# SPRING FLOOD FORECAST SERVICE ON THE SAINT JOHN RIVER BASIN

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## ABSTRACT

In the spring of 1973, a Flood Forecasting Unit was established for the purpose of Flood Forecasting on the Saint John River utilizing a computerized flood forecasting model, (SSARR), developed by the North Pacific Division of the Corps of Engineers.

This paper describes the organization of the Unit, the data collection network, application of the SSARR model to the Saint John River Basin, the daily forecast service and a description of the 1973 Spring Flood in the Saint John River Basin.

## INTRODUCTION

Flood forecasting in the Saint John River Basin is not new. It has been undertaken in the past with varying degrees of sophistication. In the early 1960's, the New Brunswick Electric Power Commission attempted to utilize a computerized forecast system. The results were somewhat unsatisfactory and the system proved cumbersome because computer processing had to be undertaken on a computer in Niagara Falls, Ontario. It was not continued and for several years following this attempt, intuition and manual methods were used to forecast floods by the New Brunswick Electric Power Commission. Also, in recent years, the New Brunswick Department of Fisheries and Environment attempted to do some forecasting for a single point location on the Saint John River.

Towards the end of 1972, the New Brunswick Electric Power Commission decided they would attempt to develop or obtain a computerized flood forecasting model which would adequately forecast floods at various points along the Saint John River and also its tributaries. The New Brunswick Electric Power Commission and the New Brunswick Department of Fisheries and Environment joined together in a search for available operational forecasting programs. As a result, a computerized flood forecasting program developed by the North Pacific Division of the United States Corps of Engineers was selected because it appeared suitable for application to conditions that exist in the Saint John River Basin and was readily available to adapt to the computing system in use.

## FLOOD FORECASTING UNIT

The objective of the Flood Forecasting Program was to undertake a flood forecast which would be consistent with the needs of individuals and organizations in the Saint John River Basin.

In order to carry out the objectives of the program, a Saint John

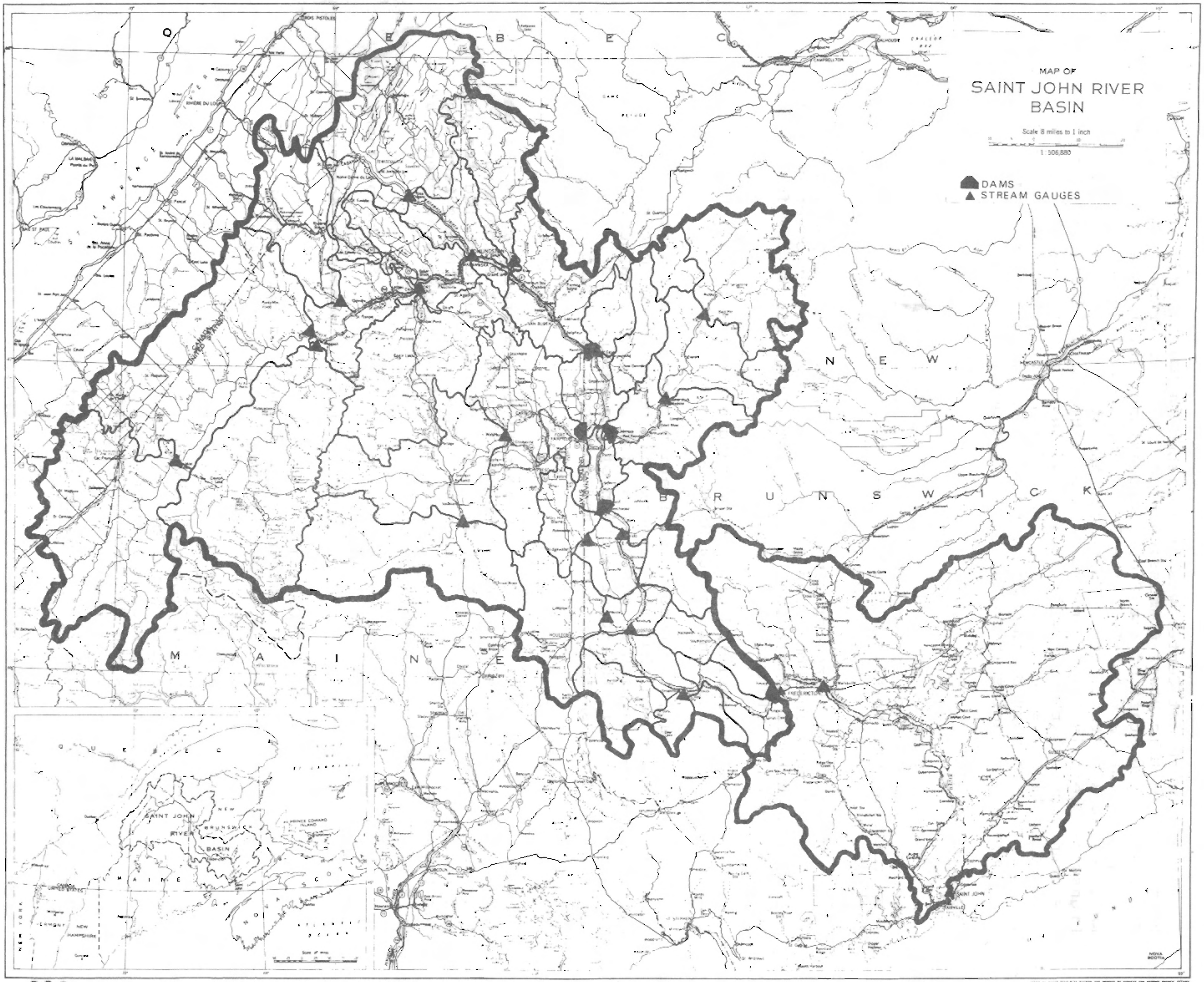

MAP OF
SAINT JOHN RIVER
BASIN
Scale 8 miles to 1 inch
1: 506,880
DAMS
STREAM GAUGES
Q U E B E C
N E W B R U N S W I C K
M A I N E
FREDERICTON
SAINT JOHN
CAMPBELLTON
NEWCASTLE
NOVA SCOTIA
SAINT JOHN RIVER BASIN
NEW BRUNSWICK
NEW HAMPSHIRE
NEW YORK



