HYDROMETRIC NETWORK PLANNING AND EVALUATION IN THE PACIFIC AND YUKON REGION

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ABSTRACT

On this paper, the development of hydrometric network planning and evaluation in the Water Resources Branch, Pacific and Yukon Region is traced from its beginnings in the late 1960's to the present and is extrapolated to future directions and expected results. The basic concept of network and the rational, based upon data use, for assigning hydrometric stations to networks are described. The distinction between network planning and evaluation is explained. Results of network evaluation ranging from correlation-regression to an audit of individual stations are reviewed. Future directions for evaluation and planning are examined leading to the expected result of better understanding of hydrometric data and its relationships with data from other sources, such as meteorologic data.

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1. INTRODUCTION

1.1 Purpose

The purpose of this paper is to trace the development and to indicate expected results and future directions in hydrometric network planning and evaluation studies in the Water Resources Branch, Pacific and Yukon Region; and to present the authors' views on the subject for discussion with IWD management.

1.2 Organization of Paper

This paper begins with definitions of key terms such as network, planning and evaluation and a discussion of basic questions concerning hydrometric networks.

The next section of the paper reviews past activities beginning with two consultants' studies which have provided the initial directions and development for hydrometric networks and continuing with development of regional equations by regression, studies using the square grid approach, single station review and the review of the hydrometric stations in the Yukon Territory.

The last section of the paper outlines the future direction of network analysis and discusses the proposed methods and expected results.

2. DEFINITIONS

Definitions of key terms are presented in this section. These definitions are necessary to explain the basic philosophy and methods particularly to the Pacific and Yukon Region.

2.1 Network

The purpose of hydrometric stations is to gather streamflow data, but this data has value only when it is used. So the purposes of the data are a central issue and a feature by which hydrometric stations may be classified. The classes (networks) currently used are:

Project

National Inventory

Major Stream

Regional

The classification of stations is not exclusive, a station in the project network could also be in the regional network if it met the criteria for basin size and natural flow.

Project network stations have clearly defined purpose and strictly speaking no analytical relationship with other stations in the project network.

National inventory stations are located at the mouth of the largest

rivers or at interprovincial and international boundaries for the purpose of gauging and providing estimates of the water resources produced within a province or a territory. National inventory stations provide background data for general use in an hydrologic atlas; at present about 20 stations gauge runoff from 91% of the total area of the Province while 10 stations account for 84% of the area of the Yukon Territory.

Major stream basins - drainage areas greater than 3000 km^2 - are generally considered too large to be included in regional analysis. The proposed approach is to operate stations on major streams where they will provide data at future points of important projects, and if these points are not known, at locations where the data can be used to derive by interpolation or systems studies the required project information. In this Region these stations are classified as major stream stations.

The term "network" is most applicable to regional stations. At all hydrometric stations the recorded data is important as a time series, but at regional stations the data is also important as a space series. The goal of regional stations is to provide data which can be used to make estimates of streamflow for ungauged basins. The interrelationship of data from regional stations to other regional stations and to other sources of data is the key concern of regional network evaluation.

2.2 Regionalization

Regionalization is a classification tool for regional network evaluation. It involves subdividing a geographic area into zones of

similar hydrologic response. Regression equations or models can be developed for each hydrologic zone. Once the zones or regions have been identified, studies can be carried out to provide estimates of how well hydrologic quantities can be estimated and to identify stations which are no longer needed (redundancies) or basins which should be gauged (gaps).

2.3 Network Planning and Evaluation

Network planning and evalution are two distinct but interrelated activities. Planning is the development of a siting strategy. Network evaluation is an examination of the data and the purposes for which data are gathered in order to judge whether the purposes of the data are being met.

Planning a network depends upon the purpose of the data. Project, national inventory and major stream stations have well defined purposes, which limit the planning activities to the search for a good station location.

Planning a "project network" involves siting of stations according to specific requirements for data. In this Region one example of a planned project network are the 13 stations around Williston Lake in Northern British Columbia. These stations were established for B.C. Hydro to help regulate Williston Lake reservoir.

Planning a "regional network" requires a development of a sampling strategy which in this Region consisted of a series of east-west

transects. This sampling strategy allowed the study of the relationship among stations and the interrelationships with data from other sources such as precipitation and physiography.

Evaluation depends upon network and takes place as the data is being gathered. Project stations are evaluated on a single station basis through the quality of data (stage-discharge relation) and examination of whether the purposes of the data have been met.

