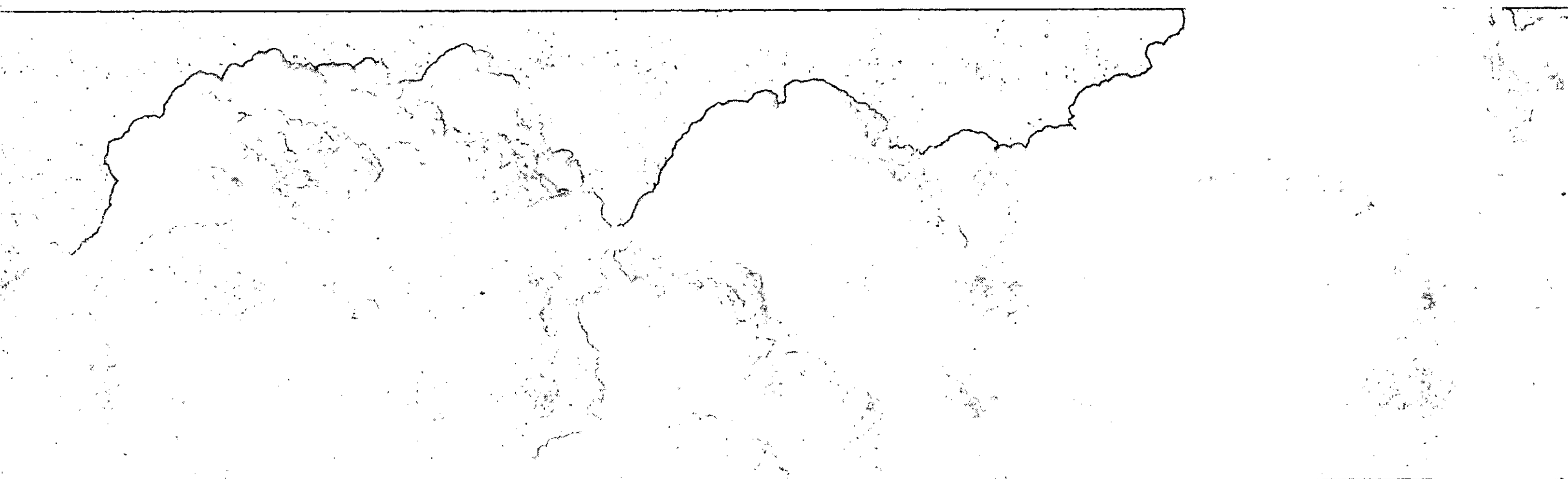
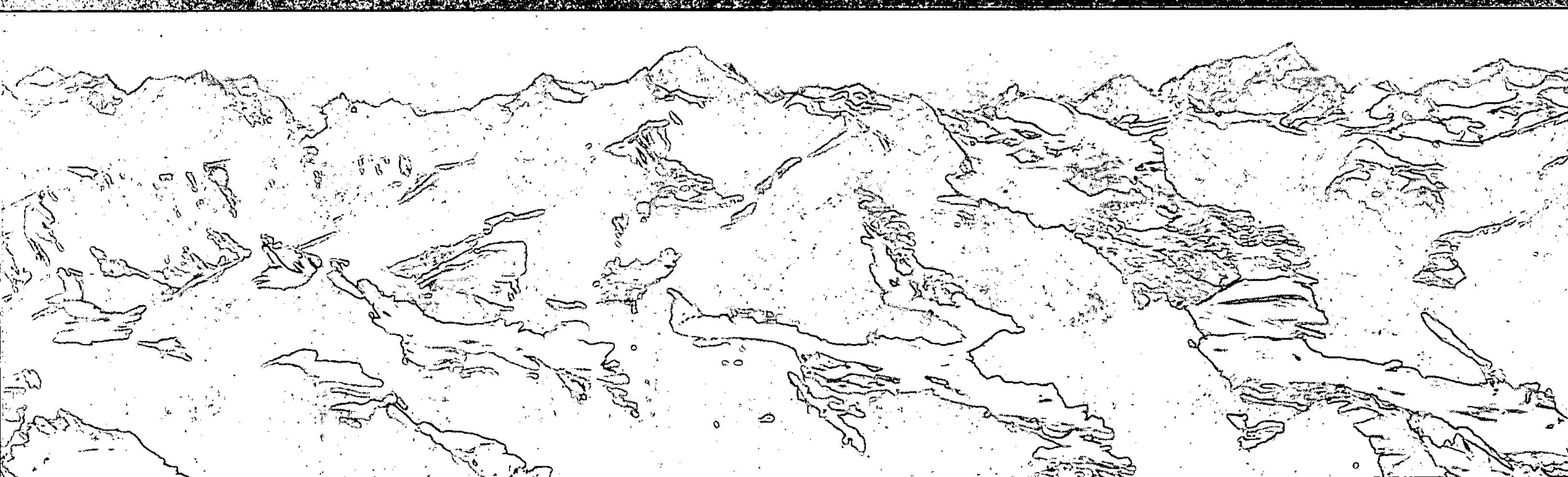
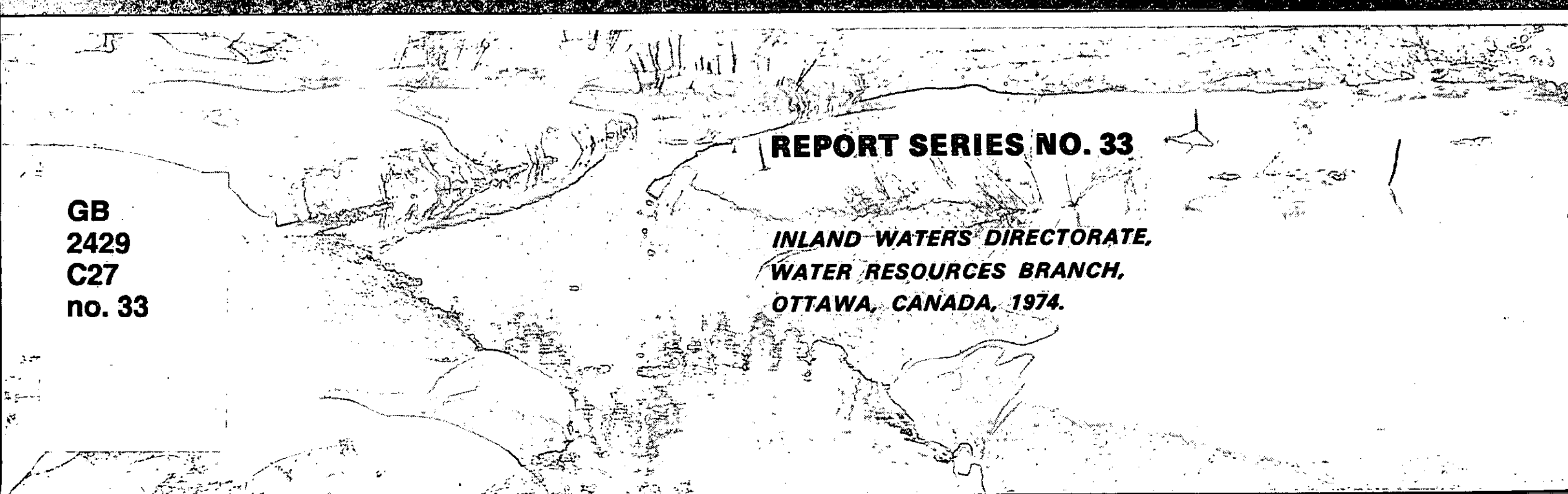
Environment Canada   Environnement Canada

Hydrological Data Bank

Present Status







REPORT SERIES NO. 33

INLAND WATERS DIRECTORATE,
WATER RESOURCES BRANCH,
OTTAWA, CANADA, 1974.