FIGURE 1

River Flood Forecast Center was established in March, 1973 at the New Brunswick Electric Power Commission Head Office in Fredericton, New Brunswick. The staff of the Flood Forecasting Center consisted of an Acting Director, a Water Resource Engineer, a Civil Technologist, an Engineering Assistant, and a Technical Assistant - all from the New Brunswick Electric Power Commission, and a Hydraulic Engineer from the New Brunswick Department of Fisheries and Environment. A subunit for data collection was set up at the Grand Falls Hydro Plant and the staff there collected most of the data for the upper portion of the basin from observers and agencies in Maine, Quebec and New Brunswick.

## HYDROLOGIC DATA NETWORK

The accuracy of the model in forecasting streamflows is highly dependent on accurate up-to-date information on actual and forecasted temperatures, precipitation, streamflow and snow accumulation data for each of the subbasins which together form the Saint John River Basin.

The existing hydrometric network was utilized where possible and this was extended in some areas so as to provide a better coverage of the basin. The network of stations used in compiling information for the model is shown on Figures 1, 2 and 3.

The network consisted of 55 Temperature and Precipitation Stations, 21 Stream Gauging Stations and 60 Snow Course Stations.

In most areas, the density of station coverage was satisfactory; however, it was hoped that the network will be expanded to cover those areas of the basin which do not have a high density of gauges. This is particularly true in the upper portion of the basin which is not heavily populated and access in the winter and spring is difficult.

## COLLECTION OF DATA

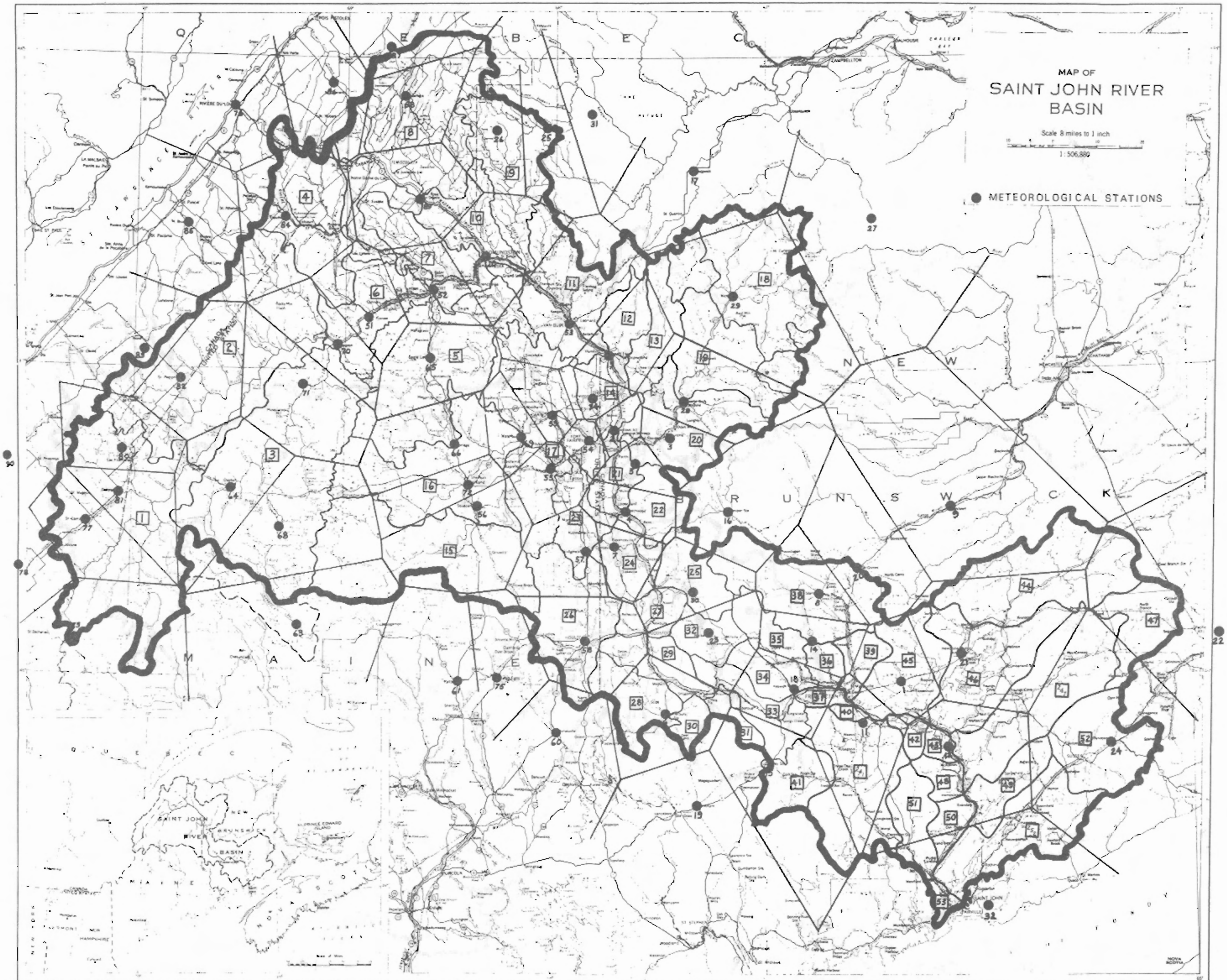
The collection of data for precipitation, temperatures and streamflow was compiled each morning at the Forecast Center for the morning forecast, and during the critical flood period data was compiled for an updated flood forecast in the afternoon. Snow course data was received for the snow courses at two week intervals, with periodic spot checks at more frequent intervals during the critical flood period.

