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# DESCRIPTION OF TEST CASES OF THE RIVICE MODEL

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## ABSTRACT

The RIVICE model is initially being tested on a simple 4 reach theoretical channel system having a total length of 270 km. The same channel system is being used for two test cases, identified as "Test Case 1" and "Test Case 2". Test Case 1 uses the steady state module BKWTR5 to theoretically test the linking between the various ice processes. A powerhouse is assumed at the upstream end with a constant discharge of water at 1.0°C. A discharge of 770 $m^3/s$ is released into 3 long mild slope channels with respective slopes of 0.3 m per km, 4 cm per km, and again 0.3 m per km. The last reach consists of a 20 km long lake section.

Test Case 2 will use the time varied ONEDSUB module to evaluate the storage and hydraulic transient effects which are produced during freeze-up. The initial water temperature, and hydraulic conditions are the same as in Test Case 1, along with the same constant meteorologic conditions during the simulation period.

Initially both cases are designed to produce simulations of the various ice processes including : water cooling; skim ice, frazil, and anchor ice generation; border ice progression; ice cover initiation; ice cover progression and collapse; and formation of freeze-up jams. Subsequently Test Case 2 will consider non uniform discharges occurring downstream from a typical peaking hydro-station and the effects on freeze-up. An effort will also be made to simulate breakup resulting from a rising hydrograph.

In addition to Test Cases 1 and 2, the RIVICE model will be tested on two field cases. The first case will consider the Saint-Lawrence River reach from Beauharnois to Mercier Bridge, and the second case will consider the Nelson River reach between Limestone and Long Spruce Generating Stations.

The Workshop presentation presents the partial test results obtained to date from Test Case 1, and a description of the remaining planned testing program.

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# 1.0 INTRODUCTION

All the major modules of the RIVICE model have been coded and tested individually. Currently (Sept. 1991) the modules are being linked together through the main program or "driver" which controls the computation logic and flow of information between modules.

This paper describes 4 tests which are being carried out and the results obtained from the first test. These are identified below as :

1) Test Case 1 involves testing the driver "top-down" on a theoretical 4 reach channel system with the steady state BKWTR5 module and all the other RIVICE modules.

2) Test Case 2 is similar to Test Case 1 but the hydraulic transient "ONEDSUB" module is used.

3) Test Case 3 will test the model on the St-Lawrence river between the Beauharnois Power Station and Champlain Bridge.

4) Test Case 4 will test the model on the Nelson River between Limestone and Long Spruce Generating Stations.

# 2.0 DESCRIPTION OF TEST CASE 1

## 2.1 Objectives

The objectives of this test case are :

- Test the input and preprocessing data system.
- Test the transfer of variables between the modules through the driver.

- Test the capability of the driver and its subroutines to correctly control the computation procedure.

- Test the functioning of the respective modules at the respective points in the driver during a complete river ice simulation, involving several ice processes. (As mentioned above, preliminary tests of the individual modules are being carried out, but additional testing is required to test the capability of each module in a full simulation mode).

- Test the capability of RIVICE to simulate ice conditions in a simple theoretical 4 reach system with the steady state BKWTR5 module. That is storage and dynamic effects of the ice and hydraulic conditions are neglected. This will facilitate manual verification of computed results.

- Test the capability of RIVICE to control automatically the simulation time interval as function of user specified limits of big changes in ice cover conditions.

- Test the driver subroutines that provide the various options to the user, such as the reloading and inputting of initial water temperature, ice transport, anchor ice, and ice cover conditions.

- To identify short term and long term improvements to the model.

## 2.2 Layout and Description of Initial Hydraulic Conditions

The purpose of this section is to describe the initial hydraulic conditions for a simple theoretical 4 reach channel system which is illustrated in Figure 1. The sketch shows a powerhouse at the upstream end where the water temperature would normally be higher than 0°C (unless it is a run-of-the-river plant). A constant discharge of 770 $m^3/s$ is released into 3 mild slope channels with respective slopes of 0.3 m per km, 0.04 m per km and again 0.3 m per km. The reach lengths of each of the channels are long enough to form uniform flow conditions at the upstream ends.

