

NOAA Technical Memorandum ERL GLERL-24

UPPER ST. LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL

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Ann Arbor, Michigan
October 1978



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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.

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

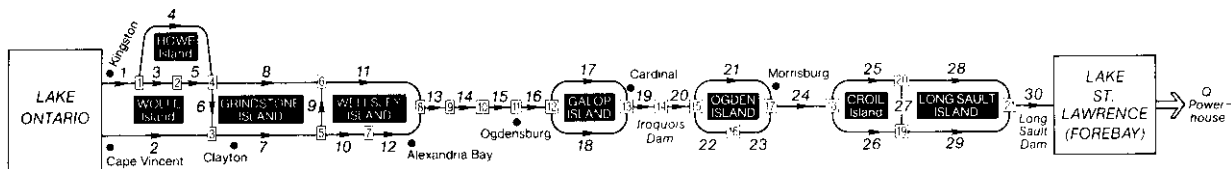


Figure 1. St. Lawrence River *conceptualized* transient model.

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

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

$$\frac{2Q}{A} Q_x - \frac{Q^2}{A^2} A_x + gAH_x + \frac{gn^2 Q |Q| \bar{A}}{2.208 \bar{A}^2 \bar{R}^{4/3}} + Q_t - \frac{T T_p}{p} = 0 \quad (2)$$

where

Q = mean discharge in a reach,

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

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

A_x = 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 $\left(T_x = C_d \rho_a V_w^2 \right)$,

T = channel top width,

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

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

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:

$$\frac{\theta(Q_d^p - Q_u^p) + (1 - \theta)(Q_d - Q_u)}{AX} + \frac{\bar{T} [(H_d^p - H_d) + (H_u^p - H_u)]}{2\Delta t} = 0 \quad (3)$$

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

where $\theta = \Delta t_m / \Delta t$, 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 $t + \Delta t$. The magnitude of A_b is

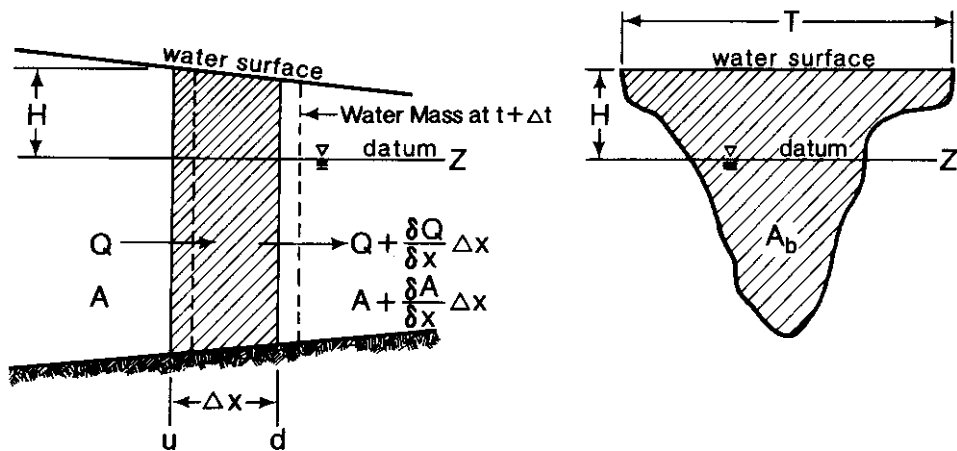


Figure 2. Definition sketch.

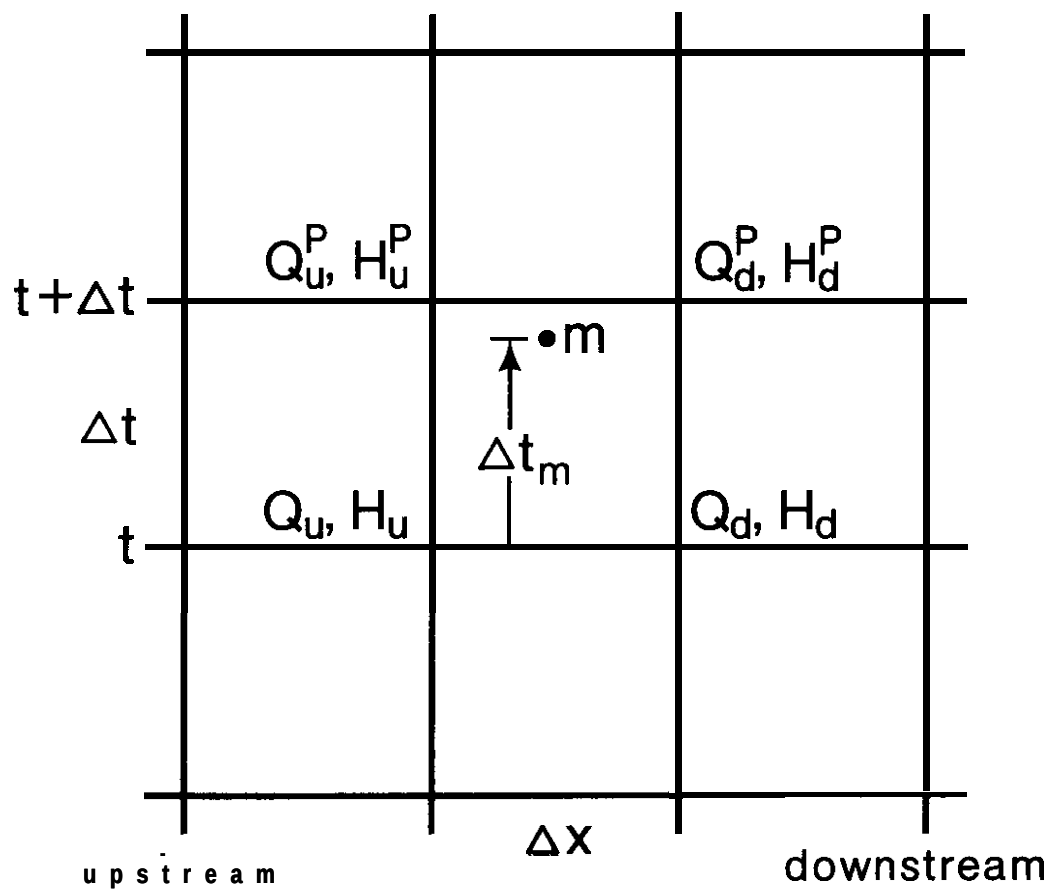


Figure 3. Time-space grid for implicit solution.

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

$$\begin{aligned} & \frac{2\bar{Q}}{\bar{A}} \left[\frac{\theta(Q_d^P - Q_u^P) + (1 - \theta)(Q_d - Q_u)}{AX} \right] + \frac{\bar{Q}^2 T}{\bar{A}^2 \Delta X} \\ & \times \left[\theta \left[(H_d^P - Z_d) - (H_u^P - Z_d)_I + (1 - \theta) \left[(H_d - Z_d) \right. \right. \right. \\ & \left. \left. \left. - (H_u - Z_u) \right] + A_{bd} - A_{bu} \right] + \frac{g\bar{A}}{\Delta X} \left[\theta(H_d^P - H_u^P) \right. \right. \\ & \left. \left. + (1 - \theta)(H_d - H_u) \right] + \frac{g_n^2 \bar{Q} \bar{Q} \bar{A}}{2.208 \bar{A}^2 R^{4/3}} \right. \\ & \left. + \frac{Q_d^P + Q_u^P - (Q_d + Q_u)}{2At} - \frac{T_x T}{P} = 0 \right. \end{aligned} \quad (5)$$

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

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

and,

$$H_u^P - H_d^P = 0 \quad (7)$$

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.

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

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:

$$\frac{\Delta S}{\Delta t} = A_s \frac{\Delta H}{\Delta t} \quad (9)$$

Substituting into equation (8) and rearranging yields

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

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

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}^{ph} = the surface area of the powerhouse reservoir pool, km^2 .

The superscript p indicates the solution at time increment $t + \Delta t$. 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

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

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

$$\frac{\partial F_{c1}}{\partial H_{iu}} = \frac{\partial F_{c1}}{\partial H_{id}} = T/2\Delta t \quad (13)$$

$$\frac{\partial F_{c1}}{\partial Q_{iu}} = -\theta/L \quad (14)$$

$$\frac{\partial F_{c1}}{\partial Q_{id}} = \theta/L \quad (15)$$

The partial derivatives of the momentum equation are approximated as

$$\begin{aligned} \frac{\partial F_{mi}}{\partial H_{iu}} = & \frac{-2\bar{Q}}{\bar{A}^2} Q_x \frac{\bar{\Theta T}}{2} + \frac{2\bar{Q}^2}{\bar{A}} A_x \frac{\bar{\Theta T}}{2} + \frac{\bar{Q}^2}{\bar{A}^2} \frac{\bar{\Theta T}}{\Delta X} \\ & - g\bar{A} \frac{\bar{\Theta}}{\bar{A}\bar{X}} + g H_x \frac{\bar{\Theta T}}{2} \frac{(7/3)\bar{Q}^2 n^2 \bar{P}^{4/3}}{\bar{A}^{10/3}} \frac{\bar{\Theta T}}{2} \\ & + \frac{4/3\bar{Q}^2 n^2 g \bar{P}^{1/3} \bar{\Theta}}{\bar{A}^{7/3}} \end{aligned} \tag{16}$$

$$\frac{\partial F_{mi}}{\partial H_{id}} = \frac{\partial F_{mi}}{\partial H_{iu}} + \frac{2g\bar{A}\bar{\Theta}}{\Delta X} \tag{17}$$

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

$$\frac{\partial F_{mi}}{\partial Q_{id}} \frac{\partial F_{mi}}{\partial Q_{iu}} + \frac{4\bar{Q}}{\bar{A}} \frac{\bar{\Theta}}{\Delta X} \tag{19}$$

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

$$\frac{\partial F_{cj}}{\partial H_{2K}} = 1 \tag{20}$$

where

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

$$\frac{\partial F_{cj}}{\partial H_{2k-1}} = -1 \tag{21}$$

where

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

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

where

IN = the number of reaches flowing into the node.

