POWER AND WATER AUTHORITY

FLOOD FORECASTING SYSTEM FOR THE LOWER DALY RIVER NORTHERN TERRTORY

REPORT 4/1988

A Baker
Water Resources Group
Darwin
March 1988

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WATER DIRECTORATE

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ABSTRACT

This report presents the flood forecasting system for the Lower Daly River. The procedures used during the development of the system are outlined. Multiple regression and graphical techniques were used to obtain an estimation of the peak stage height at Daly River Community. Predictions of time to peak stage were obtained by the use of fixed ratios between delays at the upstream section of the network and those at the Daly River Community. It was found that a consistent delay of 8 to 9 hours occurred between peak stages at Mt Nancar and those at the Daly River Community. The system was tested using independent data and found to accurately predict both peak stage heights and times to peak stage.

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1. BACKGROUND

Following a Cabinet Decision in January 1980 the Northern Territory Floodplain Management Committee (FMC) was formed to develop and implement a floodplain management policy for Northern Territory river systems.

A major component of this initiative was the development of flood warning and forecasting systems to provide adequate warning of significant flood events to communities.

This program is funded jointly by the Northern Territory and Commonwealth Governments under the Federal Water Resources Assistance Programme, with the Commonwealth providing 40% of the funding for the purchase of necessary instrumentation.

This report deals exclusively with a flood warning and forecasting system for the Daly River and is the third in a series of such reports. Flood warning systems for the Alice Springs and Katherine regions are already in operation. Figure 1 shows the location of the Daly River.

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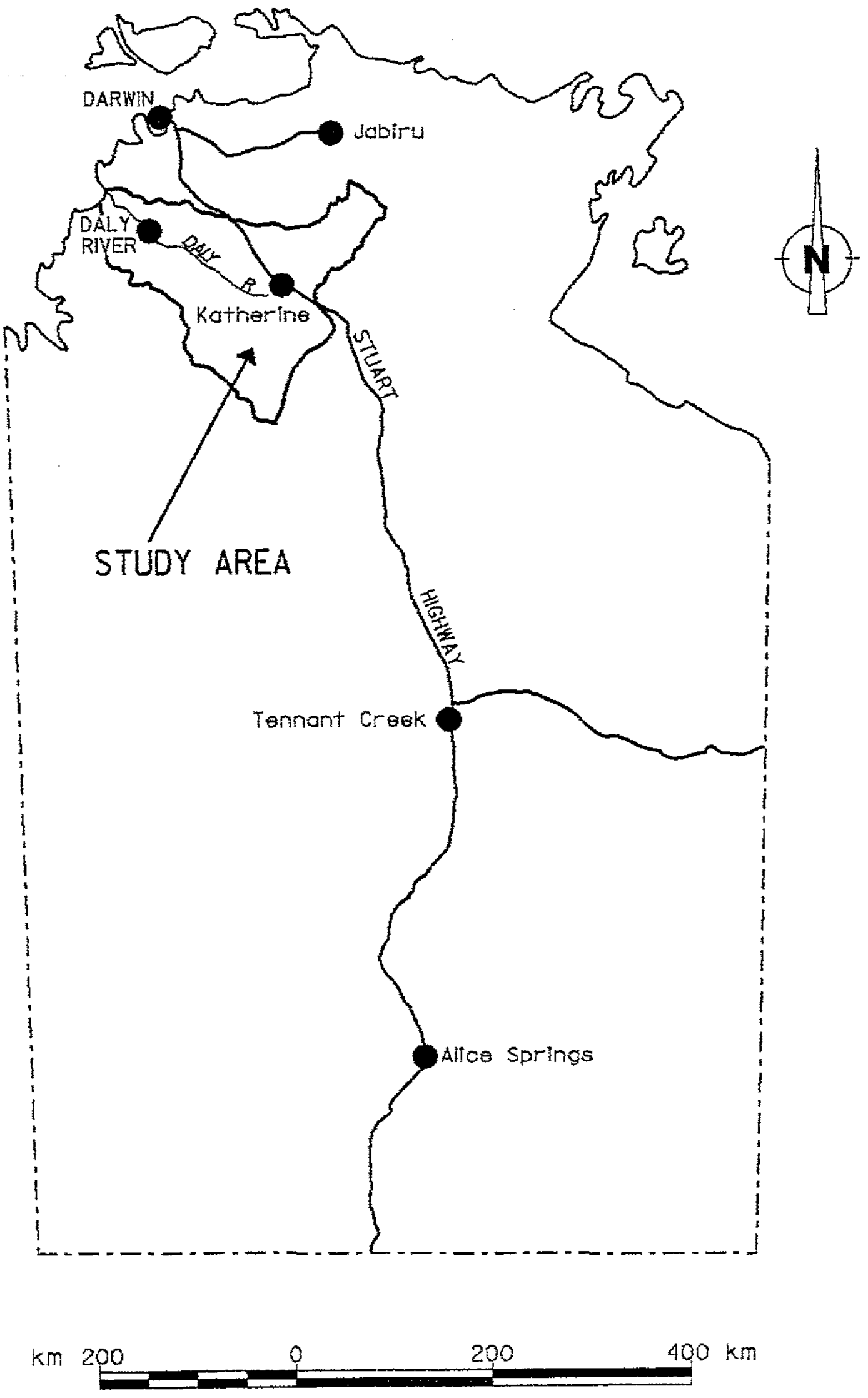

LOCALITY PLAN

Fig. 1

2. THE DALY RIVER SYSTEM

2.1 Daly River Catchment Area

The Daly River is formed by the confluence of the Katherine and Flora Rivers to the south-west of Katherine township, and drains into the Timor Sea at Anson Bay. The Daly River catchment is some 51,800 square kilometres in area, of which 48,400 square kilometres lies upstream of the Daly River Community.

Figure 2.1 shows the layout of the Daly River catchment with major tributaries and relevant gauging stations.

Catchment characteristics vary from high relief sandstone escarpment country in the north-east to arid plains of denuded skeletal soils in the south. The escarpment areas yield high run-off flows following thunderstorms and cyclonic rains, the arid areas contributing turbid flows of variable volume.

Tidal influences can extend to Mt Nancar gauging station at times of moderate flows, however at higher stages tidal effects are drowned out some distance downstream of the Daly River Community. There are no tidal effects present during floods of significant magnitude.

2.2 Daly River Flood Patterns

Flooding normally occurs below Mt Nancar on an annual basis and may comprise both local and river flooding. Above Mt Nancar the main river channel is contained within deeper banks. As a result of this, overbank flooding is less frequent than is the case on the flood plains around the Daly River Community. The community is situated on the northern bank of the river on a natural levee, some 2 km downstream of Daly River Police Station. Ground levels at the community vary from RL 14.0 m to RL 15.0 m (AHD). The community however is surrounded by low level areas which effectively isolate the settlement by road at flood levels above 12.5 metres on the Police Station gauge. Evacuation is carried out by boat to vehicles relocated on higher ground some distance from the river when flood levels reach 13.5 m on the Police Station gauge.