Environment Canada — Environnement Canada

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ERRATA

Page iii: Caption to Figure 1 should read "Basic layout of hydrological data bank."

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Abstract

Recent hydrometric network planning studies by the Department of the Environment have resulted in an initial Hydrometeorologic—Physiographic Data Bank. Conjunctive analysis of these data by means of deterministic and statistical models can permit estimation of data at ungauged areas, thus enhancing the information content of the observed data.

Hydrological Data Bank
Present Status

INTRODUCTION

Hydrometric data, whether levels, flows or sediment discharges, are affected by climate and terrain. The recent hydrometric network planning studies[1,2,6] by the Department of the Environment through consulting engineering firms have demonstrated that statistical and/or deterministic relationships can be estimated between hydrometric, climatic and terrain data, and that the use of these relations can replace, in some cases, the direct collection of data. The above studies also show that the accuracy of interpolation improves progressively from simple isoline technique to the multiple correlation technique which uses terrain information, and finally to the more complicated models which combine or interface the hydrologic data with meteorologic and terrain data, thus multiplying the amount of information in both the hydrologic and meteorologic fields. One of the main conclusions of the studies was, therefore, that improvement of data transfer techniques and combination of various data sources regarding interrelated fields are likely to significantly enhance the information content of the data or, expressed in other terms, increase the accuracy of data transfer.

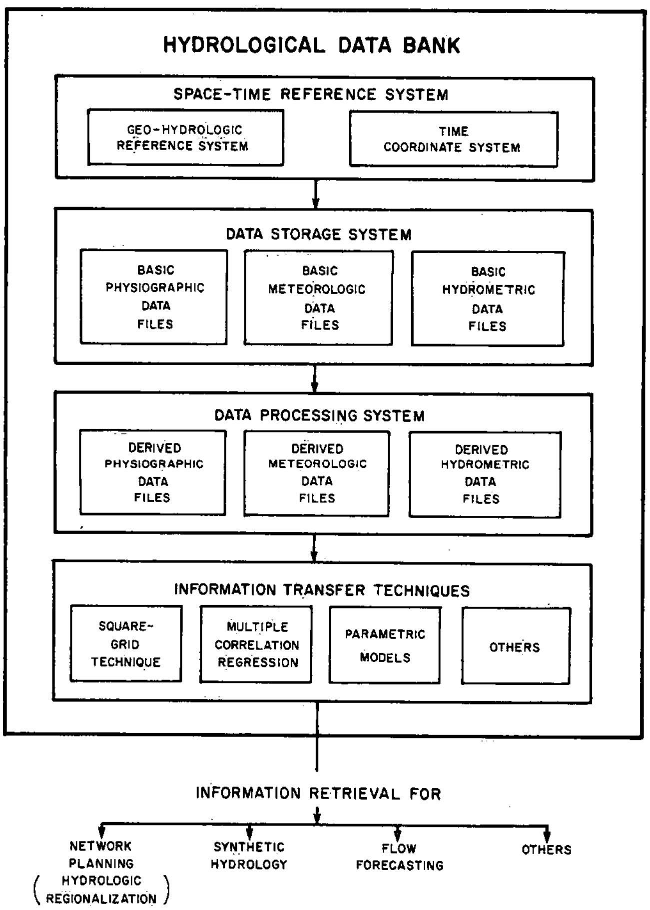

Figure 1. Basin layout of hydrological data bank.

A main conclusion of these studies was that maximum efficiency in hydrologic data transfer is achieved by storing in a 'Hydrological Data Bank' all data on hydrology, meteorology and physiographic characteristics, processing these data by means of statistical, deterministic or combined techniques, and transferring information on this basis in areas where data are missing. An initial form of the Data Bank has already been developed. The purpose of this report is to describe this Data Bank. It is considered that future techniques of data collection which will probably be based increasingly on remote sensing from aerial platforms, including satellites, will find in such a data bank an excellent and compatible system of storing data and processing and disseminating information.

INITIAL HYDROMETEOROLOGIC-PHYSIOGRAPHIC DATA BANK

The initial hydrometeorologic-physiographic data bank was generated as a by-product of the studies initiated by the Water Resources Branch for planning the hydrometric network in a series of provinces and territories[1,2,6] as well as from a water resources study of the Province of Newfoundland and Labrador, initiated earlier by the Atlantic Development Board[3].

The initial hydrometeorologic-physiographic data bank at present covers all of Canada, with the exception of Northern Ontario* and Arctic Archipelago. It consists basically of the following components (Fig. 1):

(a) Space-Time Reference System;
(b) Data Storage System; (c) Data Processing;
(d) Information Transfer Techniques;

These are described in the following sections.

*Coverage of Northern Ontario is in planning stage.

