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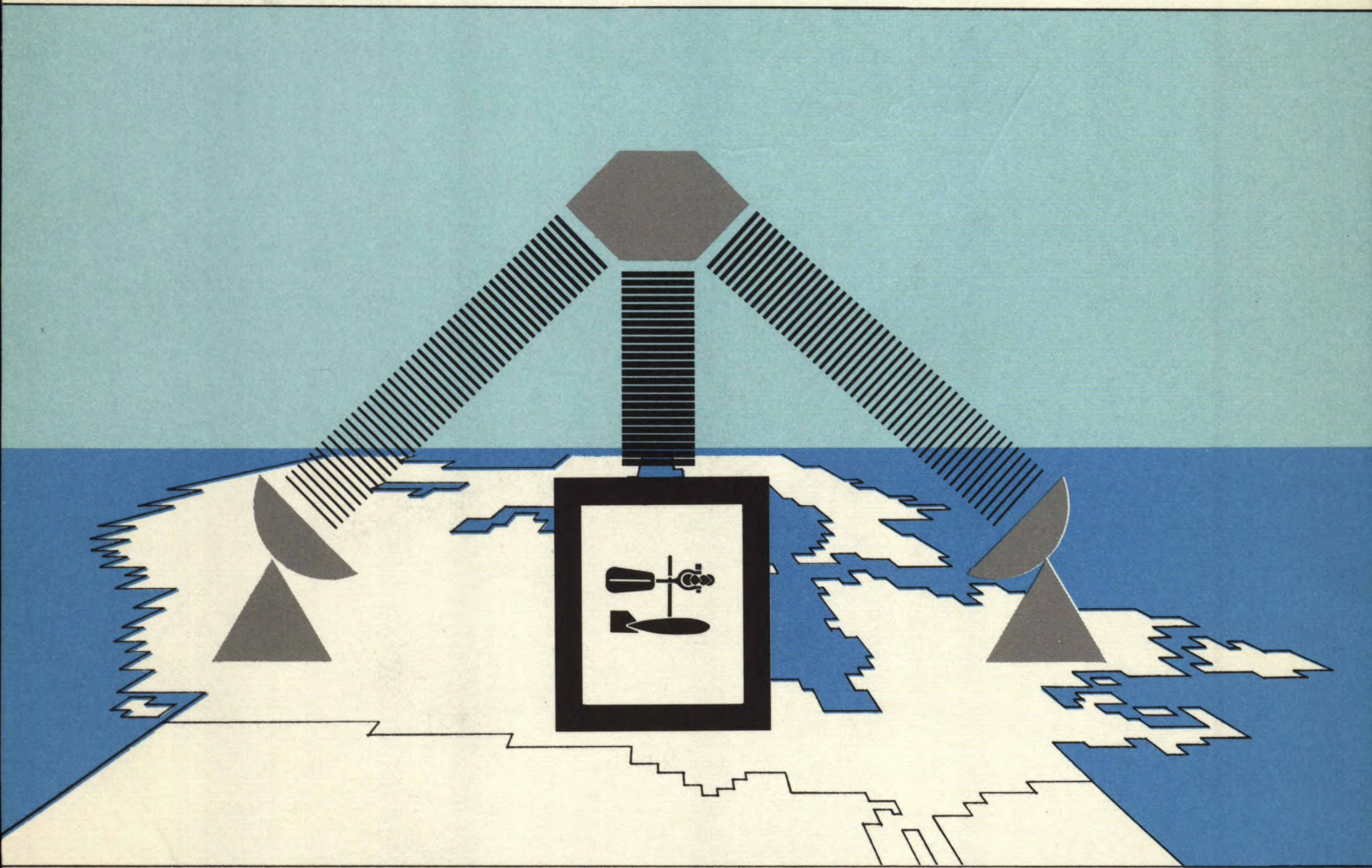
Proceedings of the First National Workshop on Network Evaluation and Planning

Comptes rendus du premier atelier national sur l'évaluation et la planification des réseaux



TECHNICAL WORKSHOP SERIES NO. 8
ÉTUDE Nº 8, SÉRIE DES ATELIERS TECHNIQUES

INLAND WATERS DIRECTORATE
WATER RESOURCES BRANCH
OTTAWA, CANADA, 1989

DIRECTION GÉNÉRALE DES EAUX INTÉRIEURES
DIRECTION DES RESSOURCES EN EAU
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PROCEEDINGS OF THE FIRST NATIONAL WORKSHOP ON NETWORK EVALUATION AND PLANNING

Comptes rendus du premier atelier national sur l'évaluation et la planification des réseaux

Winnipeg, Manitoba
October 5-6, 1988

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Inland Waters Directorate
Water Resources Branch
Ottawa, Canada, 1989

Direction générale des eaux intérieures
Direction des ressources en eau
Ottawa, Canada, 1989

Edited by Paul J. Pilon

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Foreword

Hydrometric Network Planning and Evaluation is both difficult and subjective. Different approaches may be followed, and different analytical tools applied, depending upon the purpose of investigation.

The WMO has assembled information on many different national networks, and has developed density guidelines for a range of physiographic conditions. More recently, an intercomparison of network design techniques was begun, testing several spatial analysis tools.

It is recognized that hydrometric networks must be assessed in terms of user needs for data and information. This is very difficult to quantify, since we deal with multipurpose networks serving present and future needs. The extent of the demand can only be approximated.

User surveys and interviews continue to highlight the facts that surface water quantity data and information is highly valued by many users for both economic and environmental purposes.

Many users utilize the data on a frequent basis, or on a real-time basis, and consider the present networks to be quite sparse, in relation to their applications. A recent survey of users in British Columbia, for example, established a potential demand for 1800 stations, compared to 600 active stations at present.

The role of this workshop was to bring together the various agencies who cooperate in running Canada's hydrometric networks to discuss current approaches to network planning and the value and benefits of hydrometric data.

A number of key data users discussed their requirements in terms of program operations, environmental issues, and in some cases, specific projects. This proved a useful stimulus to general discussions on value of data and benefit-cost aspects.

Useful discussions of coordination of Network Planning Activities also took place. A consensus developed that good opportunities for joint projects and information activities exists, working through the Coordinating Committees that exist in each region and province.

New techniques for planning and marketing hydrometric networks were reviewed. The application of Geographical Information Systems and optical disk technology were seen to be particularly promising.

These proceedings represent a compilation of relevant material that was submitted and discussed at the workshop. Formal papers were not required, but it is hoped that this document will serve as a useful reference for the discussions that took place.

Avant-propos

Le processus de planification et d'évaluation du réseau hydrométrique est à la fois complexe et subjectif. Il est possible d'adopter diverses approches et d'utiliser divers instruments analytiques selon le but de l'enquête.

L'OMM a recueilli de l'information sur de nombreux réseaux nationaux présentant des différences entre-eux, et a élaboré des lignes directrices sur la densité des réseaux pour une gamme de conditions physiographiques. Plus récemment, on a entrepris de comparer les techniques de conception des réseaux, en mettant à l'essai plusieurs techniques d'analyse des surfaces.

Il est reconnu que les réseaux hydrométriques doivent être évalués en termes des besoins de l'utilisateur en matière de données et d'information. Ceci est très difficile à quantifier, étant donné que nous faisons face à des réseaux à buts multiples répondant aux besoins actuels et futurs. Nous ne pouvons que faire des approximations quant à l'importance de la demande.

Les sondages et les entrevues effectués auprès des utilisateurs continuent à mettre en lumière le fait que nombre d'entre-eux accordent une grande importance aux données et à l'information sur les eaux de surface à la fois pour des raisons économiques et environnementales.

De nombreux utilisateurs ont recours aux données sur une base fréquente, ou "en temps réel", et sont d'avis que les réseaux actuels sont peu abondants relativement à leurs applications. Un récent sondage effectué auprès des utilisateurs de la Colombie-Britannique, par exemple, révèle une demande potentielle de 1 800 stations en comparaison à 600 stations bien actives à l'heure actuelle.

Le rôle de cet atelier est de réunir les divers organismes qui collaborent à la gestion des réseaux hydrométriques du Canada afin de discuter des approches actuelles à la planification des réseaux et de la valeur et des avantages des données hydrométriques.

Un certain nombre d'utilisateurs-clés ont discuté de leurs besoins sur le plan des données des points de vue des activités des programmes, des questions environnementales, et dans certains cas, des projets spécifiques. Ceci s'est avéré un stimulant fort utile pour susciter des discussions générales sur la valeur des données et les aspects de rentabilité.

Il y a eu également des discussions touchant la coordination des activités de planification des réseaux. Selon le concensus, il existe de bonnes occasion d'entreprendre des projets et des activités d'information mixtes, en collaborant avec les comités de coordination présents dans chaque région et province. Il y a eu une revue des nouvelles techniques de planification et de commercialisation des réseaux hydrométriques. L'application des systèmes d'information géographique et de la technologie des disques optiques a été perçue comme étant tout particulièrement prometteuse.

Ce compte-rendu représente une compilation des documents pertinents qui ont été présentés au cours de l'atelier et qui ont fait l'objet de discussions. Nous n'exigions pas de documents officiels, mais il est à espérer que ce document servira de référence utile sur le plan des discussions qui ont été tenues pendant l'atelier.

1. WORKSHOP AGENDA

NEP WORKSHOP PROGRAM

October 5

9:00-09:15	Welcome and Introductions	(Hale/Austford)
9:15-09:35	WRB Program Overview	(D.R. Kimmett)
9:35-10:00	Network Planning Background	(A.R. Perks)
10:00-10:20	Coffee	
10:20-12:00	Provincial Perspectives on Network Planning	(Various)
12:00-13:30	Lunch	
13:30-14:30	New Brunswick Network Study	(D. Ambler)
14:30-15:30	Recent USGS Experience in Network Planning	(W. Thomas)
15:30-15:45	Coffee	
15:45-17:00	Panel Discussion - R. Coley, Ducks Unlimited, Winnipeg M. Samp, Can. Water Resources Assoc. T. Dafoe, Water Quality Branch, Ottawa D. Fairbairn, Water Planning Branch, Regina S. Choudhary, Alberta Transportation & Utilities	(Chairperson, P. Valentine)

October 6

9:00-10:30	Related Data Networks	
	a) Meteorological	(R. Raddatz, AES, Winnipeg)
	b) Water Quality	(Evan Watt, WQB, Ottawa)
	c) Sediment	(T. Day, WRB, Ottawa)
10:30-10:45	Coffee	
10:45-11:15	Regional Hydrology in Canada	(P. Pilon, J. Power, WRB, Ottawa)
11:15-12:00	Geographical Information Systems-Applications in Network Planning	(D. Jobin, NUCOR Computing, Ottawa/J. Power, WRB, Ottawa)
12:00-13:30	Lunch	
13:30-14:00	Marketing, Data Products and Information	(A. Perks, WRB,Ottawa)
14:00-15:15	Panel Discussion - "Coordination of Network Planning Activities" - G. Tofte, WRB, Vancouver, B. Letvack, Natural Resources, Vancouver - G. Cole, Alberta Environment, Edmonton - M. Kowalchuk, WRB, Winnipeg - D.R. Kimmett, WRB, Ottawa - P. Campbell, WRB, Ottawa - J. Jasper,DINA, Yellowknife	
15:15-15:30	Coffee	
15:30-17:00	Plenary Session Rapporteurs reports, Summary and wrap-up	

2. WELCOME AND INTRODUCTIONS

"Welcome and Introduction" Opening Remarks
by R. Hale, Chief, WRB
Winnipeg, Manitoba

- It is my pleasure to welcome you all to Winnipeg and to this workshop - our first National Workshop on Network Evaluation and Planning.

- On behalf of all of the Hydrometric Agreement Coordinators I particularly welcome the participants from our federal and provincial sister agencies, Will Thomas from the USGS and to you from outside government.

- While we are into our 81st year of collecting hydrometric data in Canada and our 14th year of operation under the Hydrometric Agreements which charge us with the responsibility for network planning and this being our first national meeting on the subject some may feel that we have been lax in overseeing our network.

- This is far from the case. For the most part the extensive knowledge of our water resources, our network, and the issues which was brought to the table at Coordinating Committee meetings has been highly successful in fulfilling the needs for water resources data.

- In addition to our "seat of the pants" approach to network planning we collectively undertook a number of planning studies through consulting contracts. Invariably these reports conclude that there were insufficient data and recommended network expansion.

- Consquently, in these times of restraint, the term Network Evaluation and Planning has a very negative conotation for most of us.

- It is precisely these new pressures however that call for our increased attention to Planning.

- To set the stage for our discussions over the next two days I will address some of the issues and challenges which we are all facing as managers.

1. Downsizing: this term hardly needs definition: for the most part we have all had to or are continuing to face downsizing in terms of both budget and person years.

2. Restraint and the Golden Goose: closely related to the downsizing issue is the competition for scarce resources. We have a long history of program reviews and audits - most of which stemmed from jealousy of our resource base and our inability at defining the value of our data.

3. Increased visibility: as a matter of survival we must learn to sell ourselves
   (a) public
   (b) our clients
   (c) senior management

4. New priorities:
   (a) maximize efficiencies through modernization of our data collection, processing and dissemination of data
   (b) integration with other data collection programs
   (c) greater involvement in the interpretation of our data for such activities as - state of environment reporting, - management of toxics, - environment - economy linkages

° I am sure that some if not all of you are perplexed as to how these issues have anything to do with network planning.

° It is this question that I hope we all attempt to address over the next two days because I feel that we have to start working even more closely together if our program is to survive the current fiscal climate.

° Before I turn the floor over to Dale I would like to introduce some of my staff who will be available to assist in anyway possible, Mike Kowalchuk, Walter Bilozor, and Al Glennie

° Thank you again and lets have a good exchange of ideas.

3. NETWORK PLANNING BACKGROUND

On the Planning of Hydrometric Networks*

Alan R. Perks P. Eng.

Water Resources Branch

Inland Waters Directorate

Conservation & Protection

Good morning ladies and gentlemen. It is a pleasure to welcome you here in Winnipeg, especially since we have attendance from all across Canada at this Network Planning Workshop. I hope you find the next two days stimulating, and that this Workshop serves to increase our cooperative efforts to plan these important data networks, which so many Canadians depend upon. I would like, at the outset, to express my appreciation to Bob Hale, Water Resources Branch Environment Canada, and to Mindy Austford, Manitoba Water Resources Branch, for acting as co-hosts of this workshop.

The planning of hydrometric networks, involving data and information activities, is indeed a complex business. So it is best to start out with a definition, since several different perspectives may exist.

Presented at the National Workshop on Network Planning. Oct. 5-6, 1988, Winnipeg, Manitoba.

Network Planning, simply stated, is the process by which we strive to balance Resources versus Needs, and it involves assessing alternative ways to strike this balance -- to find the wisest choice. So it is not just a narrow technical assessment procedure; rather, Network Planning is part of the management of the entire program.

If we had unlimited resources - or no resources at all! - the planning process would be simple indeed. We wouldn't need any. The same would be true if we had no demand for data and information. But we do have resources, fixed or dwindling as they may be, and we have urgent and demonstrable needs for the information. So some degree of planning must be done to determine how best to deploy and operate the network to meet these needs.

I realize fully well that for many of you it is hard to remember to "drain the swamp when you are surrounded by alligators", as the story goes. But even in that situation, you would be better off if you had, at least, stashed a stepladder nearby the week before. Some level of planning and information is necessary to help make decisions, even during periods of crisis. It has been my experience that the tougher the situation, the more useful becomes a little planning and forethought.

We need to establish some common goals if our planning efforts are to succeed. The Water Resources Branch has developed goals and they are embedded in work plans and other related documents. These goals can be summarized as follows:

a) **reliable water data will be available to Canadian Water Managers.** The network is operated and data and information is produced, to serve the needs of water managers in the Federal and Provincial Governments, municipalities, and the private sector.

b) **Hydrometric stations will be operated for specific purposes,** whether these be current operational needs or identified regional hydrology needs. By constantly reviewing active stations, the Branch endeavours to make each station as useful as possible.

c) **Surface Water information will be made available relevant to water management problems or issues of interest to the Federal Government, Provincial cooperators, and the general public.** The usefulness of the basic data can be enhanced by abstracting from it information that relates to current economic and environmental issues.

d) **Information on the State of Canada's Water Resources will be available.** The Federal Government's primary interest is to ensure sustainable development of the Nation's Water Resources, and to do this, generalized information on surface water supplies is necessary for all parts of the country.

In a nutshell, then, the network is to be operated to meet identified needs for data and information, and strategies for adjustment will be based upon how well these needs can be met.

This brings us to the second major planning issue; the assessment of user needs. Here we must strive to keep in mind several different planning horizons: **current**; **intermediate**; and **long term.**

We have a pretty good idea of **current** needs through the activities of the Coordinators, from requests for data that are received, and from user surveys the Branch carries out. These surveys indicate a high degree of utility of the data produced for a wide range of different purposes such as flood forecasting, navigation, infrastructure design, recreation, etc.. Given the nature of their business, however, users often cannot identify where they are likely to need data in the future.

Over the **intermediate term**, say over the next 5 to 10 years, how can we anticipate where our data will be most needed? The Federal Water Policy provides a statement of the Federal government's goals for Canada's Water Resources, and outlines the most pressing issues that are foreseen at this time. The policy itself provides the most compelling assessment of the importance of our water resources to the Nation's environment and economy. The specific policy statements, on the other hand, highlight very effectively the role of surface water data and information in achieving federal goals. Addressing issues such as Water Quality Management, Interjurisdictional Water Conflicts, Municipal Water and Sewer Infrastructure, Safe Drinking Water, Interbasin Transfers, Hydroelectric Energy, Flooding, and Droughts simply cannot be achieved without comprehensive surface water data from all parts of the country. By increasing our communications with those agencies most directly involved in these issues, we can better ascertain specific opportunities for surface water information that will meet their needs, and achieve a more integrated planning of our own network at the same time.

What about the **longer term**? What kind of information will be required to meet the needs 20 and 25 years from now? Admittedly, this is a more difficult task, and we should avoid dwelling too long on the "imponderables" involved. But perhaps the best clues can be gathered from considering the trends in North American Water Management. Since we gather the data for the use of water managers, whether in government or private agencies, changes in how water is managed will influence what data and information is necessary.

Water management involves allocating a limited supply among growing and competing water uses. Changes in the way water is managed are being brought about by several different factors, including reductions in government spending, water and groundwater quality concerns, increased urbanization and other population shifts, increased development of arid areas, legislative and legal shifts, and greater local control of water resources.

The impacts of these changes have been discussed by many authors in recent years. Some of the changes often noted include;

- growing competition for water, resulting in a higher value being placed an available supplies, and ultimately goods and services being redefined in terms of their "water value". Available supplies are also declining due to surface and ground water contamination.

- Economic pressure resulting in more user-fees, cost sharing, and local financing of water programs. Concurrently, a likely shift in emphasis from water development activities to environmental programs.

- Increased focus on conservation and re-use at all phases of project development. In parts of North America, reclaimed water now costs less than a fresh water supply.

- Environmental legislation designed to hold polluters and users accountable for their impacts on available supplies. In other cases, a legal trend towards forcing users and water managers to justify their uses, needs, and management practices more rigorously, and the likely increase in the priority accorded environmental water uses (i.e. fish and wildlife habitat) versus the traditional economic uses (i.e. agriculture, industrial, etc.) in legal proceedings.

- Surface and groundwater quality problems will obviously remain on the public agenda for a long time. It will be increasingly important to integrate our network planning efforts with these related data programs.

- Basin and regional water planning will be emphasized to resolve transboundary issues and disputes. Therefore, the need for comprehensive and regional surface water information will also grow.

We can draw from some of these considerations that greater coordination of our efforts will be required to meet the needs of water managers in the future. Water management will become more integrated across disciplines and specialties, quantity and quality, surface and groundwater, basin and regional in focus.

What this means for data programs is that integrated planning of networks will be essential. While the bulk of our users will continue to need data for design analysis purposes, increased attention must be paid to the need for comprehensive regional surface water information that water managers can apply to many different kinds water issues and problems. This means overview information, facts sheets and summaries, surface water mapping, hydrologic assessments of basins and regions, and surface water information relevant to the assessment of water quality and groundwater problems. Data and information in highly accessible and convenient formats will be essential. The use of real-time water quantity data will continue to grow to serve many needs, some presently unforeseen.

Our planning efforts must ensure that the networks are deployed and information produced, in a way that permits the water managers of the future to get on with their task. To accomplish this purpose, and to meet the needs for a sustainable economy and environment, continued access to high quality surface water data will continue to be the foundation.

How do we approach the planning of a complex data and information system, which is managed through eight regional and district offices plus a headquarters operation. This is no easy task, but let us consider the planning approach from some first principles. Basic facilities planning, whether one is dealing with a transportation system, a water distribution network, or an irrigation system, follows several identifiable steps that constitute a simple planning process.

A. Establishment of Goals
B. Inventory of facilities and needs
C. Analysis of Alternatives
D. Plan selection and development
E. Report preparation.

These simple steps form the basis of most successful planning activities and reports, in many different fields. They can provide a useful framework to guide our own planning efforts, and in fact were followed in developing the WRB's "National Strategy for Network Evaluation and Planning".

We have set goals, discussed previously, that are incorporated in our Branch workplans. These may change from time to time, reflecting our sense of priorities.

Do we have sufficient information on the network we operate? No doubt we do, but it lies in many different files, offices, and memories, and has not yet been brought together in a convenient way that facilitates national and regional planning. Steps to build this inventory through Station Profiles and Geographical Information Systems should help to better organize and manage this information.

Have we assessed user needs? Many user surveys have been carried out that indicate a high degree of utility of the collected data and also a high level of user satisfaction. But we have probably not done enough to work with other government agencies and non-traditional groups to determine their needs. We are beginning to make available generalized information useful to large numbers of non-engineering users in related environmental and economic disciplines. The "Fact Sheet" described in this workshop is a good example. Basic hydrologic and interpreted information is displayed in such a way that many different engineering, environmental and other users can abstract from it information that is immediately relevant to their work.

In terms of actual technical network evaluations, many different procedures have been developed for our use, ranging from a Pragmatic Evaluation, Square-Grid Modelling, to Regression Techniques. These are being applied, today in our Regions. Using these techniques, the objective is to try to determine a priorization, or ranking of hydrometric stations. This ranking then forms the basis of selecting different management strategies, and forms a useful part of any network planning and evaluation study.

Clearly, the selection of a network plan involves many different technical financial, environmental, and socio-economic factors. We need to ensure that the non-technical considerations are well understood and accounted for in the planning process. Technical analysis will always play an important role in planning our networks, but we must increasingly explain how the data and information produced relates to many different water management issues and concerns, in both the public and private sectors. We must demonstrate the value of the data and information in supporting Federal and Provincial activities, and that we are employing the best technology to operate efficiently.

Network planning is a dynamic process that involves ongoing assessment of resources and needs. But if we worked towards documenting, even very briefly, a network plan in each region that discussed user needs and how we saw our networks developing over the next 5 years, then I feel we would have achieved a great deal and exerted our best efforts in supporting an essential program for all Canadians.

Sufficient flexibility has been provided in this approach to suit regional conditions and priorities, especially in the selection of technical procedure for network analysis, because the hydrology of Canada varies so greatly.

But the approach has been developed to produce information that will benefit both network managers and users at the same time. By carrying out the suggested types of hydrologic assessments and interpretations, we will produce information useful in deciding which stations to operate and for how long. In a different form, the same information will help users understand the hydrology of a region and apply our data better. For example, Station Profiles will help managers to more quickly review a specific station, and may also help a user assess the station's record and applicability to his problem. Regional or basin hydrology reports will provide network managers with a better sense of priorities among different stations, and at the same time provide users with better information for estimating ungauged flows.

Network Planning represents one of the more fruitful areas for cooperation between the Federal and Provincial Cooperators. Some specific suggestions that makes sense to me would include:

- Station Profiles, documenting the essential aspects of a station in a convenient format.
- Network Database and Geographic Information System applications that can display, screen, select, and evaluate networks of stations.

- Regional flood and drought reports and information providing guidance for network planning as well as useful technical guidance to users.
- Generalized surface water information such as maps, plans, and fact sheets for public consumption and for assessments of water supplies for diverse environmental and economic purposes.

The benefits of this cooperative approach would be many; better management data to assist cooperators in day-to-day decision making; information to help rationalize and justify the program; improved service to our traditional users; information products to help meet the needs among non-traditional users. I can't help but feel that this would be good for all of us, and would be a wise course of action in difficult times.

Thank you for your time and attention, and I look forward to working with you over the next 2 days.

Alan R. Perks, P.Eng.
Water Resources Branch
5 October 1988

PHASE I

NATIONAL NETWORK EVALUATION AND PLANNING STRATEGY

WATER DATA AND INFO NEEDS

A) Data for water managers and users
B) Information on water problems and issues
C) Water information for public use
D) Information to help manage the network

NETWORK PLANNING GOALS

"To ensure network meets the needs" by ensuring;
A) Data is reliable
Station matches need
Reliable interpretations & estimates can be made
B) Information is available to address issues
C) National/regional overviews available
D) Network adjustment priorities are established

DESCRIBE EXISTING NETWORK

STATION PROFILES

- active stations
- contrib'd stations

SUMMARIZED INFORMATION

Tabulations of:
- area
- record length
- uses
- others

MAPS AND PLANS

- Physioclimatic zones
- basins
- reg'd/unreg'd st'ns
- longterm stations
- small basins
- forecast network
- reg'l hydrol. network
- flood maps

Information useful for overviews, professional users, to enhance Data Books and Annual (Cost-Share) Network reports

PHASE II

DO THE NETWORKS MEET THE NEEDS?

WATER MANAGEMENT NETWORKS

i.e. "Current Needs",F1,F2,F3, FP1,FP2,P1,P2

1) Assess station data records
2) Review and match stations with needs (internally and with users)
3) Priorize & justify the stations and their operation
4) Justify the network as a whole

REGIONAL HYDROLOGY NETWORKS

(ie "Regional Representativeness"FP3)

1) Assess station data records
2) Identify long-term index stations
3) Study regional floods/droughts/Yields
4) Network analysis to establish representativeness and transferability of stations and networks
5) Priorize and justify the network

Information to Enhance Data Books

examples:
- long term means
- standard freq. curve events separated by cause
- quality of record

Information for Network Management

examples;
- listing of highest/lowest priority operational stations
- possible operational/equipment alternatives at selected stations
- listing of stations by quality of record

Information useful to professional users and for overviews, examples
- short station evaluation including frequency & flow duration curves, long term means, long term hydrograph
- technical reports or papers on flood/drought estimates for particular basin or region
- map showing stations most useful for estimating flows
- map showing long term index stations

PREPARE NETWORK PLAN

- Water management networks
- Regional hydrology networks
  - long term stations
  - short term stations
- priorities for expansion/contraction
- specific recommendations
- very short reports

4. PROVINCIAL PERSPECTIVES ON NETWORK PLANNING

NATIONAL WORKSHOP ON NETWORK
EVALUATION AND PLANNING
October 5-6, 1988
Winnipeg, Manitoba

Alberta's Perspectives on Network Planning

Introduction

Alberta needs a comprehensive network of hydrometric stations in order to meet its objectives for hydrologic analysis, flow forecasting, regulatory functions and the planning and evaluation of a variety of water resources management initiatives. Some examples are

1. Oldman River Dam and other possible damsites
2. A natural flow data base for South Saskatchewan River basin management
3. Agricultural drainage in N. Alberta
4. Floodplain management

The network that exists today has received much of its impetus from the Federal-Provincial Cost-sharing Agreement for water quantity. This agreement provides the framework for management of the network in a systematic manner. It ensures that national and regional priorities are given joint consideration in order that they can be firstly understood, protected where necessary, shared and accommodated.

Because of commitments and obligations under this agreement, continuity of the network is better protected than are many other data collection functions.

Alberta recognizes the importance of sound network planning as a tool which provides a blueprint to handle not just enhancements (increases) of the network, but also deletions from the network. Without such a plan the network could be affected negatively because of inappropriate cuts or by the creation of redundancies.

Alberta recognizes the importance of having the planning process include both those who use the data and those who operate the network. The latest Alberta network plan was produced by the data users with input from the Water Survey of Canada with respect to the feasibility of establishing stations at particular locations.

In Alberta Environment we have established a Network Review Committee which is chaired by one of our two co-ordinating committee members (Gerald Coles) with the other representatives coming from the principal user groups in the department. We feel that this committee has been meeting its terms of reference during a difficult period of cut backs. It has meant there is a co-ordinated approach to these network changes. You will have the opportunity to hear Mr. Coles outline the workings of the committee at tomorrow's panel discussion "Co-ordination of Network Planning Activities". This committee ensures that a co-ordinated provincial position is brought to the Co-ordinating Committee meetings and other contacts with our federal counterparts.

I believe, that this workshop's usefulness will be directly related to the provincial representation (attendance), i.e. proper network planning must take into consideration the interests of both levels of government.

Network Planning Initiatives in Alberta

1958 Underhill

A report on the future hydrometric requirements by the Province of Alberta for basic coverage and 5-year development plan from 1959-1963:

- envisions the network of stations that is required to give sufficient basic data so that we can prepare reports and studies on the water supply for any stream or area in Alberta.

1963 Underhill

A Hydrometric Network for Alberta. Prepared for the Technical Co-ordinating Committee on Water Research.

The proposed network was based upon a number of assumptions:

- to compare runoff from various elevations and determine relationships if any, of the runoff from different areas at the same elevation;
- to determine the relationships of runoff to annual precipitation and possible combined relationships between elevation and precipitation;

- in the final analysis to determine the runoff from the area with the minimum amount of instrumentation.

1977 (1984) Figliuzzi, Phinney (Alberta Environment and Environment Canada)

Hydrometric Network Analysis Pilot Study, for the Oldman River Basin prepared for Federal/Provincial Co-ordinating Committee. Hydrometric Network.

"To assess the capability of an existing hydrometric network in Alberta; to develop an analytical approach for planning the future development of that network, and to investigate the feasibility of applying the same approach to the entire Alberta network."

1981 Figliuzzi (Alberta Environment - Hydrology Branch)

Inadequate Hydrometric networks, A Constraint on Knowledge and Development

"Evaluates the adequacy of the existing hydrometric network by

- establishing quantitative preliminary accuracy goals for both the individual stations and for the network as a whole.

- Assessing the planning and design network in a pilot basin, (Oldman River above Lethbridge) to determine if the established goals have been met.

The analysis indicates that the hydrometric network for the pilot basin does not have a sufficient number of streamflow stations nor a long enough period of record at these stations to permit development of equations at the selected level of accuracy for transferring information to ungauged sites.

Since the pilot basin is one of the most densely gauged basins in Alberta, the report concluded that the hydrometric network in the rest of the Province will also be inadequate.

1981 Hydrology Branch

Alberta Hydrometric Network Enhancement

- A Five Year Plan 1982 - 1986

- To review and assess the existing network
- to obtain background information on future developments
- to identify a hydrometric network to meet existing and future needs
- to identify the individual basin priority in which new stations should be established.

252 new streamflow and 19 new lake level stations over five years were proposed

This was not intended to be the ultimate plan but was designed to cover a five year period only

Table 1 shows the network changes since the plan was put into effect.

	New Stations Established	Stations Discontinued
1981-82	17	0
1982-83	17	3
1983-84	22	8
1984-85	27	14
1985-86	11	8
1986-87	10	33
1987-88	7	6
	111	42

These figure dramatically demonstrate how "real world" financial constraints can distrupt the best laid plans. (During the period 1981-86 the Alberta economy experienced traumatic changes and no plan would have been immune to the consequences.)

Other network planning activities have emphasized the need for hydrometric data for flow forecasting and other water management purposes. Major emphasis was placed on the South Saskatchewan basin with additional enhancements to improve flow forecasts for the Red Deer (Dickson) and Oldman River Dams. The most important requirement to the flow forecasters was the need to have data on a real time basis.

Some Considerations for Network Planning

As Co-ordinating Committee members, and several of us are present at this workshop, we have long been faced with adopting a pragmatic approach to implementing network changes. There is, for example, little point in establishing and subsequently operating a station at a location where the quality of data will be poor.

Because of financial constraints we are constantly justifying the value of individual station, i.e. stations must qualify on their own merits, "nice to have" stations are becoming a rarity. There tends to be more emphasis on water management stations rather than long term stations required to establish regional hydrologic characteristics.

There is however more to network planning than merely taking a pragmatic approach. It is recognized that there is a requirement for a rigourous, possibly a mathematical, approach. This might ensure there is discipline to the network planning process so that we can minimize redundancies, avoid shortages (gaps) and provide more logic to the process.

Rigourous scientific methods for network design do have their limitations however, as Figliuzzi found in his work on the Oldman River Basin. He found that the scientific method could not be applied unless a given area was already at or near an optimum network density. Therefore the judgement and experience of people who use the streamflow data must play an important role in the design of these networks.

Our experience has led us to a number of conclusions regarding network planning

- a "one solution" approach should be treated with skepticism
- a network plan must be based upon a thorough knowledge of the existing network
- a network plan must remain flexible and requires periodic updating; it must be able to respond to change. Changes in the economy and decisions to proceed with major developments can occur with surprising swiftness.
- technological change and the opportunities that improved technologies afford, such as improved data collection and transmission, are beginning to play an important part in network planning.

Economics

It has long been recognized that knowledge of the availability of water is fundamental to economic development. This knowledge only becomes available when there is a viable data collection network. We have however tended to justify the collection of these data on the strength of having this basic inventory and the ability to produce competent hydrologic analyses.

We have also endeavored to ensure that our data collection procedures and systems are the most cost effective available.

It is now becoming increasingly important to justify in economic terms the cost effectiveness of our data collection networks and I feel we should be prepared to illustrate in dollar terms just how cost effective our networks are.

Later today, during the panel discussion "Value of surface water data", we will hear the views of a number of users of hydrometric data.

New Technology

Network planning has taken on an additional dimension because of the technology that is available today. Electronic storage of data and improvements in telemetry has given us the ability to store and transmit data. We have seen, in Alberta, for example a considerable amount of emphasis being placed upon the acquisition of data in real time for water management purposes - a "real time network" has emerged. Of 473 hydrometric stations under the cost-sharing agreement 120 have data transmission capabilities. An electronic data acquisition system allows us to monitor and store data on a continuous basis from a wide variety of telemetry ranging from the old telemark to the latest telemetry systems which have considerable on board data storage capabilities.

The value of these new developments have become particularly evident during the recent periods of extreme flows and water levels. In 1988 we had to deal simultaneously with drought and flood in different parts of the province. The clearly demonstrable benefits derived from "real time" data have made funding relatively easy in comparison to the problems we have had in maintaining the traditional network. Possibly there are lessons to be learned here.

New technology has also made remote control and automatic control of water management facilities possible.

In addition to the needs of water managers, public demand for water information has increased significantly. The public expect to plan their recreational pursuits, make independent environmental assessments and in many instances "just want to know". There is an expectation from the public that our organizations have a responsibility to collect high quality data and be able to produce them on demand. The network, and the data it produces, are no longer for inventory purposes only, they are now considered interactive tools.

Advances in electronics are also making it possible to address the demands of a wide variety of users. For example extra sensors to measure some parameters related to water quality can be added to the newer telemetry units with little additional effort and expense. If the hydrometric network is to continue to receive the support it has received from both levels of government we must make sure its benefits are optimized. This may well be the greatest challenge facing network planners.

Summary

1. Alberta supports the need for cost-effective network planning.

2. Network planning efforts must be coordinated between the different levels of government hence the coordinating committees for the cost-sharing agreements should play an important role.

3. The introduction and use of new technology must be considered in the planning process.

4. A worthwhile objective would be the standardization of the planning process nationally with built-in flexibility to accommodate and address regional needs.

5. Network planning must recognize the multiple uses of the networks.

6. Notwithstanding the ever-increasing emphasis on surface water information for water management purposes the importance of the regional hydrology networks must not be minimized.

DRAFT

ASSESSMENT OF HYDROMETRIC STATIONS OPERATED BY WATER SURVEY OF CANADA IN THE YUKON TERRITORY

Water Resources Branch, Inland Waters Directorate

Department of the Environment

Water Resources Division

Department of Indian and Northern Affairs

June 1988

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SUMMARY

In anticipation of possible budgetary constraints, the seventy-two hydrometric stations operated by the Water Survey of Canada in the Yukon Territory were examined to:

- identify the relative worth of each station,
- develop a one page information sheet for each station,
- provide candidate stations for relocation or discontinuation,
- provide a tool for making well-informed decisions on the management of the hydrometric network in the Territory.

To this end the USGS method (Wahl and Crippen) method was modified to include an examination of each station according to four rating factors: need for data, quality of data, economic considerations in gathering of data, and usefulness of data. Background data such as current project uses of the hydrometric data, original purpose for establishment of the station, and extent of periods of missing data were compiled in the regional office. Other current uses for the hydrometric data were provided by the supervisor and technicians of the Whitehorse sub office as well as measures for the assessment of the quality of records by examination of discharge rating curves. Cost of operating the stations was rated on the basis of data provided by the Area Engineer and the Whitehorse Supervisor and included means of access to the station and a description of field tours. The data for each station were summarized on a one page information sheet called a Hydrometric Station Profile Summary. A review committee including members of the Coordinating

Committee of the Yukon Territory Cost Sharing Agreement for Water Quantity Surveys reviewed the station profiles and determined the relative worth of each of the stations. Six stations were identified for relocation or discontinuation at this time.

10AB003	King Creek at Nahanni Range Road
09EA003	Klondike River above Bonanza Creek
09AB010	Lake Laberge near Whitehorse
09AB008	M'Clintock River near Whitehorse
09FD001	Porcupine River at Old Crow
09AG002	Quiet Lake at South Canol Road

1. INTRODUCTION

1.1 Background

This study of the hydrometric stations in the Yukon Territory was undertaken in answer to a request by the Acting Director of the Northern Affairs Program of the Department of Indian and Northern Affairs (DINA). In his request, the Acting Director expressed concern regarding possible future reduction in the number of hydrometric stations if present levels of expenditure had to be maintained and operational cost due to inflation increase could not be absorbed. In answer to this request, a proposal (Appendix A) was presented at the 10th annual meeting of the Administrators and the Coordinating Committee of the Yukon Territory Water Quantity Surveys Cost Sharing Agreement to carry out an assessment of the hydrometric stations in the Yukon Territory to determine the relative worth of each station and to identify stations for possible relocation or discontinuation. The proposal was accepted in principle but with reservations expressed regarding rating factors such as estimating "the value of water" and rating future developments and the need for baseline information.

The study area was the Yukon Territory with 72 hydrometric gauges operated and maintained by the Water Survey of Canada. The area of the Territory is 483,450 square kilometres (Source: Energy, Mines and Resources Canada, Geographical Mapping Division, recalculated 1981).

1.2 Purpose

The purpose of the study was to provide an assessment of each of the 72 hydrometric stations operated in the Yukon Territory to develop a tool by which rational, well-informed decisions may be made regarding the management of the hydrometric network when faced with budgetary constraints. As a result of this study several stations were identified as prime candidates for relocation or discontinuation on the basis of no need for the data, poor quality of data and high cost of operation.

2. METHOD

2.1 Previous Studies

Previous studies by Leith (1977) and Janowicz (1984) have shown that there are large gaps in both time and space in the streamflow data collection coverage in the Yukon Territory and that the network should be expanded rather than reduced.

2.2 Station Profiles

It was therefore decided that this study would not be a network assessment but rather an assessment of the individual hydrometric stations; a method was chosen which examined each station according to a selected set of rating factors. This approach was developed by Wahl and

Crippen (1984) to examine the relative worth of a station in a multi-purpose network; those stations with the least potential value would be candidates for discontinuation.

By using a slightly altered version with these four rating factors:

1. need for data
2. quality of data
3. economic considerations
4. usefulness of data

72 stations in the Yukon Territory were examined. Utilizing what is known about the stations for each of these factors a station profile was produced which formed the basis of each station's assessment. In order to compile this information the authors relied heavily upon the input of the field technicians and their supervisor from the Whitehorse office and the Area Engineer for the Yukon Territory.

2.3 Basic Information

Basic information included the identification of the subdivision or sub office from which the station was operated, date of compilation of the station profile, identification of station by name and number and tributary, the average annual flow for the period of record, the contributing drainage area at the location of the station as identified by its latitude and longitude coordinates. The period of record was given as well as the number of years during which there were incomplete records during the stated period. If there is regulated flow, the extent and reason for the regulation were also indicated.

2.4 Need for Data

In 1985 the Coordinating Committee of the Yukon Territory Water Quantity Surveys reviewed the data uses and funding for each of the active stations in the Territory in order to re-assess the responsibility classification to comply with the new classification guidelines. Data uses were identified under three categories:

1. data were required for current or immediate use at project stations
2. baseline data were required for planning and design of future projects at regional and major stream stations
3. data were required for national inventory of water resources at inventory stations

Stations operated for national inventory purposes were classified as Federal 4, and stations primarily collecting baseline data were classified as Federal-Territorial 3 according to the guidelines. When considering the current use category of stations it was felt that identification of specific uses of the data would be of greater benefit to management than simply to call these project stations. A categorization previously developed by Kreuder (1987) to identify the functions of project stations in British Columbia was utilized. In this analysis seven functions or categories were identified according to the station classification guidelines.

In this section of the stations profile the responsibility classification currently applicable to the station was also noted; classifications were: Federal (F2–F4), Federal-Territorial (FT2–FT3), Territorial (T2) and Territorial NCPC (T2 NCPC), when funding was provided by the Northern Canada Power Commission (now The Yukon Electrical Company Limited). The reasons why the station was established was also included by referring to an earlier report by Kreuder (1980) in which he described the history of hydrometric activities in the Territory.

2.5 Quality of Data

The first step in the assessment of the quality of the data was an examination of the available record for periods of missing or estimated data in order to identify stations with poor record recovery. A short list of stations with unusual amounts of record loss was compiled and discussed with technicians.