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

where

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

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

$$\frac{\partial F_u}{\partial H_1} = \frac{\partial F_d}{\partial H_2} = \frac{A_o}{At} \quad (24)$$

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

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

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

$$\begin{array}{ll} \partial F_d & 1 \\ \partial Q_{fb} & 2 \end{array} \quad (27)$$

$$\begin{array}{ll} \partial F_d & A_o \\ \partial H_{fb} & A_t \end{array} \quad (28)$$

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 Gaussian 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

$$\frac{g^{1/2} \bar{Q}^{2-2}}{2 \cdot 208 \bar{A}_R^{2-4/3}} + g A H_x \frac{\bar{Q}^2}{A^2} A_x = 0 \quad (29)$$

Solving for n yields

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

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 than 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), Belkon-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_m) was plotted against the ratio of the ice roughness to the Manning's roughness coefficient (n_i/n_m) from each of the three formulae (Fig. 5) in turn. A distribution of all the computed

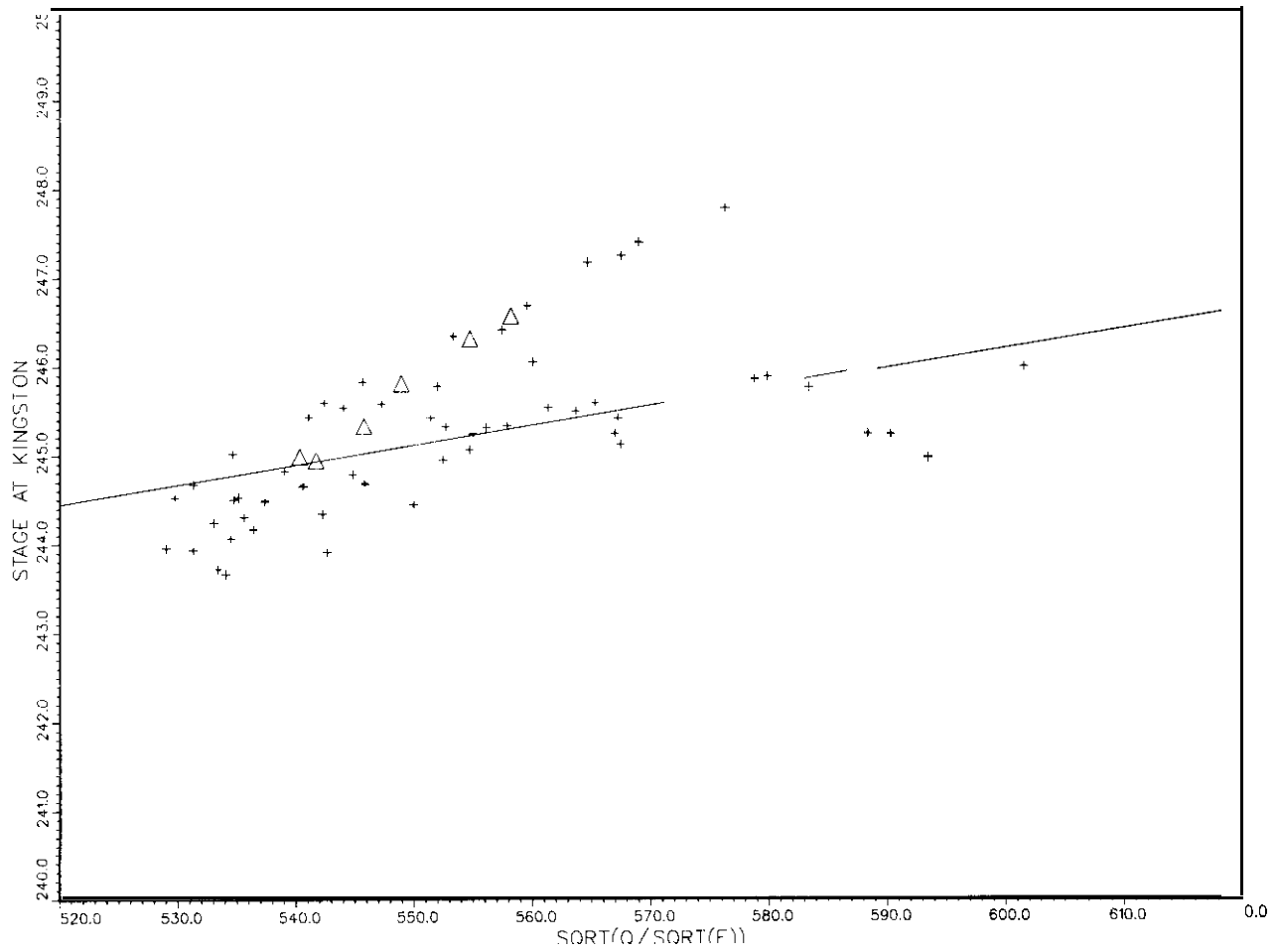


Figure 4a. Comparison of stage vs. $(Q/\sqrt{F})^{1/2}$ for prototype (+) and model (Δ) (Kingston, Ont., to Ogdensburg, N.Y.).

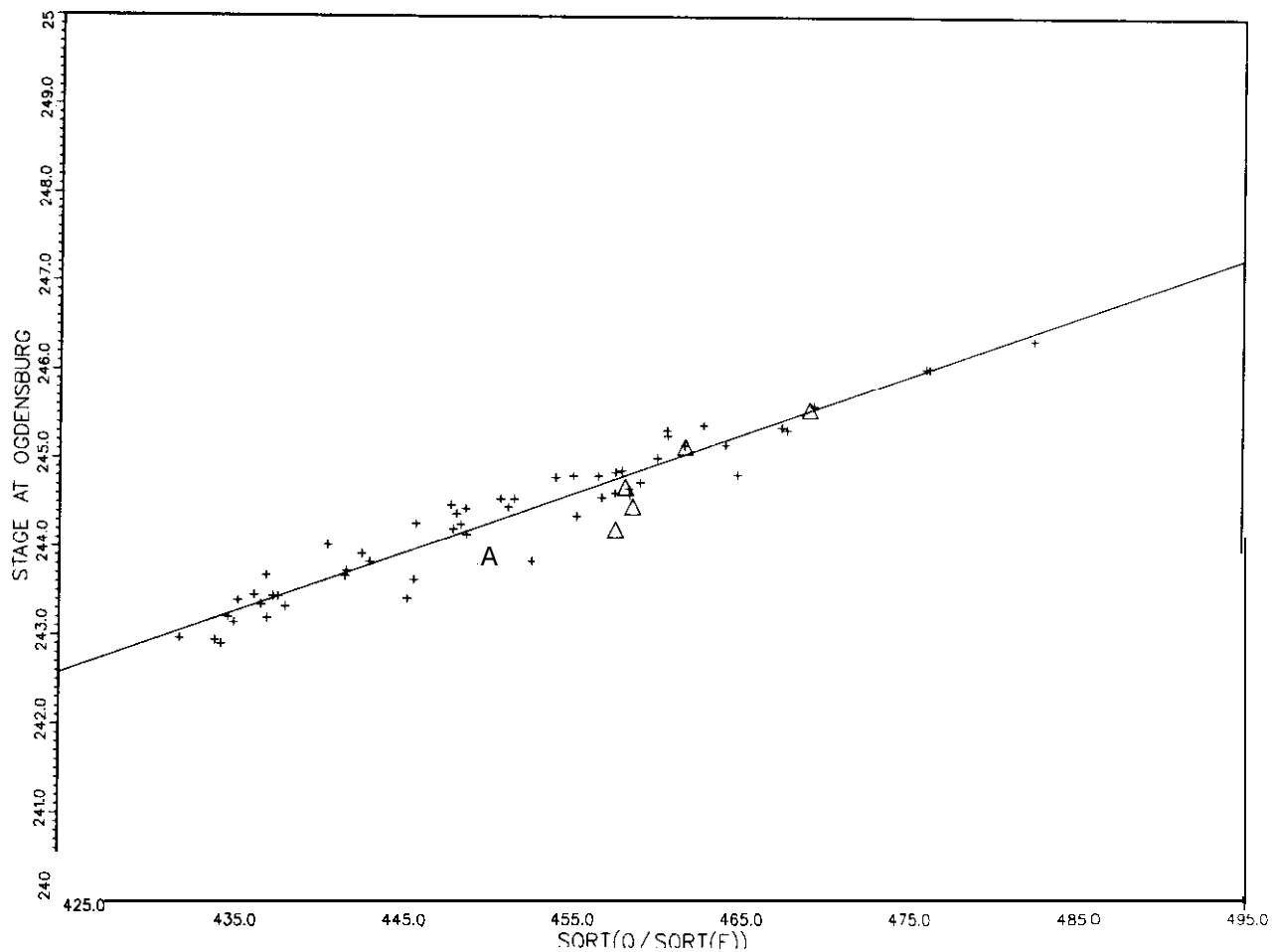


Figure 4b. Comparison of stage vs. $(Q/\sqrt{F})^{1/2}$ for prototype (+) and model (Δ) (Ogdensburg, N.Y., to Cardinal, Ont.).