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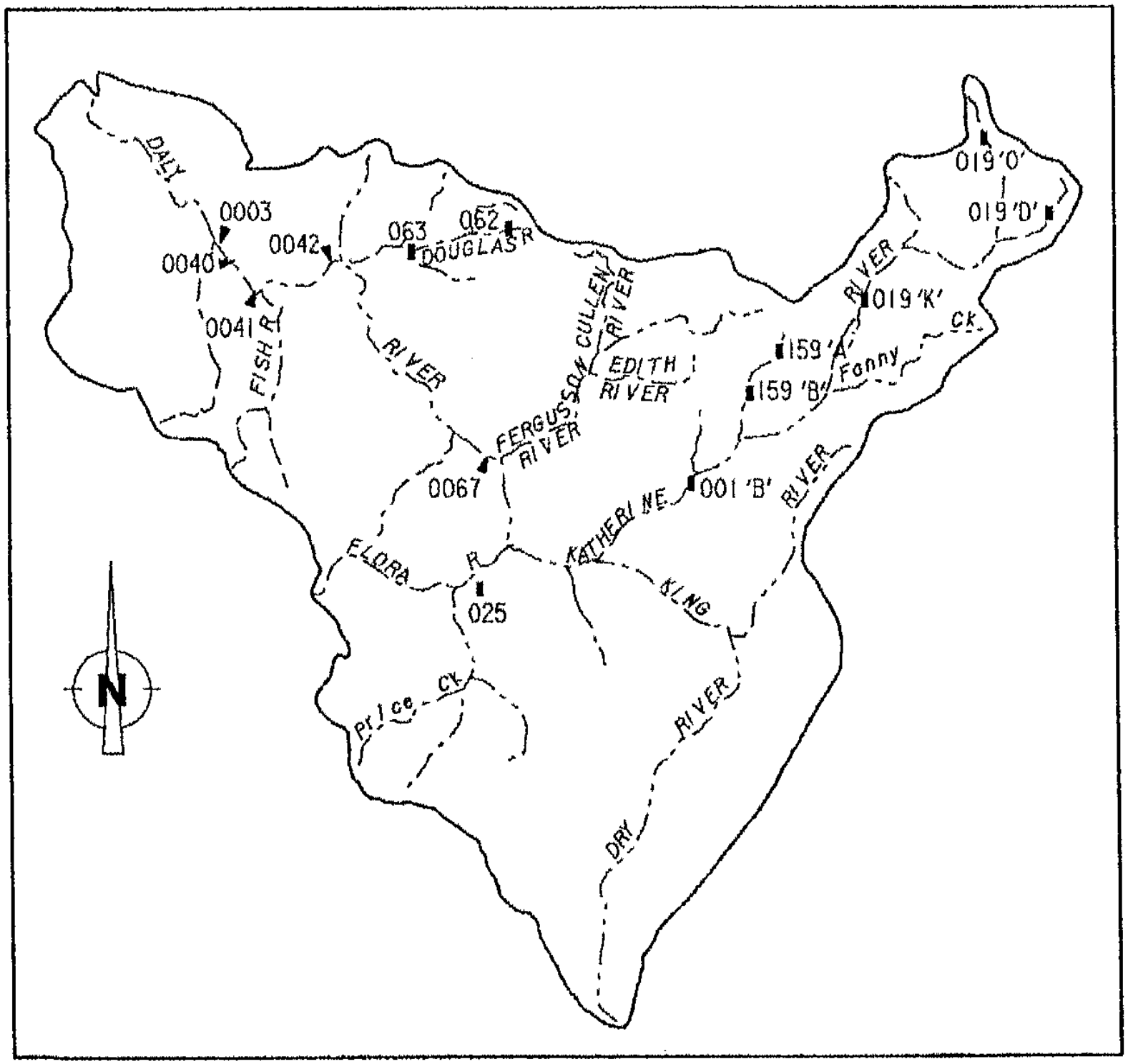

LEGEND

STREAMFLOW GAUGING STATIONS ◄

8140003	—	DALY RIVER POLICE STATION
8140040	—	MT NANCAR
8140041	—	GOURLEY
8140042	—	BEEBOOM
8140067	—	DORISVALE

PLUVIOGRAPHS ■

814001'B'	—	KATHERINE RAILWAY BRIDGE
814019'D'	—	EVA VALLEY HOMESTEAD
814019'K'	—	SLEISBACK
814019'O'	—	UPPER REACHES
814025	—	CSIRO EXPERIMENTAL FARM
814062	—	COPPERFIELD CREEK
814063	—	DOUGLAS FARM
814159'A'	—	17 MILE CREEK UPPER CATCHMENT
814159'B'	—	17 MILE CREEK BELOW FALLS

km 50 0 50 100 km

Fig. 2.1 LAYOUT OF THE DALY RIVER CATCHMENT SHOWING MAJOR TRIBUTARIES, PLUVIOGRAPH AND STREAMFLOW GAUGING STATIONS

Since 1974 the natural levee bank between the Daly River Inn and the Police Station has been overtopped on a number of occasions with subsequent scour occurring. Prior to remedial works being carried out after 1980, this section of bank was responsible for most of the overbank flooding occurring at the Daly River Community. However, at flood levels above 12.5 metres (gauge datum) inundation of areas surrounding the community can still be expected due to overtopping of the river bank at a number of sites upstream of the Daly River Police Station, and downstream of the community.

Observations of significant flood events at gauging stations along the Daly has indicated the presence of at least two different types of flooding. These flood events may be divided into those with a short peak stage duration and those with an extended or "plateau" shaped peak stage duration. The plateau shaped flood may also be sub-classed depending on whether the peak stage occurs at the start or end of the series of high stages.

Whilst the peak stage height resulting at Daly River Police Station is not directly affected by the type of flood occurring, delay times between peak stages at gauging stations along the river are highly dependant on the type of flood event.

3. AVAILABLE DATA

3.1 Pluviographs

The distribution of pluviographs in the Daly River basin is shown on Figure 2.1.

Due to the lack of pluviograph and daily rainfall data of sufficient length or distribution in the Daly River catchment the use of rainfall run-off flood forecasting methods is not discussed in this study.

3.2 Gauging Stations

The Daly River catchment area contains a large number of automatic streamflow gauge recorders.

This study uses five such gauging stations, all along the main channel of the Daly. These stations, starting with the Dorisvale Road Crossing at Claravale (GS8140067) and continuing to the Daly River Police Station (GS8140003) are described below and are shown on Figure 2.1.

(i) GS8140067 Daly River at Dorisvale Crossing

A gauging station was established at this site during the water year of 1959/60. Due to instability of the river banks the station was relocated slightly upstream of the original site in 1975.

Full gauge heights are available for all water years from 1060/61 to 1986/87 with the exception of floods from 1961/62, 1963/64, 1968/69, 1969/70, 1970/71, 1974/75, 1975/76 and 1980/81 water years.

Maximum recorded flood stage: 21.20 m (gauge datum) in 1977. Catchment area: 35800 km^2.

(ii) GS8140042 Daly River at Beeboom Crossing

A gauging station was established at Beeboom, 120 km downstream of Dorisvale during the 1981/82 water year, following a decision to close the gauging station at Gourley. Because of its siting just below the confluence of the Daly and Douglas Rivers, Beeboom allows a much earlier warning of flood events below Dorisvale then was the case at Gourley.

Maximum recorded flood stage:15.57 m (gauge datum) in 1984. Catchment area: 43300 km^2.

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(iii)GS8140041 Daly River at Gourley

This station was established during the 1959/60 water year as the principal gauging station on the Daly River. However during subsequent years it was found that a unique relationship between stage height and discharge did not exist at this site. As a result, Gourley was closed at the end of the 1980/81 water year.

Maximum recorded flood stage:16.76 m (gauge datum) in 1974. Catchment area: 46300 km^2.

(iv)GS8140040 Daly River at Mt Nancar

Mt Nancar was established in the water year of 1967/68 following the discovery of problems with the rating relationship at GS8140041. The river cross section at Mt Nancar is very stable and is now used as the principal gauging site on the Daly River. GS8140040 is located below Mt Nancar some 10 km upstream of Daly River Police Station.

Maximum recorded flood stage:17.54 m (gauge datum) in 1974. Catchment area: 47900 km^2.

(v) GS8140003 Daly River at Police Station

This station was opened during the 1951/52 water year and maximum stage heights are available from the 1952/53 water year. However until 1974 daily gauge readings were intermittent. Because of the tidal influences experienced at both low and intermediate stages a high stage automatic recorder was installed during the 1974/75 water year. Peak stage heights at this station can be directly related to the severity of flooding at the Daly River Community.

Maximum recorded flood stage:15.19 m (gauge datum) in 1957. Catchment area: 48400 km^2.