After these discussions it was decided that data recovery alone was not an adequate measure of the quality of data at a station, but that an examination of the stage discharge relation of the site was essential before the quality of high flows, low flows and average flows could be rated as good, fair or poor. As a guide to the assessment of data quality made in the report, the following statements were utilized without a lengthy and time consuming study. Data quality was rated as follows:

poor - if the stage discharge relation was not well defined; there were few discharge measurements; the section was not stable; the stability of the benchmarks was poor; channel control was not stable.

good - if the section was stable and a wide range of measurements was available to define the stage discharge relationship.

fair - if the quality was neither poor nor good.

Space was provided in this section of the station profile for additional comments to aid in the assessment of the quality of data.

Other items noted were the facilities or equipment required for discharge measurements, and the condition of benchmarks.

2.6 Economic Considerations

In this section the cost of operating and maintaining a station in good working condition was evaluated by examination of several factors such as: accessibility, number of other stations on the field tour, and number of times the station was visited during 1987. Other items noted were special equipment at the site, and requirement for sediment or water quality samples. All these factors influenced the number of visits to a station and thereby determined the cost of its operation.

Based on this information a realistic estimate of the cost of operating the station was made by the field personnel and recorded as high, average or low. Additional information under the heading of economic considerations was the cost of construction of the station, if it was established after 1975, plus any major repair or upgrading expenditures that occurred since then.

2.7 Usefulness of Data

In this section consideration was given to factors such as size of basin being gauged by the station, amount of runoff measured at the site and not measured elsewhere, usefulness for estimating monthly and annual runoff volumes at ungauged sites, and closeness to precipitation stations operated by the Atmospheric Environment Service (AES). An indication of the correlation of monthly flows with other stations was also noted for R values greater than 0.70; utilizing results of a recent DINA funded study carried out by Klohn Leonoff Yukon (1988).

2.8 Stage Only Stations

For stations where only stage or water level readings were being produced the station profile contains most of the data on background, need for information, quality and economic considerations. The section on usefulness was omitted because this information is not relevant to a stage only station.

2.9 Review Committee

After the 72 station profiles had been compiled, they were reviewed by a Committee, which included members of the Yukon Territory Coordinating

Committee, and the final recommendations prepared for inclusion in this report.

3. RESULTS

Station profile sheets were produced for 72 active stations in the Yukon Territory (available on request from the Water Resources Branch in Vancouver); 69 of these gauges were operated and maintained by technicians of the Water Survey of Canada located in Whitehorse. Two stations on the Firth and Babbage River were operated and maintained by technicians located in the sub office at Inuvik in the Northwest Territories, while the Beaver River station in the far southeast corner of the Territory was operated from Fort St. John. The two international stations on the Yukon River at Eagle and on the Porcupine River near the Boundary were maintained jointly by technicians from the office at Whitehorse and by technicians from the United States Geological Survey in Alaska. There were 60 stations where streamflow records were produced, leaving 12 where only stage data was collected. All stations were equipped with automatic recorders, 40 had cableways and 10 had data collection platforms. Miscellaneous suspended sediment samples were collected at five stations while water quality samples were obtained at two stations. Reasons for positioning data collection platforms at ten locations are listed in Appendix B.

3.1 Basic Information

The station profiles provided some interesting information on the water resources in the Territory, for example, the median length of record of the active streamflow stations in the Territory was in the 11-15 year period with 24 stations with records shorter than 11 years and 22 stations longer than 15 years; the length of record of the active flow stations is shown in Table 1.

TABLE 1

Distribution of Record Lengths of Active Flow Stations

(including 1987)

Years of Record	Number of Stations
1 - 5	11
6 - 10	13
11 - 15	14
16 - 20	0
21 - 25	6
26 - 30	2
31 - 35	9
36 - 40	3
41 - 45	2

The area of the Territory of 483,450 square kilometres with 60 streamflow gauging stations had a station density of one station per 8000 square kilometres; Table 2 lists drainage area size as sampled by the present network of stations.

TABLE 2

Drainage Area size in km^2 as samples by Active Flow Stations			
Area in km_2	Number of Stations	Area in km^2	Number of Stations
1 - 500	5	6001 - 8000	8
501 - 1000	5	8001 - 10000	3
1001 - 2000	8	10001 - 15000	4
2001 - 4000	5	15001 - 30000	4
4001 - 6000	6	30001+	12
1 - 6000	29	6001 - 30000+	31

The average annual flow measured at the stations was as low as half a cubic metre per second in Giltana Creek at the Mouth and as high as 2310 cubic metres per second in the Yukon River at Eagle, Alaska. Annual runoff for 1986 as computed in millimetres (mm) of water over a basin ranged from 72 mm in the Old Crow River basin in the northern part of the Territory to 650 mm in the South MacMillan River basin at the Canol Road crossing below the Selwyn Mountain Range in the eastern part of the Territory; annual runoff volumes for basins gauged in 1986 are shown in Figure 1 at the back of the Report.

3.2 Need for Data

In order to record the information on the purpose for which a station was originally established reference was made to an earlier study by Kreuder (1980). The following short summary was taken from his report; also shown are the number of stations still operated today:

- The early period (1944 - 1948), seven stations were established at the sites of gauges operated by the British Yukon Navigation Co. Ltd., six of the stations are still operated today.
- The Yukon Taiya proposal (1949 - 1952) to divert Yukon River headwaters into the Taiya River for development of power at the Pacific tide water in Alaska led to the establishment of twelve stations in the Territory seven of these are still being operated.
- The Yukon Taku proposal (1955) was to divert the headwaters into the Taku River for power development in British Columbia; six stations were established with three still being operated.
- The main stem proposal (1956 1958) required the establishment of five stations to provide information "on the potential of the Yukon River that will be lost or reduced by the diversion of Yukon River water to the Taku system"; three stations are still being operated.
- The Peel-Porcupine-Rat River diversion proposal (1961 - 1963) saw the establishment of three stations which are still active today.
- Mackenzie Pipeline proposal (1972) two stations were established which are still active.

- The Baseline Network proposal was presented in 1971 by the Water Survey of Canada to the Department of Indian Affairs and Northern Development (DIAND); at subsequent meetings agreement was reached for the development of a network of stations on regional and major streams to gather runoff data in a systematic and planned way.

After 1975 the acceptance of the baseline network concept resulted in the establishment of 24 regional and major stream stations. Also built were eleven stations for specific project requirements including six for the Northern Canada Power Commission now the Yukon Electrical Company Limited. Since 1984, however, only three stations have been constructed.

Identification of current project uses at stations established prior to 1973 presented some difficulties because the specific study proposals of the early years of hydrometric development were no longer relevant. Indeed, at 13 active stations which were established before 1973 current project uses could not be identified. However, most of these stations provided baseline data.

Table 3 summarizes current project, baseline and national inventory needs at 43 project stations; and baseline and inventory needs at 27 non-project stations; two stations had no identified uses.

TABLE 3

Identification of Gauging Station Needs and Uses

in the Yukon Territory (1987)

	Needs	Uses	No. of Stns.
A. Project Stations			43
a) For indicated current uses			
1. International gauging stations		2	
2. Interprovincial streams		1	
3. For operation of storage reservoirs		8	
4. For flow forecasting, spring freshet		11	
5. For assessment of current water conditions, and site of Federal DCPs		10	
6. For water quality assessment including sediment discharge monitoring		7	
7. For other project requirements such as municipal water supply, bridge and culvert design, small hydro projects		16	
b) Needed for Baseline Data (Regional and Major Streams)	16		
c) Needed for National Inventory Data	8		
B. Non-Project Stations Providing Baseline Data, (Regional and Major Stream)	25		25
C. Non-Project Stations Providing National Inventory Data	2		2
D. Stations Without Identified Uses			2
Total Needs	51		
Total Current Uses		55	
Total Stations Operated by WSC			72

It can be seen that there were 55 identified current project uses at 43 stations, or an average of 1.28 uses per station. Sixteen of the project stations also provided baseline data for planning and design purposes and eight project stations collected data for national inventory purposes. In addition to the 43 project stations there were 25 baseline stations and two inventory stations.

A number of stations were identified and categorized as national inventory stations; these were stations located near the Territory's boundaries for the purpose of gauging flow from large basins and to provide an estimate of the water resources or stream flow produced in the Territory. Table 4 lists a number of stations which gauge the largest basins affecting the Territory; the number of stations can vary depending upon the inventory coverage required. The table shows that with ten stations - eight in the Yukon Territory and one each in Alaska and Northern British Columbia - 84% of the area of the Territory was covered. As noted, two more stations would increase the areal coverage by 4% to 88%. For the purposes of a national inventory and illustration in an hydrologic atlas of Canada it may be stated that the average flow produced in the Territory was approximately 4,000 cubic metres per second (3540 = 88%) which represents an average annual runoff volume of about 250 mm over the whole area of the Territory.

3.3 Quality of Data

As was expected, the assessment of the quality of data generated a few discussions. The final rating was developed from an overview of the quality of data at all the stations and from the technicians' own opinions. Table 5 summarizes data quality ratings for 60 streamflow gauging stations and 12 stage only stations.

TABLE 4

Selected National Inventory Stations

Station Number	Basin	Drainage Area $X10^3$ km^2	Average Flow m^3/sec	Average Annual Runoff Volume $X10^6$ dam^3	mm
09ED001	Yukon River at Eagle	294.0	2312	72.9	248
09FD002	Porcupine R at Intl. Bdy	59.8	367(e)	11.6	194
10AA001	Liard R at Upper Crossing	33.4	377	11.9	356
10MA001	Peel River ab Canyon C.	25.7	192	6.1	237
08AB001	Alsek R above Bates R.	16.2	205	6.5	401
10MB003	Snake R near the Mouth	8.9	100	3.2	356
09AD001	Nisutlin R ab. Wolf R.	8.0	84	2.6	331
10BD001	Beaver R bel Whitefish R	7.3	53	1.7	228
	Sub Totals	453.3	3690	116.4	257
Less headwaters in Alaska and B.C.					
09AE001	Teslin R near Teslin	−30.3	299	9.4	312
09EC002	Forty Mile R nr the Mouth	−16.6	85	2.7	162
	Balance	406.4	3306	104.3	256
which is 84% of area of Yukon Territory					
Note:	If two stations in Northern B.C. are included, then add:				
10BC001	Coal R at the Mouth	+9.2	99	3.1	342
10AD001	Hyland R nr Lower Post	+9.5	136	4.3	454
	Balance:	425.1	3541	111.7	263
which is 88% of area of Yukon Territory					

Total area of Yukon Territory is 483,450 square kilometres.

Source: Energy, Mines and Resources Canada, Geographical Mapping Division (1981).

TABLE 5

	Quality of data Ratings				
	Good	Fair	Poor	?	Total
High Flows:	28	13	12	7	60
Low Flows:	36	13	7	4	60
Average Flows:	41	13	2	4	60
Stage Only Stations:	12	–	–	–	12

The difficulties of obtaining high flows of good quality were confirmed by the above ratings which show that at 7 stations the quality of high flows was a question that could not be answered because of insufficient data at the high end of the rating curve. In this study high flows were considered to be the annual peak flows, low flows the annual minimum flows, and average flows were those on the rating curve between the extremes.

The manner in which discharge measurements were made was listed to indicate possible future repair or maintenance costs for cableway structures, the necessity of caching boats at the stations and possibly the time required per visit. In summary: there were 40 cableways, 11 bridges and 8 boats utilized for discharge measurements at 59 streamflow gauging stations in the Territory; a special cable carrier is utilized at the Babbage River station for discharge measurements.

3.4 Economic Considerations

The assessment of the cost of operations using the factors in this section of the station profile was considerably more difficult than expected. The first item to be considered was access to the station, which was either by road, aircraft, boat or snowmobile. However, there were some complications; for example, some stations were reached by road on visits during the summer but by helicopter during the winter because the roads were closed. Visits to a station were also dependent upon availability of transportation equipment; for example, Tour 4 through the North Central part of the Territory which began at Dawson included stations along the Dempster Highway as well as stations on the Peel, Snake and Whitestone Rivers which were accessible only by helicopter. If a helicopter was available at Eagle Plains, the technician would drive to Eagle Plains, visiting stations on the Blackstone, Ogilvie and Eagle Rivers on the way; then he would board the helicopter at Eagle Plains and visit the Peel, Snake and Whitestone River stations to complete this tour. If there was no helicopter available at Eagle Plains then the tour became a helicopter trip from Dawson.

Weather conditions also aborted visits to some stations e.g. Bonnet Plume River; as well hours of daylight were very important for helicopter trips; for example, during a long summer day a technician was able to visit stations on the Donjek River, Yukon River above White River and Stewart River at the Mouth, but in winter only one of the stations was visited in a day.

Tours 4 and 5 were separate trips during the summer but were combined into one tour during the winter. The stations on the tours and means of access are listed below:

<u>Tour 4</u>

Blackstone River	road/helicopter
Eagle River	road/helicopter
Fortymile River	road (summer) helicopter (winter)
Little South Klondike River	helicopter
North Klondike River	road
Ogilvie River	road/helicopter
Peel River	helicopter
Snake River	helicopter
Whitestone River	helicopter
McQuesten River	road
Yukon River at Dawson	road
Yukon River at Eagle	road (summer) fixed wing (winter)

<u>Tour 5</u>

Donjek River	helicopter/fixed wing
Indian River	helicopter
Klondike River	road
Old Crow River	boat from Old Crow/helicopter
Porcupine R at Intl Boundary	helicopter
Porcupine R bel Bell River	helicopter
Stewart River at the Mouth	boat/helicopter/fixed wing
Yukon River ab. White River	boat/helicopter/fixed wing

Table 6 lists a summary of the various means of access to the 60 flow and 12 stage only stations.

TABLE 6

Means of Access to Stations (1987)

Flow Stations:	road	21 stations
	helicopter	17 stations
	road, helicopter	7 stations
	boat, helicopter	3 stations
	fixed wing aircraft	2 stations
	boat, fixed wing, helicopter	3 stations
	boat, fixed wing, snowmobile	1 station
	road, boat	1 station
	road, helicopter, snowmobile	1 station
	road, snowmobile	1 station
	helicopter, snowmobile	1 station
	road, fixed wing	1 station
	helicopter, fixed wing	1 station
Stage Only Stations:		
	road	10 stations
	road, helicopter, snowmobile	1 station
	fixed wing	1 station

Another factor required in the assessment of costs of operating a station was the number of station visits during 1987 which was examined from records at the Whitehorse sub office; this sub factor may be misleading as a station may be visited more than once on the same tour. Some stations require frequent discharge measurements in order to define the stage discharge relationship and to monitor benchmarks. Examples are stations on the Duke, White and Dezadeash Rivers. Many of the visits were for level checks of benchmarks and orifices. The number of visits for level checks was noted because usually two persons were required.

Several stations were visited more frequently because they were passed by technicians on different tours; for example, Liard River at Upper Crossing station was located on the Alkaska Highway near the start of the Robert Campbell Highway and also the road to Cassiar in northern British Columbia. This station was also known to have been vandalized on several occasions. As well, there was a request to collect water quality samples at this site.

In general: stations which required helicopter access were rated as expensive to operate and maintain, stations which were visited by fixed wing aircraft, boat or occasionally by helicopter were taken to be of average cost, and stations accessible by road were rated to be of low cost. Three stations with road access but with a high number of visits were included in the average cost rating.

Below is a summary of how the cost of operations was rated for 60 flow stations.

TABLE 7

Rated Costs of Operation for Active Flow Stations

Costs are high:	21 stations
Costs are average:	17 stations
Costs are low:	22 stations

The cost of operating the 12 water level stations was rated as either low or average.

As an added item of information, the costs of establishing a station plus any reconstruction costs since 1974 were listed and are shown in Table 8.

TABLE 8

COSTS OF CONSTRUCTION PROJECTS IN YUKON TERRITORY SINCE 1974
(Source: Annual Cost Sharing Reports)

YEAR	STATION	NEW	RECONSTR.	FUNDING
1975-76	08EA004 North Klondike	6,900		FT
	09CB001 White River		10,300	F
	10AB003 King Creek	800		T
	10AB002 Frances Lake	1,600		T
	10MB003 Snake River	57,600		T
1976-77	10AD002 Hyland River	12,600		FT
	09AD001 Hess River	50,800		FT
	10MD002 Babbage River	5,300		F
	09FC001 Old Crow River	29,000		T
1977-78	10BD001 Beaver River	32,300		T
	09EA003 Klondike River		4,400	T
1978-79	09EB002 Eagle River	3,000		FT
	09DD004 McQuesten River	17,600		FT
	09FA001 Whitestone River	31,500		FT
	10MB003 Snake River		5,900	FT
	09AD001 Nisutlin River	16,200		T
1979-80	Yukon River above Frank Creek		16,700	F
	09CA003 Donjek River	29,600		FT
	09CA002 Kluane River		2,300	FT
	Stewart River above Fraser Falls	29,100		T
1980-81	09CA004 Duke River	22,000		FT
	10MB004 Bonnet Plume River	33,800		FT
	09AB010 Lake Laberge	2,700		FT
	08AA008 Sekulman River	20,500		NCPC
	08AA007 Sekulman Lake	3,600		NCPC
	08AA009 Giltana Creek	1,500		NCPC
	08AA010 Aishihik River	11,000		NCPC
1981-82	09EC002 Fortymile River	20,200		FT
	09EB003 Indian River	30,100		FT
	09GA002 Quiet Lake	5,300		T
	09AD002 Sidney Creek	17,200		T
1982-83	09EA005 Little South Klondike	5,900		FT
	09AH004 Nordenskiold River	27,400		FT
	09AG003 South Big Salmon River	21,700		T
	09AA012 Wheaton River		4,700	T
1983-84	08AC001 Takhanne River	19,400		FT
	09BB002 McMillan River	44,600		FT
	10MA003 Blackstone River	34,800		FT
	09CA003 Donjek River		4,600	FT
	09FC001 Old Crow River		5,600	T
1984-85	09DD003 Stewart River at Mouth		10,600	F
	09CD001 Yukon River above White River		2,100	F
	10AA004 Rancheria River	29,800		FT
	09CA003 Donjek River		36,500	FT
	09FC001 Old Crow River		25,200	T
1985-86	09BA002 Pelly R. below Fortin Creek	37,100		F
	09CA002 Kluane River		10,300	FT
	09AB008 M'Clintock River		14,900	FT
	09AD001 Nisutlin River		4,200	FT
	09AA012 Wheaton River		17,700	FT
	10AA001 Liard River at Upper Crossing		16,200	F
1986-87	09FD002 Porcupine R at Intl Boundary	24,000		F
	10MD001 Firth River		5,800	F
	09AB009 Yukon R. above Frank Creek		10,500	F
	09BA001 Ross River		17,700	FT
	10MB004 Bonnet Plume River		6,300	FT
1987-88	09EA005 Little S. Klondike R.		7,500	FT
(est.)	09AA007 Lubbock River		15,000	F
	08AB001 Alsek River		4,500	FT
	08AA003 Dezadeash River		1,500	FT
	09AA004 Bennett Lake		1,000	FT
	09FB001 Porcupine R. below Bell R.		16,500	F

3.5 Usefulness of Data

The information contained in this section of the station profile indicated stations with streamflow data whose value could increase proportionally with the quantity of flow being measured and the size of the basin being gauged. The usefulness of data was also valued if the station was located near identified future developments. Comments regarding future development proposals were included in this section. A correlation analysis of monthly flows by Klohn Leonoff Yukon (1988) provided information on correlation coefficients which was noted on those stations where coefficients were greater than 0.70 for three cases: 1) all months, 2) high flow months (April through September) and 3) low flow months (October through March).

4. CONCLUSIONS

This method of station analysis appeared to be worthwhile in that station profiles were developed which provided a rational tool for examining stations with the object of relocating or discontinuing them.

There were difficulties with factors such as defining quality of data and cost of operation. But it was felt that these factors allowed stations with poor records or stations whose data was of relatively little value or expensive stations to be identified. The rating factor "usefulness of data" was a contributing element in the assessment where the coefficient of correlation of monthly flows was considered.

5. RECOMMENDATIONS

A. The station profiles for the active stations in the Yukon Territory have been examined by the Review Committee. This assessment identified six stations as prime candidates for relocation or discontinuation on the basis of no need for the data, poor quality of data and or high cost of operation. The profiles of these stations are shown in Appendix C.

10AB003	King Creek at Nahanni Range Road
09EA003	Klondike River above Bonanza Creek
09AB010	Lake Laberge near Whitehorse
09AB008	M'Clintock River near Whitehorse
09FD001	Porcupine River at Old Crow
09AG002	Quiet Lake at South Canol Road

The remaining station profiles are available on request from the Water Resources Branch Office in Vancouver.

B. A second group of stations was identified as candidates for relocation or discontinuation but with a conditional "maybe" attached. These stations would continue to be operated until further reductions to the network are required. The ten stations in this group are identified below:

10BD001	Beaver River below Whitefish River
09AH003	Big Creek near the Mouth
10MA003	Blackstone River near Chapman Lake Airstrip
10MB004	Bonnet Plume River above Gillespie Creek
08AA003	Dezadeash River at Haines Junction
10AD002	Hyland River at Nahanni Range Road
09BC001	Pelly River at Pelly Crossing
09AG003	South Big Salmon R. below Livingstone Creek
10AA002	Tom Creek at Robert Campbell Highway
09AH001	Yukon River at Carmacks

C. The Review Committee identified a number of stations which could be considered for possible reclassification of the responsibility category. The stations and the possible classification changes are listed below:

08AB001	Alsek River	from FT3 to F4
10BD001	Beaver River	FT3 to F4
09EC002	Fortymile River	FT3 to F4
09AD001	Nisutlin River	FT3 to F4
10MB003	Snake River	FT3 to F4
09FC001	Old Crow River	F4 to FT3
09BC001	Pelly River	F4 to FT3
09FB001	Porcupine River	F4 to FT3
09DD003	Stewart River	F4 to FT3
09AB009	Yukon R above Frank Creek	F4 to FT3
09CD001	Yukon R above White River	F4 to FT3
09AH001	Yukon River at Carmacks	F4 to FT3

D. The correlation study of monthly flows identified a number of stations which did not correlate well with other stations i.e. the R values were less than 0.70. The Review Committee recommended that a closer examination of the historical records at these stations be carried out in order to determine the reasons for the poor relationship between those stations. Listed below are stations with at least five years of record which do not correlate with other stations:

08AB001	Alsek River above Bates River
10MD002	Babbage River below Caribou Creek
09AH003	Big Creek near the Mouth
09CA003	Donjek River below Kluane River
09CA004	Duke River near the Mouth
10MD001	Firth River near the Mouth
08AA009	Giltana Creek near the Mouth
09CA002	Kluane River at Outlet of Kluane Lake
09AA007	Lubbock River near Atlin
09AH004	Nordenskiold River below Rowlinson Creek
09FC001	Old Crow River near the Mouth
10MA001	Peel River above Canyon Creek
08AA008	Sekulman River at Outlet of Sekulman Lake
10MD003	Snake River near the Mouth
09BB001	South MacMillan River at Canol Road
09AA012	Wheaton River near Carcross
09CB001	White River at Alaska Highway
09EA001	Whitestone River near the Mouth

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APPENDIX A

Study Proposal for Assessment of Hydrometric Stations in the Yukon Territory

Evaluate relative worth of individual gauging stations in order to select stations for discontinuance. Rating factors are:

- Need for information at the station
- Accuracy of data
- Economic aspects of operation
- Usefulness of data for estimating at ungauged site

A. Need for information at the station

- prepare uses survey: project stations, major stream stations, regional stations, national inventory station;
- prepare bar charts of period of record of active stations, indicate length of ice period at each station using 1984-86 three year average
- identify areal coverage i.e. outflow from drainage sub-division; number of stations in the basin, extent of ungauged area;

B. Accuracy of Data

- prepare evaluation based on flow conditions (by Operations Division)

C. Economic Aspects of Operation

- provide estimate of cost of operation i.e. inexpensive, average, expensive (to be provided by Operations Division);
- prepare an estimate of value of water at the gauging station i.e. high, moderate, low;

D. <u>Usefulness of Data for Estimating at Other Gauged Sites</u>

- complete monthly flow correlation studies at those stations not used in the Yukon River Basin Study Hydrology Report #2;
- evaluate usefulness of meteorology data in estimating streamflow data;

October 20, 1987

APPENDIX B

Positioning of Data Collection Platforms in the Yukon Territory

The following table summarizes the rationale used in the assignment of data collection platforms (DCP) to these hydrometric stations.

10BD001	Beaver River below Whitefish	Visited by Ft. St. John suboffice, in a tour of five stations. All have DCPs. Part of a study on the effectiveness of DCPs on a remote tour serviced by helicopter.
09CA003	Donjek River below Kluane River	This is one of the most expensive stations; DCP is required for trip planning.
10AB002	Frances Lake at Robert Campbell Highway	Indian Affairs require 12 months of record. WRB established a DCP to save trips. Station had to be visited each month prior to DCP installation.
09DA001	Hess River above Emerald Creek	Remote, helicopter access station. Nearby AES DCP installation (separate transmit stations). Share cost of helicopter access with AES.
09BA002	Pelly River below Fortin Creek	An expensive new station requiring establishment of stage-discharge curve.
09FD002	Porcupine River at International Bdy.	New station. International data can be used to monitor Old Crow, Eagle Whitestone system and to plan field trips to these stations.
09AG002	Quiet Lake at South Canol Road	Same as Frances Lake.
09DC003	Stewart River above Fraser Falls	Remote station. Monitor forecasting at Mayo and to plan visits. A boat is required for open water discharge measurements.
09DD003	Stewart River at the Mouth	Remote station. For ice-jamming studies and flood-forecasting and trip planning purposes.
09CD001	Yukon R ab White R.	Same as 09DD003.

APPENDIX C

HYDROMETRIC STATION PROFILE SUMMARY

BASIC DATA: 10AB003 King Creek at Nahanni Range Road

Subdivision: Yukon Territory Location: 60 56 50 128 55 40

Tributary to: Frances R-Upper Liard R Average Flow in m^3/sec: 0.114

Period of Record: 1975- (2 yrs. partial) Drainage Area in km^2: 13.7

NEED FOR DATA: Established for DIAND small stream network.

Current Project Uses: Data used for highway culvert design, small hydro projec

Other Uses: None Station Classification: T2

Comments:

QUALITY OF DATA: High Flows: Fair Low Flows: Fair Av. Flows: Fair

Discharge Measurements: Bridge

Condition of Benchmarks: Fair. Pipe benchmarks in permafrost.

Comments: Heavy silting in pond. Wading measurements have been made just downstream of bridge.

ECONOMIC CONSIDERATIONS: Access by road/snowmobile.

No. of Stations Visited this Tour: Summer: 6 Winter: 6

Cost of Operating this Station: low

Cost of Construction: $800 Cost of Repairs: None

Comments: Weir leaks slightly; noticeably at high stage. Access is by road in summer 21 km up Nahanni Range Road. In winter by snowmobile provided trail is cleared. Station is on route to Hyland station.

USEFULNESS OF DATA: Ungauged Flow at this Site in m^3/sec: 0.114

Av. Annual Runoff: 262 mm Nearest Rain Gauge: Watson Lake

Correlation Coefficient of Monthly Flows: 0.72 high flow months with 10AA001 Liard R. at Upper Crossing; 0.76 high flow months with 10AD001 Hyland River.

REVIEW COMMITTEE RECOMMENDATION: Data base likely adequate; suggest discontinuation and replacement with station on Big Creek or Ibex Creek.

CANDIDATE FOR DISCONTINUATION: Yes Compiled: March 1988

HYDROMETRIC STATION PROFILE SUMMARY

BASIC DATA: 09EA003 Klondike R. above Bonanza Creek
Subdivision: Yukon Territory Location: 64 02 34 139 24 28
Tributary to: Yukon River at Dawson Average Flow in m^3/sec: 61.2
Period of Record: 1965- (2 yrs. partial) Drainage Area in km^2: 7800

NEED FOR DATA: Established for Yukon Consolidated Gold Co.
Current Project Uses: Highway winter maintenance.
Other Uses: Baseline Station Classification: FT3
Comments:

QUALITY OF DATA: High Flows: Good Low Flows: Fair Av. Flows: Good
Discharge Measurements: Cableway
Condition of Benchmarks: 1 bedrock
Comments: Control is channel/bridge and is rated Good. Orifice can be taken out by breakup. Relatively few problems. As station is near town, an observer watches for spring levels and orifice problems.

ECONOMIC CONSIDERATIONS: Access by road near Dawson City
No. of Stations Visited this Tour: Summer: 8 Winter: 20
Cost of Operating this Station: Low
Cost of Construction: Not known Cost of Repairs: $4400 (1977)
Comments: Station is near to Dawson so has frequent visits, i.e. when technicians pass by. Two field tours.

USEFULNESS OF DATA: Ungauged Flow at this Site in m^3/sec: 39.8
Av. Annual Runoff: 247 mm Nearest Rain Gauge: Dawson
Correlation Coefficient of Monthly Flows: 0.87 high flow months with 09DD004 McQuesten R.; 0.82 all months with 09EA004 North Klondike River.

REVIEW COMMITTEE RECOMMENDATION: Correlates well with McQuesten and North Klondike Rivers but not South Klondike River; data base is adequate with more than 20 years of record.

CANDIDATE FOR DISCONTINUATION: Yes Compiled: March 1988

HYDROMETRIC STATION PROFILE: Stage Only

BASIC DATA: 09AB010 Lake Laberge near Whitehorse

Subdivision: Yukon Territory   Location: 61 05 25 135 11 57

Tributary to: Forms Yukon River main channel below Whitehorse

Period of Record: 1980-   Datum: assumed

Artificial Control: no

NEED FOR DATA: Established for federal-territorial lake survey

Current Project Uses: Not known

Other Uses: Not known   Station Classification: FT3

Comments:

QUALITY OF DATA: Good

Type of Gauge: Recorder

Condition of Benchmarks: Good. Two in bedrock.

Comments: Orifice in shallow bay, may freeze completely in cold.

ECONOMIC CONSIDERATIONS: Access by road

No. of Stations Visited this Tour: Summer: 1 Winter: 1

Cost of Operating this Station: Low

Cost of Construction: $2700   Cost of Repairs: None

Comments: Quartz clock and solar panel at station

REVIEW COMMITTEE RECOMMENDATIONS:To be discontinued. Unable to determine any currentuseof the data at this lake station.

CANDIDATE FOR DISCONTINUATION: yes

Compiled: March 1988

HYDROMETRIC STATION PROFILE SUMMARY

BASIC DATA: 09AB008 M'Clintock River near Whitehorse
Subdivision: Yukon Territory   Location: 60 36 45 134 27 27
Tributary to: Marsh L-Yukon River   Average Flow in m^3/sec: 9.58
Period of Record: 1956- (11 yrs. partial)   Drainage Area in km^2: 1700

NEED FOR DATA: Established for Yukon-Taku diversion proposal
Current Project Uses: Not known
Other Uses: Baseline   Station Classification: FT3
Comments:

QUALITY OF DATA: High Flows: Poor Low Flows: Fair Av. Flows: Fair
Discharge Measurements: Cableway
Condition of Benchmarks: Good. Pipe.
Comments: Control is poor, soft mud bed with low banks. Until 1987 upper end of stage discharge relation was defined by only one measurement at low end curves do not converge, prob. due to shifts in the bed.

ECONOMIC CONSIDERATIONS: Access by road.
No. of Stations Visited this Tour: Summer: 1 Winter: 1
Cost of Operating this Station: Low
Cost of Construction: Not known   Cost of Repairs: $14,900 (1985)
Comments: Well needs to be steamed out in spring. Station requires frequent visits. As it is close to Whitehorse office, these are not expensive. In 1987 12 discharge measurements were made to define stage discharge relation.
USEFULNESS OF DATA: Ungauged Flow at this Site in m^3/sec: 9.58
Av. Annual Runoff: 178 mm   Nearest Rain Gauge: Whitehorse
Correlation Coefficient of Monthly Flows: 0.72 high with 09AE001; 0.72 low with 09AD001. From 1956 to 1964 records are partial only.

REVIEW COMMITTEE RECOMMENDATION: Records are poor, should consider station relocation.

CANDIDATE FOR DISCONTINUATION: Yes   Compiled: March 1988

HYDROMETRIC STATION PROFILE SUMMARY

BASIC DATA: 09FD001 Porcupine River at Old Crow

Subdivision: Yukon Territory Location: 67 33 50 139 53 00

Tributary to: Yukon River, Alaska Average Flow in m^3/sec: 340

Period of Record: 1961- (7 yrs partial) Drainage Area in km^2: 55,400

NEED FOR DATA: Established for Peel-Porcupine-Rat River Diversion Study

Current Project Uses: Not known

Other Uses: Baseline Station Classification: F3

Comments:

QUALITY OF DATA: High Flows: Good Low Flows: Fair-Good Av. Flows: Good

Discharge Measurements: Boat

Condition of Benchmarks: Benchmarks are stable, but not in bedrock

Comments: Very stable channel control. For many years records have rated as good during open water and fair under ice. Orifice is taken out by ice every breakup. Manometer range of stage 50 feet. No discharge measurements made in 1987.

ECONOMIC CONSIDERATIONS: Access by heli/snowmobile winter, boat summer

No. of Stations Visited this Tour: Summer: 8 Winter: 20

Cost of Operating this Station: High

Cost of Construction: Not known Cost of Repairs: Not known

Comments: In winter there is little inflow between Porcupine below the Bell and Porcupine at Old Crow. Cheaper to get data at Old Crow. Repairs required are 2 orifices per year: one after breakup, another after peak.

USEFULNESS OF DATA: Ungauged Flow at this Site in m^3/sec: 101

Av. Annual Runoff: 193 mm Nearest Rain Gauge: Old Crow

Correlation Coefficient of Monthly Flows: 0.97 all months and high flow months with 09FB001 Porcupine R. below Bell R.

REVIEW COMMITTEE RECOMMENDATION: Station was replaced by station at the International Boundary; only consider continued operation if required for DINA flow forecasting.

CANDIDATE FOR DISCONTINUATION: Yes Compiled: March 1988

HYDROMETRIC STATION PROFILE: Stage Only

BASIC DATA: 09AG002 Quiet Lake at South Canol Road

Subdivision: Yukon Territory Location: 61 08 35 133 04 50

Tributary to: Big Salmon - Yukon River below Frank Creek

Period of Record: 1981- Datum: Assumed

Artificial Control: No

NEED FOR DATA: Established for DINA lake survey

Current Project Uses: Not known

Other Uses: Station Classification: T2

Comments: Site of federal DCP

QUALITY OF DATA: Good

Type of Gauge: Recorder

Condition of Benchmarks: Good. Tied in annually to geodetic.

Comments:

ECONOMIC CONSIDERATIONS:

No. of Stations Visited this Tour: Summer: 2 Winter: 2

Cost of Operating this Station: Average

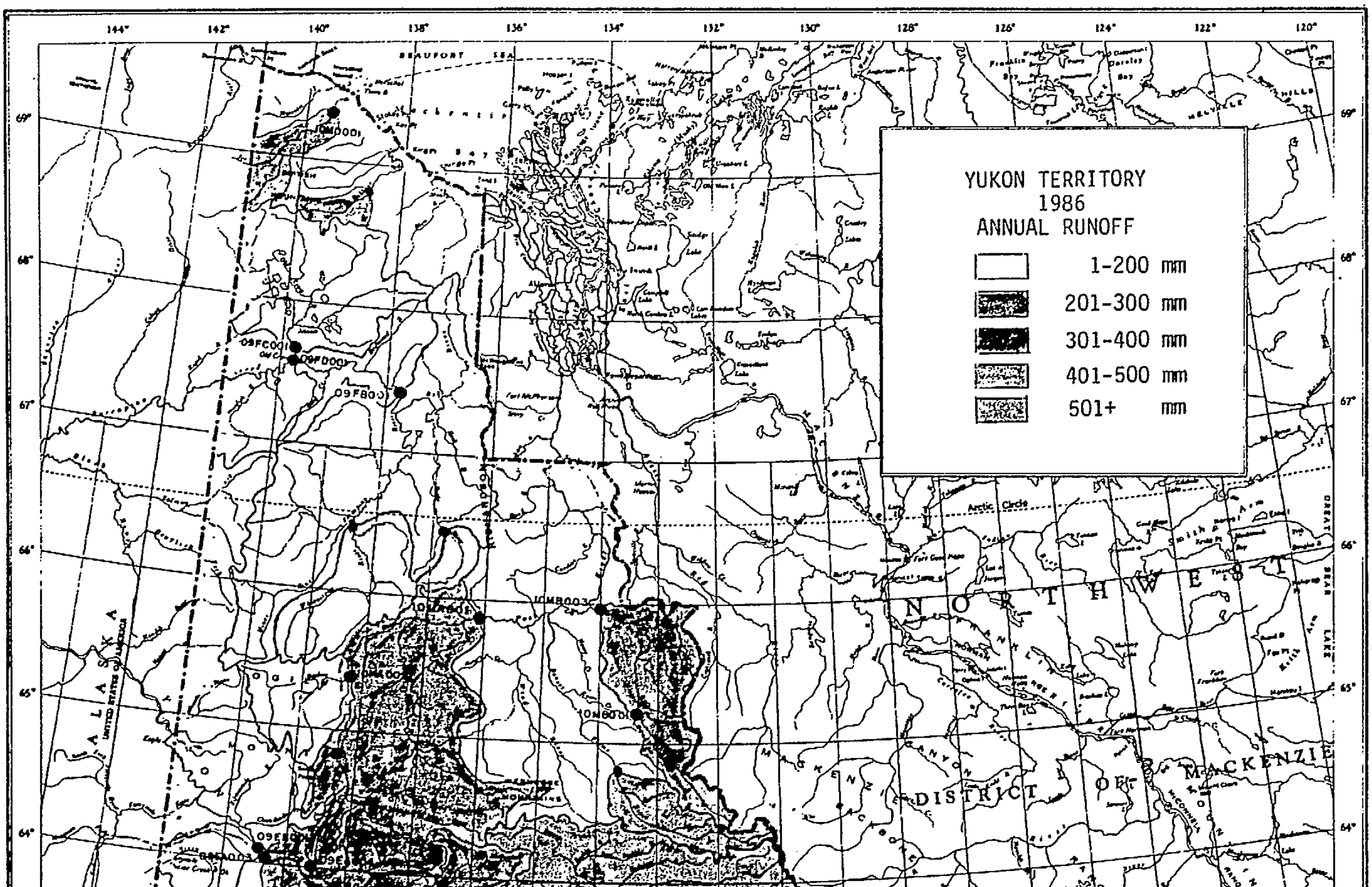
Cost of Construction: $5300 Cost of Repairs: None

Comments: Winter data collection is difficult because of problems with station access and manometer operation. Station has been closed for several months over the past two years.

REVIEW COMMITTEE RECOMMENDATIONS: No known uses. No reasons for retaining the station. The DCP should be removed and relocated to mutually acceptable location.

CANDIDATE FOR DISCONTINUATION: Yes

Compiled: March 1988


YUKON TERRITORY
1986
ANNUAL RUNOFF
1-200 mm
201-300 mm
301-400 mm
401-500 mm
501+ mm
Arctic Circle
DISTRICT OF MACKENZIE
NORTHWEST TERRITORIES
ALASKA
BRITISH COLUMBIA

MANITOBA'S PERSPECTIVE ON NETWORK PLANNING[1]

by V. M. Austford, P. Eng.
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PREAMBLE

When Al Perks asked me to speak to you about Network Evaluation and Planning, like a fool I said "sure". After all we have a good handle on our needs as well as on awareness of the network inadequacies in Manitoba. As well we had made a couple of attempts at network evaluation in the seventies and we have been through a couple of major down-sizings: one imposed by provincial restraint and one imposed by federal restraint. However the more I thought about an approach to network planning and evaluation the more I thought of things not to do rather than things to do. Of course, by tomorrow night Al will have us all pointed in the right direction.

INTRODUCTION

- The Canada-Manitoba shared-cost hydrometric network is the backbone of all surface water management activities in the Province of Manitoba. This network is operated by Water Survey of Canada on behalf of Canada, Manitoba and Manitoba Hydro. Water Survey operates just under 300 stations currently.
- This network is supplemented by a provincial hydrometric program that involves the operation of a total of 149 water level stations. Of these, 11 stations are operated on a continuous basis while the remainder are operated on a seasonal basis. In addition, Manitoba Hydro operates some 250 stations. Of these over 100 are operated on a continuous basis while the remainder are operated intermittently.
- A good overall hydrometric network is essential for the prudent use of Manitoba's natural resources.
- The existing Federal-Provincial network serves a multitude of resource users and demands.
- In these times of tough fiscal restraint, the operation of a sound hydrometric network must be ensured through the planning processes.
- Network planning is a valuable tool. It defines the requirements of the network by:
  - Understanding the use of the hydrometric network by identifying the status of current and future users and uses.

[1]Presented at Hydrometric Network Evaluation and Planning Workshop, October 5, 1988, Holiday Inn South, Winnipeg, Manitoba.

- Assisting in the resolution of competing uses and demands to ensure the needs of all may best be met.

- In these times of declining dollars, it is important that the most cost-efficient use be made of the existing hydrometric network.

NEEDS

- The Federal-Provincial hydrometric network serves a host of uses for the people of Manitoba. The data collected by the network is used by Manitoba Natural Resources; Water Resources, Fisheries and Parks and Manitoba Agriculture, Manitoba Environment and Workplace, Safety and Health, Manitoba Hydro, Manitoba Water Services Board and Towns and Municipalities.

- For practical purposes station uses can be divided into either of the categories "water management" or "regional hydrology".

- At water management stations the prime purpose of the collected data is to provide at-site information for current operational needs. These needs encompass things like:

  - Operation of the provinces water control structures for flood control and/or water supply. (eg. Shellmouth Reservoir and the Red River Floodway).
  - Flood forecasting of Manitoba's major rivers and numerous tributaries.
  - Streamflow monitoring along major streams such as the Red, Assiniboine and Souris Rivers for water supply and sanitation and water quality. The 1988 drought conditions illustrates this use.
  - Apportionment of international and interprovincial streams.
  - Hydropower operations.
  - For water management the provision of timely and accurate real-time data is of the utmost importance.

