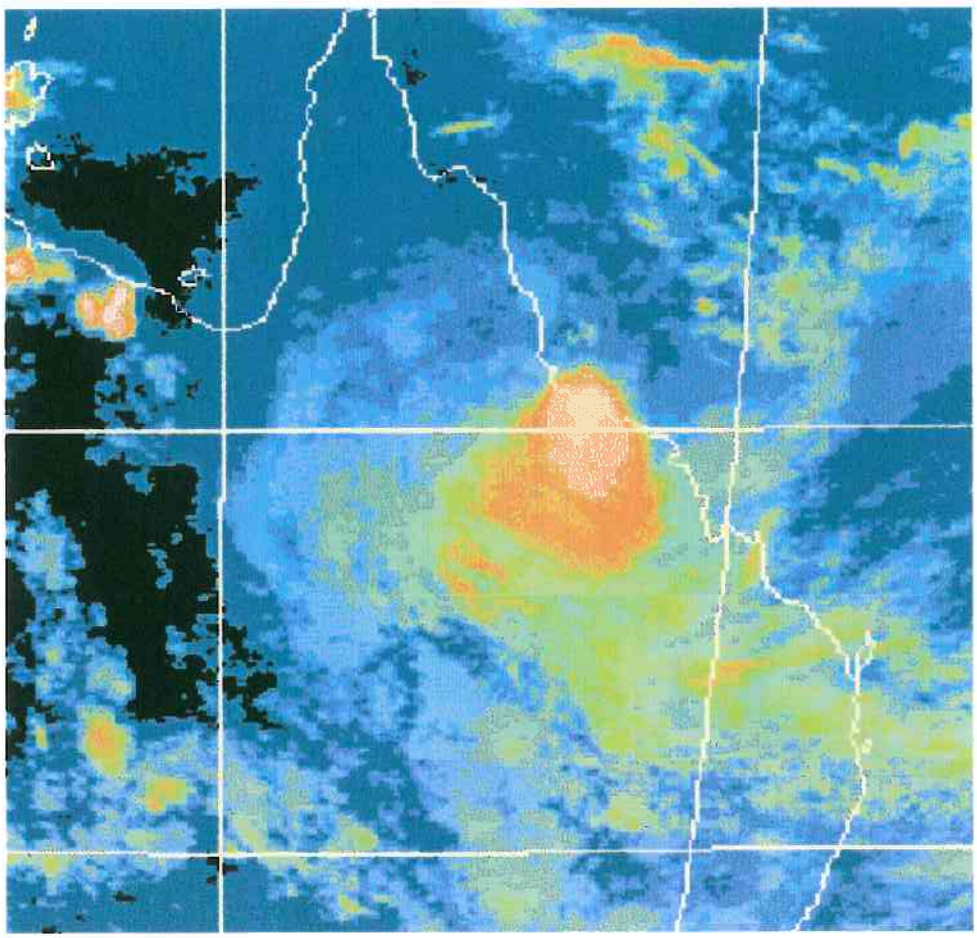
BUREAU OF METEOROLOGY
DEPARTMENT OF THE ENVIRONMENT

SEVERE WEATHER AND FLOODING

NORTH QUEENSLAND

JANUARY 1998



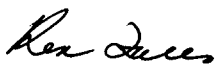
FOREWORD

The flooding in North Queensland in January 1998 associated with a tropical low, ex-cyclone Sid, was exceptional in that the focus of the heaviest rainfall was over the largest urbanised centre in northern Australia, Townsville-Thuringowa.

In almost any wet season in northern Australia a rainfall event that exceeds recorded experience is likely to occur somewhere. It is when populated areas are directly affected that an extreme rainfall event can become a disaster.

Such events can overwhelm the local infrastructure, and are a severe test of both the meteorological and hydrological warning systems, in which the Bureau of Meteorology has a lead role, and disaster response measures implemented under the auspices of the State Counter Disaster Organisation.

This report documents meteorological and hydrological aspects of this severe weather and flooding event, and provides a summary of the Bureau's warning performance. It was compiled shortly after the event, and some of the information provided here may be subject to revision on the basis of additional data or analysis.



Rex Falls
Regional Director Queensland
Bureau of Meteorology

Severe flood damage at Black River, north of Townsville.
(Photo courtesy of Queensland Newspapers)

Car swept away by floodwaters, Townsville.
(Photo courtesy of Queensland Newspapers)

Landslide at Magnetic Island.
(Photo courtesy of Queensland Newspapers)

Major flooding through the township of Ingham.
(Photo courtesy of Queensland Newspapers)

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North Queensland
January 1998

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EXECUTIVE SUMMARY

The aim of this report is to document the meteorological and hydrological aspects of the event, and to outline the warning and prediction services given by the Bureau during the period of severe weather in north Queensland in January 1998.

From 7 January to 14 January 1998, north coastal Queensland experienced extreme weather conditions and heavy rainfall which led to significant rises in most of the coastal rivers and streams from Gordonvale to Home Hill. Minor flooding occurred in the Johnstone River and adjacent rivers early during the period, but it was the intense rainfall which commenced in the Herbert River late on Friday 9 January and at Townsville on Saturday evening 10 January which caused the most damage.

Major riverine flooding resulted in the lower Herbert, the upper Burdekin River and in the Haughton Rivers. Severe flash flooding occurred in all coastal streams in the Bluewater area to Townsville with the most intense rainfall centered around Townsville itself.

The torrential rain, and flash flooding in the Townsville area tragically resulted in the loss of one life, a motorist swept from a flooded road. The region suffered extensive damage, particularly in the residential sector, businesses, and local government infrastructure, with reports indicating that the total damages bill exceeds $100 million.

The high seas, strong winds, heavy rainfalls and flooding during this period were associated with a tropical low (ex tropical cyclone *Sid*) which was steered by a deep trough system from the Gulf of Carpentaria to the Townsville region. As the low neared Townsville the trough system weakened and a strengthening high pressure ridge in the lower atmosphere blocked the path of the low. This kept the low and associated monsoon trough just to the north of Townsville and placed the region in the zone of heavy monsoon rain. A thunderstorm complex which developed just to the north west of Townsville produced very intense rainfall at Townsville during Saturday evening 10 January.

Rainfalls exceeding 1300 millimetres were recorded over the 7 day period to 9am 14 January 1998 at some locations with widespread totals from 200 to 600mm. The heavy rainfall commenced in the northern part of the region in the 24 hours to 9am 9 January with falls up to 400mm. Similar high falls were recorded in the area around Ingham in the next 24 hours to 9am Saturday 10 January. Townsville recorded 549mm in the 24 hours to 9am Sunday, the highest 24 hour fall on record in Townsville. Heavy falls continued in the region into Wednesday. The Townsville rainfall for all periods between 1 and 72 hours easily exceeded that estimated to have an average recurrence interval of 1 in 100 years.

The very intense rainfall in the lower Herbert commenced suddenly on Friday evening 9 January and stopped just as abruptly on Saturday morning. The heavy rainfall in the Townsville area commenced at about 6pm on Saturday evening and continued until Sunday morning.

Flooding in the main river systems during the period was very similar to that which occurred during Cyclone Justin in March 1997. However, the flash flooding which occurred in Bluewater Creek and the Black River and in the Townsville area was

unprecedented.

Flood levels in the Tully and Herbert River were just below the record levels reached during the March 1967 event while levels in the upper Burdekin were also below record levels.

The historical record of flood levels in Bluewater Creek and the Black River, to the north of Townsville, is less than 30 years but the peak flood heights reached during January were the highest on record.

The first flood warnings for the region were issued for the Johnstone River at 1.15pm and for the Tully River at 1.35pm on Thursday 8 January 1998. For these systems, warning times are considered adequate.

The first major weather warning for the system on the East coast was a Gale Warning for smallcraft issued at 4pm Friday for Innisfail to Lucinda, with strong winds south to Bowen, upgrading a strong wind warning that had been issued earlier.

At 4am Saturday a Severe Weather Warning was issued for the area Cardwell to Bowen warning of wind gusts to 90 km/h, very heavy rain, localised flash flooding, and beach erosion/salt water flooding problems with the morning's high tide. This was some 12 hours ahead of the disastrous events in the Townsville area. This warning also advised motorists to take care with flooded road crossings. A similar warning was issued at 7am Saturday included warning of landslides and fallen trees.

The Initial Flood Warning for the Herbert River was issued at 5am on Saturday 10 January and subsequent warnings were re-issued regularly throughout the day. As a consequence of the rapid development of the lower Herbert River flood situation, warning lead times for this event were shorter than usual. At the time of the 5am priority warning, the Herbert River at Gairloch, the reference gauge for Ingham flooding, was in minor flood at 10 metres but rising fast. By 9am, the river level had reached the major flood level of 11.5 metres, subsequently peaking at 12.3 metres later on Saturday afternoon and into the evening.

The Severe Weather Warning and Flood Warning issued at 4 pm and 4.20 pm respectively provided a more specific focus on worsening conditions in the "Townsville district". However, the accurate quantitative forecasting of rainfall amounts in tropical convective systems such as in this event is an unsolved scientific problem. Although very heavy rain was monitored on radar and in automatic rain gauges, and noted in public advices, it was not possible to predict in numerical terms the almost 500 millimetres that fell in less than 12 hours in the Townsville area.

Flood Warnings were first issued for the Haughton River at 6.55pm on Saturday evening, about 24 hours in advance of the peak at Giru.

Warnings for the upper Burdekin were first issued at 10.35am on Saturday 10 January and the river at Sellheim eventually reached a peak at 6pm the next day.

During the period, the Bureau's Warning Centre issued 14 Severe Weather Warnings, specifically for the adverse weather conditions in the Townsville area and over 60 Flood Warnings for five river basins. Included in the flood warnings were over 20 river height predictions for locations in the Tully, Herbert, Haughton and Burdekin Rivers. These were widely disseminated to emergency response agencies such as Police, Emergency Services and Local Governments, and to the media for public broadcasting.

An analysis of the flood warning rainfall and river height networks in north Queensland showed that about 70 to 80% of all (manual and automatic) stations provided adequate or better performance throughout the event. The failure rate of ALERT stations was abnormally high, about 20%, higher than the 10 to 15% usually experienced. Failure at automatic stations was due to communications problems with radio and telephone systems, instrument failure, calibration errors or incorrectly reported data. While the failure rate was higher than normal, it did not greatly inhibit the ability of the Warning Centre to provide services.

Flood forecasting models were available for the Johnstone, Tully, Herbert, Haughton and Burdekin River systems and gave guidance for river height predictions at key locations. The computer systems used in the Warning Centre worked satisfactorily during the event with the telemeter interrogation package, MASTERS, and the ALERT software, both resident on HYNET, performing robustly. However, data display and warning preparation using the Bureau's ageing regional operational computer system, AROS, is cumbersome and barely adequate by current day standards. The AROS system in Queensland is programmed for replacement with the Bureau's new generation computer system by the end of 1998, providing a substantial upgrade of these functions.

Since this event, the Bureau has been involved in a number of activities and discussions aimed at reviewing and improving all aspects of the severe weather and flood warning services. This process of review and improvement is ongoing at the time of writing this report, and includes Bureau involvement in short and long term activities such as:

* Participation in formal and informal emergency service debriefs and discussions, and development of recommendations with relevant agencies;

* Addressing of issues identified in general agency and community feedback including that from the post-event survey (to which the Bureau contributed) of Townsville & Thuringowa residents, conducted by the James Cook University Centre for Disaster Studies;

* With Townsville and Thuringowa City Councils and their Water Board, the development of proposals for an integrated flood warning system for the Ross River, and consideration of possible flash-flood warning measures for smaller streams;

* Continuation of projects to improve the forecasting of heavy rainfall, including real-time analysis of rainfall from radar and the ground-based networks;

* Re-analysis and refinement of existing real-time flood forecasting catchment models, and the development of new models for other river systems including the Ross River.

* Investigation of improved methods for alerting Bureau, Local Government personnel and the community to the potential for, and occurrence of, flood-producing rainfall;

* Fault maintenance visits to field equipment, and the identification of future preventative and upgrade measures to improve reliability;

* Review of adequacy of monitoring networks and communication methods, and identification of upgrade measures.

It is anticipated that further interactions will take place with relevant agencies, including Emergency Services and Local Government, aimed at improving warning services associated with such extreme events.

Severe Weather and Flooding
North Queensland
January 1998

1.0 INTRODUCTION

In mid January 1998, the region of north Queensland from the Cairns area to Ayr experienced extreme weather conditions, associated with ex-tropical cyclone *Sid*, with strong winds and heavy rainfall. This led to flooding in most coastal rivers and streams from the Johnstone River to the Burdekin River.

The heavy rain commenced late on 7 January in the northern part of the region around Gordonvale near Cairns and extended south to Giru by Sunday 11 January. Isolated heavy falls continued in the region up to about 14 January.

Most river and streams in the region experienced some level of riverine flooding during this period with the most severe being in the Herbert and Haughton Rivers. However, by far the most severe was the flash flooding which occurred in the area around Townsville on the weekend of 10 and 11 January.

1.1 Aim of Report

The aim of this report is to document the meteorological and hydrological aspects of the significant weather and flooding in north Queensland during the period 7 January to 14 January 1998.

The stations and places named in the report may be located by referring to the maps in Figures 1.1 to 1.4.

The report also outlines the warning and prediction services given by the Bureau in the lead-up to and during the event, and provides some review of the performance of the warning services and flood forecasting systems operated by the Bureau of Meteorology.

The report has been produced by the Queensland Regional Office of the Bureau of Meteorology. It may be used by external agencies under the conditions outlined on the title page.

1.2 Impact & Damages

At this stage it is very difficult to fully appraise the extent of damage in the areas affected. The following summary is taken from newspaper reports and Situation Reports issued by the State Disaster Co-ordination Centre during, and shortly after, the event.

A State of Disaster was declared for the Townsville area on Sunday morning 11 January 1998 and expired at 1045 on Wednesday 14 January 1998.

A disabled man was drowned when his car was washed off a road crossing in Townsville.

Damage to both private and public building was extensive in several areas throughout the region.

In Townsville, it was estimated that up to 100 residences had sustained substantial over floor inundation with hundreds more sustaining property flooding. Numerous cars were damaged by floodwaters and, at one stage, it was reported that nearly 50% of the houses in Townsville were without power. The impact on the commercial centre of Townsville was high with enormous losses. Damages were also high to local government infrastructure such as water, sewerage, roads and drainage.

On Magnetic Island, a huge land slide, estimated to be three times the size of the Thredbo disaster, caused major damage to a resort complex.

The small communities of Black River and Bluewater, just north of Townsville, suffered extensive damage. At Black River, it was estimated that flood water impacted on 48 houses with the majority being rendered uninhabitable. Fourteen(14) were totally destroyed with eight being washed away. A total of 40 residences were severely impacted at Bluewater with most being uninhabitable for some time.

Further north of Townsville, it was estimated that in excess of 100 residences experienced over floor flooding at Ingham and Halifax. At Giru to the south of Townsville, flood waters entered the town causing inundation of most properties.

Away from the urban areas, damages in the rural and agricultural sector were also high.

Numerous local and main roads were closed during the period. All major roads from Townsville to Ayr, Cairns and Mt Isa were effected at several locations for some time during the period. Several local roads in the Ingham and Townsville areas suffered significant damage due to washouts and heavy scouring. All rail services between Mackay and Cairns were disrupted and damage to the rail links occurred due to several major washouts. The Townsville Airport was closed for a period from Saturday evening 10 January.

Wave action and high seas inflicted severe damage and beach erosion occurred at several locations around Townsville and its immediate north. Seven vessels were reported to have sunk in Townsville Harbour.

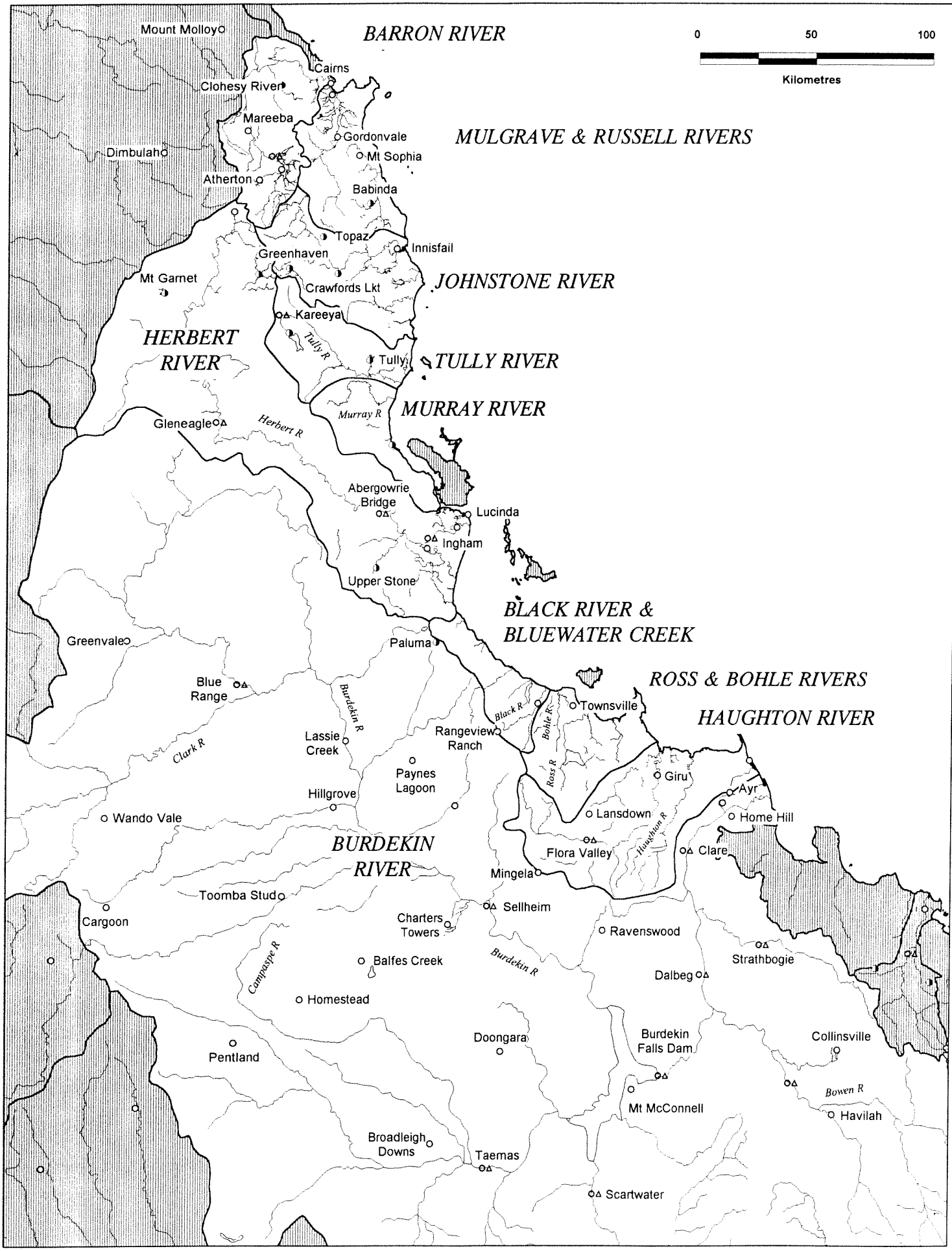
The full damage bill of the floods in north Queensland may never be accurately known but is thought to be well in excess of $100 million with the largest damages reported in the residential sector, businesses, local government infrastructure, and rural property damage and stock losses.

1.3 Sources of Data

The primary source of data for this report is the record of meteorological data and analysis held by the Bureau of Meteorology The meteorological data set includes surface and upper air weather observations, satellite pictures and digital radar images.

Rainfall and river height data collected by the Bureau's Warning Centre during the event is also used. This data includes data from radio telemetry (ALERT) systems, telephone telemeters (TMs) and manual observer stations reporting through the Remote Observer Collection System (ROCS).

Additional river height information was obtained from the Queensland Department of Natural Resources (DNR) and wave and tide data was obtained from the Queensland Department of Environment and Heritage, Coastal Management Branch.