Data was received through the co-operation of the following agencies:

- The Federal Department of Environment, Atmospheric Environment Service
- Water Survey of Canada
- New Brunswick Department of Fisheries and Environment
- New Brunswick Department of Natural Resources
- New Brunswick Electric Power Commission
- Quebec Natural Resources
- Maine Public Service
- United States Geological Survey
- National Weather Service
- International Pulp and Paper
- Maine Parks and Recreation Commission
- Maine Forest Service

and individual observers by special arrangement for the period of spring run off.

For the purpose of flood forecasting, special arrangements were made with the Atmospheric Environment Service, Environment Canada for subjective


MAP OF
SAINT JOHN RIVER
BASIN
Scale 8 miles to 1 inch
1:506,880
METEOROLOGICAL STATIONS
Q U E B E C
N E W B R U N S W I C K
M A I N E
SAINT JOHN
NOVA SCOTIA

920

FIGURE 2

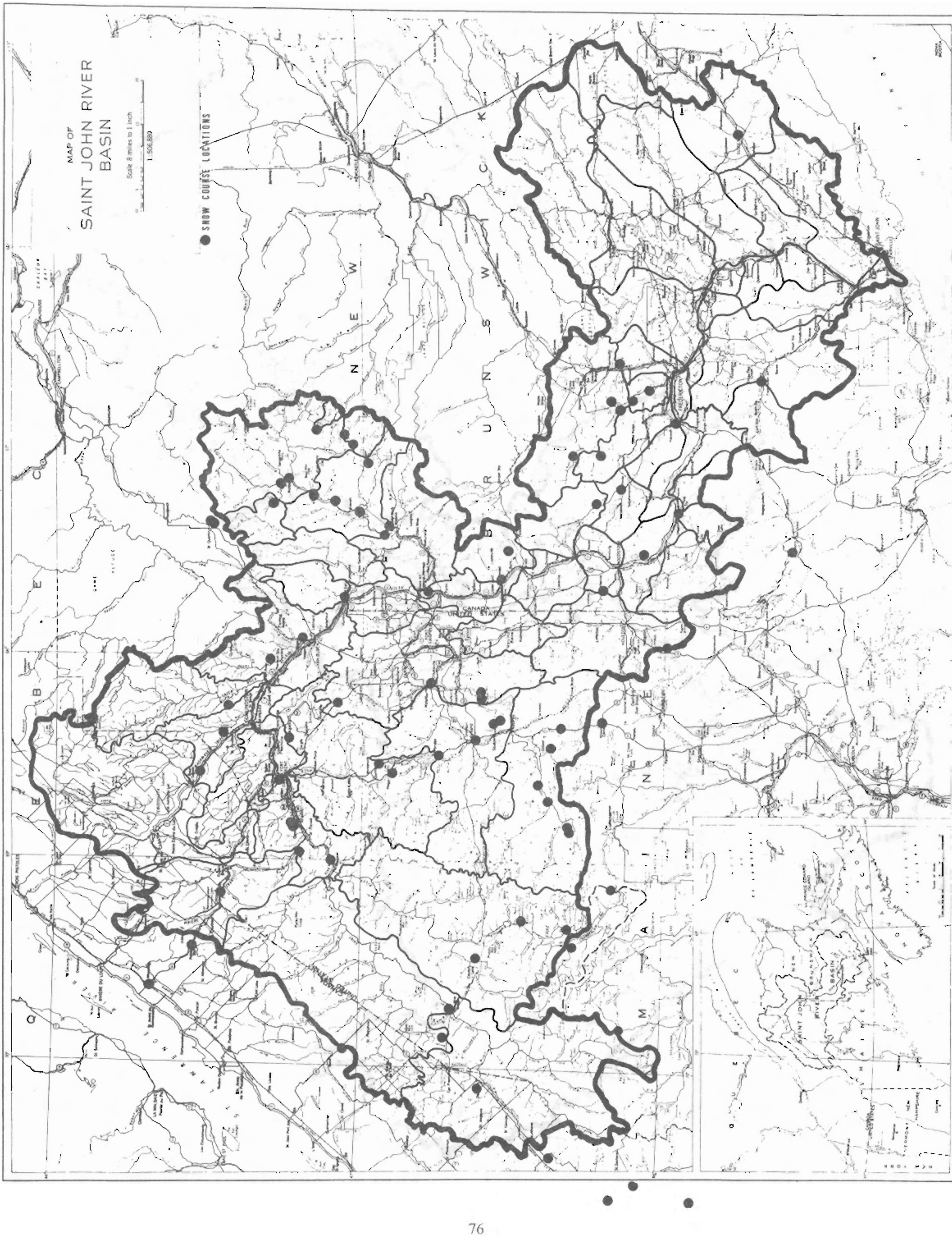

MAP OF
SAINT JOHN RIVER
BASIN
Scale 8 miles to 1 inch
1:506,880
SNOW COURSE LOCATIONS
FREDERICTON
SAINT JOHN RIVER BASIN

FIGURE 3

920

forecasts of temperature and precipitation beyond the period of the general forecasts produced at the Canadian Meteorological Center. The subjective forecasts were made by the Maritime Weather Office in Halifax and transmitted to the Fredericton Weather Office. The Fredericton Weather Office prepared forecasts for individual meteorological stations in a form which could be input to the flood forecast model for a five day period and released to the Flood Forecast Unit.