- Regional hydrology stations provide data on the occurrence and distribution of streamflows. Uses include:

  - Flood plain management studies.
  - Planning and design of all types of water resource projects.

- Most of the hydrometric stations in the network have a multitude of users and uses. An example is the Red River at Emerson.

  Hydrometric data at this station is used extensively by many federal, provincial and municipal agencies. These agencies include Environment Canada, Manitoba

Water Resources , Manitoba Fisheries, Manitoba Agriculture, Manitoba Environment and the United States Army Corps of Engineers, United States Geological Survey(USGS), Manitoba Hydro and urban centres along the Red River including the City of Winnipeg. Several of the agencies indicate multiple use of data and for the need of the data on a real time basis. The uses include operations, flood forecasting, project planning, water supply and sanitation, water quality, and morphological studies.

NETWORK INADEQUACIES

- A persistent problem of the existing hydrometric network is the shortage of data. With present fiscal constraints it has been impossible to find dollars to expand the network.
- Key gaps in the present regional network of Manitoba which have been identified are in the:
  - Non-escarpment streams west of Lake Manitoba.
  - Non-escarpment streams immediate below the Escarpment (including the Red River Valley).
  - Sub-escarpment streams, those emerging only on the lower slopes of the escarpment.
  - The Northern Interlake area between Lake Winnipeg and Lake Manitoba.
- Inadequate data in the present hydrometric network may result in:
  - Improper decision-making at the planning stage, e.g. in selection of alternatives.
  - Overly conservative designs: Commonly designers and planner when faced with uncertainties will over-design a project in order to mitigate the effects of uncertainity. Such a safety-margin approach to design results in increased costs.
  - System Design Failures: In spite of the use of safety margins, occasionally the uncertainity is under estimated and a project will fail or not provide full use of the water resource such as in water supply projects.

PAST NETWORK EVALUATIONS

A) 1972 NETWORK EVALUATION

- In 1972 a systematic review of the existing hydrometric network in Manitoba was conducted. The results are contained in the June, 1972 report "Assessment of the

Existing Hydrometric Data Network in Manitoba". The chief aim of the study was to isolate redundancies in the network and to determine the type of data and annual period of operation for which each station was required.

- In the analysis of the Manitoba hydrometric network the following procedure was followed:
  - The purpose of each streamflow station was identified according to the six data use categories:
    1. Municipal Water Supply
    2. Flood Forecasting and/or Protection
    3. Water Yield related to Power Production
    4. Recreation, Fish, and Wildlife
    5. Flood frequency Analysis
    6. Basin Yield
  - The network was evaluated based on a correlation analysis of stations suspected of having similar stream flow characteristics. The regression analysis was based on the logarithms of the monthly flows. The criteria for redundancies in the network was based on the correlation coefficient and standard deviation of the data.
- The study recommended that four stations be discontinued as they were no longer required for their intended purpose. Fifteen stations were recommended for reduction in the period of operation based on the correlation analysis.
- The study was updated a few years later. As expected more data resulted in reduced correlation coefficients. This points out the hazard in putting faith in correlation of short-term data sets.

B) APPLICATION OF SHAWINIGAN ENGINEERING CO. LTD. STUDY

- The density requirements of the hydrometric network were compared to that proposed by Shawinigan Engineering Co. Ltd in their report on "Hydrometric Network Planning Study for Western and Northern Canada". The review indicated the need for many more stations to meet the suggested density requirements.
- Example: Dauphin Lake Watershed.
  - Dauphin Lake is situated 305 km northwest of Winnipeg and 13 km east of the Town of Dauphin.
  - The gross drainage area of the Lake is 8417 km^2 .
  - Bounded on the south by the Riding Mountain National Park, on the west by the Duck Mountain Provincial Park, and on east by a divide separating Lake Manitoba and Dauphin Lake.

- Streams originating in the Riding and Duck Mountains originate at elevations of 823 m and 670 m respectively and fall to an elevation of 260 m at Dauphin Lake.
- There are seven major streams draining into Dauphin Lake , namely: the Turtle and Ochre Rivers from the south, the Vermilion, Wilson, Valley and Mink Rivers, and Edwards Creek from the west, and no major stream from the east. Theses major streams account for approximately 80 percent of the total drainage area.
- Each of these major tributaries to Dauphin Lake has a hydrometric gauging station, i.e. the Dauphin Lake Watershed is one of the more densely gauged watersheds in Manitoba.
- Even so, these stations are insufficient of define the hydrologic regime as the Watershed which consists of an Upland Plateau, escarpment slope and the lowlands areas. For instance there are no hydrometric gauging stations located on the streams originating in the sub-escarpment or lowland areas.

CONCLUSIONS

- The Canada-Manitoba Federal-Provincial hydrometric network is the backbone of all surface water management activities in the Province of Manitoba.
- In Manitoba, the Federal-Provincial hydrometric network is run in a cost-efficient manner to satisfy the needs of Manitobans.
- There are gaps in the existing hydrometric network. It is unrealistic to expect many of these gaps be filled.
- Network evaluation and planning to be effective must be used as a tool to indicate how we can get the biggest bang for our limited bucks recognizing that we cannot afford even a minimally optimal network.
- In these times of declining dollars all efforts must be made to protect the basic hydrometric network.

5. NEW BRUNSWICK NETWORK STUDY

DRAFT

AN AUDIT APPROACH TO HYDROMETRIC NETWORK EVALUATION: THE CASE OF THE NEW BRUNSWICK HYDROMETRIC NETWORK

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ABSTRACT

An evaluation of the hydrometric network in New Brunswick was performed starting from basic principles of hydrometric network design and proceeding through the analysis of the present network and its ability to meet user needs. Discharge stations used to monitor the streamflow component of the regional hydrology were assessed on their ability to contribute to the transfer of information to ungauged sites. A survey was conducted to determine users' needs. The results of the various analyses were combined using an audit approach based on selected rating factors. The final output includes specific network improvements designed to satisfy hydrometric needs and a list of network adjustment scenarios which are available as a management guide. A summary of the approach and major findings is presented here.

INTRODUCTION

The Province of New Brunswick is one of the four Atlantic Provinces of Canada, whose water resources are monitored by the Federal Government of Canada under cost-sharing agreements with the respective Provincial Governments. Water quantity data have been measured and stored on a continuous basis in New Brunswick since 1918 when hydro-power development was the main use for hydrologic data. With an area of 73,440 km^2, the Province is covered by a hydrometric network of 85 stations, of which 53 stations, representing an average density of 1 station per 1400 km^2 are located on unregulated streams and are applicable for analyzing regional hydrologic conditions.

Expansion of the network accelerated during the late 1960s and early 1970s with the increased demand for information for water supply, fisheries and flood forecasting purposes. Many stations were established to meet specific user needs, sometimes of a short-term nature. Many of these stations which had served their original purpose were retained in order to secure a longer and statistically more useful period of record. At that time, this was considered an effective method of expansion, as the network was sparse and the initial capital and operating costs for establishing the station had already been paid.

This historical expansion path has led to the present "collection" of regional streamflow and operational gauging sites, which is deficient in respect to certain network objectives, though at the same time redundant in others.

A number of methodologies were investigated to establish network criteria for regional hydrology purposes. A suggested "minimum" coverage was determined based on physiographic-climatic zones as the representative hydrologic units, as well as a "target" or "optimal" network based on hydrologic regions for which relationships could be defined for estimations at ungauged sites.

These regional hydrology criteria were subsequently input to the development of an evaluation framework which additionally incorporated consideration of user needs and cost-effectiveness criteria. The evaluation framework, which utilizes an audit approach to assess the relative contributions of both existing and proposed stations to specified network objectives, attempts to circumvent the conceptual hurdles involved in typical rigorous procedures for optimization.

Finally, a number of alternate network scenarios were identified and applied to the prioritized ordering of stations. These focused on varying objectives ranging from minimum delivery of a "public good" mandate to all-inclusive delivery of identified needs, including an "optimal" regional streamflow network.

The application of this evaluation process provided three key management tools:

- a rationale for re-allocating existing resources from lower to higher priorities;
- an ordering of priorities for allocation of additional resources; or
- an ordering of priorities for an imposed reduction of resources.

NETWORK DESIGN CRITERIA

In order to objectively assess the hydrometric network without being biased by the historical tendency toward incremental needs, criteria were developed; appropriate networks were identified which would satisfy these criteria; and these were compared with the existing network to identify deficient and/or redundant elements of the present configuration.

A. A Minimum Regional Network

An assumption was made that the minimum spatial coverage for the provision of regional streamflow information would require gauging at least one representative small, medium and large stream in each characteristic physiographic-climatic zone of the Province. This assumption reflected the belief that each such zone would comprise an area of relatively similar hydrologic characteristics.

The physiography of New Brunswick has been divided into six principal physiographic divisions (Rampton et al, 1984), which were considered sufficiently uniform for our purposes.

The climatic divisions were provided by the Atmospheric Environment Service, Environment Canada, based on the long-term average ranges of annual precipitation, annual snowfall, as well as depth of snowpack on March 31 of each year. These parameters are readily available from the climate network and have previously been significant in explaining a large part of the variability of the hydrology in New Brunswick. Other parameters, such as evaporation, are not available on a sufficiently wide basis to be considered usable.

Land use data reside on a database under the Canadian Land Use Monitoring Program (CLUMP) and are organized by drainage basin. A great deal of the Province is forest-covered, but there are large areas which have significant proportions of land classed as agricultural and marshland. Such areas were used to refine the boundaries of the physiographic-climatic zones.

From the intersection of the physiographic, climatic and land use divisions, 16 zones of similarity were delineated. Drainage basin boundaries were employed wherever possible, with the exception of large rivers such as the Saint John and Miramichi which had significant areas within more than one physiographic-climatic zone. Using the criteria of a minimum of three sites per zone (i.e. small, medium and large drainage), and including six additional sites for a number of zones which had particularly wide ranges of drainage area, a total of 54 station sites were identified for the minimum regional hydrometric network. Only 37 of these are addressed by the existing network. Further, in comparing the existing network with WMO criteria, it was noted that the present distribution of stations is less than minimum in all but a few zones.

B. A Target Regional Network

The minimum network identified above cannot be regarded as anything more than a collection of stations assumably representing areas of relatively homogeneous hydrologic charateristics, and constitutes the "least credible" capability for the provision of regional streamflow information for the Province. However, in order to provide a "reliable" regional hydrometric information base, capable of estimations for ungauged sites, spatial representation must actually be tested for statistical significance and a more enhanced database (i.e. gauging station network) is required to support this capability.

A review of data transfer techniques identified regression analysis as the most appropriate estimation tool for the task at hand. A minimum of 10 stations per homogeneous hydrologic unit were required to provide sufficient degrees of freedom for statistically significant functions to be developed for regression analysis. Application of this criterion to the 16 physiographic-climatic zones identified above would require a minimum of 160 stations; a 100 percent increase over the present network. Realism prevailed, however, and a revised approach was employed for the determination of a reduced number of representative hydrologic units.

To accomplish this task, the regional streamflow network was assessed on its ability to transfer the 1:100 year recurrence interval flood flows, the 1:20 year mean annual, and the 1:20 year 10-day mean day flows. It was assumed that these three parameters would reflect the typical needs for streamflow information.

Normally, regional streamflow transfer equations are developed using a stepwise linear regression fit by the method of ordinary least squares. Ordinary Least Squares (OLS) regression analysis (Pilot and Cheng, 1987) were applied to determine the form of the equation. However, the final analyses were performed using Generalized Least Squares (GLS) regression as modified and adapted by Thomas et al (1985). The GLS method has several advantages: it allows for data from hydrometric stations with different lengths of record to be utilized by taking into consideration the correlation and the distance between stations. GLS reduces requirement for a constant variance of the random error of the independent variable (an assumption of OLS regressions which is often violated). Additional information, which include the data mean, standard deviation and coefficient of skew along with the location of the watershed, are used to develop a weighting matrix which, in turn, is used to fit the equation. In the end, GLS ranks the stations in terms of their individual contribution to the estimating equation, providing a basis from which to assess the value of the station within the network.

An example regression equation from this study used drainage area (DA) in km^2 and mean annual precipitation (MAP) in mm to estimate the 1:2 year recurrence interval mean annual flow (Q_2) in m^3/s, This equation took the form:

$$Q_2 = \exp[-14.40688 + 1.01324 \ln(DA) + 1.51366 \ln(MAP)]$$

Through the OLS analyses, the Province was divided into regions based on the areal bias of the residuals, along with physiographic and climatic considerations. Two regions were determined for mean flows, four for drought flows and four for flood flows, not taking the Saint John River into account. GLS regression equations were then developed for each region. The results of the regressions can be summarized in terms of the range of their standard errors (S.E.) of estimate. The regression equations for the 1:20 year recurrence interval mean annual discharge produced S.E. between 11% and 13%, whereas for flood flows they ranged between 6% and 23%, and for the 10-day mean low flows, they ranged between 20% and 55%. The results of the mean flows were marginally acceptable, the overall flood flows results fell slightly short of user expectations, however, the low flows are much less acceptable. Another underlying problem is the poor representation of small watersheds in these equations, which limits their application.

In overlaying the flood, mean and low flow patterns, a number of regional boundaries were found to be coincidental. These boundaries were accordingly combined, creating a set of 7 hydrologic regions as shown in Figure 1. Using the criteria of a minimum of 10 stations for each hydrologic region (with some variations for size), a total of 77 station sites were identified for the Target Regional Hydrology Network. Only 51 of these are addressed by the existing network.

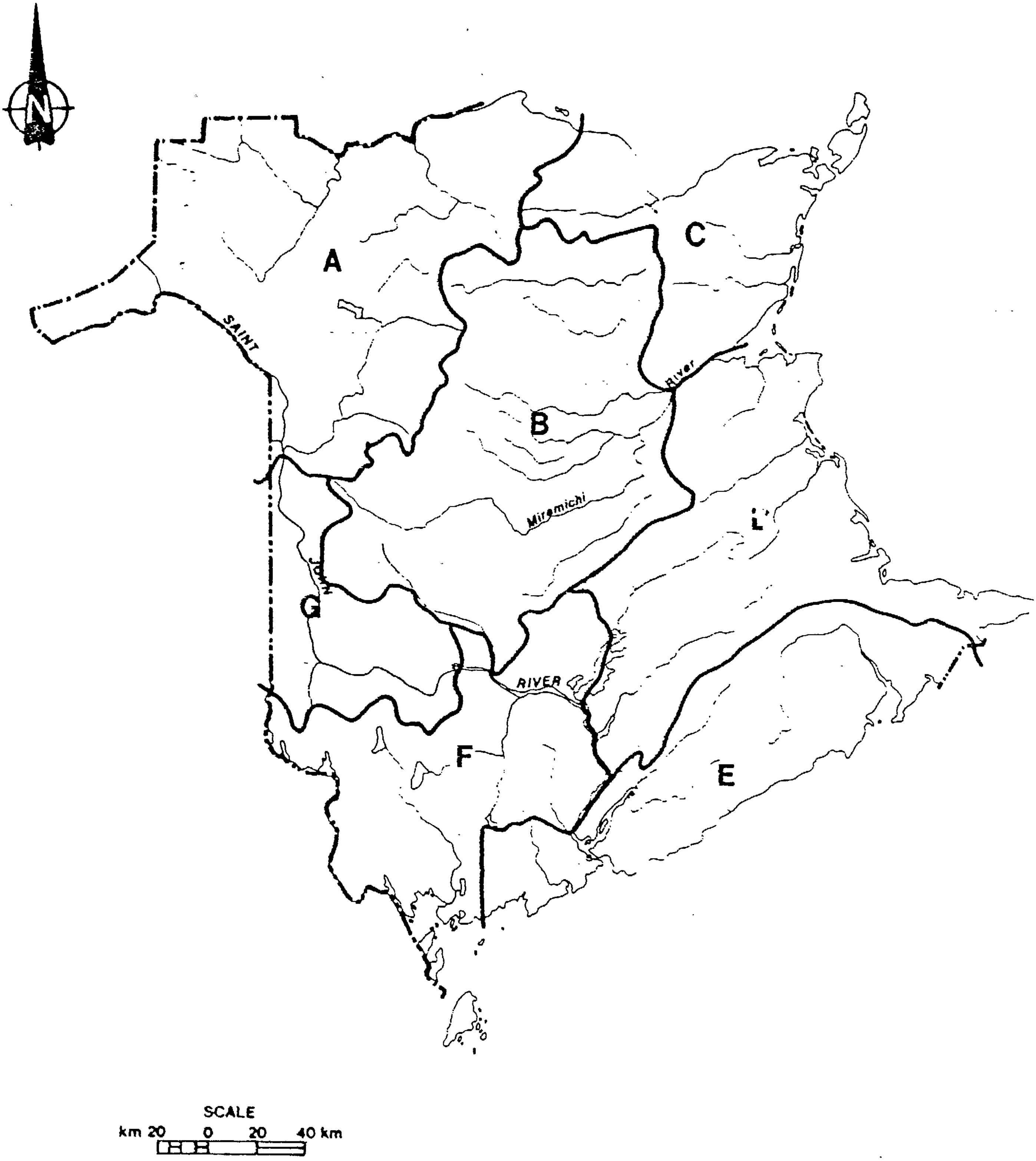


Figure 1. Homogeneous Hydrologic Regions of New Brunswick

ASSESSMENT OF USER NEEDS

It was realized, of course, that not all user needs will be met by a regional streamflow network. There are additional activities which require site-or-purpose-specific hydrometric information, usually on a real-time basis, which can only be provided by actual gauging sites rather than by a regional information base. Such activities include monitoring for operational, forecasting or mandated purposes. It was noted, however, that some operational stations could also support the regional hydrology information base.

In an attempt to ensure that all user needs were accounted for, surveys were conducted to determine the data users, the types of data required, and the frequency of use. As expected, of the 251 (from 505) questionnaires returned, it was found that government agencies, consultants, utilities, and academic institutions had the greatest need for hydrometric data. Some interesting findings of the survey included:

- 80% of the respondents required hydrologic data, of whom 85% required interpreted data;
- over 50% of the respondents to the question on data transfer indicated a desire for an accuracy of $\pm$ 10%;
- 50% felt that the station coverage was inadequate; and
- a high percentage of users used the data on at least a monthly basis.

ECONOMIC CONSIDERATIONS

The combined set of regional and operational needs comprises the demand for hydrologic information. The combined set of gauging stations and data transfer capabilities comprises the supply. Optimization will occur when there are no deficiencies perceived by the demand community <u>and</u> there are no redundant sites operated to provide this information. Budget constraints will dictate the level of optimization possible.

Optimization was regarded in this study as an approximate rather than a definitive concept. Rigorously determined optimal networks, regardless of their mathematical merit, were likened to the mythical unicorn: dreamt about, sung about, painted and sculpted, but never actually witnessed, and thereby of limited practical use. This perception is based on a number of significant reasons: First, a particular hydrologic record is available to and is shared by many users in varying degrees and with significantly varied economic consequences. The apportionment of benefits to each use therefore becomes either impossible or arbitrary, as does the aggregation of these benefits. Second, as one of the most important applications of regional streamflow information is to serve unanticipated needs, the full set of demands is never finite; consequently nor the full set of benefits. Third, error analysis typically focusses on with/without single-purpose situations, far removed from our present situation of a reasonably mature network serving multiple needs. And finally, error analysis by itself is incomplete in that it prescribes performance only on the basis of statistical criteria (i.e. tests of significance) without being able to assign a level of benefit to the satisfaction of these criteria.

Despite the inabiltiy to quantify benefits, the literature nevertheless generally acknowledges that the benefits of hydrometric networks are high relative to their costs. This impression is largely derived from the "public good" values associated with centralized networks. That is, assuming that governments require at least a core network to meet mandated and stewardship responsibilities for water management, then there will be economies of centralization and enhanced reliability derived through adding-on to this core network rather than establishing a plethora of mini-networks of varying consistency and quality for individual needs as they arise.

Furthermore, it has been estimated (Table 1) that, for a single-purpose hydrologic project (e.g. a secondary highway bridge), there can typically be at least a 70% saving in cost between computing a design flow with and without access to established data at or near that site. This factor would be significantly magnified for larger projects involving multiple design points.

Approximately $40 million is expended annually by the Province of New Brunswick alone on public transportation and water works infrastructure requiring hydrologic design data. The cost implications of undertaking these efforts in the absence of established data are apparent, particularly when one adds in federal and municipal public works, as well as the whole array of other uses identified by the user surveys.

Having acknowledged the complexities of attaching specific magnitudes to the benefits of hydrologic information, the task remained to develop a methodology which would focus on relative rather than finite determinations.

AN AUDIT APPROACH TO NETWORK EVALUATION

The methodology developed to accomplish this task was based on a framework proposed by Wahl and Crippen (1984), who compiled a set of priority considerations for rating each station in a network. These were based on: the need for information at the site, accuracy of data, economic aspects of operation, and usefulness of data for transfer to ungauged sites.

This framework was modified and expanded to develop the "audit-approach" applied in this study. Three groupings of priority considerations were identified: 1) Site Characteristics; 2) Client Needs; and 3) Regional Importance of Water Resources. Table 2 identifies the scoring structure and rationale for each of these priority considerations.

The Station Audit exercise itself was accomplished by the convening of a Roundtable session, comprising all team members and the operators and managers responsible for the network. <u>All stations were organized on a basin basis and were individually assessed or "audited", in terms of the extent to which they contributed to the full set of priority considerations</u>. The fundamental tenet of the Roundtable, in all respects, was to achieve consensus among participants. Because of the

TABLE 1

EXAMPLE OF PUBLIC SAVINGS DERIVED FROM A REGIONAL NETWORK

Project: A small highway bridge. The hydrology requirement is a design flow for a bridge over a river with a 250 km2 watershed.

A. Cost **with** Existing Hydrologic Record at or near Site:

– Field visit	1 – 2 days
– Perform frequency analysis and evaluate	1 day
– Select design flow and report	1 day
	3 – 4 days @ 450/day = 1,350 – $1,800

B. Cost **without** Existing Hydrologic Record at or near Site:

– Field Visit	1 – 2 days
– Information gathering (maps, plans, rainfall, land use, etc.)	2 – 3 days
– Select, set-up and calibrate model	3 – 5 days
– Perform and evaluate model computations	2 – 3 days
– Select design flow and report	1 – 2 days
	9 – 15 days @ 450/day – $4,050 – $6,750

Notes:

1. The public saving in design costs only, for this project alone, may be as much as 70%. Provincial expenditures alone, for such hydrometric-data-dependent works exceed $40 million annually. Federal and private expenditures are additional. These are supported by a network operating cost of $0.3 million annually.
2. The estimated savings are for a small single-purpose project. These would be substantially magnified for any multi-purpose projects involving larger areas and multiple design points.
3. Accuracy of the "modelled" flow will be less than that for the established record.
4. The modelled flow will not typically be applicable for regional hydrology information, while the established record would be, i.e., the established record will be available for any number of projects.

TABLE 2
NEW BRUNSWICK NETWORK EVALUATION
STATION AUDIT

PRIORITY CONSIDERATIONS	MAX. AVAIL. POINTS	RATIONALE
A) SITE CHARACTERISTICS		
1) Mean annual flow (cms) .... - less than 25 .... 2 - 25 to 125 .... 4 - greater than 125 6	6	- larger drainages provide a more representative sample for the Province as a whole.
2) Water level only .... - water level station .. 3 - other 0	3	- these stations provide less information than a flow station.
3) Quality of record	15	- the better the quality of record the greater the information value.
4) Period of record (years) .... - 0 to 5 .... 10 - 6 to 10 .... 7 - 11 to 15 .... 5 - 16 to 25 .... 3 - 26 to 40 .... 7 - greater than 40 10	10	- short records need to be extended in order to establish a record. Once the record is established it is of decreasing value, with the exception of very long records which become valuable for index purposes.
5) Proximity to climate station	5	- stations whose record may be readily related to comparative met data have added information value.
B) IDENTIFIED CLIENT NEEDS		
I. Regional Hydrology		
6) Identified for minimum natural .... flow network.	9/0	- only stations identified as essential for regional hydrology were assigned these points.
7) Regional hydrology priority code .... (importance for estimation)	9	- stations which would contribute to enhanced data transfer capabilities were scored here
8) Importance for long term index ...... monitoring/inventories	8	- primarily stations serving the national index network, as well as some others of importance for trans-boundary areas.
9) Importance for 'special' regional .... hydrology needs (e.g. small basin data, tech. pilot projects, etc.)	10	- also includes special studies and jurisdictional responsibilities.
10) Client priority .... a) water supply .... 10 b) 'other' infrastructure .... 8 transp. sewerage etc.) c) flooding .... 6 d) environmental impacts .... 7 (including health) e) fisheries .... 6 f) energy .... 8 g) navigation & recreation 5	10	- based on user surveys and station audit. Weightings were determined by a consensus of team members.
11) Also serves identified operational ... need	6/0	- extra points assigned for stations which served both regional and operational needs.

.../continued

TABLE 2 cont'd.
NEW BRUNSWICK NETWORK EVALUATION
STATION AUDIT

PRIORITY CONSIDERATIONS	MAX. AVAIL. POINTS	RATIONALE
II. Operational (regulated/site specific)		
12) Importance for federal obligations/responsibilities (Treaties, Agreements, Boards, etc.)	10	- only stations serving formal federal commitments were included here.
13) Importance for provincial/ responsibilities (Agreements, Boards, etc.)	10	- only stations serving formal provincial commitments were included here.
14) Client Priority	10	- based on user surveys and station audit. Weightings were determined by a consensus of team members.
a) water supply 8		
b) 'other' infrastructure (transp., sewerage, etc.) 5		
c) flooding 9		
d) environmental impact (incl. health) 8		
e) fisheries 7		
f) energy 8		
g) navigation & recreation 5		
15) Also serves regional hydrology need	6/0	- extra points assigned to stations which served both regional and operational needs.
C) REGIONAL IMPORTANCE OF WATER RESOURCE		
I. Value of Water Resources in Basin		
16) Population density	5	- a pro-rated general indicator of intensity of water use.
17) Municipal water use	9	- pro-rated from MUNDAT inventory of surface supplies; adjusted for sources outside basin.
18) Industrial water use	9	- pro-rated from Industrial Water User Survey inventory of surface supplies
19) Fisheries priority	8	- generalized CLI sport fishing capability.
20) Hydro potential	8	- based on DOE inventory of major potential sites and Acres study of potential small scale sites.
- major 8		
- small scale 4		
- none identified 0		
21) Economic Pressure	7	- based on capital works identified in RSCC Register and Informetrica inventory of capital works.
II. Magnitude of Water Resource Problems in Basin		
22) Flooding	8	- priority sites identified by federal and provincial DOEs.
23) Water quality problems/issues	9	- ambient values provided by WQB; point sources identified by EP.
24) Water shortage potential	10	- Water Use Analysis Model using high-growth projections and hypothesized lowflows.

consensus-building approach, the resulting information generated, and the integrating nature of the exercise, the Roundtable session was regarded by all, as one of the most valuable elements of the whole evaluation exercise.

Both existing and proposed new stations were rated against the same factors and ranked together on the basis of the composite of points accumulated for each priority consideration. Proposed stations comprised either those suggested by the data transfer exercise for regional hydrology, or those necessary to address specific needs not currently being served.

The higher the total Station Audit points accumulated by a particular station, the higher is the relative value of benefits derived from that station. No attempt was made to determine a dollar value for benefits; only an ordering of relative worth. The total set of existing and proposed stations was then prioritized or ranked in order of accumulated Station Audit points.

A simplistic gauging strategy based on this ranking would be to simply include as many stations as possible, in descending order of points as permitted by a particular budget level, using a constant average operating cost. It was realized, however, that the operating agencies will regard certain priority considerations (e.g. formal commitments) as totally non-discretionary (i.e. must be fully satisfied), and others as relatively more discretionary depending on the resources available.

These "constraints of practicality" were incorporated into the construction of a set of alternate network scenarios. The scenarios ranged from a minimum public good mandate (i.e. formal commitments, minimum regional network and long-term index), to an all-inclusive option addressing all identified needs including an "optimal" regional hydrometric network. The impacts on network objectives of each of these alternatives were investigated and the resulting increase or decrease in operating cost was identified. The implications for adding new stations to address deficiencies or closing existing stations which became redundant for a particular scenario, were also identified.

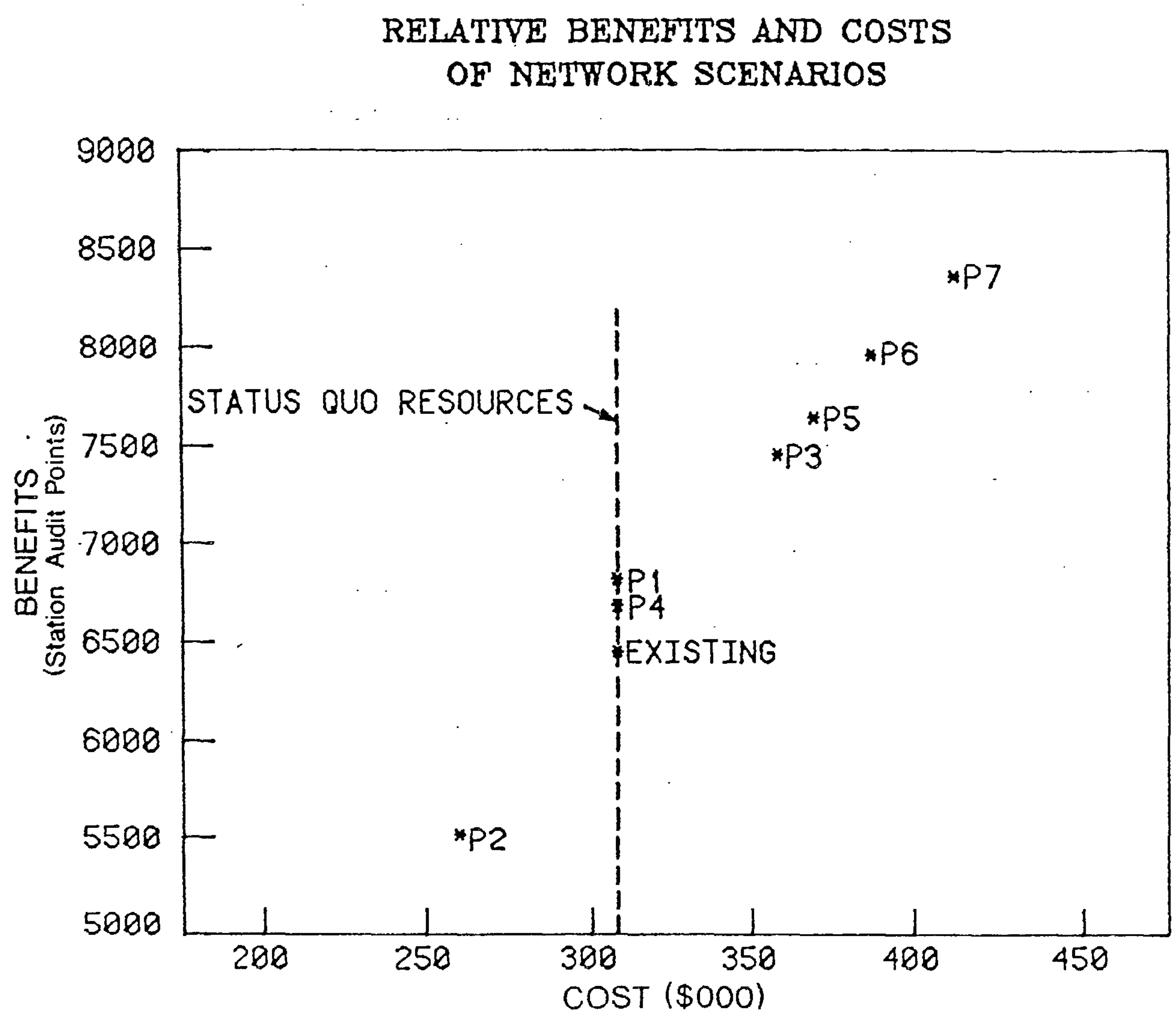
Rather than presenting these scenarios as network goals per se, the intent was to: a) identify areas in which improved network performance could be achieved as a short-term goal without requiring any additional resources, and b) provide a guide by which management could assess the impacts of their intentions (whether austerity-or-expansionary-minded), within the context of a 5-10 year network plan. These scenarios are illustrated in relative benefit-cost terms in Figure 2.

CONCLUSIONS AND RECOMMENDATIONS

The overall assessment of the network points to a mature network which is reasonably well-targeted, not excessive and, in fact, deficient in some respects.

The analysis indicated that the network was adequate for estimating mean annual and flood flows but less than adequate for the

Figure 2.



RELATIVE BENEFITS AND COSTS
OF NETWORK SCENARIOS
BENEFITS
(Station Audit Points)
9000
8500
8000
7500
7000
6500
6000
5500
5000
STATUS QUO RESOURCES
*P7
*P6
*P5
*P3
*P1
*P4
*EXISTING
*P2
200
250
300
350
400
450
COST ($000)

estimation of low flows. The primary deficiency was inadequate representation of small basins.

Some deficiencies can be addresssed via re-allocation of resources in the short term; others can only be achieved by selective expansion of the network over the long term.

The Station Audit Framework was found to be a useful integrating tool, bringing together under one umbrella, all the relevant considerations for network evaluation: "suitability" of the station site, representation of the regional hydrology, usefulness for estimation purposes, servicing of client needs and attention to water planning priorities. The framework is admittedly a subjective one. However, the professional attitudes of all team members, the structuring of the framework so as to provide objective guidelines for the assessment process, the comprehensive approach to consistently assessing each and every station against all priority considerations, and the consensus - building approach, helped to make subjectivity a tool rather than a detriment.

The methodology applied in this evaluation overcomes the historical tendency to simply augment the network in response to incremental needs. Instead, technical, user, and socio-economic concerns were balanced together to determine sets of network objectives against which network performance can be assessed. Appropriate gauging strategies were identified for the achievement of these objectives.

The methodology is flexible, in that objectives can be modified and assumptions revised based on management priorities and the results can be readily identified. The evaluation framework is a general one which is easily adapted and applied to most situations.

The major recommendations drawn from the findings are summarized below. The overall objective was to create a rationalized and more cost-effective network. This can be accomplished by:

1. using the results of this study to establish both short and long term goals for the network. The short term goal would be to ensure that the identified Minimum Network requirements are met through re-allocation of resources. The longer term goal would be to develop an enhanced regional streamflow estimation capability as represented by the more comprehensive Target Network;

2. establishing a Network Evaluation and Planning Subcommittee responsible for on-going network analysis, communications with the user community, and preparation of an annual implementation plan for network adjustments and integrated network planning;

3. emphasizing the importance of regional hydrometric needs in planning and operating the network, and assessing any tendency toward downsizing of the network, against the potential loss in public savings and reduced service to the public;

4. pursuing integrated hydrologic network planning with the operators of related atmospheric, water quality and groundwater data programs;

5. working towards increased automation of the data collection activities;

6. implementing a marketing strategy to broaden the user base and increase the interaction and communication with users; and

7. preparing more interpreted information designed to assist users and enhance the utility of the collected data for many applications.

ACKNOWLEDGEMENT

The authors acknowledge the contributions to this project from their fellow team members of the Water Resources Planning Division of New Brunswick Department of Municipal Affairs and the Environment, and the Atmospheric Environment Service, Water Planning and Management Branch, and Water Resources Branch of Environment Canada.

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6. RECENT USGS EXPERIENCE IN NETWORK PLANNING

EDITOR'S NOTES

The following two items are technical memoranda contributed by the United States Geological Survey (USGS). They are intended to highlight some of their activities regarding:

1) new procedures for hydrologic regression and network analysis using generalized least squares; and

2) guidelines for the operation of a crest-stage program and the program's intended purpose.

Following these two memoranda are copies of the overheads as presented by Mr. W.O. Thomas, Jr.

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

In Reply Refer To:
WGS-Mail Stop 415

April 22, 1987

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM NO. 87.08

Subject: PROGRAMS AND PLANS--New Procedures for Hydrologic Regression and Network Analysis Using Generalized Least Squares

New procedures for hydrologic regression and network analysis using generalized least squares regression are described in the attached report. These procedures will be of interest to personnel involved in regionalizing streamflow characteristics and evaluating the stream-gaging network. These new procedures are an extension and improvement of procedures known as Network Analysis for Regional Information (NARI) that are documented in U.S. Geological Survey Water-Supply Paper 2178.

The generalized least squares program provides many advantages over ordinary least squares regression. The regression coefficients are estimated by taking into consideration the time-sampling error in the dependent variable and the cross correlation between sites. A weighting matrix is computed so that each watershed in the data set is weighted proportional to the accuracy (variance) and cross correlation of the dependent variable. The prediction error for ungaged sites is partitioned into model error and sampling error (including both time- and spatial-sampling errors). The model error is that portion of the total error (prediction error) that cannot be reduced by additional data collection. On the other hand, the sampling error can be reduced by operating the existing stations longer, or by installing new stations, or some combination of both. This approach to error analysis makes generalized least squares regression a useful tool for network design and analysis. Using generalized least squares, it is possible to determine the existing or proposed stations that are most important in reducing the sampling error. This provides the data manager with a tool to determine the specific stations (including proposed stations) that are providing the most information in a regional sense.

Additional input data are needed in the generalized least squares over that required in ordinary least squares regression. The preparation of this input data is time consuming if done manually. Therefore, ANNIE, an interactive data processor, is being used to prepare these input files. ANNIE and the associated Watershed Data Management (WDM) File is used for Office of Surface Water application programs and provides a mechanism for not only preparing the input data but also to store and manipulate data, make transformations, prepare tables and plots, and guide the user through the analysis.

ANNIE/WDM has been developed for several years, and new features are continually added to the system. The development of this system is being coordinated by Alan Lumb, Office of Surface Water, and its purpose is to facilitate hydrologic analyses and particularly the use of hydrologic and hydraulic models. The ANNIE/WDM system is also very helpful in managing data for a statistical analysis such as generalized least squares regression. Only a brief overview of ANNIE/WDM is provided in the attached document. More detailed documentation of ANNIE/WDM is available from the Office of Surface Water.

The attached report contains an example of using ANNIE and generalized least squares to develop regression equations for estimating flood discharges and to analyze the regional hydrology network in southeastern Illinois. The regional hydrology network is composed of those stations useful in estimating streamflow characteristics at ungaged sites.

A magnetic tape of the ANNIE/GLS programs including the necessary run files, message files, Command Procedure Language (CPL) routines, and test data can be obtained by sending a blank tape to Kate Flynn in the Office of Surface Water (FTS 959-5313 or KMFLYNN@RVARES). Please put your name and address on this tape so that it is easy to identify who sent the tape. The test data and example output are the same as given in the attached report.

Technical questions on the generalized least squares regression program should be directed to Gary Tasker, Northeastern Region Research (FTS 959-5892), or Will Thomas, Office of Surface Water (FTS 959-5318). Additional copies of the attached documentation are also available from the Office of Surface Water.

Verne R. Schneider
Chief, Office of Surface Water

Attachment

WRD Distribution: FO-LS, SL

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA 22092

In Reply Refer To:
WGS-Mail Stop 415

April 14, 1988

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM NO. 88.07

Subject: PROGRAMS AND PLANS--Guidelines for the Operation of a Crest-Stage Program

Knowledge of the magnitude and frequency of flooding is required for the design of transportation facilities such as bridges and culverts, flood-control structures such as reservoirs and levees, and for floodplain management and the establishment of flood-insurance rates. These flood-frequency analyses generally require only the instantaneous annual peak discharge. Many years ago, the U.S. Geological Survey (USGS) recognized the cost-effectiveness of using crest-stage gages to collect instantaneous flood-peak data. These partial-record stations can be operated for a small portion of the cost of a continuous-flow station. Even though these gages are relatively simple to install and operate, the quality-assurance procedures for computing annual peak discharges should be comparable to those used at continuous-flow stations. This memorandum restates and clarifies procedures for operating a crest-stage program.

Existing crest-stage gages can be former flood-hydrograph sites operated as part of the small-streams program, discontinued continuous-flow gaging stations, or stations originally established as crest-stage stations. In all cases, the primary problem is in establishing and maintaining a current stage-discharge relation. Suggestions for developing a sound stage-discharge relation will be provided as well as suggestions for improving documentation procedures and analyzing the crest-stage network.

Stage-discharge relations

1. Develop the stage-discharge relation initially by making direct or indirect high-water measurements, developing a theoretical culvert rating, or using step-backwater techniques, depending on what is appropriate.

2. Obtain direct or indirect measurements every couple of years to verify the high-water range of the stage-discharge relation. Identify the priority of making measurements at crest-stage stations in the District flood plan. Whenever possible, measurements should be obtained for major flood events.

3. Maintain and utilize upstream and downstream gages if both upstream and downstream water-surface elevations are required to compute flow through the culvert.

   At many culvert sites, the stage-discharge relations were developed during the days of the small-stream program. In many instances, these relations are being used today without measurements or high-water marks to verify the relation or flow condition. Not only is it important to verify stage-discharge relations by measurements, it also is important to obtain high-water marks to verify the type of flow condition and utilize elevations at upstream and downstream gages, if warranted.

4. Plot the stage-discharge relation and all measurements above a certain stage and identify the types of discharge measurements.

Documentation procedures

1. Maintain a listing of direct and indirect measurements at each station, and clearly identify the type of measurement.

2. Number the stage-discharge relations, identify the periods of applicability, and document how each stage-discharge relation was developed.

3. Maintain current station descriptions, run levels at intervals identified in the quality-assurance plan, and provide all appropriate field offices copies of pertinent information such as stage-discharge relations, station descriptions, level summaries, etc., so the station can be properly operated.

4. Write a brief station analysis documenting how the annual peak discharge was computed, identifying which stage-discharge relation was used, the type of flow condition, noting whether measurements were made on the peak, describing how the dates of the peaks were determined, etc.

