1984 REVIEW OF THE NORTHERN TERRITORY
SURFACE HYDROLOGIC INFORMATION NETWORK

VOLUME 1

Report for Stage 2 of Water Division Project No. 3041

Prepared By: T J Verhoeven and A Deen
Water Division
Darwin
October 1984

10:REP3
SYNOPSIS

The review and upgrading of the Northern Territory surface hydrologic information network to meet future data needs is described in two volumes. Volume One describes the current setting of data collection, processing and analysis. The network design concepts adopted, and the factors considered in the design and review of networks of gauging and meteorological stations, are described.
**CONTENTS**

**SYNOPSIS**

**TABLE OF CONTENTS**

**LIST OF TABLES**

**LIST OF FIGURES**

**CONCLUSIONS AND RESOLUTIONS**

**CHAPTER 1**

**INTRODUCTION**

Background
Objectives
Scope of this document

**CHAPTER 2**

**HISTORY OF THE SURFACE HYDROLOGIC NETWORK IN THE NORTHERN TERRITORY**

Gauging Stations
Climate Stations

**CHAPTER 3**

**NETWORK DESIGN CONCEPTS**

Why have networks?
Classification
Resource inventory network
Project station network
Integration

**CHAPTER 4**

**NETWORK DENSITY**

**CHAPTER 5**

**THE PROCESS OF NETWORK DESIGN**

Design team
Design process

**CHAPTER 6**

**NETWORK REVIEW**

Review process
Duration of station operation

**CHAPTER 7**

**DATA PROCESSING AND ANALYSIS**

**CHAPTER 8**

**FUNDING**

Past funding arrangements
Present costs
Future funding

**CHAPTER 9**

**REFERENCES**

**APPENDIX 1**

**MINIMUM STREAMFLOW RECORD LENGTHS**

10:REP3
(iv)

LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 3.2</td>
<td>Network design: Classification of gauging stations.</td>
</tr>
<tr>
<td>Table 4</td>
<td>Minimum network density</td>
</tr>
</tbody>
</table>

LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 4</td>
<td>Stream Gauging Network Density Zones</td>
</tr>
<tr>
<td>Figure 5.2</td>
<td>Australian Water Resources Council: Drainage Divisions and River Basins within the Northern Territory</td>
</tr>
</tbody>
</table>
CONCLUSIONS AND RESOLUTIONS

Conclusion 1  It is concluded that the present surface hydrologic network in the Northern Territory is in need of major review. (Section 1.1).

Resolution 1  There are two main classes of network: the resource inventory network to provide a quantitative understanding of the variability of hydrologic events areally and with time, and the project station network to provide information for present and imminent project needs (Section 3.1).

Resolution 2  The station classification system is based on the current main purpose of each station (Section 3.2).

Conclusion 2  It is concluded that hydrologic data networks should be an integration of stations collecting information on streamflow, water bodies, climate and catchment. Furthermore, these networks should be integrated with groundwater inventory networks (Section 3.5).

Resolution 3  The surface hydrologic collection program includes streamflow (discharge, water quality, sediment load, peak/low partial flows), water bodies, climate and catchment (Section 3.5).

Resolution 4  For the resource inventory network, the network design team sets the appropriate density of stations after considering local factors listed in Chapter 4.

10:REP3
(vi)

Conclusion 3  It is concluded that the network design team includes professional and technical staff based in Darwin, Katherine and Alice Springs; hydrologists who have the best working knowledge of hydrologic characteristics of the regions under consideration. This team must have access to advice from water planners and other users (Section 5.1).

Conclusion 4  It is concluded that the design of the project station network is straightforward, being based on the information requirements of the specific user (Section 5.2).

Resolution 5  Examination of the resource inventory network includes design of the required network for the Northern Territory, and then incorporation of existing stations, where suitable, within the network. The steps in this design process are set out in Section 5.2.

Conclusion 5  It is concluded that both the resource inventory and project networks must be reviewed at regular intervals to evaluate their effectiveness (Section 6.1).

Resolution 6  Following establishment of the networks, annual reviews are to be conducted jointly by the Senior Engineer Projects and the Principal Technical Officer. The timing of these reviews and their scope are detailed in Section 6.1.
Resolution 7  Following this study detailed network reviews (entailing data processing, analysis and application of new technology) are to be conducted at five-yearly intervals. The next such review is to be completed in 1990.

Conclusion 6  It is concluded that there is no simple test which indicates the length of operation of a station. Guidelines are given in Section 6.2; accuracy goals for the Northern Territory need to be established.

Conclusion 7  It is concluded that to have an effective hydrologic information system, data needs not only be collected but also processed, analysed and used (Chapter 7).

Resolution 8  Records of all stations are to be processed and readily available on computer media and as hard copy within twelve months of the end of each water year (Chapter 7).

Resolution 9  Water Division is to embark on a program of hydrologic analysis of data collected at each station, as part of the input to the five-yearly review (Chapter 7).

Resolution 10  Water Division is to develop the ability to reliably fill-in missing record using modelling and correlation techniques appropriate to the various hydrologic regimes in the Northern Territory (Chapter 7).
As a general rule the funding of the construction and operation of project stations is to be met by the client (Section 8.3).

It is concluded that the Commonwealth is to fund the costs of operating national resource inventory stations, (currently 120 stations) with the Northern Territory to fund the remaining stations (Section 8.3).

