TOLH.AND.SDQ.LE.TOLQ) GO TO 105
  100 CONTINUE
  105 CONTINUE
      DO 110 N=1,NR
      HBUP=R(N,16)
      HBDN=R(N,17)
      R(N,16)=R(N,20)
      R(N,17)=R(N,21)
      R(N,21)=2*R(N,17)-HBDN
      R(N,20)=2*R(N,16)-HBUP
      QBUP=R(N,18)
      QBDN=R(N,19)
      R(N,18)=R(N,22)
      R(N,19)=R(N,23)
      R(N,22)=2*R(N,18)-QBUP
  110 R(N,23)=2*R(N,19)-QBDN
      HL=R(1,16)+R(1,18)*R(1,16)/(64.4*(R(1,4)*(R(1,16)-R(1,8))
     + R(1,6)-10.075*R(1,14)*R(1,4))**2.)
      HLDN=R(NEXIT,17)
```

```
      'GO TO 30
  120 CONTINUE

     FINAL OUTPUT

      DO 3363 IOPUT=1,3
      REWIND 7
      IRE2=IOPUT*10
      IRE1=IRE2-9
      IF (NCOND.LT.141 GO TO 3290
      WRITE(6,3418) (J,J=IRE1,IRE2)
      GO TO 3291
 3290 WRITE(6,3420) (J,J=IRE1,IRE2)
 3291 WRITE(6,3419)
      WRITE(6,3417) TWORD(ITIMINT)
 3293 IF(IOPUT-2) 3251,3252,3253
 3251 READ(7,1014) (OUT(I),I=1,21)
      GO TO 3300
 3252 READ(7,1015) (OUT(I),I=1,21)
      GO TO 33i0
 3253 READ(7,1016) (OUT(I),I=1,21)
 3300 IF (EOF(7)) 3363,3301
 3301 WRITE(6,1017) (OUT(I),I=1,21)
      GO TO 3293
 3363,CONTINUE
  121 CONTINUE
   56 FORMAT(# ICE FORMED ON REACH ≠,I5)
   57 FORMAT(≠ ICE MELTED ON REACH ≠,I5)
   58 FORMAT(# PERIMETER CHANGES IN CHANNEL U.S., D.S. = ● #,2Fl0.0)
  202 FORMAT(8A10)
  418 FORMAT(F5.0,31(F5.0,F6.2))
  560 FORMAT(1H0,20X,≠  COMPUTED H'T           ≠,
     /≠      CAPE VINCENT    ≠,
     1 (4X,F6.2)/,≠      KINGSTON        ≠, (4X,F6.2)/,
     ≠      OGDENSBURG 2  ≠, (4X,F6.2)/,≠      CARDINAL        ≠,
     (4X,F6.2)/,≠      IR'IQUOIS:
     '3H.W.   ≠, (4X,F6.2),/
     3              ≠      IRIQUOIS T.U. ≠,
     1 (7X,F6.2)/,≠      YADDINGTON      ≠, (7X,F6.2)/,
     ≠      MORRISBURG 3  ≠, (7X,F6.2)/,
     ≠      LONGSAULT DAM  ≠, (7X,F6.2)////)
  561 FORMAT(≠ DISCHARGE AT P.H.= ≠,F10.0,≠ NTS= ≠,F10.0)
  776 FORMAT(2X,A10,2X,10F11.4)
  780 FORMAT(1H0,35X,≠PRINTOUT OF CHANNEL CHARACTERISTICS ARRAY FOR
     REAC  1HES ≠,I2,≠ TO ≠,I2,/)
  902 FORMAT(2I5)
  903 FORMAT(3F5.0,I5,2F6.2,F10.0,3I5)
  904 FORMAT(5X,15F5.2)
  905 FORMAT(5X,7F10.0,5X)
```