5. Update the Peak-Flow File promptly after the end of the water year and qualify all annual peaks appropriately. Maintain a current listing of annual peaks and stages in the station folder for review purposes.

6. Maintain District quality-assurance procedures for reviewing the crest-stage program, and document this review process.

Regional/Network Analysis

The recently developed generalized least squares regression procedure provides a useful method for regionalizing streamflow characteristics and for evaluating the stream-gaging network (see Office of Surface Water Technical Memorandum 87.08 dated April 22, 1987).

In particular, this procedure is useful for evaluating the crest-stage network and making modifications in the network to maximize regional flood information. The following comments on this procedure are pertinent.

1. Analyze the crest-stage network whenever a regional flood study is completed, approximately every 5 to 10 years. An analysis of the crest-stage network and those continuous-flow stations used for regional information should be a part of every proposed regional flood study. Once the regional analysis is complete, an evaluation of the network requires minimal effort.

2. Determine those existing crest-stage stations that contribute most to reducing the prediction error of the regression equations. Evaluate possible improvements in regional information by establishing new stations using the generalized least squares regression procedure. Operate those stations that maximize regional information (i.e., minimize prediction error) for a given operating budget. Since most crest-stage stations are operated to define the flood hydrology of a region, the generalized least squares regression procedure provides a mechanism for determining the best locations for these stations. An example of using generalized least squares regression for network analysis in Kansas is given in Water-Supply Paper 2303.

The successful operation of a crest-stage program requires a variety of skills including knowledge of hydraulics, frequency analysis, and regionalization techniques. Adequate training in all these areas should be obtained for those involved in the operation of the crest-stage program.

Charles W. Boning

Charles W. Boning
Acting Chief, Office of Surface Water

WRD Distribution: A, B, S, FO, PO

This memorandum supersedes Surface Water Branch Technical Memorandum No. 74.17.

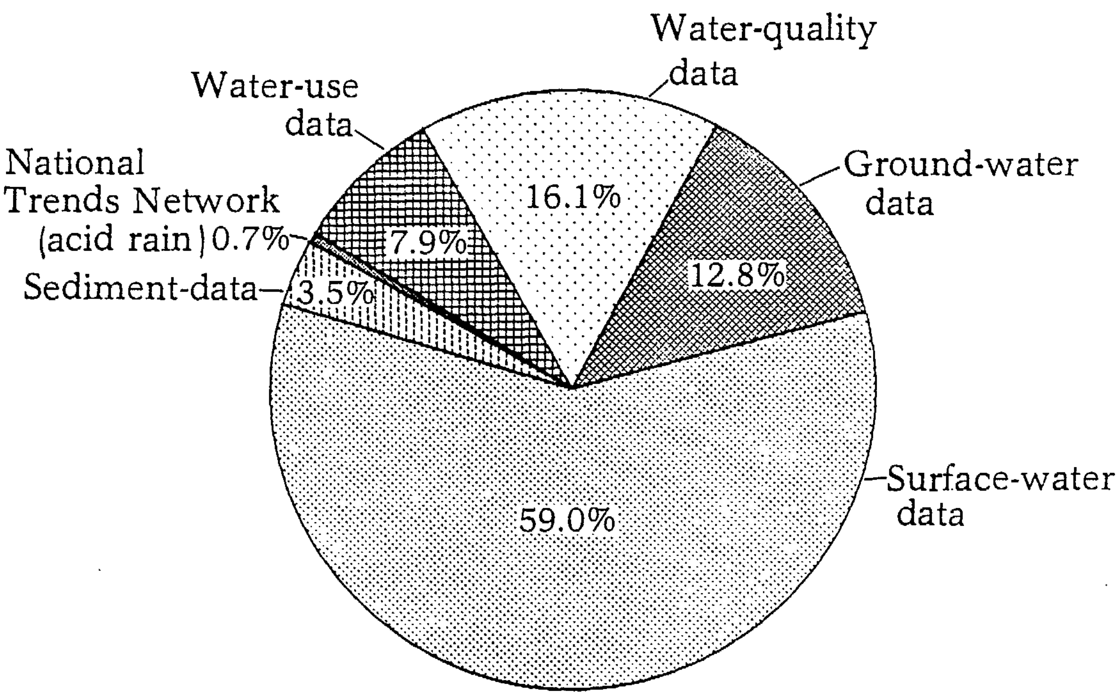
NATIONAL WORKSHOP ON NETWORK EVALUATION AND PLANNING

Winnipeg, Manitoba
October 5-6, 1988

Topics to be discussed -

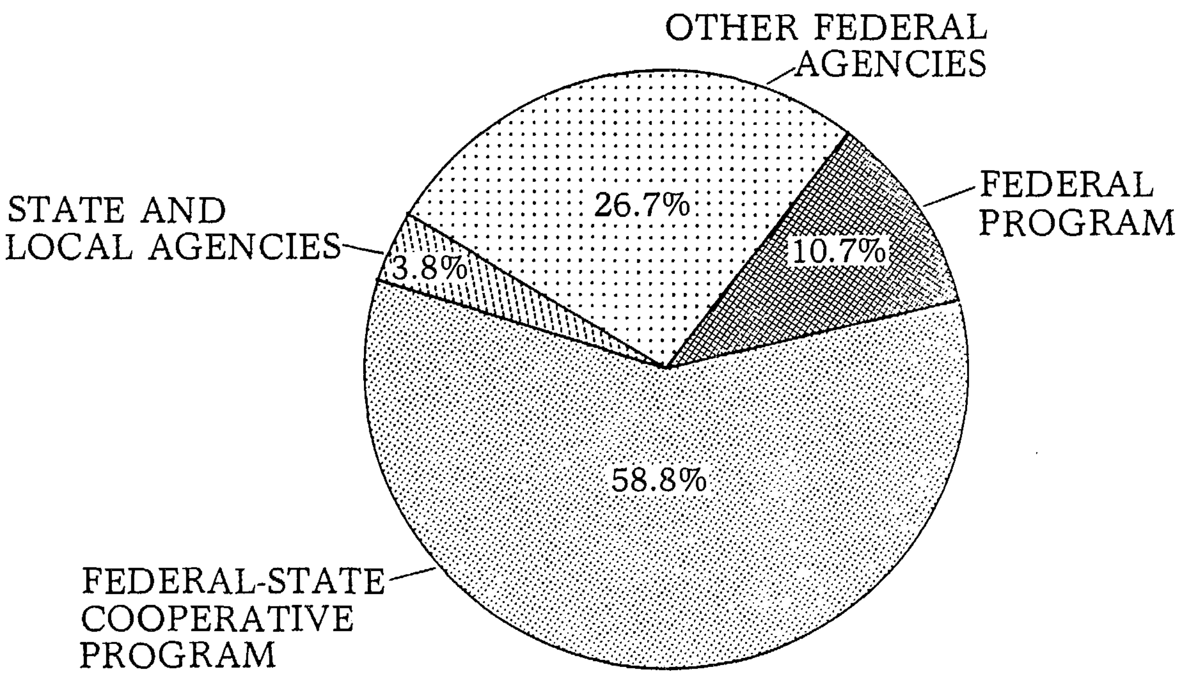
1. An introduction to the USGS stream-gaging program
2. USGS nationwide cost-effective analysis
3. USGS approach to analyzing the regional hydrology network
4. Activities of American Society of Civil Engineers (ASCE)
5. Activities of Federal Interagency Working Group on Network Analysis
6. World Meteorological Organization (WMO) project on comparison of network analysis techniques

DISTRIBUTION OF FUNDS



TOTAL FUNDING FOR DATA COLLECTION
IS $93.2 MILLION, FISCAL YEAR 1986

SOURCES OF FUNDS



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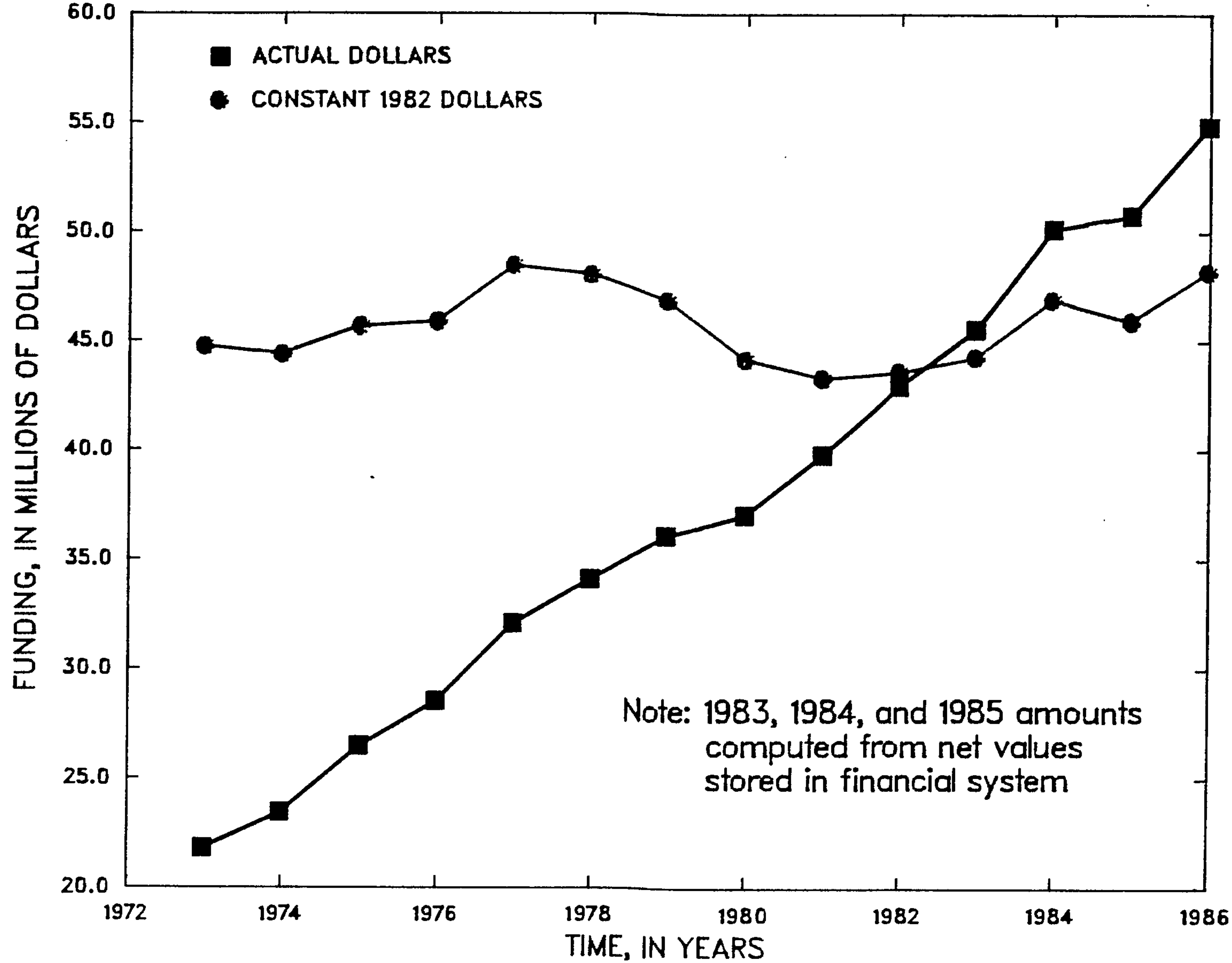
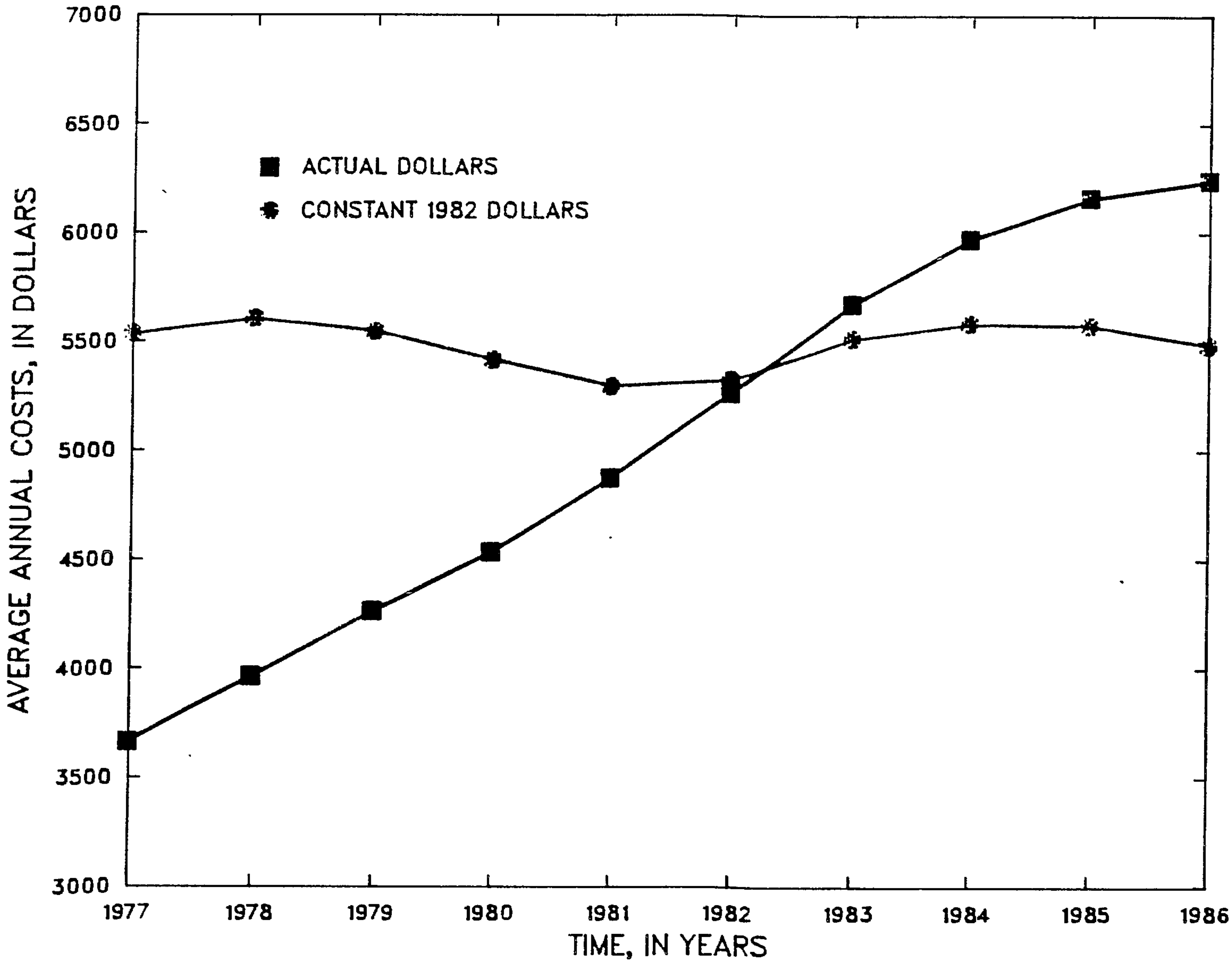


Funding provided for Surface-Water data collection and analysis, fiscal years 1973–86.



Average annual costs of streamflow gaging station operation, 1977–1986.

COST-EFFECTIVE ANALYSIS OF THE U.S. GEOLOGICAL SURVEY STREAM-GAGING PROGRAM

A nationwide analysis (1983–87) that included the following three steps –

- identify the principal uses of the streamflow data

- identify less costly alternative methods of providing the needed streamflow information

- define strategies for the operation of the necessary stations that minimize the uncertainties in the streamflow records

RESULTS OF DATA USE SURVEY

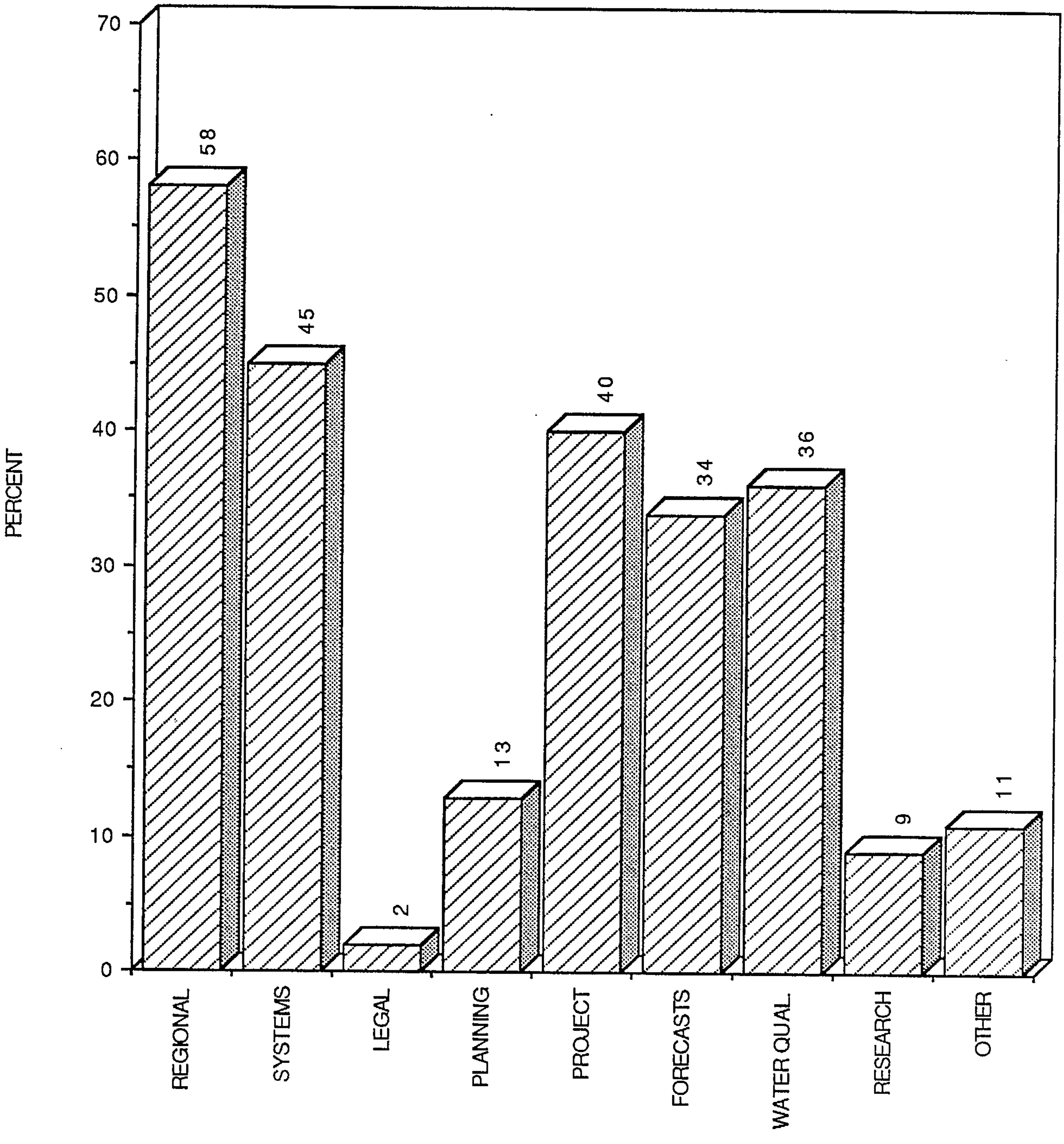
Based on an analysis of 3,493 stations operated in 33 States -

- 51 stations were identified as not having sufficient justification to continue their operation

- 48 more short-term special study stations should not be continued beyond completion of respective studies

- these 99 stations represent about 3 percent of the 3,493 stations analyzed

SURFACE-WATER DATA USE



ALTERNATIVE METHODS OF PROVIDING STREAMFLOW INFORMATION

1. Operate partial–record stations
   - crest stage stations
   - low flow stations
   - flood hydrograph stations

2. Utilize hydrologic flow routing models

3. Utilize statistical techniques such as multiple regression analysis

4. Utilize hydraulic flow routing models

5. Utilize watershed models

BASIC PHILOSOPHY

The stream-gaging activity should not be considered a network of observation points but rather an information system in which data are provided by both observation and synthesis.

ALTERNATIVE METHODS ANALYSIS

Summary of alternative methods analysis for 38 States –

– flow routing model and/or regression analysis were applied at 268 stations

– flow routing model used at 98 stations

– regression methods used at 233 stations

– joint application of both methods at 63 stations

ALTERNATIVE METHODS ANALYSIS

Summary of the accuracy of simulated daily flows for both the hydrologic flow routing model and multiple regression analysis at the 268 stations.

Percent of time daily flows are within 10 percent	Number of stations
75	39
85	21
95	3

The flow routing model and regression analysis generally gave comparable results.

USE OF A HYDROLOGIC FLOW ROUTING MODEL

The U.S. Geological Survey office in Tacoma, Washington is using a hydrologic flow routing model (CONROUT) to estimate daily flow data at two former gaging stations.

- at one station, daily flows are provided to the cooperator on a bimonthly basis (including six discharge measurements used to check model results)

- at the other station, daily flows are provided to the cooperator on an annual basis

RESULTS OF UNCERTAINTY ANALYSIS

1. The present accuracy of streamflow records could be achieved with about a 5 percent reduction in budget if field activities were altered.

2. Conversely, an improvement in accuracy of about 10 percent could be achieved with the present budget if field activities were altered.

3. In general it is difficult to implement the "optimal" operating strategy so modifications are made.

4. Results indicate that two-thirds of the time the error in estimating the instantaneous discharge is about plus or minus 8 percent.

5. About 5 percent of the stage record is lost each year due to equipment malfunctions.

6. The Kalman-filtering techniques provides a means to compute the accuracy of streamflow records at a single station and to compare the accuracy at several stations.

BRIEF DESCRIPTION OF TECHNIQUE

MODEL FORM FREQUENTLY USED IN HYDROLOGIC REGRESSION

$$Q = b_o X_1^{b_1} X_2^{b_2} \ldots X_k^{b_k}$$

WHERE b_i = REGRESSION PARAMETERS

X_i = PHYSIOGRAPHIC AND CLIMATIC PARAMETERS

Q = A STREAMFLOW CHARACTERISTIC

MODEL FORM BECOMES LINEAR BY TAKING NATURAL LOGARITHMS OF ABOVE EQUATION

$$\ln Q = \ln b_o + \sum_{i=1}^{k} b_j \ln X_j$$

GENERALIZED LEAST SQUARES REGRESSION

Estimation of regression coefficients by taking into consideration the

-- variance (time-sampling error) of streamflow characteristics

-- correlation of streamflow characteristics between nearby stations

The total prediction error (variance) is partitioned into model and sampling error (including both time- and spatial-sampling errors).

This partitioning of errors makes it possible to identify errors due to inadequacies of model formulation versus deficiencies in the data base. Therefore, USGS personnel are encouraged to analyze the network as part of any regional flood study.

AVERAGE SAMPLING ERROR

$$\text{AVERAGE SAMPLING ERROR} \cong \frac{(k+1)\,\gamma^2}{N} + \frac{\bar{r}\,\bar{s}^2}{n_1}\left(1 + \frac{\bar{r}\;Z_p^2}{2}\right)$$

WHERE n_1 = LENGTH OF LONG CONCURRENT RECORDS

k = NUMBER OF INDEPENDENT VARIABLES

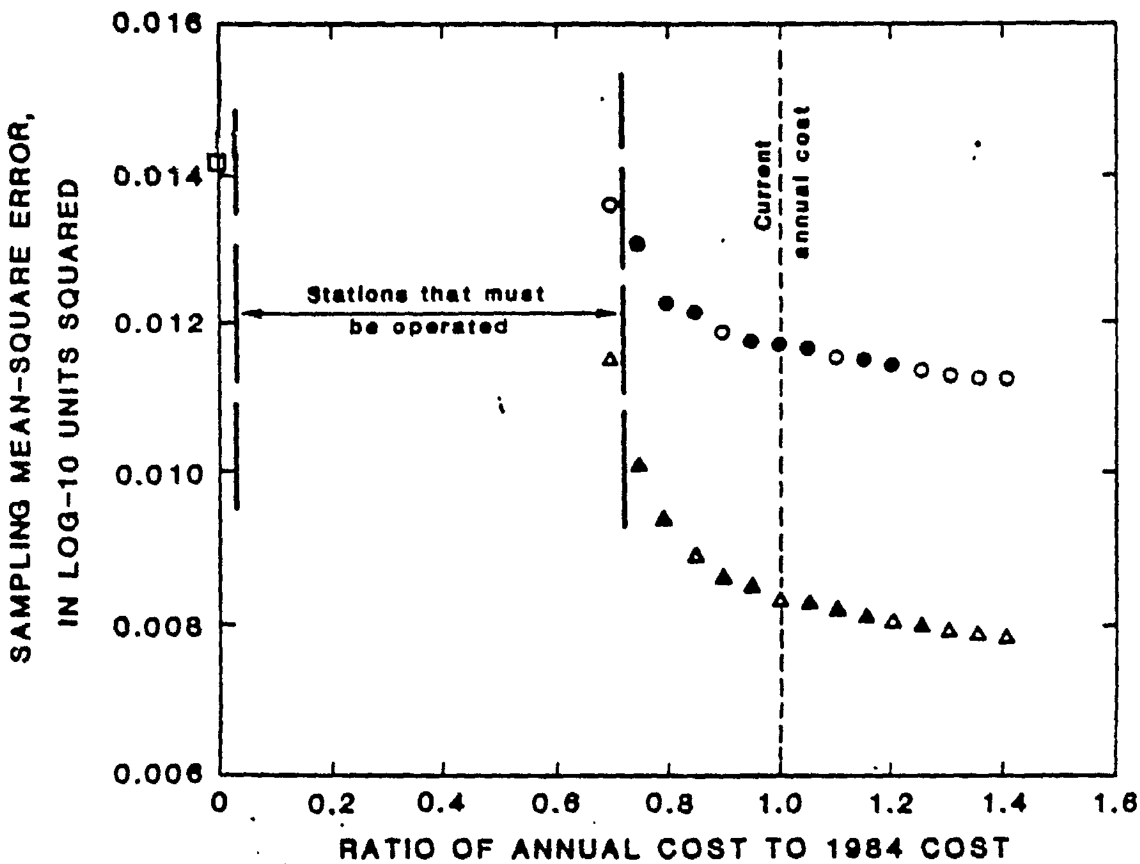
N = NUMBER OF STATIONS

$\bar{r}$ = AVERAGE CROSS CORRELATION COEFFICIENT

$\bar{s}^2$ = AVERAGE VARIANCE OF ANNUAL DATA

Zp = STANDARD NORMAL DEVIATE FOR EXCEEDANCE PROBABILITY p

γ^2 = MODEL ERROR



EXPLANATION

ZERO-YEAR PLANNING HORIZON

□ No current stations continued, no new stations

5-YEAR PLANNING HORIZON

○ Current station

● New station

20-YEAR PLANNING HORIZON

△ Current station

▲ New station

SURFACE WATER QUANTITY STATIONS
Continuous-record stations
Partial-record stations

Water Management Stations - generally continuous record	Regional Hydrology Stations - continuous or partial record
Locations - contact with cooperators	Locations - GLS technique
Types of data - data use surveys	Types of data - Streamflow characteristic of interest
Duration - contact with cooperators	Duration - GLS technique or reduction in time-sampling error
Frequency - Uncertainty analysis	Frequency - Uncertainty analysis or type of data being collected

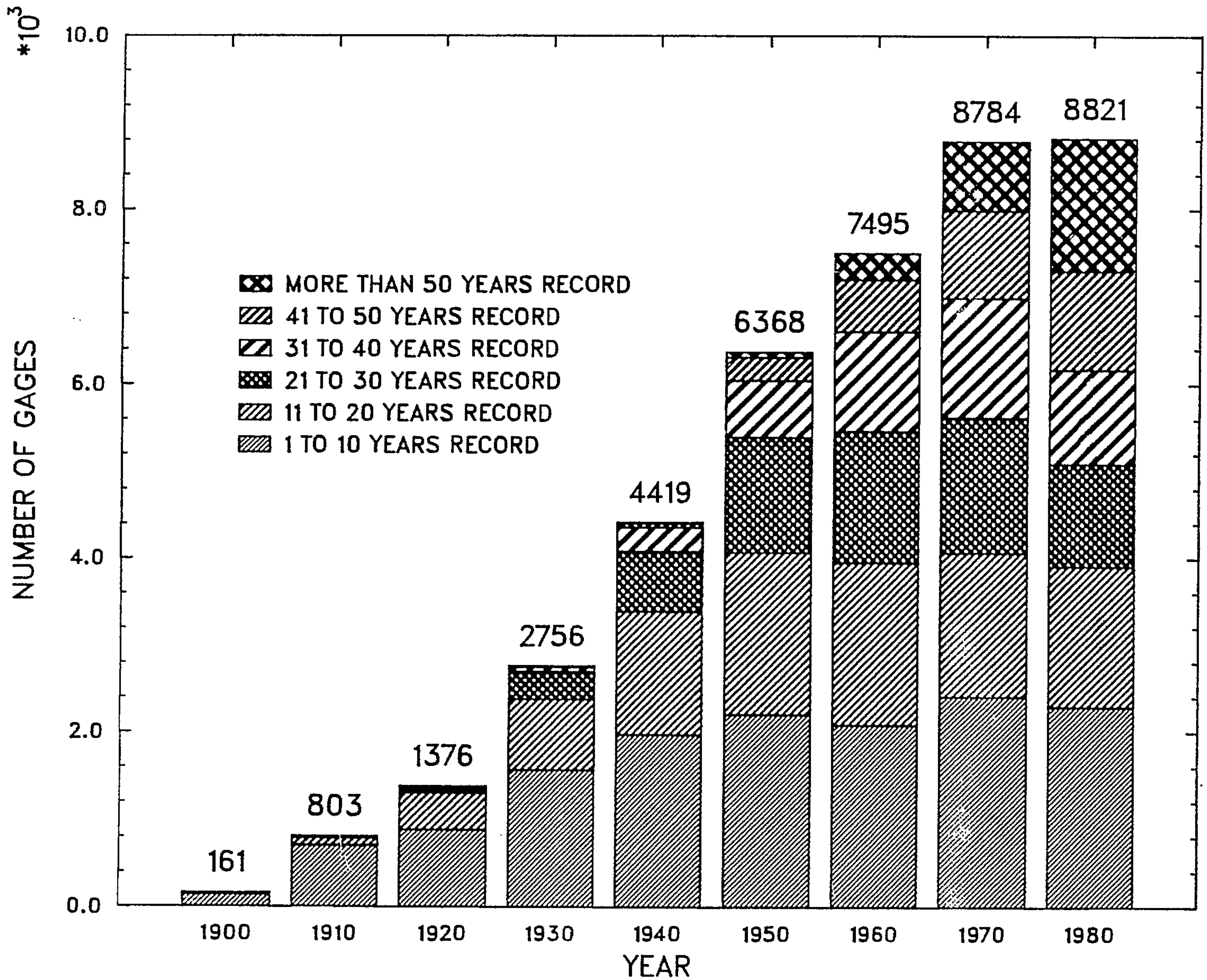
ACTIVITIES OF ASCE

Over the last few years the ASCE has been very supportive of the USGS stream-gaging program by -

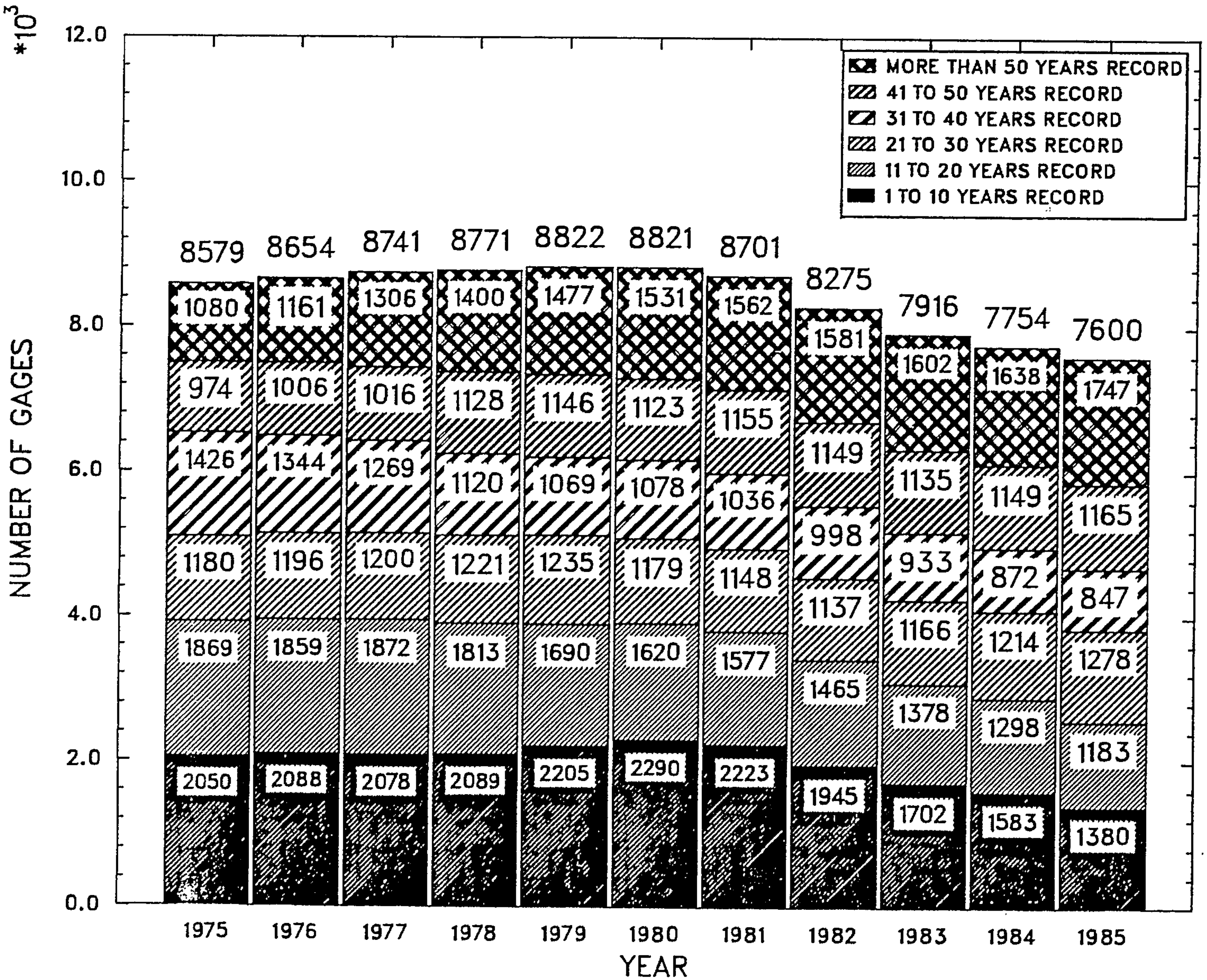
- assembling a list of case studies using USGS hydrologic data (to date 126 cases in 31 States have been submitted to ASCE)

- writing articles in Civil Engineering Magazine stressing the need to collect hydrologic data

- writing letters to Chairman of House of Representatives and Senate Appropriations Subcommittees identifying the need for hydrologic data

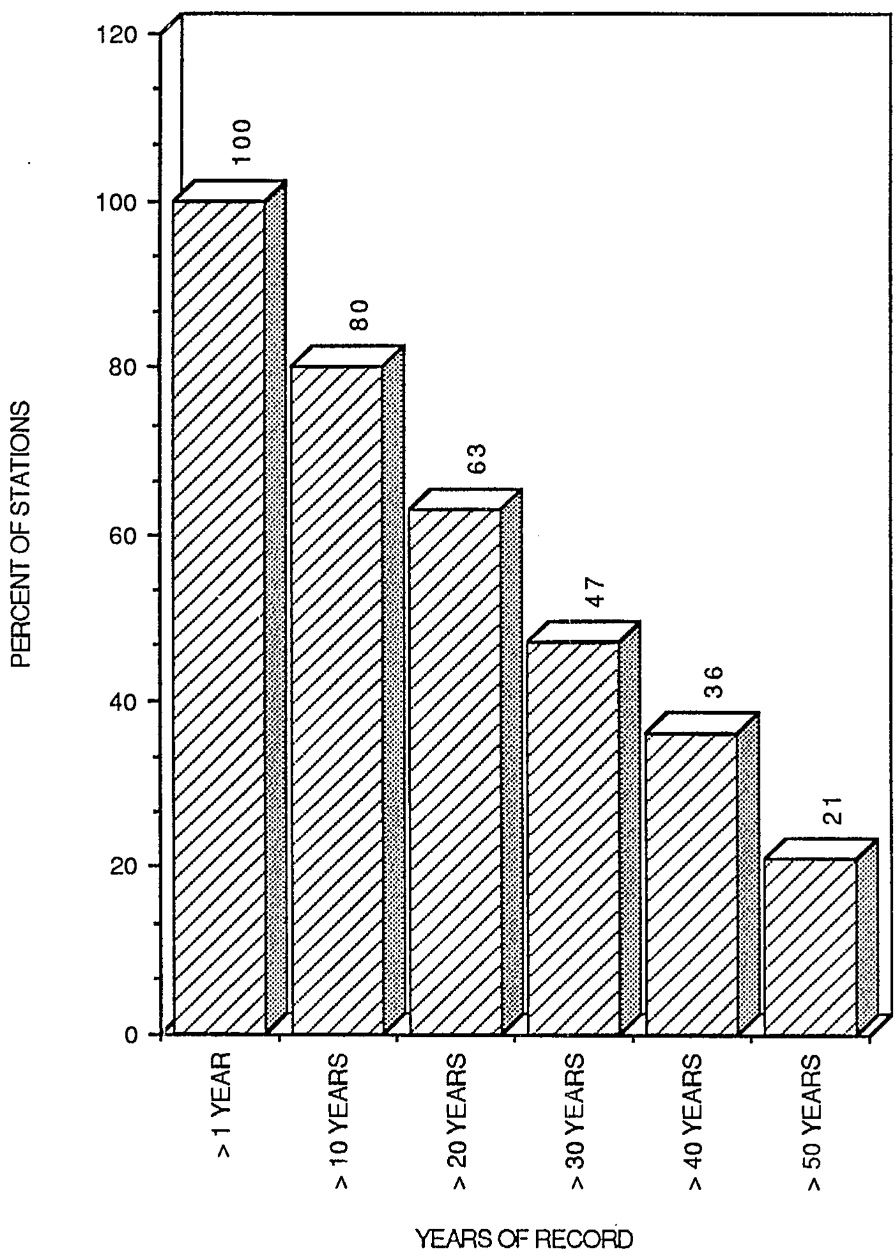


Number of daily–record gages in operation during year shown



Number of daily–record gages in operation during year shown

**PERCENT OF OPERATING STATIONS (1984)
VERSUS YEARS OF RECORD**



ACTIVITIES OF FEDERAL INTERAGENCY WORKING GROUP ON NETWORK ANALYSIS

The working group was established to encourage interagency coordination in the planning, installation, use and management of hydrometeorological data networks.

Major activities to date -

- Providing input to a Issue Paper on better ways to operate and finance the national stream-gaging program

- Developing a mechanism for identifying the present stream-gaging program and the data needs of all Federal agencies

- Discussing applicable network analysis techniques

WMO COMPARISON OF NETWORK ANALYSIS TECHNIQUES

Objective - To develop procedures for comparing network analysis techniques.

As a first step, two USGS techniques will be compared to establish the procedures - NARI and NAUGLS.

Each of the above techniques gives an estimate of the true predictive accuracy of the regression equations for a given budget and planning horizon.

This estimate of the true predictive accuracy is compared to the "actual" predictive accuracy based on 146 long-term (>30 years) stations in the Mid-western USA.

The streamflow characteristic of interest is the annual mean flow.

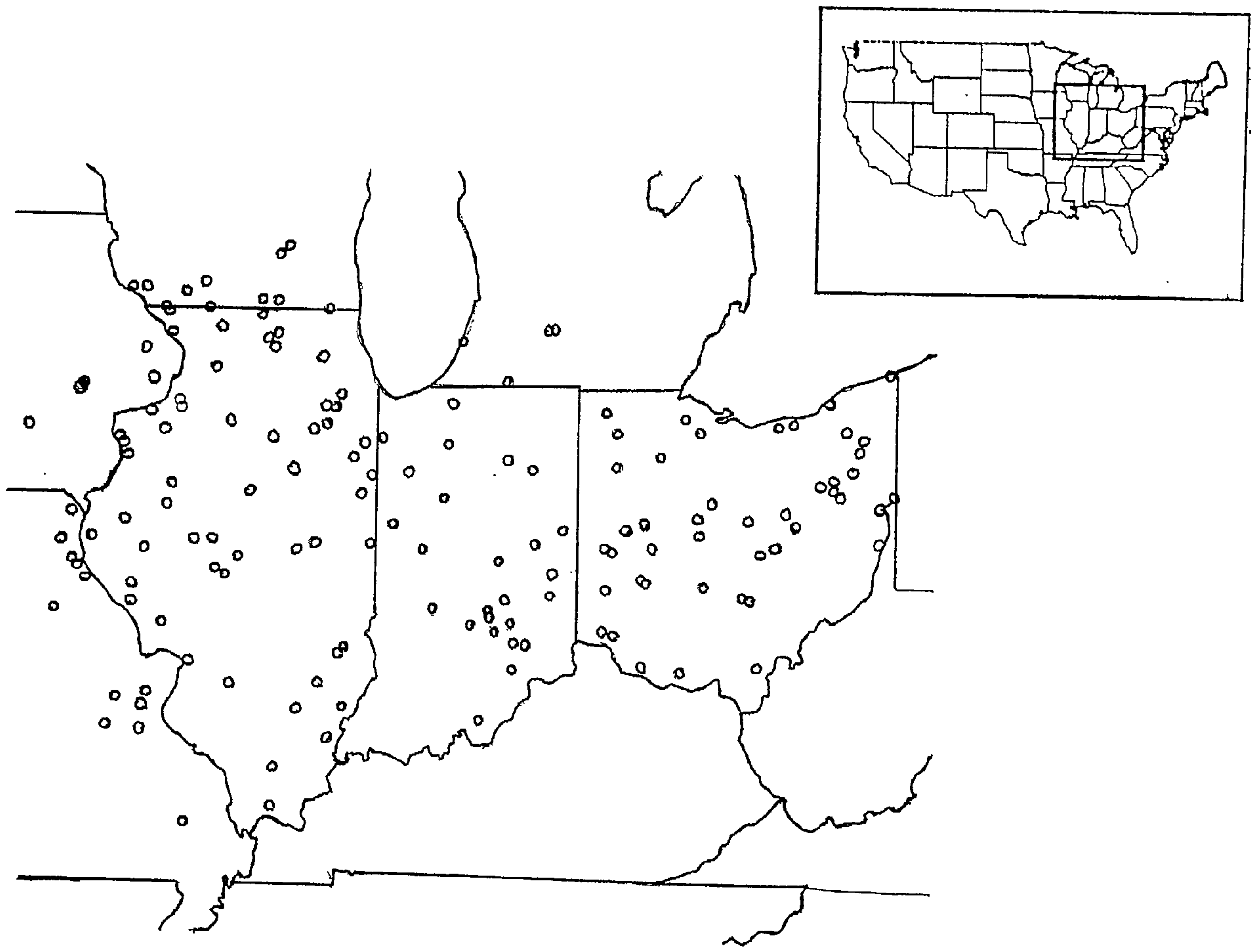


Figure 1: Location of long-term stations used in the analysis (HYNET PROJECT).