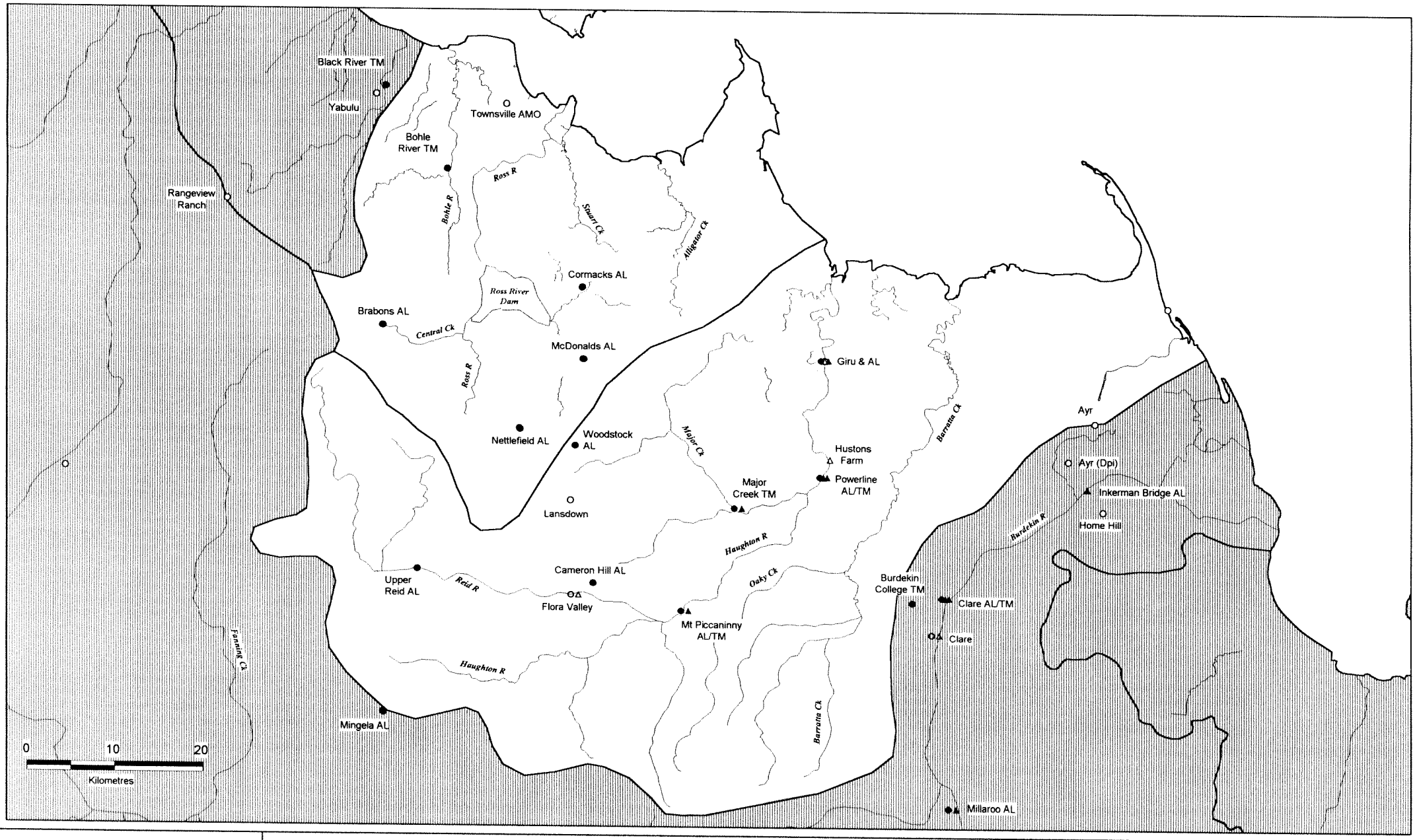


◗ Manual Heavy Rainfall Station o Daily Reporting Rainfall Station △ Manual River Station	**NORTH QUEENSLAND COASTAL RIVERS**	**Figure 1.1** Page 6

- Manual Heavy Rainfall Station
- Daily Reporting Rainfall Station
- Manual River Station
- Telemetry Rainfall Station
- Telemetry River Station

HERBERT, TULLY, JOHNSTONE & BARRON RIVERS FLOOD WARNING NETWORK

Figure 1.2

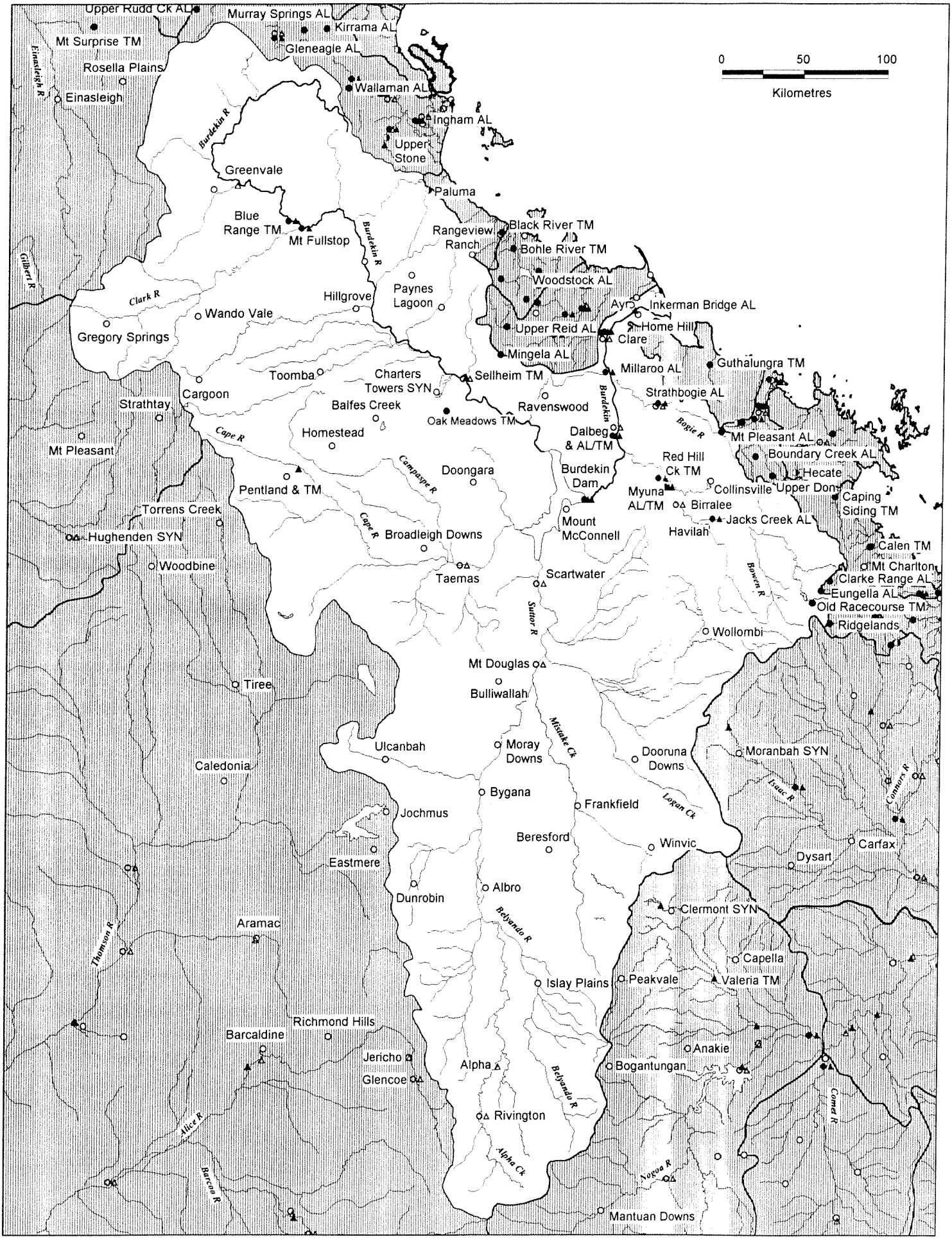


- Manual Heavy Rainfall Station
- Daily Reporting Rainfall Station
- Manual River Station
- Telemetry Rainfall Station
- Telemetry River Station

HAUGHTON and ROSS RIVERS

FLOOD WARNING NETWORK

Figure 1.3



- Manual Heavy Rainfall Station
- Daily Reporting Rainfall Station
- Manual River Station
- Telemetry Rainfall Station
- Telemetry River Station

BURDEKIN RIVER
FLOOD WARNING NETWORK

Figure 1.4

2.0 METEOROLOGICAL CONDITIONS

2.1 Tropical Cyclone *Sid*

Tropical cyclone *Sid* was named late on Boxing Day 1997 and weakened below tropical cyclone intensity 48 hours later. However it continued to meander around the Top End of the Northern Territory and Gulf of Carpentaria as a tropical low and at 9 am 8 January 1998 it was approaching the community of Kowanyama along the eastern Gulf of Carpentaria. The track of ex tropical cyclone *Sid* from Kowanyama over to the Townsville region is shown in Figure 2.1.

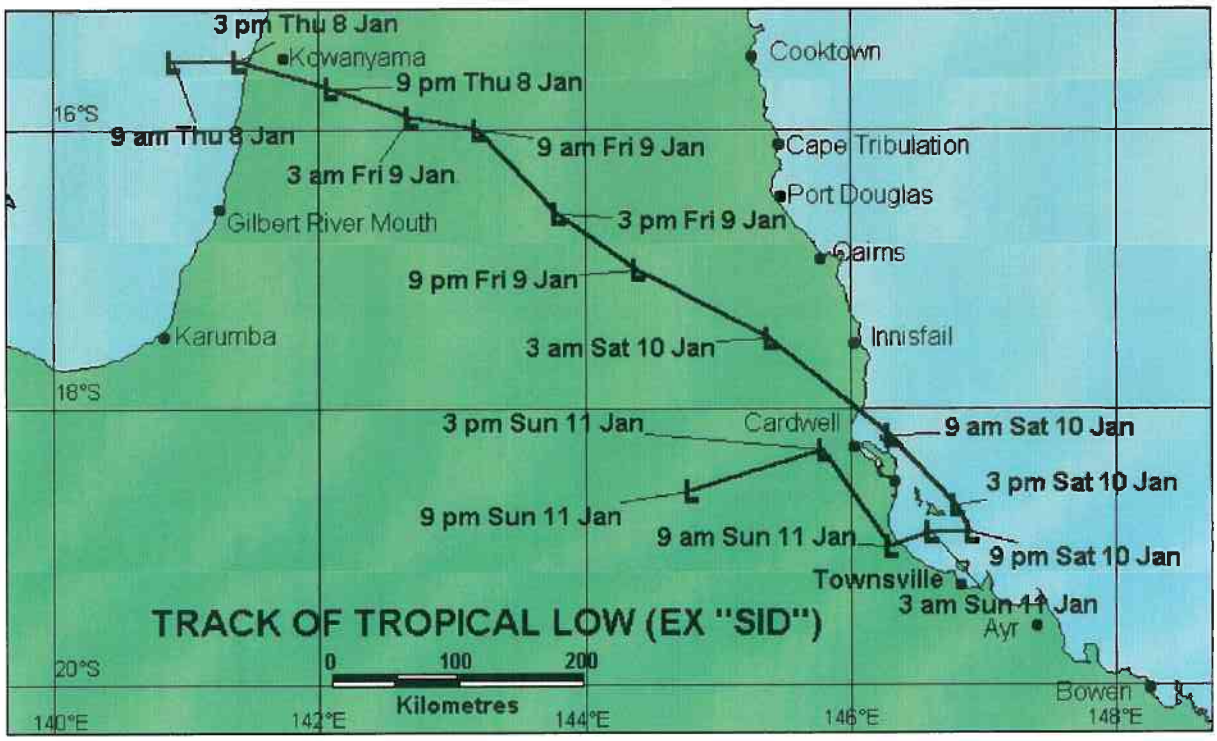


Figure 2.1 Track of Tropical Low (ex *Sid*)

2.2 Upper Atmosphere Changes

At 9am 9 January 1998 a trough at the 200 hPa level (Figure 2.2) lay from Victoria up to the Northern Territory with strong upper northwesterly winds over most of Queensland. By 9am 10 January 1998 the trough had moved westward and strong northwesterly winds continued to blow over Queensland at high levels.

At lower levels in the troposphere (Figure 2.3) the upper trough system was reflected by a trough (left hand panels in Figure 2.3) lying from near Adelaide up to the tropical low crossing Cape York Peninsula. The 850 hPa, 700 hPa and 500 hPa levels are represented in Figure 2.3 and by 9am 10 January 1998 (right hand panels) the trough was less defined indicating it had weakened at these lower levels as the upper trough moved west. Also by 9am 10 January 1998, heights had risen over southern Queensland and New South Wales at 850 hPa and 700 hPa as strong ridging was developing in the Tasman Sea.

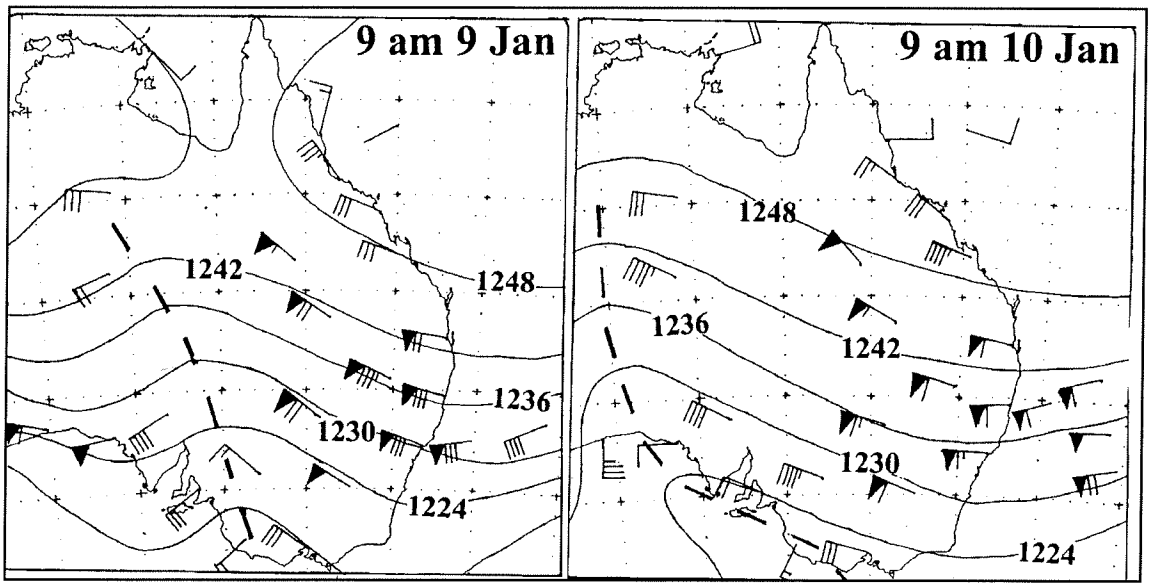


Figure 2.2 **Wind Plots at 200hPA**
(Flag/barb/half barb denote 50/10/5knots & height contours(decametres)

2.3 Movement of the Low in the Upper Atmosphere

The deep trough system initially provided the steering mechanism for the low moving it southeastward across Cape York Peninsula towards Townsville. As the trough weakened by 9 am 10 January 1998 the steering was weakened particularly in the lower parts of the troposphere where the developing ridge blocked the path of the low.

At 500 hPa and 200 hPa at 9am 10 January 1998 however the trough was still evident west of the low and north to northwesterly winds blew across the low at these levels. This had the effect of displacing the rain areas when they developed towards the southern side of the low.

2.4 Mean Sea Level Development

At 3pm 9 January 1998 (top left Fig 2.4) the low was 220 km west of Cairns with the dashed line marking the location of the monsoon trough north of Cooktown. By 9pm the monsoon trough was near Cairns and rapidly moving southwards to a band of strong winds developing between Cardwell and Bowen.

By 3 am 10 January 1998 the monsoon trough merged with this band of strong winds and the heavy rains began to develop in the zone just south of the monsoon trough. During monsoon situations along the eastern coast of Queensland the heaviest rain is always recorded just to the south of the area where the monsoon trough crosses the coast. The low then remained very slow moving just to the north of Townsville for the 24 hours after 9am 10 January 1998. This kept the Townsville area in the zone of heavy rain over this period.

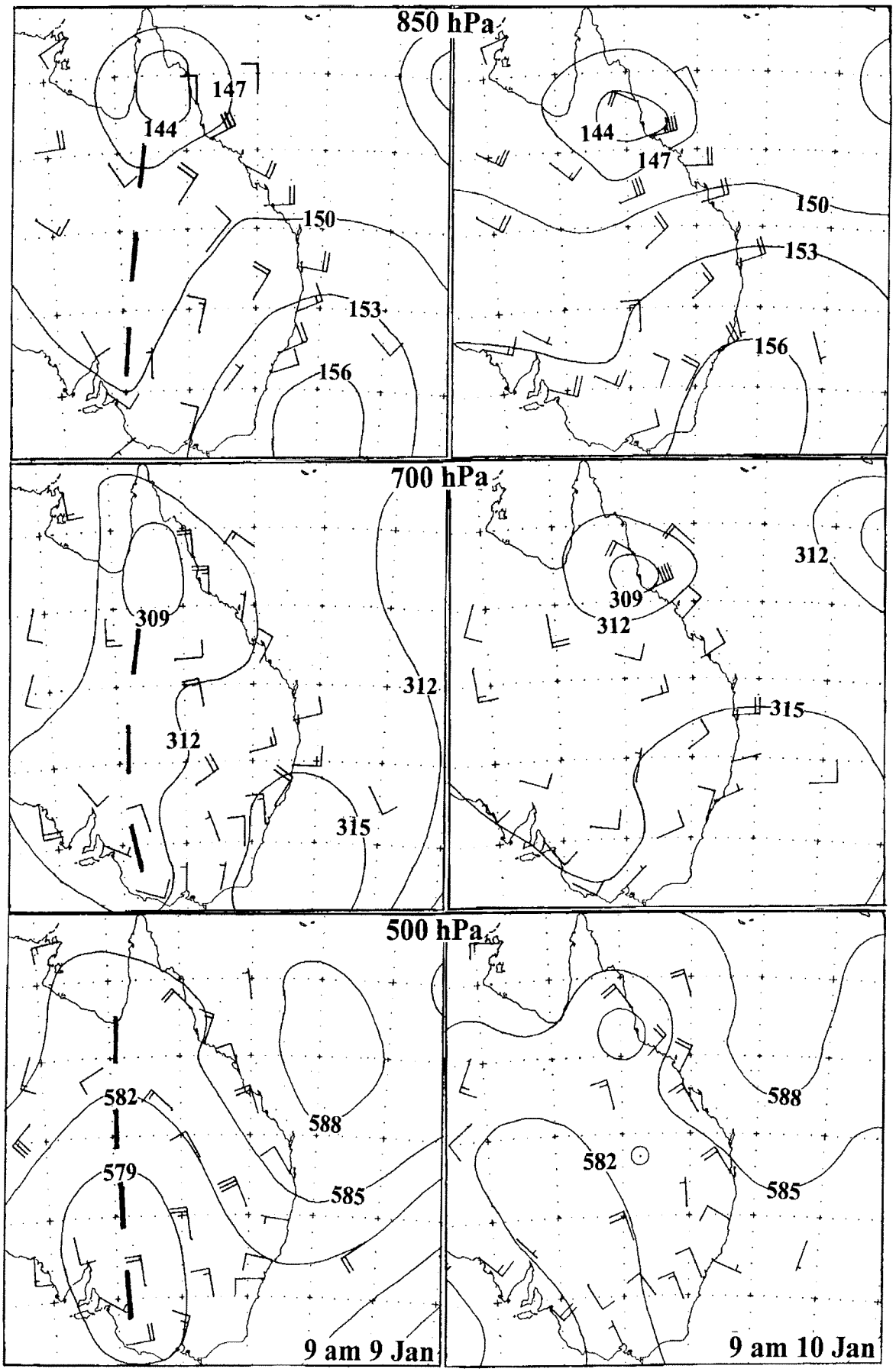


Figure 2.3 Wind plots and height contours(decametres) for 850, 700 and 500 hPa

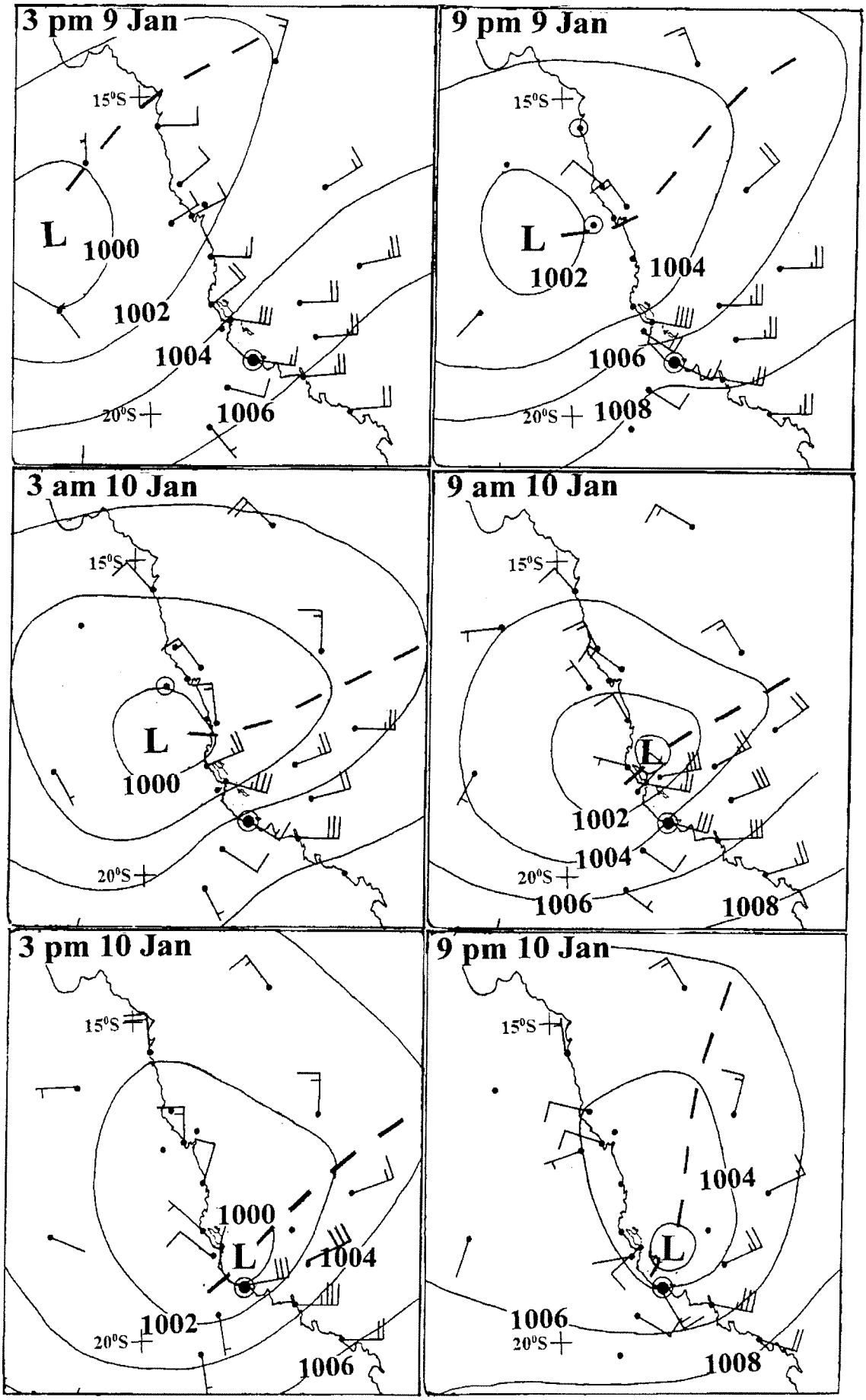


Figure 2.4 Mean Sea Level Pressure Distribution (hPa) and Wind Plots

2.5 Upper Wind Vertical Profile

Extreme heavy rain events in Queensland have in the past been found to be associated with winds which back in direction with height. The direction from which these wind blow from is generally confined to the northeast quadrant. For example the heavy flood rains in Southeast Queensland in 1992 were associated with winds which backed with height from low level easterlies to middle level northerlies. The heaviest flood rains in Southeast Queensland in May 1996 were associated with low level easterly winds which backed with height to middle level northeasterlies.