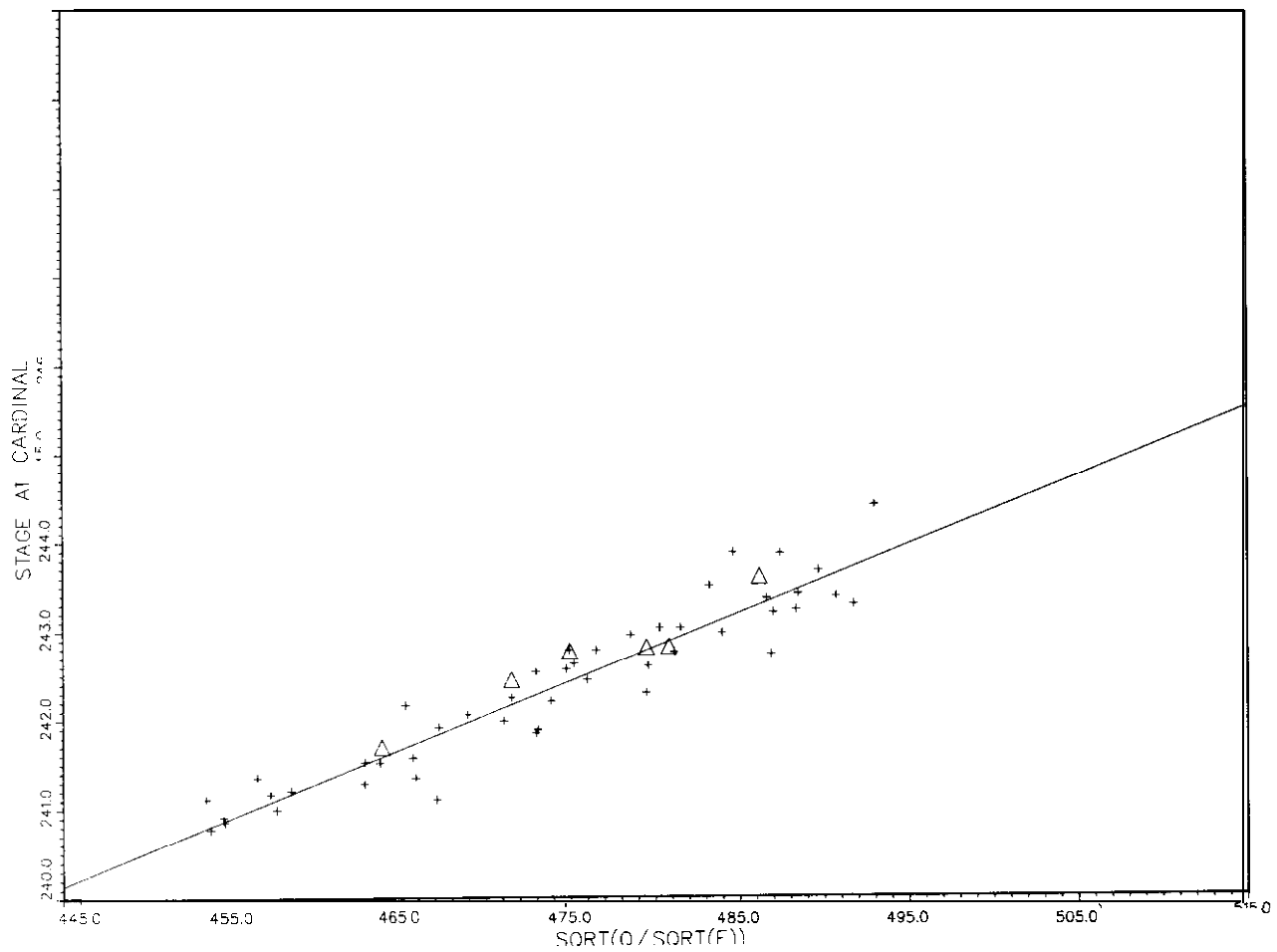


Figure 4c. Comparison of stage vs. $(Q\sqrt{F})^{1/2}$ for prototype (+) and model (Δ) (Cardinal to Morrisburg, Ont.).

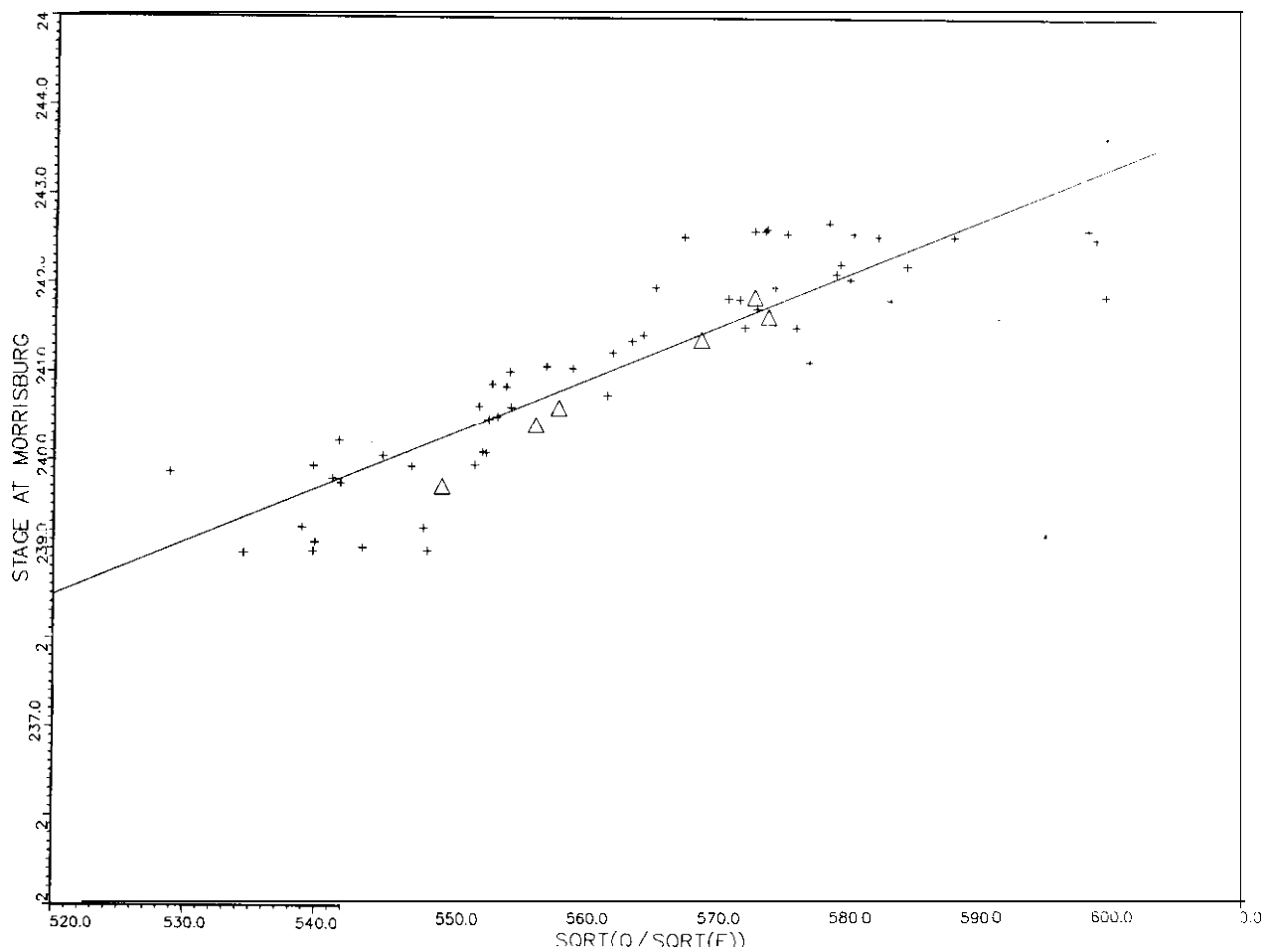


Figure 4d. Comparison of stage vs. $(Q/\sqrt{F})^{\frac{1}{2}}$ for prototype (+) and model (Δ) (Morrisburg to Long Sault, Ont.).