Results for experiments 1–4. Planning horizon is 5 years, operating budget is ten stations, existing number of stations are 10 (Exp 1), 20 (Exp2), 30 (Exp 3), or 40 (Exp 4).

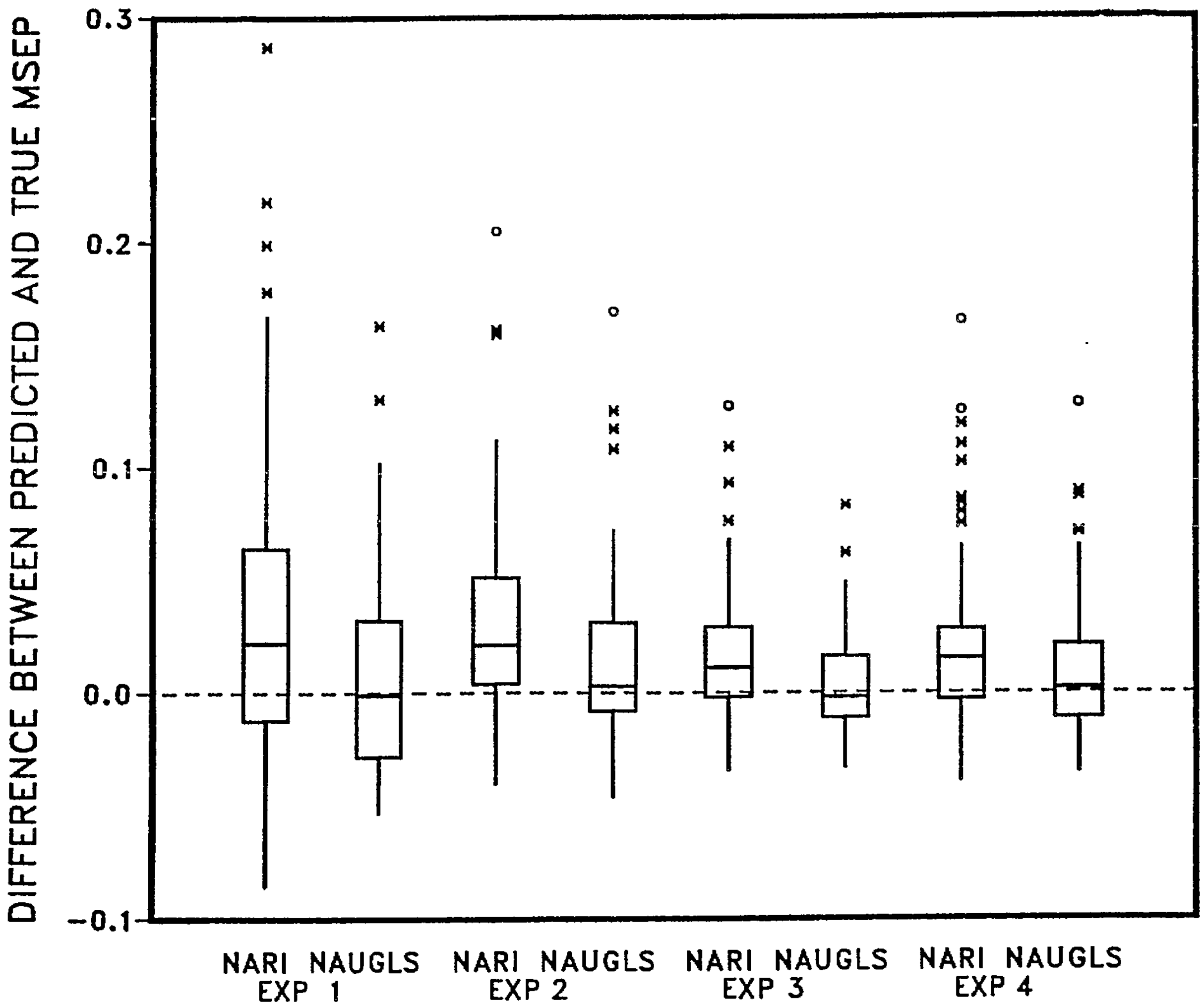


Figure 2

Results for experiments 5–8. Planning horizon is 14 years, operating budget is ten stations, existing number of stations are 10 (Exp 5), 20 (Exp 6), 30 (Exp 7), or 40 (Exp 8).

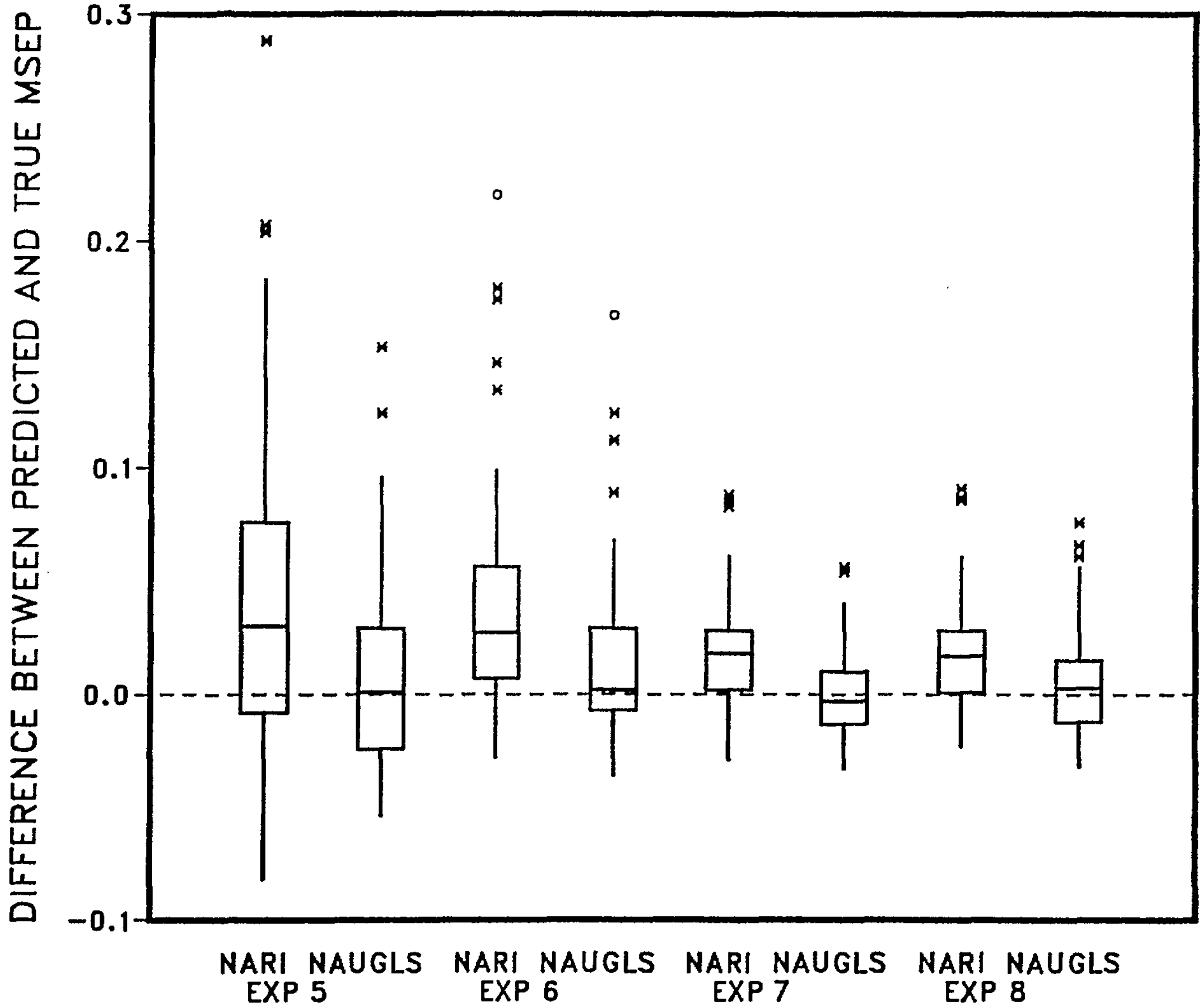


Figure 3.

RESULTS FOR EXPERIMENTS 9–10. PLANNING HORIZON IS TEN YEARS, OPERATING BUDGET IS 25 STATIONS, EXISTING NUMBER OF STATIONS ARE, 15 (EXP 9) OR 25 (EXP 10)

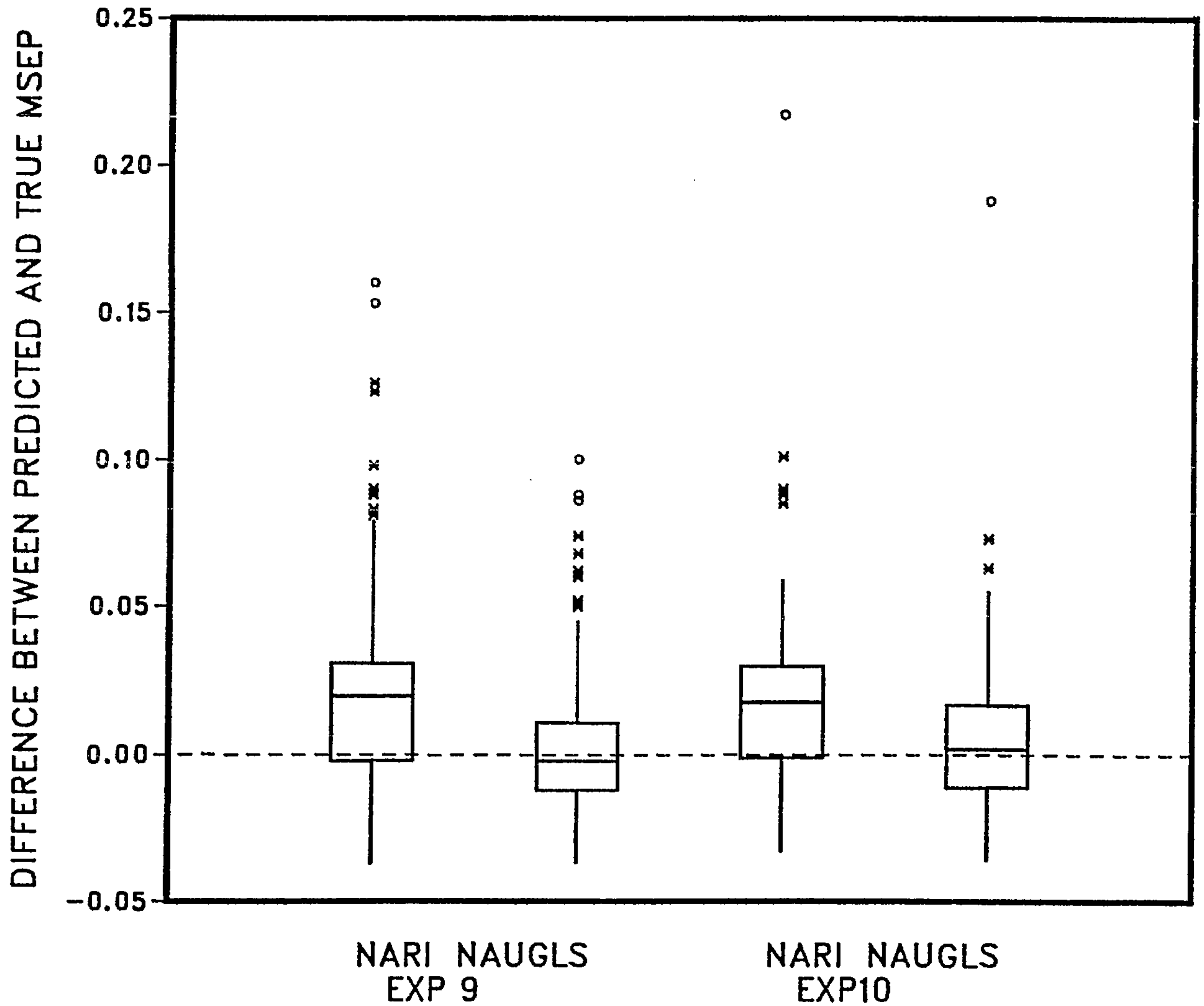


Figure 4

EDITOR'S NOTE:

The following letter and attached statement represent some of the efforts being made by professional associations in the United States in an attempt to influence their streamgauging network. These two items were contributed by the USGS.

AMERICAN SOCIETY OF CIVIL ENGINEERS

Washington Office
1667 K Street, N.W., Suite 750
Washington, D.C. 20006
(202) 785-4454

March 31, 1988

The Hon. Robert Byrd
Chairman
Appropriations Subcommittee on
the Interior and Related Agencies
SD-122 Dirksen Senate Office Bldg.
Washington, D.C. 20510

Dear Chairman Byrd:

Attached is the statement of the American Society of Civil Engineers (ASCE), American Association of Engineering Societies (AAES), National Society of Professional Engineers (NSPE), and American Water Works Association (AWWA), concerning the Administration's Fiscal 1989 budget request for the U.S. Geological Survey's surface water data collection programs.

ASCE, AAES, NSPE, and AWWA, representing over one-half million engineers, urge the committee to reject proposed cuts in the USGS Federal Program and Federal-State Cooperative Program for basic water data collection. We respectfully request that fiscal 1988 funding of $22.57 million in the Federal Program, and $59.64 million in the Cooperative Program be maintained for fiscal 1989.

USGS water data collection activities are vital to the proper management of the nation's precious water resources. Efficient and sound water project design and operation depends on a reliable data base. Your attention to the concerns expressed in the attached statement is greatly appreciated.

Sincerely,

Casey Dinges

Casey Dinges
Legislative Affairs
Manager

Enclosure

STATEMENT OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS

ON BEHALF OF THE

AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES
NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS
AMERICAN WATER WORKS ASSOCIATION

ON THE

U.S. GEOLOGICAL SURVEY

FISCAL YEAR 1989 BUDGET REQUEST

SUBMITTED TO THE

SUBCOMMITTEE ON INTERIOR AND RELATED AGENCIES

COMMITTEE ON APPROPRIATIONS

UNITED STATE SENATE

MARCH 31, 1988

The American Society of Civil Engineers (ASCE), on behalf of the American Association of Engineering Societies (AAES), National Society of Professional Engineers (NSPE), and American Water Works Association (AWWA), representing over one-half million engineers, strongly opposes the Administration's proposed FY89 budget cuts for the U.S. Geological Survey's surface water data collection and analysis activities. We believe these cuts would limit unwisely the nation's future ability to manage its precious water resources, and could, in the long run, cost the nation more through over-built or inadequate water facilities. This is a classic case of penny-wisdom and pound-foolishness. At a minimum, for fiscal 1989 Congress should maintain fiscal 1988 funding levels of $22.57 million in the Federal Program for data collection and analysis and $59.64 million in the Federal-State Cooperative Program.

The cost of collecting water data is not great, but the impact of such data is immense and far-reaching. These data are critical to a wide range of activities, including reservoir operation; water quality and supply studies; water law court decisions; wastewater treatment discharges into streams; drainage structures for highways, bridges and culverts; flood insurance and management studies; detention pond studies for urban runoff control; planning and design of hydroelectric projects; water basin planning and investigation; forensic analysis; environmental impact analysis; and ice forecasting, jam and control studies. How can engineers devise optimum responses, and design the most cost-effective facilities, if they have incomplete and inadequate hydrologic data? The Federal cost of basic water data collection and analysis, $73.2 million in fiscal 1988, or about one-half the water resources investigations budget, pales when compared to the cost of facilities which will be based on inadequate data as well as to the potential loss of property and life that can occur if errors in design result from use of a faulty data base.

Surface water data collection activities are carried out in the Federal Program and the Federal-State Cooperative Program of the U.S. Geological Survey's Water Resources Investigations Division (WRD). The Administration's $19 million FY89 request for the Federal Program is $3.5 million or 16% below the FY88 appropriation of $22.5 million. The Cooperative Program is budgeted at $55.9 million, $3.7 million or 6% below the FY88 appropriation of $59.6 million. Because the Cooperative Program is funded on a 50/50 matching basis with the states, the $3.7 million Federal cut will be matched by the states for a total cut of $7.4 million.

Analysis of the proposed overall U.S.G.S. budget cut of $22.7 million (5%) in fiscal 1989 reveals that $16.4 million or 72% of this cut will come from the Water Resources Investigations function which only comprises 33% of the overall U.S.G.S. budget. In other words, WRD would be burdened by a vastly disproportionate share of the U.S.G.S budget cut, thereby jeopardizing water data collection.

It is difficult to predict exactly which gauging stations will be eliminated under this budget proposal. There is no doubt, however, that hundreds of data collection stations will be threatened. The $3.5 million cut in the Federal Program could result in the loss of 80 continuous recording stations. This would mean that 20% of the continuous recording stations supported by the Federal Program would be eliminated. These are recording stations that are designed to be permanent in order to provide an absolutely reliable data record.

The $3.7 million cut in the Cooperative Program could lead to the termination of 450 to 500 continuous recording posts, or 10% of all continuous recording stations supported by the Cooperative Program. These closures would also destroy the complete reliability of the data that needs to be obtained.

Cuts of this magnitude, particularly when considered with previous funding cutbacks, raise very serious implications. Between fiscal years 1981-1987 the total number of surface water data collection stations was reduced from 17,000 to 10,624, a 37% cut.

The U.S. Geological Survey has used cost sharing arrangements with non-federal agencies to stretch further the federal funds appropriated for water resource data collection. Whereas we believe complete federal funding is the best way to ensure continuity of data collection over multi-decade time periods, cost sharing is a feasible and attractive alternative to reduced data collection. It should be noted, however, that in recent years, the states have been willing to spend considerably more than the Federal Government in the Cooperative Program for data collection and analysis (for example, $12.8 million more in fiscal 1988).

We believe that the U.S.G.S. basic water quantity data collection activities are:

1) essential, because the value of hydrologic data increases with both the length and continuity of the record;

2) the logical responsibility of the Federal Government because the states cannot possibly assume the support and leadership role of U.S.G.S. for interstate water systems;

3) cost-effective, because coordinated water data collection eliminates overlapping and duplicative efforts.

Data analyses as well as research and development of new predictive techniques can be accomplished by innumerable public or private water-resource agencies, as the need arise, if the long-term basic data exists. If the data is lacking, no one, including the U.S.G.S., can manufacture it. Accordingly, this activity must be one of U.S.G.S.'s highest priorities.

ASCE, AAES, NSPE, and AWWA urge the Congress, at the very least, to reject the proposed cuts for U.S.G.S. surface water data collection activities, and maintain fiscal 1988 funding levels of $22.57 million in the Federal Program for data collection and analysis and $59.64 million in the Federal-State Cooperative Program.

The Administration's proposed cuts in water data collection are particularly puzzling in light of recent enactment of major water resource legislation, including The Water Quality Act of 1987 (P.L.100-4), The Omnibus Water Resources Development Act of 1986 (P.L.99-662), and The Safe Drinking Water Act Amendments of 1986 (P.L.99-339). The efficient annual expenditure of billions of dollars in these programs will be seriously undermined by cuts in basic water data collection.

AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers (ASCE), founded in 1852, is the oldest national engineering society in the United States. Membership, held by 100,000 individual professional engineers, is about equally divided among engineers in private practice; engineers working for federal, state or local governments; and those employed in research and academia. The Society's major goals are to develop engineers who will improve technology and apply it to further the objectives of society as a whole, to promote the dedication and technical capability of its members and to advance the profession of civil engineering.

AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES

The American Association of Engineering Societies (AAES) is a multi-disciplinary organization dedicated to advancing the knowledge, understanding, and the practice of engineering in the public interest. Located in Washington, DC, AAES includes 13 member societies, 6 associate societies, and 3 regional societies representing over 500,000 engineers in industry, government and education.

NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS

The National Society of Professional Engineers (NSPE), is a professional society, representing more than 75,000 engineers of all disciplines nationwide. The members are organized into 54 state and territorial societies and 535 local chapters, and work in industry, education, private practice, construction, and government.

AMERICAN WATER WORKS ASSOCIATION

The American Water Works Association (AWWA) is a 107 year old scientific and engineering association, which is the largest association of drinking water professionals in the world. AWWA has over 44,000 members which includes utility operators, engineers, scientists, professors, health regulators, environmentalists, and many other people that have a genuine interest in drinking water. AWWA's membership also includes 3,000 utilities which supply 70% of the nation's drinking water.

March, 1988
CE Magazine

WATER DATA FUNDING SURVIVES

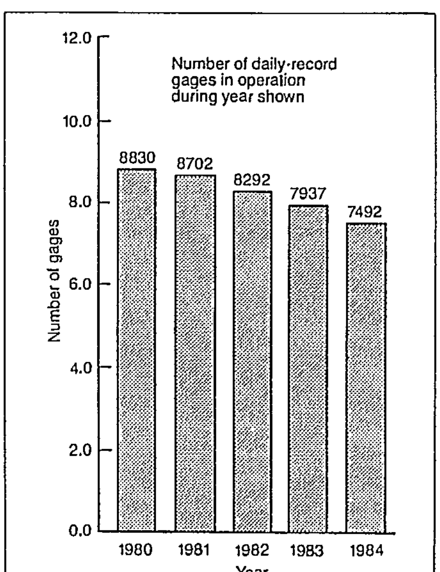
Thanks in large measure to the efforts of ASCE, particularly the key contacts, fiscal 1988 funding for the U.S. Geological Survey's (USGS) surface water data collection program was spared the budget axe. The final outcome of the issue was not clear until enactment of a massive, $603 billion appropriations bill in December 1987, known as the "Continuing Resolution" (Public Law 100-202). The October stock market crash prodded Congress and the White House into negotiating a deficit reduction package large enough to supercede the automatic, across-the-board program cuts under the revised Gramm-Rudman-Hollings (GRH) law (P.L. 100-119). USGS water data collection would have suffered losses under GRH sequestration. The budget summit achieved greater deficit reduction than GRH, while not cutting water data collection.

The administration's original fiscal 1988 budget request for USGS surface water data collection - $20.9 million for the federal program and $48.9 million for the federal-state cooperative program - would have resulted in unavoidable network reductions. After years of cuts in basic water data collection, ASCE is pressing Congress to avoid further cuts (see graph). ASCE told Congress last May that increases of $1 million in the federal program and $2.3 million in the cooperative program were necessary to maintain current services. Due to 50/50 percent matching requirements, a $2.3 million shortfall in the cooperative program would be matched by the states for a total cut of $4.6 million. The states were actually prepared to increase their support for the cooperative program by $12.8 million above fiscal 1987 levels had there been federal matching dollars.

ASCE's May 5, 1987 statement to the Appropriations Committees, which was endorsed by the American Association of Engineering Societies and the National Society of Professional Engineers, argued that USGS water data collection activities are essential, cost-effective and the logical responsibility of the federal government. Then-President Barge pointed out that "the value of hydrologic data increases with both the length and continuity of the record." Barge called the proposed cuts "a classic case of penny-wisdom and pound foolishness," which "would limit unwisely the nation's future ability to manage its precious water resources." In addition, scores of ASCE key contacts from around the country wrote letters to Congress describing the various uses of surface water data, such as: reservoir operation; water quality and supply studies; water law court decisions; wastewater treatment discharges into streams; drainage structures for highways; bridges and culverts; flood insurance and management studies; detention pond studies for urban runoff control; planning and design of hydroelectric projects; water basin planning and investigation; forensic analysis; environmental impact analysis; and ice forecasting, jam and control studies.

A number of ASCE members have also provided the Washington Office with case studies which underscore the importance of USGS water data collection and often appeal to the parochial interests of legislators on Capitol Hill. The Appropriations Committees agreed with ASCE and restored adequate funding in P.L. 100-202.

Funding for USGS water data collection comes from several sources: direct appropriations to the USGS federal and cooperative programs; the states' matching contribution under the cooperative program; and other federal agencies needing basic water data, such as the National Weather Service and the Soil Conservation Service. A GRH sequestration of funds would cause great harm to surface water data collection. USGS and other supporting agencies would face direct cuts, and the states would match the USGS cuts in the cooperative program. A GRH sequester led to the loss of 361 data collection sites in fiscal 1986.



USGS has not yet released statistics for years subsequent to 1984.

The Office of Management and Budget (OMB) touched off a controversy last year when it announced that $5 million in state contributions to the cooperative program would be held and counted as deficit reduction, in the event of a GRH sequester. P.L. 100-202 made GRH void for fiscal 1988. However OMB never clarified its position regarding the sequestration of state funds. OMB's policy "infuriated the states," said one federal official.

An Interagency Advisory Committee on Water Data, which includes, among others, the Departments of Interior, Agriculture, Commerce, Defense, Energy, Transportation and such independent agencies as EPA, has been studying the national stream-gauging network for several years. In December, 1987 the Committee met to discuss ways to better manage and coordinate data collection, and how to pay for it. Since funds to support USGS data collection come from a variety of agencies, a single funding source mechanism for surface water data collection may be proposed.

ASCE is represented on the Advisory Committee on Water Data for Public Use which meets semiannually with the Interagency Advisory group.

USGS is entering the final year of a five year study to define and document the most cost effective means of furnishing stream flow information.

As Congress begins to grapple with the administration's $1.1 trillion fiscal 1989 budget, ASCE will work to educate more Congressmen and other organizations about the importance of USGS water data collection.—Casey Dinges, Legislative Affairs Manager, ASCE, Washington, D.C.

SURFACE WATER DATA COLLECTION

Approved by the National Water Policy Committee on July 30, 1987.
Approved by the Committee on Policy Review on August 21, 1987.
Adopted by the Board of Direction on October 24, 1987.

Policy

The American Society of Civil Engineers supports the basic surface water data collection programs of the Federal, state and local governments. ASCE urges the Congress to provide adequate funding to the U.S. Geological Survey (U.S.G.S.) for these programs, and to fully match the level of funding committed by the states under the Federal-State Cooperative Program for data collection.

Issue

The U.S.G.S. provides the foundation of the basic data collection program for surface water in the United States. In recent years, statutory directives and budget cuts have forced the USGS to implement significant reductions in the Nation's water data gathering network. Between fiscal years 1981-86, the total number of streamflow gauging stations declined from 17,000 to 10,740, a 37% reduction. The number of continuous record gauging stations operated by the U.S.G.S., which are of critical importance, fell from 8,830 in Fiscal Year 1980 to 7,079 in Fiscal Year 1986, a 20% reduction.

Rationale

The U.S.G.S. basic water data collection program is of vital importance to water resource planning, design, and operation in the United States. Civil engineers rely on these data for numerous projects, including: flood control, pollution control including acid precipitation, bridges, dams, and navigation. Reductions in surface water data collection will have long-term adverse effects on the efficiency and certainty of planning, design and operation of projects. Of particular concern is the need to maintain the length and continuity of the hydrologic data record, because interruptions in data collection can cause extreme hydrological events to go unrecorded.

Due to the interstate nature of many river basins, basic water data collection is an appropriate responsibility of the Federal government. Moreover, one lead agency must be assigned the task of collecting and reporting these data in a uniform manner. This responsibility has traditionally been assigned to and should remain with U.S.G.S. in cooperation with other Federal agencies and state and local governments.

ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

KEY ALERT

1667 K Street, N.W., Suite 750 Washington, D.C. 20006 (202) 785-4454

April 11, 1988

VITAL WATER DATA IMPERILED AGAIN

The Administration's fiscal 1989 budget request for the U.S. Geological Survey would lead to severe cutbacks in the agency's essential surface water data collection programs. The Federal Program for surface water data collection and analysis would be cut $3.5 million (16%) from $22.5 to $19 million. The Federal-State Cooperative Program for data collection would be cut by $3.7 million (6%) from $59.6 to $55.9 million. The states will match this $3.7 million cut for a total cut of $7.4 million in the Cooperative Program.

- The $3.5 million cut in the Federal Program could eliminate 80 continuous streamflow recording stations, or 20% of the continuous recording stations supported by the Federal Program.
- The $3.7 million cut in the Cooperative Program could lead to termination of 450 to 500 continuous streamflow recording posts, or 10% of all such stations supported by the Cooperative Program.
- The number of daily-record gages in operation has already declined 13% since 1980.
- Surface water quantity data is utilized by numerous federal agencies, such as the Environmental Protection Agency and the National Weather Service, in carrying out their respective missions. In addition, many state and local government agencies, as well as private companies depend on the water data gathered by the U.S. Geological Survey.

YOU ARE URGED TO WRITE LETTERS IN OPPOSITION TO THESE CUTS TO THE COMMITTEE CHAIRMEN WITH JURISDICTION OVER THIS ISSUE.

Address your letters the following way:

The Honorable Robert Byrd
Chairman
Appropriations Subcomm. on the
Interior and Related Agencies
SD-122 Dirksen Building
Washington, DC 20510

Dear Chairman Byrd:

The Honorable Sidney Yates
Chairman
Appropriations Subcomm. on the
Interior and Related Agencies
B-308 Rayburn Building
Washington, DC 20515

Dear Chairman Yates:

You may want to include the following points in your letter:

- The cost of water data collection is not great. Moreover, such data are critical to a wide range of activities including reservoir operation; water quality and supply studies; wastewater treatment discharges; environmental impact analysis; water law court decisions; planning and design of water projects; and drainage structures for highways and bridges.

- Basic water data collection is the logical responsibility of the federal government, because states cannot possibly assume the support and leadership role of U.S.G.S. for interstate water systems. In addition, the value of hydrologic data increases with both the length and continuity of the record.

- The efficient expenditure of billions of dollars in the recently enacted Water Resources Development Act of 1986 (P.L.99-662) and the Water Quality Act of 1987 (P.L.100-4) depend on reliable water data.

If you can, cite specific examples of how important USGS water data is to your work. Please send a copy of your letter to Senator Byrd to both of your U.S. Senators, and a copy of your Yates letter to your Congressman. When writing to Congress, present yourself as an interested citizen and civil engineer, not as a member of ASCE. Your letter will be most effective that way.

The Honorable ________
U.S. House of Representatives
Washington, DC 20515

Dear Representative ________

The Honorable ________
United States Senate
Washington, DC 20510

Dear Senator ________

Thank you very much. Please send the ASCE Washington Office copies of the letters you send and any replies you receive (see letterhead for address). After you have written your letters, give this Key Alert to another civil engineer and urge him or her to write as well.

7. PANEL DISCUSSIONS - VALUE OF SURFACE WATER DATA AND INFORMATION

EDITOR'S NOTE:

The following 13 pages are excerpted from the report entitled "Economic Evaluation of the Hydrometric Data" by Acres Consulting Services Limited, Niagara Falls, Ontario, 1977. Pages 23 to 35 of the above mentioned report are included herein as a starting point of discussion regarding the "Value of Surface Water Data and Information".

Contributions, in order of presentation, are by:

1) Mr. R. Coley
Chief Engineer
Ducks Unlimited Canada
Winnipeg, Manitoba

2) Mr. T. Dafoe
Chief, Monitoring and Surveys Division
Water Quality Branch
Inland Waters Directorate
Ottawa, Ontario

3) Mr. D. Fairbairn
Head, Planning Division
Water Planning and Management
Inland Waters Directorate
Regina, Saskatchewan

4) Mr. M.S. Choudhary
Bridge Planning Engineer
Bridge Planning Branch
Alberta Transportation & Utilities
Edmonton, Alberta

3 - ECONOMIC BENEFITS OF THE NETWORK

Economic benefits are generated by the use of hydrometric data for the design and operation of various categories of hydraulic projects. For this study fourteen major project categories were considered,with design and/or operating benefits being associated with each as shown in Table 3.1. Design benefits are taken as reflecting the reduction in overall cost of design and construction of facilities made possible by the availability of hydrometric data. Operating benefits, on the other hand, represent the economic returns provided as a result of the more efficient utilization of existing programs attributable to the use of hydrometric data.

For several project categories it was possible, using information gathered from user interviews, to quantify benefits for particular project types on an annual basis. The estimates of these values and the methodology employed to determine them are given in the following sections under the heading for each project type. Likewise, in the case of those project categories for which quantification was not possible, a brief summary of benefits accruing to each and their significance is discussed.

3.1 - Hydroelectric

The major use of hydrometric data for this project type is for project design and construction. Interview respondents indicated that hydropower day-to-day operations were guided largely by information internally produced by the operating organizations concerned. However, one agency did indicate considerable dependence on WSC data for operating purposes.

TABLE 3.1

MAJOR HYDROMETRIC DATA USES

Project Type	Design Benefits	Operating Benefits
Hydroelectric	*	*
Withdrawals	*	
Navigation		*
Flood forecasting		*
Flood mitigation	*	*
Bridge and culvert	*	
Storm-water drainage		
Low flow augmentation	*	*
Waste disposal	*	
Water quality assessment	*	
Water management and apportionment	*	*
Recreation		*
Investigation and research	*	
Other		

NOTE: This table is based on telephone survey results.

During planning of hydropower projects, benefits derived from employing hydrometric data in the design of water conveying and controlling structures are significant. Few respondents indicated a range of figures for these benefits, the most conservative being 5 percent of total construction expenditure. An estimate of 1977 construction expenditure for electrical power generating stations, including water conveying and controlling structures, is provided on line (4) in Table 3.2. Of this total expenditure, 65 percent was assumed to be made on structures sensitive to hydroelectric analysis (Acres, 1967, page D2). This value is given on line (5) of Table 3.2. The design benefit was taken as 5 percent of this later figure or $64.3 million per year. This value and the distribution by province are given on line (9) of Table 3.2.

3.2 - Withdrawals

This category covers applications of data to municipal and industrial water supply and irrigation. The user surveys indicated that municipalities did not utilize hydrometric data for design or operations and the provision of water supply was therefore excluded from the analysis of benefits. In the case of irrigation development, significant design benefits were indicated by one agency who suggested a figure of 10 percent of total construction expenditure. An estimate of expenditures for irrigation and land reclamation is given on line (2) in Table 3.2. Ten percent of this expenditure figure is given on line (12) of Table 3.2., and indicates a value of benefits of $9.5 million for 1977.

TABLE 3.2

COMPUTATION OF BENEFITS
(Annual Value $ x 10^3)

BASE VALUE	B.C.	Alberta	Sask.	Manitoba	Ontario	Quebec	N.B.	Nova Scotia	P.E.I.	Nfld.	Canada
Construction											
(1) Dams & reservoirs	9,444	7,541	8,357	2,784	15,771	6,288	975	1,668	215*	550*	57,613
(2) Irrigation & land reclamation	6,056	20,895	11,892	6,111	33,066	11,100	887	1,268	178*	450*	95,062
(3) Highway, road & street	407,457	334,353	134,328	115,939	839,888	702,695	135,583	84,951	14,365	102,633	2,933,551
(4) Electrical power generating plants including water controlling & conveying structures	240,708	112,670	40,855	167,692	312,052	938,120	92,727	105,513	1,265	68,697	1,979,823
Hydraulic Structures											
(5) 65 percent of (4)	156,460	73,235	26,555	108,999	202,833	609,778	60,272	68,583	822	44,653	1,286,884
Navigation											
(6) Seaway shipping costs											438,300
Flooding											
(7) Flood damages	3,836	2,909	1,439	1,584	12,862	9,661	1,054	1,285	185	863	35,78
Water Quality and Waste Disposal											
(8) Sewage systems and disposal plants	78,879	47,287	20,183	12,409	288,962	178,249	11,644	17,682	2,640	20,800	691,[illegible]
BENEFITS											
Hydraulic Structures Construction											
(9) 5 percent of (5)	7,823	3,661	1,327	5,449	10,141	30,488	3,013	3,429	41	2,232	64,344
Bridges & Culverts Construction											
(10) 1 percent of (3)	4,074	3,343	1,343	1,159	8,399	7,027	1,356	849	143	1,026	29,335
Flood Control Construction											
(11) 5 percent of (1)	472	377	418	139	788	314	48	83	11	27	2,880
Withdrawal Construction											
(12) 10 percent of (2)	805	2,089	1,189	611	3,307	1,110	89	127	18	45	9,506
Flood Damage Prevention											
(13) 10 percent of (7)	383	290	143	158	1,286	966	105	128	18	86	3,578
Navigation Benefits											
(14) 3 percent of (6)											
Water Quality and Waste Disposal											
(15) 1 percent of (8)	789	473	202	124	2,890	1,782	116	177	26	208	6,916
TOTAL	14,346	10,233	4,622	7,640	26,811	41,687	4,727	4,793	257	3,624	129,659

*The disaggregation of Statistics Canada values is based on the percentage distribution between Nova Scotia and New Brunswick. The total for the two categories was distributed 55 percent to category (1) and 45 percent to category (2)

NOTE: Values are projection of 1977 construction expenditures based on 1972 - 1976 levels of total construction work performed. It should be noted that the sum of the provincial estimates does not exactly equal the projected Canadian total due to the use of least-squares curve fitting techniques on each item individually.

3.3 - Navigation

It was indicated by the National Harbours Board that stream height and flow measurements were used to anticipate low levels in the Saint Lawrence Seaway and Montreal Harbour. The respondent indicated that, as a result, considerable savings accrue to those involved in shipping through this waterway. The benefits were modeled as a percentage of total expenditures on shipping of goods through the Port of Montreal. These expenditures were estimated by examining the tonnages of various commodities passing through the port and their origins and destinations. For the most significant group of commodities, average per ton shipping charges were received from various shipping companies. They were then used to estimate total charges for the 1976 shipping year. Unfortunately, reliable tonnage estimates were not available for 1977, and figures for 1976 were employed. These values are given on line (6) in Table 3.2 and in Table 3.3.

The telephone interview indicated that a saving of 3 to 5 percent on total charges was attributable to anticipation of low levels. The lower estimate of 3 percent was selected as most conservative and was used to derive an estimated benefit of $13.1 million dollars, shown on line (14) of Table 3.2.

3.4 - Flood Forecasting

The principal benefit attributable to this activity derives from the increased opportunity for floodproofing and, as a result, reduced flood damages. Since floodproofing is totally dependent on accurate forecasts, which are in turn only possible through the use of hydrometric analysis, the entire

TABLE 3.3

TONNAGES AND CHARGES
ON MAJOR COMMODITIES
LOADED AND UNLOADED
IN THE PORT OF MONTREAL

Commodity	Tonnages[1] (tons x 10^6)	Average Charges[2] ($/ton)	Shipping Costs ($ x 10^6)
Wheat	3.3	6.00	19.8
Fuel oil and gasoline	6.0	8.00	48.0
Containers, general and bulk cargo	5.7	65.00	370.0
Total			438.0
3 percent of total			13.1

Sources

1 - Statistics Canada, Shipping Report Part IV

2 - Upper Lakes Shipping, Atlantic Container Line, Manchester Line, Montreal Shipping and Shell Tanker Canada Limited

benefit of floodproofing was assumed to be the result of the hydrometric system operations.

It has been estimated that floodproofing can reduce flood damages over the range of 5 to 15 percent, depending on the severity of the flood (Acres, 1973, page 43). It was assumed that the median figure of 10 percent was most representative of a national average in damage reductions. Unfortunately, annual Canadian flood damage satistics are not available. As a proxy for these, the values of damages in the twelve border states of the United States were employed. From annual damage estimates, a per capita damage figure was calculated for the years 1970 to 1974. An average figure for this period was taken and adjusted for differences in personal income and currency value to establish a value for flood damage per person in Canada of $1.18 for 1974. This value was then inflated by the Canadian Price Index to establish a value of $1.53 per person in 1977 dollars. This figure was then multiplied by the national and provincial population statistics to yield an estimate value for flood damages of $35.9 million. This value is consistent with 1974 figures (one of the worst years on record) reported in Canada Water Year Book 1976 (Fisheries and Environment Canada, 1976). A summary of U.S. damage statistics is given in Table 3.4 and Canadian damage estimates and benefits are given on lines (7) and (13) of Table 3.2.

3.5 - Flood Mitigation

Under this heading we include those projects which cover the design and operation of flood control structures and systems. The operation of such systems does benefit significantly from the availability of data, but there appears to be no ready method by which these benefits can be quantified. The agencies contacted pointed out that effective operation would not be possible without the aid of hydrometric data, since the

TABLE 3.4

FLOOD DAMAGE AND POPULATION STATISTICS

	1970	1971	1972	1973	1974
For the Border States					
Flood damages ($ x 10^3)	25,977	59,469	99,813[2]	116,863	91,623
Population (x 10^3)	61,200	61,542	61,667	61,641	61,670
For Canada					
Flood damage per person	.42	.92	1.61	1.66	1.18

1 - Washington, Idaho, Montana, North Dakota, Minnesota, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire and Maine.