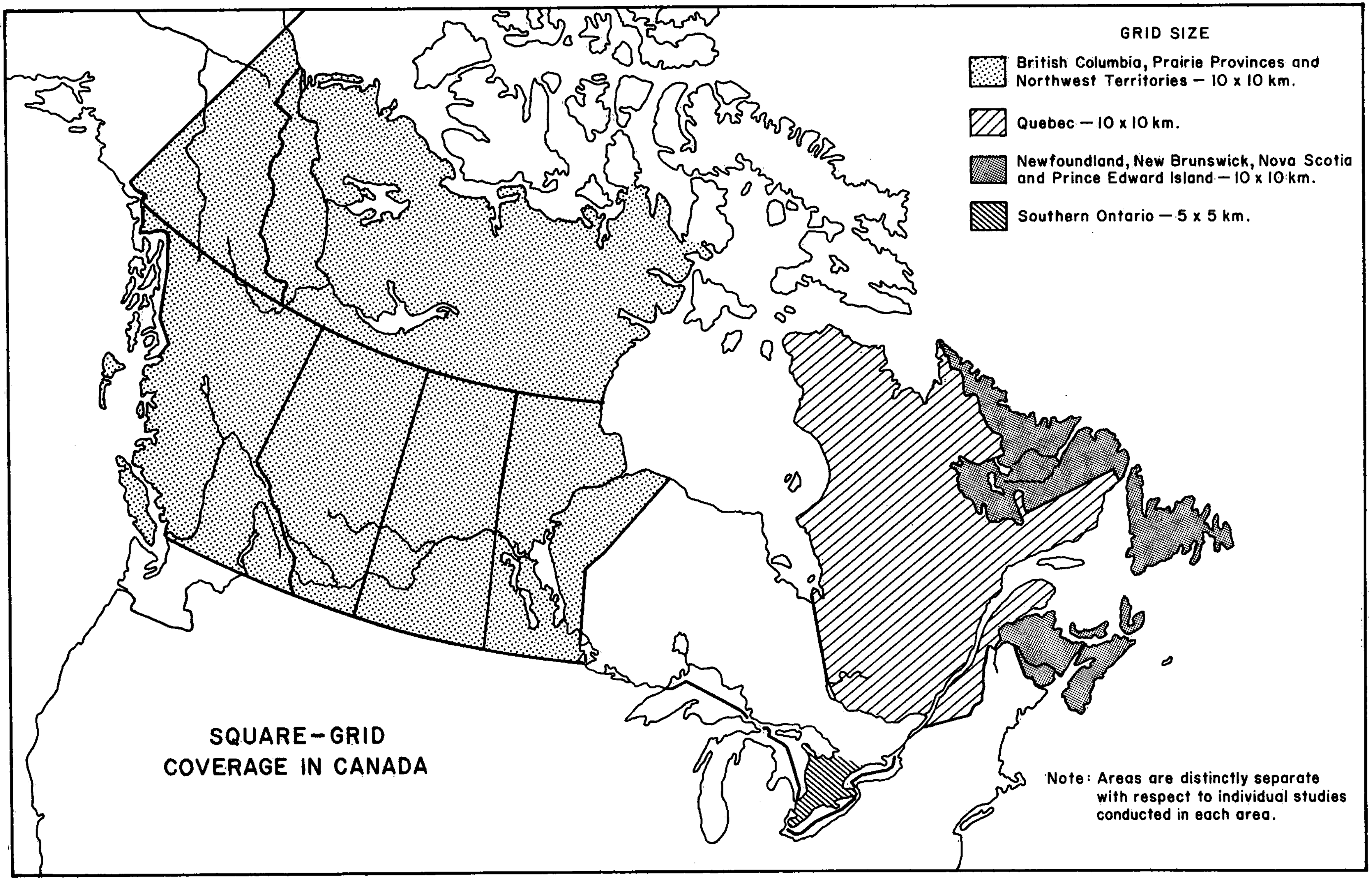

Figure 2. Square-grid coverage in Canada.

SPACE-TIME REFERENCE SYSTEM

The Space-Time Reference System consists of a Geo-Hydrologic Reference System and a Time Coordinate System.

The Geo-Hydrologic Reference System contains two elements. The first element is a Square Grid System and consists of a matrix of squares covering the area investigated and corresponding to the universal transverse Mercator reference system. Squares of 10 x 10 kilometers were used in most cases, the only exception being Southern Ontario where the size of the square was 5 x 5 kilometers. Figure 2 indicates the square-grid coverage in Canada. A means of combining a system of larger squares in areas with smooth terrain with squares of smaller sizes in areas, where the terrain is more rugged, could be included in the system and provide flexibility in application. Such a system is being investigated in British Columbia. The index number of the line and column of the square which is uniquely related to the UTM identification system gives the required indication on the location of each square, including its longitude and latitude. This part of the Geo-Hydrologic Reference System indicates also whether the square is located entirely inside the continental area, or partially on the sea.

The second element of the Geo-Hydrologic Reference System is a Drainage Path System, which consists of a technique of identifying the runoff path, starting with the divide between basins and ending at the sea. This indicates in each area containing a divide between basins the number of district basins being supplied by the runoff of the square considered, and the corresponding areas and direction of outflow with respect to the adjacent squares. For areas without divides, the "inflowing squares" and the square in which the outflow occurs are indicated (Fig. 3). This permits establishing at any point of the area the drainage basin above it,* the composition of squares and square subdivisions constituting it, the flow path of any additive to the water, etc.

The Time Coordinate System consists of an origin and reference time intervals, both of which can be selected arbitrarily according to the requirements of the data bank. The referenced time intervals may in most cases be months, with the possibility of using subdivisions such as days, hours, and so on.

*In recent use of this system, some errors were discovered with respect to incorrect coding on maps and computer files.

DATA STORAGE SYSTEM

The Data Storage component consists of physiographic data stored in each square and meteorologic and hydrometric data stored in the squares in which the stations are located.

The physiographic data stored at the present stage consist basically of the following records:

- elevation of the southwest corner of the square.
- percentage of square covered by forest, marshes, lakes, barren land, urbanized land, agricultural land, and sea.
- in some areas where the information is available, an index of soil permeability.

Meteorologic data stored are limited at present to the monthly temperature and precipitation time series at the stations located in the area.

Hydrometric data stored consist of the daily flows and sediment time series at the selected stations* located in the study area.

DATA PROCESSING SYSTEM

The Data Processing component contains three groups of operations.

The first group includes the computation of "derived" physiographic characteristics such as slopes, barrier heights, distance to the oceans and shield factors in the eight directions of the compass[6]. All these factors can be readily computed for each square from the physiographic data stored earlier.

The second group of processing operations contains the computation of the physiographic characteristics of various river basins. It is to be noted that such computations can be made automatically for any river basin at any point.

The third group of processing operations carries out the analysis of the meteorologic and hydrometric data and produces long term, annual, monthly and daily means, and

*The selection of these stations which number roughly 600 is based on the suitability of the station record to be used for data transfer purposes.