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

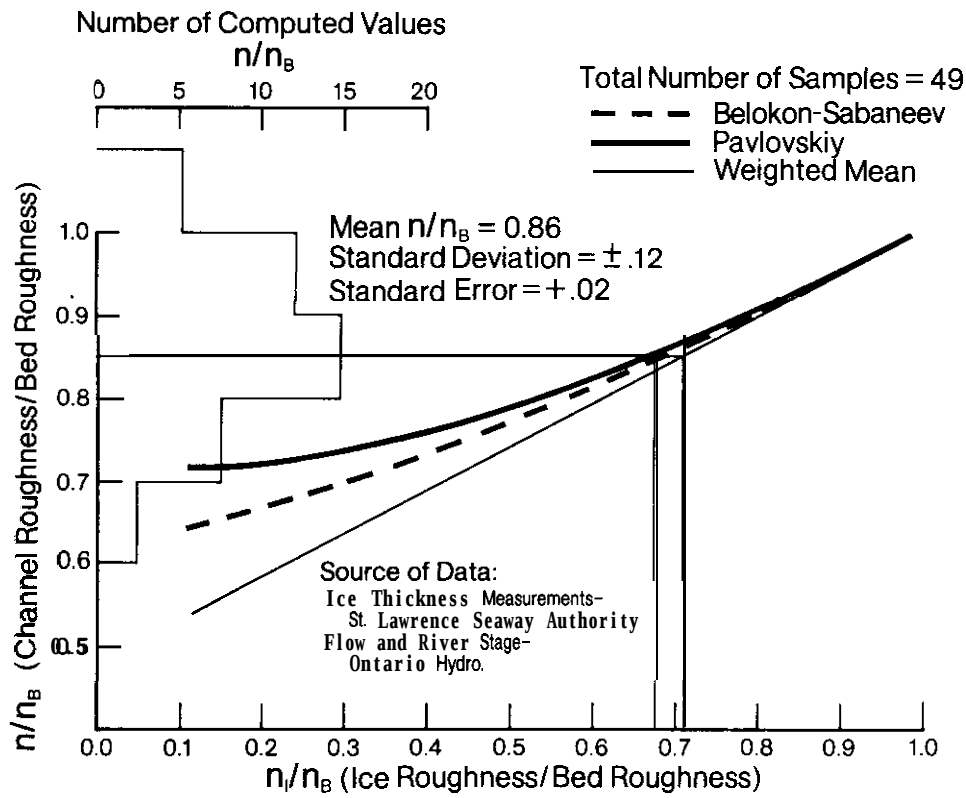


Figure 5. Determination of composite roughness in ice-covered channel.

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

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

where

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

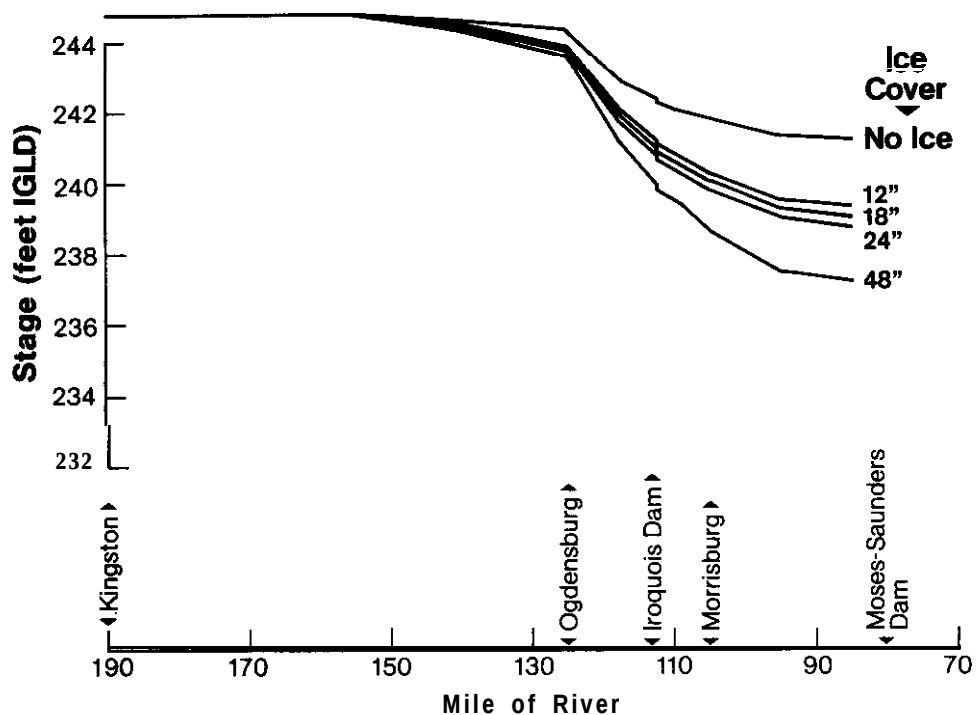


Figure 6a. Sensitivity of river profile to ice thickness. (Flow = 245 thousand cubic feet per second.)

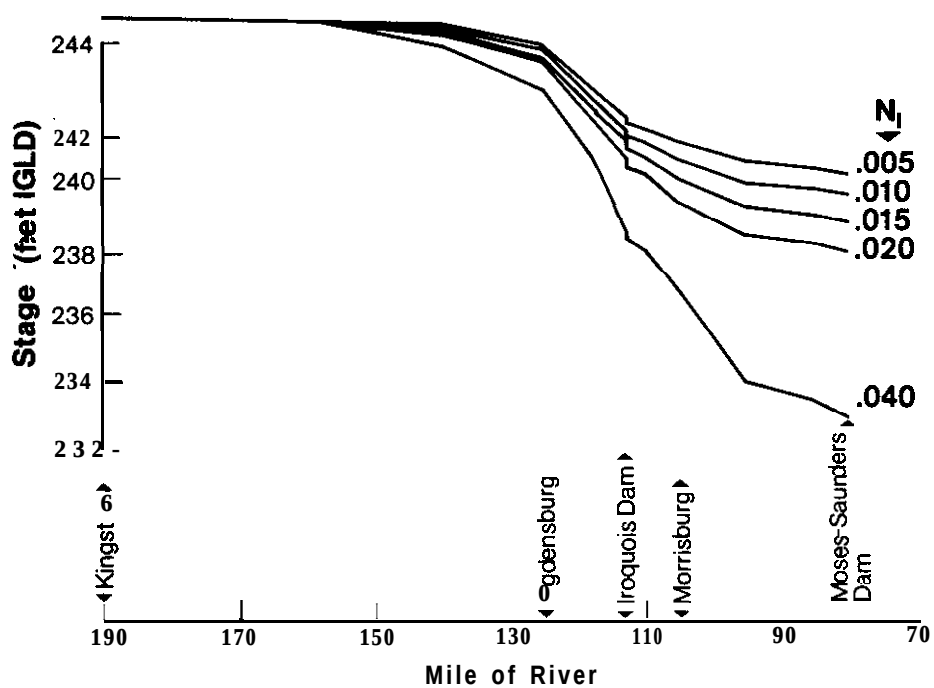


Figure 6b. Sensitivity of river profile to ice roughness. (Flow = 245 thousand cubic feet per second.)

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

$$Q_1 = Q_2 = Q_3 = Q_4$$

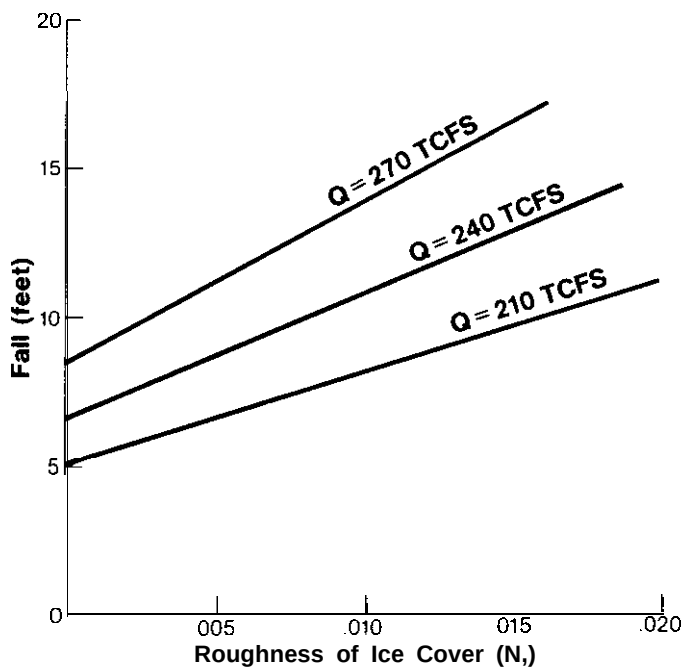


Figure 7a. *Sensitivity of fall to ice-cover roughness with 12-inch ice cover (Lake Ontario to Ogdensburg, N.Y.).*

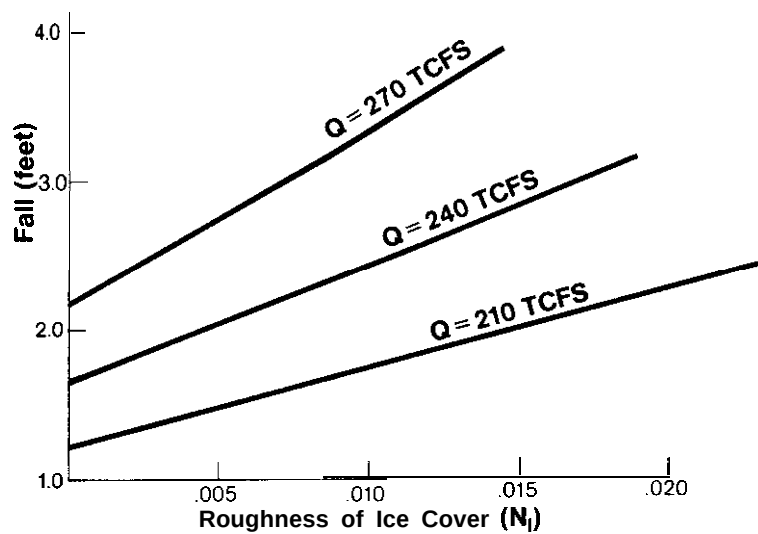


Figure 7b. *Sensitivity of fall to ice-cover roughness with 12-inch ice cover (Ogdensburg, N.Y., to Cardinal, Ont.).*