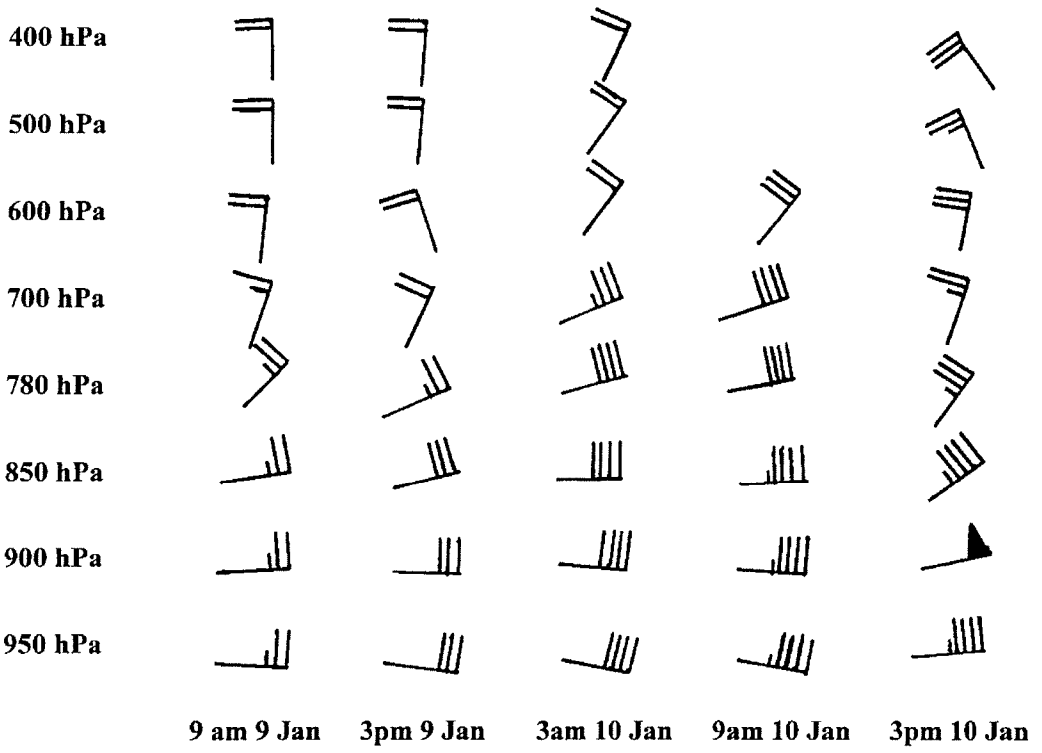


Figure 2.5 Upper Wind Observations at Townsville AMO

In Figure 2.5 the evolution of the vertical wind profile at Townsville up to 3pm (0500 UTC) 10 January 1998 is examined. The latter time was just before the heaviest rain began to fall at Townsville. The winds increased in speed at lower levels over the 30 hour period and kept a backing with height profile. Notice that in time the wind directions below 500 hPa became confined to the northeast quadrant. Additionally the winds at the lowest levels turned north of easterly which gave these low level winds a larger normal component on to the coast near Townsville.

2.6 Thunderstorm Activity

The heaviest rain fell at Townsville in the six hours after 7pm 10 January 1998 and this was during a period when almost continuous thunder and lightning was reported at Townsville. The cause of this phenomena is investigated in Figure 2.6.

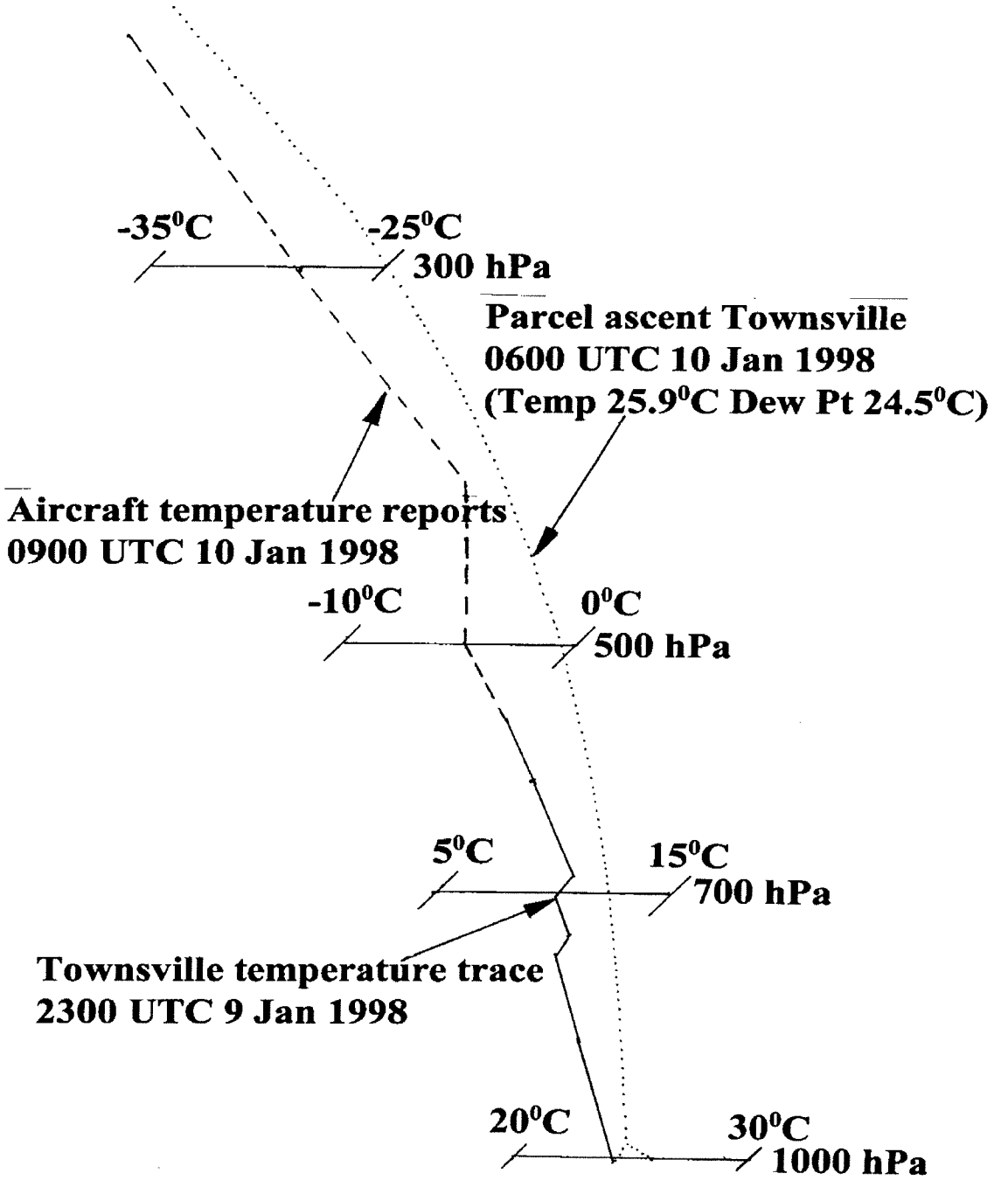


Figure 2.6 **Upper Temperature Profile at Townsville**
Dotted line is a moist adiabat which marks the saturated adiabatic lapse rate.

The 9am meteorological balloon flight at Townsville on 10 January 1998 only recorded temperature readings up to 550 hPa after which heavy rain on the payload formed into ice and prevented further ascent. The vertical temperature profile at Townsville that morning is plotted in Figure 2.6. This temperature trace is extended to higher levels from aircraft reports received in the Townsville area around 7 pm 10 January 1998.

The temperature and dewpoint at Townsville progressively increased during 10 January 1998 and by 4pm the temperature at station level was 25.9°C and the dewpoint was 24.5°C.Parcels of air with these properties near the monsoon trough would be lifted and cooled at the saturated adiabatic lapse rate. This cooling with height profile is denoted in Figure 2.6 and notice that the parcels would be expected to be warmer than the measured temperature profile. This means that late in the afternoon on 10 January 1998 the warm moist air lifted in the vicinity of the monsoon trough was warmer and therefore more buoyant than the environment and therefore able to ascend to high altitudes. Such moist buoyant air in the vicinity of a strong lifting mechanism like the monsoon trough is extremely conducive to thunderstorm development. This thunderstorm activity almost certainly accounted for the extreme rainfall rates over short periods experienced in Townsville on the evening of 10 January 1998.

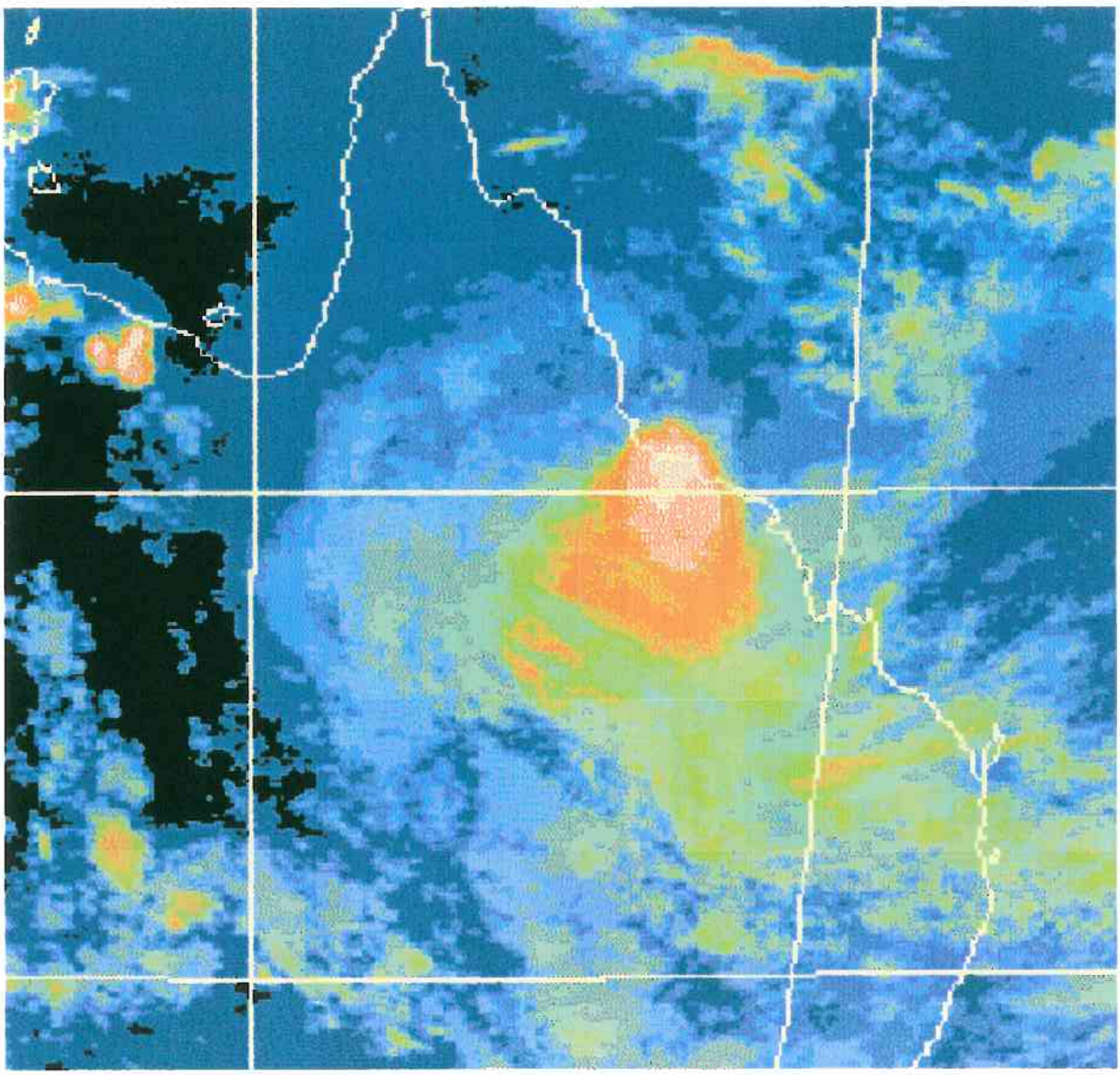


Figure 2.7 Infrared Satellite Photograph at 7pm 10 January 1998

The thunderstorm complex which produced the heaviest rain at Townsville during Saturday evening can be seen on the Japanese Geostationary Satellite infrared photograph taken at 7pm Saturday (Figure 2.7). The cloud tops which were colour coded white can be seen over the Townsville region. From the temperature scale on the photograph these cloud tops were colder than minus 68°C and extended up to an elevation above 14 km.

2.7 Sea Conditions

Sea conditions generated by ex-tropical cyclone Sid were quite exceptional. Large waves combined with very high tides and floodwaters to cause severe damage along The Strand in Townsville. Pathways and parts of the road were washed into the sea and reports indicate that damage costs there may reach $10 million.

Increases in sea level (storm surges) accompany tropical cyclones when they approach the coast causing salt water inundation. Even weaker systems such as ex tropical cyclone *Sid* can cause the sea level to rise primarily from gale force onshore winds. The maximum storm surge the low produced was 0.55 metres however this occurred near low tide. The highest actual sea level recorded was 3.935 metres at 8.21 am 11 January 1998 which was 0.075 metres below the highest astronomical tide expected at Townsville and represented a storm surge of 0.4 metres.

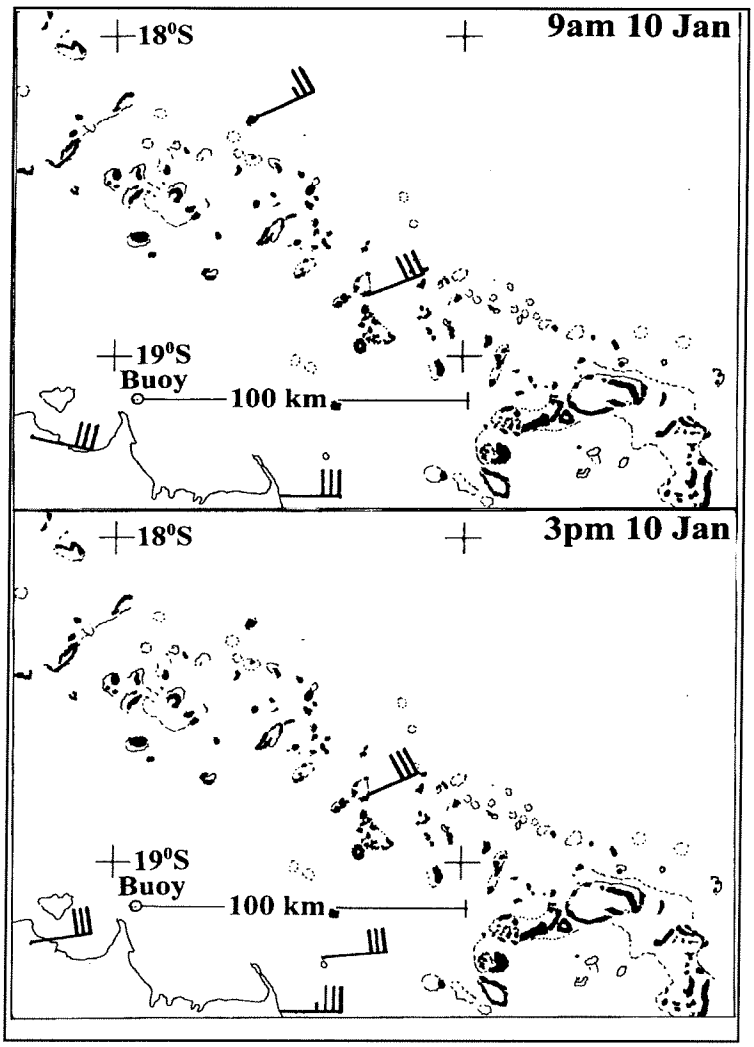


Figure 2.8 **Automatic Weather Stations Observations near Townsville Wave Rider Buoy**

Large waves are rarely observed along the tropical east coast waters of Queensland due to the protection by the Great Barrier Reef and the limited lengths of open water. The Beach Protection Authority of Queensland maintains a wave recording station at Townsville with the waverider buoy being located in waters 20 m deep and 8.3 km northeast of Cape Cleveland. The wave parameters recorded include:-

Hsig- the average height of the highest one third waves in a record and
Hmax- the highest individual wave in a record.

The Townsville wave recording station recorded a Hsig of 2.93 metres and a Hmax of 5.41 metres at 3pm 10 January 1998. The highest Hsig recorded at the Townsville station since it was installed in 1975 is 3.58 metres so the waves generated by ex tropical cyclone *Sid* represent a near extreme event for Townsville.

To explain these large waves Figure 2.8 shows available wind observations and location of the offshore reefs at 9am and 3pm 10 January 1998. The wind observations indicate an area of winds averaging 30 knots probably extended over open waters out to 100 km east of the waverider buoy. From Figure 2.4 this wind field had been relatively constant in direction and wind speed over these waters from 3pm 9 January 1998. Winds averaging 30 knots over a fetch of open water 100 km long for 7.5 hours can generate waves with Hsig 3.2 metres.

2.8 Numerical Model Rainfall Prediction

The Australian regional numerical models rainfall forecast for the 24 hour period to 9am 11 January 1998 (Figure 2.9) indicated that the heaviest rainfall would be close to but offshore from Townsville.

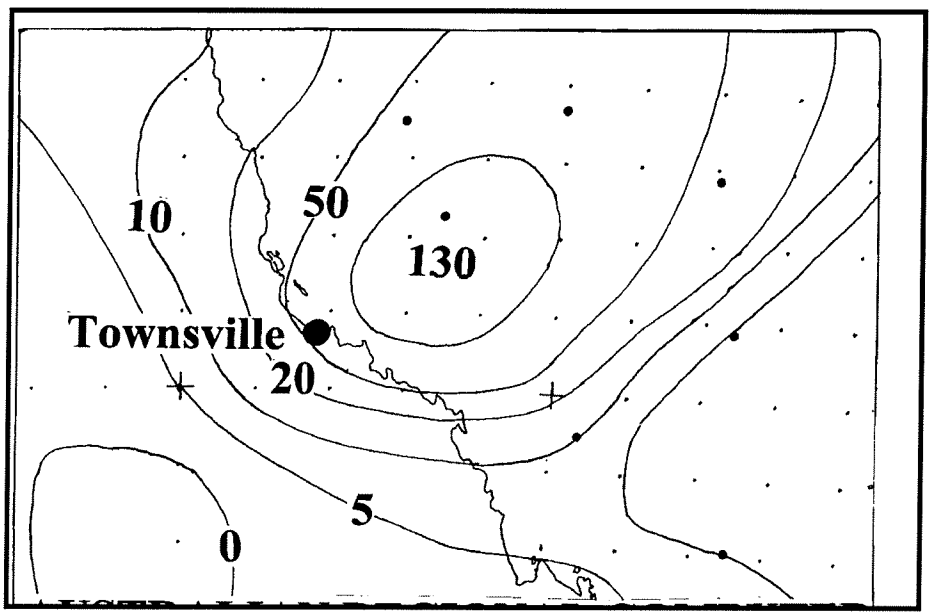


Figure 2.9 **Australian Regional Model** - Rainfall Forecast(mm) for 24 Hrs to 9am 11 Jan

Overseas global model outputs showed disagreement as to whether the heavy rain would be overland or offshore as illustrated in Table 2.1 below. Therefore, while computer forecasts provided good guidance on the possibility of heavy rain in the Townsville area, they did not indicate the severity of the situation

Table 2.1 Rainfall forecasts from Global Numerical Computer Models

Forecast period	United States Global Model	United Kingdom Global Model
48 to 72 hours to 9am 11 January 1998	Maximum rainfall zone of 90mm near Townsville	50 mm near Townsville with 100 mm maximum offshore
24 to 48 hours to 9am 11 January 1998	Maximum rainfall zone of 100 mm just west of Townsville	50 mm near Townsville with 120 mm maximum offshore
0 to 24 hours to 9am 11 January 1998	Maximum rainfall zone of 82 mm at Townsville	50 mm near Townsville with 150 mm maximum overland south of Charters Towers

Whereas the Australian regional numerical model had limited success in predicting the location and amount of rainfall in the Townsville area, the "experimental" Australian global numerical model was quite successful in forecasting the event.

In collaboration with CSIRO, the Bureau has recently installed an NEC SX-4 (32 processor) supercomputer which is mainly used for running a suite of atmospheric and climate models. The major benefit lies in the fact that these models can now be run at significantly higher vertical and horizontal resolution than previously, and within a similar computational timeframe. The current "operational" global model has a horizontal resolution of about 150 km and 19 levels in the vertical - while the "experimental" global model has a horizontal resolution of about 65 km and 29 levels in the vertical.

The "experimental" global model was run in hindcast mode with a base analysis time of 9pm Friday 9 January 1998, the day before the torrential rain fell in the Townsville area. Appearing at Figures 2.10 and 2.11 are the forecast precipitation contours for the 24 hour periods to 9pm Saturday 10 January and 9pm Sunday 11 January respectively. The model output shows successive rainfall maxima of 284 mm and 168 mm to the immediate north of the Townsville area. Not only is the location reasonably correct but the magnitude is also of the right order. As noted earlier, 549 mm was registered at Townsville Airport in the 24 hours to 9am Sunday 12 January.

Even more encouraging from a forecasting perspective are the 48-96 hour predictions of the same extreme event with a base analysis time of 9pm Wednesday 7 January (not shown here). In respect to precipitation forecasts, similar model results were achieved at the much longer time range. Not as useful however was the output from various runs of the "operational" global model (not shown here) which significantly underestimated the amount of precipitation in the Townsville area.

The "experimental" global model is expected to become the "operational" global model later in 1998 with the output available to forecasters in realtime.