The Commonwealth is to be approached to fund the construction of any new stations which will form part of the national resource inventory network. The Northern Territory will fund construction of new stations which form part of the local network (Section 8.3).
1. INTRODUCTION

1.1 Background

Information of varying length on the behaviour of Northern Territory rivers is available for 391 stream gauging locations. At 221 of these locations (including both resource inventory and specific project stations) water level recording and in many cases calibration are still being carried out. In addition, a network of 102 pluviographs (rainfall monitoring stations) is operated in conjunction with the stream gauging stations.

The hydrologic network has expanded considerably since the first stream gauging stations were commissioned in the early 1950's. In addition, stations have changed status, while project stations (including monitoring of effluent releases, tides, water quality and sediment transport) have been added. Often the information collected has been of use both for a specific project and for resource inventory purposes.

The hydrologic network has been reviewed periodically, the last review being by the Snowy Mountains Engineering Corporation (Reference 10) and by Kingston in 1980 (Reference 4). Since that review a number of events have occurred which, when combined, make the present appraisal of the network mandatory. These events include:

(i) National (Reference 9) and Northern Territory (Reference 12) studies which examined the Territory's water needs.

(ii) Arising from (i) the development within Water Division of five and twenty-year programs of water resource investigation and management. These programs helped clarify the hydrologic monitoring/data collection requirements.
-2-

(iii) The addition of more components to the network (for example water quality monitoring) but a reduction of in-house manpower resources to operate and maintain it. This has necessitated examining ways to streamline data collection and keep to a minimum the number of stations (by using multi-purpose stations for example); cost-effectiveness.

(iv) Preparation of a report on network design by the Australian Water Resources Council (AWRC) in 1982 (Reference 1). This latest, nationally-recognised approach differs from the approach used by Kingston (Reference 4).

(v) The digitising and computer storage of a large volume of data, and the rating of more stations, enabling review of the continuation of these stations.

1.2 Objectives

The objectives of this study are:

1. Review the network of resource inventory stations within the Northern Territory for the measurement of precipitation, streamflow, surface water quality and sediment load.

2. Review the operation of project stations, including those monitoring tides, surface water supply (bulk collection) and effluent release.

3. Make recommendations for change (if any) to the networks to meet the data requirements for the five-year and twenty-year programs of water resource investigation and management; prepare a program for implementing these changes.
1.3 Scope of this Document

This report forms Volume One of the surface hydrologic network review. The document sets out the history of surface water data collection to show how the present monitoring points have been identified. It goes on to outline a framework for the design, density, practice and review of the Northern Territory's surface water network. The questions of information distribution and of 'who pays?' are addressed.

An earlier document was circulated for comment to a broad cross-section of the public sector of the water industry; data users including planners and designers in Water, Roads and Public Works Divisions; other government departments; investigations staff throughout Water Division; and staff who develop, operate and maintain the networks. Discussion on that document (which included a seminar held in August 1984) has been incorporated in this Volume.

Volume One then concludes Stage Two of the study and finalises the philosophy of the Territory's surface water networks.

Stage Three will entail applying the above approach Territory-wide, resulting in a physical network which meets both Commonwealth and Territory data collection needs. Stage Three will be reported in Volume Two. Volumes One and Two will thus form the surface hydrologic network review for the Northern Territory.
2. HISTORY OF THE SURFACE HYDROLOGIC NETWORK IN THE NORTHERN TERRITORY

Sketch notes on the history of the Northern Territory's hydrologic network are presented. Both resource inventory and project networks are discussed (as defined in Chapter 3).

2.1 Gauging Stations

2.1.1 Discharge and water levels

As pointed out in Chapter 1, 221 stations (the total of both the resource inventory and the project networks) are at present being operated, although information is available for 391 such stations. Kingston (Reference 4) has summarised the development of these networks, including the rationale in siting stations, the setting of priorities, and the economic benefits of the network. His report covers resource inventory stations and project stations (project investigations, project research, flood warning, tidal). His report does not include project operations stations (water supply bulk collection; effluent discharge) or statutory accounting stations. The classification system was based on that used in this report, but made complex in an attempt to classify multi-function stations. Recommendations which he made for upgrading of the networks were not followed through; the only growth in the network since 1980 has been in project stations.

2.1.2 Water quality

There is a loosely defined project network of stations to monitor surface water quality; stations in the Alligator Rivers Region, Rum Jungle Rehabilitation project, and at Mary Ann Dam fall into this category.
A network of 27 stations in the humid zone was initiated in 1973/74 and operated until 1978/79 (H Wilson pers comm).

There is no resource inventory network to routinely measure water quality parameters. Kingston (Reference 4) recommended that the network be re-established and upgraded but to no avail. As pointed out in Chapter 3, a program for sampling key quality parameters at all resource inventory stations has been introduced in this year.

Water quality baseflow surveys in major areas as recommended by Kingston (Reference 4) have been and are being conducted. Volume One of a series of reports (Reference 11) was released in 1983.

2.1.3 Sediment load

To date only project stations have been operated, notably in the Alligator Rivers Region, and to collect data as part of the investigation for a multi-purpose dam at Alice Springs. Most measurements have been of suspended sediment, although a small number of bed load measurements have been made.

The collection of this information, and future monitoring requirements are the subject of a programmed study in 1984/85: Project 4016 'Review of Sediment Yield of N.T. Rivers'.