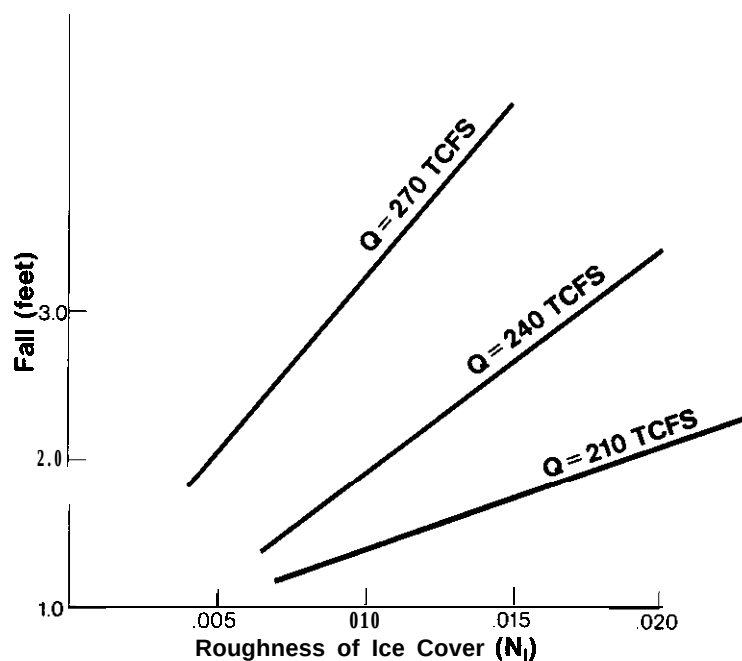


Figure 7c. Sensitivity of fall to ice-cover roughness with 12-inch ice cover (Cardinal to Morrisburg, Ont.).

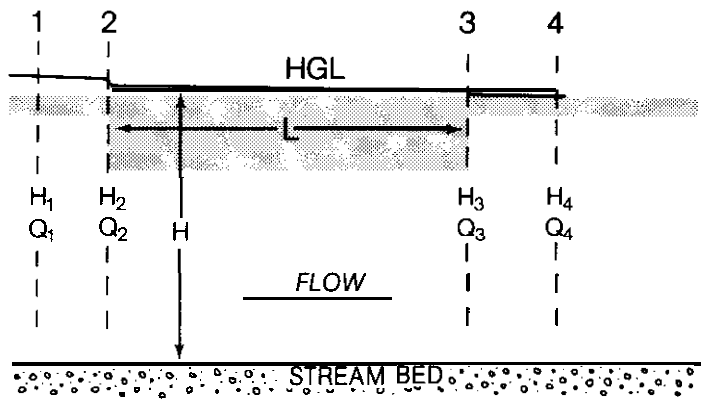


Figure 8. The hanging dam.

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				
				0-0.1 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

$$h_1 + \frac{v_1 |v_1|}{2g} = h_4 + \frac{v_4 |v_4|}{2g} + f_L + h_e + h_d, \quad (32)$$

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

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

Rewriting equation (32) yields

$$\begin{aligned} h_1 + \frac{v_1 |v_1|}{2g} = h_4 + \frac{v_4 |v_4|}{2g} + \frac{Q^2 n^2 L}{2.208 A^2 R_2^{4/3}} + 1.0 \left(\frac{v_2^2 - v_1^2}{2g} \right) \\ + 0.5 \left(\frac{v_3^2 - v_4^2}{2g} \right) \end{aligned} \quad (33)$$

Since $v_2 = v_3$ and $\frac{Q}{A} = v$, the equation reduces to

$$h_1 + \frac{1.5 Q |Q|}{2g A_1^2} - h_4 - \frac{1.5 Q |Q|}{2g A_2^2} - \frac{Q |Q| n^2 L}{2.208 A^2 R_2^{4/3}} = 0. \quad (34)$$

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.

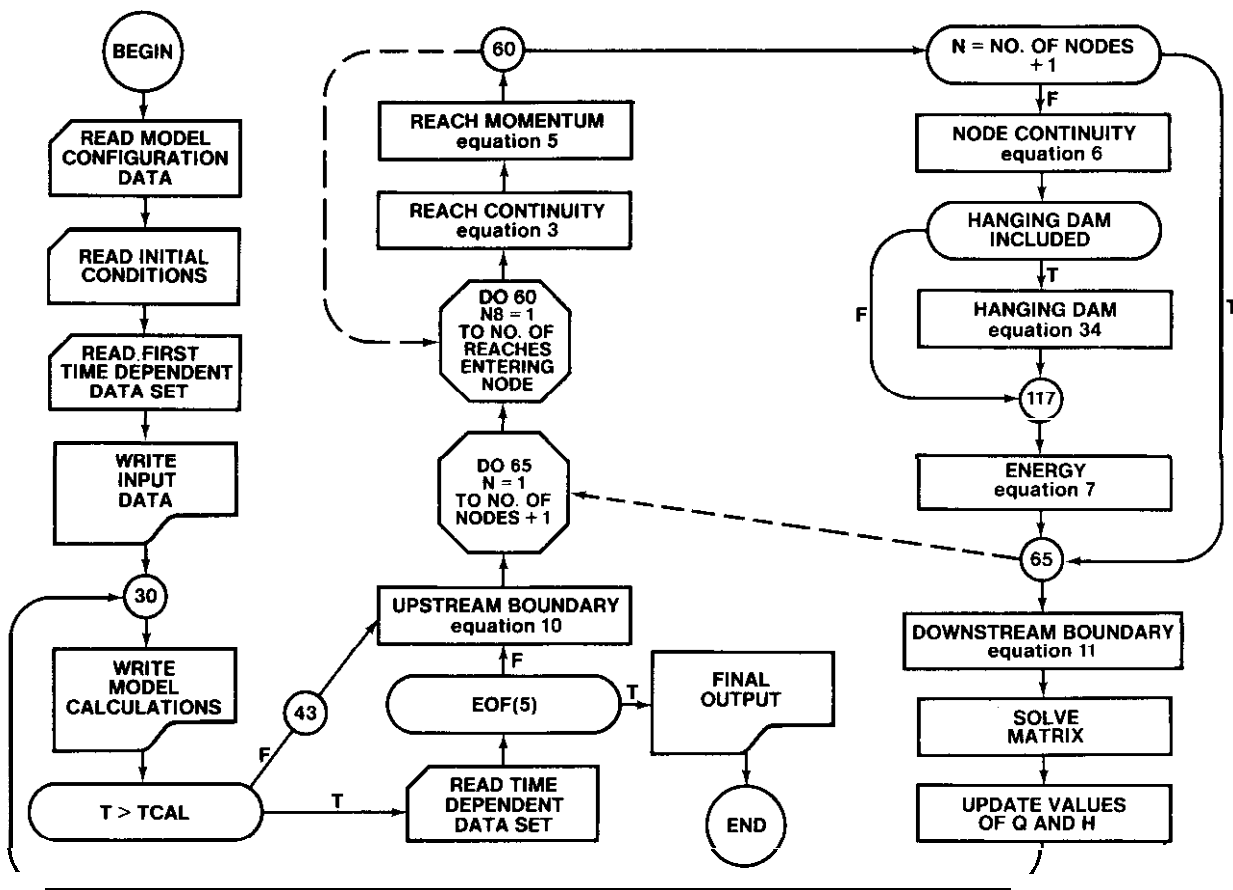


Figure 9. Flow chart.

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.

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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
 APPROPRIATELY REDUCING NR AND NB. LAKE ONTARIO
 IS ALWAYS ASSUMED TO BE THE UPSTREAM BOUNDARY.