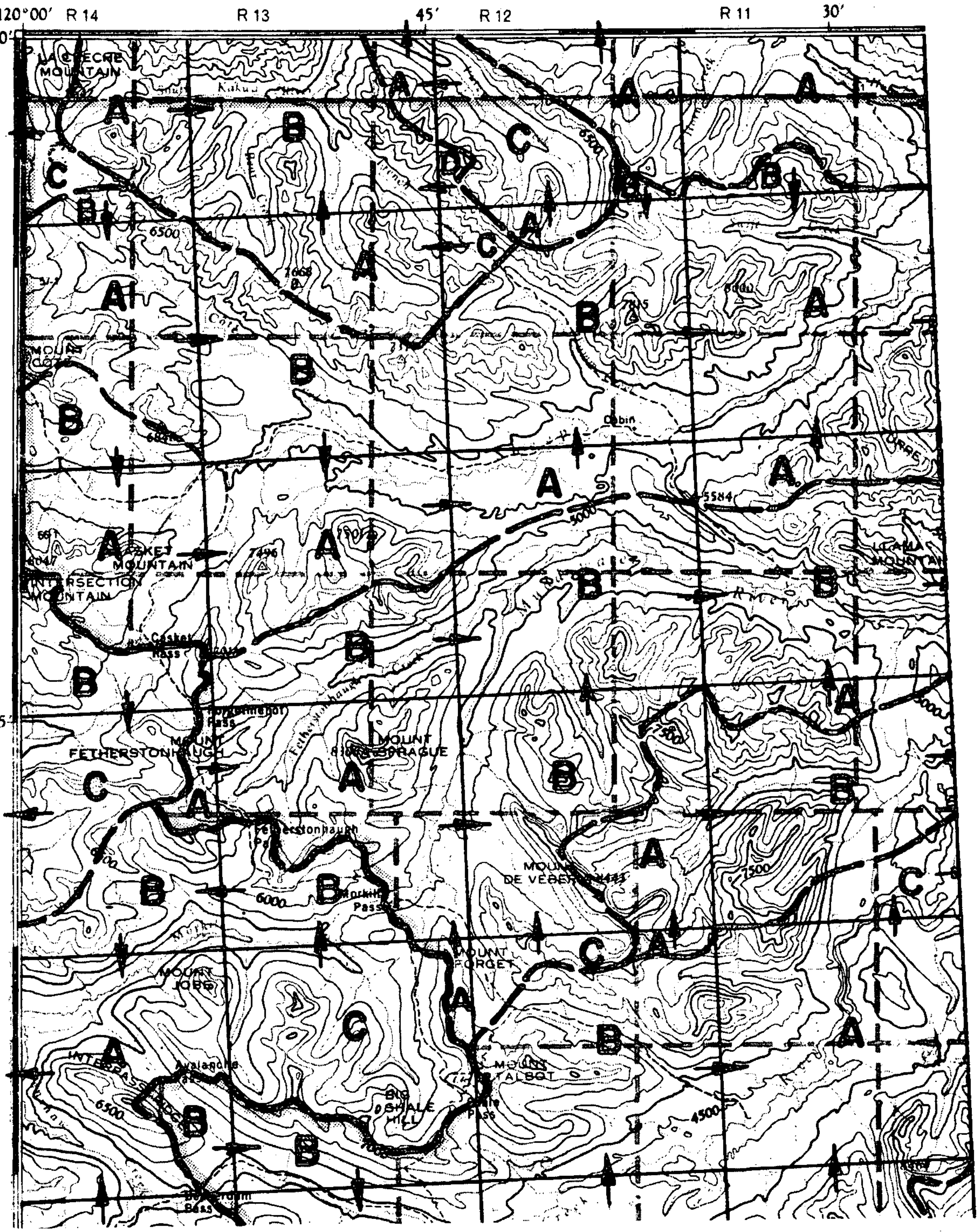

Figure 3. Systematic representation of method of determining drainage area along a river.

other statistics of these values; namely regression coefficients of the monthly or daily correlations, between data at various stations, etc.*

INFORMATION TRANSFER TECHNIQUE

The Information Transfer Techniques component contains statistical and deterministic models, based mainly on combined use of physiographic and climatologic, physiographic and hydrologic, or of all three groups of data, to produce estimated information for any point (square or basin within the study area).

The present data bank contains primarily three information transfer techniques, namely, Square Grid Technique, Multiple Correlation Regression and Parametric Models.

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*Other features, not included yet, such as determination of unit hydrograph and recession curves could be readily incorporated in the processing unit using existing programs.

Square Grid Techniques is composed of the simple water balance relation between runoff, precipitation and evapotranspiration and the correlation between the square grid hydrometeorologic information and the square grid physiographic characteristics[4].

Multiple Correlation Regression Technique correlates the hydrologic characteristics to the watershed average square-grid physiographic characteristics[1].

Parametric Models represent a simplified mathematical formulation of watershed hydrology and simulate continuous monthly or daily hydrographs[6].

POTENTIAL USES OF THE HYDROLOGICAL DATA BANK

An example of the results obtained using the square grid technique of combining physiographic and climatologic data is shown on Figure 4, which is a digital map of the distribution of average temperatures in southern Ontario based on a multiple regression between the average temper-

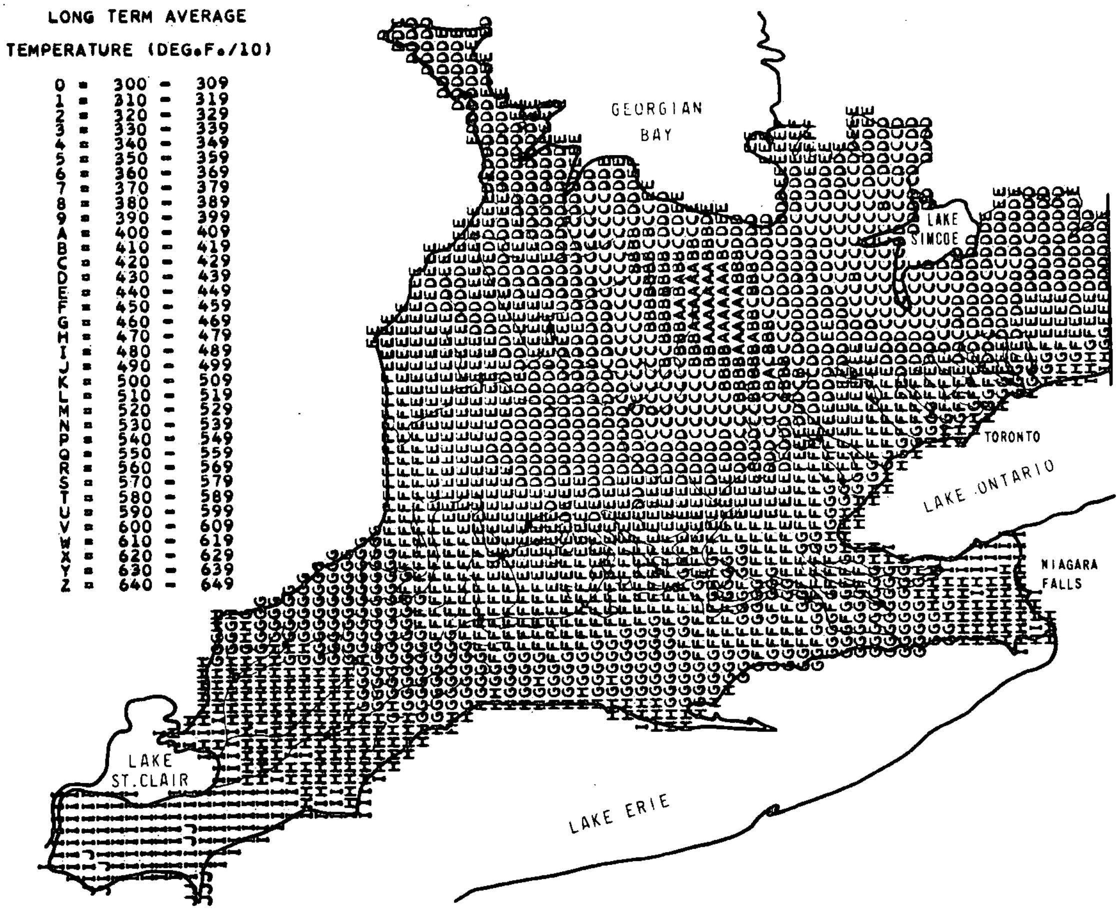

Figure 4. Distribution of average annual temperature in Southern Ontario.

ature of the stations located in the area and the physiographic characteristics of the squares in which the stations are located.

An example of the results obtained using the square grid technique of combining hydrologic, meteorologic and physiographic data[4] is illustrated on Figure 5, which presents the distribution of mean annual runoff obtained using this technique in southern Ontario. The application of the relation obtained between mean annual runoff and physiographic factors to a group of test stations excluded from the derivation of the correlation illustrates the order of magnitude of individual errors to be expected when such methods are used (Table 1).