APPLICATION OF THE SSARR MODEL

The Corps of Engineers computerized Streamflow Synthesis and Reservoir Regulation Model, (SSARR), was obtained in early February, 1973. The reader is referred to the Program Description and User Manual for a detailed description of the model which is beyond the scope of this paper.

A simplified flow chart of the model is shown in Figure 4 for a typical watershed application. This figure also shows typical curves which were developed for each of the subbasins in the Saint John River Basin as shown in Figure 1. The system diagram for the Saint John River Model is shown in Figure 5, and indicates the order in which each of the subbasins were computed.

The preparation and calibration of the model began in early February, and because of a desire to have the system operational before the 1973 spring run off, an interagency task force was brought together from existing staff of the New Brunswick Electric Power Commission, the New Brunswick Department of Fisheries and Environment, and the Inland Water Directorate.

The first task in model calibration consisted of making numerous computer runs for each of the subbasins using a fall rainstorm which occurred in September and October, 1969. These runs provided the initial model parameters for simulation of run off from the subbasins and river routing in the main channel. The second task consisted of model calibration for snow melt conditions. For this, the spring run off of 1961 was used to obtain the parameters required for snow melt simulation.

Due to the short time available, calibration was carried out using only these two historic events, one of which included snow melt. The model was operational for flood forecasting in the Saint John River on March 26, 1973 and after a two week period, for final adjustment of parameters and initial conditions, the model was formally put into operation.

DAILY FORECAST SERVICE

The Flood Forecasting Program was run each morning prior to the critical period, and during the critical flood period additional runs were carried out each afternoon based on an updated weather forecast received at 1:00 p.m. each day from the Fredericton Weather Office. As each new run was made, the previous day's forecast was updated to correct for changes in input forecast data and antecedent conditions in the basin.

For the 1973 spring run off, a four day forecast was used which predicted flows at various points along the river and this information was released daily to the media by the Flood Forecasting Center.

The actual and forecast hydrographs and associated precipitation and temperature are shown on Figure 6 for Fort Kent and Figure 7 for Mactaquac.

NEW BRUNSWICK FLOOD OF 1973

The 1973 spring run off on the Saint John River approached or exceeded the maxima of record at hydrometric stations on the main stem of