4. EXTENSION OF HISTORIC FLOOD DATA

In an attempt to gain a suitably correlated relationship between the Daly River Police Station and those gauging stations upstream, it was necessary to obtain a complete record of peak stage heights for the longest time period possible.

With the exception of Beeboom which was opened in the 1981/82 water year, records at all gauging stations display significant gaps in completeness. Historic records for all stations are shown in Table 4(a). It was decided to remove gaps in the records by the use of linear regression relationships between gauging sites. The aim was to gain a complete set of maximum flood stage heights from the 1970/71 water year to the present. Any records available before this time were used as independent tests to ascertain the accuracy of the final correlation equations.

Because of the closure of GS8140041 at Gourley in the 1980/81 water year it was not possible to use peak stage data from it for the prediction of future flood levels downstream. However, since Gourley represents a complete record of maximum stage heights between the 1960/61 and 1980/81 water years it is a valuable aid in the process of infilling missing stage data for other gauging stations along the river.

4.1 Extension of Data for GS8140067 at Dorisvale

As shown in Table 4(a) there are a number of gaps in the peak flood stage heights at Dorisvale. Missing values for Dorisvale were obtained by the use of a linear correlation between the peak stages at Gourley and Dorisvale gauging stations. This relationship is shown in Figure 4.1.

4.2 Extension of Data for GS8140040 at Mt Nancar and GS8140003 at Daly River Police Station

It was found during the present study, and formerly by Power, Pidsley and Reinhardt (Reference 1), that a good linear relationship exists between the peak stage heights at Mt Nancar and those at Daly River Police Station. As a result of this all gaps in historical data at both Mt Nancar and Daly River Police Station were infilled using the relationship shown in Figure 4.2.

TABLE 4(a)
HISTORICAL PEAK FLOOD STAGE DATA
(All depths to gauge datum in (metres)

WATER YEAR	GS8140067 DORISVALE	CS8140042 BEEBOOM	GS8140041 GOURLEY	GS8140040 MT NANCAR	GS8140003 DALY RIVER POLICE STN
1960-61	NR	NR	6.01	NR	5.71
1961-62	NR	NR	8.37	NR	8.23
1962-63	12.81	NR	9.88	NR	8.61
1963-64	NR	NR	9.47	NR	8.46
1964-65	6.99	NR	7.93	NR	7.47
1965-66	18.74	NR	14.58	NR	13.05
1966-67	17.46	NR	13.83	NR	12.28
1967-68	18.86	NR	14.78	NR	13.17
1968-69	NR	NR	13.59	NR	12.18
1969-70	NR	NR	7.67	NR	7.07
1970-71	NR	NR	11.69	11.62	NR
1971-72	17.37	NR	14.35	14.87	13.04
1972-73	18.27	NR	14.10	14.41	NR
1973-74	21.71	NR	16.76	17.54	14.90
1974-75	NR	NR	12.86	13.04	11.40
1974-75*	NR	NR	12.39	12.84	11.40
1975-76	NR	NR	16.28	17.53	14.27
1975-76*	20.21	NR	14.83	15.36	13.06
1976-77	21.20	NR	16.66	16.85	14.77
1976-77*	20.19	NR	15.06	NR	13.23
1977-78	15.64	NR	12.85	NR	11.18
1978-79	15.40	NR	12.98	12.89	11.31
1979-80	18.43	NR	14.30	14.63	12.72
1979-80*	14.60	NR	12.34	12.31	10.83
1980-81	NR	NR	14.26	14.55	12.69
1980-81	15.62	NR	12.40	12.20	10.67
1981-82	14.25	11.87	NR	11.70	10.27
1982-83	10.46	8.33	NR	12.13	10.70
1983-84	20.05	15.57	NR	15.69	13.38
1983-84*	14.16	11.57	NR	11.99	10.58
1984-85	13.04	11.63	NR	NR	11.46
1985-86	6.38	5.80	NR	6.74	6.19
1986-87	19.97	15.40	NR	14.87	12.80

NR = no available record
* = 2nd flood event in water year

Zero gauge datum in m AHD

BEEBOOM:	13.39 m
GOURLEY:	4.59 m
MT NANCAR:	1.21 m
DALY RIVER POLICE STATION:	1.34 m

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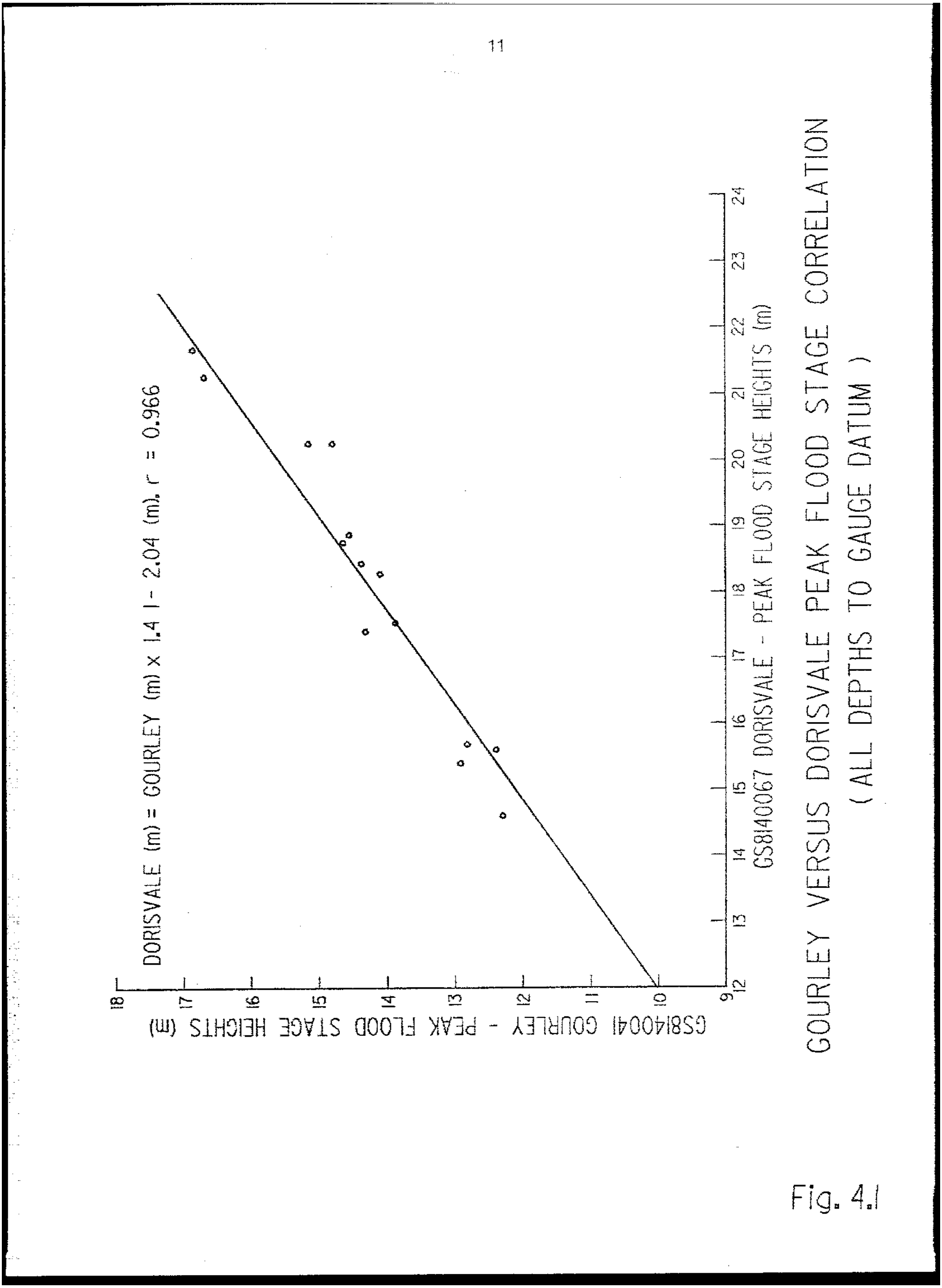
4.3 Extension of data for GS8140042 at Beeboom

The extension of a data set for Beeboom posed a much larger problem, due to the short length of historical data available for the site. It was proposed to use the Gourley data to extend the available stage height record at Beeboom, however since these record sets did not overlap another relationship was needed. Beeboom was correlated against both Dorisvale and Mt Nancar, with Dorisvale providing the better relationship. A plot of these correlations is shown in Figure 4.3

A complete record of derived peak stage heights used in the flood warning analysis is shown in Table 4(b).