CARD 3 (AND 4)

FORMAT(16F5.4)

R((N,13) - MANNINGS ROUGHNESS COEFFICIENTS FOR
 OPEN WATER 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 NECESSARY 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(3F5.0,15,2F6.2,F10.0,3I5)
DTT - TIME INCREMENT
TMAX - ENDING TIME
P S I - 3.75
KIT - NUMBER OF NEWTON RAPHSON ITERATIONS ALLOWED.
8 IS A SAFE MAXIMUM SINCE THE MODEL USUALLY
SUCCEEDS IN 4
HL - INITIAL STAGE AT LAKE ONTARIO
HLDN - INITIAL STAGE AT DOWNSTREAM RESERVOIR
AR - AREA 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-DONOT 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(F10.0,15)
ARES - AREA OF DOWNSTREAM FOREBAY IN SQUARE MILES
(USUALLY 15.)
NEXIT - REACH ENTERING FOREBAY (USUALLY 30)

CARD 11

FORMAT(2I5)
NUMOF - NUMBER OF 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)- BOUNDARY OR NODE AT WHICH THE DAM OCCURS

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

35

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 (AND 4) 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.
H KING- CONTROLLING STAGE AT KINGSTON. IF H KING
 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 NEW 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

[illegible][illegible]

39

Output

```
*****
*****
***** PRINT OPTION 0 *****
***** ALL INTERMEDIATE *****
***** CALCULATIONS ARE *****
***** PRINTED OUT. *****
*****
***** ST LAURENCE RIVER HYDRAULIC TRANSIENT MODEL *****
***** DEVELOPED BY *****
***** GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY *****
***** ANN ARBOR, MICHIGAN *****
***** JULY 1978 *****
***** INCLUDES: *****
***** 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 LAURENCE 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

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

NODAL POINT INFORMATION

14
11

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	0	0	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	35100.0000	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	125000.0000	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	1660.0637	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

0280.0230.0280.0370.0250.0320.0470.0380.0330.0350.0360.0300.0290.0260.0330
0330.0380.0260.0310.0260.0330.0330.0400.0400.0400.0470.0470.0400.0400

----- 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. 1. 0. 1. 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.

REACH 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 1. 0. 0. 0. 3. 0. 0. 0. 0. 0.

DISCHARGE AT P.M.= 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 241.06 241.06 240.64 240.64 240.01 240.01 239.95 239.95 239.85 239.85
 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. 11133. 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 244.92 244.92 244.87 244.66 244.49 244.29 243.87 243.87 243.84 242.58
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 244.98 244.97 244.97 244.97 244.96 244.96 244.96 244.96 244.94 244.94
FLOW 122229. 157675. 117179. 5049. 117179. -20557. 178232. 101671. 40601. 137176.

REACH 11. 12. 13. 14. 15. 16. 17. 18. 19. 20.
STAGE 244.91 244.92 244.85 244.56 244.32 244.05 243.44 243.44 243.44 242.34
FLOW 142727. 137176. 279903. 279909. 279910. 279920. 215831. 64092. 279931. 279941.

REACH 21. 22. 23. 24. 25. 26. 27. 28. 29. 30.
STAGE 241.00 241.00 240.58 240.58 239.93 239.93 239.87 239.83 239.83 239.77
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

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	244.86	243.45	243.46	242.02	242.43
FLOW	142755.	137191.	279946.	279946.	27999.6	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.	180313.	201364.	78580.	279944.

	COMPUTED HY
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 244.98 244.97 244.97 244.96 244.96 244.96 244.96 244.94 244.94 244.94
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.
CAPE VINCENT
KINGSTON
OBERNSBURG
CARDINAL
TRIQUOIS H.W.
TRIQUOIS T.W.
WADDINGTON
MORRISBURG
LONGSAULT DAM

----- 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 244.98 244.97 244.97 244.96 244.96 244.96 244.96 244.94 244.94 244.94
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.
CAPE VINCENT
KINGSTON
LONGSAULT DAM

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----- 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 241.17 241.17 240.77 240.76 240.15 240.15 240.10 240.06 240.06 240.06
FLOW 153102. 126997. 126991. 280073. 101039. 178913. 100383. 201400. 78513. 279879.

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

	COMPUTED HT
CAPE VINCENT	244.97
KINGSTON	244.98
OGDENSBURG	244.09
CARDINAL	242.25
IRIQUOIS H.W.	241.69
IRIQUOIS T.W.	241.54
WADDINGTON	241.17
MORRISBURG	240.76
LONGSAULT DAM	240.00

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----- 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.

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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.

Output

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*****
*****
***** PRINT OPTION 0 ***** ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL *****
*****
***** ALL INTERMEDIATE ***** DEVELOPED BY *****
***** CALCULATIONS ARE ***** GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY *****
***** PRINTED OUT. ***** ANN ARBOR, MICHIGAN ***** INCLUDES: *****
***** ***** JULY 1978 ***** ICE CONDITIONS *****
*****
***** * * * * * PERIOD: NONE TO NONE *****
***** * * * * * PURPOSE: SIMPLE DRAWDOWN *****
*****
*****
*****
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GEOGRAPHICAL KEY TO REACH NUMBERS

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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..... 8

ICE IS INCLUDED

HANGING DAM IS INCLUDED

NUMBER OF HANGING DAMS..... 1
 BOUNDARY 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	0	0	0
	2		8	9	1011	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	1	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	7290.0000
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	242.8000	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	14600.8505
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	168900.0000	57600.0000	232500.0000
D.S. AREA	50000.0000	43800.0000	108700.0000	200000.0000	86300.0000	150000.0000	76800.0000	168900.0000	57600.0000	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 YMK	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

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	244.96	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.M.= 280000. NTS= 280000.

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

[illegible]

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

Output

```
*****  
***** ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL *****  
***** DEVELOPED BY *****  
***** GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY *****  
***** ANN ARBOR, MICHIGAN ***** INCLUDES:  
***** JULY 1978 ***** ICE CONDITIONS  
***** HANGING DAM *****  
***** 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 INCREME NT.... 1.00 HRS  
ENDING TIME..... 1.0 HRS

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

ICE IS INCLUDED  
-----

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

59

| NODAL POINT INFORMATION |                     |                     |                  |    |    |   |   |   |   |
|-------------------------|---------------------|---------------------|------------------|----|----|---|---|---|---|
| NO.                     | NO. OF              |                     | REACHES INVOLVED |    |    |   |   |   |   |
|                         | INCOMING<br>REACHES | OUTGOING<br>REACHES |                  |    |    |   |   |   |   |
| 1                       | 1                   | 2                   | 1                | 3  | 4  | 0 | 0 | 0 | 0 |
| 2                       | 1                   | 1                   | 3                | 5  | 0  | 0 | 0 | 0 | 0 |
| 3                       | 1                   | 2                   | 2                | 6  | 7  | 0 | 0 | 0 | 0 |
| 4                       | 3                   | 1                   | 4                | 5  | 6  | 8 | 0 | 0 | 0 |
| 5                       | 1                   | 2                   | 7                | 9  | 10 | 0 | 0 | 0 | 0 |
| 6                       | 2                   | 1                   | 8                | 9  | 11 | 0 | 0 | 0 | 0 |
| 7                       | 1                   | 1                   | 10               | 12 | 0  | 0 | 0 | 0 | 0 |
| 8                       | 2                   | 1                   | 11               | 12 | 13 | 0 | 0 | 0 | 0 |
| 9                       | 1                   | 1                   | 13               | 14 | 0  | 0 | 0 | 0 | 0 |
| 10                      | 1                   | 1                   | 14               | 15 | 0  | 0 | 0 | 0 | 0 |
| 11                      | 1                   | 1                   | 15               | 16 | 0  | 0 | 0 | 0 | 0 |
| 12                      | 1                   | 2                   | 16               | 17 | 18 | 0 | 0 | 0 | 0 |
| 13                      | 2                   | 1                   | 17               | 18 | 19 | 0 | 0 | 0 | 0 |
| 14                      | 1                   | 1                   | 19               | 20 | 0  | 0 | 0 | 0 | 0 |
| 15                      | 1                   | 2                   | 20               | 21 | 22 | 0 | 0 | 0 | 0 |
| 16                      | 1                   | 1                   | 22               | 23 | 0  | 0 | 0 | 0 | 0 |
| 17                      | 2                   | 1                   | 21               | 23 | 24 | 0 | 0 | 0 | 0 |
| 18                      | 1                   | 2                   | 24               | 25 | 26 | 0 | 0 | 0 | 0 |
| 19                      | 1                   | 2                   | 26               | 27 | 29 | 0 | 0 | 0 | 0 |
| 20                      | 2                   | 1                   | 25               | 27 | 28 | 0 | 0 | 0 | 0 |
| 21                      | 2                   | 1                   | 28               | 29 | 30 | 0 | 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   | 242.8000    | 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      | .021        | .0320      | .0400       | .0380       | .0330      | .0350       |
| ICE THK    | 0.0000      | 0.0000      | 0.0000      | 0.0000     | 0.000       | 0.0000     | 0.0000      | 0.0000      | 0.0000     | 0.0000      |
| MANNINGS R | .0280       | .0230       | .0280       | .0370      | .021        | .0320      | .0400       | .0380       | .0330      | .0350       |
| 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     | 0.000       | 0.0000     | 0.0000      | 0.0000      | 0.0000     | 0.0000      |
| D.S. Q     | 0.0000      | 0.0000      | 0.0000      | 0.0000     | 0.000       | 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     | 0.000       | 0.0000     | 0.0000      | 0.0000      | 0.0000     | 0.0000      |
| D.S. QP    | 0.0000      | 0.0000      | 0.0000      | 0.0000     | 0.000       | 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    | 242.2100    | 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

[illegible]

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

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| 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. | 234.09 |
| 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 MRS  
TIME ENDING..... 97.0 MRS

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<br>INCOMING<br>REACHES | NO. OF<br>OUTGOING<br>REACHES | REACHES INVOLVED |    |    |   |   |   |  |  |
|-----|-------------------------------|-------------------------------|------------------|----|----|---|---|---|--|--|
| 1   | 1                             | 2                             | 1                | 3  | 4  | 8 | 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  | 499700.0000 | 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 | 39000.0000  | 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 | 80400.0000 | 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  | 49700.0000  | 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