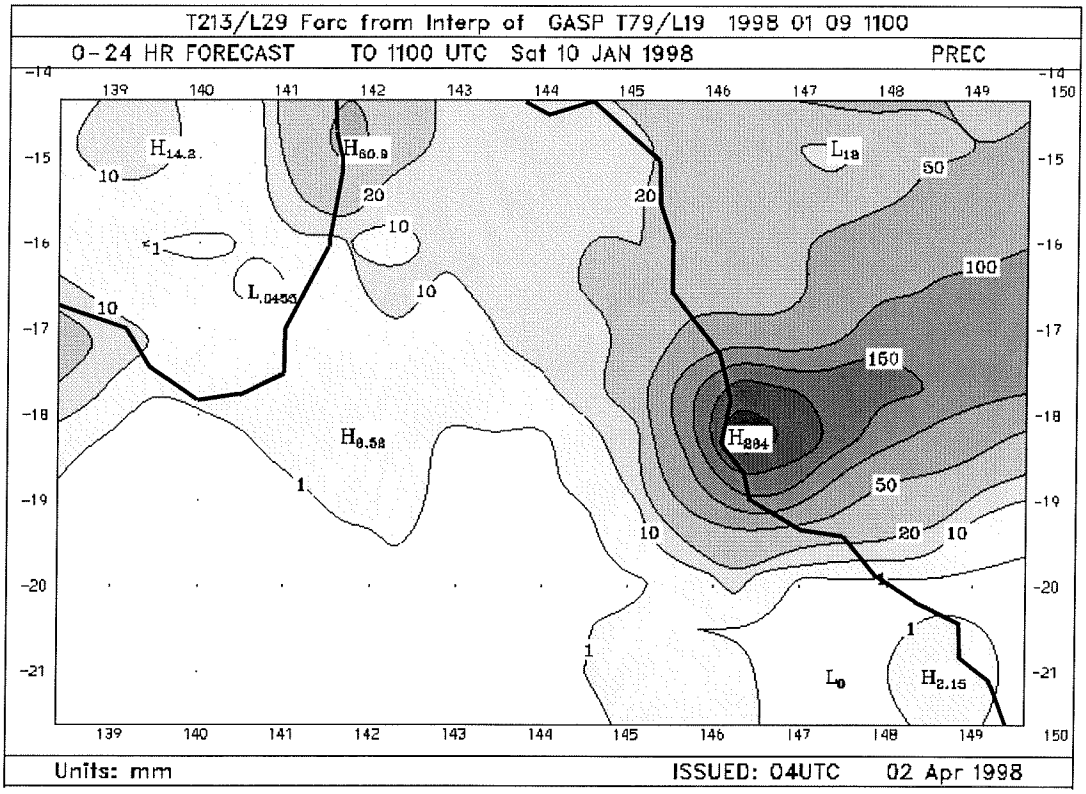


Figure 2.10 **"Experimental"Australian Global Model**
Rainfall Forecast (mm) for 24 hours to 9pm Sat 10 January

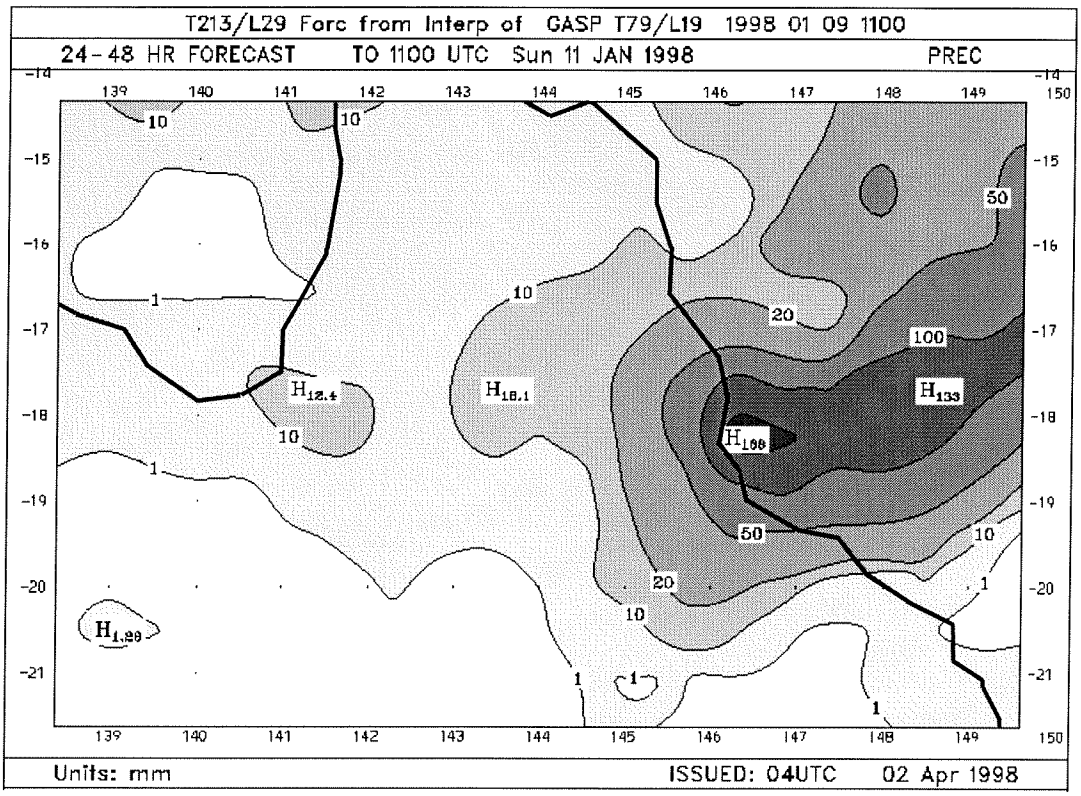


Figure 2.11 **"Experimental"Australian Global Model**
Rainfall Forecast (mm) for 24 hours to 9pm Sun 11 January

3.0 RAINFALLS

This section reports on the rainfall which occurred in north Queensland over the period between 7 to 14 January 1998. Particular details of the rainfall in the Townsville and Thuringowa area on the weekend of 10 and 11 January is contained in Appendix A.

3.1 Rainfall Totals

Table 3.1 shows the daily (24 hrs to 9am on the day indicated) and total rainfalls of stations in the effected river basins for the period 8 January to 14 January 1998. Refer to Figures 1.1 - 1.4 for the location of the stations in Table 3.1. The highest daily rainfall at each station is shown highlighted.

Note that in some cases, the totals do not add up to the individual daily records due to missing observations or observations not reported.

Daily totals in excess of 300 mm were recorded in the northern part of the region by 9am Friday 9 January. Similar falls were still being recorded in the Paluma area up to 9am Wednesday 14 January. By far the highest official daily totals for the region were recorded at Townsville (549mm) and Ranchview Ranch (507mm) in the 24 hours to 9am Sunday 12 January 1998. There were reports of higher rainfalls from unofficial stations as detailed in Appendix A.

Along the coastal strip of the region, seven day total rainfalls to 9am Wednesday 14 January ranged from 450mm in the north at Gordonvale to 227mm in the south at Home Hill. While the highest totals were confined to the coast, seven day totals in excess of 200 mm were common in the western side of the upper Burdekin catchment.

Table 3.1 Daily Rainfall (mm) - Gordonvale to Home Hill

Station Name	January 1998							Total
	8 Thu	9 Fri	10 Sat	11 Sun	12 Mon	13 Tue	14 Wed	
Upper Carpenteria - District 30								
Greenvale	3/2		101	56	0.4	24	23	217/8
Gregory Springs		4	18	20	20	45	54	199
Hillgrove	21			129	28	3		219
Homestead	5		13	179			26	245
Pentland	2		10	208	37	3		284
Toomba	12			191			24	221
Wando Vale	22		41	40	8	4		115

Station Name	January 1998							Total
	8 Thu	9 Fri	10 Sat	11 Sun	12 Mon	13 Tue	14 Wed	
North Coast Barron - District 31								
Babinda	57	359	192		11	4	39	662
Gordonvale	8	388			36/3	9	13	453
Greenhaven	57	137	141	2	49	17	14	417
Herberton	3	41	67	3		15	16	145
Kareeya	49	105			182/3		17	399
Koombooloomba	39	118			238/3		26	421
Malanda	2	80	52		64	40	8	246
Mt Garnet	1	16	51		0	1	2	71
Mt Sophia	9	347	148		3	2		509
Ravenshoe			77				3	110
Topaz	25	220	162	5	8	11	58	489
North Coast Herbert - District 32								
Abergowrie Br	33	84	233	23	0	36	32	441
Cardwell	68	82	147	44	6	79	57	483
Gairloch	30	122	311	34		53	53	603
Gleneagle	55		141	2				241
Halifax	39	80	260	6	32	21	30	468
Ingham	50	155	321	35		60	58	679
Innisfail	147	113	108		12	119	29	528
Lassie Ck Stn			52	264	20		16	384
Lucinda	32	61	244		12/2	21	31	401
Paluma	159	110	307	340	163	281	283	1643
Rangeview Ranch			110	507	239	149	37	1117
Townsville	12	2	46	549	82	163	30	884
Tully	120	171	284	10	2	118	43	748
Yabulu		2	66	341	69	146	27	651

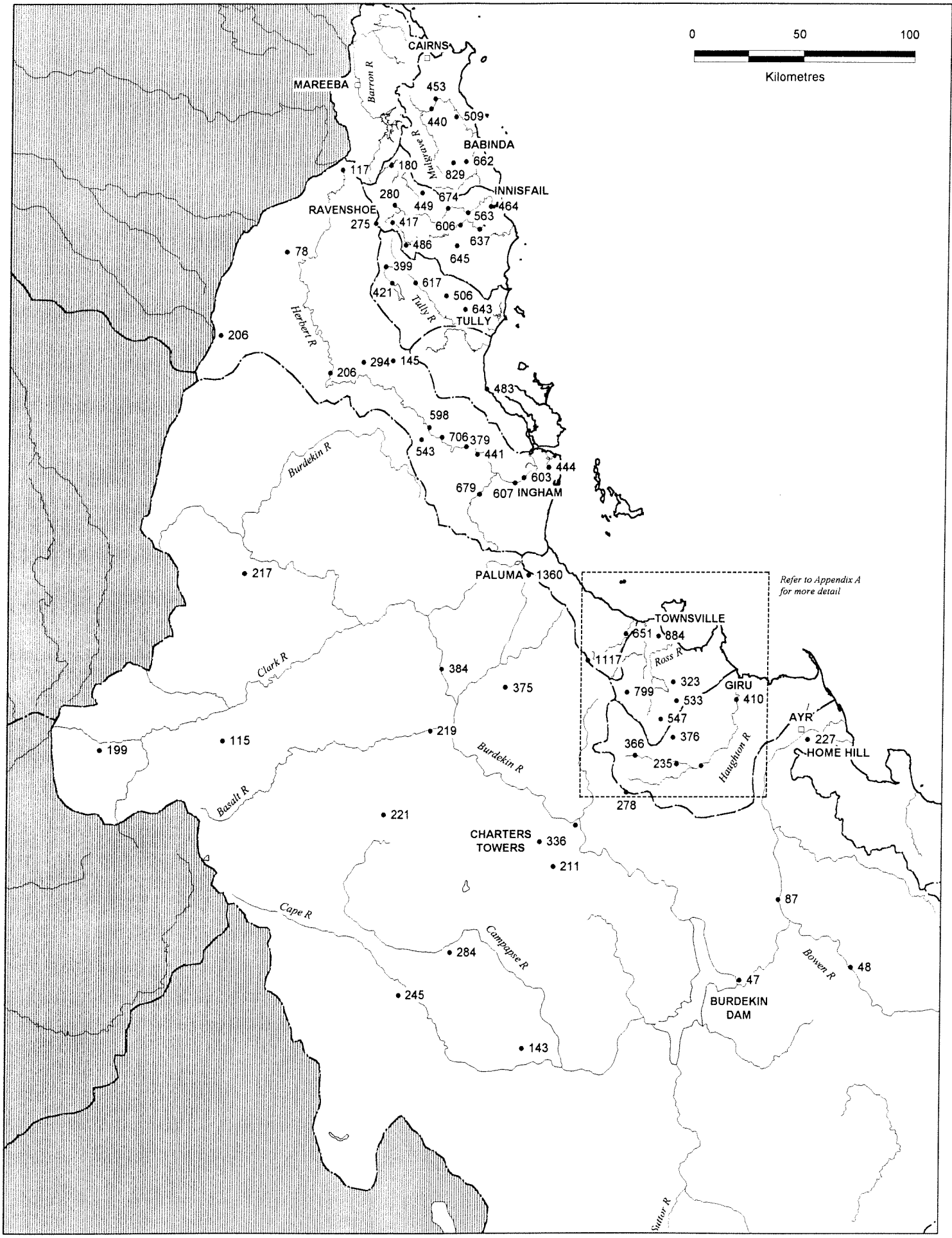
Station Name	January 1998							Total
	8 Thu	9 Fri	10 Sat	11 Sun	12 Mon	13 Tue	14 Wed	
East Central Coast - District 33								
Home Hill	7				180/3	16	3	206
Flora Valley			27	115		67	16	235
Giru		0.6	41	256	77	13	22	410
Lansdown	5		40	162		59		376
Mingela	4			120	111	35	8	278
Paynes Lagoon			18	273	40	18	14	375
West Central Coast - District 34								
Balfes Ck								151
Broadleigh Downs				113	20		10	143
Burdekin Dam				33	7			47
Charters Towers	56		5	186	79	9	1	336
Doongara	11		5				4	112
Sellheim	44			145		6		195

A map showing the extent of rainfall in the region over the seven days is shown in Figure 3.1

Table 3.2 shows the average daily catchment rainfall for rivers from the Mulgrave-Russell to the lower Burdekin River with averages over 100 mm highlighted. The table shows clearly the movement of the heavy rainfall from the north to the south over the period.

Table 3.2 Average Daily Catchment Rainfall (mm)

Catchment	January 1998							Total
	8 Thu	9 Fri	10 Sat	11 Sun	12 Mon	13 Tue	14 Wed	
Mulgrave-Russell R	21	301	97	3	5	8	13	448
Johnstone River	32	123	111	0	20	22	25	333
Tully River	29	118	181	2	22	43	19	414
Upper Herbert River	17	29	101	1	2	11	10	171
Lower Herbert River	30	68	225	16	4	80	40	463
Haughton River	3	0	12	181	72	28	3	299
Ross River Above Dam	0	1	22	312	134	71	11	551
Upper Burdekin River	28	21	92	101	28	46	30	346
Cape River	3	2	14	103	27	11	12	172
Lower Burdekin River	3	0	3	43	18	9	7	83



NORTH QUEENSLAND
Rainfall map for the 7 days ending 0900 14/01/98

Figure 3.1

3.2 Rainfall Temporal Patterns

Temporal patterns are graphical representations of the rainfall with respect to time and help to define the onset and cessation of the heavy rainfall, typical intensities and the periods of heaviest rain.

Temporal patterns, shown in the figures below, have been compiled for selected stations in the Tully (Tully), Herbert (Zattas), Ross (Townsville) and Haughton (Woodstock) Rivers.

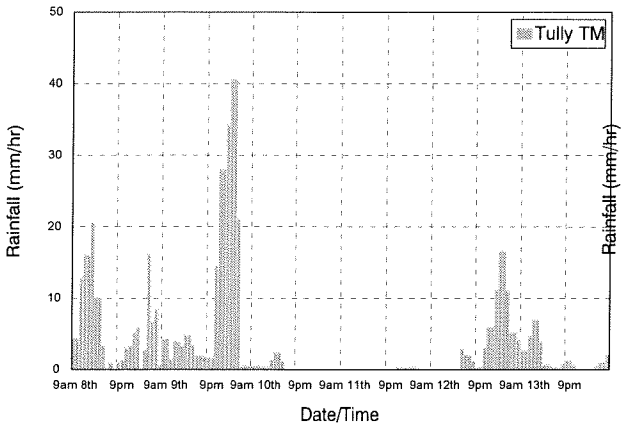


Figure 3.2(a) Temporal Pattern - Tully

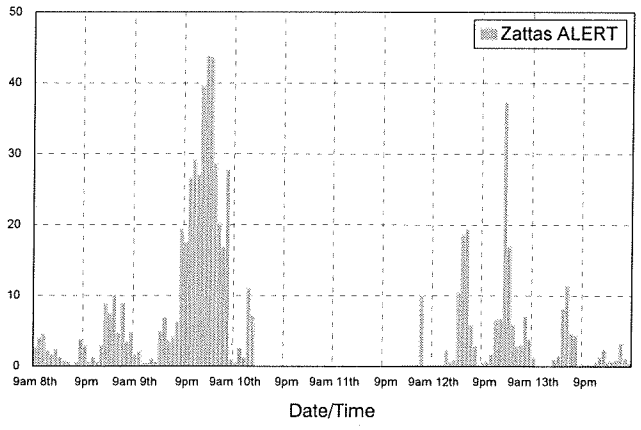


Figure 3.2(b) Temporal Pattern - Zattas

At Tully, there were several periods of heavy rainfall in excess of 10mm/hr on 8 January but the heavier rainfall commenced at about midnight on 10 January and continued for 7 hours. Rainfall intensity was generally above 20mm/hr for this period with the maximum intensity exceeding 40mm/hr for two consecutive hours.

Until 8pm on 9 January rainfall rates at Zattas were quite low, typically below 10 mm/hr. However, from about 8pm 9 January, the heavy rainfall commenced abruptly and for a period of about 12 hours, rainfall intensities were at or above 20mm/hr. The heaviest rainfall occurred in two hours early on 10 January when rates of 40mm/hr were exceeded for two hours. At about 10am Saturday, the heavy rainfall eased quickly. Further periods of intense rainfall were recorded at Zattas on Monday 12 and Tuesday 13 January but, despite being heavy, only lasted one or two hours.

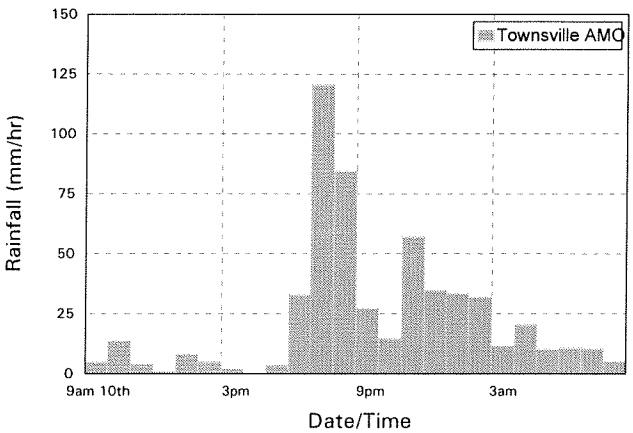


Figure 3.2(c) Temporal Pattern - Townsville

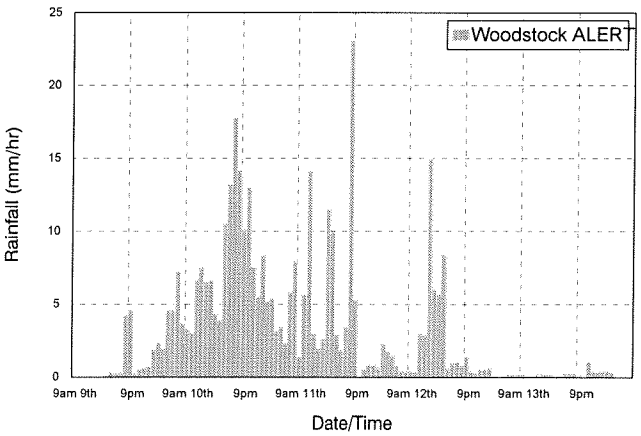


Figure 3.3(d) Temporal Pattern - Woodstock

As indicated in Figure 3.2(c), the heavier rainfall commenced at Townsville AMO at about 6pm on Saturday 10 January and continued until about 3am. During this period, rainfall rates over

30mm/hr were maintained for about 9 hours with a brief easing around 10 and 11pm. The most intense hourly rainfall was over 130mm from 7.16pm to 8.16pm. (Refer to further details in Appendix A.)

Even though there were few periods of rainfall which exceeded 25mm in any one hour, the rainfall at Woodstock (Fig 3.3 (d)) in the Haughton River was constant over 36 hours.

3.3 Record Rainfalls

An analysis of daily rainfall totals was carried out at selected stations and compared with climatological records, as shown in Table 3.4. In some cases, the records extend back as far as 1871 but the record length is at least 60 years.

Table 3.4 Comparison of Record Daily Rainfall Totals

Station	Rainfall / Date			
	Record	2nd Highest	3rd Highest	Jan 1998
Tully 032042 1925- 032146 1983-	606 12/02/1927	502 13/01/1953	500 02/03/1935	284 10/01/1998
Ingham 032024 1892-1970 032078 1968-	489 24/03/1990	480 02/02/1945 480 05/01/1980	459 21/01/1952	321 10/01/1998
Townsville 032047 1871-1951 032040 1940-	549 11/01/1998	488 21/01/1892	381 28/12/1903	549 11/01/1998
Giru 033028 1932	593 03/03/1946	341 31/01/1978	338 08/03/1950	256 11/01/1998

Table 3.4 shows that, with the exception of Townsville, the daily rainfalls recorded at Tully, Ingham and Giru were well below that recorded during other events.

The records at the current Townsville station at the Airport Meteorological Office only commence in 1940 and, for this station, the previous record was 366 mm in March 1946. However, there was a rainfall station at Townsville Pilot station (032047) between 1871 and 1951 where the record daily rainfall was 488 mm in January 1892.

An analysis of the 7 day totals at both of the Townsville stations indicates that the 7 day total for the January 1998 event was the highest on record:

- 884mm ending 9am 14 January 1998 (AMO)
- 838mm ending 9am 18 January 1953 (AMO)
- 807mm ending 9am 26 January 1892 (Pilot)

3.4 Rainfall Frequencies

Rainfall frequencies were examined at four stations in the region; Tully TM, Ingham ALERT, Townsville AMO and Woodstock ALERT for durations between 1 and 72 hours.

At Tully and Woodstock the Average Recurrence Intervals (ARIs) of the rainfall was not particularly significant, generally well below a 5 year event.

At Ingham, the most significant durations were the 6 and 12 Hours which are estimated to be between the 10 and 20 Year ARI.

Table 3.5 Average Recurrence Intervals (Years) of Selected Stations

Station	Duration (hrs)						
	1	3	6	12	24	48	72
Tully TM	-	<1	2-5	1-2	1-2	2-5	2-5
Ingham AL	2-5	2-5	10–20	10-20	2-5	5-10	2-5
Townsville AMO	>100	>100	>100	>100	>100	>100	>100
Woodstock AL	<1	<1	1-2	1-2	1-2	<1	<1

At Townsville, every duration from 1 hour to 72 hours exceeded the 100 Year ARI. The frequency of the Townsville rainfall is examined in more detail in Appendix A.

4.0 FLOODS

Coastal rivers and streams from the Mulgrave-Russell system in the north to the Burdekin River in the south experienced significant river rises in the period 7 to 14 January 1998 with flooding in most of the larger river systems being well above major levels.

The first incidence of flooding occurred in the Johnstone River on 8 January. Stream levels rose quickly and were high for a few days but only caused minot to moderate flooding.