With a Manning n equal to 0.035 and the channel cross-sections indicated in Figure 1, the initial steady state hydraulic conditions are calculated by hand to be as follows :

Discharge = 770 $m^3/s$

| Channel Reach | Slope | Mean Velocity | Normal Depth |
|---|---|---|---|
| 1 | 0.0003 | 1.18 m/s | 4.03 m |
| 2 | 0.00004 | 0.58 m/s | 6.20 m |
| 3 | 0.0003 | 1.19 m/s | 4.03 m |
| 4 (Lake) | 0.0 | 0.019 m/s | 104. m |

## 2.3 Meteorologic Conditions

The initial water temperature is 1°C throughout the channel system described in Section 2.0. The following constant winter meteorologic conditions are imposed over the period of simulation which is taken as 2 months (60 days).

a) Air temperature, TAIR(JJ) = -30 (°C)
b) Wind speed, WINDI(JJ) = 2 (m/s)

c) Clear sky, CLPC(JJ) = 50 (%)
d) Relative humidity, HRL(JJ) = 70 (%)
e) Shade factor, FSH(JJ) = 0.05 (fraction)
f) Rain, YR(JJ) = 0.0 (mm)
g) Snowfall, YS(JJ) = 0.0 (mm)
h) Solar radiation, QSR(JJ) = 0.0 (Kcal/$m^2$/hr)
i) Mist, FMIST(JJ) = 0.0 (decimal fraction)

where JJ = 1 to NSNTOT. (NSNTOT) = Total number of cross-sections in the channel system).

## 2.4 Results Obtained to Date

### 2.4.1 Hydraulic Conditions

A comparison between the computed and theoretical normal depth flow conditions are given below. (See Figure 1 for the layout of Test Case 1 and the theoretical flow conditions).

| CHANNEL REACH NO | BOTTOM SLOPE | VELOCITY (m/s) | | NORMAL DEPTH (m) | |
|---|---|---|---|---|---|
| | | THEORY | CALCULATED | THEORY | CALCULATED |
| 1 | 0.0003 | 1.19 | 1.3 | 4.03 | 4.2 |
| 2 | 0.00004 | 0.58 | 0.60 | 6.20 | 6.10 |
| 3 | 0.0003 | 1.19 | 1.3 | 4.03 | 3.9 |
| 4 (lake) | 0.0 | 0.018 | 0.018 | 104.0 | 104.0 |

The computed depth tends to be slightly lower than the theoretical normal depth for the following main reason : The steady-state BKWTR5 module computes a pseudo-two dimensional velocity distribution across the channel in order to evaluate the local flow velocity in front of the border ice as it is progressing across the river. Even though no border ice is included in these initial test results, a non-uniform velocity distribution is computed across the channel as function of the conveyance of each sub-section and a common slope of the energy grade line. This normally results in a slightly lower flow depth as indicated in the above table. (Another reason for the deviation between the theoretical and calculated values is that the interpolation routine slightly modified the slope of the cross-section.

The profile of the mean velocity is shown in *Figure 2.*

### 2.4.2 Heat Balance, Ice Generation, and Anchor Ice Conditions

Following establishment of initial hydraulic conditions described above, the heat balance, ice generation and anchor ice conditions were calculated without invoking border ice, and the other ice cover modules.

The water leaving the powerhouse continues to be at 1°C. The water cools as a function of distance, and the following three types of ice are generated :

- Frazil ice in suspension.
- Frazil ice floating on the surface.
- Skim ice (or moving sheet ice).

The formulations for computing the heat fluxes, water temperature, and each of the above ice quantities are described by Holder and Saadé(1).

The preliminary results of the simulated profile of heat flux at the air-water interface, and accumulated quantities of generated ice are shown in Figures 3 and 4 respectively.