[illegible]

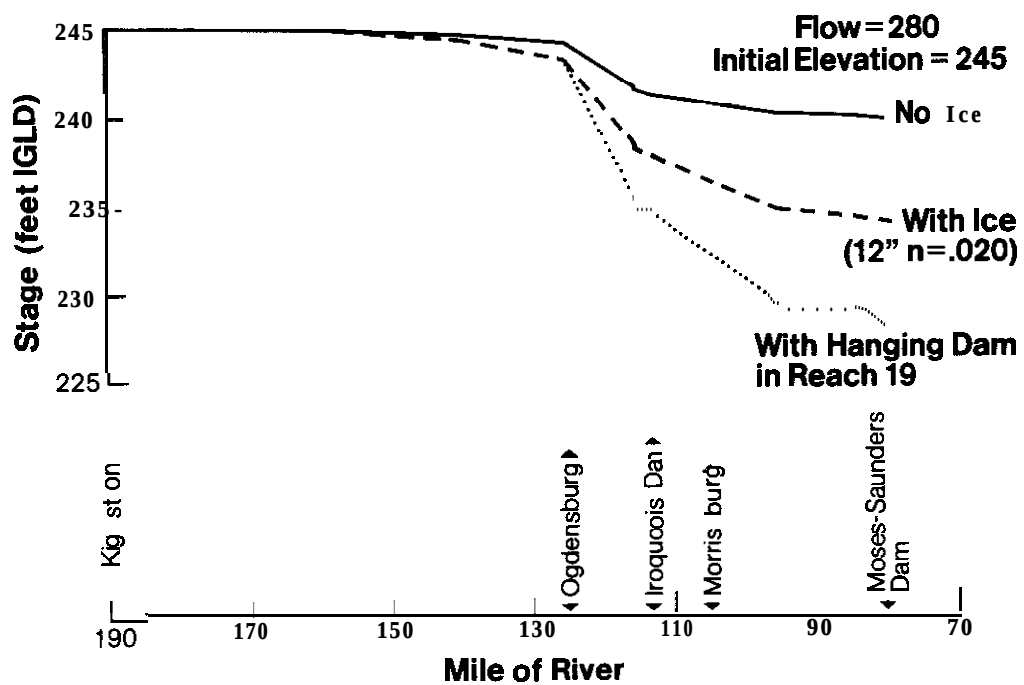


Figure B. 1. River profiles for example problems a, b, and c.

#### 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

[illegible]

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|      |       |       |       |       |       |       |       |       |       |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1    | 1     | 0.75  | 8     | 24500 | 24500 | 734c. | 1     | 2     | 0     |
| 15.  | 30    |       |       |       |       |       |       |       |       |
| 2    |       |       |       |       |       |       |       |       |       |
| ISO  | 0     |       |       |       |       |       |       |       |       |
| TSO  |       |       |       |       |       |       |       |       |       |
| 4500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 |
| 4500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 |
| 4500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 |
| 4500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 | 24500 |
| 0    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| 0    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| 0    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| 0    | 3     | 0     | 0     | 0     | 0     | 0     | 3     | 0     | 0     |
| 0    | 0     |       |       |       |       |       |       |       |       |

|         |       |        |       |
|---------|-------|--------|-------|
| 254214  | 24507 | 238350 | 24507 |
| 227330  | 24508 | 224800 | 24510 |
| 225120  | 24508 | 223260 | 24508 |
| 223880  | 24511 | 223410 | 24555 |
| 221990  | 24503 | 222925 | 24514 |
| 223930  | 24517 | 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 | 24503 |
| 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 | 24504 |
| 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 *****

***** NO INTERMEDIATE *****
***** CALCULATIONS ARE *****
***** PRINTED OUT. *****

***** ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL *****
***** DEVELOPED BY *****
***** GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY *****
***** ANN ARBOR,MICHIGAN ***** INCLUDES: *****
***** JULY 1978 *****

***** 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= | BSQH,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----- |

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----- 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-----

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----- 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-----
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----- 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 | 1           | 2           | 3           | 4         | 5           | 6           | 7           | 8           | 9          | 10          |
|-----|-------------|-------------|-------------|-----------|-------------|-------------|-------------|-------------|------------|-------------|
| 0.  | 115. 245.07 | 146. 245.07 | 107. 245.06 | 5. 245.06 | 109. 245.06 | -19. 245.06 | 165. 245.06 | 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. 245.07 | 166. 245.07 | 94. 245.07  | 38. 245.04 | 127. 245.04 |
| 2.  | 115. 245.08 | 147. 245.08 | 110. 245.07 | 5. 245.07 | 110. 245.07 | -19. 245.07 | 166. 245.07 | 94. 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. 245.04 | 156. 245.04 | 86. 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  | 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 | 5. 245.07 | 109. 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  | 245.02    | 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. 245.01 | 152. 245.01 | 86. 245.01  | 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 | -17. 245.01 | 164. 245.01 | 94. 245.01  | 38. 245.00 | 126. 245.00 |
| 20. | 142. 245.14 | 174. 245.14 | 124. 245.10 | 7. 245.10 | 121. 245.07 | -17. 245.07 | 175. 245.07 | 94. 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 | -17. 245.03 | 169. 245.03 | 94. 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. 245.05 | 173. 245.05 | 94. 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. 245.06 | 88. 245.06  | 36. 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  | 36. 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 | -24. 245.11 | 171. 245.11 | 100. 245.12 | 39. 245.09 | 130. 245.09 |
| 40. | 123. 245.15 | 156. 245.15 | 114. 245.14 | 5. 245.14 | 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. 245.13  | 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. 245.07 | 168. 245.07 | 94. 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 |

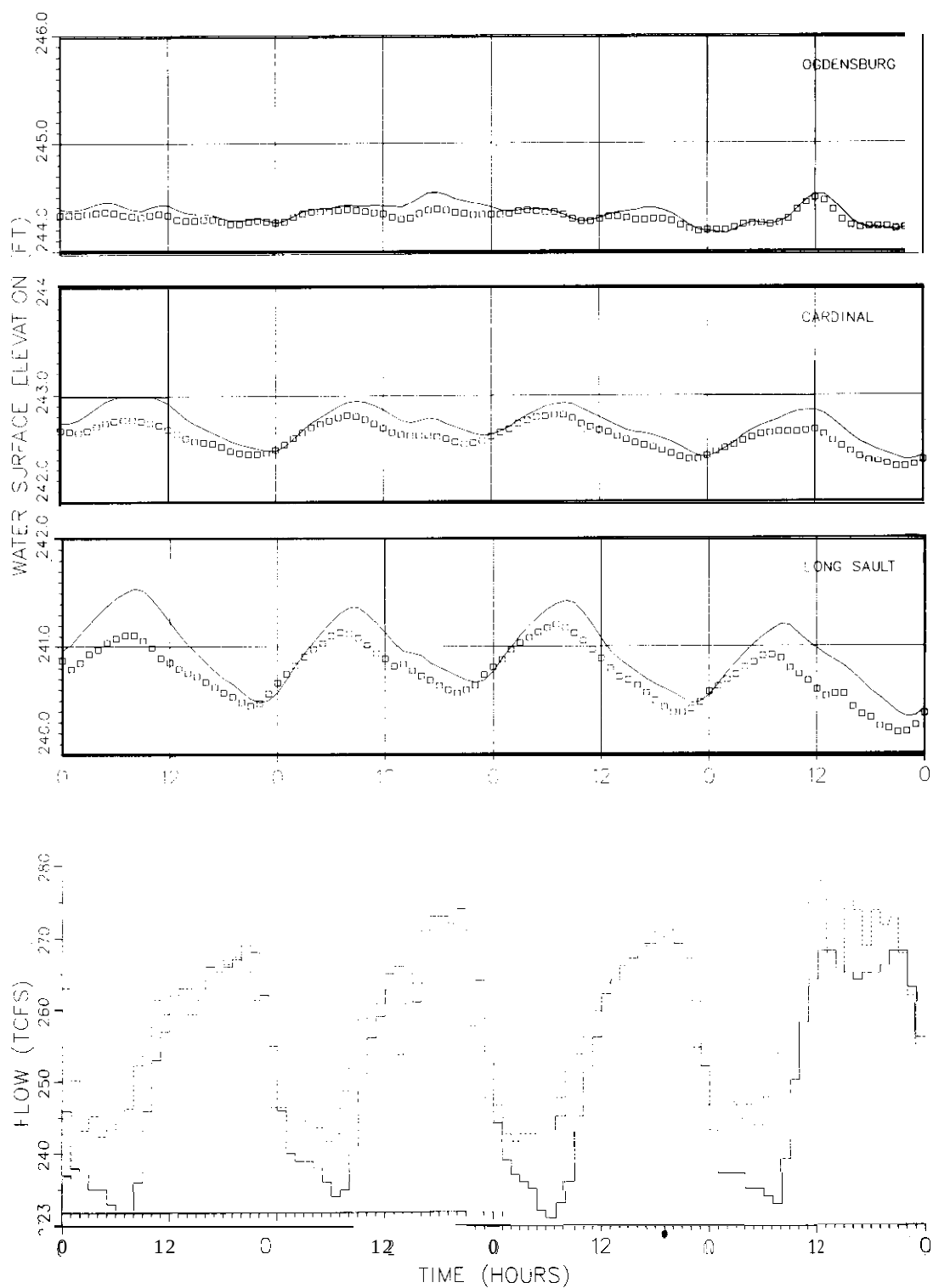
|     |      |        |      |        |      |        |    |        |      |        |      |        |      |        |      |        |     |        |      |        |
|-----|------|--------|------|--------|------|--------|----|--------|------|--------|------|--------|------|--------|------|--------|-----|--------|------|--------|
| 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. | 242.58 |
| 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. | 244.77 | 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   |        |
|--------|------|--------|------|--------|------|--------|------|--------|------|--------|------|--------|------|--------|-----|--------|------|--------|------|--------|
| NRS    | 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 | 265. | 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