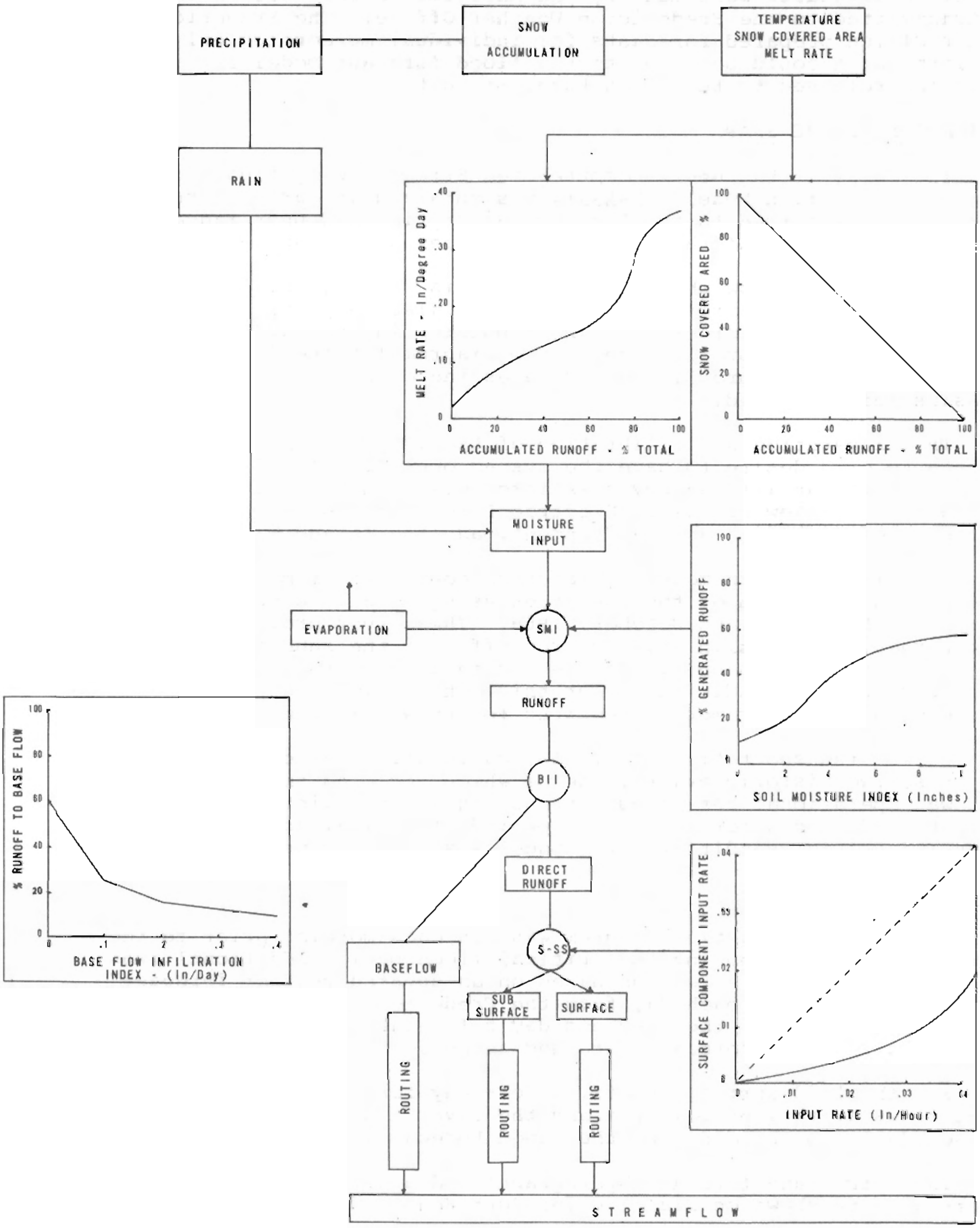



Figure 4 - SSARR WATERSHED MODEL

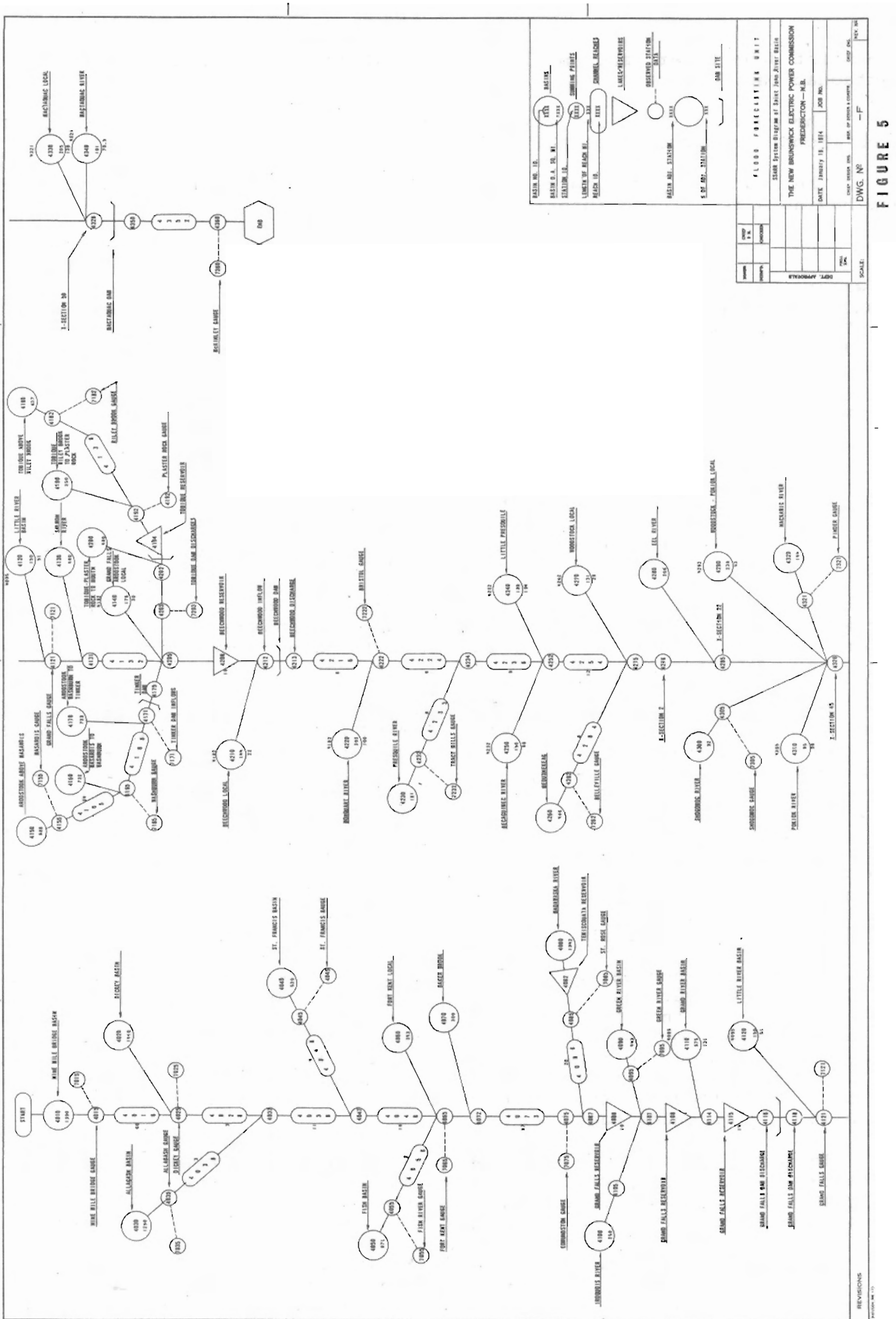

FLOOD FORECASTING UNIT
SSARR System Diagram of Saint John River Basin
THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
FREDERICTON — N.B.
DATE January 18, 1974
JOB NO.
DWG. Nº
-F
SCALE:
DEPT. APPROVALS
REVISIONS
START
END
DAM SITE

FIGURE 5

the Saint John River, and on almost all tributaries upstream of the Mactaquac Dam.

The extreme flood conditions were the result of the accumulation of high flood discharges from all tributaries.

The mean daily discharge below Mactaquac is estimated at 393,000 cfs and having a recurrence interval of 84 years.