VERSUS DORISVALE PEAK FLOOD STAGE CORRELATION

(ALL DEPTHS TO GAUGE DATUM)

Fig. 4.1

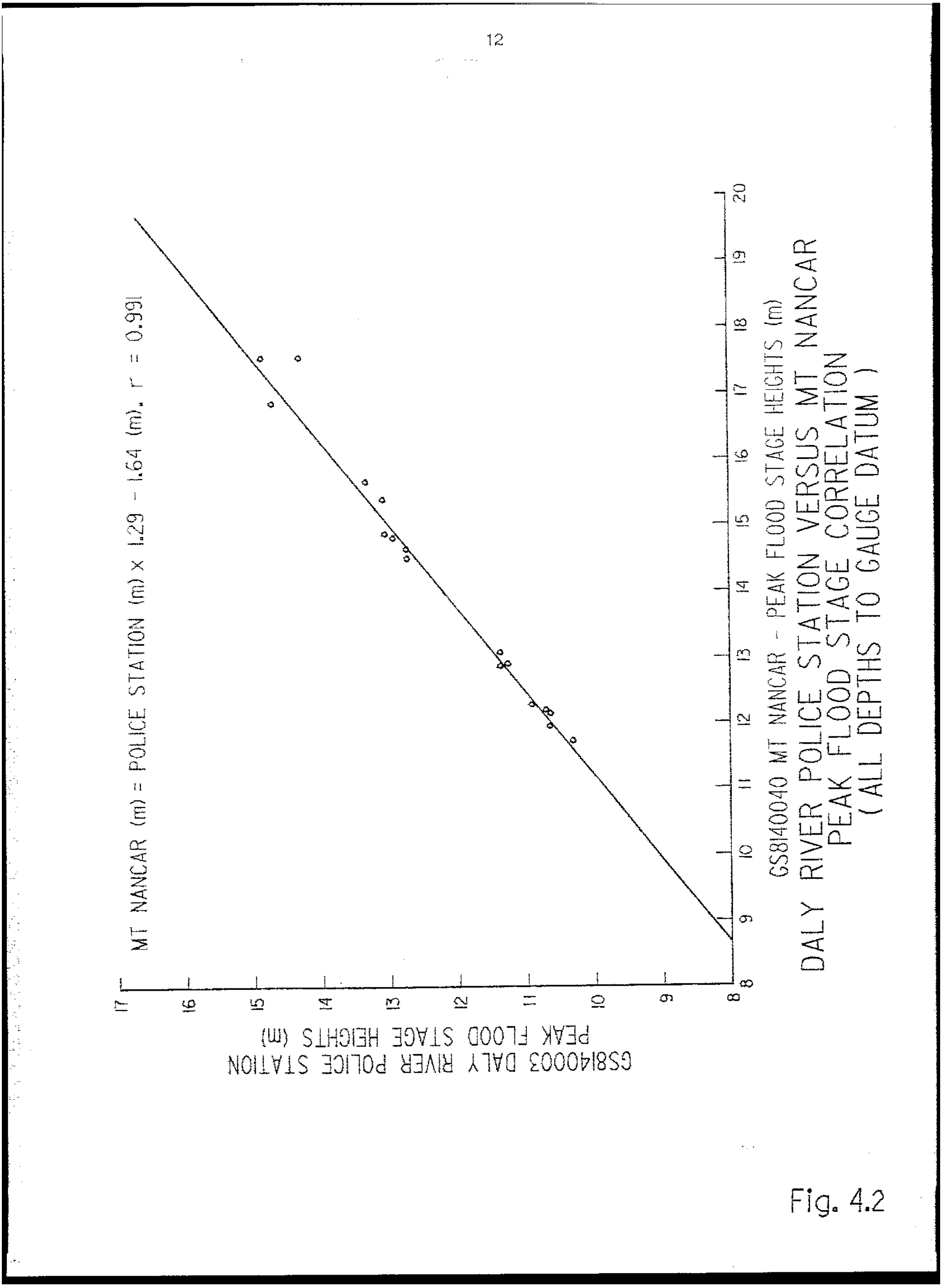

DALY RIVER POLICE STATION VERSUS MT NANCAR - PEAK FLOOD STAGE CORRELATION
(ALL DEPTHS TO GAUGE DATUM)
GS8140040 MT NANCAR - PEAK FLOOD STAGE HEIGHTS (m)
MT NANCAR (m) = POLICE STATION (m) x 1.29 - 1.64 (m). r = 0.991
8
9
10
11
12
13
14
15
16
17
18
19
20
GS8140003 DALY RIVER POLICE STATION
PEAK FLOOD STAGE HEIGHTS (m)