2 - Excludes New York and Pennsylvania which suffered unusually severe damages in 1972.

Sources

Climatological Data: National Summary, National Climatic Center, Asheville, North Carolina, 1975.

Statistical Abstract of the United States, U.S. Dept. of Commerce, Washington, D.C., 1975.

maintenance of appropriate reservoir levels and rates of spill over controlling structures, especially during periods of abnormal flows, depend on the availability of this information. In general, those surveyed indicated that no alternative source of information appropriate to their needs was available, and that the continued operation of the hydrometric system was therefore essential to their operations.

In the case of design and construction of facilities for flood control, a rough estimate of the value of benefits was possible. Expenditures on dams and canals, exclusive of hydroelectric, irrigation and marine-related work, were taken as representative of expenditures in this field. Estimates of these values for 1977 are provided in Table 3.2. A design and construction saving similar to that for hydroelectric structures of 5 percent was used to estimate an annual benefit of $2.8 million for 1977. The national and provincial distribution is given on line (11) in Table 3.2.

3.6 - Bridge and Culvert Design

For this category, design benefits predominate. The value of these benefits is a function of construction expenditures on roads and highways. Information supplied by an interview respondent suggested that approximately 10 percent of road expenditures was on bridges and culverts and, of this, a 10 percent saving of the costs of bridges and culverts arises from use of hydrometric data. The resulting benefit, 1 percent on the total construction expenditure on highways, roads and streets (Table 3.2, line (3)), is given on line (10) and is approximately $29.3 million per year.

3.7 - Water Quality Assessment and Monitoring of Waste Disposal

Respondents who were involved in these two areas indicated that the availability of hydrometric data was of some benefit. Only one respondent quantified the benefit suggesting it equal to 1 percent of the cost of sewerage system and disposal plants. Cost estimates are given on line (8) in Table 3.2 and the benefits are estimated on line (15). For Canada the total benefit is $6.9 million per year.

3.8 - Low-Flow Augmentation

The analysis of flows for both design and operation is, of course, completely dependent on the availability of hydrometric data. However, it is difficult to identify what the value of operating benefits is and therefore it was not possible to attach a monetary value to these studies. As in the case of flood mitigation, those interviewed felt that their activities were totally dependent on operation of the hydrometric network, and that they would have to replicate the existing system in the event that the data collection program was curtailed or terminated.

3.9 - Storm Drainage

The provision of storm drainage is largely the responsibility of municipal governments. The response to interviews carried on with municipal employees indicated that they made no use of hydrometric data supplied by the DOE for storm drainage or other purposes. As a result, no benefits were identified as arising from the design or operation of storm drainage systems. This neglect of hydrometric data seems to be largely attributable to the poorer coverage on small and urban basins.

3.10 - Management and Apportionment

The user survey has indicated that the management and apportionment of water resources benefit greatly from the provision of streamflow and stage data. The information supplied to the responsible bodies allows them to estimate total supply and natural flows, both of which are necessary for the efficient and equitable allocation of water resources. Those surveyed indicated that hydrometric data were irreplacable in their operations. Unfortunately no exact value can be related to the benefits arising in this area.

3.11 - Recreation

It was not clear from the response received just what role hydrometric data plays in this area. The data are presently employed to regulated water levels in canals and waterways used by pleasure craft. However, it is not clear whether the information supplied plays an integral role in this function. Very limited benefits are also derived in other activities related to recreation. In summary, insignificant benefits in recreation are attributed to the hydrometric network.

3.12 - Investigation and Research

Unlike the case of recreation, hydrometric data employed for research purposes provide a major source of benefits, although it is difficult to assess these in monetary terms. Individuals contacted stressed the considerable assistance resulting from the cases in which the use of meteorological, topographic or other information could be used to augment or replace hydrometric data.

3.13 - Total Benefits

In conclusion, twelve of the fourteen categories identified (Table 3.1) received some benefit from the use of information provided by the hydrometric system. For seven of these, it was possible to make a quantitative estimate of these benefits. These values are presented in summary form in Table 3.5. The total benefit for Canada, estimated by the above methods, is $129.6 million per annum. In addition, considerable unquantifiable benefits were identified in flood mitigation and low-flow operations, management and apportionment activities, investigations and research. Less significant benefits of a nonmonetary character were also associated with recreation. Finally, insignificant benefits were received by those involved in the categories storm drainage or other.

TABLE 3.5

TOTAL ESTIMATED BENEFITS

Project Type	Estimated Benefits ($\$ \times 10^6$)
Hydroelectric	64.3
Withdrawals	9.5
Navigation	13.1
Flood forecasting	3.6
Flood mitigation	2.9
Bridge and culvert design	29.3
Water quality and waste disposal	6.9
Total	129.6

PRESENTATION TO
THE HYDROMETRIC NETWORK PLANNING WORKSHOP
OCTOBER 5, 6, 1988
WINNIPEG, MANITOBA

INTRODUCTION

Ducks Unlimited was very pleased to be invited to make a presentation to this national workshop on network evaluation and planning. We believe it is very important to obtain input from private sector users such as Ducks Unlimited Canada as part of your network planning process, together with government users such as various provincial Water Resources Branches.

Ducks Unlimited Canada has been in business for the last 50 years, with a goal of preserving, restoring, developing and maintaining waterfowl breeding habitat throughout Canada. During the last 50 years, we have developed 3,500 projects ranging in size from small 10-acre marshes near Brandon, Manitoba to the 350,000-acre Cumberland Marshes Project located in the Saskatchewan River Delta northeast of Saskatoon, Saskatchewan. Figure 1 and 2 attached indicate the extent of Ducks Unlimited projects across Canada. As indicated in Figure 1, our activities cover every province and every territory in Canada. Each star represents a Ducks Unlimited marsh or complex of marshes. Figure 2 illustrates in more detail our activities in the prairie provinces.

During the last 50 years, Ducks Unlimited has developed 2.2 million acres of waterfowl habitat, and in order to accomplish this, we have spent over $300 million. Our present annual budget is in the order of $45 million. We anticipate that over the next 20 years, we will spend about $1 billion towards our goal.

APPLICATION OF WATER SURVEY OF CANADA DATA

Most of Ducks Unlimited projects throughout Canada have water control structures and require water management. These controls consist of stoplog or gated, concrete or steel overflow weirs or culverts. We also construct dams and dykes and excavate channels. Of prime importance is the hydrological data required by our engineering staff to design these structures. An integral part of the input is the streamflow data obtained from Water Survey of Canada (I would expect that next to the various provincial Water Resources Branches, Ducks Unlimited is probably the biggest user of Water Survey of Canada data on a continuing basis).

More specifically, this data is used to assist our staff for the following design criteria:

A. Flooding

Our dykes and controls must be designed to handle design floods. As our projects are normally located in low hazard areas, the design flood is usually a 2% or a 1% flood. In order to determine the magnitude of this flood, Water Survey of Canada streamflow data is required as this value is statistically determined from previous events. In addition to design floods, as part of our project operation, control works must be sized such that the project will be functional during a 10% flood during nesting season.

B. Yield

An integral part of establishing project feasibility is the determination of yield from the drainage basin. As a goal, we attempt to have the project functional during a 10% drought event during nesting season (mid-May to mid-July). If we are not able to attain this goal, then waterfowl productivity has to be subtracted during drought events when the benefits are determined.

C. Project Operation

Our biological design staff use average, low and high flow hydrographs as an integral part of their analysis.

VALUE OF WATER SURVEY OF CANADA DATA

The data provided by Water Survey of Canada is essential for Ducks Unlimited to do business. An analogy would be the weather data provided to Air Canada pilots prior to flight departure - they could not carry out their tasks without this data.

About 60% of the $300 million spent in the past by Ducks Unlimited has been for physical works. If Water Survey of Canada data was not available to the extent to which it is today, a considerable amount of guesswork would be required as part of our design. If we were extremely lucky, 50% of the works constructed would be sized correctly. The remaining works would be either too large or too small. If the works were too large, then funds would be wasted because these funds could have been used for other projects desperately required to assist the waterfowl resource. If the works were too small, then we would have experienced excessive repair and maintenance to keep these works in tact. Assuming that the extent of wastage or excessive repair and maintenance was about 25% of the capital costs of these works that were not sized properly, then DU would have wasted close to $25 million if the data was not available for use. This analysis does not include loss to others such as property damage or livestock loss to downstream landowners or the loss of human life.

Regarding future costs, with the above assumptions except that only 40% of our funds would be used for engineering works, then the funds that would be wasted would be about an additional $50 million over the next 20 years.

Another impact from the reduction of quantity of Water Survey of Canada data would be in an increase of design time for each project. Considering the number of projects that are designed by DU staff throughout Canada each year, even if one extra day was all that was required to compensate for additional analyses that would be required for each project, this amount would translate into an extra cost to Ducks Unlimited of about $100,000/year.

INPUT FOR FUTURE NETWORK PLANNING

Based on Ducks Unlimited's needs, we wish to provide you with the following input:

1. We strongly recommend that you not downgrade your network. This does not mean that Water Survey of Canada should not be carrying out management decisions to ensure that their operations are efficient and cost effective. Of course, there may be a few stations that have become redundant. However, as far as Ducks Unlimited is concerned, some expansion is required. In 1985, DU carried out an intensive internal study that indicated that 26 additional continuous recording stations were required as a high priority, and 57 additional continuous recording stations were required as a second priority (see attached table). We require expansion into smaller drainage basins (basins in the order of 10 to 50 square miles). Ducks Unlimited is not as interested in the "high profile" flow stations that have political consequences such as the St. Lawrence River at the Ontario/Quebec border, or even the Assiniboine River

at Winnipeg. Rather, Ducks Unlimited is interested in such stations as Kenton Creek at Kenton. Over the past two years, we have designed three projects with a capital cost in the order of $1 million based on the streamflow data from this "low profile" station located northwest of Brandon, Manitoba.

2. We recommend that you continue to maintain the quality of your data and, in order to accomplish this, we strongly suggest that you not pursue the alternative of privatization. Once again, this does not mean that you should not be running your organization similar to private industry where cost effectiveness and efficiency of both staff and equipment is important. DU staff are very satisfied with the quality of the data provided and we would be concerned if privatization did occur that quality of data may be jeopardized by the pursuit of profit.

3. We suggest that you consider expanding your services to provide data manipulation. By providing "final product" data manipulation such as frequency analyses, regression analyses, data correlation, regional analyses, Water Survey of Canada may be able to augment their revenue from users, as of course it would be expected that the user would have to pay for these additional services.

CONCLUSION

In summary, we appreciate the opportunity of making this presentation to you. We would encourage you to continue to draw input from users as part of your network planning including the private sector.

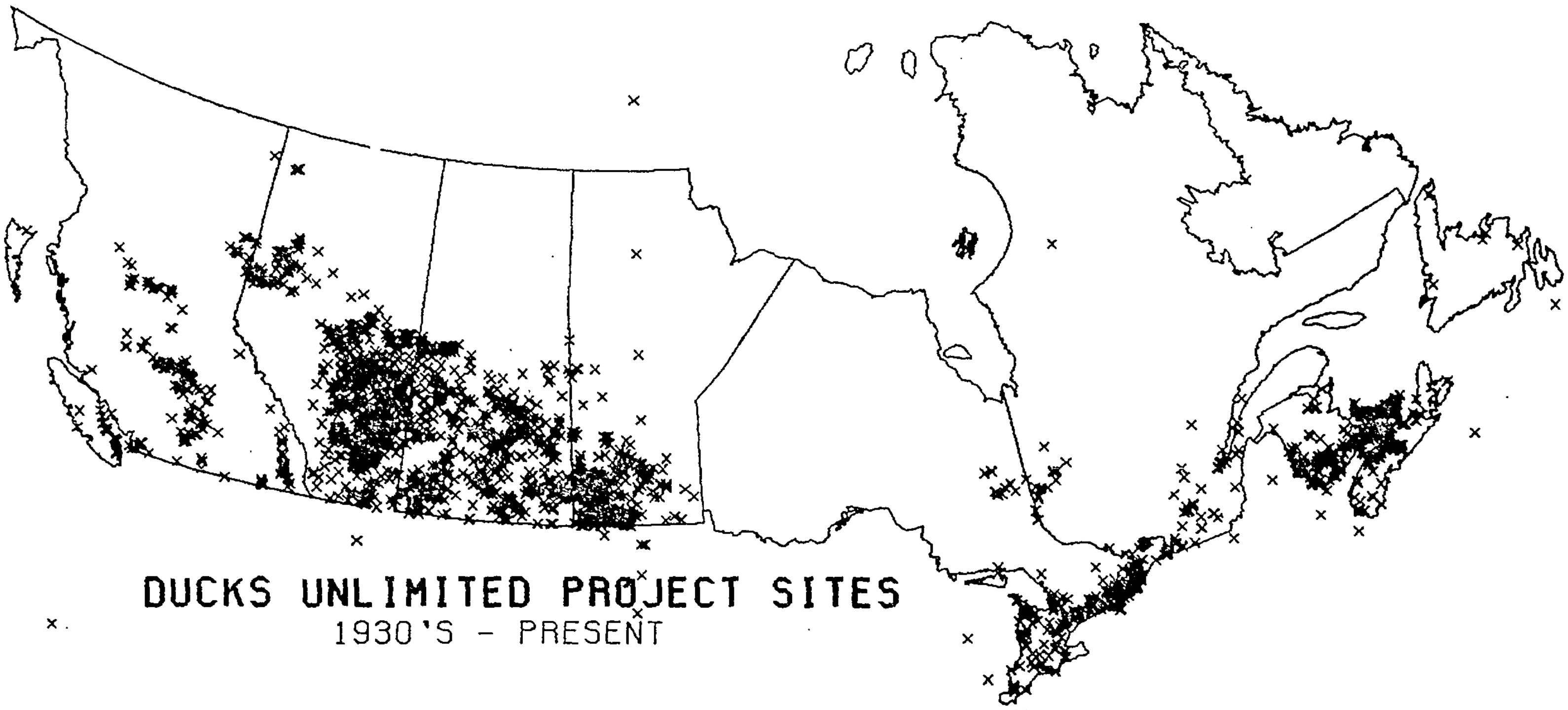


FIGURE 1

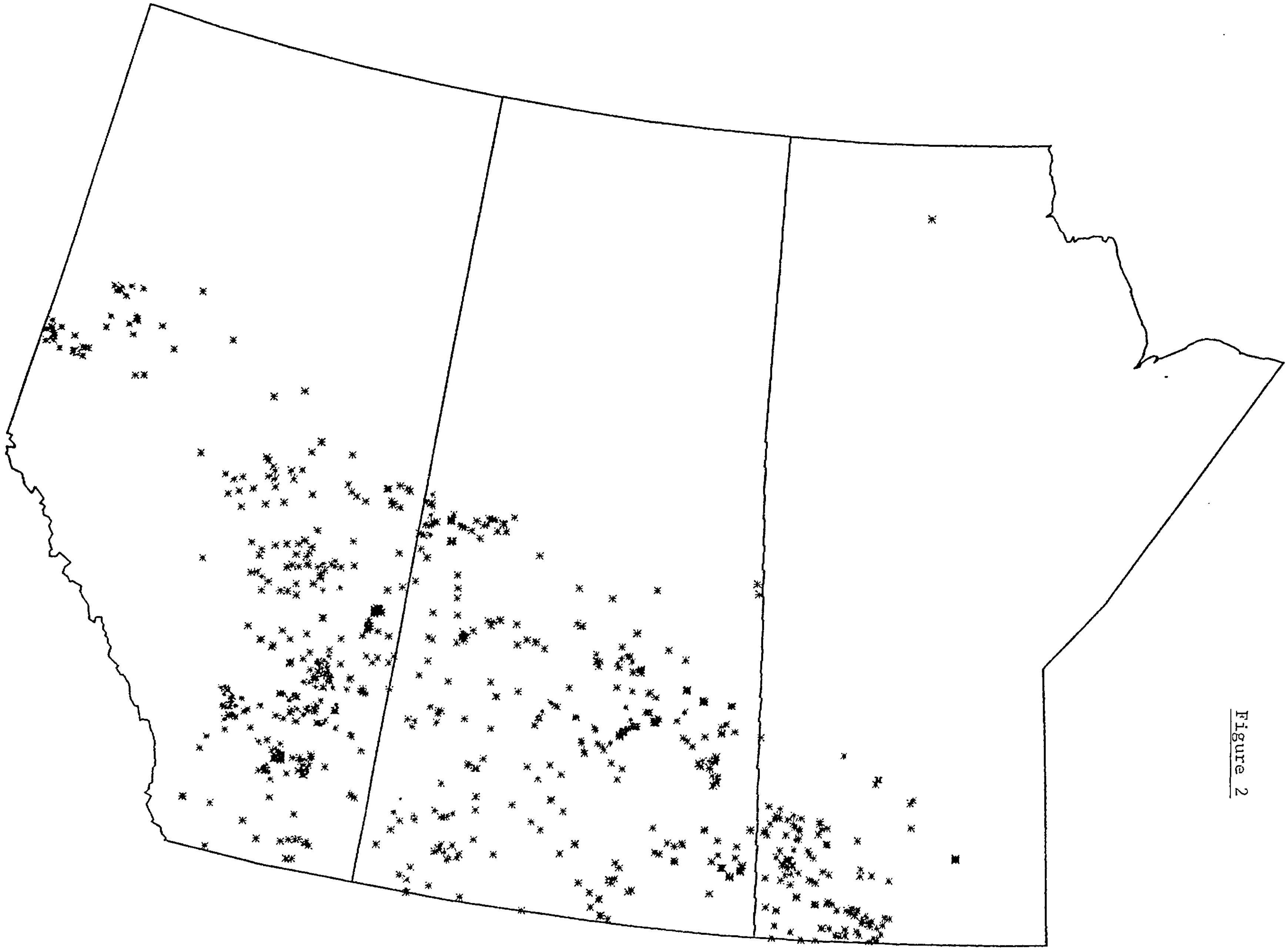


Figure 2

HYDROMETRIC NETWORK REVIEW

PROVINCE	TOTAL REQUEST		HIGH PRIORITY (1)	SECOND PRIORITY (2)
1. Maritimes	2 Stations in N.B. 3 Stations in N.S.	Map Available	Nil	5 Stations
2. Quebec	10 Stations	Maps Available & Site List	3 Stations	7 Stations +10 Crest Gage
3. Ontario	7 Stations Now 6 Stations Future	Maps Available & Site List	1 Station +2 Crest Gage Projects	6 Stations +15 DU Struct. with Crest Gages
4. Manitoba	6 Stations	Site List Available	2-3 Stations	3 Stations +30-50 Crest Gages
5. Saskatchewan	8 Stations	Maps Available	8 Stations	20 Recorders for DU Projects + Many DU (25) Crest Gaged Projects
6. Alberta	1985 Proposal to Monitor 6-10 Projects Via Staff Gages and Paid Observers			
7. British Columbia	27 Stations	Site List Available	11 Stations	16 Stations
8. Yukon	Nil at this Point			
9. NWT	Nil at this Point			
		TOTAL	26 Stations +2 Crests	57 Stations +-100 Crests

THE VALUE OF WATER QUALITY DATA

(Presentation made at the Workshop on Network Evaluation and Planning)

Winnipeg, October 5,6, 1988

The value of water quality data is a difficult commodity to place a value upon. During this short presentation I will attempt to explore a few ways by which a "value" can be placed on water quality data. These will be rather qualitative and not expressed in hard currency.

The value of the water resource in Canada has been estimated to be between 8 billion to 24 billion dollars (Muller 1985). Comparatively the cost of federal water quality data aquisition is approximately 9 million dollars. The cost of provincial water quality data aquisition is estimated to be in the order of 10 million to 20 million dollars. The investment in assuring that the quality of this valuable resource is small indeed when compared to the value of the resource.

A paraphrasing of economists' definition of the value is the " Cost to render water quality suitable for its intended use". Another is the "cost of the next alternative". As an example of the latter would be the situation where a thermal hydroelectric plant could not use in-stream water for cooling and had to go to cooling towers and recycling. For something closer to here, there is the example of the cost to municipal water users in Manitoba resulting from the proposed Garrison Diversion Unit. In that case it was calculated, based on projected water quality due to the irrigation return flows and other activities, that the cost to provide water to the 21,000 persons at pre-Garrison quality would be approximately 1.9 million dollars per annum (1976 dollars). This would represent about $200 per person per annum at today's prices.

In assessing the value of water quality data we should look at what uses the data are used for. Some of these are:

- identify/quantify changes
- assess regulatory measures
- assess suitability for specific uses
- describe condition or state
- assess impacts of activities inside or outside the basin
- establish objectives
- determine non-compliance

As well it is useful to look at who the users of the data are. Some of these are:

- the Water Quality Branch
- other government agencies (NH&W, DFO, etc.)
- International Joint Commissiion
- Prairie Provinces Water Board
- water resource managers
- the provinces
- consultants
- private sector

The data is interpreted and transformed into information. In addition to the data users the following groups use the information developed by the Water Quality Branch:

- -the public
- -politicians
- -senior managers
- -environmental NGOs

As can be seen the uses and users of water quality data are varied and extensive. The data are used to resolve and define problems society faces on a daily basis. Not all of these problems are quantifiable nor should we expect them to be. In their more expansive moments economists have been known to claim to be able to provide a value to a "sunset over Lake Ontario". With that in mind we have nonetheless been struggling for years to define the value of a duck. The duck has many values depending on the arguments being made for its role in the project under consideration. The question of value becomes more poingnant when ones substitutes whooping cranes for ducks. Can we really value water when it is something that is so basic to our existence? As shown above for individual projects one can measure the mitigation costs, the replacement costs or the value of an alternate water supply; but we must ask the question "Is this the total value?". In most cases I believe the answer would be "No".

In the instructions I was given to prepare for this presentation, one of the items to addressed was that of educating users, senior management and politicians of the value of these data. I have left this to last because what I say may perhaps be unconventional to some of you.

When it comes to educating the public about the value of water quality data I feel it would be a waste of money, not because they can't understand, but because they already do and they are already demonstrating this very pointedly. We are continually questioned about the quality of our environment, how they can help to prevent or clean up problems, and pressuring government to do something because the problems have been going on long enough. The public has a sense that is attuned to quality and are very aware of what is going on around them. The media have done a lot to develop this awareness amongst the public and to a large extent we have provided information to the media to assist them.

When it comes to politicians they get their message from the public who elect them. They tend to follow the issues to which the public are sensitive . Besides, they don't tend to get involved with issues where they stand alone. For these reasons educating the politicians would not be a cost-effective exercise.

This leaves the senior managers. I feel, this is the area where education on the value of data would be most valuable. Senior managers are constantly bombarded with imposed priorities such as down-sizing, effectiveness, efficiency, affirmative action, language training and others that they don't have the time to reflect on the value of the programs they are to administer. To educate them we must strive to get more time on their agendas to demonstrate how our data is valuable and why it should get higher priority than the many adminstrative issues they have to handle. Senior managers are perhaps lulled into the false assumption that since they have so many good scientific people looking after the programs things are running themselves and their involvement or direct support isn't necessary. This may once have been the case but in today's world it isn't. To help our senior managers we must be sensitive to their needs and provide them with quality information with to defend their programs. We must develop better marketing strategies and tools. We have to produce better and more appropriate products. The demand for these products has been created. It is up to us to satisfy this demand.

THE ECONOMICS OF WATER

Discussion Notes Prepared For
Water Resources Branch.
Network Planning Workshop
October 5, 6, 1988
Winnipeg, Manitoba

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WPM - WNR - 1988

October 1988

The Economics of Water

A. Introduction

Within the context of sustainable economic development, and in particular, water resources management, it is important to develop an understanding of the different methodologies used for valuing water. It is perhaps appropriate to lift a quote from the Report of the National Task Force on Environment and Economy which states that "we must seek to value environmental amenitities such as recreational opportunities and aesthetic attributes that contribute to quality of life. It is not appropriate to quantify all intangible values in terms of dollars and cents, nor is it appropriate to base all decisions solely on cost-benefit analysis, however methods do exist which can be used to apply economic weights or values to environmental resources, attributes, effects and benefits which are not otherwise bought and sold. We should use these methods where they make sense and where they can contribute to fair and equitable decision making." Consequently, in this section the issues and methodologies underlying water valuation will be discussed. In addition, some estimates of the value of water in different uses will be presented in order to examine some of the empirical work done thus far.

B. The Economics of Value

i) The Concept of Value

In defining the value of a commodity, the academic literature often differentiates between two types of value. The marginal value of a commodity is the amount one is willing to pay for an additional unit or willing to accept to give up another unit. Meanwhile, the total value of the commodity is the amount one is willing to pay rather than having to give up the commodity altogether. Deciding which approach is more appropriate depends on the situation.

ii) Common Criteria

Rather than using the traditional notion of economic efficiency many economists advocate that resources should be allocated so as to exploit all opportunities for mutually advantageous trades (i.e. water should be allocated to its most valuable use). Otherwise appropriate side payments between potential users could make both sides "better off".

In addition, Muller argues that "in choices between mutually exclusive alternatives, water should be allocated to the users for whom water has the highest average value, subject to appropriate compensation for the original users. In choosing between uses in which marginal adjustments are possible, water should be allocated so that the marginal willingness to pay for water is the same in all uses".

However some caution should be taken with the above comments on situations where the choices are mutually exclusive. One should also consider how much water each choice will be consuming or degrading if it is chosen. The point here is that we still want to observe the environmental threshold. Therefore, in mutually exclusive choices even if one option has a higher average value, if too much of the resource will be utilized, or if the quality and quantity of the resource will be drastically affected and consequently the future use of that resource affected, it may be advisable to use the other option. Obviously this does not apply if the future use of the resource was included in calculating the average value.

iii) Differences Between Willingness-To-Pay (WTP) and Willingness-To-Accept (WTA)

In the academic literature, "empirical estimates frequently show WTA exceeds WTP by substantial margins." An example of this may be when a non-smoker is questioned on how much he values a non-smoking environment. He may indicate on a survey that he would allow smoking if he was to accept $5 from the smoker. However, if smoking was allowed, he would only pay $3 for someone to stop smoking. Therefore, there is a discrepancy between the amount he would be willing to accept to allow smoking and the amount he would be willing to pay to stop smoking and depending on which question was used, the value of a non-smoking environment to the individual will differ. This discrepancy may also be a reason why the benefit-cost method is often rejected.

iv) Consumer Surplus

Currently, in situations where water is a final good (i.e. recreation) there is debate over whether consumer surplus should be included in the valuation of water. Consumer surplus is the difference between the amount of money that the consumer is willing to pay for a given quantity of a good and the amount that the consumer actually pays. A prime example of this concept is when a man, who when purchasing a crowbar to pry open a treasure chest, states that if necessary he would be willing to pay twice the price of the crowbar. The difference between what he would pay and what he does pay is his consumer surplus. Whether to include consumer surplus "is of considerable practical significance since the inclusion of consumer surplus can double the value estimate as compared with its exclusion".

One argument proposed for its exclusion is:

The principal purpose for estimating shadow prices is for use in making public investment or allocation decisions, in which case the estimated values are compared with the costs of the alternatives foregone. If costs or the value of the alternatives foregone by a public investment are market prices, they do not include consumers' surplus. Inclusion of consumer's surplus on the value or benefit side of the comparison is then conceptually inconsistent and unfairly inflates one element of the comparison. The inclusion of consumers' surplus is thus likely to encourage the production of goods which would be eliminated by conventional market criteria. There thus appears to be some merit to the suggestion that only those benefits be claimed which could be captured by a single price.

v) Increment versus Decrement

Another issue mentioned in the literature is that for two reasons the value of a decrement to the water supply may be greater than that of an equivalent increment. "First, removing a quantity of a resource involves moving back up the marginal value function to a higher level. Second, the value foregone by decreasing resource supplies should probably include a measure of the value of the sunk investment which would be written off in such an instance. In the field of water resource management, such questions have been studied in connection with exhaustion of nonreplenishing ground water stocks or with the potential for reallocating irrigation water to municipal uses."

C. Special Problems in the Evaluation of Water Resources

i) Physical Aspects of Water Supply and Use

Water is unique, in contrast to other resources, since its use at a specific time and place does not mean it cannot be used at a later date for the same or another purpose. Thus water used for hydro-electric power at the upper reaches of a river may still be used for recreation or irrigation downstream.

ii) Economic Aspects of Water Resources as Affecting Valuation

There are a number of economic factors that affect the value of water. "According to our basic conceptualization, the measure of value is the increment to total value in any productive use from an additional unit of water supply (the demand for the resource), with time, place and quantity specified. Various factors influence this relationship, including the sector, the type of product within the sector, the demand for the product, the physical productivity of the site where the water is utilized, the level of development or capital investment in the site, and transportation, storage and processing costs for off-stream use."

D. Methods for Measuring the Value of Water

i) The Survey Method

A common method used to evaluate water is through surveys in which people would be willing to pay to prevent environmental damage or to obtain environmental improvements. In addition, the survey usually provides as much detail as possible about the project. A major advantage about the survey method is that it can be applied without the elaborate assumptions required by other methods, although a number of sources of bias may be present. These include strategic bias on the part of respondents and bias induced by lack of information about the changes, lack of realism of the payment mechanism and the starting point of the questions. A further problem noted ...is that questions attempting to gauge required compensation may be met with hostility. Finally, Freeman (1979, 1982) notes that even if their responses are unbiased, respondents have little incentive to provide accurate information. Nevertheless, the survey method appears to obtain results comparable to imputed market methods when applied to the same problems.

ii) The Travel Cost, Cost of Perfect Substitutes and Property Value Method

Market based measures infer willingness-to-pay from observed behavior. They include travel cost, cost of perfect substitute, weak complement and property value methods. In the travel cost method, costs incurred by people travelling various distances to a recreation site are used to formulate a demand curve for the site. The demand curve is then used to estimate the consumers' surplus from the recreational activity. The cost of perfect substitute method uses the cost of purchasing a perfect substitute to derive a WTP for water. In the property value method, the value of water is calculated by subtracting the added value to an area close to the water from the value of real property in the vicinity of the water.

iii) Residual Imputation as a Method of Resource Valuation

"Resource Valuation is essentially a problem of assigning a price" to resources or commodities in the absence of markets to perform the function. Residual imputation is a procedure which achieves this by allocating the total value of output to each of the resources used in a single productive process.

...The technique is based upon two major postulates: (1) the market prices of all resources, except the one to be valued, are equal to the returns at the margin (value of the marginal product) afforded by those resources, and (2) the total value of output can be divided into shares such that each resource is paid according to its marginal productivity and the total value of output is completely exhausted."

"While residual imputation appears to be a very simple technique for estimating shadow prices or resource values it is subject to limitations which should be recognized by the user. These limitations may be conveniently discussed in four broad categories: (1) the problem of exact exhaustion of the total product, (2) the question of price equal value marginal product of all resources except the one whose value is being estimated, (3) the problem of omitted variables, and (4) problems of estimation when price supports or subsidies or other exogenous influences are exerted on production."

iv) Recreation

Recreation is distinct from the other water uses for two reasons. First, unlike other uses of water such as agriculture and municipal uses, recreational use usually does not alter the water resource. Secondly, despite a series of debates, in the academic literature, several methodologies consistently stand out that deal with recreation. Consequently, the following paragraphs will briefly introduce the reader to some issues and methodologies in recreational use.

The value of water in recreational and in direct uses is still measured by the minimum amount of compensation which would be accepted by the present users of the resource. [However,] there is considerable disagreement over whether it is reasonable to approximate this amount by consumers' willingness to pay to retain environmental services which they presently enjoy. Some, for example Russell (1981), argue that the large discrepancies which are observed between estimates of the willingness to accept compensation (WTA) and willingness to pay (WTP) are the result of strategic behavior on the part of survey respondents, while others, for example Meyer (1979 and 1981) argue that market based WTP measures do systematically undervalue true WTA and that the continued use of these low estimates has led to their rejection by many fish and wildlife agencies.

Regardless of the outcome of this debate, most reported estimates of recreational values have been based on the willingness to pay concept. A number of methods have evolved to measure WTP. They are discussed in Freeman (1982), Knesse (1984) and also reviewed in the Canadian context by Adamowicz and Phillips (1983). Among these are the contingent valuation method, the travel cost method and the hedonic price index.

(a) Contingent Valuation Method (CVM)

Contingent Valuation studies attempt to derive WTP estimates by directly asking survey respondents what value they would put on nonmarket resources if a market and method of payment were put in place. Bishop and Boyle (1987) discuss the advantages and disadvantages of contingent valuation and argue that for willingness-to-pay measures of value, contingent valuation has been shown to perform fairly well in field and laboratory experiments. However, they hastily add that the recent validation research involved direct use values only. Thus, further research will be needed to expand the contingent valuation's usefulness to indirect and intrinsic values. In the meantime, Boyle and Bishop feel that contingent valuation is the only procedure capable of measuring these other components and thus it is consistent with the current state of the art for valuing nonmarketed environmental assets.

Schulze, d'Arge and Brookshire (1981) argue that the strategic bias is irrelevant and that contingent valuation studies conform reasonably well to estimates obtained by alternative techniques. However, Rowe and Chestnut disagree and offer a vigorous rebuttal.

(b) Hedonic Price Method

Hedonic price studies derive a willingness to pay estimate from data relating expenditures on water related activities to days spent, income, and other variables measuring the quality of the experience.

(c) Travel Cost Method

As mentioned earlier, the travel cost method acknowledges that people travel different distances for recreation and thus uses the costs of travelling to derive a demand curve and willingness to pay estimates for the recreation site.

E. Estimates

For the most part willingness to pay has been used to value water in its current use. However more accurate estimates of the economic value of water in any use require much more specific information on the nature of the change in water supply being contemplated and the alternatives available. Nevertheless, the estimates om Table 1 provide considerable insight into the value of water in the Canadian economy.

Table 1

Selected Estimates of the Economic Value of Water, Canada

Use	--Average Net WTP--		--Total Net WTP--	
	Low ($/Ml)	High ($/Ml)	Low (M$)	High (M$)
Municipal	100	2430	288	6968
Irrigation	0	36	0	109
Tnermal Power	9	9	169	169
Industrial Uses				
Paper	87	87	251	251
Chemical	76	76	217	217
Primary	16	43	44	118
Petroleum	19	19	10	10
Food & Bev.	124	124	53	53
Subtotal			613	613
Total Withdrawal Uses			1070	8590
Hydroelectricity			4226	6553
Waste Assim.(a)	1	4	645	2272
Sports Fishing(b)	20	74	1677	6309
Seaway Navigation			0	0
Freshwater Fishery			0	0
Total Instream			6549	15134
Grand Total			7619	23724

Notes:
(a) Average WTP in C$/kg of BOD removed.
(b) Average WTP in C$/fishing day.

There are two problems with the estimates presented in Table 1.

The greatest uncertainty lies in the estimates of the value of water for municipal use, which run from $288 million to $7 billion. This is because some minimum supply of residential water is as close to an necessity as any economic good can be and consequently estimates of the total consumers' surplus derived from access to residential water are extremely high. However, the total consumers' surplus from residential water greatly overstates the willingness to pay for raw water from current sources if any reasonable substitutes are available. The low value in Table I assumes that alternative water supplies can be obtained for an increase of 20% in the average cost of municipal water supply.

The second greatest uncertainty lies with the recreational value of water and the WTP estimates for fishing. "Based on published estimates of the value of a fishing day, the total willingness to pay for sports fishing could range from $1.7 to $6.3 billion. It is important to notice that the willingness to pay for sports fishing is quite comparable to the willingness to pay for hydroelectricity, which ranges from $4.2 billion to $6.6 billion. Benefits from other recreational uses of water and from non-participatory values of water (such as option, existence and bequest value) were shown to be very substantial but it was not possible to derive a national total."

However, estimates have been developed by others for other recreational uses of water. "The study by Greenly, Walsh and Young (1981), indicates that willingness to pay to preserve high quality recreational uses of water range may be as high as $110 per household in the Denver, Colorado, area and it is reasonable to expect that Canadians would be willing to pay equivalent amounts."

F. Omissions and the Limitations of the Estimates of the Value of Water

(a) Existence, Option and Bequest Value

Although estimates for existence, option and bequest values are not included in Table 1, they are important and receiving attention in the academic literature.

i) Existence Value

Existence value is the amount people would be willing to pay to maintain a resource in its natural state even if they never intend to use it.

ii) Option Value

Option value is the amount people are willing to pay to leave their options open rather than commit themselves to a project which may do irreversible damage to a resource especially since new technology in the future may prove that the project is actually undesirable.

iii) Bequest Value

Bequest value arises from the fact that many people derive pleasure from the knowledge that natural environments will be available for the enjoyment of future generations. "Greenly, Walsh and Young (1981) and Walsh, Loomis and Gillman (1984) report that these non-participatory values may be comparable in magnitude to the willingness to pay for recreational activities. In addition, others claim that non-participatory values accounted for more than half of an estimated willingness to pay of $237 per household per year."

(b) Limited Usefulness of Average Value

"Average net willingness to pay for water is a good guide to resource allocation when the decision is to allocate large blocks of water amongst mutually exclusive uses such as waste assimilation and recreation. In many cases, however, water can be reallocated among uses in fairly small increments, as is would be the case when irrigation water is reduced to provide additional industrial process water. Under these circumstances it is the marginal value of water, not the average, which should be considered. Unless there is quantity rationing, the marginal value of water will generally equal its price."

(c) Need for Precisely Specified Compensation

Currently there is debate over whether willingness-to-pay accurately measures compensation. Some feel that "WTP estimates seriously underestimate the loss experienced by people deprived of access to water-based resources. ... This is important because individual users rarely have the chance to decide individually whether to accept compensation for a water development project. Thus we have very little market based information on which to calculate the value of water to non-participants and recreational users and we run the risk of depriving these groups of their access to water without appropriate compensation."

(d) Neglect of Future Prices and the Irreversibility of Investment in Water Projects

Other issues that must be looked at in project evaluation is neglect of future prices and the irreversibility of investment in water projects. If projects are undertaken and if new technology in the future reveals that the prices used are not accurate, then perhaps the project should not have been undertaken in the first place.

Porter (1982) and Fisher (1983) provide useful expositions of the consequences of irreversibility. The most important consequences are that present decisions about the allocation of water resources must take into account the probability trends in prices in the future as well as the probability that over time more information about the benefits or damages from an environmental project is likely to become available.

The logic behind this position is simple. Because of the dwindling supply of natural environments and the increasing demand for recreational activities associated with them, the willingness to pay for the preservation of the environment is likely to grow over time. At the same time, increasing technological developments are likely to render the gains from developing water resources progressively smaller. Consequently today's value for water in non-consumptive uses is probably an underestimate of its future value and irreversibly reallocating water to development uses may impose costs greater than the benefits obtained. Fisher (1983) argues that this, together with the possibility that improved information about the consequences of development will emerge in the future, constitutes a strong argument in favor of a conservative approach to the development of natural resources.

G. Summary and Conclusions

There are many concepts, issues, and methods to be utilized in the evaluation of water. Firstly, project evaluation must differentiate between the marginal value of a commodity, the amount one is willing to pay for an additional unit or willing to accept to give up another unit, and the total value of a commodity, the amount one is willing to pay rather than having to give up the commodity altogether. In addition, evaluators must decide whether to use willingness-to-pay or willingness-to-accept in valuing water as well as whether to include consumer surplus in situations where water is a final good.

There are several methodologies mentioned in the academic literature. In the survey method, people are asked directly what they would be willing to pay to prevent environmental damage or to obtain environmental improvements. One advantage of this method is that it can be applied without the elaborate assumptions required by other methods, however, a number of sources of bias may result. Nevertheless, some feel that the survey method appears to obtain results comparable to imputed market methods when applied to the same problems.

Another common method is the contingent valuation method (CVM), where individuals are directly asked what value they would put on an non-market resources if a market and system of payment were put into place. Although the CVM appears to perform quite well in direct use values, further research is required to determine the contingent valuation's usefulness to indirect and intrinsic uses.

The estimates given in Table 1 were based on the average willingness to pay principle. However, there is a great range of uncertainty in the case of municipal water supplies and sports fishing. In addition, the estimates do not take into account existence, option and bequest values. In addition, there are several limitations to the estimates, namely: (1) limited usefulness of average value, (2) need for precisely specified compensation, and (3) neglect of future prices and the irreversibility of investment in water projects.

VALUE OF SURFACE WATER DATA AND INFORMATION

Prepared For

NATIONAL HYDROMETRIC NETWORK PLANNING WORKSHOP

Winnipeg, Manitoba

October 5 - 6, 1988

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VALUE OF SURFACE WATER DATA AND INFORMATION

Alberta Transportation & Utilities has the mandate and responsibility to provide a safe and dependable public transportation system in the Province. As a result the Department constructs bridge structures as overpasses, railway separations as well as crossings over rivers and tributaries. At present there are approximately 12,500 public bridge crossings in the Province. The Department presently has an annual capital budget in the order of 50 Million Dollars for bridge construction and maintenance.

Depending on the size of the stream, the crossing may include steel or concrete culvert structure(s) or single to multi-span bridge structure. We have constructed large culvert structures up to 8.4 m dia round SPCSP and 11 m x 7 m concrete arch. The size of bridge structure has varied from 6.0 m single span standard precast or timber to a proposed 760 m multi-span bridge over Peace River.

The design of a bridge crossing combines highway geometrics and standards with hydrotechnical considerations. The design hydraulic conditions are estimated from the basin hydrology. The following hydrologic criteria are used for the design of major bridge structures.

- 100 - year flood for primary highways and major secondary roads.
- 50 - 100 year flood for secondary roads and well travelled local roads.
- 50 - year flood for local roads

The above are rough guidelines only. Each situation is assessed individually and design conditions are estimated based on consequences and risk. As a result, the value of surface water data and information is tremendous to the Department in assessing the hydrologic and hydraulic conditions for bridge crossings over rivers. The availability of water survey information is important as it is used in assessing implications against existing bridges as well as for the planning and design of proposed crossings. Such considerations include flooding, erosion and bed scour.

HOW ARE THE DATA APPLIED? WHAT ARE YOUR SPECIFIC APPLICATIONS?