The combined use of physiographic, meteorologic and hydrologic data has already been discussed[4]. The application of the same method in other areas of Canada (southern Ontario, western and northern Canada) has resulted in a significant reduction of the error of estimate, as illustrated on Figure 6. It shows that while simple conventional isoline methods lead to errors of estimate of

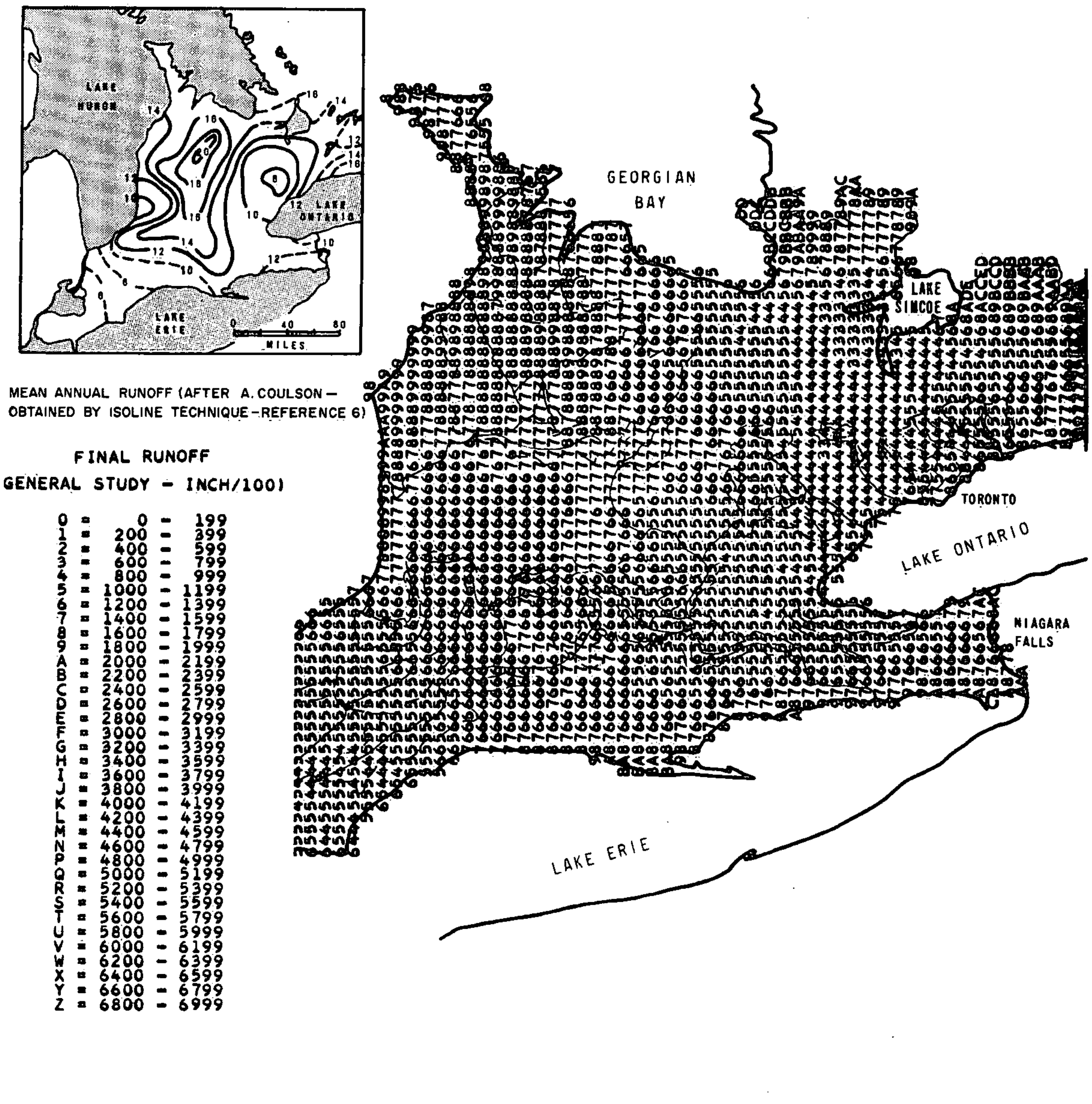

Figure 5. Southern Ontario pilot area: mean annual runoff distribution.

the order of 70% at densities of about one station per 10,000 square miles, the use of correlations between physiographic and hydrologic data reduces this error for the same density range to 46%, while the combined use of physiographic, meteorologic and hydrologic data reduces the error for these densities to a level of 20%. It follows that a combined use of physiographic, meteorologic and hydrologic data reduces the error to less than a third as compared to the isoline method and to less than one-half as compared to the multiple regression model.

TABLE 1. Comparison of Actual and Predicted Average Annual Runoff for some Test Stations in Southern Ontario (Runoff in inches).

Actual	Predicted	(Act./Pred.)	Station
16.61	15.06	1.102	Saugeen River near Walkerton
15.99	14.37	1.102	Maitland River near Donnybrook
11.77	12.74	0.923	Grand River at Galt
11.26	11.96	0.941	Speed River below Guelph
12.22	12.68	0.963	Grand River at Brandford
12.92	13.25	0.974	North Thames River below Fanshawe dam
14.00	13.24	1.057	North Thames River at London
10.64	10.50	1.012	Credit River at Erindale
8.84	8.90	0.993	Etobicoke Creek near Summerville
8.21	9.07	0.904	Humber River at Weston
10.06	9.41	1.068	Little Don River near Lansing
12.47	13.16	0.947	Thames River near Ealing
13.16	12.91	1.018	Big Otter Creek near Vienna

The use of this initial data bank in conjunction with a parametric model[1,6] has indicated the possibility of synthesizing on this basis traces of hydrologic time series at any point of the study area. A comparison of actual and synthesized flows in southern Ontario is indicated in Figure 7. The preliminary results obtained indicate that such a method would further reduce the data transfer error. Moreover, the technique has also indicated the significant potential of the data bank used in this manner to produce information on water stored in the basin under various forms as illustrated in Figure 8, which shows a comparison between the water stored in solid form in a basin as computed by the model from precipitation, temperature and runoff data and the water content of snow obtained from a snow course measured in a neighboring basin[8]. Because of this, the data bank used in conjunction with the parametric model appears to have significant promise in the area of flow forecast. This aspect of the potential uses of a hydrologic data bank is discussed in another paper[7], based on which a comparison between forecast and recorded spring flows (with/without perfect meteorological forecast) is shown in Figure 9.

Furthermore, the data bank based on the square grid reference system can be used for hydrologic regionalization which is essential for network planning and other hydro-