Fig. 4.2

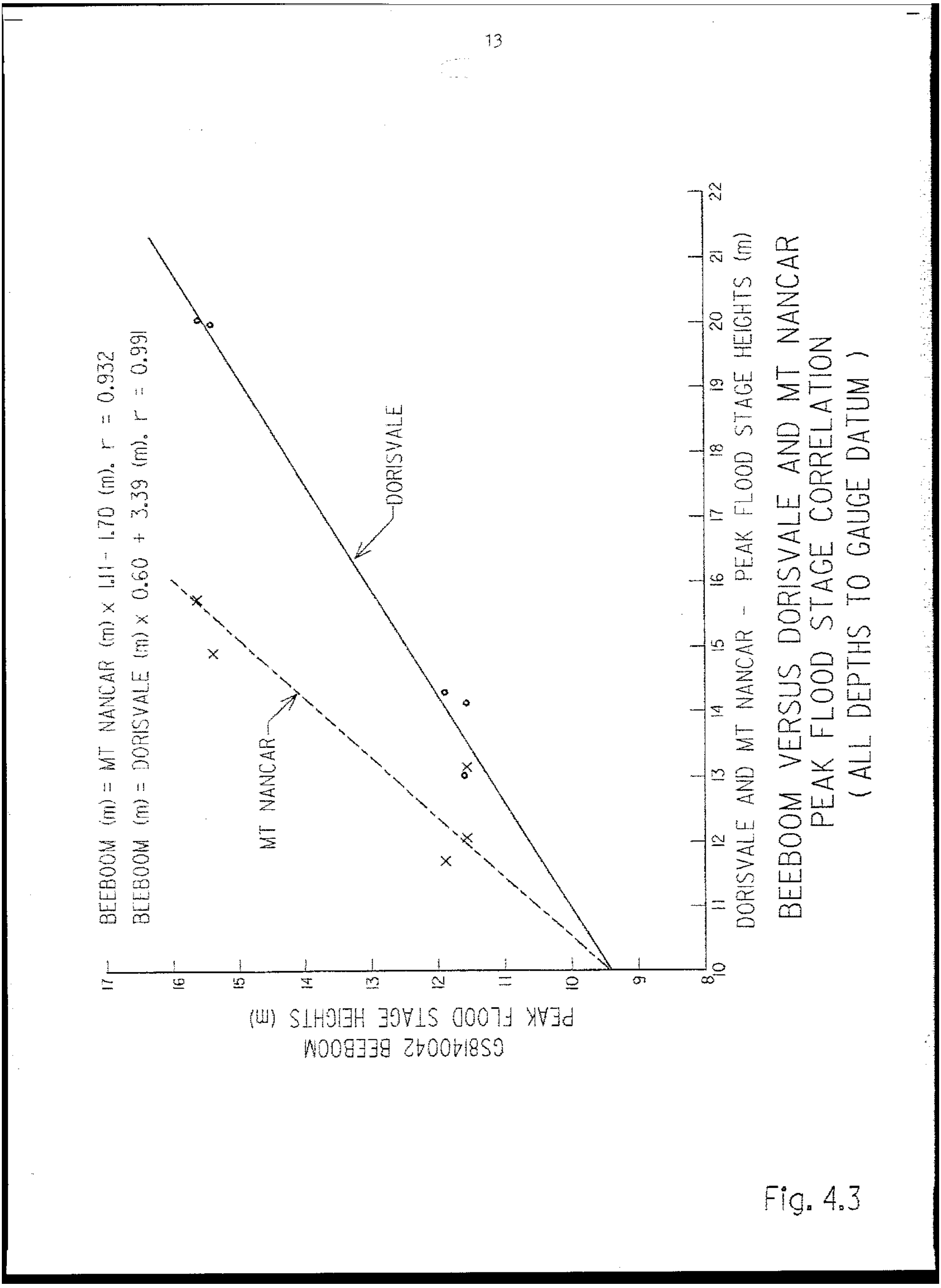

BEEBOOM (m) = MT NANCAR (m) x 1.11 - 1.70 (m). r = 0.932
BEEBOOM (m) = DORISVALE (m) x 0.60 + 3.39 (m). r = 0.991
MT NANCAR
DORISVALE
PEAK FLOOD STAGE HEIGHTS (m)
DORISVALE AND MT NANCAR - PEAK FLOOD STAGE HEIGHTS (m)
BEEBOOM VERSUS DORISVALE AND MT NANCAR
PEAK FLOOD STAGE CORRELATION
(ALL DEPTHS TO GAUGE DATUM)
GS8140042 BEEBOOM
PEAK FLOOD STAGE HEIGHTS (m)

Fig. 4.3

TABLE 4(b)
COMPLETE RECORD OF ANALYSIS DATA
PEAK FLOOD STAGE HEIGHTS (METRES GAUGE DATUM)

WATER YEAR	GS8140067 DORISVALE	GS8140042 BEEBOOM	GS8140040 MT NANCAR	GS8140003 DALY RIVER POLICE STATION
1970-71	14.44	12.05	11.62	10.28
1971-72	17.37	13.81	14.87	13.04
1972-73	18.27	14.35	14.41	12.44
1973-74	21.71	16.42	17.54	14.90
1974-75	16.09	13.04	13.04	11.40
1974-75	15.43	12.65	12.84	11.40
1975-76	20.92	15.94	17.53	14.27
1975-76	20.21	15.52	15.36	13.06
1976-77	21.20	16.11	16.85	14.77
1976-77	20.19	15.50	15.43	13.23
1977-78	15.64	12.77	12.79	11.18
1978-79	15.40	12.63	12.89	11.31
1979-80	18.43	14.45	14.63	12.72
1979-80	14.60	12.15	12.31	10.83
1980-81	18.07	14.23	14.55	12.69
1980-81	15.62	12.76	12.20	10.67
1981-82	14.25	11.87	11.70	10.28
1982-83	10.46	8.33	12.13	10.70
1983-84	20.05	15.57	15.69	13.38
1983-84	14.16	11.57	11.99	10.58
1984-85	13.04	11.63	13.14	11.46
1985-86*	6.38	5.80	6.74	6.19
1986-87	19.97	15.40	14.87	12.80

* 1985-86 peak flow was not included in the regression analysis as it was too small to be considered as a flood.

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5. FLOOD WARNING SYSTEM HARDWARE

Telemetry stations have been in operation at Mt Nancar and the Daly River Police Station since the 1986/87 water year. These stations can be interrogated from either the Darwin head office or from any telephone outlet using a portable computer and modem.

Telecom services will be provided to Beeboom and Dorisvale in 1988 and both stations will be fully equipped by the 1988/89 wet season.

The components of the flood warning system are envisaged to be similar in type to those outlined in the Katherine Flood Warning Report by Stewart and Gebhardt (Reference 2). Whilst this system has proved reliable in the forecasting of flooding on the Katherine River it may be more advantageous in future to install "off-the-shelf" systems.

Installation of such total systems would minimise the problems of incompatible components, should expanded operations be required and avoid situations where staff leave taking their knowledge of any "in house" systems with them.

The primary purpose of this report however is the development of a flood forecasting system and at the time of writing suitable flood warning hardware had not been decided upon.

6. FLOOD FORECASTING SYSTEM

A flood forecasting system for the Daly River has been developed using as a data base the peak flood stage heights shown in Table 4.2.

Whilst the basis of this system is the prediction of flood levels at the Daly River Police Station and therefore the Daly River Community, watch points have been selected from Emergency Services experience and through the regression relationships developed for each of the gauging stations used in the study.

Should the water level in the river reach these watch points at any station in the system, a flood forecasting program should be initiated.

The watch points are:

GS8140067 DORISVALE	:	13 m
GS8140042 BEEBOOM	:	12 m
GS8140040 MT NANCAR	:	13 m
GS8140003 DALY RIVER POLICE STATION	:	11.5 m

The Flood Forecasting System comprises two separate parts:

a) Prediction of peak flood heights
b) Prediction of the time to peak flood height

6.1 Estimation of Flood Heights

A multiple regression analysis was carried out on the peak stage data shown in Table 4(b) in order to derive a relationship between peak stages at Daly River Police Station and those at the gauging stations upstream. Because of the number of stations used in this study regression analyses were carried out on various combinations of the gauging stations. This ensured that should any one station fail, predictions could be made from levels at the remaining sites in the flood warning network.

A number of predictive equations were derived as shown below. Correlation coefficients are included to show the strength of the relationship for each equation.

6.1.1 Prediction of maximum stage height at Daly River Police Station given peaks at all stations upstream

Use the following Equation 6.1

PS = D x 0.02 - BB x 0.01 + MtN x 0.75 + 1.50

Coefficient of multiple correlation r = 0.995

where PS is the flood height in metres (gauge datum) at GS8140003 (Daly River Police Station)

D is the flood height in metres (gauge datum) at GS8140067 (Dorisvale)

BB is the flood height in metres (gauge datum) at GS8140042 (Beeboom)

MtN is the flood height in metres (gauge datum) at GS81400040 (Mt Nancar)

(all units are in metres)

6.1.2 Prediction of maximum stage height at Daly River Police Station given peaks at Beeboom and Dorisvale

Use the following Equation 6.2

PS = D x 0.92 - BB x 0.77 + 6.87

Coefficient of multiple correlation r = 0.915

6.1.3 Prediction of maximum stage height at Daly River Police Station given peaks at Mt Nancar and Dorisvale

Use the following Equation 6.3

PS = D x 0.010 + Mt N x 0.75 + 1.45

Coefficient of multiple correlation r = 0.992

6.1.4 Prediction of maximum stage height at Daly River Police Station given peaks at Mt Nancar and Beeboom

Use the following Equation 6.4

PS = BB x 0.01 + Mt N x 0.76 + 1.43

Coefficient of multiple correlation r = 0.992

6.1.5 Prediction of maximum stage at Daly River Police Station given only peaks at Dorisvale.

Use the following Equation 6.5

PS = D x 0.43 + 4.90

Coefficient of correlation r = 0.904

6.1.6 Prediction of maximum stage at Daly River Police Station given only peaks at Beeboom.

Use the following Equation 6.6

PS = BB x 0.63 + 3.59

Coefficient of correlation r = 0.874

6.1.7 Prediction of maximum stage at Daly River Police Station given only peaks at Mt Nancar.

Use the following Equation 6.7

PS = MtN x 0.76 + 1.44

Coefficient of correlation r = 0.992

A comparison of historical and predicted peak stage heights is shown in Table 6.1. As can be seen from Table 6.1 predicted values at Daly River Police Station are highly dependant on the value of the peak occurring at Mt Nancar gauging station. Equations 6.2, 6.5 and 6.6 which use only Dorisvale and Beeboom stages give less accurate predictions of the peak stages than any of the regression equations containing Mt Nancar.