For regional stations network evaluation is most important and its object is to identify redundancies and gaps in the network and to provide a measure as to how well estimates of hydrologic quantities such as mean annual runoff may be made at ungauged basins. Relationships between hydrometric and other data such as physiographic and meteorologic data are important as is a model to make use of the relationships.

Other considerations that also enter the evaluation process are the size of errors that can be tolerated, the length of record that will be needed and the costs of acquiring the data.

2.4 Evaluation Techniques

Network evaluation for the project, national inventory and major stream networks in the Pacific and Yukon Region is single station analysis concentrating on the purpose of the data and the quality of the data as indicated through the stage-discharge relation. Evaluation is generally by the Audit Method.

The techniques of regional network evaluation are the techniques of data transfer which provide the tools to use streamflow data and apply to ungauged areas. Three basic methods of data transfer have been used by the Planning and Studies Section; these are:

a) correlation and regression analysis,
b) regionalization of the statistical parameters of the hydrologic variable,
c) deterministic input-output modelling and regionalization of the model paramteters and the input variables i.e. the square grid approach.

2.4.1 Correlation and Regression Analysis

These methods attempt to establish relationships between concurrent observations at short-term and long-term stations. From these relationship, the records at short-term stations can be extended to represent longer series. The U.S. Geological Survey has developed a technique to choose a set of stations for discontinuance when budgetary or other pressures require a reduction in stream-gauging activities. This technique takes advantage of the correlation between records at pairs of stream gauges to transfer information from the retained station to the discontinued station. Information about the average stream flow or annual flood is estimated both with and without each of the stations. The selection of stations to be discontinued is done on the basis of maximizing the relative information of the reduced network.

2.4.2 Regionalization of the Statistical Parameters of the Hydrologic Variable

This technique is used in developing regional information on the frequency or statistical characteristics of the components of the streamflow hydrograph such as annual, seasonal, monthly, peak or low flow values. The statistical parameters are calculated from observed data. These are then related to pertinent physiographic characteristic of the gauged basins by regression analyses. The regression models can then be used to estimate frequency characteristics of the hydrologic phenonmenon of interest for the basin of interest.

2.4.3 The Square Grid Approach

The model parameters and input variables such as precipitation and temperature can be regionalized by regression analysis in conjunction with the square grid technique for use in applying the model to ungauged areas. Alternatively, calibration of the model parameters can be performed on a nearby gauged watershed of similar physiographic characteristics. Calibration of some models can be done on as little as one year of historic flow data but to ensure that the parameter values selected are correct for a wide range of hydrologic conditions, the calibration should be longer and should include a very wet and very dry year. Generally, up to ten years should be used for model calibration.

2.4.4 The Audit Method

This method is an adaptation of that of Wahl and Crippen (1984) to examine the relative worth of a station in a multipurpose network. The four rating factors used are: need for data, quality of data, economic consideration and usefulness of data. Utilizing what is known about the stations for each of these factors a station profile is produced which forms the basis of each station assessment. Stations of least value are considered to be candidates for discontinuation.

3. REVIEW OF PAST AND CURRENT ACTIVITIES

3.1 Network Planning Activities

Network planning activities began in 1969 with the active participation of the Planning and Studies Section in the examination of the existing hydrometric data collection program in British Columbia in cooperation with the Consultant Ingledow and Associates Limited. In 1970 the consultant Shawinigan Engineering Co. Ltd. provided guidelines for the long range development of hydrometric networks in British Columbia and the Yukon Territory.

Based on the recommendations of the consultants' reports, the Planning and Studies Section developed plans for a regional network in B.C. in 1970, a regional network in the Yukon Territory in 1971 and a major stream network for B.C. and Y.T. in 1975.

With the cooperation of the provincial Water Management Branch (BCMOE) and the Department of Indian and Northern Affairs (DINA) for the Territory the establishment of new regional stations began in 1971 and of new major stream stations in 1976 and is continuing on a limited scale. In 1987 two new major stream stations were built in northern B.C.; plans for 1988 include a new regional stations in the Tatshenshini River in the southern part of the Territory and a new major stream station on the Bell Irving River in northern B.C. Both new stations will be cost shared with DINA and BCMOE respectively. In a recent examination of hydrometric station uses in the Yukon Territory, 41 stations or 57% of the existing network were identified as regional or major stream stations.

3.2 Network Evaluation Activities

It should be stated that although network evaluation activities are described under a separate heading, the planning and evaluation of hydrometric networks should be a continued cyclic process of data collection, data analysis and interpretation and design directed towards the goals of more efficient and effective production of the required information.