```
 906 FORMAT(5X,15F5.0)
 907 FORMAT(F10.0,I5)
 908 FORMAT(15F5.4)
 909 FORMAT(≠TROUBLE IN MATRIX AT IER=≠,I5,≠KIT=≠,I5)
 910 FORMAT(6F10.4)
 911 FORMAT(≠NUMBER OF ITERATIONS=≠,I5,≠SDH,SDQ=≠,2(1X,F8.2))
 912 FORMAT(≠+ROUGHNESS FOR EACH REACH:≠/2(1X,15F6.4/))
 913 FORMAT(≠+ICE THICKNESS FOR EACH REACH:≠/2(1X,15F6.0/))
 914 FORMAT(≠+ICE ROUGHNESS FOR EACH REACH:≠/2(1X,15F6.4/))
 915 FORMAT(≠+PERIMETER FOR EACH REACH:≠/2(1X,15F6.0/))
 918 FORMAT(/20(≠-≠),≠TIME IN≠,A5,≠=≠,F6.2,≠LAKE ONTAR 10 = ≠
    1,F6.2,≠LAKE ST LAURENCE=≠,F6.2,20(≠-≠))
 919 FORMAT(≠REACH≠,10(F5.0,3X)/,≠STAGE≠,10(F6.2,2X)/,
    ≠FLOW  ≠, 110(F8.0)/)
 939 FORMAT(10X,2F10.0,3F5.2,I5)
1014 FORMAT(F5.0,10(F5.0,F6.2),20(11X))
1015 FORMAT(F5.0,10(11X),10(F5.0,F6.2),10(11X))
1016 FORMAT(F5.0,20(11X),10(F5.0,F6.2))
1017 FORMAT(F5.0,2X,10(F5.0,F7.2,≠  ≠))
3417 FORMAT(1X,A5,1X,10(2X,≠Q≠,5X,≠H≠,4X))
3418 FORMAT(≠1REACH:≠,10(I7,6X))
3419 FORMAT(7X,10(≠------------+≠))
3420 FORMAT(≠0REACH:≠,10(I7,6X))
4002 FORMAT(≠HANGING DAM ROUTINE IS  ENTERED≠)
4003 FORMAT(4F12.4)
7600 FORMAT(≠1≠)
7601 FORMAT(≠1≠,55(≠*≠),≠DATA FOR ST LAURENCE MODEL≠,55(≠*≠)/≠≠,
    1   55(≠*≠),3X,2A10,3X,55(≠*≠)///)
7602 FORMAT(4X,≠NUMBER OF REACHES≠,28(≠.≠),I5,33X,
    1≠TIME INCREMENT.....≠,F6.2,A5/4X,≠NUMBER OF NODAL POINTS≠,
    223(≠.≠),I5,33X,≠TIME ENDING......≠,F6.1,A5/4X,≠PSI≠,42(≠.≠)
    3,F5.2/4X,≠AREA OF LAKE ONTARIO≠,25(≠.≠),E9.3,≠ SQ.FT.≠/4X,
    4≠AREA OF DOUNSTREAM FOREBAY≠,19(≠.≠),E9.3,≠SQ.FT.≠,19X,
    5≠NUMBER OF NEWTON-RAPHSON ITERATIONS......≠,I3/4X,
    6≠NUMBER OF REACHES FLOWING FROM UPSTREAM......≠,I5,30X,
    7≠OUTPUT OPTION≠,28(≠.≠),I3/4X,≠REACH ENTERING FOREBAY≠,
    8 23(≠.≠),I5///)
7603 FORMAT(6X,≠ICE IS INCLUDED≠/6X,15(≠-≠)///)
7634 FORMAT(6X,≠HANGING DAM IS INCLUDED≠/6X,23(≠-≠)/4X,
    1≠NUMBER OF HANGING DAMS......≠,I5/4X,
    2≠BOUNDRY OR NODE............≠,3F5.0/4X,≠REACH≠,22(≠.≠),
    3F5.0/4X, 3≠THICKNESS≠,18(≠.≠),3F5.2,/4X,≠LENGTH≠,21(≠.≠),
    3F5.0/4X, 4≠MANNINGS ROUGHNESS..........≠,3F5.3///)
7605 FORMAT(4X,≠INITIAL DISCHARGE≠,13(≠.≠),F10.0,≠CFS≠/4X,
    1≠INITIAL NET TOTAL SUPPLY......≠,F10.0,≠CFS≠///)
7606 FORMAT(21X,≠NODAL POINT INFORMATION≠/21X,25(≠-≠)/8X,
    1≠NO.≠,6X,≠NO. O    F NO. OF≠,9X,≠REACHES INVOLVED≠/16X,
    2≠INCOMING≠,2X,≠OUTGOING≠/13X,2(3X,≠REACHES≠)/)
7607 FORMAT(4I10,5I5)
```