## 2.5 Future Testing to Complete Test Case 1

Test Case 1 will include linking the following modules to the driver and analytically verifying the corresponding results obtained from the following simulation tests :

- Testing the border ice module BORDICE.
- Testing the ice cover initiation module ICECI.
- Testing the ice cover evolution module after complete ice covers have formed.
- Testing the evolution of hydraulic conditions during freeze-up as the extent of border ice and complete ice covers increase.
- Testing the evolution of ice covers during break-up and formation of break-up ice jams. (The discharge will be increased until break-up occurs).
- Testing the capability of the output module to generate summary output tables.
- Testing the model's, capability of automatically controlling the simulation time interval as a function of calculated big changes in hydraulic and/or ice cover conditions; (i.e. the computations are repeated with an automatically calculated reduced time interval if big changes in ice cover are encountered, and vice versa).

## 3.0 DESCRIPTION OF TEST CASE 2

### 3.1 Overall objectives

The overall objectives of Test Case 2 is to link ONEDSUB in RIVICE and to simulate the capabilities of the model to correctly predict dynamic effects occurring during ice cover freeze-up. Subsequently attempts will be made to simulate the highly dynamic effects associated with break-up of ice covers.

### 3.2 Description of Testing Program

In summary, the Test Case 2 program will consists of the following :

- Repetition of the simulation tests similar to Test Case 1 (described in section 2.0)

  However, the hydraulic transient ONEDSUB module will be used instead of the steady state BKWTRS module.

- Analysis of ice conditions subjected to a rising hydrograph

  From 770 $m^3/s$ to 5000 $m^3/s$ (see Figure 5). The effects on the following ice processes will be examined and verified:

  a) Heat balance including water temperature, skim and frazil ice generation, and anchor ice generation and release.

b) Reduction in growth rate of border ice and its anticipated break-up.

c) Reduction in the progression and/or potential telescoping of ice covers in reach 3.

d) Erosion of the expected hanging dam in the reservoir as sketched in Figure 6, and corresponding deposition of ice fragments downstream in reach 4.

e) Expected partial break-up of the ice cover in reaches 1 and 3, and ice jamming in the downstream end of each of theses reaches, or in reaches 2 and 4.

- Simulation of ice conditions downstream, a powerhouse used for peaking purposes.

  The initial steady state conditions will be established under the discharge of 770 $m^3/s$, used previously, and a 1°C water temperature considered throughout the channel system. Subsequently the discharge varies over a 24 hr cycle outlined in Figure 7.

  The objectives of this test is to evaluate the capability of the model to simulate transient conditions downstream of a powerhouse, and to compare the ice regime obtained under the cyclical discharge pattern with that obtained with a constant relatively low discharge of 770 $m^3/s$.

## 4. TEST CASE 3 - ST-LAWRENCE RIVER REACH

Excellent prototype date is available on the St-Lawrence River in the Montreal region. The ice conditions of the river were well documented during intensive winter field observations and measurements during the early to mid 80's for the Lachine Rapids Project (Project Archipel) undertaken by Hydro-Quebec. The proximity of Montreal's Dorval Airport with its meteorological data supplies the input data necessary for the heat balance module.

All three type of generated ice (SKIM, FRAZIL and ANCHOR) are known to occur under certain weather conditions within the reach as well large expanses of border ice.

The river reach between Beauharnois Power Station and Mercier Bridge is planned for testing RIVICE's capabilities of simulating the above mentioned ice types.

Unfortunately, the only ice process not covered in this reach is ice cover progression. The ice passes straight through from one end to the other without stopping anywhere. It is suggested that a reach of the Nelson River be used to test ice cover progression, as described below.

## 5.0 TEST CASE 4 - NELSON RIVER REACH

In the winter of 1989-90, the reservoir of Limestone Generating Station was partially impounded in the final stage of construction of the plant. The purpose of this was to form and maintain a stable ice cover through the winter. The cover began to form in mid-November and had advanced 23 km upstream by mid-winter. The point where it stalled was approximately 1.5 km downstream of Long Spruce Generating Station. The ice cover was up to 5 m thick in some areas. Water levels were monitored continuously at Long Spruce, at Limestone, and at 3 gauge locations along the river. River flows were known on an hourly basis throughout the winter, and varied daily from about 1000 to as much as 4500 $m^3/s$. The average flow was approximately 2300 $m^3/s$.