2.2 Climate Stations

2.2.1 Rainfall

The Bureau of Meteorology has the responsibility for providing the general network of rainfall and climate data stations for Australia.
However, as Brown (Reference 3) has noted, the number of gauges (daily read or pluviograph) is insufficient in the western two thirds of Australia, including the Northern Territory. The Bureau's reason for this is the sparse population and the difficulty of obtaining observers. To make up this shortfall of information, Water Division currently operates 102 pluviographs, with an additional number of daily read rain gauges, where detailed monitoring of rainfall within gauged catchments is important. These are operated for either resource inventory or for project purposes in conjunction with a stream gauge. Information is available for 169 such stations, as 67 are closed.

### 2.2.2 Other data

Water Division has operated other climate measuring equipment including evaporation pans for project purposes. There is no resource inventory network of such stations.
3. NETWORK DESIGN CONCEPTS

3.1 Why Have Networks?

The central question which should be asked when considering a study such as this is:

WHY ARE WE COLLECTING HYDROLOGIC INFORMATION?

The answers will help clarify the purpose of the networks, and hence the design of the networks themselves.

The occurrence of hydrologic events is random both areally and in time. It is the variation of these events and their magnitude which is of importance; it is the variations which require study. A designed network is one which minimises the resources necessary to study these variations; its aim is the collection of data adequate to meet present and foreseeable needs, within an acceptable time frame and with a minimum of monitoring stations.

What is the value, or the economic benefit, of this data? Whilst easy to state, it is extremely difficult to quantify, and only now has the AWRC commenced a study on this subject for Australia. The only documented attempt to quantify the value of water data has been conducted in Canada. A study by Acres Ltd produced a benefit of cost ratio of 9.3 to 1 for the present Canadian network, after considering the major identifiable uses of data. In addition the value of data accumulates with time as the sum of the studies and decisions influenced by the data increases.
Brown (Reference 2) states that the value of data may be:

(i) A certain fraction of the capital cost of structures or developments which depend on hydrologic design. For example, the cost of new bridges, culverts and other drainage structures in the Territory in 1983/84 was $15.06 million, this being 35 percent of the total cost of roads. The availability of reliable data, if it makes only ten percent difference in cost, represents $1.5 Million.

(ii) The incremental value of the data in savings achieved by less conservative designs. For example, using analysis based on collected data Verhoeven (Reference 13) was able to show that for a dam on the Todd River upstream of Alice Springs, a change in design costing an extra $2.3 million would result in flood attenuation benefits of $17.5 million.

(iii) Assessed on the basis of the consequences of failure plus the total cost of restoring the facility which failed.

Network design concepts considered have been reported on in detail by Brown (Reference 2), Langbein (Reference 5), Moss (Reference 7) and others. It is not intended to 'reinvent the wheel' in this study, but to conform to recommended Australian practice as set out by the AWRC design document (Reference 1).

There are two main classes of networks; the multi-purpose network (resource inventory network) and the use-specific network (project stations). The resource inventory network has been described by Langbein (Reference 5) as a basic network to explain the regional hydrology; it looks to the future. The project network has been described by him as responding to present and imminent project needs; it provides point data; it serves the present.

10:REP3
3.2 Classification

To reduce subjectivity and hence more effectively design and review networks, a classification system is required which reflects the purpose of each station. The system is based on the current main purpose of each station, which is not necessarily that for which the station was originally established.

The classification system for gauging stations (quantity and quality) is based on that considered appropriate by the AWRC (Reference 1) and which has been successfully applied to Western Australia (Reference 8). The classifications are shown on Table 3.2, and discussed in the remainder of this chapter.

The classification system for meteorological stations is also based on two main classes of network; resource inventory and project.

10:REP3
### TABLE 3.2

**NETWORK DESIGN: CLASSIFICATION OF GUIDING STATIONS**

1. **RESOURCE INVENTORY NETWORK:**
   - Catchments to assess regional water resources and to monitor and understand time trends and and spatial variations in the runoff characteristics.
   1. **PRIMARY STATIONS:**
      - **Base Stations** to measure time variance.
      - (i) **Bench Mark Stations:**
        - Selected primary stations with stable or protected catchments in which long-term variations are attributable to climatic factors alone.
      - (ii) **Mainstream Stations:**
        - Generally catchments 1 000 km² which measure significant resources. (The number and location of these stations dictated by topography and drainage patterns.)
      - (iii) **Index Stations:**
        - Catchments 1 000 km² which measure runoff (quantity and quality) characteristics from significant variations in the physical environment - i.e. rainfall, landforms, vegetation and landuse.
   1. **SECONDARY STATIONS:**
   - Stations with a finite period of operation to measure spatial variance.
   - (i) **Mainstream Stations:**
     - Usually catchments 1 000 km² measuring significant resources - operate until an adequate estimate of the flow and quality characteristics can be obtained, either directly or by correlation.

2. **PROJECT NETWORK:**
   - Stations established for a specific purpose, to operate for periods determined by that purpose.
   2. **PROJECT INVESTIGATION STATIONS:**
   - Stations for specific investigations such as proposed damsites, groundwater recharge, diversions or flood control systems, or other water resources development or water quality investigation. (Either discontinued or reclassified at the end of the specific investigation.)
   2.1 **PROJECT INVESTIGATION STATIONS:**
   - Stations operated for research related to a specific project, including environmental stations in the Alligator Rivers Region, Ram Jungle Rehabilitation.
   2.2 **PROJECT RESEARCH STATIONS:**
   - Stations required for operating water storage or distribution systems, and for operating effluent release systems.
   - (i) **System Flow Stations:**
     - Stations recording regulated flows for compiling flow budgets or for analysis.
   - (ii) **Current Use Stations:**
     - Stations providing information for management and operation functions as distinct from flow recording purposes. (Records not kept.)
### TABLE 3.2 (cont.)