```
7610 FORMAT(1X,13(≠*≠),20X,10(≠*≠),50X,10(≠*≠),2A10,13(≠*≠))
7620 FORMAT(/////)
7621 FORMAT(1X,136(≠*≠)/1X,136(≠*≠))
7622 FORMAT(1X,13(≠*≠),20X,10(≠*≠),50X,10(≠*≠),20X,13(≠*≠)/1X,
    1 13(≠*≠),20X,10(≠*≠),
    2≠ST LAURENCE RIVER HYDRAULIC TRANSIENT  MODEL   ≠,10(≠*≠),
    320X,13(≠*≠)/1X,13(≠*≠),3X,≠PRINT OPTION≠,I2,3X,10(≠*≠),50X,
    410(≠*≠),20X,13(≠*≠)/1X,13(≠*≠),20X,10(≠*≠),19X,≠DEVELOPED BY≠,
    519X,10(≠*≠),20X,13(≠*≠)/1X,13(≠*≠),A6,≠INTEPMEDIATE≠,10(≠*≠)
    6,≠   GREAT LAKES ENVIRONMENTAL RESEARCH LAPORATORY≠,
    710(≠*≠),20X,13(≠*≠)/1X,13(≠*≠),≠  CALCULATIONS ARE  ≠,10(≠*≠)
    8,16X,≠ANN ARBOR,MICHIGAN≠,16X,10(≠*≠), ≠    INCLUDES:≠,7X,
    913(≠*≠)/1X,13(≠*≠),4X,≠PRINTED OUT.≠,4X,10(≠*≠),15X,2A10,
    115X,10(≠*≠),20X,13(≠*≠))
7623 FORMAT(1X,13(≠*≠),20X,10(≠*≠),50X,10(≠*≠),20X,13(≠*≠)/1X,
    113(≠*≠),20X,10(≠*≠),≠ PERIOD:≠,2A10,≠TO≠,2A10,10(≠*≠),20X
    2,13(≠*≠)/1X,13(≠*≠),20X,10(≠*≠),10X,≠PURPOSE:  #*2410*10X*
    310(≠*≠),20X,13(≠*≠)/1X,13(≠*≠),20X,10(≠*≠),50X,10(≠*≠),20X,
    413(≠*≠))
7625 FORMAT(////51X,≠GEOGRAPHICAL KEY TO REACH NUMBERS≠/51X,33(≠-≠)
    1///48X,≠1.....KINGSTON≠/48X,
    2≠2.....CAPE VINCENT≠/48X,
    3≠3.....NORTH O  F WOLFE ISLAND≠/48X,
    4≠4.....NORTH OF HOWE ISLAND≠/48X,
    5≠5.....SOUTH OF HOWE ISLAND≠/48X,
    6≠6.....FLOW RETWEEN WOLFE  IS.  AND GRINDSTONE IS.≠/48X,
    7≠7.....SOUTH O  F GRINDSTONE ISLAND≠/48X,
    8≠8.....NORTH OF GRINDSTONE ISLAND≠/48X,
    9≠9.....FLOW EETWEEN GRINDSTONE  IS.  AND WELLSLEY IS.≠/47X,
    1≠10.....SOUTH OF WELLSLEY ISLAND≠/47X,
    2≠11.....NORTH O  F WELLSLEY ISLAND≠/47X,
    3≠12.....SOUTH O  F WELLSLEY ISLAND≠/47X,
    4≠13.....SOUTH OF GRENADIER ISLAND≠/47X,
    5≠14.....HILLCREST POINT≠)
7626 FORMAT(47X,≠15.....BROCKVILLE≠/47X,
    7≠16.....OGDENSPURG≠,/47X,
    8≠17.....NORTH OF GALOP ISLAND≠/47X,
    9≠18.....SOUTH OF GALOP ISLAND≠/47X,
    1≠19.....CARDINAL≠/47X,
    2≠20.....IROQUOIS≠/47X,
    3≠21.....NORTH O  F OGDEN ISLAND≠/47X,
    4≠22.....WADDINGTON≠/47X,
    5≠23.....SOUTH OF OGDEN ISLAND≠/47X,
    6≠24.....MORRISPURG≠/47X,
    7≠25.....NORTH OF CROIL ISLAND≠/47X,
    8≠26.....SOUTH OF CROIL ISLAND≠/47X,
    9≠27.....FLOW BETWEEN CROIL IS. AND LONG SAULT IS.≠/47X,
    1≠28.....NORTH OF LONG SAULT ISLAND≠/47X,
    2≠29.....SOUTH O  F LONG SAULT ISLAND≠/47X,
    3≠30.....LONG SAULT DAM≠)
     STOP
     END
```