The Nelson River in this reach is approximately 1000 m wide and has an average bed slope of approximately 0.001. The controlled and monitored conditions for this period provide prototype data which can be used to test the modules of RIVICE which control ice cover evolution. An exception to this will be the Border Ice Module, because of the limited extent of border ice formation in this reach of the Nelson River. If time permits, RIVICE will also be tested on the 100 km reach of river between Limestone Generating Station and the estuary at Hudson Bay, in which there is less, but still ample information on the ice cover characteristics.

## REFERENCES

1) Holder, G. and R. Saadé; Design of Heat Balance, Ice Generation and "Cover Modules", 6th Workshop on the Hydraulics of River Ice, Oct. 23-25, Ottawa.

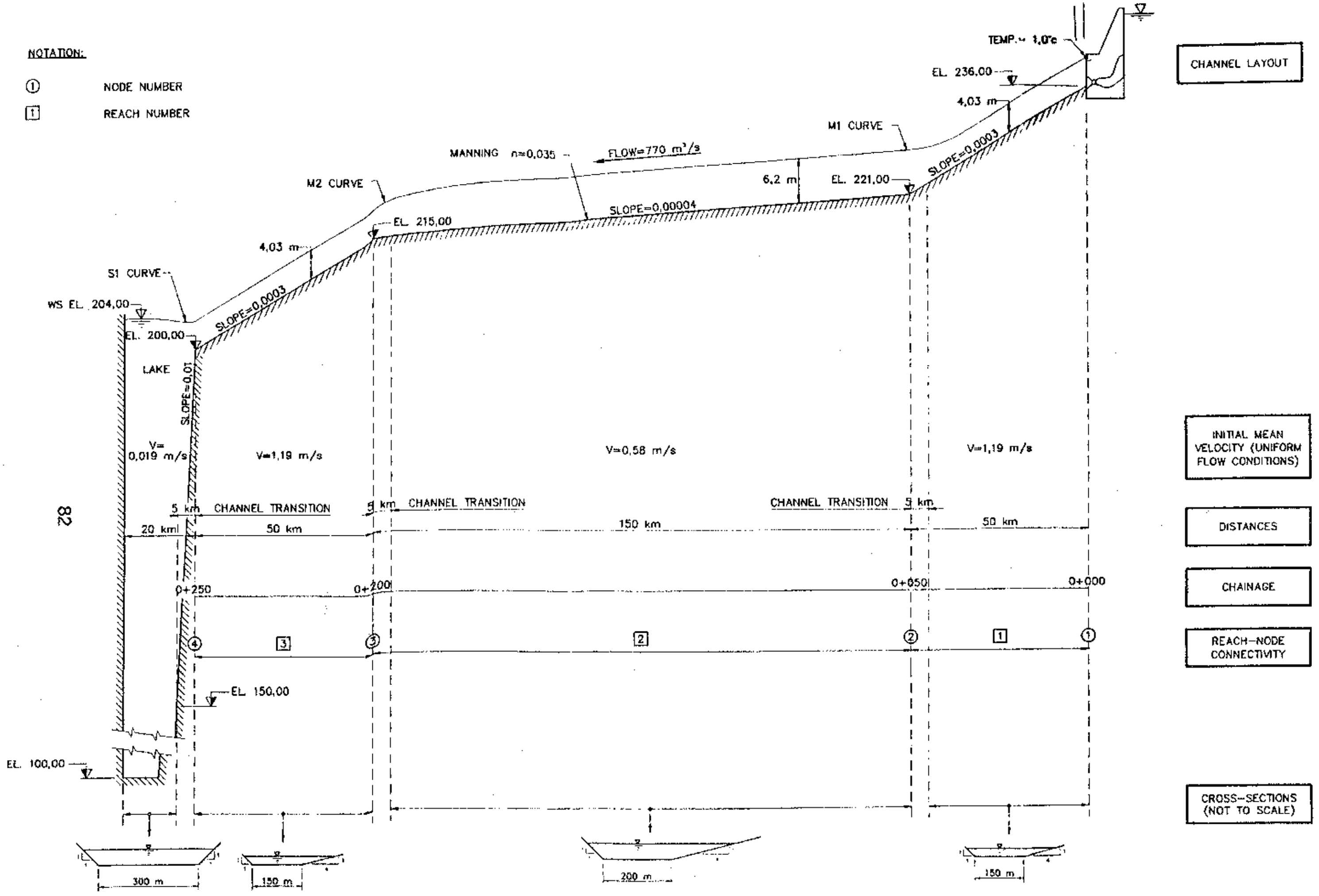

FIGURE 1

LAYOUT AND DESCRIPTION OF INITIAL FLOW CONDITIONS

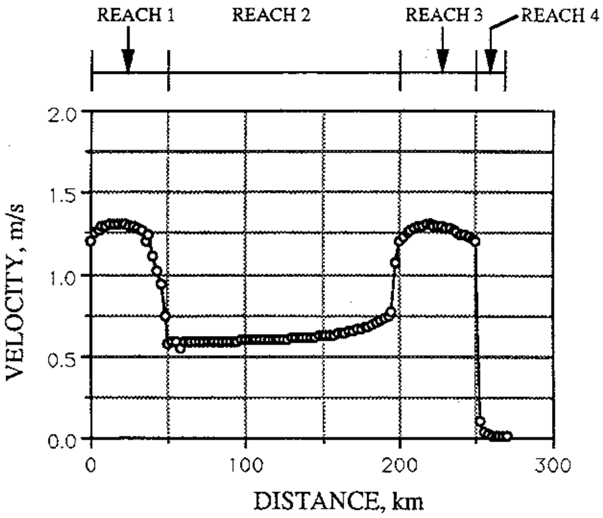

Figure 2. Mean Velocity Distribution for Initial Flow Conditions.

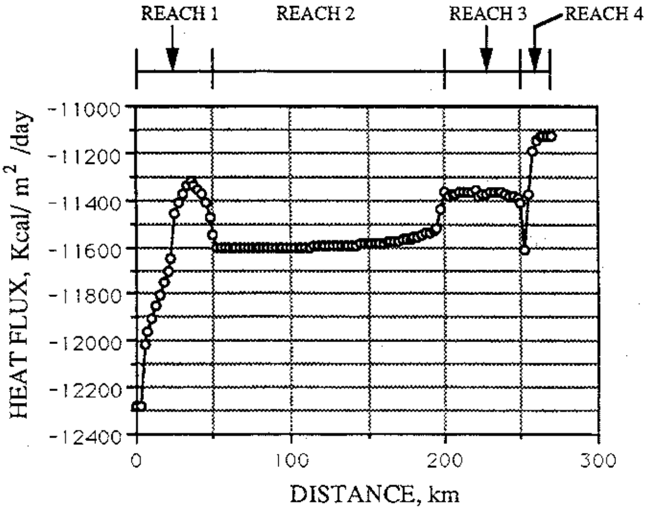

Figure 3. Profile of the Heat Flux at the Water-Air Interface.

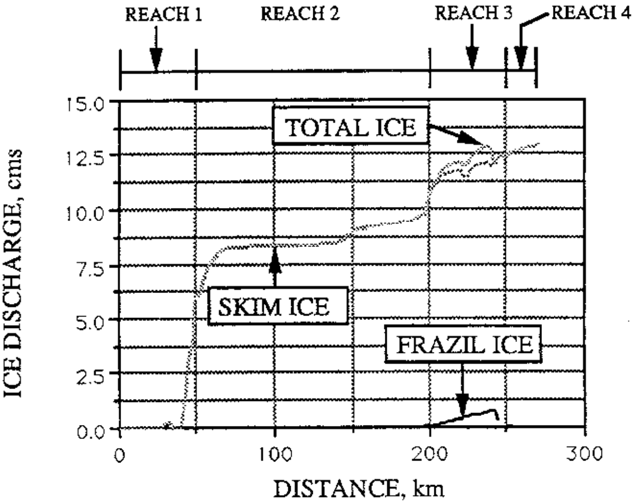

Figure 4. Profile of Accumulated Quantities of Ice Generated.