Therefore if peaks from all stations upstream of Daly River Police Station are known, Equation 6.1 should be used. However, since the time delay between peak events at Mt Nancar and the Police Station is normally only in the range of 8 to 9 hours, an earlier less accurate prediction can be made using equations 6.2, 6.5 or 6.6.

A graphical relationship between successive stations downstream of Dorisvale is given in the Appendix, however this should be used for preliminary estimates only and not for final peak level predictions at Daly River Police Station.

6.2 Estimation of Time to Peak Flood Height

The prediction of delay times between gauging stations along the flood warning network presents a more difficult problem than the estimation of peak flood

TABLE 6.1
ISTORIC AND PREDICTED PEAK STAGE HEIGHTS
DALY RIVER POLICE STATION (GS8140003) (GAUGE DATUM) (m)

WATER YEAR	HISTORICAL PEAK STAGE	PEAK STAGE USING EQN 6.1	PEAK STAGE USING EQN 6.2	PEAK STAGE USING EQN 6.3	PEAK STAGE USING EQN 6.4	PEAK STAGE USING EQN 6.5	PEAK STAGE USING EQN 6.6	PEAK STAGE USING EQN 6.7
70/71	10.28	10.33	10.91	10.33	10.33	11.11	11.18	10.27
71/72	13.04	12.80	12.26	12.80	12.80	12.37	12.29	12.74
72/73	12.44	12.46	12.67	12.46	12.46	12.76	12.63	12.39
73/74	14.90	14.85	14.25	14.85	14.85	14.24	13.94	14.77
74/75	11.40	11.41	11.67	11.41	11.41	11.82	11.81	11.35
74/75	11.40	11.25	11.36	11.25	11.26	11.54	11.56	11.20
75/76	14.27	14.83	13.89	14.83	14.84	13.90	13.63	14.76
75/76	13.06	13.19	13.56	13.19	13.19	13.59	13.37	13.11
76/77	14.77	14.32	14.02	14.32	14.32	14.02	13.74	14.25
76/77	13.23	13.24	13.55	13.24	13.24	13.58	13.36	13.17
77/78	11.18	11.22	11.46	11.22	11.22	11.63	11.64	11.16
78/79	11.31	11.29	11.35	11.29	11.29	11.52	11.55	11.24
79/80	12.72	12.63	11.74	12.63	12.63	12.83	12.69	12.56
79/80	10.83	10.85	10.98	10.85	10.85	11.18	11.25	10.80
80/81	12.69	12.56	12.58	12.56	12.56	12.67	12.56	12.50
80/81	10.67	10.77	11.45	10.77	10.77	11.62	11.63	10.71
81/82	10.28	10.39	10.87	10.39	10.39	11.03	11.07	10.33
82/83	10.70	10.70	10.10	10.69	10.68	9.40	8.84	10.66
83/84	13.38	13.44	13.37	13.44	13.44	13.52	13.40	13.36
83/84	10.58	10.61	11.02	10.66	10.60	10.99	10.88	10.55
84/85*	11.46	11.46	9.94	11.47	11.48	10.51	10.92	11.43
86/87	12.80	12.82	13.42	12.82	12.82	13.49	13.29	12.74

* 1984/85 Flood consisted of large inflows from the Fish River downstream of Beeboom Gauging Station.

heights. As shown in Figure 6.2, the time lag between peak events at Dorisvale and Daly River Police Station varies markedly and with no apparent relationship to the magnitude of the flood.

Whilst delay time depends largely on the type of flood experienced ie: sharp rise and recession or extended peak stage flood, accurate predictions of the lag cannot be made by this means alone.

The method of analysis employed in this study involved the evaluation of ratios of lag time between stations at the upper end of the network and those nearer the police station. Table 6.2 shows calculated ratios for significant flood events where accurate lag times were recorded between the 1970/71 and 1986/87 water years. As shown in Table 6.2 the delay times for Dorisvale to Beeboom versus both Dorisvale to Mt Nancar and Dorisvale to Daly River Police Station provide the most consistent values.

Therefore the prediction of total delay times between peak levels at Dorisvale and those at either the Daly River Police Station or Mt Nancar may be calculated by using the following equations.

$$T(D\text{-}MtN) = \frac{T(D\text{-}BB)}{0.51} \quad \text{: Equation 6.8}$$

$$T(D\text{-}PS) = \frac{T(D\text{-}BB)}{0.46} \quad \text{: Equation 6.9}$$

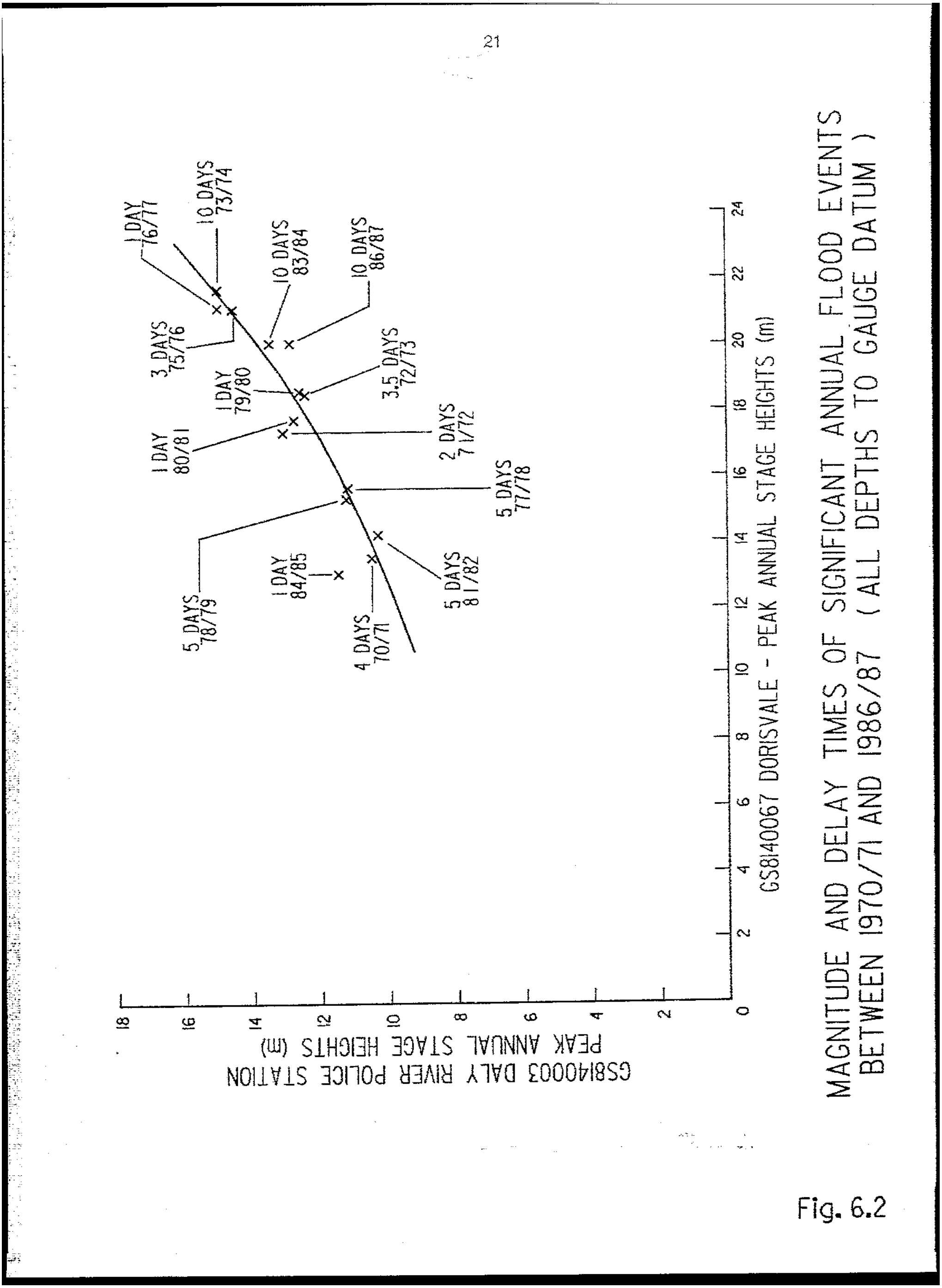
where:

T(D-MtN) is the delay between the time of peak stage at Dorisvale and the time of peak stage at Mt Nancar in hours.