The flood of April, 1973 was caused by a combination of two factors: storm precipitation from April 27 to April 29 and snow melt. The amount of water available for spring run off is dependent on the volume of accumulated precipitation in the form of snow. Snowfall during the winter of 1972-73 was much above normal over most of the basin and varied for 34 to 193 per cent of the average.

The Temperature Index/Degree Day approach was used in the model to calculate snow melt over the basin by the equation:

$$M = (TA - TB)R$$

where M = melt in inches
TA = mean daily temperature (°F)
TB = base temperature (32°F)
R = melt rate in inches of water per degree day as a function of accumulated seasonal run off.

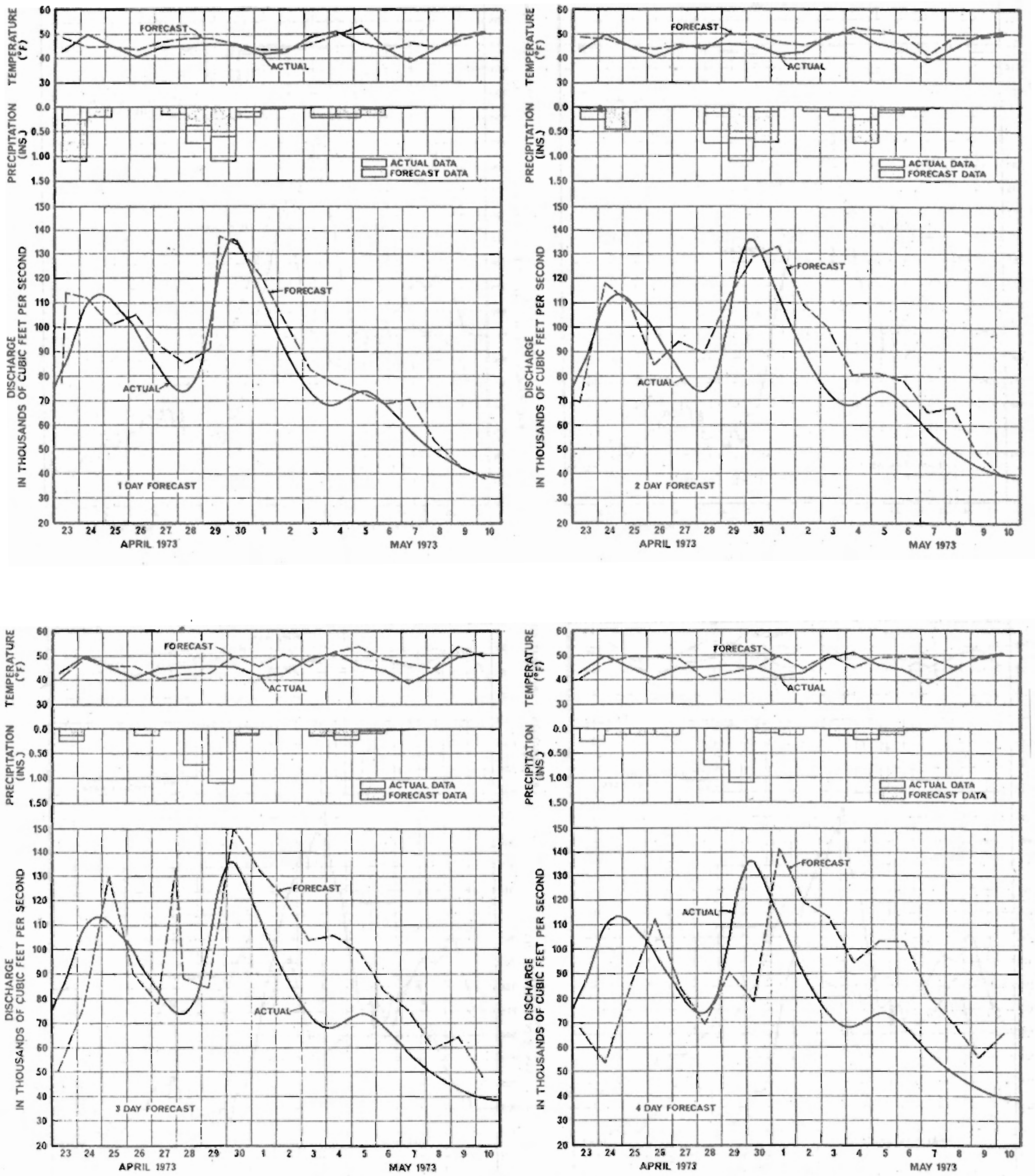
Melt rates are variable during the snow melt season and also vary for each subbasin. A typical melt rate curve is shown in Figure 4 as a function of accumulated seasonal run off with value range from 0.02 inches per degree day to a high of 0.40 inches per degree day.

Most of the tributaries on the Saint John River began to rise about April 17 as the result of snow melt. A warm frontal system which dropped about an inch of rain on the basin between April 22-23 caused most rivers to rise rapidly and peak about April 24. Cooler weather moved in following the rain frontal system and discharges of the river began falling until April 27 when a major storm moved into the area. These peaks on April 24 and 25 were now more or less equal to previous recorded maximums in the basin. Because these peaks were of such a high order of magnitude, it was thought that the Saint John River had reached its annual spring peak when discharges gradually declined from April 25 to April 27. However, the total melt of about seven inches left considerable snow on the ground in the Northern part of the basin.

On April 27 and 28, an extensive frontal system moved slowly across the Saint John River Basin producing mild temperatures and heavy precipitation of about two inches in the area above Fort Kent with lesser amounts in the lower part of the basin. This precipitation accompanied by warm temperatures caused the remaining snow to melt and rivers began rising very rapidly without having fully receded from the previous peak. Figure 6 shows the combining effect of snow melt and rain on the hydrograph at Fort Kent and Figure 7 for below Mactaquac.