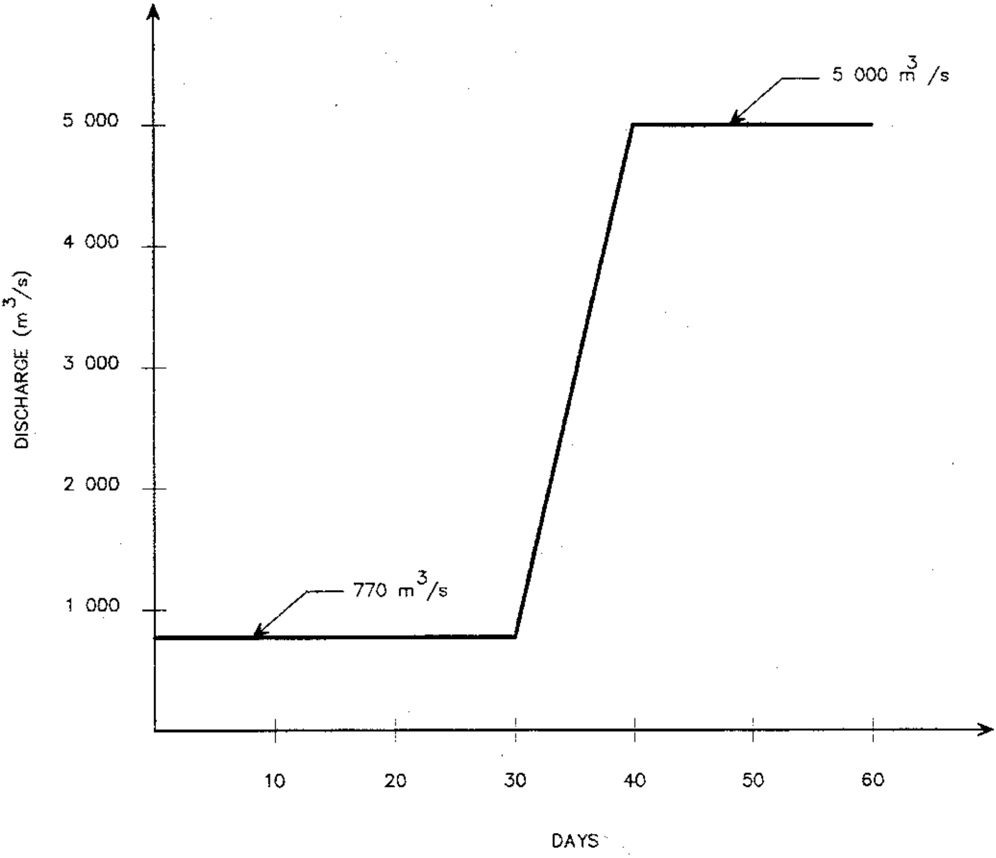

FIGURE 5 : RISING HYDROGRAPH EXAMPLE

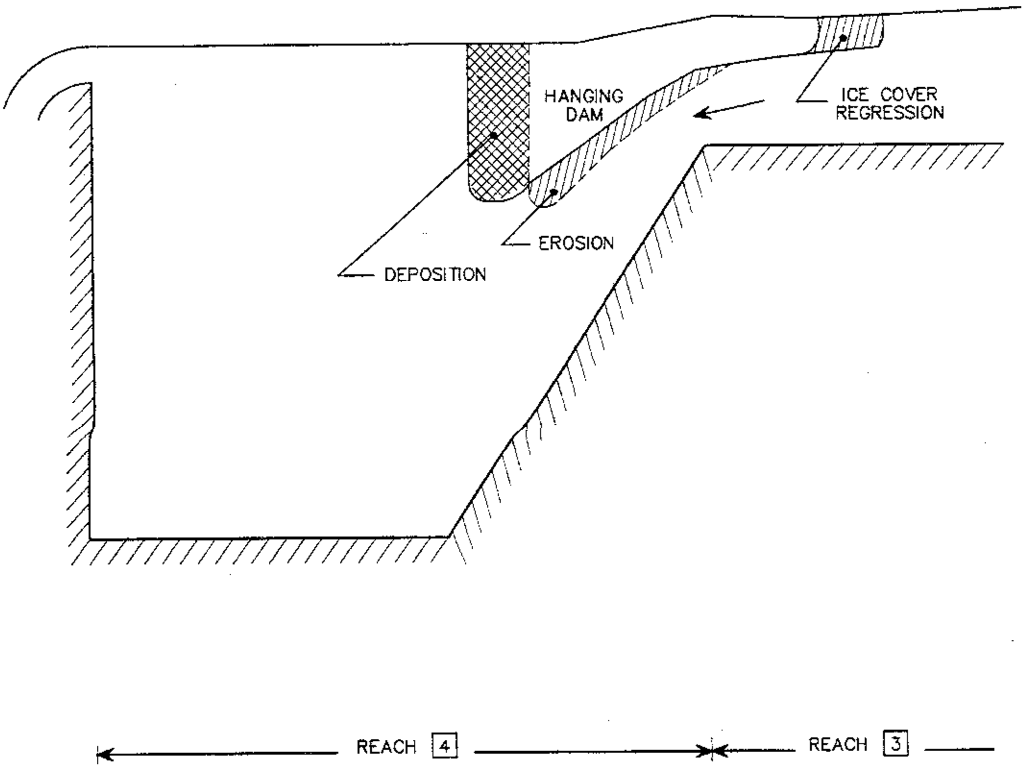

FIGURE 6 : EXPECTED ICE