**NETWORK DESIGN: CLASSIFICATION OF CROOKING STATIONS**

<table>
<thead>
<tr>
<th>Index Stations:</th>
<th>Partial Record Stations:</th>
<th>Hydrologic Response Stations:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchments &gt; 1000 km² measuring runoff (quantity and quality) characteristics from particular types of landscape or landuse. Important to have a range of catchment sizes, including small catchments to provide storm runoff data from natural, agricultural and urban environments. Operate until an adequate estimate of the flow and quality characteristics can be obtained, either directly or by correlation.</td>
<td>Stations recording either peak flows, low flows or water surface levels which can be used for flood or drought frequency studies.</td>
<td>Small catchment measuring the effects on runoff (quantity or quality) characteristics of specific types of, or changes in, landuse or land treatment.</td>
</tr>
</tbody>
</table>

### 2.4 STORATORY ACCUMULATING STATIONS:

Stations providing water data for accounting purposes under legal or statutory agreements or obligations (probably operate indefinitely).

### 2.5 FLOOD WARNING STATIONS:

Stations operating solely for flood warning purposes.

### 2.6 TIDAL STATIONS:

Stations operating solely for monitoring tidal variation. Both indefinite and finite period stations.

### Footnotes:

(a) Multipurpose stations fulfilling more than one function should be listed in the classification in which they provide most value, not necessarily that for which they were installed.

(b) These are instances where more than one recording installation is required to determine the natural flow at a given locality.
3.3 Resource inventory network

The function of the resource inventory network is to provide information on the water resources of a region for general planning and design, to detect long term trends, and to provide information for the many unanticipated data demands. This network should be seen as a part of the national resource inventory network with attendant Commonwealth responsibilities. Although stations are established and operated at locations which may not be developed in the future, the selection of those locations should be in catchment types in which development is foreseeable. Such a selection, based on engineering judgement, should allow for the transfer of data to ungauged catchments with a high degree of reliability. In many respects then, the resource inventory stations can be viewed as 'project' stations.

As noted at the beginning of this chapter, the resource inventory network should be designed to provide a quantitative understanding of the variability of hydrologic events both areally and in time. This has been found to be most efficiently achieved by having a mix of primary and secondary stations (the terminology refers to the duration of the monitoring period, and not, as is sometimes thought, to the importance or value of the data obtained).

Primary stations operate for a very long period of time (or indefinitely), measuring variations with time. They provide the baseline data on climatic or environmental long term trends.

Secondary stations operate for a finite period to sample variations areally; when the station has enough record to allow satisfactory correlation with the primary network it is closed. The instrumentation from that station is then moved to sample a different catchment type or size. The duration of operation of these stations is discussed in chapter 6.
The combination of primary and secondary stations provides the most cost effective method of achieving both the long term monitoring and the widespread sampling necessary for water resources assessment. This is done with a minimum of stations operating at any one time.

Referring now specifically to gauging stations, the classifications of Bench Mark Stations (Primary Stations), and Partial Record Stations and Land Use Hydrologic Response Stations (Secondary Stations) are clearly explained in Table 3.2.

Mainstream stations usually measure the total resource of a basin or river system. As such these catchments are too large or complex to provide information about runoff characteristics which could be transferred accurately to other locations. The number and size of mainstream catchments is determined by regional topography and drainage patterns.

The number and location of index stations is related to environmental factors. The index catchments are selected to sample the hydrologic characteristics from significant variations in rainfall, landforms, geology, soils, vegetation and land use. To improve their usefulness for transfer of information to ungauged catchments, these index stations should be selected in a range of catchment sizes.

### 3.4 Project station network

Both gauging stations and meteorological stations in this category are established and operated for a particular purpose or project. In most instances the data from project gauging stations is not applicable to resource inventory/assessment, or improving the understanding of hydrologic processes, whereas the data from the meteorological station does add to resource inventory/assessment. These stations are generally discontinued at the end of the specific project.
The gauging classifications include stations for Project Investigation, Project Research, Operations, Statutory Accounting, Flood Warning, and Tidal. These are clearly described in Table 3.2. The meteorological classifications include stations for Project Investigation, Project Research, and Flood Warning.

3.5 Integration

The most cost effective way of monitoring the different variables required by planners, designers and others is to ensure that hydrologic data collection networks are integrated. The collection program incorporates the following:

- streamflow
  - discharge (continuous)
  - water quality
  - sediment load (both suspended sediment and bed load)
  - peak flow/low flow partial records

- water bodies (lakes and reservoirs)
  - level
  - water quality

- climate
  - rainfall (daily, continuous)
  - evaporation
  - dewpoint and other data

- catchment
  - relief, geology, soils, natural vegetation
  - history (land use and vegetation condition)

As pointed out by the AWRC (Reference 1) the Bureau of Meteorology has the responsibility for providing the general network of rainfall and climate data stations for Australia.

10:REP3
However, the Bureau's network is sparse. Where detailed monitoring of rainfall within gauged catchments is important (either for resource inventory or for project purposes) it is up to the Northern Territory to carry out such monitoring.