3.2.1 Development of the Data Banks

In British Columbia the procedures chosen to evaluate the existing network were correlation and regression techniques which attempt to define the relationship of the terrain physiography and climate with hydrograph characteristics within hydrologic zones. In order to proceed,

therefore, the development of the physiographic and hydrologic data banks was essential. The extraction of physiographic data began in 1970 and has continued on an intermittent basis until this year when a contract was awarded for the extraction of physiographic data from the remaining ten percent of the area of the Province. The development of the hydrologic data bank proceeded with the compilation of annual peak flow data and their statistical parameter such as means, standard deviation, n-year estimates etc. in "Magnitude of Floods in B.C." (1974 last revised in 1986) "Magnitude of Floods in the Yukon Territory" (revised in 1986). Similar compilations were produced using 7-day low flow data.

3.2.2 Regionalization Studies

Network evaluation studies using the physiographic and hydrologic data banks were initiated in 1974 with the publication in the IWD Report Series of the first report in the series "Streamflow Regionalization in British Columbia" by R.M. Leith entitled "Regression of Mean Annual Floods on Physiographic Parameters". The series continued with "Regression of Mean Annual Flows on Physiographic Parameters" (1976); "Statistics of Mean Annual Flow" (1977); and finally "Regression of Low Flows on Physiographic Parameters" (1978). These studies represented current techniques of network evaluation and information transfer through the regionalization of statistical parameters of the Hydrograph in order to estimate frequency characteristics of the hydrograph characteristics of interest for the basin of interest. Other studies in which the regionalization of hydrograph characteristics was the method of data transfer and network evaluation were completed in 1977: "A Study of

Selected Hydrologic Quantities of the Yukon Territory for Examination of Pipeline Proposals"; 1978: "The Reliability of Low Flow Regional Equations in British Columbia"; 1979: "Status Report on Regionalization of Monthly Streamflows through Box-Jenkins Models"; 1983: "Contribution of GOES Data to Hydrologic Regionalization in Southern British Columbia"; 1986: "Physiographic Parameters: Estimation and Application to Hydrologic Regionalization"; and finally 1988: "Assessment of the Hydrometric Network in Southeast British Columbia" and "Flathead and Elk River Basins Network Analysis Using Generalized Least Squares" in draft.

3.2.3 Square Grid Technique

While the regionalization studies utilized basin averaged physiographic parameters, the slowly growing accumulation of physiographic data from a 2 km by 2 km sized grid soon made it possible to try another information or data transfer technique for the purpose of evaluating the hydrometric network. This new technique was developed by S.I. Solomon and described in 1968 in his paper "The Use of a Square Grid System for Computer Estimation of Precipitation, Temperature and Runoff". In this technique the model parameters and input variables such as precipitation and temperature are regionalized by regression analysis and then with the square grid technique estimates of runoff volumes for ungauged basins can be made. Several studies have been completed, beginning in 1975 with Leith's paper "Generation of Annual Runoff Data in Two Small Basins in Southern British Columbia by the Square Grid Technique"; and continuing with "Carnation Creek Modelling Activities" (1978); and finally a recently completed study of the application of the square grid technique

to estimate annual runoff volumes for a large area (60,000 km^2) in southeastern British Columbia.

3.2.4 Use of Satellite Data

Considerable work was done by Leith in the use of remotely sensed data from geostationary satellites (GOES) to estimate regional values of annual runoff volumes. It was shown that satellite data in digital format do contribute to delineation of regions and to improvement of mean annual runoff estimates over those made with physiographic data.

3.2.5 Other Studies

Prof. A.K. Wong (1980) provided a report on the use of non-numeric data, such as soil type and biogeoclimatic classifications, in hydrologic regionalization. He also provided recommendations on the use of information measures applied to annual runoff maps and the use of similarity-dissimilarity measures to identify "typical" basins i.e. ones for which regional equations will provide good estimates or to identify "atypical" basins i.e. ones where good estimates would not be expected, i.e. if data were needed, the basin would have to be gauged.

4. FUTURE DIRECTIONS AND EXPECTED RESULTS

4.1 Future Directions

The general direction of network planning and evaluation activities in the Pacific and Yukon Region is to continue the analysis of the existing hydrometric network in the Region with emphasis on identification of gaps and redundancies in the network coverage. Since streamflow processes are highly variable in time and space, the major concern for regional network analysis is to provide models of hydrologic processes which incorporate as much physically based data as possible. This is necessary so that the best use may be made of data from various sources in assessing the contribution of that data in modelling streamflow. With good physically based representation, the value of streamflow data may be assessed.