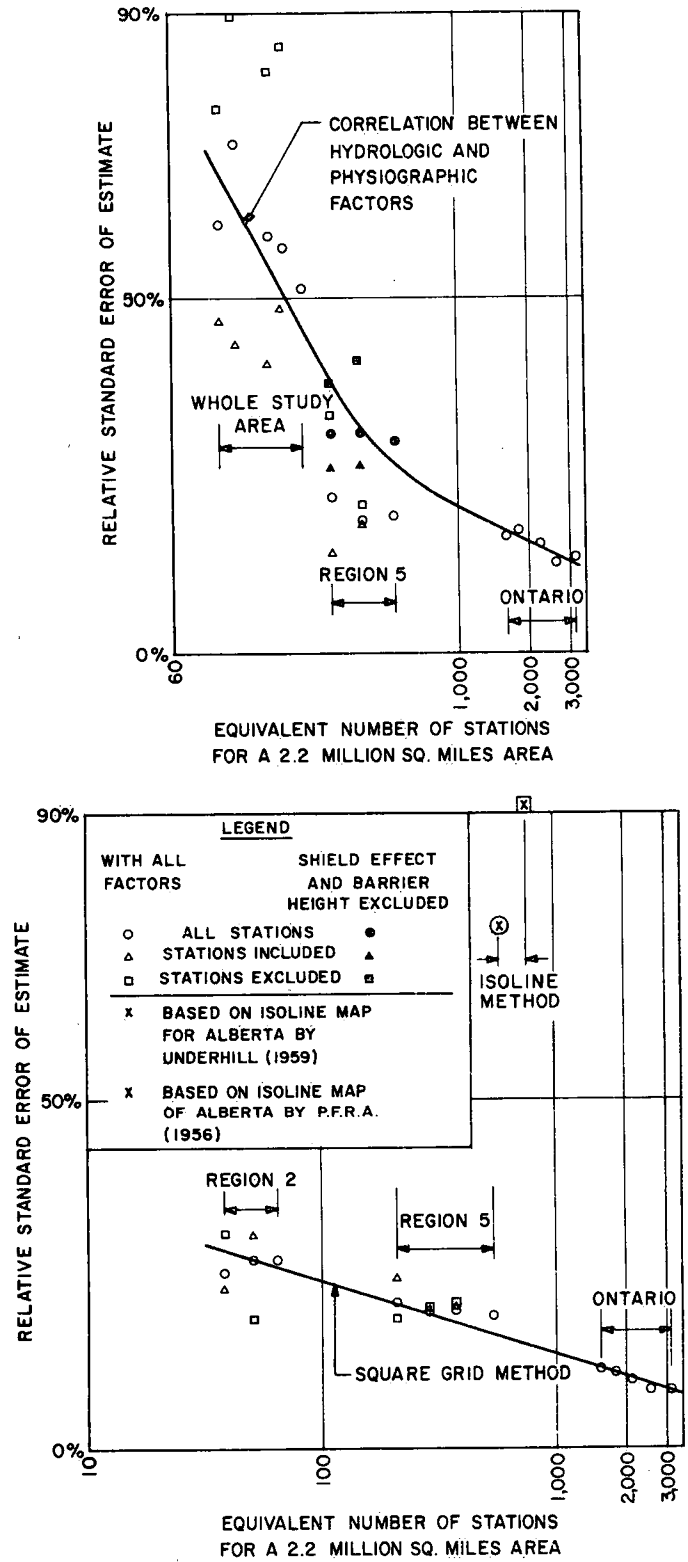

Figure 6. Relative standard error *vs.* equivalent number of stations.

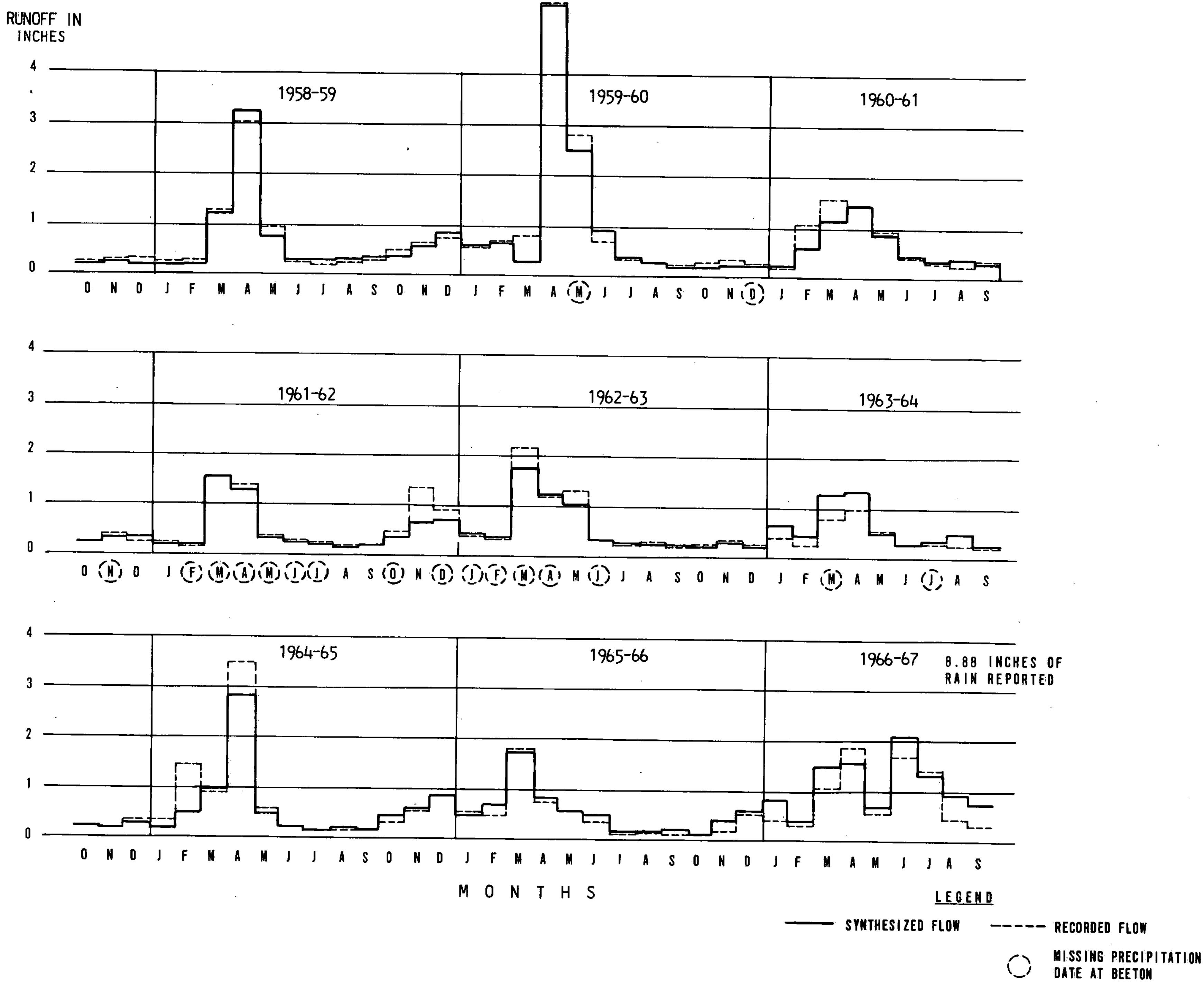

Figure 7. Parametric model comparison of actual and synthesized runoffs for Nottawasaga River near Baxter,

logic problems. The hydrometric network planning studies[1,2,3,6] have indicated the usefulness of two types of hydrologic regions: statistical-hydrologic regions and physiographic-hydrologic regions.

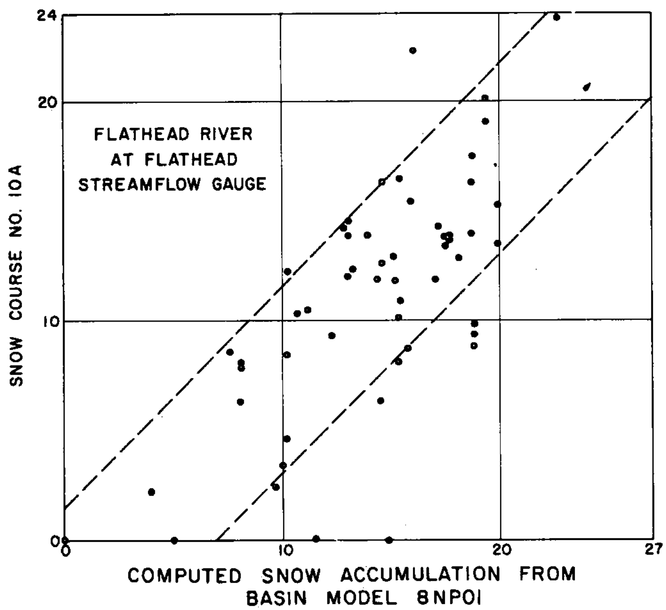

Figure 8. Comparison between snow course data from the Kootenay River Basin and solid accumulation from parametric model in a neighbouring basin (inches of water equivalent).