The AWRC has stated that water quality assessment of surface waters should be fully integrated with the streamflow assessment program. As a result of the Water 2000 study (Reference 9) a program of field measurement of key water quality parameters at all resource inventory stations has been introduced:

- pH and temperature (physical parameters)
- specific conductance (chemical parameters)
- turbidity (index of catchment erosion)

The stream gauging network will therefore reflect water quality data needs as well as water quantity and flood flow data needs.

Discussion to this point has centred on the surface hydrologic networks. It is obvious though that these networks should be integrated with groundwater monitoring networks, especially in large sedimentary basins or where water movement into or out of a groundwater system, such as along the Daly River, is important. Groundwater monitoring networks throughout the Northern Territory are either being established or under review during 1984/85. The surface hydrologic network design team must liaise with the groundwater network design/review teams to ensure networks are integrated efficiently.
4. NETWORK DENSITY

It is up to the network design team to set the appropriate density of stations for each region. This is done after considering various factors which include:

(i) the level of social and economic development, and the resulting required level of development of available water resources in the future.

(ii) the hydrologic variability of the region, and the amount of information (level of understanding) available now.

(iii) special regional characteristics or problems requiring hydrometric data.

Once the gauging network has been designed, it is desirable to be able to check it against an independent guide to the minimum density of gauging stations appropriate to the region without causing undue economic loss or restricting future development. The AWRC (Reference 1) has modified the guidelines which were prepared by the World Meteorological Organisation (Reference 15), adapting them to Australian conditions. These Australian guidelines, discussed at length in Reference 1, are listed in Table 4; the zones to which they refer are shown in Figure 4. The network density or 'area per station' values used for the three climatic zones in the Northern Territory are to be entered in Table 4 when Stage 3 of this study is completed.

It is repeated that these broad guidelines are not a substitute for consideration of local and regional needs. They are not to be used as justification for the networks. Thus the density of stations on the more extensive areas of Aboriginal land (away from areas which are more likely to be developed) is likely to be far less than indicated by the broad guidelines.
The density of stations in the meteorological networks is even more difficult to establish objectively. Station numbers will depend on:

(i) The data required to define areal variations in rainfall frequency – intensity – duration relationships, and areal variability of evaporation.

(ii) The degree to which rainfall information can be used as an input to rainfall-runoff modelling techniques to estimate missing periods of streamflow records, to estimate the records of gauging stations which have been or are to be discontinued, and to complement the resource inventory gauging network.

(iii) Specific project requirements, including pluviographs for flood modelling and flood warning systems.

(iv) Opportunities provided by technological changes. The future use of multi-channel electronic data loggers will slash data collection and processing costs. The result will be the ability to automatically collect and store streamflow, rainfall and other information at the one site on one instrument; the incremental cost of collecting and storing more than one variable will be negligible.
### TABLE 4  MINIMUM GAUGING STATION NETWORK DENSITY

km² per station

<table>
<thead>
<tr>
<th>CLIMATIC ZONE FOR N T</th>
<th>AWRC GUIDELINES</th>
<th>VALUES ADOPTED FOR NORTHERN TERRITORY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mountains* and ranges</td>
<td>Flat Terrain</td>
</tr>
<tr>
<td>Tropical or humid zone (summer rain)</td>
<td>300 to 1000 1000 to 2500</td>
<td></td>
</tr>
<tr>
<td>Transitional zone (semi arid)</td>
<td>600 to 2000 2000 to 5000</td>
<td></td>
</tr>
<tr>
<td>Arid zone</td>
<td>3000 to 7000 7000 to 20 000</td>
<td></td>
</tr>
</tbody>
</table>

*Note: The Mountains and Ranges category refers to areas with much greater areal variability than the Flat Terrain Category.*
CLIMATIC TYPES
Köppen Classification (1938)

A  Hot Moist Climates
B  Dry Hot to Warm Climates
C  Temperate Moist Climates
BW Very Dry Hot to Warm Climates

Extract from climate map: Atlas of Australian Resources

FIGURE 2 Stream Gauging Network Density Zones
5. THE PROCESS OF NETWORK DESIGN

5.1 Design team

To satisfy most information needs surface water data must be collected over many decades (refer to Chapter 6). Because of the long lead time and associated costs, network design and review are important activities and not to be taken lightly. The design team must thus include hydrologists who have a good working knowledge of the hydrologic characteristics of the region under consideration. In the Northern Territory that means using the information and talents of engineers, scientists and technical staff based in Darwin, Katherine and Alice Springs; not just a small group of professionals based in Darwin. The design team must have access to advice from water planners and other potential users.

5.2 Design process

The design of the project network of both gauging and meteorological stations is based on the information requirements of the specific user; station type, location, mode of operation and length of operation, as well as data processing and analysis are tailored to the client's requirements.

Design of the resource inventory network is based on the best current understanding of the factors which affect the hydrology of the region. Although this study is a major review rather than an initial design, the approach will be to design the required network and then to utilise existing stations, where suitable, within that network.

The steps in the design process include:

1. Compilation of relevant information in map form, including:
   - climate and rainfall distribution
2. Definition of regions considered to have similar hydrologic characteristics, by overlaying the above maps. These regions provide the guide to areal variability.

3. Identification of mainstream catchments by examining the major rivers and their likely behaviour. Gauging stations should be located at sites such as points of future development, at the start of the flood plain, at the head of the estuary.

4. Identification of index gauging stations to sample environmental factors or hydrologic regions having a range of catchment sizes. The use of nested catchments should be considered to maximise information gained for the effort expended.