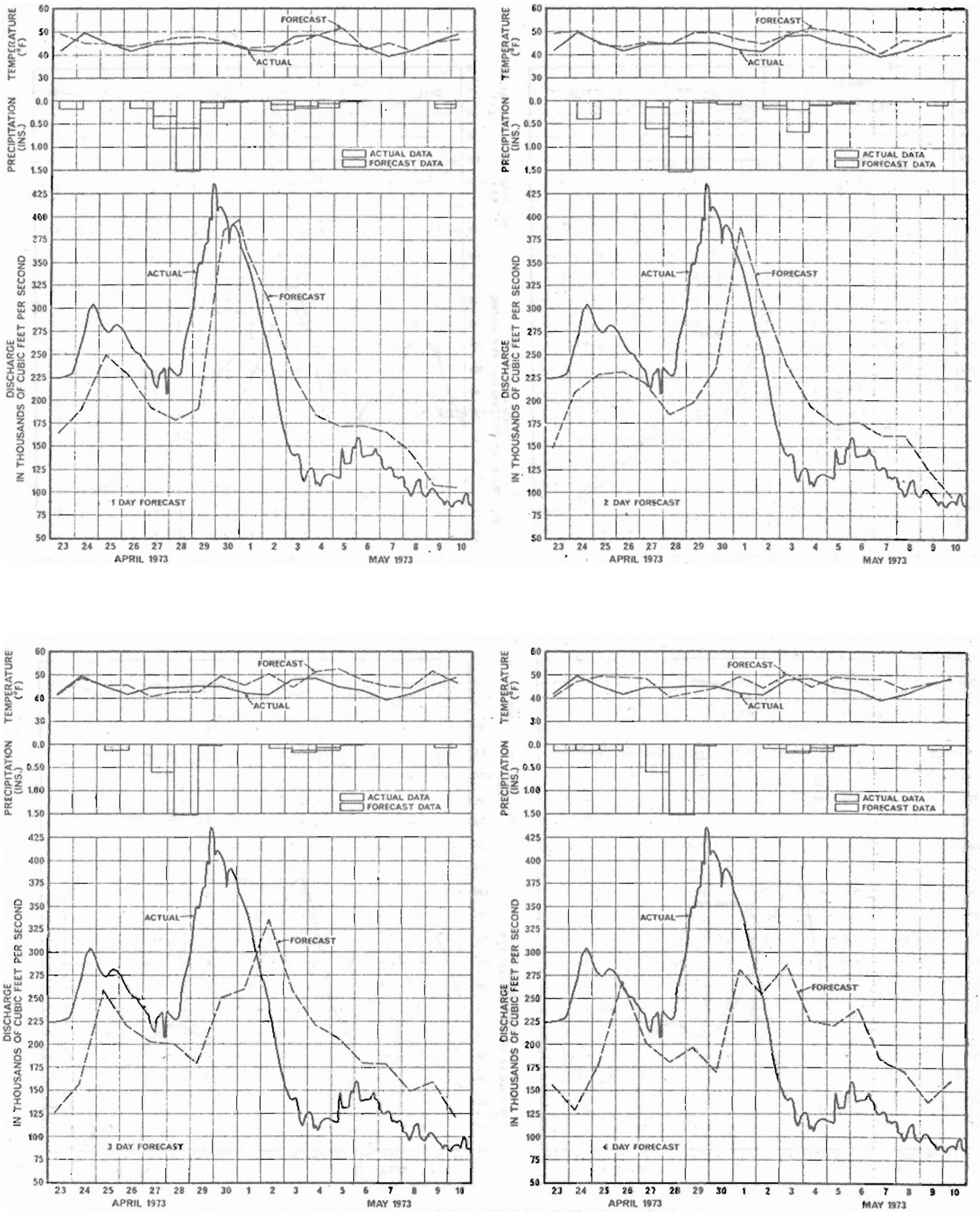
In general, local run off from the drainage area downstream of the Mactaquac Dam was not particularly high during April and May, the water equivalent of the snow cover being less than four inches in most places, and by April 27 most of the snow had melted and the river had receded.

Recorded run off in inches was approximately 10.0 inches above the Mactaquac Dam and in the order of 3 to 4 inches for streams in the lower basin. However, the main effects of the flood were felt along the lower




**1973 SPRING FLOOD HYDROGRAPH**
**OF THE SAINT JOHN RIVER AT FORT KENT**

**FIGURE 6**




**1973 SPRING FLOOD HYDROGRAPH**
**OF THE SAINT JOHN RIVER AT MACTAQUAC**

**FIGURE 7**

portion of the Saint John River from Mactaquac Dam to the Reversing Falls at Saint John, and it was in this reach of the river that the most extensive flooding damage occurred.

This stretch of the river is influenced by the Reversing Falls at the mouth of the River which restricts the outflow of the River, and causes the build-up of water upstream. Figure 8 shows water level profiles of the lower reach of the River and indicates how the general water surface slopes changed as the volume of water stored in the channel and lake system increased during the flood period.

## FLOOD DAMAGES

Damaging floods in the province of New Brunswick are not uncommon but the 1973 flood was probably the most destructive and most widespread of all. In a damage study carried out under the direction of the Inland Water Directorate, the total economic cost of the flood is estimated to be $12,000,000. The major portion of the damages, 91 per cent, was in the Saint John River Basin. A detailed report of the damages is contained in a report compiled by the Inland Water Directorate, Halifax, Nova Scotia on the 1973 New Brunswick flood.