The Tully River at Euramo reached moderate flood level at 6am 9 January and remained above the Bruce Highway approaches to the Euramo Bridge until the evening of Sunday 11 January. This level was well below that reached during the March 1967 flood, as indicated in Table 4.1

Table 4.1 January1998 Flood Peaks: A Comparison with Record Floods

Catchment	Station	January 98 Flood		Flood Class	Record Flood	
		Date/Time	Height (m)		Date	Height (m)
Tully River	Bolinda Estate	10/01/98 0000	5.18	na	na	na
	Euramo	10/01/98 0900	8.80	Moderate	March 1967	9.37
Herbert River	Gleneagle	10/01/98 1200	7.55	Moderate	March 1967	17.73
	Nash's Crossing	10/01/98 0800	10.50	Major	March 1997	8.95
	Zattas	10/01/98 0800	10.12	Major	March 1967	11.10
	Abergowrie	10/01/98 1720	15.76	Major	March 1977	17.48
	Abergowrie Br	10/01/98 1500	17.20	Major	March 1967	20.65
	Peacock Siding	10/01/98 n/a	14.20	Major	March 1997	13.90
	Ingham	10/01/98 1500	15.65	Major	March 1967	16.20
	Gairloch	10/01/98 1500	12.30	Major	March 1967	12.70
	Halifax	10/01/98 2100	5.42	Major	March 1967	5.35
Haughton River	Mt Picaninny	11/01/98 0400	5.75	Major	January 1978	9.09
	Powerline	12/01/98 0000	9.72	Major	January 1978	11.50
	Giru	11/01/98 2000	2.72	Major	March 1997	2.65
Burdekin River	Sellheim	11/01/98 1800	20.15	Major	March 1946	21.79
	Burdekin Falls Dam	12/01/98 2100	4.93	Minor	February 1991	6.82
	Dalbeg (Manual)	13/01/98 0300	14.25	Minor	April 1958	23.09
	Inkerman Br	13/01/98 1500	9.25	Minor	April 1958	12.62

Rapid river rises occurred in the lower Herbert River on Saturday morning 10 January as a result of the extremely heavy overnight rain. The level reached at Gairloch was one of the highest on record, just above the March 1956, March 1977 and March 1997 floods but still 0.3 metres below the March 1967 level. A further burst of heavy rain on

Tuesday12 January again resulted in rises in the lower Herbert but they were significantly lower than the flood levels reached on 10 January.

The major flooding in the Haughton River at Giru is thought to be one of the highest on record but levees at Giru may have a significant impact on flood levels in the area.

The flash flooding which occurred in the Townsville area on the weekend of 10 and 11 January was the worst on record.

Major flooding developed in the Burdekin River above Burdekin Falls Dam on 10 January but the main flood waters did not peak at Inkerman Bridge until Tuesday 13 January causing minor flooding in the area.

4.1 Johnstone River

Heavy rainfall commenced in the Johnstone River catchment on Wednesday 7 January although light rainfalls up to 69 mm had been recorded daily in the previous week. The heaviest falls were in the lower flood plain around Innisfail, with 7 day totals of 663 mm recorded at Nerada and 644 mm at Mena Vale. On the Atherton Tablelands, totals were much less, ranging from 180 mm at Malanda to 374 mm at Greenhaven. The majority of the rain fell in the period between 3am on Thursday 8 January to 11pm on Friday 9 January.

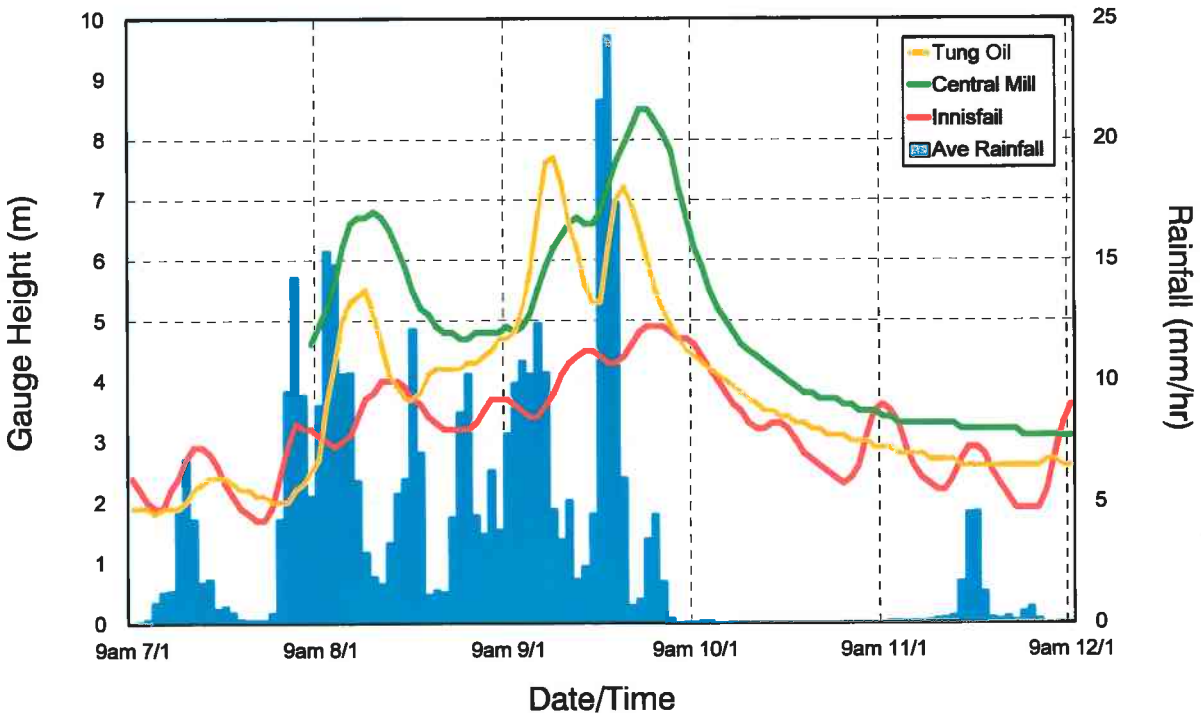


Figure 4.1 Johnstone River

With the onset of the heavy rainfall burst on 8 January, river levels upstream of Innisfail started to rise rapidly, responding to the intense rainfall bursts. Several peaks were recorded at the gauging stations, with an initial peak occurring at 3pm on 8 January followed by a second higher peak overnight on 9/10 January. The North Johnstone River reached 7.2 m at Tung Oil at 12am on 9 January, just above the minor flood level, and 8.6 m at Central Mill on the South Johnstone River at 3am on the next morning. The flood level at Central Mill was 0.6 m above moderate flood level. At Innisfail the river reached

4.95 m at 3am on 10 January, 0.05 m below minor flood height, and occurred 5 hours before high tide.

4.2 Tully River

Heavy rainfall commenced in the Tully River on the morning of Thursday 8 before easing in the afternoon. The rainfall became intensified during the morning of Friday 9 and became heavier during that night reaching an average rainfall intensity of 22 mm/hour. The rainfall then generally eased until the evening of 11 January and the next morning when average rainfall intensities of 6 to 9 mm/hour were recorded.

Some of the more significant 7 day rainfall totals including 654 mm at Tully, 622 mm at Bolinda Estate and 523 mm at Jarra Creek.

Initial rises were recorded in the Tully River at Bolinda Estate on Wednesday 7 January. The onset of heavy rainfall on 8 January accelerated the rate of rise and an initial peak of 2.74 metres was reached that afternoon. River levels continued to fluctuate until the heavy rainfall commenced on Friday 9 January. This caused renewed rises in the river and a peak of 5.18 metres was reached on that evening. Levels receded on the morning of 10 January and, although the rainfalls of Sunday 11 and Monday 12 caused renewed rises, the river did not reach minor flood level.

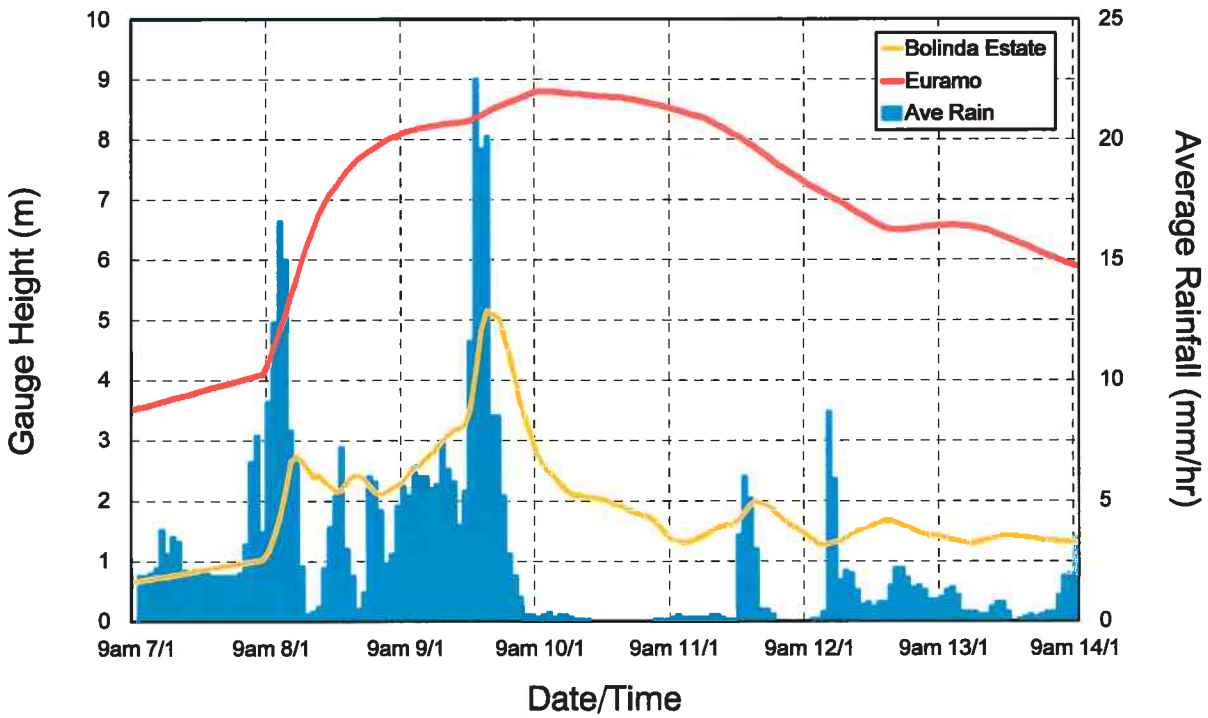


Figure 4.2 Tully River

At Euramo, the Tully River began to rise slowly on Wednesday 7 January. The rate of rise increased on Thursday 8 with the onset of heavy rainfall and was nearing a peak of about 8.3 metres on the evening of Friday 9. However, the heavy rainfall on that evening caused renewed rises in the Tully River and a peak of 8.8 metres, about 0.7 metres above the highway, was reached at Euramo on the morning of Saturday 10 causing moderate flooding. The river receded and was approaching minor flood levels when the renewed rainfall of the Sunday 11 and Monday 12 caused another short rise. The river eventually fell below minor flood level on the morning of the Wednesday 14.

4.3 Herbert River

Rainfalls in the upper Herbert River above Gleneagle from 7 January to 14 January 1998 varied widely from 78mm at Mt Garnet to 206mm at Upper Rudd Creek in the western part of the catchment to nearly 300mm around Gleneagle.

While there was a significant rise at Gleneagle, the peak occurred at noon on Saturday 10 January from local heavy rainfall with a later lower peak on Sunday evening 11 January. Neither peak had any impact on the major flood peak at Gairloch but did cause relatively high levels in the lower catchment to be maintained longer than normal.

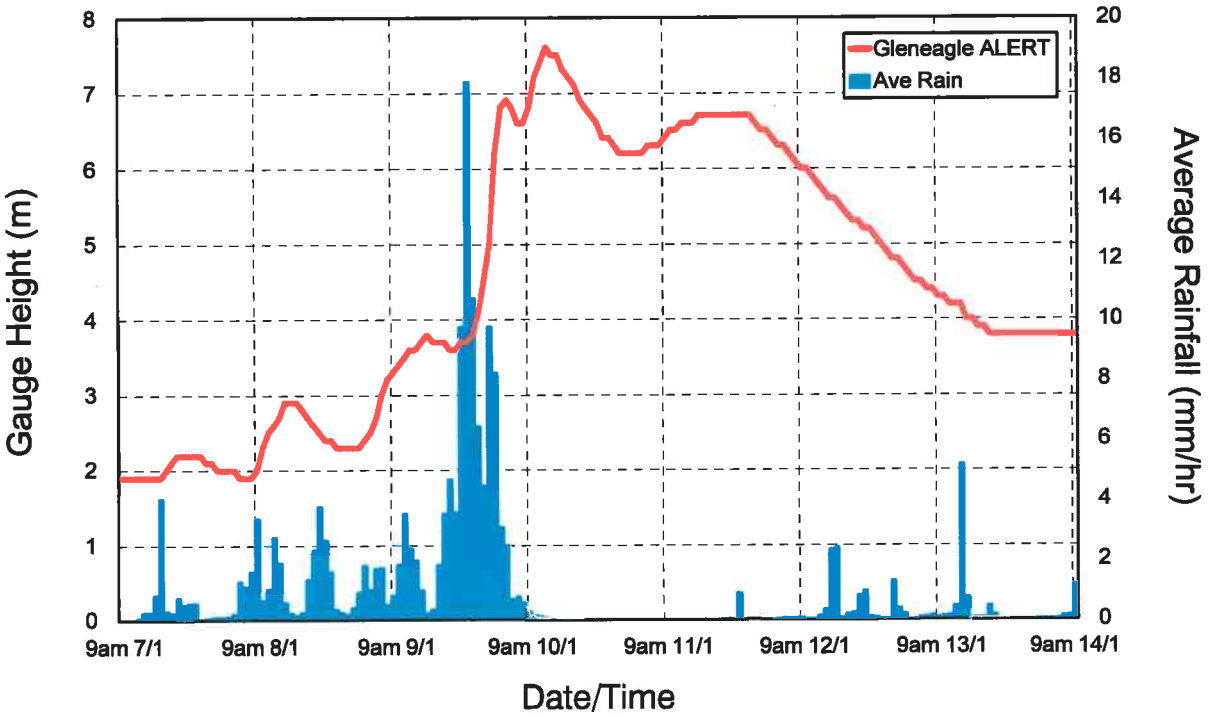


Figure 4.3 Upper Herbert River

Rainfalls in the lower Herbert River catchment from 7 January to 14 January 1998 included 707 mm at Zattas, 697 mm at Gowrie Creek, 675 mm at Peacock Siding, 626 mm at Ingham and 598 mm at Nash's Crossing. Highest totals were recorded in the Zattas area (707mm) which were significantly higher than the totals recorded in the Abergowrie area only 10km away.

Between 9am 7 January and 11pm Friday 9 January, constant light rain fell on the lower catchment with the occasional heavier burst up to 5mm/hr. Heavy rainfall up to 25mm/hr commenced on the evening of 9 January and continued into the early hours of Saturday 10 before ceasing abruptly at 9am Saturday to isolated showers. From Sunday only isolated rainfalls were reported up to noon on Monday 12 January when further moderate falls with intensities up to 10mm/hr which continued until Wednesday 14 January.

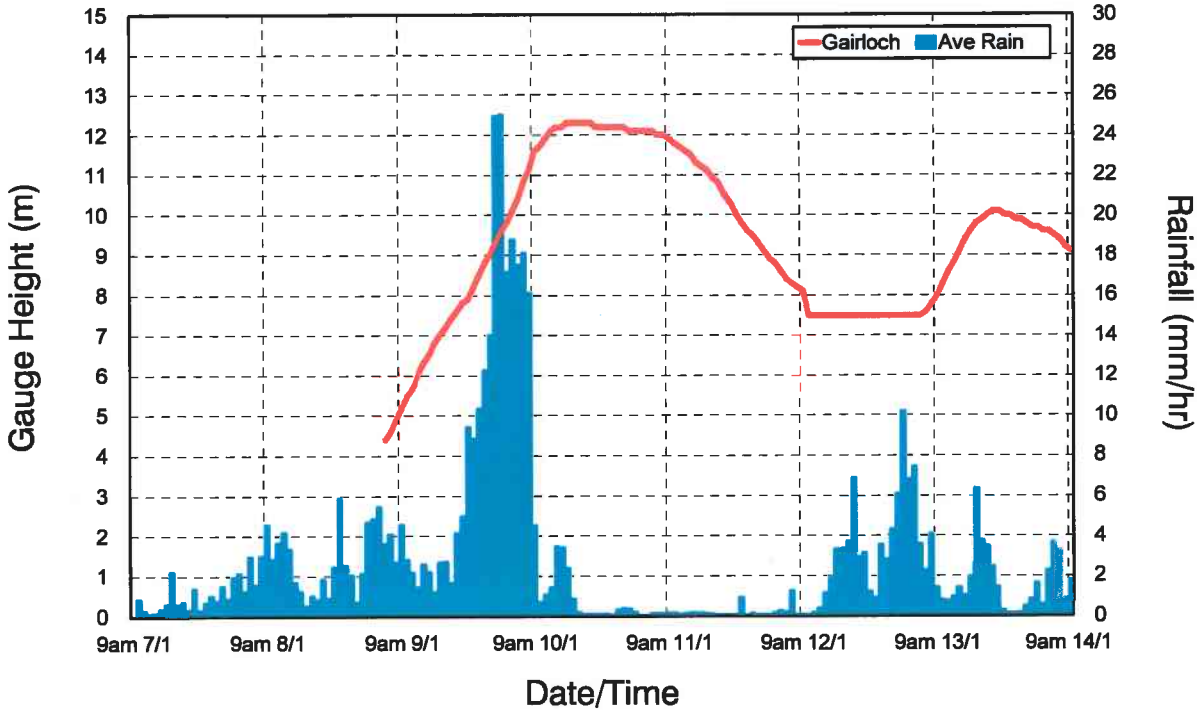


Figure 4.4 Lower Herbert River

At the commencement of the heavy rainfall on Friday evening 9 January, the Herbert River at Gairloch was already just over 8 metres having risen slowly from early light rain. By 9am Saturday morning, Gairloch had reached the major flood level of 11.5 metres. The rate of rise then slowed before the river reached a peak of 12.3 metres. It maintained this level overnight Saturday before commencing to fall slowly in the early hours of Sunday morning. The river at Gairloch rose quickly with the rate of rise similar to the March 1997 flood.

At Halifax, the Herbert River rose rapidly and reached the major flood level of 5.0 metres at 4am Saturday 10 January. This was only about 5 hours after the onset of the heavy rain and 5 hours before the onset of major flooding at Gairloch. The river rose slowly to 5.5 metres during the next 6 hours and maintained a similar level until 4pm Sunday 11 January.

The rain on Monday and Tuesday caused renewed rises at Gairloch, shown in Figure 4.5, and resulted in a 1.0 to 1.3 metres rise at Halifax.

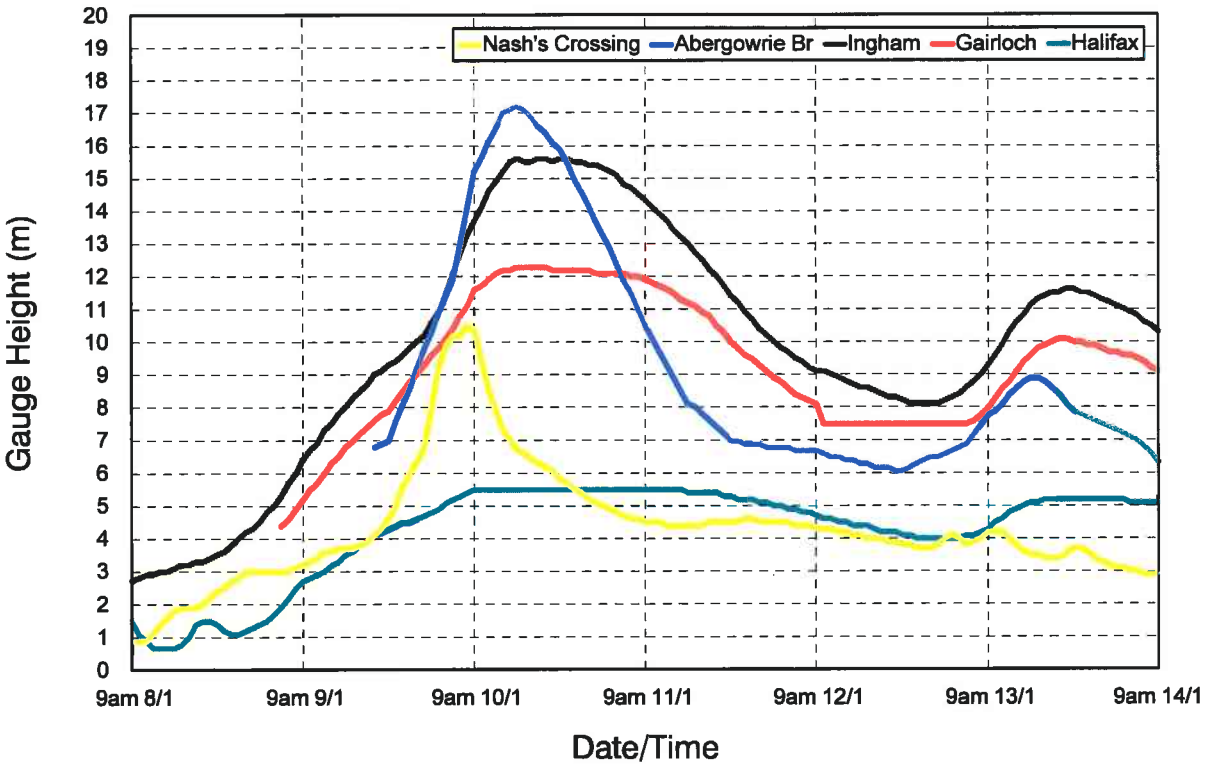


Figure 4.5 Lower Herbert River Levels

4.4 Haughton River

The flooding in the Haughton River catchment was a result of the same storms that caused major flooding in Townsville. There were insignificant rainfalls reported prior to Friday, 9 January, when light rainfall started on the northern boundary of the catchment around Nettlefield and Woodstock in the early morning. The rain started to become very heavy from midday to 6pm on 10 January with rainfall intensities exceeding 28 mm/hr for the 3 hour period from 2pm to 5pm at Nettlefield. The rainfall only started to ease during Sunday 11 but constant rainfall continued with the occasional heavy bursts until Tuesday 13.

In the west of the catchment, rainfall was less intense with two significant bursts recorded during the afternoons of Saturday 10 and Sunday 11. Constant rain however continued until Tuesday 13. In the south of the catchment rainfall totals were much less. The 4 day totals from 9am 9 January to 9am 13 January ranged from 540mm at Nettlefield and 360mm at Woodstock in the north, to 182mm at Major Creek and 160mm at Clare in the south.