5. Identification of gauging and meteorological stations required to satisfy the data needs for any particular regional problem requiring solution such as areal variability of rainfall, salinity, or the hydrology of wetlands.

6. Examination of existing gauging and meteorological stations; assessment of their suitability in the network.

7. Consideration of practical problems involved in establishing and operating stations in the area being considered.

10:REP3
8. Check the gauging network against the independent guide (Chapter 4) to the minimum density of gauging stations.

9. Check the meteorological network against the factors noted in Chapter 4, and against these stations operated by the Bureau of Meteorology.

The final network should provide a balanced sampling of the major rivers and various hydrologic regions. This may involve the design team considering a number of designs which would be developed and compared until the most cost effective network is attained.

Of the network design/reviews conducted by the various States, that carried out by Western Australia in 1982 (Reference 9) most closely meets the study proposed for the Northern Territory. Many of the hydrologic regimes for Western Australia and the Northern Territory are similar, land use and likely development in the northern part of that State is similar, the level of and problems of data collection are similar, and that State has used the AWRC document (Reference 1) as the basis for its design. The review of the resource inventory network in the Northern Territory uses as a guide the review carried out by Western Australia.
6. NETWORK REVIEW

Both the resource inventory and the project networks must be reviewed at regular intervals to evaluate their effectiveness. Modifications need to be made where necessary.

Unfortunately, there is no simple test which indicates that a station is adequately serving its purpose or that it should be closed. A necessary starting point is that all data collected should be processed and analysed to determine the variability of the hydrologic characteristics with time and areally. Use rainfall data to estimate missing periods of streamflow record. Past reviews conducted on the Territory network (either ad hoc examinations or the formal review by Kingston in 1980) have been incomplete because they lacked this analysed data base. Even now a complete review cannot be conducted because much of the data backlog is still unprocessed and most stations are not fully rated.

However, data being collected now is being stored on the computer, and large in-roads are being made in the data backlog. Concurrently, both technical and professional staff are engaged in a defined program of gauging station rating and rating curve extension.

It is likely that much of the data will have been processed and analysed in five year's time. An objective should be to conduct a complete and major review in 1990, under the supervision of the Principal Engineer Surface Water. This review would also incorporate the effects of technological change which may influence operational costs and network design.
Meanwhile, annual reviews should be conducted, identifying inadequacies in the data base and evaluating individual stations by considering:

- percentage of data capture
- accuracy of the processed data
- reliability of the record
- consistency of the data collected with time
- ability of the station to perform its classified function
- operating difficulties
- costs of operation

These annual reviews should be conducted jointly by the Senior Engineer Projects and Principal Technical Officer, using the staff resources available to them Territory-wide, in particular the Engineer 2 (Hydrology) and Senior Technical Officer Computations and Analysis. The reviews should be completed early in the calendar year (making use of the previous year's data and allowing time to have stations constructed or upgraded during the following dry winter months. The annual reviews should be incorporated in Water Division's project 1005 'HYDROGRAPHIC OPERATIONS'.

The review team should consult with senior officers of other Divisions and Departments, and other interested bodies. These meetings would aim to ensure that:

(i) all the hydrologic and climatic data required is being collected.

(ii) clients and potential users of the data give advance notice of data requirements.

(iii) the various data networks are integrated as efficiently as possible.
(iv) the various groups do not duplicate their data collection efforts.

(v) the groups collecting data exchange views on topics including instrumentation and techniques, the quality of record, data presentation format.

6.2 Duration of station operation

As indicated earlier, there is no simple test which indicates for how long a station should be operated. However, various researchers have calculated the minimum record length as a guide, for different purposes, in different hydrologic regimes and for varying accuracy goals.

In the resource inventory gauging network, primary stations are defined as being of long term or indefinite duration. To illustrate this, McMahon (Reference 6) has calculated that the time to obtain sufficient information to specify the mean annual flow to within 10% accuracy in an average Top End stream is 40 years, whilst in central Australia this rises to greater than 150 years. If 5% accuracy is required, the times increase to 160 years and greater than 620 years respectively. More details are presented in Appendix 1. However, to specify the 1-in-10 year low annual flow (say for water supply design calculations) would require even longer record length. For the Adelaide River, the required record length allowing for an error of 10% is 150 years (compared to 25 years for mean annual flow).

As another example, the Water Resources Commission of New South Wales has adopted a compromise specification (Reference 14). Based on an examination of the coefficients of variation for that State (see Appendix 1), the historical record already available (larger and higher density than the NT), comparison with overseas achievements, and allowing what appears to be a reasonable length of record, the necessary length of record would vary from about 25 years in the Top End to 55 years in central Australia (for accuracy goals of 12% and 17% respectively).
For secondary gauging stations, review will entail both the adequacy of the data collected and the need for further record. The duration of operation of these stations is dependent on obtaining good correlation of flows and water quality with a nearby primary station. As a guide, the length of operation of these stations is expected to be no greater than half that of nearby primary stations; far less if good correlation is obtained. When correlation of a suitable accuracy to simulate the long term flow (and water quality characteristics if necessary) is achieved, the secondary station should be closed under that classification. However, data collection may still be continued at that site if required, but under a different classification; for example a secondary station may be reclassified to a flood warning station.