T(D-PS) is the delay between the time of peak stage at Dorisvale and the time of peak stage at Daly River Police Station in hours.

T(D-BB) is the delay between the time of peak stage at Dorisvale and the time of peak stage at Beeboom in hours.

The use of equations 6.8 and 6.9 should normally give acceptable long term predictions of the time to peak stage, however, if any anomalies are noted in the estimation of the time lags it should be remembered that the peak level at Daly River Police Station will occur approximately 8 to 9 hours after the peak stage at Mt Nancar.



MAGNITUDE AND DELAY TIMES OF SIGNIFICANT ANNUAL FLOOD EVENTS
BETWEEN 1970/71 AND 1986/87 (ALL DEPTHS TO GAUGE DATUM)

Fig. 6.2

TABLE 6.2

RATIO OF TIME INTERVALS BETWEEN PEAK STAGE LEVELS AT DALY RIVER GAUGING STATIONS

WATER YEAR	DORISVALE TO BEEBOOM / DORISVALE TO MT NANCAR			DORISVALE TO BEEBOOM / DORISVALE TO POLICE STATION			DORISVALE TO BEEBOOM / BEEBOOM TO MT NANCAR			DORISVALE TO MT NANCAR / BEEBOOM TO POLICE STATION			DELAY BETWEEN MT NANCAR AND POLICE STATION
1971-72	27/56	=	0.48	27/64	=	0.42	27/30	=	0.90	30/38	=	0.78	8 hours
1972-73	30/56	=	0.54	30/64	=	0.47	30/27	=	1.11	27/35	=	0.77	8 hours
1975-76	41/88	=	0.46	41/96	=	0.87	47/55	=	0.87	47/55	=	0.85	8 hours
1976-77	4/12	=	0.33	4/20	=	0.20	4/8	=	0.50	8/16	=	0.50	8 hours
1978-79	59/96	=	0.61	59/10	=	0.57	59/37	=	1.59	39/45	=	0.82	8 hours
1979-80	59/94	=	0.62	59/10	=	0.55	59/35	=	1.69	35/49	=	0.71	14 hours
1980-81	59/90	=	0.60	54/10	=	0.52	54/36	=	1.50	36/50	=	0.72	14 hours
1981-82	56/104	=	0.54	56/11	=	0.48	56/48	=	1.17	48/60	=	0.80	12 hours
1982-83	36/88	=	0.41	36/96	=	0.37	36/52	=	0.69	52/60	=	0.87	8 hours
1983/84	100/256	=	0.39	100/24	=	0.41	100/156	=	0.64	156/144	=	1.08	-12 hours
1983-84*	36/62	=	0.58	36/70	=	0.51	36/26	=	1.38	26/34	=	0.76	8 hours
1986-87	96/176	=	0.54	96/18	=	0.52	96/80	=	1.20	80/88	=	0.91	8 hours
	Mean	=	0.51	Mean	=	0.46	Mean	=	1.10	Mean	=	0.80	Mean = 9.09#
	SD	=	0.10	SD	=	0.10	SD	=	0.10	SD	=	0.14	SD = 3.51#

where: All Beeboom data before 1981/82 was derived from delay between Dorisvale and Gourley and multiplied by an appropriate distance factor.
SD = Standard Deviation
* Second Yearly Flood Event
# 1983-84 Flood omitted due to failure to isolate a satisfactory peak stage height during an extended high stage plateau at both Mt Nancar and Daly River Police Station.
Times are quoted in hours.

47a:SWP

7. TESTING OF FLOOD FORECASTING SYSTEM

Flood events on the Daly River between 1970/71 and 1986/87 water years provided the data base for all analysis in this report. As a result of this any effective testing of the accuracy of the flood forecasting system requires the use of independent data outside of this time interval.

7.1 Testing of Flood Height Forecasting System

Any testing of this system using the regression equations is not possible due to the unavailability of data for Mt Nancar and Beeboom gauging stations before the 1970/71 water year. However, comparison may be carried out using the graphical method contained in the Appendix which requires only Dorisvale peak stages. Results of this testing are shown in Table 7.1.

TABLE 7.1 COMPARISON OF HISTORICAL AND PREDICTED PEAK STAGE HEIGHTS AT DALY RIVER POLICE STATION USING THE GRAPHICAL METHOD
(all heights in metres Gauge Datum)

WATER YEAR	GS8140067 DORISVALE	GS8140003 POLICE STN HISTORIC	GS8140003 POLICE STN PREDICTED
1965/66	18.74	13.06	12.79
1966/67	17.46	12.28	12.27
1967/68	18.86	13.17	12.84

7.2 Testing of Time to Peak Flood Height Forecasting System

Verification of the time forecasting system was again more difficult than the corresponding stage component. It was decided the only acceptable approach was to test the system using secondary flood events after the 1980/81 water year. This approach enabled the use of Beeboom gauging station and at the same time included data independent of the previous analysis.

Comparison of historic and predicted peak stage height times for the February 1984 flood are shown in Table 7.2.

TABLE 7.2 HISTORIC AND PREDICTED PEAK STAGE HEIGHT TIMES FOR FEBRUARY 1984 FLOOD EVENT

TIME OF PEAK STAGE AT DORISVALE	PREDICTED TIME OF PEAK AT MT NANCAR	HISTORIC TIME OF PEAK AT MT NANCAR	PREDICTED TIME OF PEAK POLICE STN	HISTORIC TIME OF PEAK AT POLICE STN
31.1.1984 1800 hrs	3.2.1984 1600 hrs	3.2.1984 0800 hrs	4.2.1984 0100 hrs	3.2.1984 1600 hrs

As can been seen by the comparison in Table 7.2 the best degree of accuracy that can be expected with the use of equations 6.8 and 6.9 is in the region of 8 to 10 hours. However, it should be noted that accurate prediction of the time of peak stage at the Police Station is possible by the addition of 8 to 9 hours to the time of peak stage at Mt Nancar.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

A flood forecasting system has been developed for the Lower Daly River. It has been validated by the use of independent data. However, a complete testing program will not be possible until future flood events occur in the Daly River.

The short length of record for Beeboom gauging station necessitated the extension of data using other gauging stations. Nevertheless, multiple regressions carried out on historical data after the 1980/81 water year provided similar results to those obtained from the extended data set.

The estimation of times to peak stage height are largely dependent on the type of flood occurring. Any use of the equations to predict delay times should be accompanied by suitable qualitive assessment by a person familiar with flooding patterns along the Daly River.

Whilst the prediction of peak stages at the Daly River Police Station provide the basis of this report, estimation of rising stages at the Police Station are also important in the formulation of a complete flood forecasting system.

Initial predictions using rising stages at Dorisvale can be made by using the graphical technique described in the Appendix. However, for more accurate predictions of the rising stage at Daly River Police Station equation 6.7 should be used and a delay of 8 hours between the stage at Mt Nancar and the predicted stage at the Police Station employed.