The concentration of the rainfall in the north of the catchment was reflected in the rise of river levels in the Haughton River catchment being first recorded at Powerline due to the significant inflow from Major Creek. River levels started to rise at 5am on 10 January in response to the initial rainfall and then started to rise rapidly later in the day around 6pm following the heavy rainfall. Levels rose to an initial peak of 8.91 m by 11.30am on Sunday 11, followed by a second peak of 9.43 m early in the morning of Monday12, as the flood flows arrived from the upper Haughton River catchment. The peak flood level of 9.43 metres was 1.43 m above the major flood level.

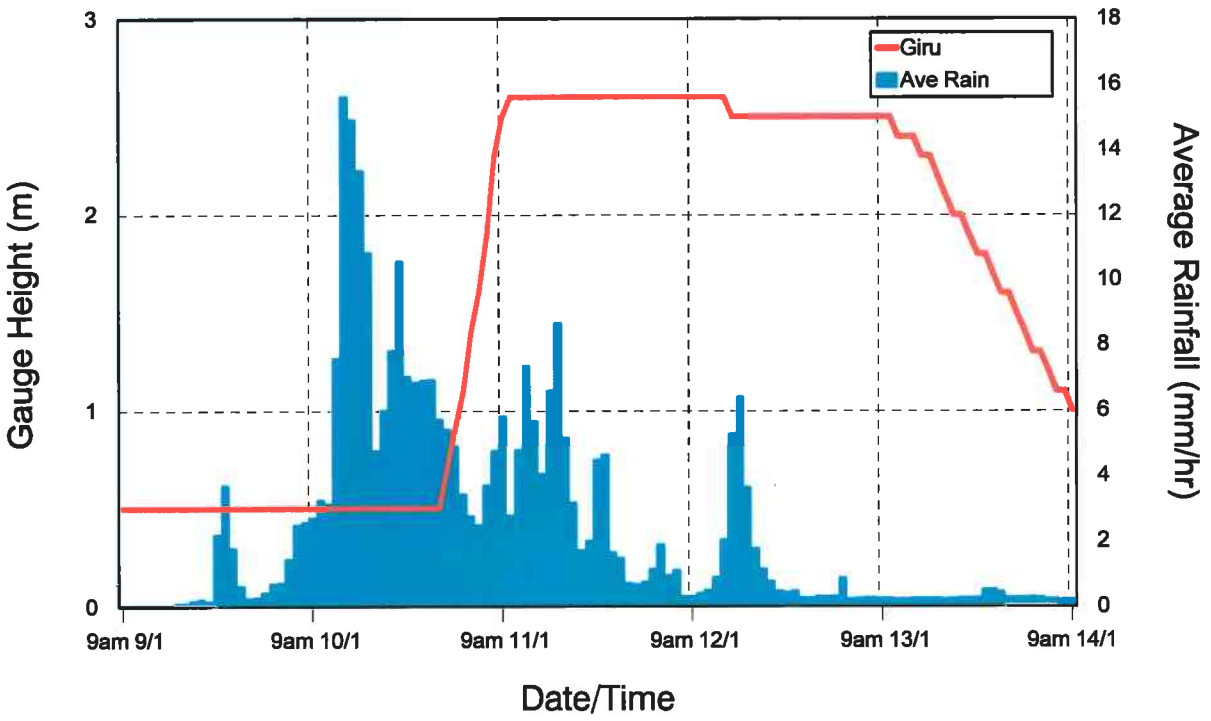


Figure 4.6 Haughton River

At Giru the river started rising steadily rise at 6am on Sunday , 11 January, reaching a peak level of 2.72 m by 11am and then maintaining this peak level for the next few days. The level at Giru was unaffected by the renewed rises in the headwaters although the level was maintained by continuing rainfall. This level was 0.50 m above the major flood level. Flood levels only started to drop significantly on Tuesday13 and by 9am, Wednesday 14 January flood levels had fallen below the minor flood level.

4.5 Burdekin River

Steady rainfall commenced in the upper Burdekin catchment on Wednesday 7 January and continued until 15 January. The heavier falls were concentrated on the eastern edge of the catchment around Paluma to Rangeview Ranch where 7 day totals up to 14 January of 1360mm and 1117mm were recorded respectively. On the western side of the upper catchment, 7 day totals were much lower at around 200 mm. Generally only light rain was recorded up to 9pm Friday 9 January but from this time to10am on Sunday 11, very heavy falls occurred, with rainfall intensities typically in excess of 10 mm/hr for over 36 hours.

The other two main rivers catchments upstream of the Burdekin Dam, the Cape River and the Suttor River, received significantly less rainfall with 7 day totals varying from 284 mm at Pentland and 127 mm at Balfes Creek in the west, to 20-50 mm in the Suttor River catchment. Downstream of Burdekin Dam, isolated high rainfalls of 187 to 303 mm were recorded along the catchment boundary with the Pioneer River, but elsewhere only light rainfall was recorded.

The heavy rainfall in the upper Burdekin catchment caused rapid rises in river levels, commencing at Mt Fullstop at 2.30am and at 5.30pm at Sellheim on Saturday 10 January. At Sellheim, river levels rose by nearly 20m in just over 24 hours, from 1.99m at 5.30pm

in to 20.5 m the next day at 7pm. The peak flood level was 5.15 m above the major flood level. Moderate flooding also occurred on the Cape River but no significant rises were recorded in the Belyando/Suttor system.

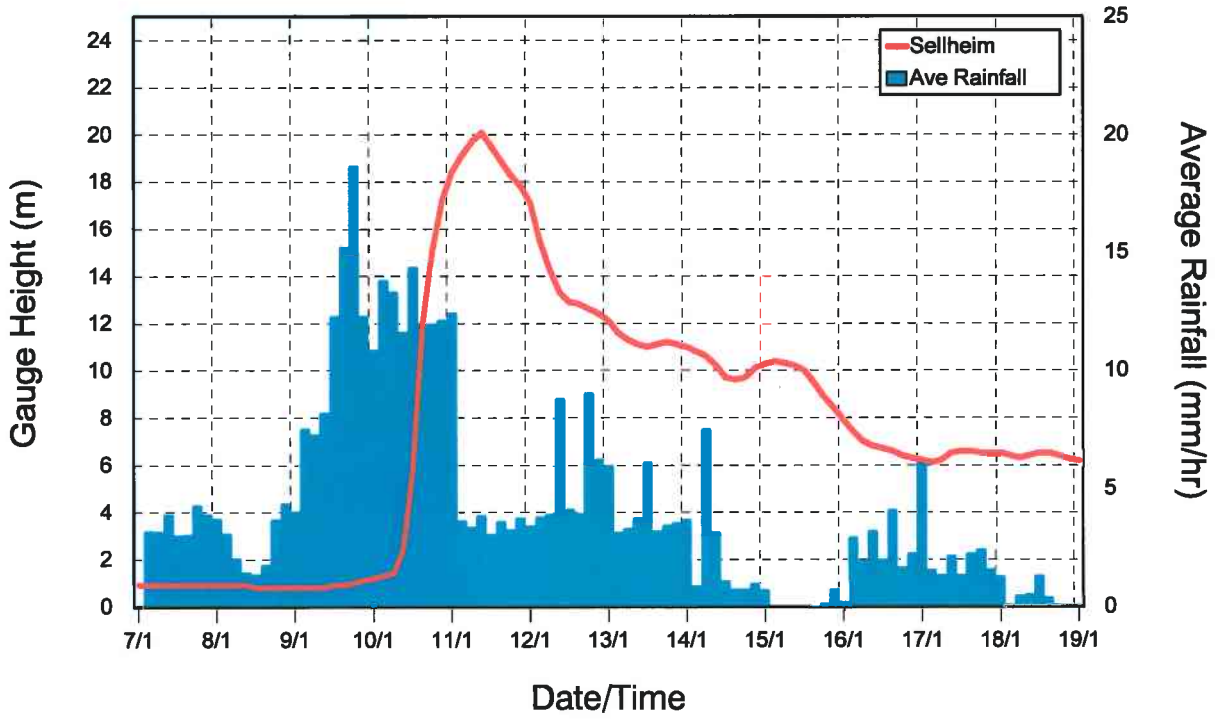


Figure 4.7 Upper Burdekin River

Peak flows from the upper Burdekin River were lessened by the large storage effect of Burdekin Dam although the dam was full at the start of the flood. The headwater level at the dam was 0.25 m above the spillway at the start of the event and responded to the incoming flood waters at 9pm on Sunday 11, approximately 48 hours after the start of the heavy rainfall. The flood level over the Burdekin Falls Dam spillway eventually reached 4.93 m above the spillway crest at 3pm on Tuesday13, 0.57 m below moderate flood level. Flood waters gradually moved downstream with little impact from any local catchment runoff. At Inkerman Bridge the river levels started to rise at 2pm on Monday 12 January and eventually peaked at 9.25m a day later causing minor flooding.

4.6 Other Rivers

Table 4.2 indicates the peak heights reached at DNR river height stations in the coastal rivers around Townsville. Records at these stations are relatively short, only 28 years at the oldest station. The floods in Bluewater Creek and the Black River were metres higher than previously recorded while the Bohle River flood was only 0.68 metres higher than March 1997.

Table 4.2 January1998 Flood Peaks in Townsville Area: A Comparison with Record Floods

Catchment	Station	Records Commence	January 98 Flood		Comments
			Date/Time	Height (m)	
Bluewater Creek	Bluewater	16/11/1973	10/01/98 2000	9.70	2.55 metres above the next highest flood in Jan 1994
Black River	Bruce Highway	13/03/1973	10/01/98 2130	9.38	1.13 metres above the next highest flood in Feb 1991
Bohle River	Mt Bohle	08/05/1970	11/01/98 0200	8.23	0.68 metres above the next highest flood in Mar 1997
Ross River	Ross River Dam Headwater	10/01/1974	13/01/98 0130	2.72	0.66 metres below the highest flood in Feb 1991

With the exception of the Ross River, Bluewater Creek, the Black and Bohle Rivers responded very quickly to the heavy rainfall which commenced on Saturday evening 10 January. The time between the onset of the heavy rainfall and the peaks at the recording stations was only a matter of a few hours. Catchments which respond to rainfall in less than six hours are described as "flash flood."

The routing effect of the Ross River Dam resulted in the peak discharge from the Dam occurring some 48 hours after the period of heaviest rainfall.

Figure 4.8 shows the relationship between the hourly rainfall recorded at Yabulu and the Black River hydrograph. It indicates that the time between the heavy rainfall between 6 and 7pm on 10 January and the flood peak at the Black River station is only about 2-3 hours.

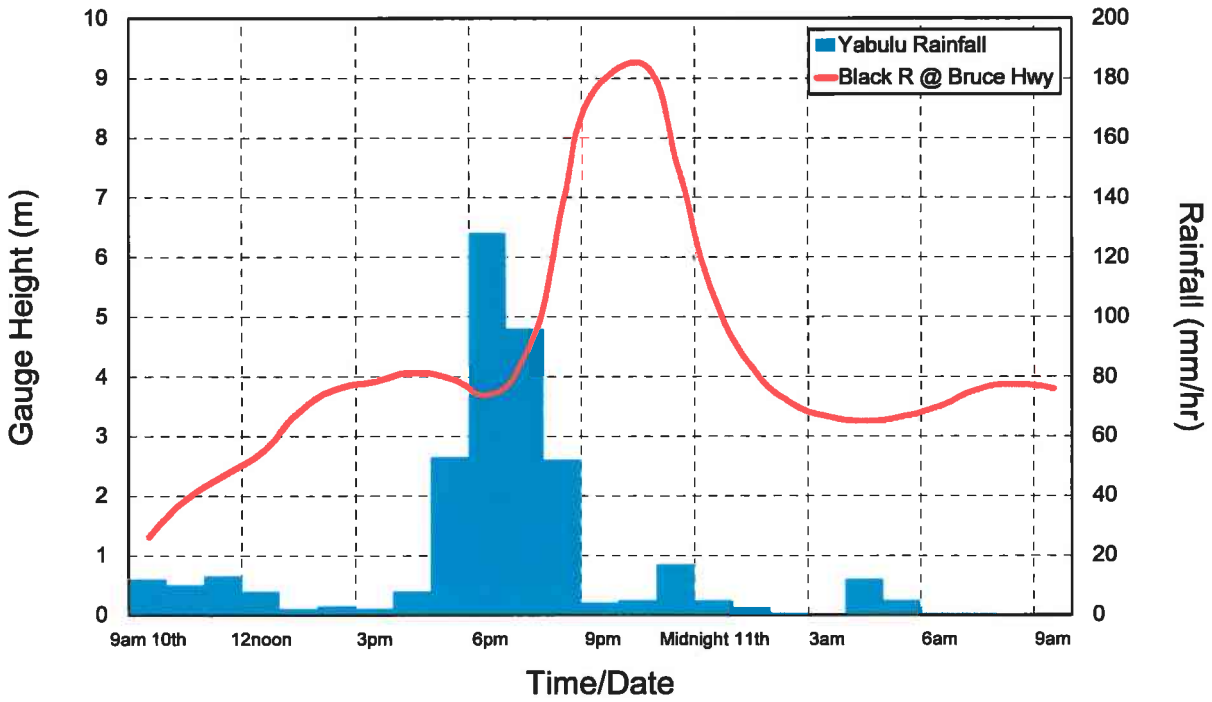


Figure 4.8 Black River

5.0 FLOOD MONITORING AND WARNING SYSTEMS

5.1 Radar

In this region, the Bureau operates weather radars at Cairns, Townsville Airport and on Mount Stuart to the immediate west of Townsville. During this event, the radars generally provided radar images to the Townsville Meteorological Office and to the Bureau's Warning Centre in Brisbane at 10 minute intervals. However, there were some gaps because of temporary communication failures and balloon flights in the case of the airport radar.

Two particularly significant radar sequences are described below and are given in Figures 5.1 and 5.2. In these Figures, the radar echoes indicate areas of rainfall. An estimate of the intensity of rainfall (in millimetres per hour) is given by the colour, although this can only be used as a guide to the actual rain rates measured at the ground surface.

Heavy Rain in the Herbert River

At 6pm 9 January 1998, weather radars, Figure 5.1(a), showed scattered areas of precipitation along the coast north of Ayr and an area overland west of Innisfail which marked the location of the tropical low (ex *Sid*). Around this time the monsoon trough was moving down the coast towards Cairns (refer to Figure 2.4). By 9pm the monsoon trough was just south of Cairns and the radar showed, Figure 5.1(b), a band of heavy rain generated by the trough crossing the coast around and to the north of Innisfail. This band of heavy rain then rapidly developed, Figures 5.1(c) and (d), and at 3am 10 January 1998 the northern edge of this rain band crossed the coast near Cardwell. The mean sea level analyses at this time (Figure 2.4) showed that this band of heavy rain was located just to the south of the monsoon trough.

The explosive development of this rain band which inundated the Herbert River catchment is explained by the mean sea level sequence in Figure 2.4. At 9pm 9 January 1998 a zone of strong to gale force winds was developing between Cardwell and Bowen while the low and monsoon trough were still near Cairns. The low and monsoon trough then moved down towards the Cardwell area and the gale force winds began flowing into the region of convergence just to the south of the monsoon trough.

Extreme Rainfall in the Townsville Area

Around 3pm 10 January 1998 the atmosphere in the vicinity of Townsville (refer to Section 2.6) had become very conducive to the development of thunderstorms. At this time, the reflectivity areas (colour coded pink and red) show areas where thunderstorms were developing, Figure 5.2 (a). Between 4pm and 5pm an area of storms to the west northwest of the city rapidly, Figures 5.2 (b) and (c), developed in size and intensity. After 5pm, this area of storms moved towards Townsville and by 7.30 pm, Figure 5.2(d), it lay directly over the city where it remained stationary causing torrential rain for several hours. The movement of the storm complex was related to a slight eastward movement of the tropical low between 3pm and 9pm (refer to Figure 2.4).