In the project network, project stations (gauging or climatic) should be closed once the data requirements have been met. However, some of the gauging stations may be re-opened under another classification for other data needs; for example a project station collecting urban drainage design data, may, at the end of the project, be reclassified to an index secondary station in the resource inventory network.
7. DATA PROCESSING AND ANALYSIS

If we again ask the question posed in Chapter 3, "Why are we collecting hydrologic information?", it can be seen that hydrologic networks on their own are not enough. Brown (Reference 2) points out that a 'hydrologic information system' is required. Raw data has no use; it only becomes valuable when it has been processed, analysed and used.

Whilst the subjects of data processing and analysis are not explicit in this study's objective, they are related to the purpose of network design, operation and review, and so require some comment.

It is important that the following activities be maintained, or in some cases commenced, to ensure hydrologic data collection is efficient and cost effective.

1. The records of all stations should be processed and readily available on computer media and as hard copy within twelve months of the end of each water year. At present all stream gauging and tidal station records are being entered on computer storage within six months of the end of each year. Tables giving station details; daily instantaneous max. and min. stage; and max., min., and mean daily discharge (if rating curves have been prepared) are available. The first of the series of annual reports containing this information is being prepared, to be published in March 1985.

Computer software to enable the processing and presentation of related rainfall, water quality and sediment yield information is still to be developed, with targets of one, one and five years respectively.
2. As part of the major five yearly reviews, Water Division should carry out simple hydrologic analyses of the data collected at each station. Analyses can include:

- station-station correlations for which some computer software is already available in-house.

- catchment rainfall-runoff modelling studies using daily or monthly data. Computer software is available in-house.

- general hydrologic studies including flood frequency analysis updates, flow duration curves.

- general studies of water quality and sediment transport characteristics and trends.

3. Water Division needs to develop an ability to reliably fill-in missing record using modelling and correlation techniques appropriate to the various hydrologic regions. The regular application of these techniques will take up to ten years, depending on data availability.

4. Eventually, both uncorrected and corrected hydrologic information should be available for users.
8. FUNDING

8.1 Past funding arrangements

Prior to 1983/84 funding of the construction and operation of gauging and climatic stations, and of data processing was shared between the Northern Territory and Commonwealth Governments. The funding of most project stations was the responsibility of the Northern Territory, although special project stations associated with environmental monitoring in the Alligator Rivers region were funded by the Commonwealth. Funding of national assessment (now resource inventory) stations was contributed to equally by the Northern Territory and the Commonwealth. The multi-use classification of stations clouded the funding issue.

In 1983/84 further complexities were introduced:

(i) Increasing recognition that project stations should be funded by the client; either construction alone (Palmerston Development Authority) or construction and operation (Rum Jungle Rehabilitation Project).

(ii) A reduction by 30% of the Commonwealth's contribution to the inventory network.

This network review/design, with its associated simplification of station classification, is the appropriate time to re-establish the funding framework.

8.2 Present costs

Since 1983/84 gauging station construction, major maintenance and upgrading, as well as access, have been carried out by contractors. Costs per station have ranged from approximately $10,000 to $40,000 depending on the work required and the location in the Northern Territory.
The average cost in 1983/84 to operate each station was $8,400. This cost includes six-weekly station inspections, minor maintenance, data processing, and allowance for professional and senior technical staff input.

8.3 Future funding

From July 1984 funding should be simplified to the following general framework:

(i) As a general rule the funding of the construction and operation of project stations (both gauging and climatic) is to be met by the client. Construction and operation are defined above; the construction costs will be site specific while the operation costs should be an average station cost for the Northern Territory. Exceptions to this proposal will be made in certain instances. For example, the operation costs of project stations operated for another Division of this Department would be met by Water Division.

(ii) The Commonwealth has indicated that as of 1984/85 it will fund the operation costs of 120 resource inventory gauging stations in the Northern Territory which are of importance to the national network.

(iii) It is proposed that the construction of new resource inventory stations which form part of the national network, particularly in areas of poor coverage such as in the Western Plateau and Lake Eyre Drainage Divisions also be funded by the Commonwealth. A precedent was to have been set in 1984/85, with the Commonwealth funding the construction of stations in the Pilbara and Kimberley regions in Western Australia. This arrangement was not proceeded with, and the Commonwealth's stance in 1985/86 will be closely monitored.

10:REP3
(iv) The construction and operation of the remaining stations in the resource inventory network will be funded by Water Division. The construction and operation of climatic stations in this network, beyond those operated by the Bureau of Meteorology, will be funded by Water Division. Final numbers will be finalised in Stage 3 of this study.
9. REFERENCES


6  McMAHON, T A: "Low flow and yield data requirements"; in Workshop on Surface Water Resources Data; Australian Water Resources Council; Canberra; 1983.
7 MOSS, M E; "Some basic considerations in the design of hydrologic data networks"; in AGU Chapman Conference, Design of hydrologic data networks; Proceedings of Conference at Tucson, Arizona; 1978; American Geophysical Union.


12 TRANSPORT AND WORKS, DEPARTMENT OF; "Water Northern Territory"; Darwin 1984


APPENDIX 1  MINIMUM STREAMFLOW RECORD LENGTHS

This information has been obtained from a paper prepared by McMahon (Reference 6).

A2.1 Coefficient of variation

Coefficient of variation $C_v = \frac{\text{standard deviation}}{\text{mean}}$

Values for $C_v$ within the Northern Territory (Figure A2.1) vary from:

(i) 0.5 to 1.0 in the Tropical Zone (with a sub zone of 0.5 to 0.75 in the Top End north of Katherine);

(ii) to an adopted value of 1.25 in both the Transitional and Arid Zones. The actual value of $C_v$ is probably higher in these zones, but has not been calculated because of the paucity of data.