COVER EVOLUTION DUE TO INCREASING DISCHARGE

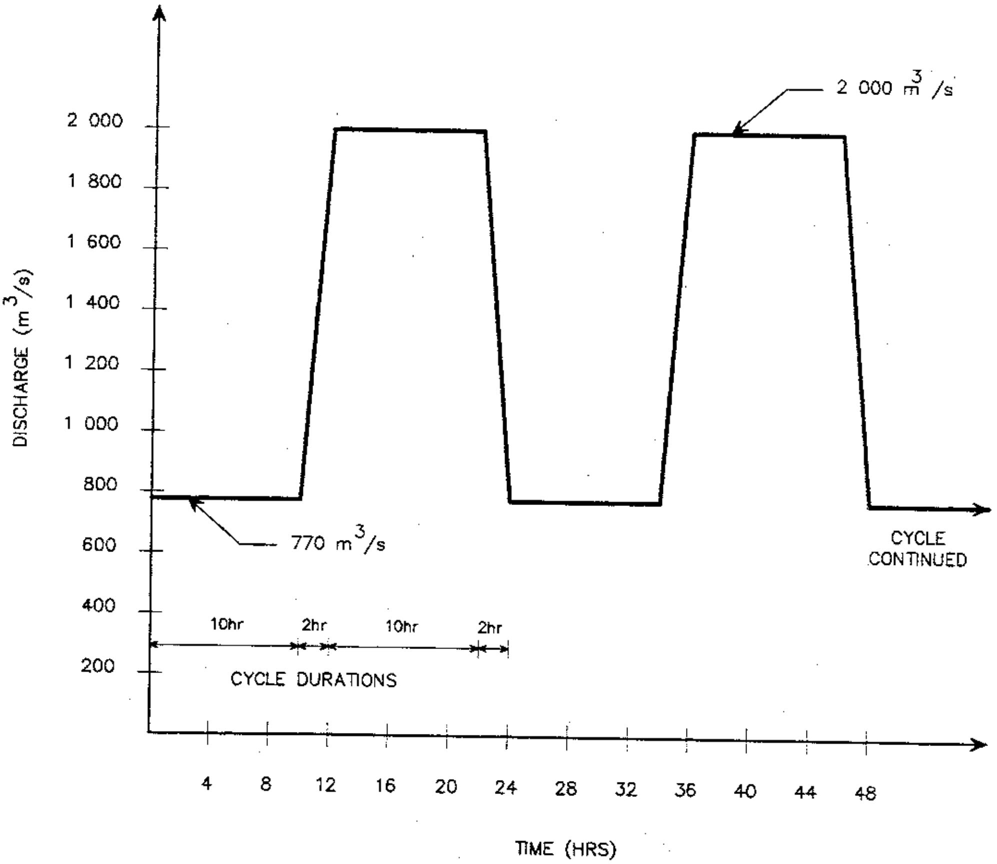

FIGURE 7 : EXAMPLE DISCHARGE PATTERN DOWNSTREAM OF A POWERHOUSE