Statistical-hydrologic regions are defined as regions within which certain relations between hydrologic and physiographic correlations are valid and there are no regionally grouped residual errors. The delineation of such regions could be made by assuming initially that the whole study area constitutes one single hydrologic region, computing the corresponding hydrologic-physiographic correlations and analyzing the residual errors. If these errors show regional trends, and if it is not possible to introduce a new variable to account for these trends, the area can then be subdivided according to the regional error grouping and the procedure repeated until the residual errors become randomly distributed. Using these procedures in an earlier study, two such statistical regions were defined in the Island of Newfoundland[3]. In the southern Ontario study[1], three such regions were defined corresponding roughly to the basins of the three Great Lakes draining the area. The western and northern Canada studies[6] have resulted in the delineation of five hydrologic-statistical regions as indicated in Figure 10. It should be noted that the statistical region limits may be different for various hydrologic characteristics used as the delineation criterion.

Physiographic-hydrological regions are defined as regions within which the physiographic characteristics significant from a hydrologic viewpoint vary within narrow limits and where consequently it may be expected that the hydrologic regime varies in a similar manner.

It should be noted, however, that the rejection of a physiographic characteristic from the correlation can occur not only because it is not statistically significant but also because it is not well sampled (there is no representative sampling of the corresponding characteristic by the gauged basins). The significance of such characteristics should be tested by stratified sampling in areas with large variation of the given parameter and quasi-constant values of other characteristics.

Tables summarizing results of correlations between hydrologic and physiographic characteristics in southern Ontario from which the selection of the most significant physiographic characteristics can be made were published elsewhere[1]. On the basis of these tables, four physiographic characteristics were selected for southern Ontario (proportion of urbanized land, barrier height in SW direction, latitude and permeability index). The variation range of each characteristic was divided in three shades. The combination of shades and characteristics resulted in a number of 81 regions.

Using the computerized data storage system which was developed for the application of the square grid method, a map of the areal distribution of the physiographic-hydrologic regions was developed. Checks made on the very few basins located entirely within the same physiographic-hydrologic region indicate that their regime is indeed quite similar. It should be noted that without the hydrologic data bank such delineation of hydrologic regions would be a very difficult if not an impossible task.

CONCLUSION

The Hydrological Data Bank as outlined above is visualized as a system which is evolutionary. The various components of the bank are expected to progressively improve as more physiographic and hydrologic data become available and the techniques for data handling, analysis and synthesis evolve.

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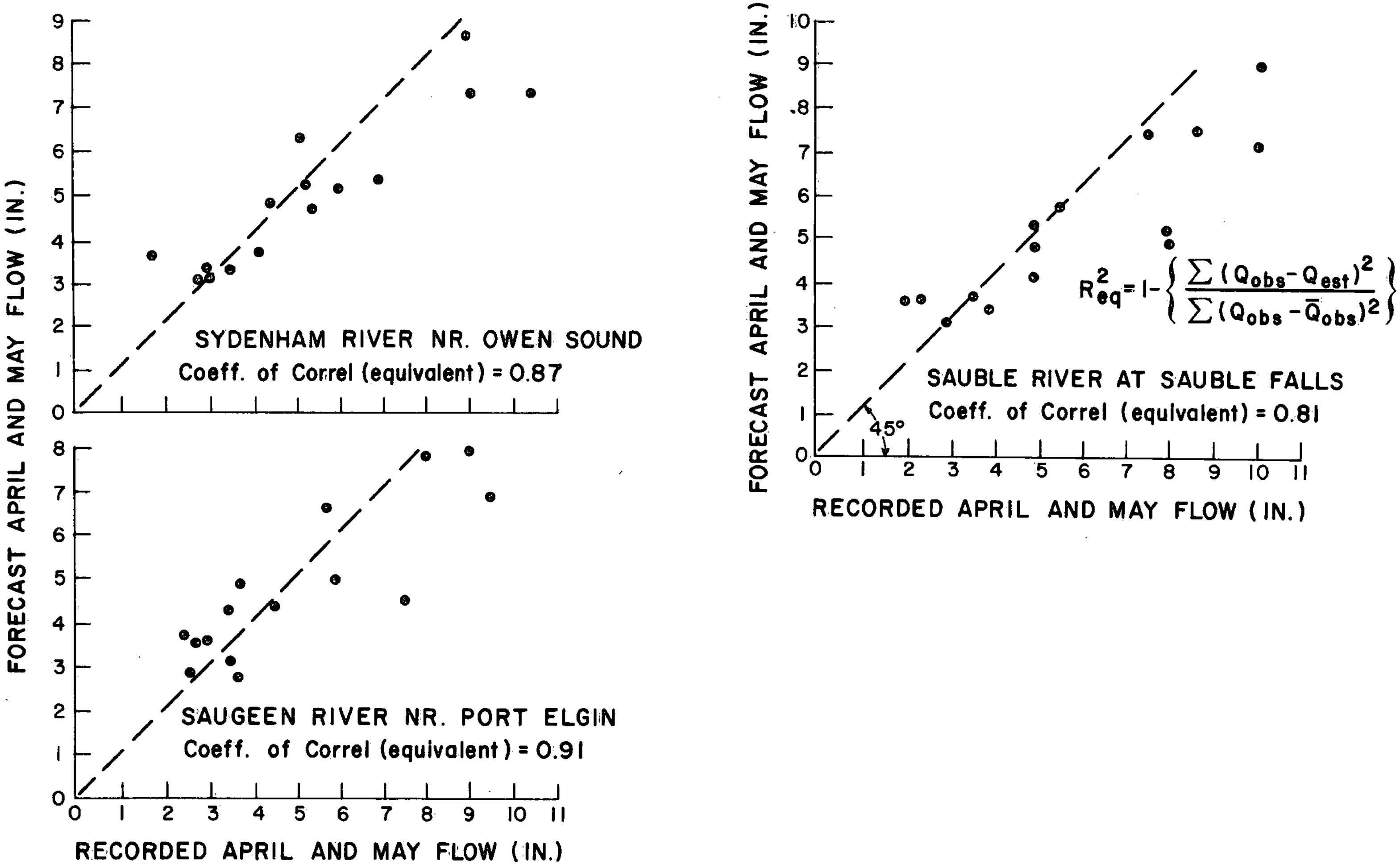

Figure 9a. Forecast and recorded April and May flows based on the use of perfect meteorological forecast.