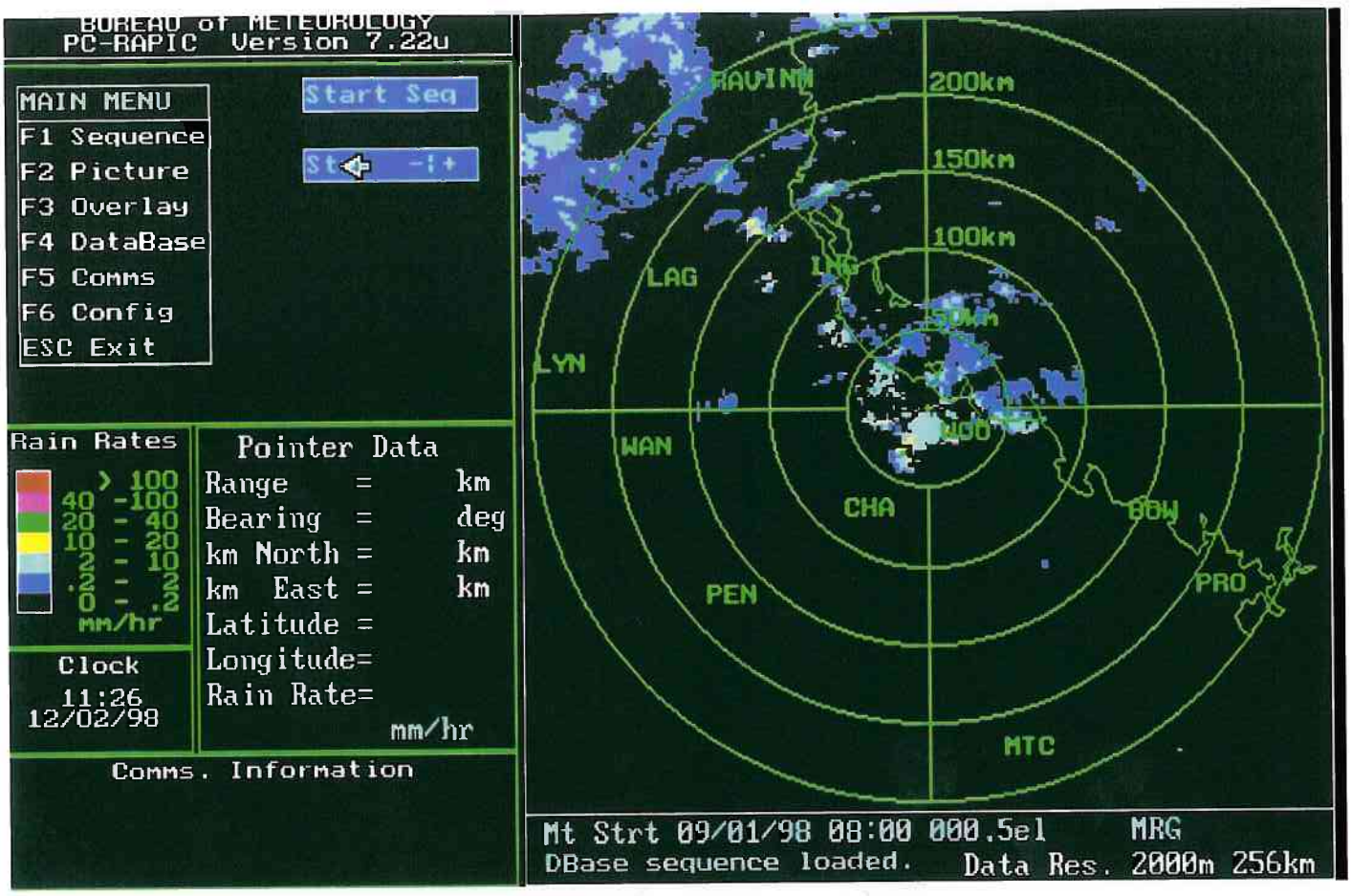


Figure 5.1(a) Mt Stuart Radar 6pm 9/1/98

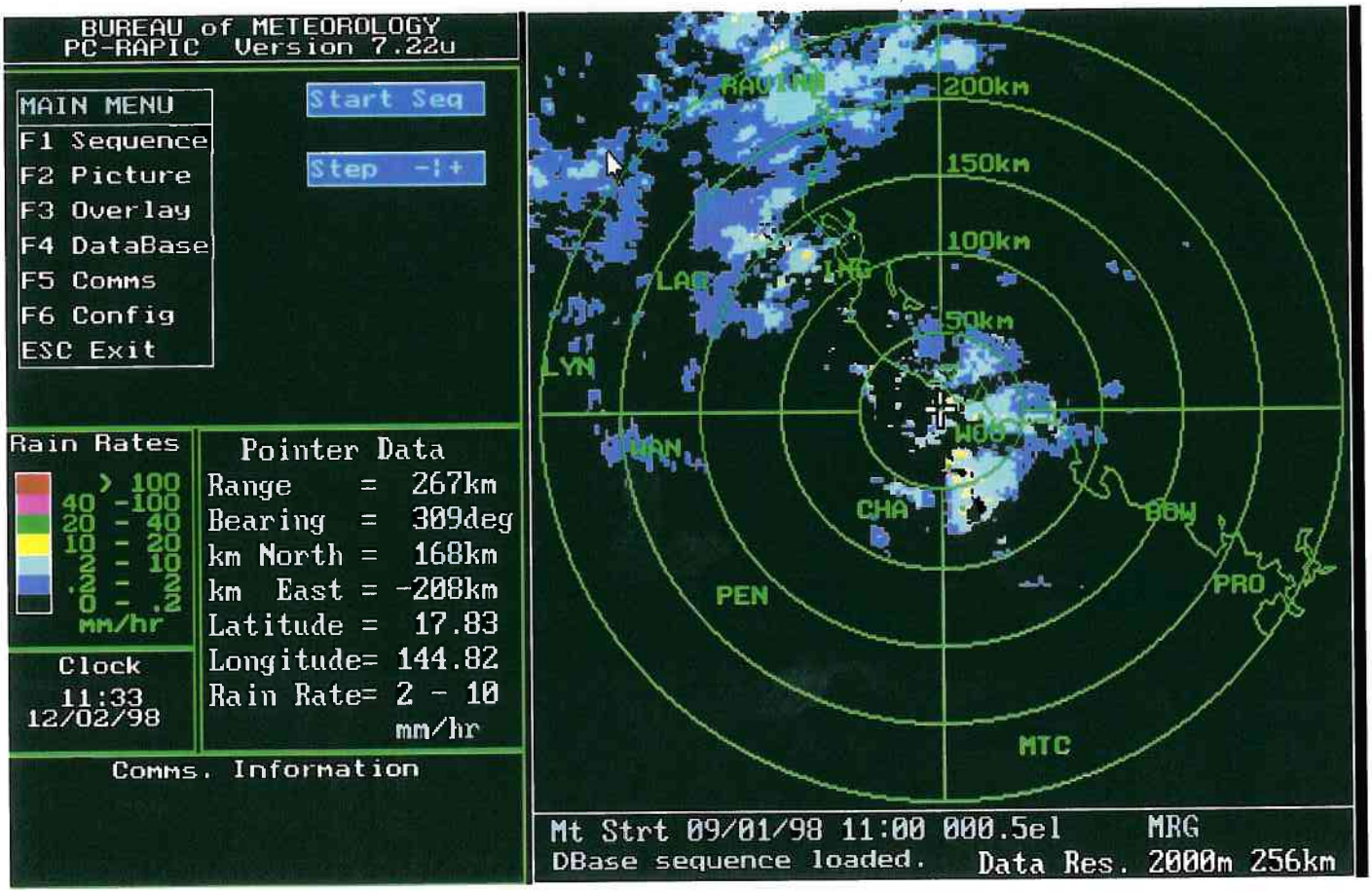


Figure 5.1(b) Mt Stuart Radar 9pm 9/1/98

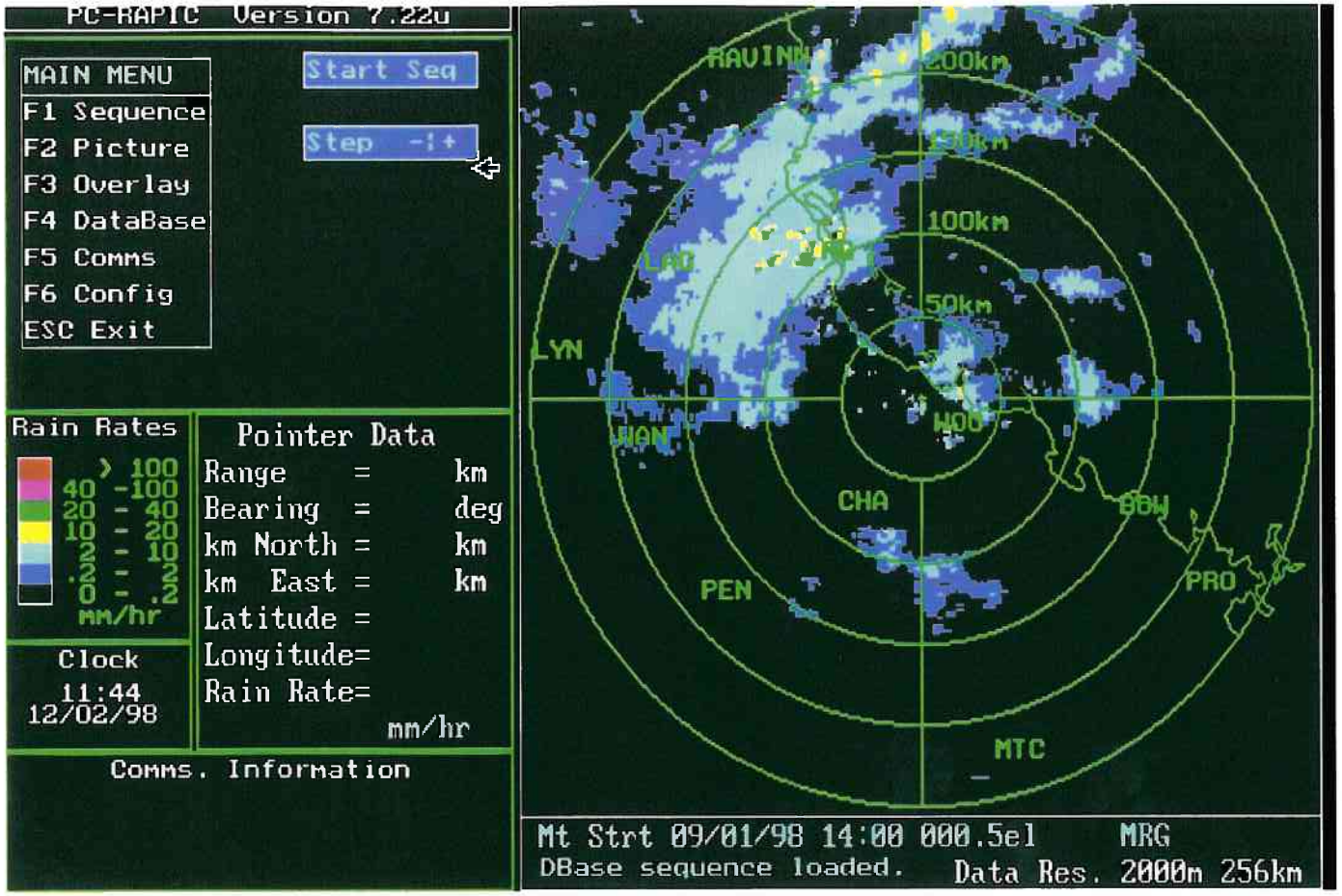


Figure 5.1(c) Mt Stuart Radar Midnight 9/1/98

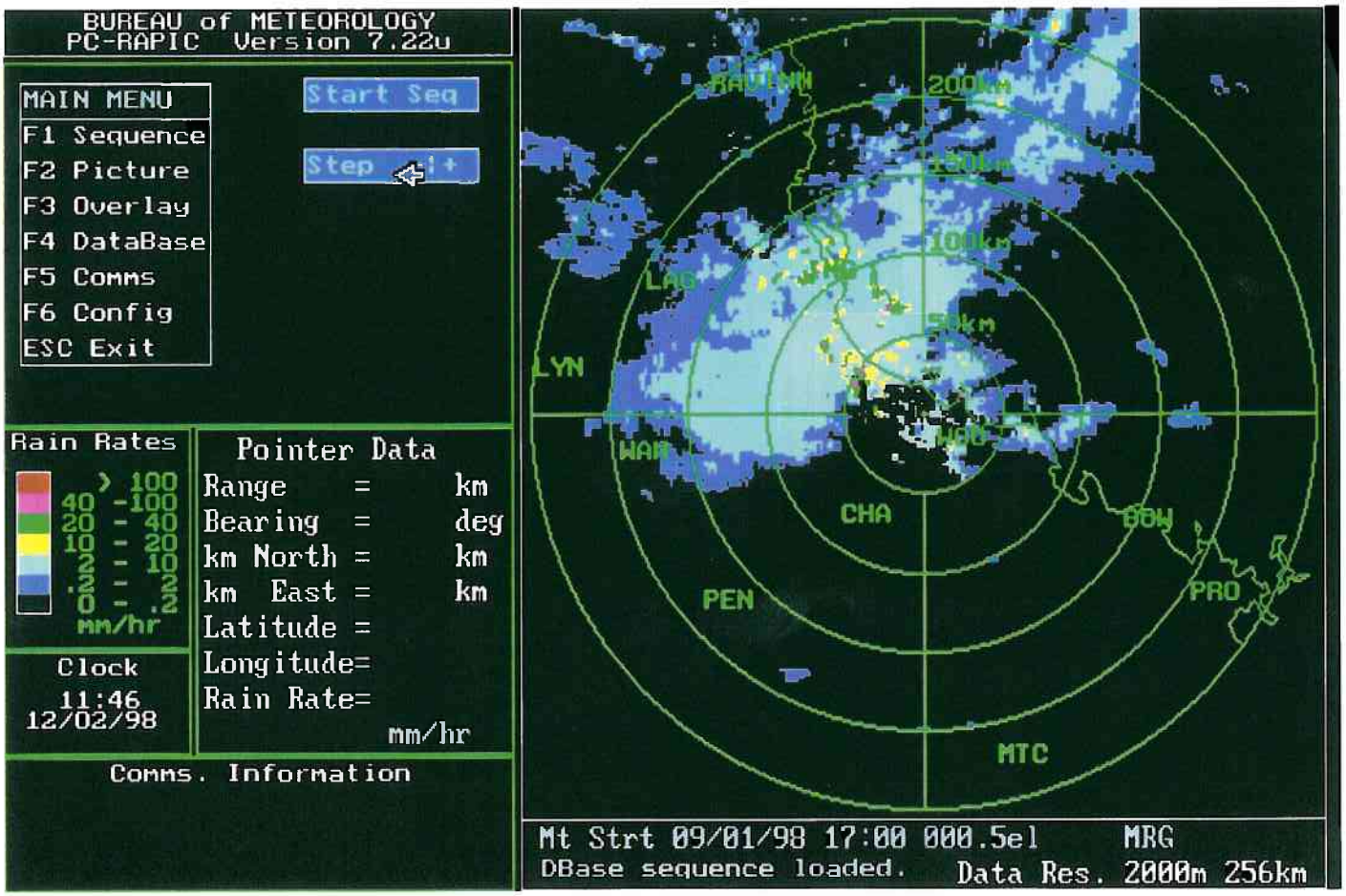


Figure 5.1(d) Mt Stuart Radar 3am 10/1/98

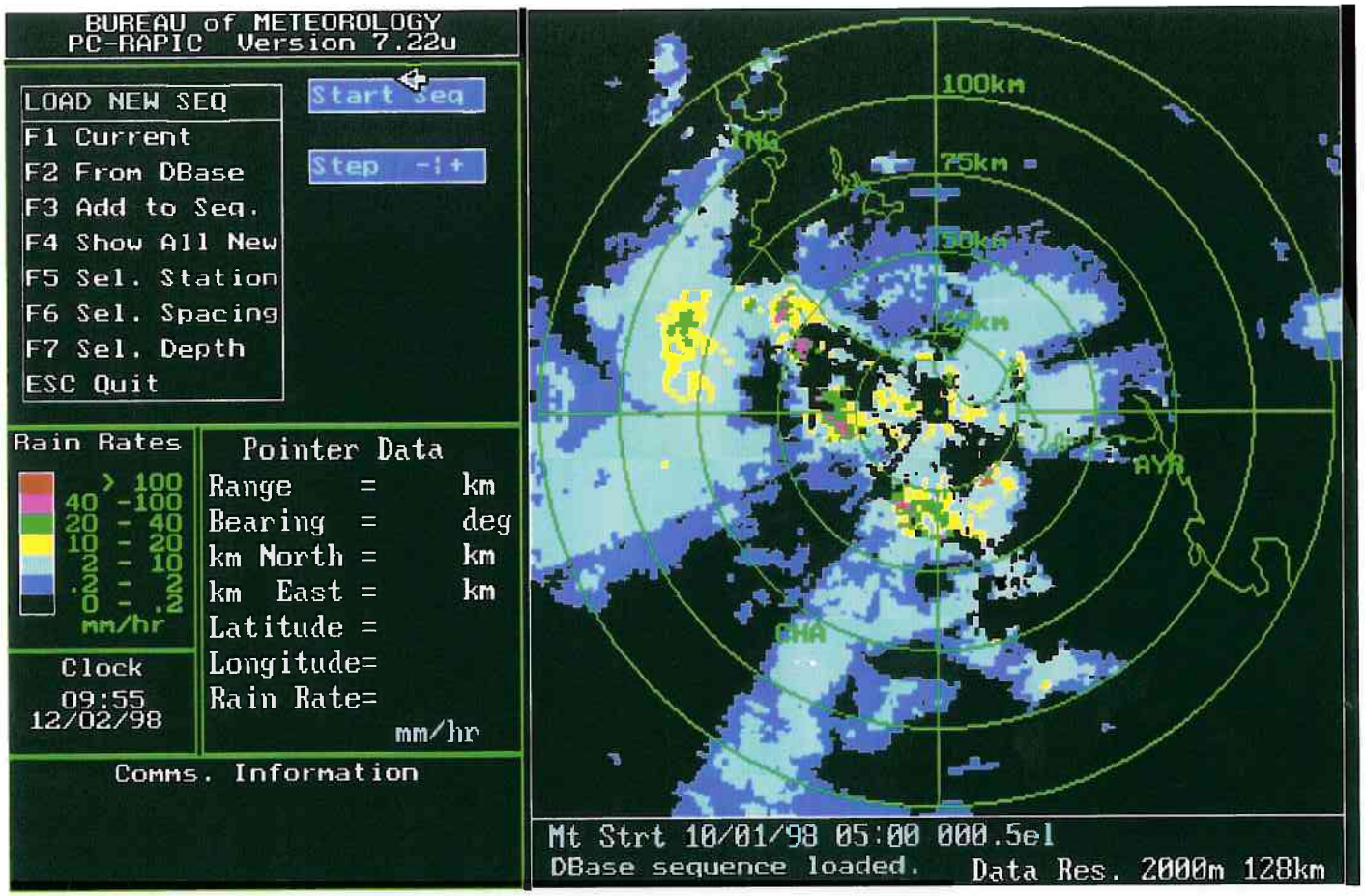


Figure 5.2(a) Mt Stuart Radar 3pm 10/1/98

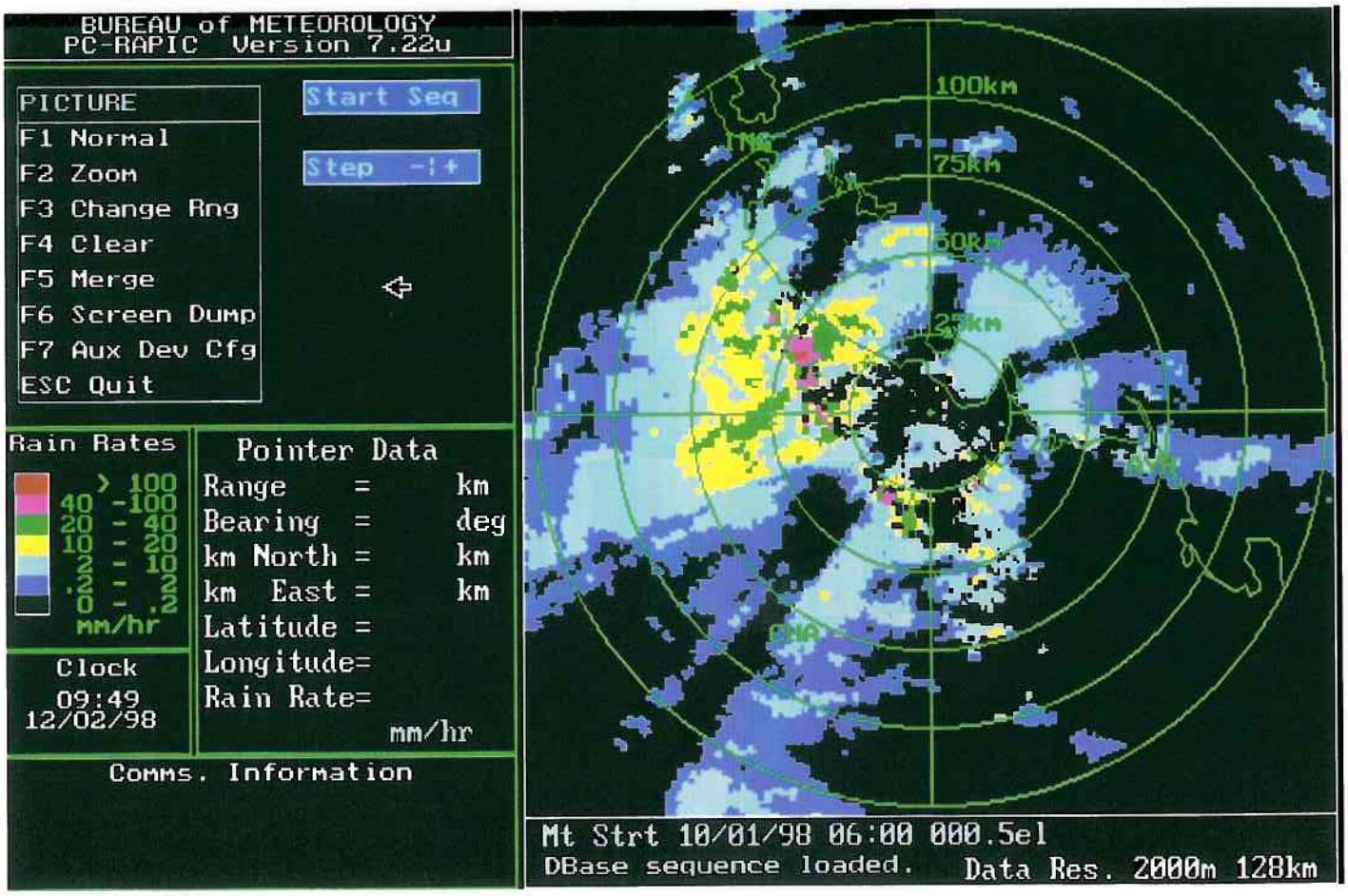


Figure 5.2(b) Mt Stuart Radar 4pm 10/1/98

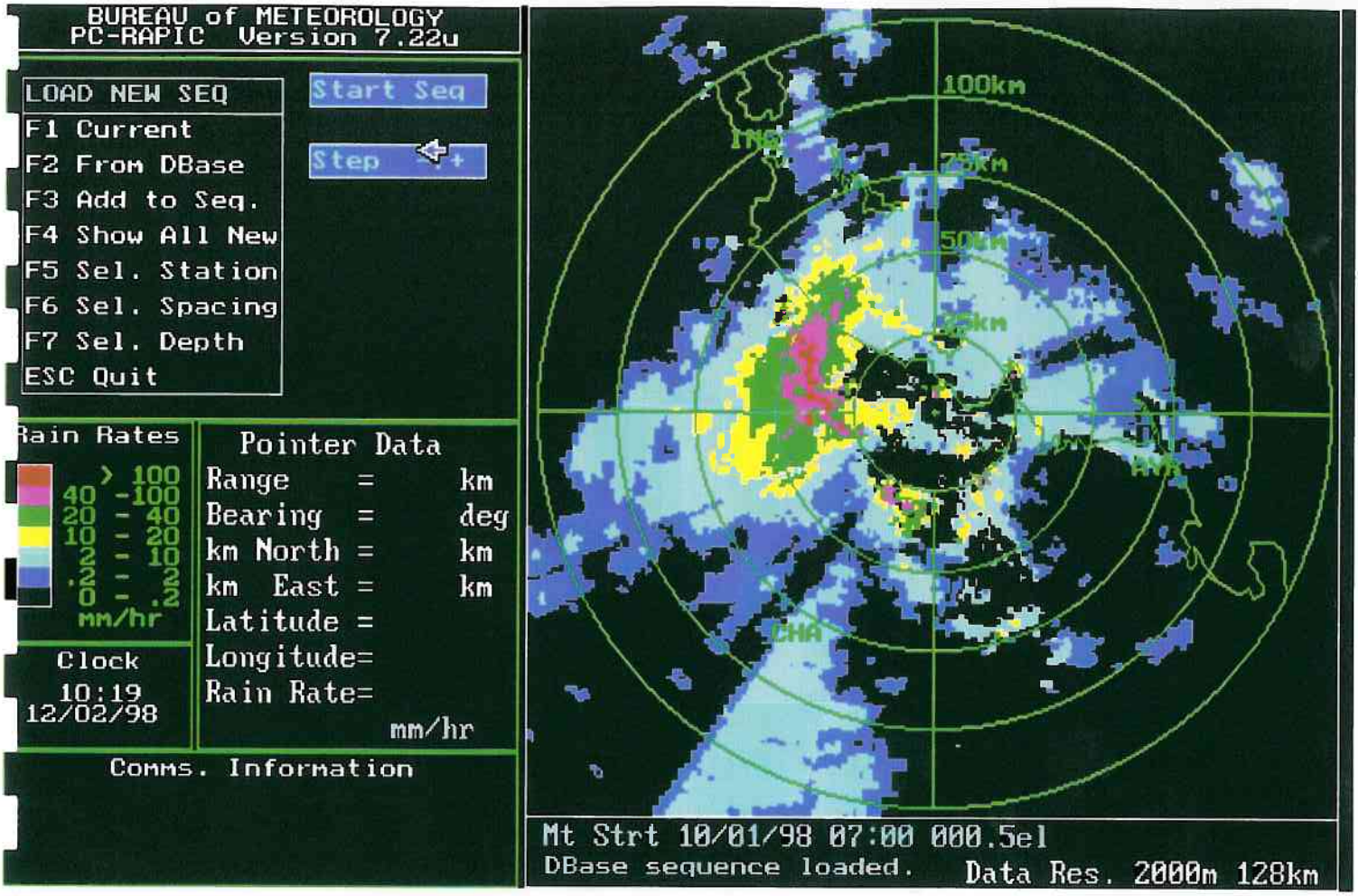


Figure 5.2(c) Mt Stuart Radar 5pm 10/1/98

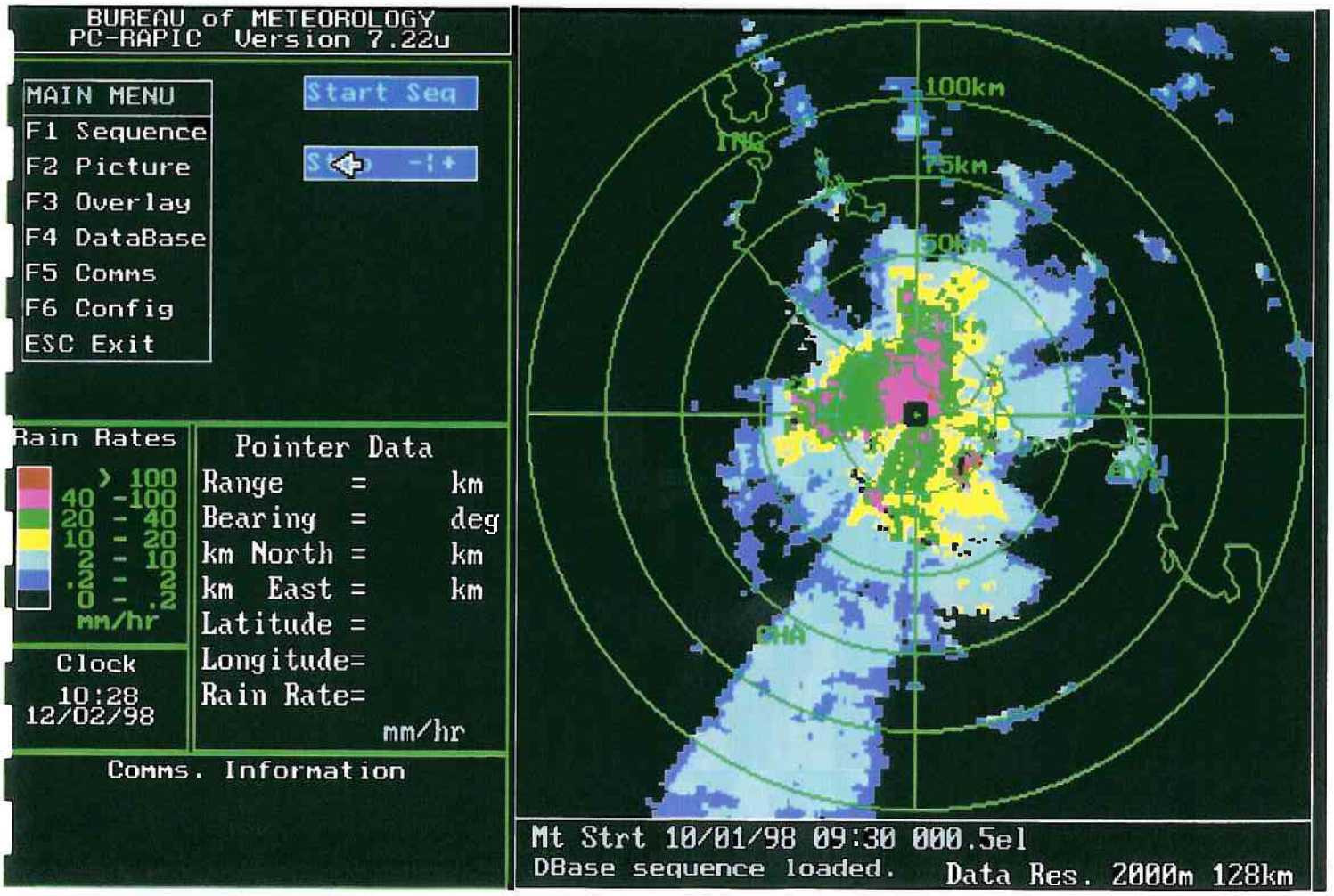


Figure 5.2(d) Mt Stuart Radar 7.30pm 10/1/98

5.2 Flood Warning Networks

A performance analysis has been carried out on the flood warning networks in north Queensland. These networks comprise rainfall and river height stations which report to the Bureau's Warning Centre via radio telemetry (ALERT), telephone telemetry (TMs) and manual readings reported by volunteer observers reporting through the Remote Observer Collection System (ROCS).