A2.2 Mean annual flow

From Table 7 of McMahon's paper, the minimum record length to specify the mean annual flow for various errors is:

<table>
<thead>
<tr>
<th>$C_v$</th>
<th>Minimum record length (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Allowing 5% error</td>
</tr>
<tr>
<td>0.5 to 0.75 (Top End)</td>
<td>100 to 220</td>
</tr>
<tr>
<td>0.75 to 1.0</td>
<td>220 to 400</td>
</tr>
<tr>
<td>1.25 (Transitional and Arid Zones)</td>
<td>greater than 620</td>
</tr>
</tbody>
</table>
A2.3 Low annual flow

To specify the once in ten year low annual flow requires even longer record length, as shown in Table 8 from McMahon's paper.

For example, in the northern part of the Top End with a $C_v$ of 0.5 (say the Adelaide River), and allowing for an error of 10%, the required length of record from Table 8 is 150 years (compared to 25 years for mean annual flow).
Adopt coefficient of variation = 1.25

Coefficient of variation > 1.5

FIGURE A2.1 Coefficient of Variation of Annual Flows
TABLE 7 (McMahon)

Minimum record lengths for given accuracy of mean annual runoff
(years)

<table>
<thead>
<tr>
<th>Std. error of mean annual flow</th>
<th>Coefficient of variation of mean annual runoff $C_v$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>0.05 (5%)</td>
<td>25</td>
</tr>
<tr>
<td>0.1 (10%)</td>
<td>7</td>
</tr>
<tr>
<td>0.25 (25%)</td>
<td>1</td>
</tr>
<tr>
<td>0.5 (50%)</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 8 (McMahon)

Minimum record lengths for given accuracy of once in ten year low annual flow

(years)

<table>
<thead>
<tr>
<th>Std. error of 1/10 year low annual flow</th>
<th>Coefficient of variation of mean annual flow $C_v$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>0.05 (5%)</td>
<td>35</td>
</tr>
<tr>
<td>0.1 (10%)</td>
<td>9</td>
</tr>
<tr>
<td>0.25 (25%)</td>
<td>1</td>
</tr>
<tr>
<td>0.5 (50%)</td>
<td>-</td>
</tr>
</tbody>
</table>
### TABLE 3.2

**NETWORK DESIGN: CLASSIFICATION OF GAUGING STATIONS**

<table>
<thead>
<tr>
<th>1. RESOURCE INVENTORY NETWORK:</th>
<th>2. PROJECT NETWORK:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchments to assess regional water resources and to monitor and understand time trends and spatial variations in the runoff characteristics.</td>
<td>Stations established for a specific purpose, to operate for periods determined by that purpose.</td>
</tr>
</tbody>
</table>

#### 1. PRIMARY STATIONS:

- **Bench Mark Stations:** Base Stations to measure time variance.
- **Mainstream Stations:** Generally catchments 1,000 km² which measure significant resources. (The number and location of these stations dictated by topography and drainage patterns.)
- **Index Stations:** Catchments 1,000 km² which measure runoff (quantity and quality) characteristics from significant variations in the physical environment – i.e. rainfall, landforms, vegetation and landuse.

#### 1. SECONDARY STATIONS:

- **Stations with a finite period of operation to measure spatial variance.**

#### 2. PROJECT NETWORK:

- **Investigation Stations:** Stations for specific investigations such as proposed damsites, groundwater recharge, diversions or flood control systems, or other water resources development or water quality investigation. (Either discontinued or reclassified at the end of the specific investigation.)
- **Research Stations:** Stations operated for research related to a specific project, including environmental stations in the Alligator Rivers Region, Hum Jungle Rehabilitation.
- **Operation Stations:** Stations required for operating water storage or distribution systems, and for operating effluent release systems.

#### 3. PROJECT NETWORK:

- **System Flow Stations:** Stations recording regulated flows for compiling flow budgets or for analysis.
- **Current Use Stations:** Stations providing information for management and operation functions as distinct from flow recording purposes. (Records not kept.)
TABLE 3.2 (cont)
NETWORK DESIGN: CLASSIFICATION OF GAUGING STATIONS

(ii) Index Stations: Catchments 1 000 km² measuring runoff (quantity and quality) characteristics from particular types of landscape or landuse. Important to have a range of catchment sizes, including small catchments to provide storm runoff data from natural, agricultural and urban environments. Operate until an adequate estimate of the flow and quality characteristics can be obtained, either directly or by correlation.

(iii) Partial Record Stations: Stations recording either peak flows, low flows or water surface levels which can be used for flood or drought frequency studies.

(iv) Landuse - Hydrologic Response Stations: Small catchment measuring the effects on runoff (quantity or quality) characteristics of specific types of, or changes in, landuse or land treatment.

2.4 STATUTORY ACCOUNTING STATIONS: Stations providing water data for accounting purposes under legal or statutory agreements or obligations (probably operate indefinitely).

2.5 FLOOD WARNING STATIONS: Stations operating solely for flood warning purposes.

2.6 TIDAL STATIONS: Stations operating solely for monitoring tidal variation. Both indefinite and finite period stations.

FOOTNOTES:-
(a) Multipurpose stations fulfilling more than one function should be listed in the classification in which they provide most value, not necessarily that for which they were installed.

(b) There are instances where more than one recording installation is required to determine the natural flow at a given locality.