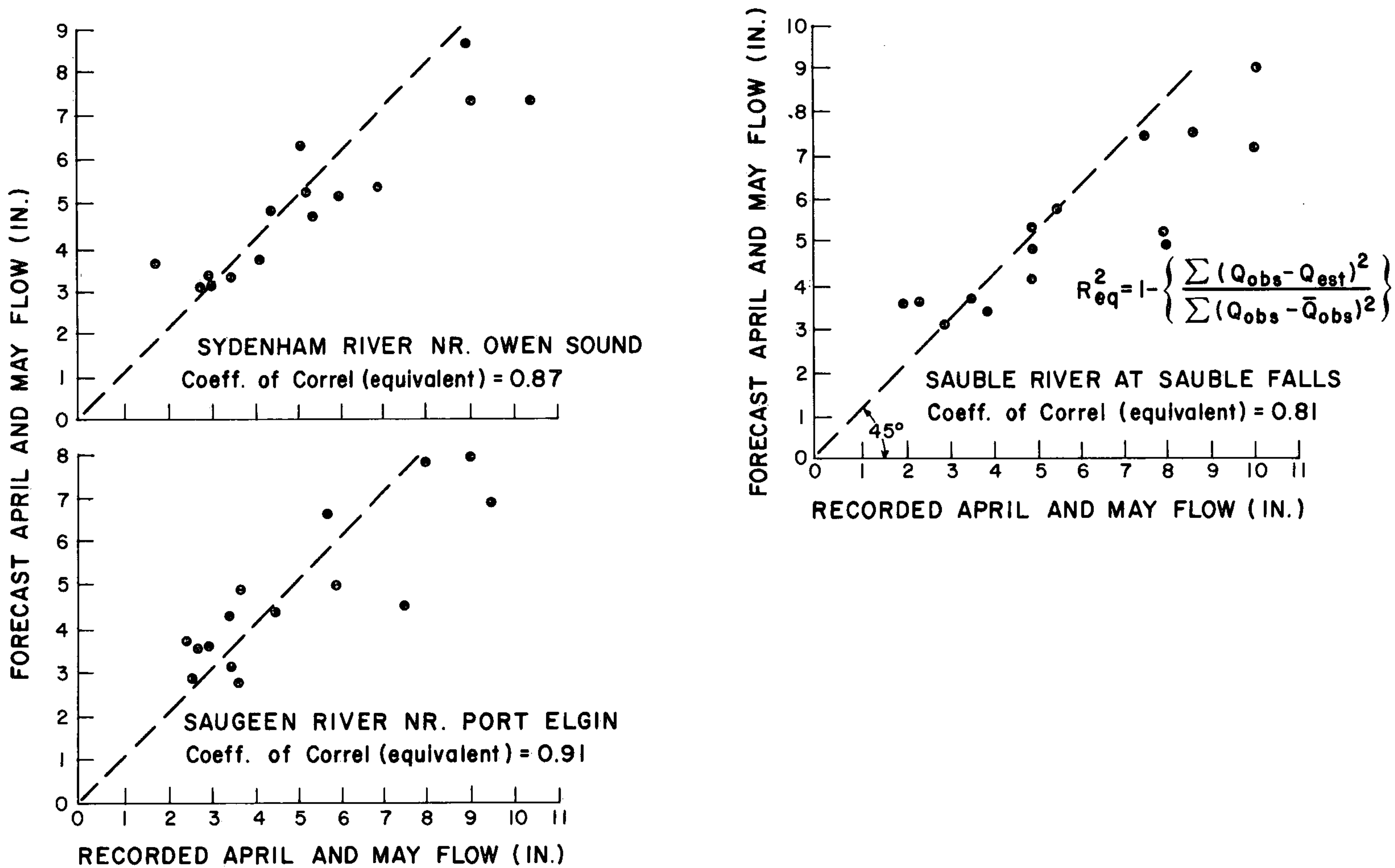

Figure 9b. Forecast and recorded April and May flows without the use of perfect meteorological forecast.

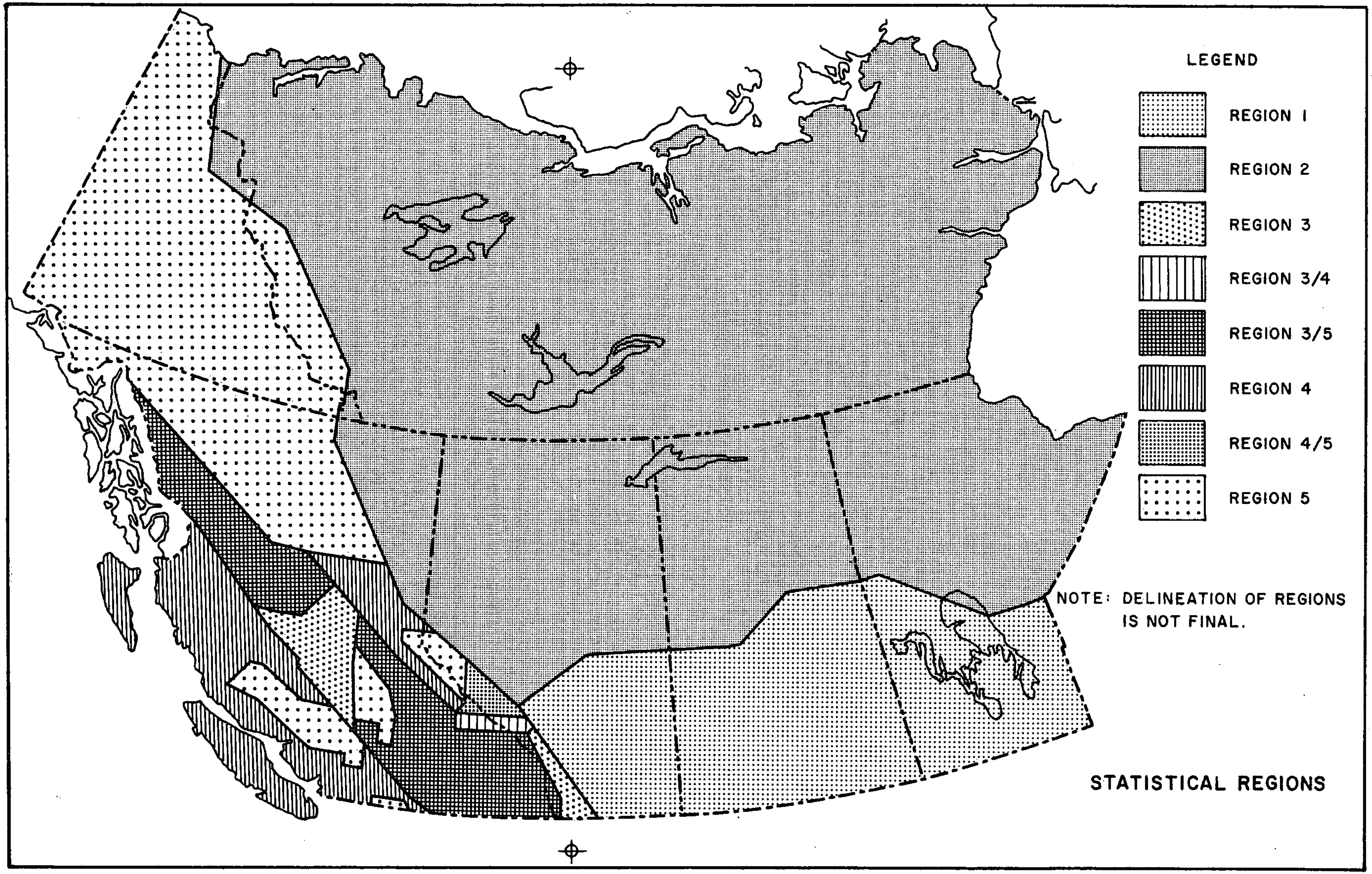

Figure 10. Hydrological-statistical regions in Western and Northern Canada.

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