The multiple regression equations 6.1 to 6.4 should not be used as they require appropriately delayed rising stage events at each station which are not possible to identify until the peak stage has been reached at all stations in the regression equation.

8.1.1 Prediction Process

Gauging Station Watch Points

GS8140067	Dorisvale	: 13 m
GS8140042	Beeboom	: 12 m
GS8140040	Mt Nancar	: 13 m
GS8140003	Daly River Police Station	: 11.5 m

A flood forecasting program should be initiated with the rise of water above any of the watch points given above.

Preliminary estimation of stages at Daly River Police Station and Community may be calculated using both rising and peak stages at Dorisvale on the graphical method described in the Appendix. More accurate predictions of the stage of the Police Station will be possible as rises occur at Mt Nancar and Equation 6.7 can be used.

Peak stage at the Police Station may be calculated using the regression Equations 6.1 to 6.8 as peak levels become available at the upstream stations.

Initial prediction of the time of peak stage at Daly River Police Station may be made by using the equations given in Section 6.2, however, a final estimation of the peaks stage time should be made by adding 8 hours to the time of peak stage at Mt Nancar.

8.1.2 Flood Warning System

Agreement has been reached for the siting of telemetry stations at both Dorisvale (GS8140067) and Beeboom (GS8140042). At the time of writing provision had been made for the investigation of suitable "off-the-shelf" data logging hardware. However, no concrete decision has yet been made on the appropriate systems to be installed.

8.2 Recommendations

It is recommended that data collection be continued at all gauging stations in the flood warning network during any future flood events. This data should then be used to extend the existing data base and provide more accurate predictions during subsequent floods.

It is further recommended that more liaison with Emergency Services be initiated with the goal of providing the most complete flood forecasting procedure with the resources available.

9. REFERENCES

1. POWER, N.A., PIDSLEY, D.G. & REINHARD, R.G.: Lower Daly River Basin Investigation Of Flood Protection And Flood Forecasting; Draft Report, Water Division, Department of Transport and Works, October 1980.

2. STEWART, B. & GEBHARDT, G., (1987); Flood Warning And Forecasting System For Katherine, Northern Territory; Power and Water Authority, Water Resources Group, June 1987.

APPENDIX

CALCULATION OF PEAK STAGE HEIGHT AT DALY RIVER POLICE STATION USING THE GRAPHICAL METHOD

The graphical presentation in Figure A1 allows the calculation of preliminary estimates of the stage height at Daly River Police Station, given a peak stage at Dorisvale or any station downstream.

As peaks are reached at gauging stations downstream more accurate predictions may be made with the use of the regression equations 6.1 to 6.4.

The graphical method may be used by following a simple set of instructions.

They are:

1. Plot the peak stage height at Dorisvale on the Dorisvale Axis.

2. Draw a vertical line downwards until it hits the Beeboom - Dorisvale regression line.

3. At this point draw a horizontal line until it hits the Mt Nancar - Beeboom regression line.

4. At this point of intersection draw a vertical line until it hits the Police Station - Mt Nancar regression line.

5. Finally draw a horizontal line to the Police Station Axis. This value is the preliminary estimate of Peak Stage Height at Daly River Police Station.

47:SWP

-A2-

A Simple example is shown on Figure A1:

Assume a peak height of 20.80 metres has occurred at Dorisvale (GS8140067).

Step 1 Plot 20.80 on the Dorisvale axis

Step 2 Draw a vertical line until it touches the Beeboom - Dorisvale regression line.

Step 3 Step 2 gives a value of 16.0 m for the peak at Beeboom. Now draw a horizontal line to the Beeboom - Mt Nancar regression line.

Step 4 Step 3 gives a value of 16.05 m for the peak at Mt Nancar. Now draw a vertical line to the Mt Nancar - Police Station regression line.

Step 5 By drawing a horizontal line from the point found in Step 4 we arrive at a peak stage of 13.70 m for Daly River Police Station.

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A3

LINEAR REGRESSION RELATIONSHIPS FOR SUCCESSIVE GAUGING STATIONS
DALY RIVER (ALL DEPTHS TO GAUGE DATUM)

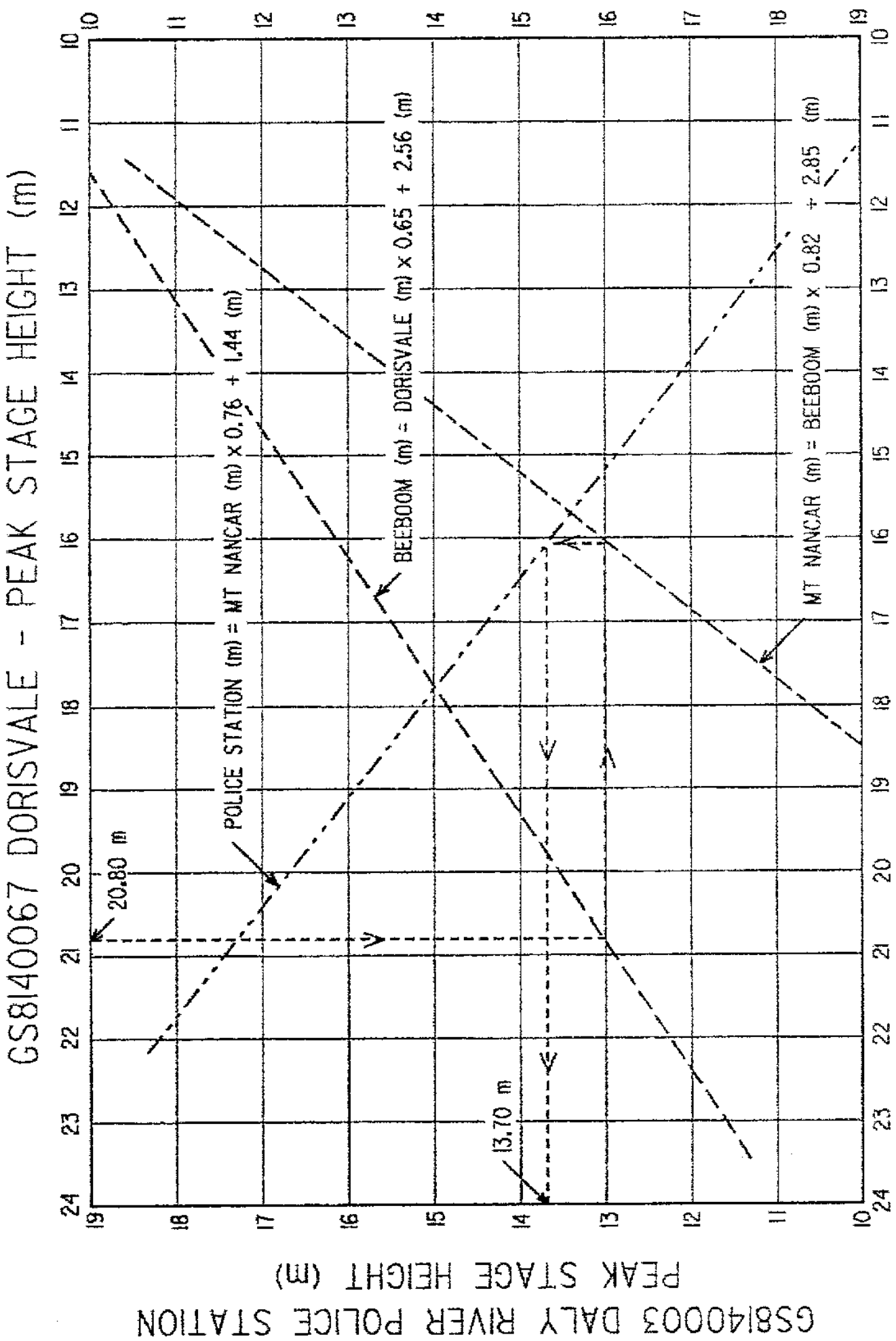

Fig. A1