The available surface water data and information on a given stream have a major bearing in the hydraulic design of bridge crossings. The historical stream flow records and stage - discharge relationships provide the real life history and basis for predicting floods as well as low flows in a given tributary. The following are typical applications of surface water data carried out on fairly routine and daily basis related to bridge crossings.

- Preliminary studies and assessments of future road corridors including stream crossings and related implications, bank protection works and estimated costs.
- Detailed hydrotechnical designs of bridge crossings including waterway opening, assessments of flood stages, channel velocities, bank and bed erosion and design of remedial flood protection schemes.
- Studies of low flows and required measures for environmental mitigation.

- Assessments of ice flows and potential for jamming against or interaction with bridge piers.

- Assessment of flooding and erosion against existing bridge structures in view of changing hydrologic information.

For the ungauged basins, the information from the neighbouring gauged streams is utilized using regional analysis, unit hydrograph and other emperical methods.

IMPORTANCE OF SURFACE WATER DATA

As discussed above, the surface water data are used for hydrotechnical applications related to existing as well as proposed river crossings. The surface water measurements form an integral part of a design exercise. The quality of such an assessment is very much dependent on the quality of data available.

The hydraulic design for a river crossing is based on the design flood. With the lack of surface water data, it may be difficult to arrive at realistic and reliable estimates and the level of confidence may be reduced.

Here are some examples showing possible implications:

- Over estimating the design flood may result in:

  a) Higher flood stage and higher and longer bridge structure and therefore increase in costs. For example; 1 m raise in the height of the bridge structure may have implication of 4 to 6 m in extra bridge length and additional capital expenditure.

  b) Relatively more severe design hydraulic conditions and increased potential for erosion. Depending on the availability of rock riprap or other bank protection materials, the river training and flood protection cost may substantially increase.

  c) Depending on the foundation conditions, the increased potential for erosion may be reflected in additional measures for pier design (additional piles or deeper penetration) resulting in additional expenditure.

  d) On relatively wider rivers, increased potential for scour may require deeper pier foundations and extensive construction techniques and therefore substantial increase in construction costs.

  e) Over-estimating the flowing ice conditions (dependent upon river flows) may result in relatively massive piers and additional capital expenditure.

- Under-estimating the design flood on a stream may result in:

  a) Under-estimating the bank protection required and more frequent maintenance.

  b) In extreme and rare events, this may result in scour at foundations or piers or even dislodging of the structure especially in case of debris carrying streams.

c) Excessive floods may result in relatively more severe damage in case of a steel culvert (SPCSP) including structural failure in rare situations.

d) Road washouts may occur at locations where roadway embankment may encroach into the river resulting in reconstruction costs along with loss of traffic use.

In view of above possible scenerios, it is obvious that the availability of additional surface data will certainly aid in arriving at more reliable hydrologic designs for bridges with greater degree of confidence. The value of surface water data and information lies in the fact that it may help in designing and constructing economical as well as dependable transportation facilities in the Province.

The northern part of the Province is relatively less developed. This vast undeveloped land however has enormous potential for future growth and resource activity including oil, gas and forest related industries. This is reflected by recent announcements or construction starts of a pulp mill and the expansion of oil sands projects. This area will require additional construction of road corridors and bridge crossings in the near future as the resource industry develops and expands further north. Unfortunately this area of the Province has sparse coverage of hydrometric networks. The most of the gauge sites (with shorter term historical records) are located in thin north - south bands closer to the eastern and the western provincial boundaries. As a result the vast tracts of land with numerous streams and tributaries are ungauged. The lack of data makes the statistical techniques to arrive at hydrologic design parameters risky with relatively lower level of confidence. Therefore there is certainly the need for expanded network systems and data base in this part of Province of Alberta. This will help save public expenditure in future transportation related and other developmental projects in construction as well as in maintenance.

HOW CAN WE EDUCATE USERS, SENIOR MANAGEMENT, POLITICIANS AS TO THE VALUE OF THE DATA?

The value of surface water data should be demonstrated in terms of "dollars well spent at this stage to provide better service in near future" to realize multi-fold savings on capital and maintenance costs. The value of surface data increases substantially with time as these show relatively longer term historical trends and are more reliable to use. The additional data will certainly aid in completing more reliable and cost effective designs with higher level of confidence. This will entail in multifold cost savings on construction and maintenance of future transportation and other developmental projects.

CAN YOU QUANTIFY IN DOLLARS THE BENEFITS?

The benefits for the hydrometric networks and data base are envisaged to be enormous. The hydrometric information will provide better understanding of rivers and tributaries in question and will therefore help to handle developmental aspects and combat environmental concerns in a better and adequate fashion. The principal that applies in this case is "Dollars better spent NOW to help provide Better Services and Multi-fold Savings in future." Therefore there is need to develop realistic scenerios and demonstrate the risk and implications attached to hydrotechnical designs in situations where no hydrometric data or only scarce data are available. This should help justify the benefits in dollar values.

8. REGIONAL HYDROLOGY IN CANADA

A Brief Note on Regional Hydrology

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For presentation at

the National Workshop on Network Evaluation and Planning,

Winnipeg, Manitoba 5-6 October 1988.

1. Introduction

Hydrologic regions are often delineated in an arbitrary manner, coincident with recognized geographical, political or administrative areas. Such regions are likely to contain drainage basins with a diversity of surface conditions, whose actual runoff or flow characteristics may not be comparable.

Alternatives to forming regions along a "geographical" basis exist. These "alternative" techniques allocate basins to regions or groups by one of two general processes:

(a) classification by the statistics of some prescribed flow descriptor (e.g. 100-year flood, median 10-day low flow).

(b) classification by a basin's physical characteristics.

1.1 Statistical Regions

Power (1986) describes a "statistically homogeneous zone... as an area within which it is possible to relate to an acceptable degree of accuracy, hydrologic and physiographic characteristics, by means of a set of equations or a computational model. The hydrologic factors may be components of the streamflow hydrograph such as annual flow, flood flow or low flow, or frequency characteristics such as the mean or the coefficient of variation".

Thus, statistical hydrologic regions can be defined as regions within which certain relations between hydrologic and physiographic characteristics are valid. 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 (Solomon and Davis, 1970).

This approach is illustrated by Condie et al. (1986) for Southern Ontario using the Index Flood Approach.

A frequency analysis is performed for all pertinent hydrometric locations. Frequency curves are then "indexed" by dividing by for example the site's 2-year flood. "Homogeneous" Index Flood Regions are then derived whereby the indexed frequency relationships have similar slopes on a probability plot. Thus a homogeneous region would include sites having similar indexed curves. The study in Southern Ontario found three such regions.

In order to estimate design floods at ungauged sites using this approach, an equation relating the 2-year flood and basin characteristics must be obtained. This value is used to "de-index" the regional curve. Condie et al (1986) found three statistically homogeneous regions for the Q-2 relations.

An important note is that both steps of the Index Flood Approach found three regions (one for the growth curves and a second for the Q-2 relationships). A more important observation is that the two do not geographically correspond.

Thus, in the application of one approach to determine flood flows, two different "homogeneous" groupings were found for southern Ontario.

If a second approach, such as Direct Regression, were used to estimate flood quantiles, it is possible that new statistically homogeneous zones could be formed for each quantile.

This may appear to be a proliferation of zones, but it is consistent with the definition. [It also has been shown to provide usable results (Tasker 1982).]

1.2 Physical Characteristics Region

A physically homogeneous zone may be defined as "an area within which all parts have a generally uniform topography, geology and vegetative cover and are subject to similar climatic variations" (Power, 1986). Regions would be delineated by prescribed physiographic characteristics which would "vary within narrow limits and where consequently it may be expected that the hydrologic regime varies in a similar manner" (Solomon and Davis 1970).

Solomon and Davis (1970) report on a physiographic regionalization of Southern Ontario. Four physiographic characteristics were selected - proportion of urbanized land, barrier height in the SW direction, latitude, and permeability index. The variation range of each characteristic was divided into three shades. This process resulted in 81 regions.

In comparison, Ingledow and Associates (1969) identified 29 zones as being "physically homogeneous" in British Columbia.

1.3 Comparison of Approaches

Acres International Limited (1988), in a study on small-scale hydro in Ontario, recognized that the two approaches are quite different. They noted that the number of homogeneous regions is reduced when using statistical regionalization. The reason for this reduction is that variability in the hydrologic characteristics from gauge to gauge will be explained by the independent variables included in the regression equation. Statistically based regionalization is therefore an attempt to account for neglected characteristics not included in the regression analysis which may be common to a region.

The study by Condie and Harvey (1987) demonstrates this characteristic of statistical analyses. They found that one regional regression equation was adequate for predicting the frequency regime of annual mean flows in the province of New Brunswick.

An example of a national regionalization is found in the UK's Flood Studies Report (Natural Environment Research Council, 1975). They presented regional frequency curves for 10 geographical regions in Great Britain. These regions are shown in Figure 1 together with the regional frequency curves. Wiltshire (1986) comments that "the steep frequency curve of region 7 and the flatter curve of region 10 reflect the differences in basin geomorphology between the drier southeast and the wetter northwest of England. Many of the remaining homogeneous regions are seen from Figure 1 to have similar frequency curves". The point being that the geographic regions should be altered to reflect statistically homogeneous zones. This would possible result in a reduction in the number of boundaries and an estimation process which would be simpler to apply.

2. Importance of Regional Studies

Hydrologists often wish to transfer information collected at gauged sites to ungauged sites, or to improve estimates at gauged sites. This hydrometric information is used for the design and operation of various hydraulic projects. Design benefits reflect the ability (accuracy) to obtain reliable and precise information. The goal is to allow the efficient design, operation, and/or construction of facilities.

The estimation of the benefits for particular project types on an annual basis has been attempted in the past. Acres Consulting Services Limited (1977), for example, gave a conservative estimate of benefits from the hydrometric program as $129.6($10^6$). A good portion of these derived benefits stems from applications of regional studies for bridge and culvert design (flood flows) to water quality and waste disposal (low flows).

It is evident that the hydrometric network is of essential importance for all designers, operators, and managers of water resources systems. Analysis of the national network is required to ensure that data collected are meeting the needs of users.

Currently, we are in a period of restraint and the network is being exposed to unprecendented scrutiny. In addition, we have been witnesses to rapid technological developments such as the DCP program which open new avenues for both products and users. Given these factors, there is an increasing need for a concise rationale with regards to the directing of resources.

An important aspect in the directing of resources lies with the development of strategies for the management of the network. It is advantageous to review strategies in order to demonstrate their effect on the usefulness of the data to users. Tools which can assist the analyst in the function can vary from pragmatically oriented approaches (Wahl and Crippen, 1984) to the application of a series of statistically oriented programs, including techniques such as Generalized Least Squares (Thomas et al., 1985). Regardless of the approaches taken, it is important that the results be heavily seasoned with engineering judgement.

Network analyses may, as well, be performed in an attempt to throw light on "difficult-to-answer" questions. Given economic constraints, the evaluation of sites as to their contribution in regional relationships may prove useful. "Which site(s) contribute most (least) to the development of regional estimators of hydrologic indices?" "What kind of basin would be most beneficial in deriving such relations?" "How effective are alternate methods for providing streamflow information?" These types of questions, as well as many others, must be considered for effective and efficient network development.

3. Approaches to Regional Studies

Regional studies form an important aspect of network evaluation and planning. These studies incorporate information obtained from basic inventories of sites. Inventories provide a necessary starting point for analytical studies. Information can include number of sites, their location, watershed boundaries, type of data, periods of data, watershed characteristics, etc.

From the inventory of stations, sites can be selected for particular studies. Data can be screened to ensure their integrity, as well as to determine if certain traits such as trends or jumps are detectable. This screening is intended to provide a better understanding of the hydrology of the site.

Once stations have been individually scrutinized, groups of these stations can then be used for regional estimation of hydrologic indices and for network analyses purposes. Results of these analyses can lead to measures of accuracy. That is, statements regarding the ability of the network to estimate hydrologic indices at ungauged locations can be made. Studies can also highlight certain characteristics of the network. For example, does the network adequately determine hydrologic characteristics or have we uncovered certain short-comings which have previously been undetectable. Studies can indicate which basins tend to contribute most to regional information and conversely, which tend to contribute least. This leads to a possible "priorization" of sites according to regional importance for hydrologic studies. In a time of economic restraint, this can prove useful when adjustments to the network are necessary. Even if economic downsizing is not at issue, these processes indicate how adjustments could be made so that the network can provide greater amounts of information.

The steps to the approach described above are shown in Figure 2. These steps are flexible and can change depending on the questions that are to be answered, the resources and time that are available to perform the studies, and the sophistication of methods one wishes to adopt.

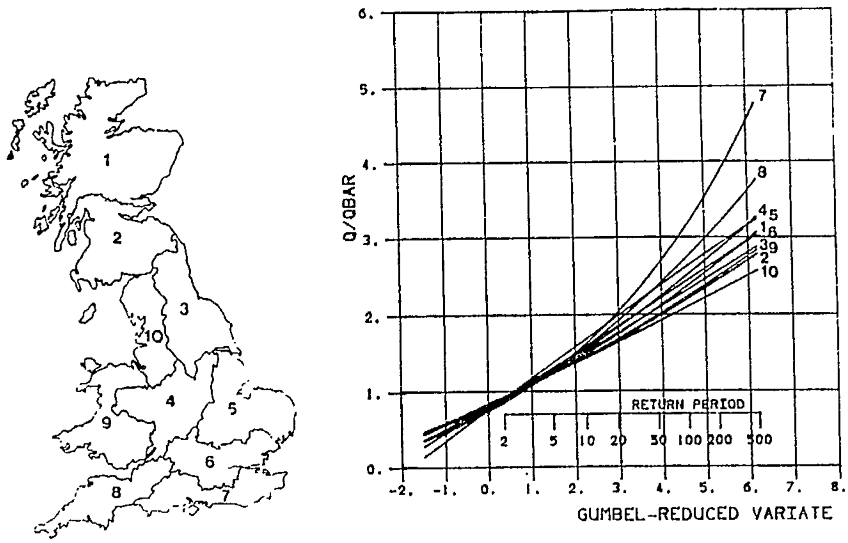

Fig. 1 Regional flood frequency curves in Britain. (Wiltshire, 1986)

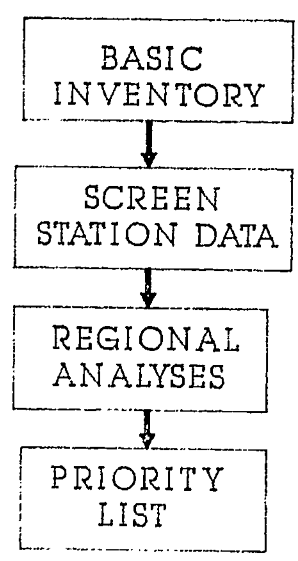

Fig. 2 An approach to station priorization.

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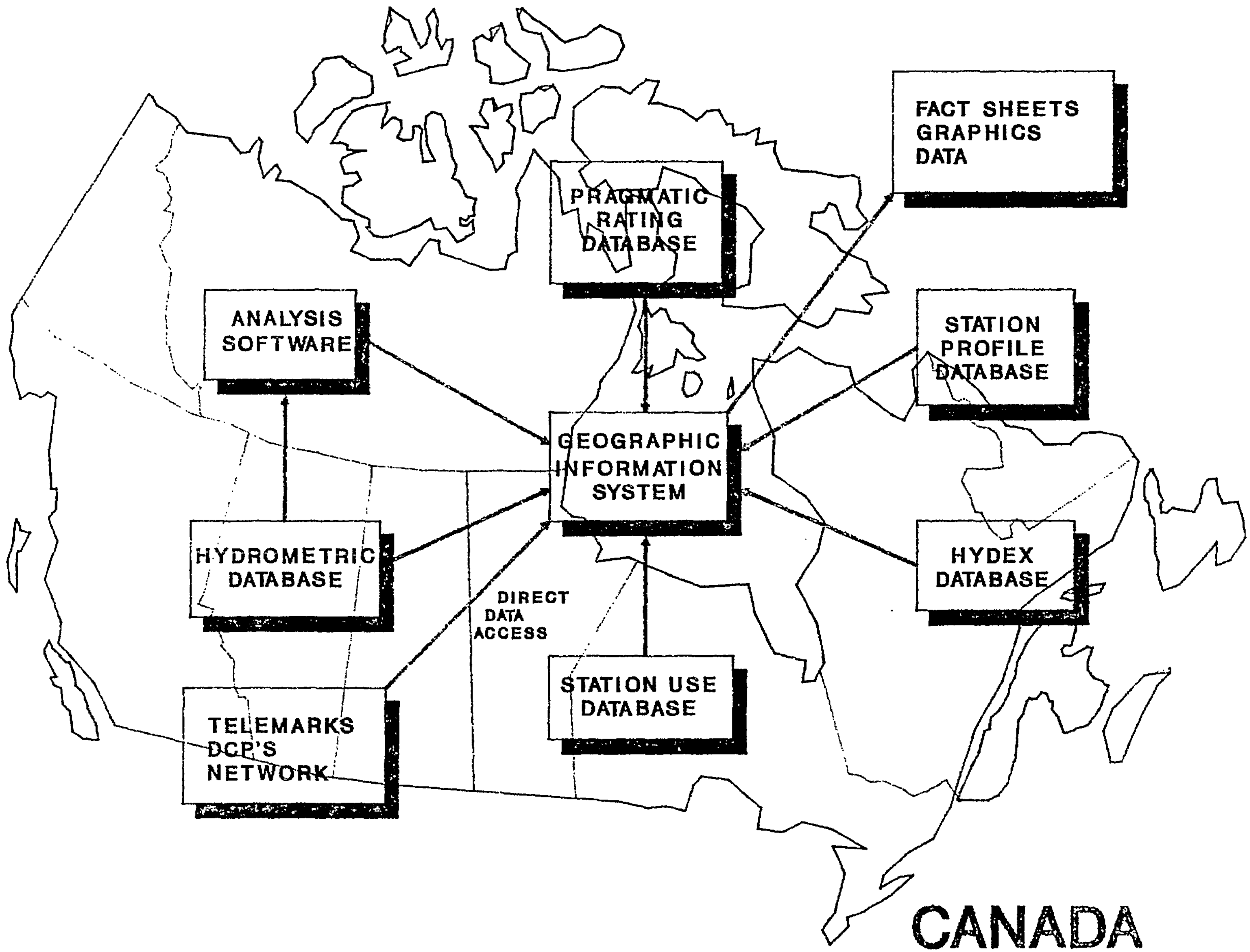
9. GEOGRAPHICAL INFORMATION SYSTEMS - APPLICATIONS IN NETWORK PLANNING

APPLICATIONS OF A GIS FOR WRB USE *

- **Network analysis and display**
- **Input to distributed models**
- **Integration with other databases**

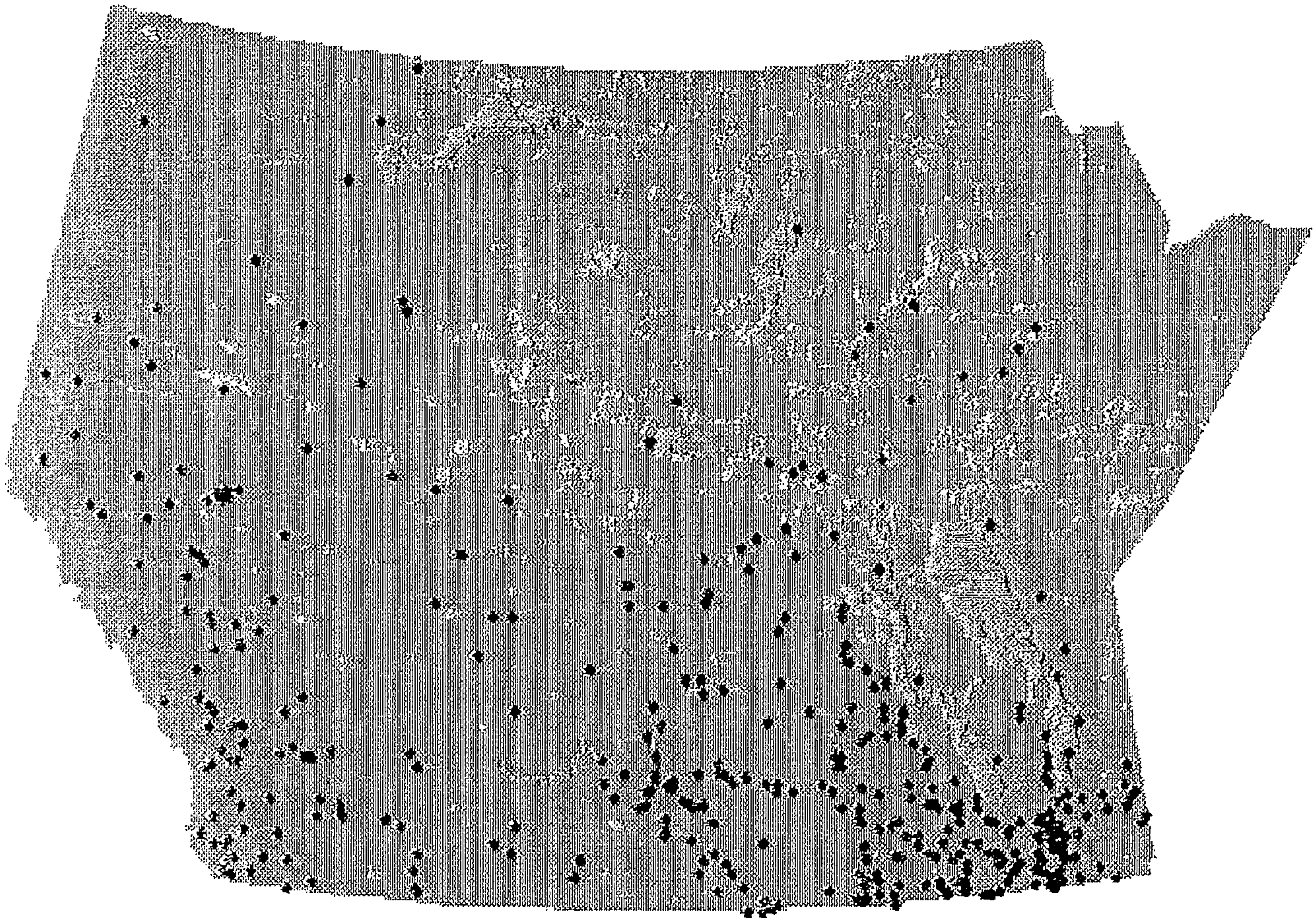
* : by Mr. J.M. Power
Water Resources Branch
Inland Waters Directorate
Ottawa, Ontario

: as part of the "Geographical Information Systems - Applications in Network Planning" presentations.


FACT SHEETS
GRAPHICS
DATA
PRAGMATIC
RATING
DATABASE
ANALYSIS
SOFTWARE
STATION
PROFILE
DATABASE
GEOGRAPHIC
INFORMATION
SYSTEM
HYDROMETRIC
DATABASE
HYDEX
DATABASE
DIRECT
DATA
ACCESS
STATION USE
DATABASE
TELEMARKS
DCP'S
NETWORK
CANADA

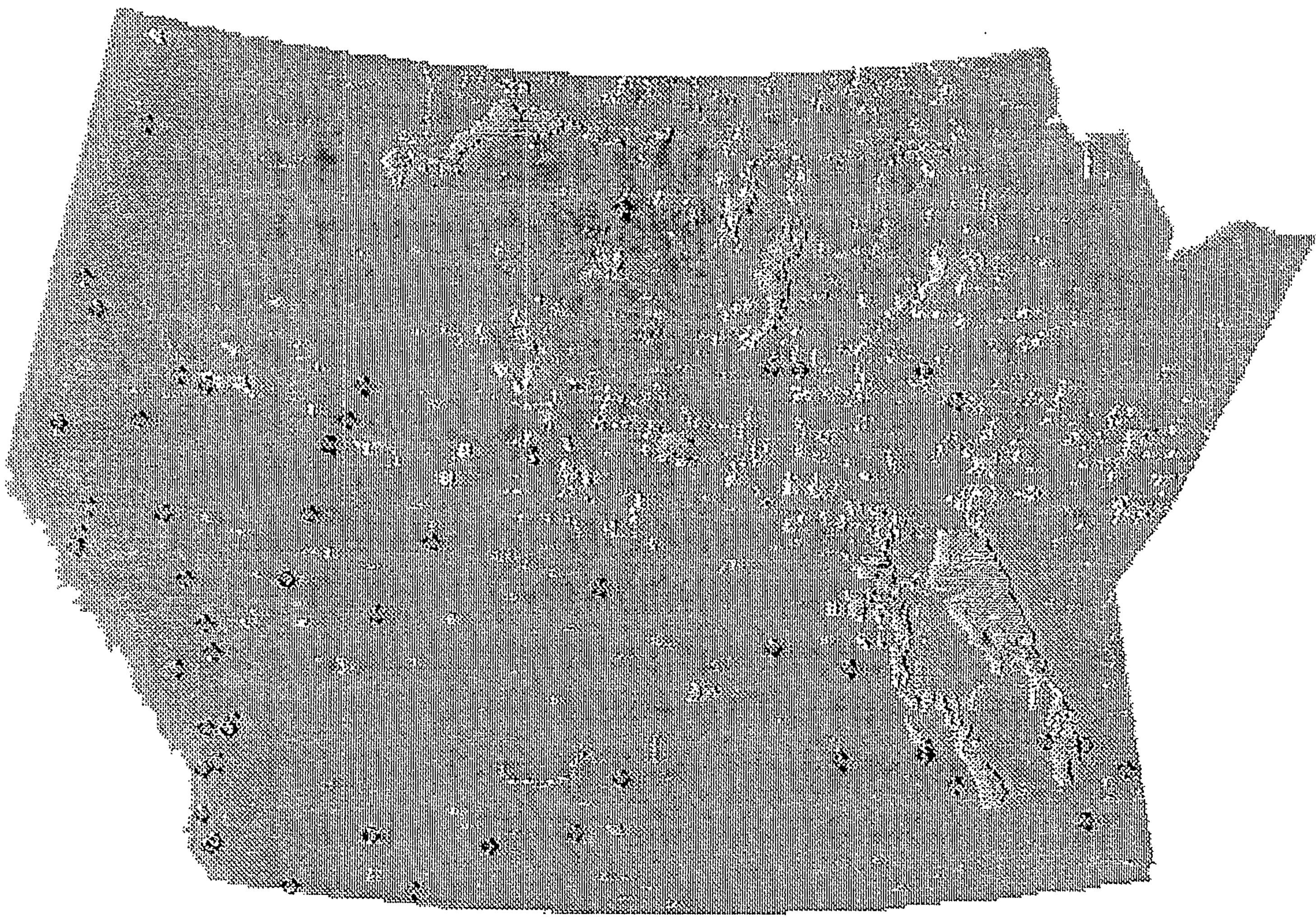
WSC Stations used in Forecasts

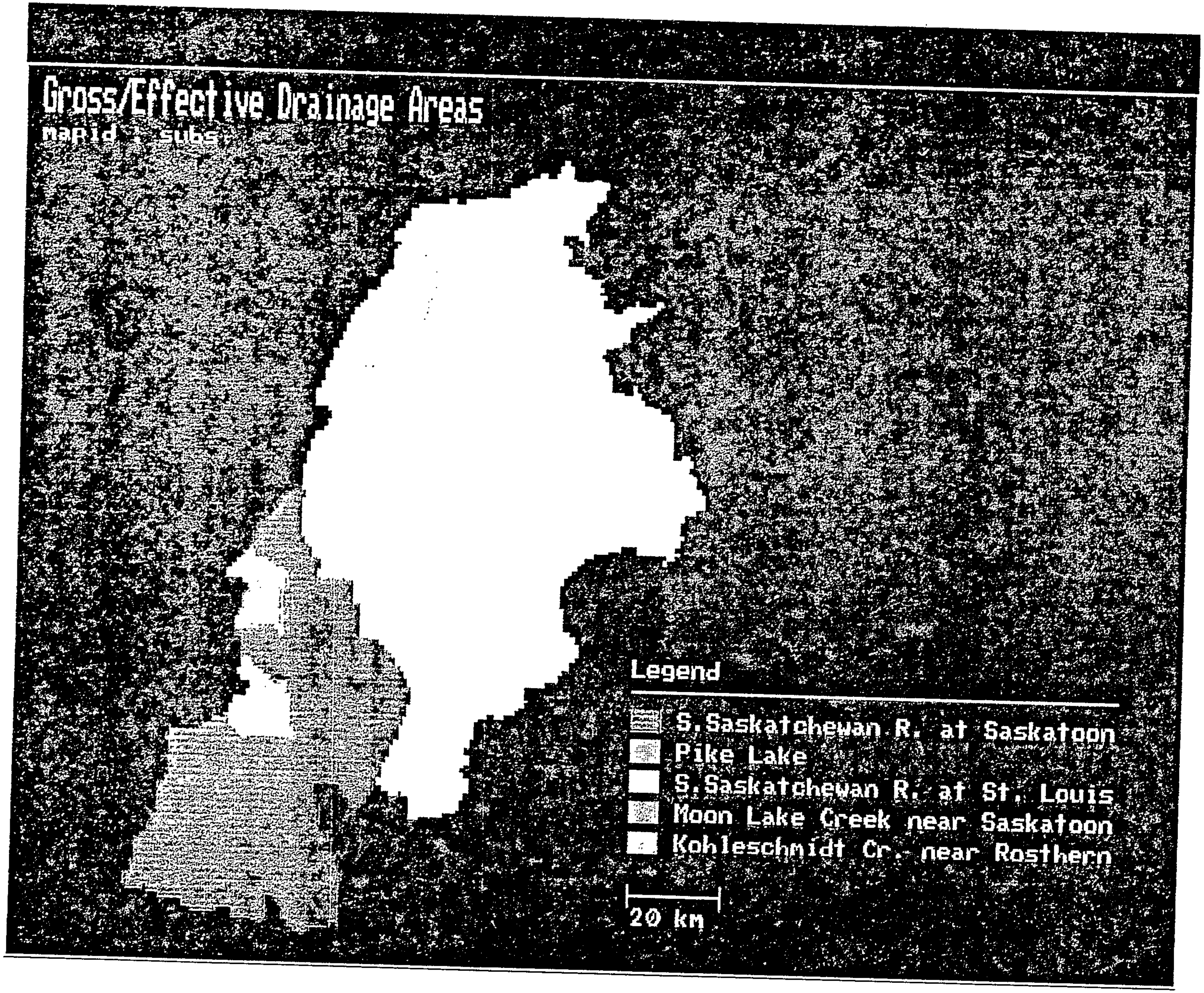
mapid : mask



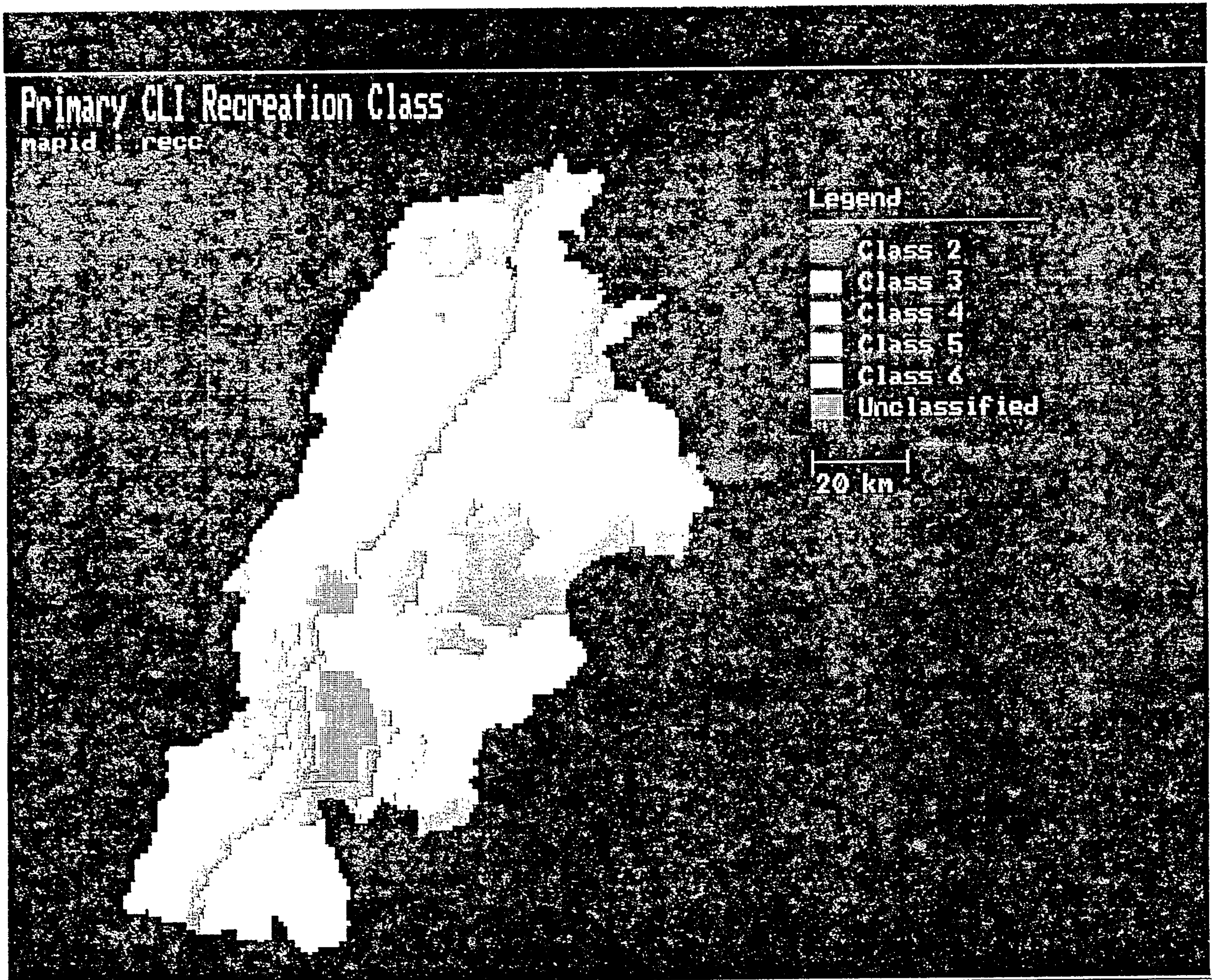
WSC Basins (1000 sq km

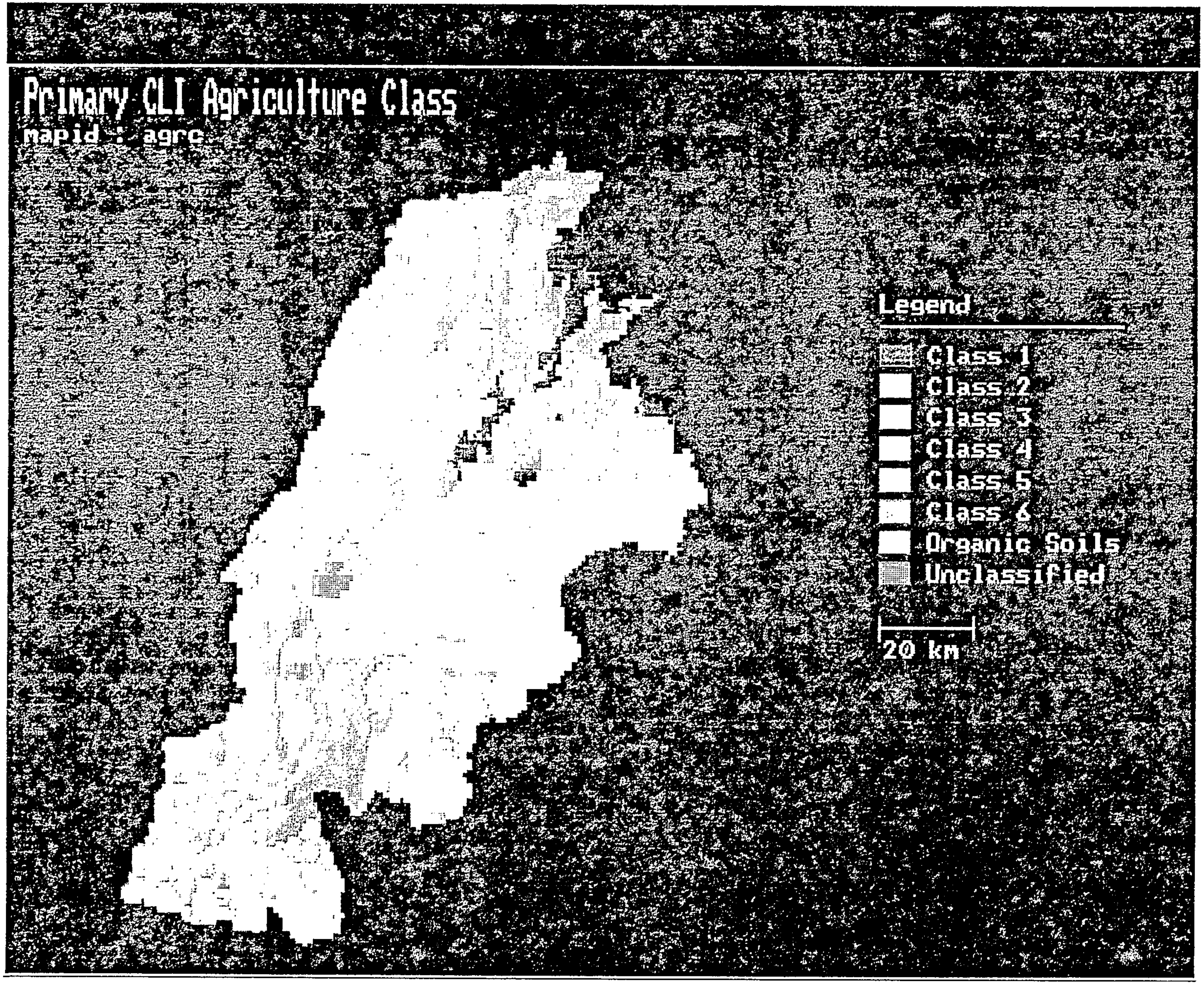
mapid : prfc

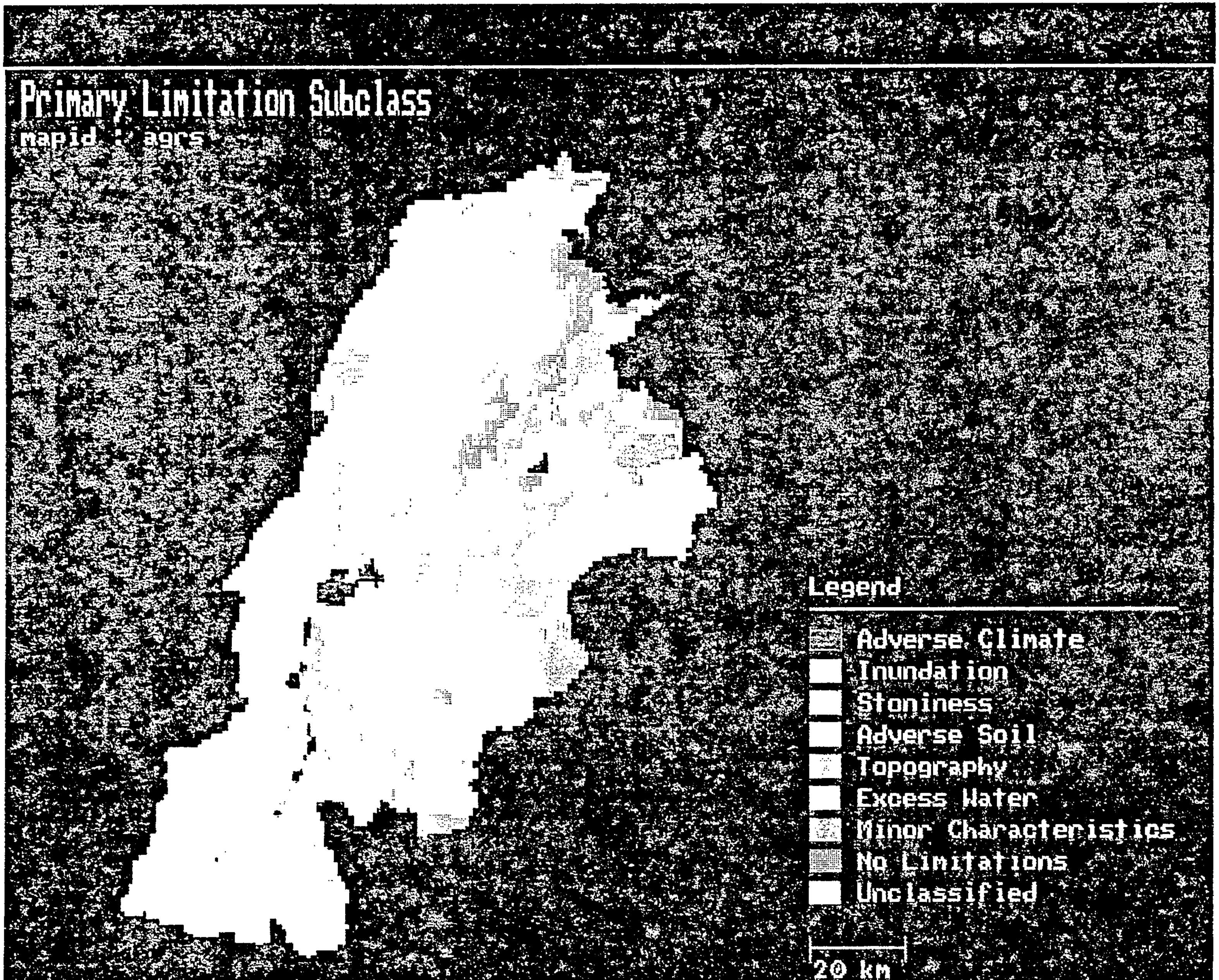




Gross/Effective Drainage Areas
Legend
S.Saskatchewan R. at Saskatoon
Pike Lake
S.Saskatchewan R. at St. Louis
Moon Lake Creek near Saskatoon
Kohleschmidt Cr. near Rosthern
20 km


Primary CLI Recreation Class
mapid : recc
Legend
Class 2
Class 3
Class 4
Class 5
Class 6
Unclassified
20 km


Primary CLI Agriculture Class
mapid : agrc
Legend
Class 1
Class 2
Class 3
Class 4
Class 5
Class 6
Organic Soils
Unclassified
20 km


Primary Limitation Subclass
mapid : agrs
Legend
Adverse Climate
Inundation
Stoniness
Adverse Soil
Topography
Excess Water
Minor Characteristics
No Limitations
Unclassified
20 km

FUTURE DEVELOPMENTS

- CD DATABASE LINKED TO GIS
- DISTRIBUTED PHYSICAL MODELLING
  - *HYDROTEL* – DTM INPUTS
- DIGITIZE ALL WSC WATERSHEDS IN CANADA
- EXPERT SYSTEMS – ASSIST IN DATA SELECTION

10. PANEL DISCUSSION - "COORDINATION OF NETWORK PLANNING ACTIVITIES"

NATIONAL WORKSHOP ON NETWORK
EVALUATION AND PLANNING
October 5-6, 1988
Winnipeg, Manitoba

Implementing Network Change in Alberta *

BACKGROUND

The past years have given us some unique experience in implementing change and it is some of these experiences that I would like to share with you today.