## EMERGENCY MEASURES

Emergency measures were commenced on Saturday, April 28 when the New Brunswick Emergency Measures Organization was informed by the Flood Forecast Center that severe flooding was expected. A detailed description of the Emergency Measures Organization is contained in their report on the 1973 flood.

## DISCUSSION

In examining the results of this first serious attempt at flood forecasting, it is obvious that considerable savings in flood damage and personnel hardship were achieved.

The SSARR flood forecasting model gave good results considering the limited time available in calibrating it prior to the 1973 flood. The possibility of extensive flooding was predicted approximately three days in advance of its occurrence in the Fredericton area. Undoubtedly, more refinements in the model could be made, however, there is a very close link between the meteorological forecasts and the river flow forecasts. The accuracy of flood forecasts and the period of advance warning will continue to depend on meteorological forecasting capabilities.

Since extreme floods in New Brunswick are partially caused by rainfall, the ability to predict them in advance is limited by technology in the field of precipitation forecasting.

With the lessons learned during the 1973 flood, it is hoped that the accuracy of the model will be improved as more experience is gained in the field of flood forecasting. Also, it is hoped to have the model calibrated to predict water level elevations in the Saint John River below Mactaquac Dam in time for the 1974 spring run off.

With the success of this year's effort in the field of flood forecasting, it is hoped that an even greater effort will be concentrated in this area in the future, and that greater emphasis will be placed on the collection of hydrological data for this purpose and in the field of quantitative weather forecasts.

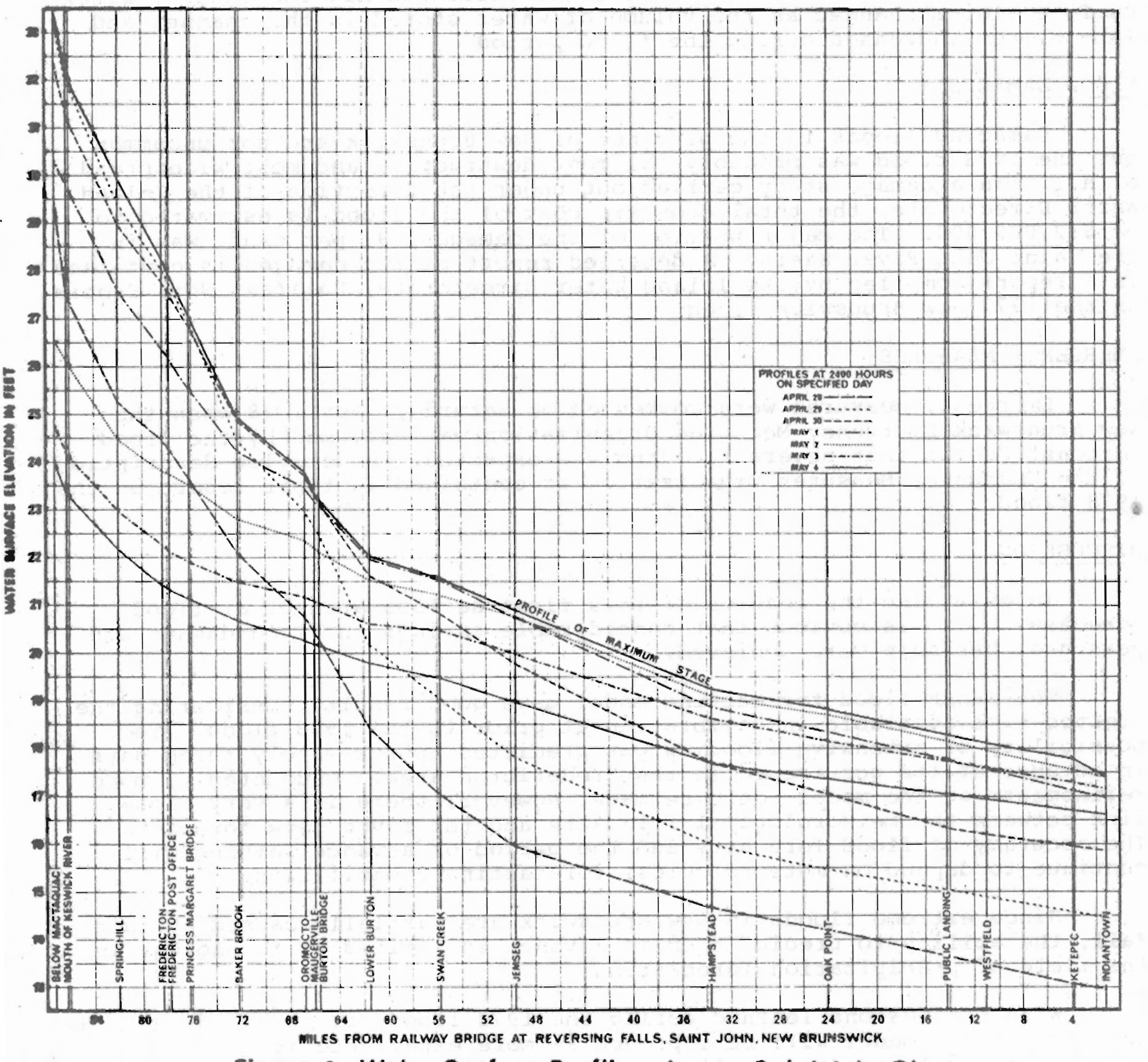



**Figure 8 Water Surface Profiles – Lower Saint John River**