4.2 Expected Results

Expected results may be summarized as short term and long term. The short term results, expected in 1988-89 are:

i) to complete abstraction of physiographic data for British Columbia;

ii) to complete the Audit of all hydrometric station on Vancouver Island;

iii) to produce annual runoff maps for Vancouver Island.

Long term results are:

i) to complete an Audit of all hydrometric stations in the Pacific and Yukon Region;

ii) to expand runoff maps to cover all B.C. and to produce runoff maps for monthly streamflows;

iii) to provide an evaluation of the Regional Network through square grid analysis.

This will provide descriptions of the characteristics of regional hydrology in British Columbia. In addition, if requested, the grid square analysis provides excellent opportunities to examine the contribution of data from land use and land cover, from remote sensing and from general circulation models. This in turn could provide inputs to climate variability studies.

Certain components of the Future Directions and Expected Results for network planning and evaluation in the Pacific and Yukon Region are examined in detail in the following sections.

4.3 Preparation of Data Banks

As shown in Section 3.2.1 the development of the physiographic and hydrologic data banks is essential in the evaluation of the hydrometric network. It is intended to complete the extraction of the physiographic data for all parts of the Province. Concurrently, the extracted data should be transferred from the map sheets onto a computer tape for

storage and easy access. The extraction of the data is currently being completed on contract; the data entry is complete for 65% of the area of the Province, presently the possibility of awarding a contract for data entry is being studied.

The map coverage in the Yukon Territory is not extensive at the scale of 1:50,000 and it is not possible to utilize the square grid approach for network analysis in the Territory.

The hydrologic data bank consists of streamflow, precipitation and temperature data which can be obtained from readily available sources in non-processed format. Some work is involved in tailoring the basic data to our requirements, but no major problems are expected. Streamflow data bases should be updated every five years or so, to include new stations in the statistical data base. There is good opportunity to access the provincial snow survey data bank for additional network analysis studies.

4.4 The Square Grid Approach

The availability of the large physiographic, hydrometric and meteorologic data banks makes it possible to apply the square grid technique for estimating monthly and annual runoff volumes in ungauged areas to any part of British Columbia.

The square grid is a means of bringing together data from various sources: hydrometric, meteorologic, and physiographic. This allows for a distributed approach to modelling streamflow, whereas regression upon

basin mean values is a lumped approach which does not allow for the distribution of physiographic quantities in a basin.

The proposed direction is to utilize the square grid approach exclusively for the planning and evaluation of the hydrometric network in British Columbia. This is necessary so that the best use may be made of data from various sources in assessing the contribution of that data in modelling streamflow. With a good physically based representation the value of streamflow data may be assessed.

4.5 Runoff Maps

The square grid method can also be used to produce maps showing variations in annual or monthly runoff volumes in the Province. Several years can be analyzed so that variability can be studied and areas with highly variable runoff volumes can be identified. Hydrologic zones can then be delineated and a gauging strategy within these zones be developed. Depending on data and accuracy requirements hydrometric stations can be relocated within the zone or Province.

4.6 Network Assessment by the Audit Method

This method is a new approach in network assessment in this country. It was used for the first time on a large scale in the examination of the relative worth of 72 stations in the Yukon Territory. The method is applicable to project stations, to lake stations, to stations not recording natural flow, that is, all those stations which cannot be

included in network evaluation using correlation or regression modelling techniques. It is intended to continue the audit approach with stations in selected areas of the Province such as the 56 stations on Vancouver Island. The assessment of the hydrometric network on Vancouver Island using the audit method will have expected results which will enable the identification of stations which are:

1) prime candidates for discontinuation or relation;
b) useful for pair-wise correlation;
c) useful for the squre grid technique of estimating runoff volumes in ungauged areas;
d) gauging natural flow and which can be the input to developing annual runoff maps.

4.7 Pair-Wise Correlation

This method assesses the results of the correlation between pairs of hydrometric stations and attempts to come to a recommendation regarding the discontinuation or relocation of stations. In the Yukon Territory network assessment a correlation analysis of monthly flows provided information on those pairs of stations with high correlation coefficients. It is intended to continue pair-wise correlation analysis of not only monthly and annual flow volumes but also of annual flood values in order to be able to identify stations whose records can be simulated well enough so that these stations can be considered for discontinuation or relocation.