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

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```

 ST LAWRENCE RIVER HYDRAULIC TRANSIENT MODEL

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```

DIMENSION R(30,23),R(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 NTS0
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
4,0,0,0,0,0,0,4.,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.,0,0,0,0,0,0,9.,17.,18.,1510.,1510.,60.4,60.4,42.78,42.74,151
20.,1510.,1660.,.030,.0000,1.,0,0,0,0,0,0,10.,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.,165.2,225.0,42.74,42.56,3620.,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,
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.,142.4,165.0,42.37,42.33,32.40,3240
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.,0,0,0,0,0,0,0,0,20.,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.,0,0,0,0,0,0,0,0,0  
 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.,0,0,0,0,0,0,0,0,0/

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 13,2,1,17,18,19,0,0,0,0,14,1,1,19,20,0,0,0,0,  
 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/

A R E A FUNCTION INCLUDING I C E C O V E R (.075\*R(N,14) I S 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,IPURF

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)
```

DOWNSTREAM BOUNDARY AND REACH NUMBER

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

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

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

READ IN HANGING DAM INFORMATION, BOUNDARY, REACH, THICKNESS OF 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)
1 4 8 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,NR
 11 WRITE(6,7607) (B(I,J),J=1,9)
 WRITE(6,7608)
 DO 779 N1=1,21,10
 N2=N1+9
 WRITE(6,7609) 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  
UPSTREAM RESERVOIR ELEV AND DOUNSTREAM ELEV  
AREA OF UPSTEAM RESERVOIR, TIME INTERVAL (1=HR, 2=DAY,  
3=WEEK,4=MONTH) PRINT FORMAT AND ISICE)

```
READ(5,903) DTT,TMAX,PSI,KIT,HL,HLDN,AR,ITIMINT,IPRTYP,ISICE
FACTOR=3600.
NCOND=TMAX/DTT+.99999
DT=720*FACTOR
TCAL=25920000.
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=DIS0
NTS2=NTS0-.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) GO TO 30
 WRITE(6,912) (R(J,13),J=1, NR)
 IF(ISICE.EQ.0) GO TO 30
 WRITE(6,914) (RICE(J),J=1, NR)
30 TH=T/FACTOR
 IF(IPRTYP.NE.0.AND.T.LT.TCAL) GO TO 40
 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),R(22,16),R(24,16),R(30,16)
33 CONTINUE
35 CONTINUE
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 TO 39
 DIS2=DIS
 GO TO 43
39 HLDN=HLDN-DELH
 GO TO 43
41 CONTINUE
 NR2=2*NR
 OUT(1)=TH
 DO 417 IOA=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

 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

 READ IN TIME DEPENDENT DATA

 IF(ISICE.EQ.0) GO TO 487
 D O 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 IFCNHDC .GT.0) GO TO 113
482 IF(ISICE.EQ.0) G O TO 49
 D O 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
5 4 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 O 43
4 2 HLDN=STAGE
43 CONTINUE
 TAUX=6.77 E-6*WIND*ABS(WIND)
 DO 100 K6=1,KIT
 DO 45 I=1,122
 DO 45 J=1,31
45 C(I,J)=0.0
 DO 46 I=1,1122
4 6 D(I)=0.
. UPSTREAM BOUNDARY CDND AT KINGSTON AND. PSEUDOREACH ABOVE CAFE
VINCENT. REACH=1=KINGSTON, REACH F.2 IS PSEUDO REACH
 QOUT=0.0
 QPOUT=0.0
 DO 44 N=1,NUMUP
 QOUT=QOUT+R(N,18)
 QPOUT=QPOUT+R(N,22)
4 7 AP=(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=1
 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.
 IF(RTIR22I.LT.G.1) C1=0.
 THETA=AR/DT
 IF(HKING.NE.0) GO TO 252
 C(1,N2H)=(1-AP*C1)*THETA
5 0 C(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
2 5 2 C(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))
* C1
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
UPSTREAM BOUNDARY COMPLETE
P=0
N4=NB+1
DO 65 N=1,N4
IF(N.EQ.N4) GO TO a 4
N7=B(N,2)
GO TO 86
a 4 N7=1
86 CONTINUE
DO 6 0 N8=1,N7
P=P+1
PERR=PER(P)
AREAR=AREA(P)
DAP=PSI*(R(P,5)*1R(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))

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 • 11(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 CO MPLETED. 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)GO T O 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 T O 63
 FALL=.014*(R(20,20)-239.)-(R(20,22)-280000)*
1.000001-.19
 IF(FALL.GE.0.)GO T O 63
 C(N1,IHOUT)=C(N1,IHOUT)+.014
 D(N1)=D(N1)+FALL
63 CONTINUE
65 CONTINUE

```

CONDITIONS AT NODES COMPLETED. NOU DODOWNSTREAM BOUNDARY

```

 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 T O 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)

```

REVERSE SIGN OF EQUATION MATRIX

```

 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
7 0 SDH=0
SDQ=0
N3=4.*NR
CNR=1.0
IF(K6.LT.3) CNR=0.5
```

UPDATE VALUES OF HP AND QP BASED ON DELTA SOLUTION VECTOR

```
DO 7 2 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)
7 2 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(1,18)/(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 3310
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. = ● #,2F10.0)
202 FORMAT(8A10)
418 FORMAT(F5.0,31(F5.0,F6.2))
560 FORMAT(1H0,2GX,# COMPUTED H'T #,
/ # CAPE VINCENT #,
1 (4X,F6.2)/,# KINGSTON #, (4X,F6.2)/,
OGDENSBURG 2 #, (4X,F6.2)/,# CARDINAL #,
(4X,F6.2)/,# IRIQUOIS:
'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 ONTARIO = #
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(#OREACH:#,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 DOWNSIDE 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#BOUNDARY 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. OF#,#X,#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(##),
 3 20X,13(##)/1X,13(##),3X,#PRINT OPTION#,I2,3X,10(##),50X,
 4 10(##),20X,13(##)/1X,13(##),20X,10(##),19X,#DEVELOPED BY#,
 5 19X,10(##),20X,13(##)/1X,13(##),A6,#INTERMEDIATE#,10(##)
 6,# GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY#,
 7 10(##),20X,13(##)/1X,13(##),# CALCULATIONS ARE #,10(##)
 8,16X,#ANN ARBOR,MICHIGAN#,15X,10(##),# INCLUDES:#,7X,
 9 13(##)/1X,13(##),4X,#PRINTED OUT.#,4X,10(##),15X,2A10,
 1 15X,10(##),20X,13(##))
7623 FORMAT(1X,13(##),20X,10(##),50X,10(##),20X,13(##)/1X,
 1 13(##),20X,10(##),# PERIOD:#,2A10,#TO#,2A10,10(##),20X
 2,13(##)/1X,13(##),20X,10(##),10X,#PURPOSE: #*2410*10X*
 3 10(##),20X,13(##)/1X,13(##),20X,10(##),50X,10(##),20X,
 4 13(##))
7625 FORMAT(////51X,#GEOGRAPHICAL KEY TO REACH NUMBERS#/51X,33(##)
 1///48X,#1.....KINGSTON#/48X,
 2#2.....CAPE VINCENT#/48X,
 3#3.....NORTH OF WOLFE ISLAND#/48X,
 4#4.....NORTH OF HOWE ISLAND#/48X,
 5#5.....SOUTH OF HOWE ISLAND#/48X,
 6#6.....FLOW BETWEEN WOLFE IS. AND GRINDSTONE IS.#/48X,
 7#7.....SOUTH OF GRINDSTONE ISLAND#/48X,
 8#8.....NORTH OF GRINDSTONE ISLAND#/48X,
 9#9.....FLOW BETWEEN GRINDSTONE IS. AND WELLSLEY IS.#/47X,
 1#10.....SOUTH OF WELLSLEY ISLAND#/47X,
 2#11.....NORTH OF WELLSLEY ISLAND#/47X,
 3#12.....SOUTH OF WELLSLEY ISLAND#/47X,
 4#13.....SOUTH OF GRENADIER ISLAND#/47X,
 5#14.....HILLCREST POINT#)
7626 FORMAT(47X,#15.....BROCKVILLE#/47X,
 7#16.....OGDENSBURG#/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 OF OGDEN ISLAND#/47X,
 4#22.....WADDINGTON#/47X,
 5#23.....SOUTH OF OGDEN ISLAND#/47X,
 6#24.....MORRISBURG#/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 OF LONG SAULT ISLAND#/47X,
 3#30.....LONG SAULT DAM#)
 STOP
 END

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