The 1980's have been very turbulent times for the Alberta hydrometric network as they have for the Province as a whole. We started out the decade with a very ambitious 5-year plan which envisaged the addition of 50 stations per year. (In fact we only installed 94 new stations over the period 1981-1986.) The need for the expansion was based on a requirement for basic hydrologic information in connection with a host of proposed energy related projects (and some of these were very large) to be located in several different parts of the province. The expansion phase had only just started when the political and economic situation related to energy changed dramatically and we were faced with the problem of reducing the size of network in order to comply with general directives from senior management to restrain spending.

* : by Mr. P. Valentine for Mr. G. Cole,
Alberta Environment

NETWORK INCREASES

The expansion phase was relatively easy to handle. The need for data in connection with large projects, to be built mainly in the northern part of the province, where the hydrometric network was extremely sparse, appeared self evident. Our desire to upgrade the network in areas where other projects were proposed was also supported at a time of economic growth and expanding revenues. I would emphasize here that although this phase did not last long, a great deal of work was done by our federal counterparts to accommodate the Province's desire for rapid expansion of the network. The Water Quantity agreement was shown to be flexible enough to adapt to a change in demand. Even though the plan was never fully implemented, the resources were made available by both levels of government and implementation did start. This was made possible by both parties to the agreement working with the highest degree of cooperation. It is our belief it is essential that any change to the hydrometric network must be implemented with the full support and cooperation of both parties to the agreement. The goals of the data users and the network operators should be the same.

NETWORK DECREASES

As you can imagine the constraint phase of our network development was much more difficult to deal with. The need for a mechanism to coordinate the interests of many different data users was required to deal with probable reductions in the network.

For this purpose, a Network Review Committee of three was established. The committee was made up of Gerald Coles as chairman, who, as a member of the Coordinating Committee and not a data user, could be considered neutral. The other representatives were from two of the department's largest data users, the Hydrology Branch who are most interested in the long term network and the River Forecast Centre whose interests are more concerned with real time data and water management functions. The Committee also consulted the other main users of hydrometric data in the Department in order to to find out which stations they saw as the most important.

It soon became obvious that given the financial situation at the time, curtailing new construction and other stop gap measures were not going to result in large enough savings. Reductions in the actual operating budget would therefore be necessary. Any one who has been through this exercise knows this is the hardest thing for network planners to do. In consultation with our federal colleagues we investigated how the savings could be made.

The possible alternatives were:

1. Reduce the number of station visits per year.
2. Reduce the number of visits to remote sites.
3. Actually cut the number of stations in the network.

The basic decision was made not to compromise the quality of the data. If cuts were to be made, it would be in quantity not quality.

The problem came down to which stations should be cut. It soon became obvious that from a provincial perspective, water management stations with a well defined purpose were much easier to defend than stations which had been established to define hydrologic characteristics. Fortunately, many of the stations with long term records were designated "Federal" and therefore were not subject to provincial constraint. Also, "Federal-Provincial" stations were also protected to some extent because the province would only receive 50% of the savings derived from cutting them. This "protection" feature of the network (which could operate in both directions), is possibly one of the most important benefits of the Federal-Provincial agreement. However, this protection of the long term stations, made our task even more difficult. We were forced to look at the operating performance of individual stations. WSC supplied us with lists of stations with less than ideal sites and which were not always producing good data. After a great deal of agony and soulsearching we selected the stations to be cut from the ones that were not giving good data and water management stations which we eventually agreed were not being used as much as some others.

In 1986-87 we discontinued 33 stations and over the last four years we have discontinued a total of 61 stations. I am sure we will regret some of these cuts in years to come. However, we do feel we used the correct approach when we eliminated the stations producing the poorest quality data. Close consultation with WSC and the data users were the most important factors in this process. What we learned was that reviewing station performance and eliminating poor stations are as much part of network planning as establishing new stations. There has been a recognition that the resources we have to run the network are finite and we must optimize the value we get for our money. I believe new technology presents tremendous opportunities to help get more value from the existing network. The introduction of data collection platforms for example, as given us "real time" data in remote areas which has helped improve flood forecasts and has reduced data losses.

OTHER NETWORK CHANGES

I would like to suggest that the following directions for change could be implemented in the future. These changes stress enhancements to the existing network:

1. Installation of more updated telemetry to make more "real time" data available to users. The benefits that these data bring to water resources management are frequently overwhelming in relation to the incremental cost. As Paul Valentine mentioned yesterday 25% of the Alberta hydrometric is now continuously monitored on a "real time" basis and it is difficult to imagine how we got away without some of these data in the past.

2. In cooperation with other users, install sensors at existing stations to measure additional parameters particularly in relation to water quality. These changes would make the network more relevant to a variety of users and thus help ensure further financial support in the years ahead.

Finally we should all strive to maintain the health of the existing hydrometric agreement. The agreement is the foundation on which hydrometric planning must be based in this country.

NETWORK REVIEW COMMITTEE

Objective

To establish an efficient and effective mechanism for evaluating existing data networks - hydrometric and climatological.

Terms of Reference

1. The Committee will be chaired by G. A. Coles, Head, Water Survey Section with representatives from River Forecast Centre, D. Graham, Hydrology, E. Kerr and River Engineering as required.

2. The Committee will conduct periodic reviews of the networks and will review any proposed changes.

3. The Committee will report to the Branch Heads' Committee through the Director.

4. The Committee is an internal review group charged with advising the Division on networks.

5. Items for review may be brought before the Committee by any of its members.

EDITOR'S NOTE:

The following three pages are contributed by:

1) Mr. D.B. Letvak
Senior Hydrological Engineer
Water Management Branch
Province of British Columbia

and

2) Mr. G. Tofte
Regional Chief
Water Resources Branch
Pacific & Yukon Region
Inland Waters Directorate
Vancouver, British Columbia

The three pages represent the outline used on the overheads and the notes used for the presentation.

OUTLINE

A. COOPERATIVE WATER QUANTITY SURVEYS AGREEMENT

Coordinating Committee Responsibility

a) Ongoing

i) Plan and Review Networks
ii) Determine and Review Station Designations
iii) Assure Standards
iv) Review expenditures
v) Estimate New Costs

b) Annually

i) Prepare Schedules
ii) Meet
iii) Report to Administrators

B. THE AGREEMENT

a) Signed: March 14, 1975
b) Between: Canada/Provinces/Territories
c) Why: Cost-Sharing for basic water quantity data

C. PLAN

a) WHAT, WHY

i) Regional Network
ii) Major Stream Network
iii) Annual Canvas
iv) Special Planning Studies
v) Year 2000 Plan

D. REVIEW

a) WHAT, WHY

i) Review of Station Use
ii) Circulation of Stations
iii) Review of Data Quality

E. RESOURCES

a) WHAT, WHY

i) Combine Planning and Reviewing Results

NETWORK PLANNING WORKSHOP
ROLE OF THE COORDINATING COMMITTEE

October 5, 1988

1. PLAN

A. What we do

Work and develop with a number of Network Planning Strategies

a. Regional Network
b. Major Streamflow Network
c. Annual Canvas by Provincial and Federal members to determine additional requirements
d. Special Planning Studies - Okanagan Basin, McKenzie Basin, Yukon Basin, Stikine-IskutBasin
e. Year 2000 Plan

B. Why we do it that way

a. Regional Network: a network planning strategy that is based on relating physiographic parameters and runoff characteristics so that we can transfer this to ungauged sites. The concept is supported by both Provincial and Federal Committee members. Implementation is being done within existing resources.

b. Major Streamflow Network: common sense high priority network, that was designed to fill obvious data needs in B.C. and Y.T. Again the concept is supported by Provincial and Federal members. Implementation is being done within existing resources.

c. Annual Canvas: this is a practically driven process that is based on communication with users and aimed at getting the best use of available resources and ensuring that we work in the highest priority areas.

d. Special Planning Studies: responding to management demands for studies of a multi-use and multi-agency.

e. Year 2000 Plan: part of a politically driven review of the role of government in the year 2000.

2. REVIEW

A. What we do

a. Review of station use: in 1985 to comply with the new guidelines.

A. What we do (contd)

b. Circulation of stations: proposed for discontinuation or where major repairs are required. Done annually with Provincial, Federal and some local agencies.

c. Review of stations with Data Quality or Operating Problems. Done annually by Committee.

B. Why we do it this way

a. Review of station use: all 720 stations in B.C. and Y.T. were reviewed and the station use was categorized to conform to the guidelines that related to the designation of funding responsibility.

b. Circulation of stations: the user's are canvassed annually to ensure that stations are not discontinued if the data is still required.

c. Review of stations: a process designed to avoid operating stations where we are collecting sub standard records.

3. RESOURCES P.Ys AND $

A. What we do

Committee uses the results of the Planning and Review processes combined with the available resources - people and dollars - and logistical considerations to identify the network additions, deletions and classification changes. This becomes the actual network that will be operated in the following year and is the practical result of the planning and reviewing process.

B. Why we do it

To do the best job within the context of the Water Quantity Cost-Sharing Agreement and within our resource limitations.

WHERE TO

PLANNING

We will continue to use our basic planning and management methods as described. We will routinely incorporate new tools such as the GIS and the HNIS (Hydrometric Network Information System). This is a proposed information system incorporating station uses, funding responsibility, provincial, management regions and other relevant information.

RESOURCES

Communication to senior management essential to keep selling our program and retaining our existing resource base.

HYDROMETRIC NETWORK PLANNING AND EVALUATION IN THE PACIFIC AND YUKON REGION

W.L. Kreuder, Head, Planning and Studies Section

R.M. Leith, Regional Hydrologist

Water Resources Branch

Vancouver, B.C.

September 29, 1988

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.

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.

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 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.

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.

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, 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

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.

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 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.

Notes on Presentation to Panel Discussion -
"Coordination of Network Planning Activities"
National Workshop on Network Evaluation and Planning,
October 5 - 6, 1988, Winnipeg

M. Kowalchuk
Hydrology Division
Water Resources Branch
Environment Canada

Network Evaluation and Planning in the Province of Manitoba

I will speak briefly on the cooperative approach that we will be taking in Manitoba with regard to network evaluation and planning.

By way of introduction to my presentation, a number of points that have been made over the past two days bear repeating. We have heard described how networks, especially hydrometric networks, have generally evolved in response to specific data needs, and that with current economic pressures we must place greater emphasis on rationalizing the network against the various competing demands. We must do this from a cost and function point of view. We must be assured that the network is managed well and that it will respond to the issues of the day, such as drought and water supply, as some of you have had to deal with this past summer, water quality, water diversion, wildlife conservation, and so on.

It was pointed out also that before we can resolve the issue of competing demands and identify effective networks, we must first gain a clear understanding of the networks that presently serve provincial, federal and other user needs. In doing so we must recognize the important role that technical analyses play in evaluating the quality of the data and relative worth of individual stations. Clearly, the task of network evaluation and planning requires the cooperative involvement of at least the major data users and those agencies responsible for the water resource.

In Manitoba, the Coordinators of the Cost-Share Agreement established a Subcommittee on Network Evaluation and Planning (NEP). The Subcommittee's task is to undertake and/or coordinate joint work-share projects that will lead towards improving the existing network.

The Subcommittee is composed of one member from the Water Resources Branch of Environment Canada, one member from the Manitoba Water Resources Branch, and one member from Manitoba Hydro. The Subcommitee's objectives, procedures and reporting structure are specified in a formal Terms of Reference (TOR). The TOR provide for other participants as well, as may be required where integration of networks, i.e. water quality, meteorological, is considered.

The Subcommittee has developed a 3-year Workplan with four primary goals (on flip chart). Corresponding to each of the goals, a number of achievable projects and products have also been defined. I will not describe these in detail as the workplan will only be submitted to the Coordinating Committee next week, but I will describe in general terms what we propose to do and perhaps identify the projects we can initiate in the first year.

You will note the goals (on the flip chart) are numbered 1 through 4. This numbering does not necessarily signify order of importance but rather a logical sequence.

- Workplan Goal 1

> "Enhance the understanding of the hyrometric network curently serving provincial, national, and other user needs."

We propose to compile a basic inventory of the network and prevailing hydrologic conditions by summarizing the important uses (and potential uses) and attributes of each station. These are the "Station Profiles" some of you have heard about. This data can form part of a computer data base which could serve effectively in classification reviews and other management and planning activities. I might point out that the participating agencies have all made some progress on these. About 25% of the "profiles" are now complete.

. Workplan Goal 2

> "Undertake and/or identify studies and projects required to facilitate effective network planning, design and evaluation".

As an important first step we can work towards improving the utility and availability of the collected data. This can be accomplished by preparing "Fact Sheets" for select stations and basins. The Subcommittee has prepared one such Fact Sheet for the Red River at Emerson. The Fact Sheet is displayed in the poster area, and as you may have noted, it contains a range of information such as drainage basin area, annual runoff values, frequency and flow duration curves, and so on. This is basic interpreted data or information that is compiled at a station during the course of routine data reviews, regional studies, and now, network related studies. With little additional effort, this information can be packaged as you see in the Emerson example. The Fact Sheet will be most useful to many users.

We propose also to undertake some regional assessments of floods, droughts, and yields.

. Workplan Goal 3

> "Assess the ability of the network to provide reliable water quantity information to meet identified needs (operations, regional hydrology).

Avenues of approach may include conducting data users workshops and questionnaire surveys in conjunction with technical analyses. The Water Resources Branch of Environment Canada will be hosting a District Data Users Workshop in February of next year. The Subcommittee can play an active role in developing the workshop program and in participating in the discussions.

In terms of technical analyses, we propose a "pragmatic approach" as devised by Whal and Crippen and as had been applied in the Atlantic Region. The Water Resources Branch of Environment Canada has completed a preliminary assessment of the network using this approach. The Subcommittee could build on this preliminary effort.

In addition, we will be investigating the feasibility of compiling a data base linked to a GIS which would integrate physiographic, hydrologic, climatologic and other information. This capability would contribute significantly to network studies as we have seen demonstrated.

- Workplan Goal 4

> "Design alternative network configurations and sampling strategies recognizing opportunities for integration of networks (water quality, meteorological, sediment)."

At the end of the 3 year study period, we will prepare a network plan identifying "management" and "regional" networks and provide recommendations regarding network optimization and priorities. As appropriate, we will identify alternative methods of providing or improving streamflow information utilizing techniques such as flow routing, regression analyses and watershed modelling.

In conclusion, I would like to state that we recognize the value of a cooperative approach to network planning and I would like to believe that we have made a good start.

11. PLENARY SESSION - RAPPORTEURS REPORTS

EDITOR'S NOTE

The following section consists of Rapporteurs' reports for three of the four sessions of the workshop. The rapporteurs were:

1) Mr. R.J. Bowering
Head, Hydrology Section
Manitoba Water Resources Branch
Winnipeg, Manitoba

October 5, 1988 - Afternoon Session

2) Mr. D. Ambler
Regional Hydrologist
Water Resources Branch
Inland Waters Directorate

October 6, 1988 - Morning Session

3) Mr. B. Yee
Boundary Waters Engineer
Water Resources Branch
Inland Waters Directorate
Regina, Saskatchewan

October 6, 1988 - Afternoon Session

The rapporteur's report for the morning session of October 5, 1988 was not available at the time of publication.

Network Planning Seminar

October 5, 1988 Afternoon session

Rapporteur: Rick Bowering

New Brunswick Network Study

Don Ambler and Sol Devar described their network study for New Brunswick. They considered socio-economic factors as well as hydrologic factors.

Their hydrologic study included assessment of minimum station density, attempts at data transfer, and regional analysis. The target network, based on hydrologic criteria was found to be 77 stations.

The socio-economic study was based on surveys and discussions. They priorized the network and set benefit/cost ratios for various network scenarios.

They found that the socio-economic considerations carried more weight in the network design study.

Recent USGS Experience in Network Planning

Will Thomas from the USGS provided an interesting presentation on network planning in the United States. In 1983 a cost effectiveness analysis study was initiated. The aim was to identify principal uses of the streamflow network and to identify lower cost alternatives. They surveyed 3500 stations and found a few redundancies and stations where the data requirement had ended.

They then examined alternate methods that could be used to acquire or generate data at a lower cost. Some of the findings were that small improvements can be made with fine tuning of the field program. However such changes are often not logistically realistic. They also found that on average five percent of the record is lost each year.

Mr. Thomas complimented the ASCE in their lobbying effort for maintenance of hydrologic monitoring. He also stated that a federal interagency group on network analysis has been established to examine ways to streamline data collection through coordination, network analysis, etc.

PANEL DISCUSSION on VALUE OF WATER

Question: How can you demonstrate and quantify the value of surface water to your agency?

Five speakers from varied backgrounds were on the panel.

1. Ron Coley - Ducks Unlimited

Ron opened with the surprising, but probably correct suggestion that Ducks Unlimited is most likely the largest single user of hydrometric data in Canada. Yet he didn't realize that people have discussions like these about network planning.

After reviewing the uses DU makes of the data Ron stated that the data is essential to their program. He estimated that without data Ducks Unlimited would have wasted $25 million on over and under-built structures over their first 50 years. Wastage over the next 20 years would be a further $50 million.

Recommendations:

- No downsizing of the network. A recent DU study indicated a high priority need for more stations, especially in small drainage basins.
- Maintain data quality. Do not privatize.
- Provide a data analysis service to users on a cost recovery basis.
- Include the private sector users in Network Analyses.

A possible conflict could arise with Ron's third recommendation. If the federal government provides more than very basic data analysis it could be considered to be providing unfair competition to the consulting firms.

2. Manfred Samp - Canadian Water Resources Association (CWRA)

In speaking for the CWRA Manfred spoke on behalf of a very diverse group of data users. He too stated that hydrometric data is essential for all water related programs.

He later made the very useful suggestion that CWRA could follow the lead of ASCE in lobbying the Federal and Provincial Governments about the importance of maintaining a strong data base. All data users would be well advised to do the same.

3. Tom Dafoe - Water Quality Branch, Environment Canada

Tom made an attempt to quantify the value of water quality rather than quantity data. He suggested the cost of data collection could be compared to the value of the resource, or could possibly be related to water treatment costs. However both methods have serious weaknesses. He then asked the value of a sunset over Lake Ontario, or of a duck. At some point economic analysis just doesn't fit.

Tom made a useful distinction between data and information. He suggested that we do not need to educate the masses. Most of the public and politicians are already aware of water issues. This is evident in the increasing demands water managers are getting for information. We must respond by promoting ourselves more effectively; by providing better products; by providing information rather than just data.

4. Dave Fairbairn - Water Planning and Management, Environment Canada

Dave questioned the validity of economic analyses that have been made on the value of hydrometric data. He suggested that we should differentiate between evaluating the benefits to the data user or to the society as a whole. Without a much narrower definition he would have little confidence in a study which found a benefit-cost ratio of 20:1 for collecting hydrometric data.

On the general topic of network planning Dave suggested that the quality of the record being collected should be considered as a variable. We all know that some data records are better than others. We have the choice of adding another station, or upgrading an existing station where quality is inadequate.

Dave aroused some in the audience by suggesting that regional hydrologic analysis should not be the basis for network design. After all, only a small percentage of the stations in most networks are used solely for regional hydrology. Al Perks later responded that the regional hydrology stations provide data for a wide range of needs beyond regional hydrology. Will Thomas added that the management-type station are considered to be a given in network analysis. The only real flexibility is in selecting the number of regional hydrology stations.

5. Saeed Chaudhary, Alberta Transportation and Utilities.

Saeed opened by describing his department's usage of hydrometric data. They use data for high flow and low flow analyses, fish passage design, scour analysis, and ice studies. Like the previous speakers, Saeed stated that they couldn't design their structures properly without hydrologic data. Large amounts of money would be wasted in terms of over designs and structure failures.

Saeed observed that future transportation development in Alberta will be in the north where the network is very sparse. There is a strong need for more data there.

Discussion

The general discussion that followed the presentations centered on why we attempt to put a value on hydrometric data collection. Paul Valentine suggested that it is required to convince senior management of the importance of maintaining the data base. Russell Boals asked why we go to so much effort for such a small group. Perhaps they could be persuaded by a study of a demonstration sample. Perhaps also we strive for too much accuracy in determining benefits. Maybe a rough estimate which can be presented authoritatively would do the trick.

Finally Saeed Chaudhary reminded the participants that the value of data for a particular station increases with the period of record. We are therefore investing not only in the present, but also in the future when we maintain and improve our hydrometric data base in Canada.

HYDROMETIC NETWORK PLANNING WORKSHOP
OCTOBER 5/6, 1988
WINNIPEG, MANITOBA

RAPPORTEURS REPORT
FOR
OCTOBER 6 MORNING SESSION

RELATED DATA NETWORKS

[A] METEOROLOGICAL

THE PRESENTATION WAS GIVEN BY R. RADDATZ OF THE ATMOSPHERIC ENVIRONMENT SERVICE. MR. RADDATZ BEGAN BY NOTING THAT THERE ARE MANY SIMILARITIES IN PLANNING THE HYDROMETRIC AND METEOROLOGIC NETWORKS. SUCH THINGS AS STATION DENSITY AND THERE LOCATIONS ARE COMMON TO BOTH PLANNING APPROACHES. A DEFINITION OF THE CURRENT STATE IS NEEDED FROM BOTH TYPES OF NETWORKS. VARIOUS TYPES OF MET NETWORKS ARE OPERATED. THESE INCLUDE A SYNOPTIC OR BROAD SCALE NETWORK, UPPER AIR STATIONS, A CLIMATIC NETWORK AMD VARIOUS SPECIAL PURPOSE NETWORKS. PLANNING IS DONE FROM A BASIS OF MANDATE, POLICIES, STANDARDS, AND FOR ANALYTICAL REASONS. THE MAIN GOAL IS TO DEFINE THE CLIMATE OF CANADA. THE COST OF STATIONS IS CARRIED BY EITHER THE PROPONENT OR THE COOPERATOR. THERE IS A DIFFICUTY IN PLACING MET STATIONS AT HYDROMETRIC STATIONS AS STANDARDS FOR MET STATIONS ARE NOT ALWAYS FOUND AT THE SITES. THE PLANNING CRITERIA FOR MET STATIONS INCLUDES ASKING IF POINT TO POINT DATA TRANSFER IS POSSIBLE, OR IF POINT TO SURROUNDING AREA TRANSFER IS POSSIBLE OR CAN POINT DATA BE USED TO MAKE ISOLINES TO THEN GIVE DATA IN UNGAUGED AREAS. THE ACCURACY OF THE MET DATA IS APPLICATION DEPENDENT, IE. IS IT FOR RECREATION USE OR RESEARCH USE? MR. RADDATZ ENDED HIS TALK BY GIVING A CASE STUDY EXAMPLE.

[B] WATER QUALITY

THE TALK WAS GIVEN BY E. WATT RATHER THAN R. KWIATKOWSKI AS NOTED ON THE AGENDA. MR. WATT BEGAN BY NOTING THAT FEDERAL/PROVINCIAL AGREEMENTS ARE BEING DEVELOPED MUCH AS THE SURFACE WATER AGREEMENTS BEGUN IN 1975. THE WATER QUALITY BRANCH LEAD ROLE IS TO DEFINE THE QUALITY OF CANADA'S AMBIENT WATER. THE BRANCH IS THE HOME OF NAQUADAT, THE NATIONAL WATER QUALITY DATABASE. THE BRANCH DESIGN DIFFERENT NETWORKS FOR DIFFERENT REASONS BUT ALL ARE TO THE SAME STANDARDS. FLEXIBILITY IS WANTED IN THE NETWORKS LEADING TO SOME ASPECTS CHANGING FROM TIME TO TIME. TODAYS REASONS FOR PLANNING ARE ALONG THE ECOSYSTEM APROACH. THE BASIC PLANNING OBJECTIVES INCLUDE PLANNING FOR THE TRACKING OF TRENDS, TO HELP JUDGE DRINKING WATER STANDARDS, TO HELP IN EMERGING ISSUES, AND TO SUPPORT SOE AND EIS EFFORTS. THERE IS A SO-CALLED FIXED NETWORK OF KEY, LONG-TERM REGULAR SAMPLING STATIONS. THESE ARE MOSTLY AT WRB STATIONS WHILE THERE ARE ALSO SPECIAL PURPOSE NETWORKS. THESE ARE RECURRENT, SPECIAL PURPOSE, CAUSE-EFFECT, SOURCE OF POLLUTION TYPE STUDIES. THE MONITORING OF BOUNDARY WATERS IS ALSO A MANDATED NETWORK PLANNING DESIGN CRITERIA. ISSUES NETWORKS ARE LOOKING INTO THE LRTAP AND DIOXIN ISSUES OF THE DAY. THE INDEX NETWORK IS ABOUT 80 TO 100 STATIONS ACROSS CANADA.

[C] SEDIMENT

DR. T. DAY PRESENTED THE TALK ON THE SEDIMENT NETWORK. THE SEDIMENT SECTION IS IN THE WATER SURVEY OF CANADA IN OTTAWA. THE MAIN PURPOSE IS TO ADVICE ON SEDIMENT ISSUES, TO PROVIDE DATA, DEVELOP METHODS AND STANDARDS. THERE HAVE BEEN 800 SITES IN CANADA WHILE AT THIS TIME THERE ARE ABOUT 200 ACTIVE SAMPLING SITES. THE CURRENT CHALLENGE IS TO MINIMIZE THE EFFECTS OF DOWNSIZING WHILE MAXIMIZING INTEGRATION WITH OTHER NETWORKS. DIVERSIFICATION IS NEEDED IN ORDER TO LINK TO TODAYS EMERGING ISSUES. A COMMUNICATIONS

CHALLENGE EXISTS TO GET THE SEDIMENT DATA WIDLEY USED. THE NETWORK IS RELATIVELY STABLE. THE SECTION HAS A SKILLS PROBLEM LEADING TO A NUMBER OF CONTRACTED OUT PROJECTS. AN IMPORTANT CURRENT JOB IS TO DEVELOP SEDIMENT STATION PROFILES AND MANAGEMENT PLANS FOR EACH STATION. DATA ANALYSIS HAVE BEEN ELEMENTARY TO DATE. THERE IS A SHIFTING OF PRIORITY FROM LONG-TERM STATIONS TO MISCELLANEOUS STATIONS. AN EXAMPLE OF THE DIVERSIFICATION IS FOUND IN ONTARIO AND ALBERTA SEDIMENT CHARATERISTICS REPORTS. THE REPORTS ARE MOVING TOWARDS MULTI- DISCININIPLARY, MULTI-ISSUE AND MULTI-SITE STYLES. INTEGRATION WITH OTHER NETWORK PLANNING IS BEING LOOKED INTO HOWEVER, THERE MAY BE PROBLEMS WITH SITE STANDARDS. AS WITH OTHER NETWORKS THERE IS A COMMUNICATIONS CHALLENGE TO SELL AND DEFEND THE SEDIMENT DATA AND SURVEYS.

REGIONAL HYDROLOGY IN CANADA

THIS SESSION WAS INTRODUCED BY A. PERKS. IT WAS NOTED THAT A NATIONAL APPROACH IS NEEDED. THERE ARE MANY WAYS TO DEFINE REGIONAL HYDROLOGY. THESE RANGE IN FORM FROM RATHER RANDOM TO HIGHLY TECHNICAL METHODS.

P. PILON WAS INTRODUCED AS A REPLACEMENT TO J. POWER AS NOTED ON THE AGENDA. MR. PILON BEGAN WITH A QUESTION," WHAT IS A REGION? " THERE ARE TWO MAIN WAYS TO DEFINE A HYDROLOGIC REGION. THESE ARE STATISTICAL AND PHYSICAL. AN EXAMPLE USED IN ONTARIO WAS REFERENCED WHERE INDEX CURVES WERE USED TO DEFINE FLOW AT UNGAUGED SITES IN 3 INDEX REGIONS. ALSO, A PHYSICAL APPROACH WAS USED BY SELECTING 4 PARAMETERS. THIS RESULTED IN 81 REGIONS IN SOTHERN ONTARIO ALONE. USING THE SAME METHODS IN BRITISH COLUMBIA GAVE 29 ZONES. A SUBSTANTIALLY DIFFERENT AREA IN SIZE AND TOPOGRAPHY. THERE MAY BE TROUBLE AT TIMES WITH THE REGIONALIZATION WHEN THE AUTHORS HAVE ROSE COLOURED GLASSES AND END UP WITH SELF-FULFILLING ANWSERS. A REPORT DONE BY ACRES LTD. IN 1988 WAS REFERENCED. ALSO

MENTIONED WAS A REPORT DONE IN GREAT BRITAIN. THE WATER RESOURCES BRANCH HAS BEEN TRYING TO DEFINE THE MEAN ANNUAL FLOOD ACROSS CANADA. THIS SOUNDS SIMPLE BUT HAS BEEN DIFFICULT. REGIONAL STUDIES HAVE BEEN CARRIED OUT LEADING TO BENEFITS IN TERMS OF DESIGN INFORMATION, AND CO-OPERATION AMONG THE PLANNING AGENCIES. FLOOD FLOWS AND LOW FLOWS HAVE BEEN REGIONALIZED IN SOME AREAS. THE APPLICATION OF NEW TECHNIQUES AND NEW STRATEGIES IS LEADING TO BETTER WATER RESOURCE DECISIONS. MR. PILON ENDED BY NOTING THE APPROACH TO REGIONAL STUDIES. THIS INCLUDES AN INVENTORY PHASE, A DATA SCREENING PHASE, AND AN ANALYSIS PHASE AND A LIST OF PRIORITIES PHASE BASED ON THE FINDINGS.

GEOGRAPHICAL INFORMATION SYSTEMS-
APPLICATIONS IN NETWORK PLANNING

THE LAST SPEAKER OF THE SESSION WAS MR. D. JOBIN. HE SPOKE ON GIS, GEOGRAPHIC INFORMATION SYSTEMS. THEY HAVE BEEN DEVELOPED TO HELP MANAGE LARGE DATABASES. THEY HAVE BEEN AROUND FOR ALONG TIME AND ARE EXPENSIVE TO DEVELOP. THEY ARE A RECOGNIZED TOOL FOR INTEGRATING DIGITAL DATA WITH MAPS. THE MAIN ELEMENTS ARE INPUT, OUTPUT, ANALYLIS AND ACQUISION. MOST PEOPLE CANNOT AFFORD THESE TYPES OF DATABASES. ALL OF THE BASES ARE REFERENCED TO SOME SORT OF COORDINATE SYSTEM. THE DATABASES INTEGRATE MANY PARAMETERS AND ARE A POWERFUL MANAGEMENT TOOL AS CHANGES CAN BE MADE FAST AND DATA ACCESS IN FAST.
MR. J. POWER WAS INTRODUCED TO CONTINUE THE SESSION. HE OUTLINED THE WRB USE OF SUCH DATABASES. THESE INCLUDE THE PRODUCTION OF DISPLAYS AND FOR DATA ANALYSIS, TO INPUT TO MODELS AND TO HELP INTEGRATE THE DATA FROM OTHER DATABASES. THE USE OF GIS IS A VEHICLE OR CORE FOR MANAGEMENT TO USE. WRB OUTPUTS FROM APPLICATIONS WILL INCLUDE FACT SHEETS, DISPLAY GRAPHICS. EXAMPLES WERE SHOWN OF OVERLAYS ON WATERSHED MAPS. FUTURE USES BEENING CONSIDERED INCLUDE LINKING TO THE CD-ROM DATA SETS, DISTRIBUTED MODEL APPLICATIONS, DIGITIZING OF WSC BASIN

DELINEATIONS AND AS AN ADD ON TO EXPERT SYSTEMS.

MR. JOBIN CONTINUED BY OUTLINING THE DATA ACQUISITION PROCEDURES. NEW HARDWARE HAS MADE IT VERY MUCH LESS EXPENSIVE THAN PREVIOUSLY. MANY SOURCES OF MAPS ARE ALREADY IN DIGITAL FORM, THIS AIDS IN THEIR INTEGRATION INTO GIS. IT NOW COSTS 70 TO 90 DOLLARS TO DIGITIZE A MAP BY SCANNING. THIS IS VERY ACCURATED AND READY FOR USE IN GIS. THE MAIN ISSUE, THAT OF REDUCING THE COST OF DATA AQUISITION HAS BEEN OVERCOME BY THE USE OF SCANNERS.

NATIONAL WORKSHOP ON NETWORK
EVALUATION AND PLANNING

RAPPORTEUR'S REPORT FOR OCTOBER 6, 1988 AFTERNOON SESSION

Presenter: Al Perks, Chief, Hydrology Division, WRB, Environment Canada, Ottawa
Topic: Marketing, Data Products, and Information

"How can we get the message out and enhance the value of our information?"

Our target audiences are:

1. senior management,
2. professional users, and
3. the general public and other non-traditional users.

Marketing to the professional user may be done through presentations and displays at technical conferences and workshops. Marketing to the public may be done through the media.

Al opened the floor to the audience for discussion on what things should be considered when "marketing" to the senior manager. Al noted that it can be difficult to sell the value of scientific information to the non-technical manager. Following are some the points raised in the discussion.

- make clear to them the benefit/cost ratio
- explain why your program is in existence and how you address the program
- show your program efficiencies
- clearly show how your program addresses current issues
- show how your program applies to future development
- show that your justifications are scientifically sound
- show your role in developing expertise in the field of hydrology
- show your client base
- show how your data is critical to decision making
- develop scenarios of the consequences of less hydrometric data or no hydrometric data

Following Al's presentation there was a panel discussion on the "Coordination of Network Planning Activities".

Presenter: Gord Tofte, Regional Chief, WRB, Environment Canada, Pacific and Yukon Region

Gord described the Federal-Provincial cooperative water quantity surveys agreement in place in the P & Y Region and the role of the F-P coordinating committee.

The committee:

- plans and reviews the hydrometric network,
- determines and reviews the cost-sharing status of the hydrometric stations,
- assures standards,
- reviews expenditures,
- and estimates new costs.

Presenter: Jess Jasper, DIAND, Yellowknife

Jess, similar to Gord, described the role of the coordinators in the NWT. The current areas of cooperation are in: water quantity data collection, the flood damage reduction program, and in water quality data collection. Future areas of cooperation will include: the integration of data networks, and in basin studies. He noted that the coordinators had to contend with constraints in budgets and person-years, and external pressures (public and political) which were producing unequal emphasis on different aspects of the programs.

Presenter: Paul Valentine, Alberta Environment, Edmonton

Paul described the 5 year network expansion program which Alberta had developed in the early 1980's. Budgetary restraints resulted in only partial completion of the expansion program, and the F-P coordinating committee had to reduce costs by either reducing the number of station visits or by reducing the number of stations. They decided to cut quantity not quality.

Paul said that in the present state of restraint, network managers would have to stress enhancements to the existing network. He foresees an increase in the real-time network and he suggested that increasing the number of sensors at DCPs would make the network more relevant to additional users.

Presenter: Mike Kowalchuk, Regional Hydrologist, WRB, Environment Canada, Winnipeg

Mike stated that the network coordinators had a responsibility to manage the network and had to respond to issues. The Fed-Prov coordinating committee in Manitoba had recently struck a joint network planning and evaluation sub-committee. The sub-committee has developed a 3-year work plan with the following goals:

Goal 1 Enhance the understanding of the current network. This would be done through an inventory of current station purposes and data users.

Goal 2 Undertake and identify studies and projects to facilitate effective network planning, design, and evaluation.

Goal 3 Assess the network for its ability to provide reliable information to meet identified needs.

Goal 4 Design alternative network configurations and sampling strategies recognizing opportunities for integration of networks (water quantity/quality, sediment, meteorological).

Presenter: Percy Campbell, Chief, Water Survey of Canada Division, WRB, Environment Canada, Ottawa

Percy presented a slide show which was the people's choice for Best Use of Colour and Special Effects. The slide show was on the future direction of the WSC and future trends for automation, both in the field and in the office. Percy noted that the future direction of the WSC was clear, however the path and timing was not.

Several questions were raised by the audience after the slide show, particularly about costs of the new equipment, training of WSC technicians, and reliability of the new electronic equipment. Dale Kimmett, Director, WRB and Percy both addressed these questions. Their response was that it would cost less to equip a station with the new electronic equipment than with the traditional analog equipment; that the WRB management had developed a Career Development Program which would include training of the technicians in the new technology; and that the new electronic equipment is more reliable than the old traditional equipment.

12. WRAP-UP

National Workshop on Hydrometric Network Planning

October 5 -6, 1988

Winnipeg, Manitoba

The following conclusions and recommendations were adopted at the plenary session of the Workshop.

1. Increased cooperative efforts between the Federal and Provincial agencies involved are necessary to better plan and evaluate the hydrometric networks. The establishment of Network Planning Subcommittees, on a regional basis, would be a good vehicle to accomplish this. Such subcommittees would meet on a regular basis, under the auspices of the Coordinators, with a mandate to develop proposals for joint projects and work-sharing, new interpreted products and information, increased contact with and input from users regarding network planning, and integrated planning of hydrometric, water quality, and meteorological data needs.

2. The preparation of information on the value of surface water data and information, and its role in environmental, socio-economic, and water management decision-making is considered to be very important. A working group composed of WRB and the Coordinators of Alberta, Ontario, and Nova Scotia will work towards assembling and documenting relevant material for the workshop attendees.

3. Better understanding of how hydrometric, water quality, and meteorological data needs are linked, is an important aspect and should be pursued nationally and regionally as fully as practical.

4. Involvement of users from the private sector in hydrometric network planning constitutes an important follow-up to the last two workshops. A series of user workshops should be held on a regional basis, aimed at identifying user needs for data and information, which might lead to other planning alternatives.

5. The application of Geographical Information Systems, and new more convenient data storage and distribution media (ie optical disks), are important initiatives that should be implemented for the benefit of the cooperating agencies and users as quickly as possible.

A.R. Perks, P. Eng.
Water Resources Branch

13. LIST OF PARTICIPANTS

LIST OF PARTICIPANTS

NAME		ORGANIZATION
1.	Daniel Jobin	Nucor Computing Resources Inc.
2.	Rick Bowering	Manitoba Water Resources
3.	Bob Harrison	Manitoba Water Resources
4.	Rick Raddatz	AES - Environment Canada - Wpg.
5.	Charlie Stevens	Ontario Hydro
6.	Don Ambler	WRB - Atlantic
7.	Mike Renouf	WRB - Regina
8.	J.R.R. Bourdages	IWD - Longueuil
9.	Charlotte Bastein	IWD - Longueuil
10.	Ron Coley	Ducks Unlimited
11.	Henry Westermann	WRB - Yellowknife, NWT
12.	Bob Hale	WRB - Winnipeg
13.	Saeed Choudhary	Alberta Transportation & Utilities Edmonton
14.	Manfred Samp	Canadian Water Res. Association
15.	Minay Austford	Manitoba Water Resources - Wpg.
16.	Bob Phinney	WRB - Guelph
17.	Jack Wedel	WPM - Yellowknife
18.	Will Thomas	U.S. Geological Survey - Reston, VA
19.	Brian Johnson	WRB - Regina
20.	Wasi Ullah	Nfld. Evnrionment, St. John's
21.	Val Chacko	Water Quality, Environment Canada
22.	Brian Yee	Environment Canada - WRB, Regina
23.	Peter Abel	Manitoba Hydro, Winnipeg
24.	Robert Chang	Ont. Ministry Natural Resources
25.	Vir K. Khanna	Calgary, Alberta - WRB
26.	Kim Kelly	Regina - WRB
27.	Herb Doane	N.S. Environment
28.	Evan Watt	WQB - HQ
29.	Paul Valentine	Alberta Environment
30.	Paul Pilon	WRB - HQ
31.	Percy Campbell	Water Survey of Canada - HQ
32.	Bruce Letvak	Min. of Environment - Prov. of B.C.
33.	Jesse Jasper	DIAND - Yellowknife
34.	Bill Brimley	IWD - Darthmouth
35.	Zal Davar	IWD - Darthmouth
36.	Chris Katopodis	Freshwater Institute - Winnipeg
37.	Len Kamp	WRB - Guelph
38.	Herman Goertz	WRB - Guelph
39.	Alex Banga	Sask. Water
40.	Arthur G. Redshaw	IWD - Yellowknife, NWT
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43.	Dave Fairbairn	IWD - Regina, Saskatchewan
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47.	Tom Dafoe	WQB - Hull
48.	Wally Kreuder	WRB - Vancouver

LIST OF PARTICIPANTS (Cont'd)

49.	Michael Kowalchuk	WRB - Winnipeg
50.	George Hanson	WRB - Winnipeg
51.	R. Boals	WRB - Regina
52.	Dale Kimmett	WRB - HQ
53.	L. Warner	WRB - Calgary
54.	J. Power	WRB - HQ
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56.	G. Totte	WRB - Vancouver