All manual and automatic are included in the analysis, including those operated by State and Local Government agencies.

Rainfall Stations

In the area of interest, there are about 80 rainfall stations specifically available for flood warning, plus an additional 60 daily reporting rainfall stations. Table 5.1 indicates the number of stations in each catchment and the method of reporting. This table excludes daily rainfall stations which only report once per day at 9am and have limited flood warning value in fast responding catchments.

It is difficult to determine the reliability of the daily reporting rainfall stations as they are not required to report zero rainfall. Some 70 to 80% of the expected reports were received from the daily rainfall stations in Rainfall Districts 30, 31,32, 33 and 34. There was only a small number of stations which did not report during the event. The percentage of missing reports appeared to be slightly higher on the weekend of the 10-11 January than for other days in the period.

Of the 21 TMs, about 70% reported well, with no reports or partial reports received from the remainder. This may have been attributed to instrument failure during the event or changes in telephone numbers or instruments not being functional at the start of the event.

Table 5.1 Flood Warning Networks

Basin	Rainfall			River Height		
	ROT	TM	ALERT	ROT	TM	ALERT
Johnstone River	3	2	14	0	3	7
Tully River	3	6	0	2	3	0
Herbert River	5	4	14	6	7	7
Ross River	0	0	4	0	0	1
Haughton River	0	2	7	3	3	3
Burdekin River	1	7	8	14	9	11
Total	12	21	47	25	25	29

ROT - Manual station reporting by Remote Observer Terminal
TM - Automatic station reporting by telephone telemetry
ALERT - Automatic station reporting by radio telemetry

Of the 47 ALERT rainfall stations, 9 stations or 20% suffered some form of failure during the event. Four of these stations were in the Haughton River system which accounted

for just over half of the ALERT rainfall network in the Haughton River. Four rain gauges failed in the Johnstone network but, because of the relatively large number of stations in the network, this had much less impact. One rain station out of 14 failed in the Herbert. The failures were attributed to blockages due to droppings and faulty reed switches in the Tipping Bucket Rain Gauges and electronics failures.

River Stations

Nearly 80 river height stations were operational in the effected catchments at the commencement of the event, equally divided between manual, telephone telemeters and radio telemeters.

Reliability of the 25 volunteer observer river height stations appears to have been high with most of the expected reports being received in the Warning Centre. There were only one or two stations which did not report as expected.

Generally, the river height telephone telemetry stations proved very reliable with only about 3 stations (10%), either not available due to communications problems, instrument failure or incorrect data.

The availability of data from ALERT river height stations was less than normally expected in a severe weather event with either total or partial failure at 8 out of 29 stations.

5.3 ALERT Systems

The Warning Centre receives real time flood data from a number of rainfall and river height ALERT systems installed in north Queensland. With the exception of the Ross River, the ALERT systems were installed as cooperative projects between the Bureau and the respective Local Government. In north Queensland, there are five ALERT systems, listed in Table 5.2, which provide real time information direct to both the local Council and to the Warning Centre in Brisbane.

Overall the reliability of stations within ALERT systems in north Queensland was below that which is normally expected. Out of a total of 76 ALERT sensors, approximately 58 sensors or 80% of the network worked without fault throughout the event. About 20% of the network either did not send any data during the event, or did not accurately report. Some of the non- reporting stations were due to unserviceable equipment prior to the start of the event.

Table 5.2 summarises the performance of north Queensland ALERT networks during the event.

Table 5.2 Local Government ALERT Systems

ALERT System	Base Station	No of Sensors	Failures	Details of Failures
Johnstone River	Johnstone Shire Council (Innisfail)	21	6	4 rain stations incorrectly reporting 1 river station complete failure 1 river station partial failure
Herbert River	Hinchinbrook Shire Council (Ingham)	21	4	1 rain stations incorrectly reporting 3 river stations incorrectly reporting
Ross River	Townsville-Thuringowa Water Board (Dam)	5	0	
Haughton River	Burdekin Shire Council (Ayr)	10	5	4 rain stations incorrectly reporting 1 river stations incorrectly reporting
Lower Burdekin River	Burdekin Shire Council (Ayr)	19	0	
Total		76	15	

Past experience shows that typically 85-90% of stations function during floods. The failure rate was unacceptably high in the Johnstone, Herbert and Haughton systems. The highest failure rate was in the rain gauges where blockages and faulty switch mechanisms accounted for most of the failures.

Of the failures at river height stations, two could be attributed to gas leakages or running out of gas and the rest electronic failures.

5.4 Flood Forecasting Models

During the event, several hydrologic models, listed in Table 5.3, were used for assistance in predicting river heights and/or assessing the likely degree of flooding.

The models on the whole were an effective way of assembling and displaying a large volume of data and provided good quality guidance for river height predictions at many locations.

Table 5.3 Flood Forecasting Models

Basin	Catchment	Model
Tully River	Tully River to Euramo	Unit Hydrograph
Herbert River	Upper Herbert River to Gleneagle	URBS Runoff-Routing Model
	Lower Herbert River to Halifax	URBS Runoff-Routing Model
Haughton River	Haughton River to Giru	URBS Runoff-Routing Model
Burdekin River	Upper Burdekin River to Sellheim	URBS Runoff-Routing Model
	Cape River to Taemas	URBS Runoff-Routing Model
	Belyando/Suttor River to Scartwater	URBS Runoff-Routing Model
	Burdekin Falls Dam	URBS Flood Routing Model
	Lower Burdekin River to Inkerman Bridge	URBS Runoff Routing Model

The URBS model works by dividing the catchment up into many small areas. The depth of rainfall and the volume of runoff from each subarea is estimated. Runoff from each subarea is routed through the catchment and the forecast height hydrographs plotted and compared with the observed height at each river height station in the system

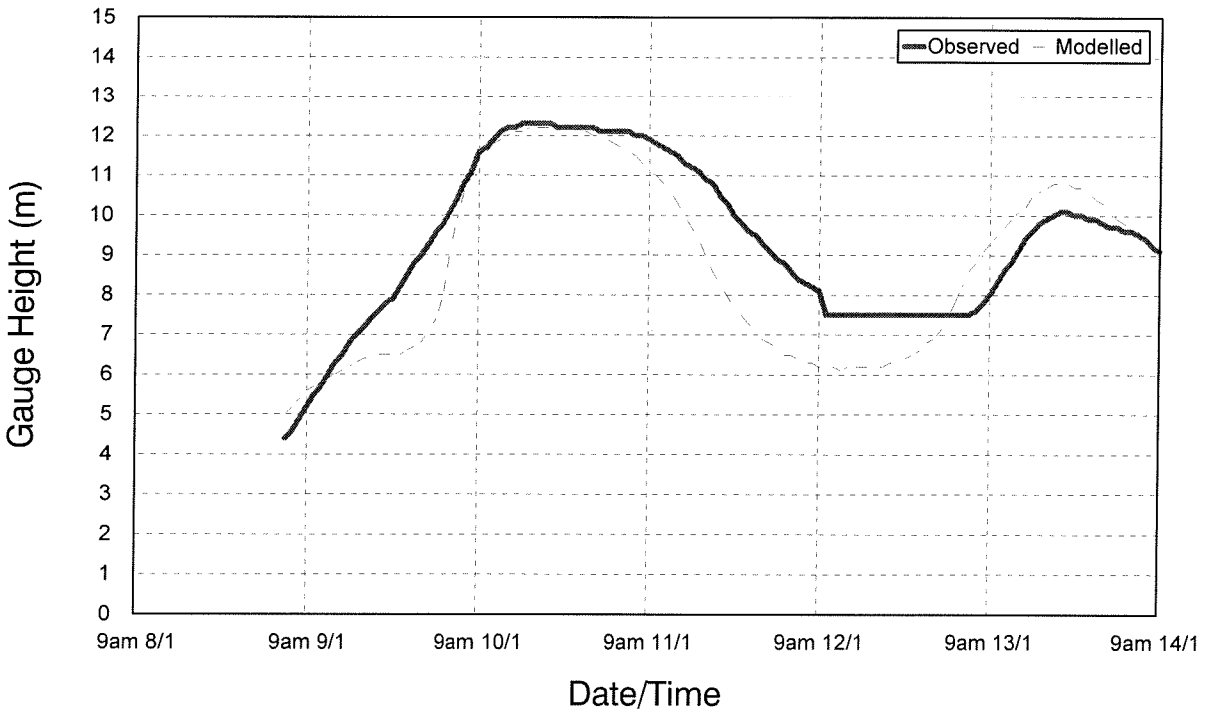


Figure 5.3 URBS Model - Herbert River at Gairloch

Figure 5.3 shows the results of the URBS model in simulating the flood heights at Gairloch solely from the observed rainfall. While the model underestimated the rising limb, it gave a good estimate of the peak, overestimated the rate at which the river fell and gave a reasonable estimate of the second peak. There is significant improvement in the modelled results at Gairloch by including observed heights/flows from upstream river stations, but

forecast lead times are naturally reduced. During this flood event, with high rain rates and fast river rises in the lower Herbert valley, the model predictions were sensitive to the accuracy of forecast rainfall.

The Haughton River URBS model, shown in figure 5.4, reproduced well the rising limb and peak flood level at Giru during the flood. Recommended model parameters were adopted with an initial loss of 70 mm and there was a very close fit to the observed rising limb. The predicted peak flood level was 2.5 m , 0.2m below the actual peak. This peak

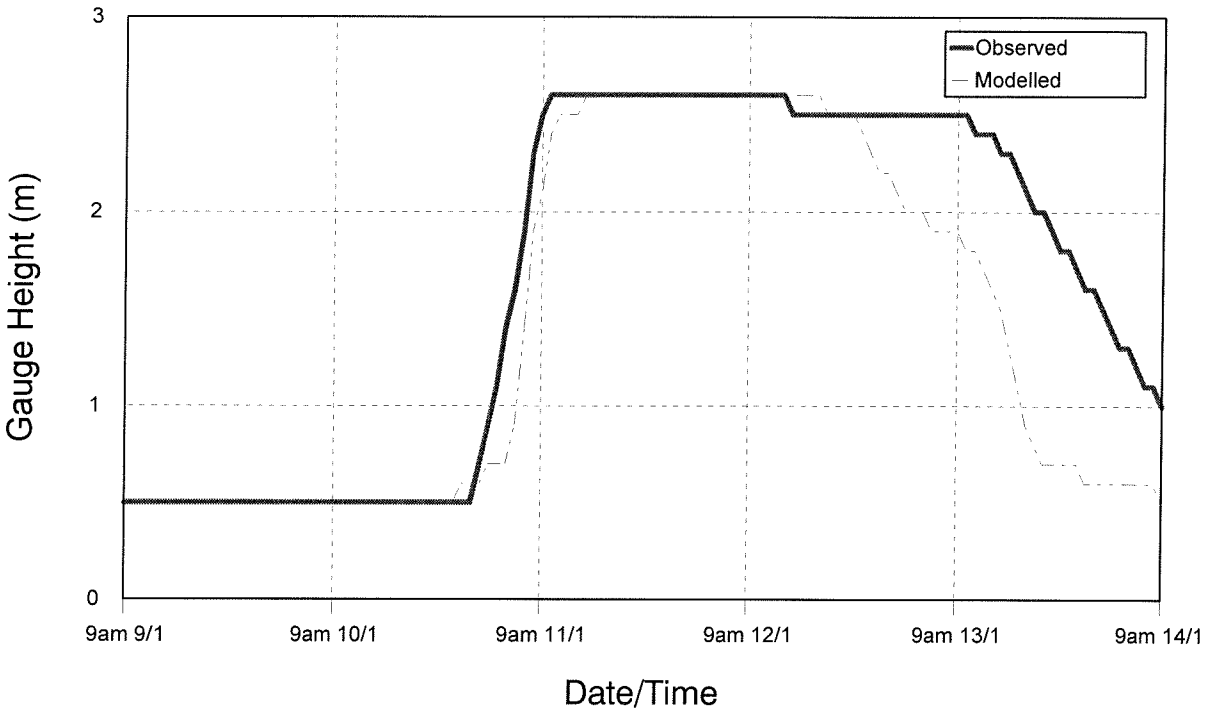


Figure 5.4 URBS Model Results - Haughton River at Giru

level was predicted at least 11 hours before it occurred using the URBS model, although the timing of the peak was not as accurate. The model however under predicted the duration at which the flood levels were maintained by over 12 hours and there was a very poor match to the recession. Data collected during this flood event will be used to refine the flood model calibrations.

5.5 FWC Computer Systems

The computer systems used in the Warning Centre remained operational during the event with little down time. The PC network used for flood forecasting, HYNET, proved to be reliable during the duration of the event. The telemeter interrogation package, MASTERS, resident on HYNET, polled up to 100 TM rainfall and river height stations every 1 to 3 hours and reliably delivered the data to the ALERT database. The ALERT software allowed flood forecasting staff to display data in tabular, graphical and map form. Modelling software also worked well.

There was a major communications failure at the Mt Stuart Weathernet link. This link allows data from several of the ALERT systems to be sent directly to the Warning Centre in real time. Fortunately, the backup system of downloading data via telephone from each of the systems proved reliable. As in past events, the system in AROS to prepare warning texts was slow and cumbersome.

6.0 WARNING SERVICES

During the period 8 to 16 January 1998, three types of public warnings were issued to advise of extreme weather conditions in north Queensland:

* Strong Wind/Gale Warnings
* Severe Weather Warnings
* Flood Warnings

Strong Wind/Gale Warnings alerted small craft operators while Severe Weather Warnings provided general advice of wind and sea conditions, heavy rainfall and flash flooding. The Flood Warnings gave more specific information about riverine flooding. All were issued from the Bureau's Warning Centre in Brisbane.

The Warning Centre issued 14 Severe Weather Warnings, summarised in Table 6.1, for the coastal areas in northern Queensland between 4am 10 January to 4pm 11 January 1998.

Table 6.1 Severe Weather Warning Schedule: 10 - 11 January 1998

Date/Time of Issue	Area
0400 10/01/98	Coastal communities between Cardwell and Bowen
0700 10/01/98	Coastal communities between Cardwell and Bowen
0700 10/01/98 (Re-issued)	Coastal communities between Cardwell and Bowen
1000 10/01/98	Herbert-Burdekin region
1300 10/01/98	Herbert-Burdekin region
1600 10/01/98	Herbert-Burdekin region
1900 10/01/98	Herbert-Burdekin region
2200 10/01/98	Herbert-Burdekin region
0400 11/01/98	Herbert-Burdekin region
0400 11/01/98 (Corrected)	Herbert-Burdekin region
0700 11/01/98	Herbert-Burdekin region
1000 11/01/98	Herbert-Burdekin region
1300 11/01/98	Herbert-Burdekin region
1600 11/01/98	Herbert-Burdekin region

The Warning Centre issued 66 Flood Warnings, summarised in Table 6.2, for rivers in northern Queensland with nearly half of these warnings issued on Saturday 10 and Sunday 11 January.

Table 6.2 Flood Warning Schedule: 8 - 16 January 1998

Catchment	First Warning	Final Warning	Number of Warnings	Number of Predictions
Johnstone River & Adjacent Coastal Streams	1315 08/01/98	0720 09/01/98	4	0
Tully River	1335 08/01/98	1555 12/01/98	14	6
Herbert River & Adjacent Coastal Streams	0500 10/01/98	1240 12/01/98	12	6
	0805 13/01/98	0940 15/01/98	6	3
Haughton River	1855 10/01/98	0940 14/01/98	14	2
Burdekin River	1035 10/01/98	0945 16/01/98	16	4

In addition to the Flood Warnings, River Height Bulletins containing the latest river height observations for key stations in each catchment were issued at regular 3 hourly intervals during the period.

The Severe Weather Warnings, Flood Warnings and the River Height Bulletins were widely disseminated to the media for public broadcast, to response agencies such as the Department of Emergency Services, Police and Local Governments and to a wide range of other agencies requiring weather and flood information.

Warning Centre staff, and staff from the Bureau's Townsville office, were in regular telephone contact with the Department of Emergency Services and Local Governments throughout the period of the event and also provided regular updates to the media through live and taped interviews.

There was considerable consultation with staff from the Johnstone, Hinchinbrook and Burdekin Shire Councils with regard to river height predictions, supply of data and short term rainfall forecasts.

6.1 Strong Wind/Gale and Severe Weather Warnings

The first major warning for this system on the East Coast was a Gale Warning for small craft issued at 4pm Friday 9 January 1998 for Innisfail to Lucinda, with strong winds south to Bowen, upgrading a strong wind warning that had been issued earlier.

At 3.30 am Saturday 10 January 1998, the duty officer of the Department of Emergency Services was advised that a Severe Weather Warning for flash flooding was about to be issued for the area Cardwell to Bowen. This Warning was issued at 4 am (see top of next page) and forecast the possibility of wind gusts to 90 km/h, very heavy rain, localised flash flooding, and beach erosion/salt water flooding problems with the morning high tide. This warning also advised motorists to take care with flooded road crossings.

A similar warning at 7am Saturday included warning of landslides and fallen trees.

A message switching problem in the warning dissemination system resulted in these two warning failing to reach all intended recipients. The 7am warning was reissued at 8.30am Saturday to all addressees.

TOP PRIORITY
SEVERE WEATHER WARNING ISSUED BY THE BUREAU OF METEOROLOGY,
BRISBANE AT 4 am EST Saturday 10 January 1998.

For coastal and island communities between Cardwell and Bowen.

At 4 am a 999 hPa low was located on the coast near Innisfail and a high pressure ridge is strengthening along the Central Coast. Between these two systems a band of gales is intensifying between Cardwell and Bowen.

LAND GALES
Wind gusts to 90 kilometres per hour are expected which may bring down power lines and damage weaker structures.

Very heavy rain is falling with localised flash flooding expected.

Some road crossings are flooded and motorists should take care.

Water levels on the high tide this morning could reach the level of the highest tide of the year.

Residents and campers in low-lying seaside areas may experience some salt water flooding and should consider moving to higher ground. Large waves are expected with beach erosion.

For further advice, contact your local police or SES.

The next Severe Weather Warning will be issued at 7 am

This warning from the Weather Bureau is available on Telecom Dial-it in Townsville (077) 1196
Facsimile copies of this warning may be obtained by polling 019 725 278.

Severe Weather Warnings for the Herbert-Burdekin Region were then issued at 10am and 1pm, with the latter predicting that weather conditions about the coast would slowly improve during the following next 6 to 12 hours as the main rain influence moved inland.

However, as described earlier, the weather situation changed dramatically mid-afternoon with a heavy thunderstorm complex building on the ranges to the near west of Townsville. As the thunderstorm influence was expected to be steered over the Townsville area later that day, the Severe Weather Warning was promptly updated at 4pm.

Heavy rain and strong squally winds were forecast to persist between Ingham and Home Hill and over the adjacent inland. Weather conditions north of Townsville (but not including the city itself) were expected to slowly improve. A similar Severe Weather Warning was issued at 7pm (and reproduced over the page) with no clearance predicted in the Townsville area. Both the 4pm and 7pm warnings also included reference to stream rises and local flooding.

Severe Weather Warnings were subsequently issued at 3 hourly intervals until 4pm on Sunday, by which time the weather conditions around Townsville had significantly improved.

PRIORITY
SEVERE WEATHER WARNING FOR THE HERBERT-BURDEKIN REGION
ISSUED BY THE BUREAU OF METEOROLOGY BRISBANE
at 7pm EST Saturday 10 January 1998.

At 7pm a slow moving 998 hPa tropical low was located just inland from Cardwell with a firm coastal ridge to the south.

A band of heavy rain and strong squally winds persists between Ingham and Home Hill and into the adjacent inland.

Weather conditions north of Townsville should slowly improve overnight with the rain and squally winds extending south to Bowen during the morning.

Flood warnings are current for the Tully, Herbert, Upper Burdekin and Haughton Rivers. Stream rises and local flooding will continue in coastal streams between Ingham and Home Hill.

Some road crossings are flooded and motorists should take caution.

In the 9 hours to 6pm, general rainfalls between 50 and 100mm were reported with local falls to 200mm.

For further advice contact your local police or SES.

The next Severe Weather Warning will be issued at 10pm.

6.2 Flood Warning - Johnstone River

The first flood warning for the Johnstone River was issued at 1.15pm on 8 January following the intense rainfall and the rapid rises in the North Johnstone and South Johnstone Rivers. The warning referred to heavy rainfalls in the lower catchment and the forecast for heavy rainfall over the next 24 hours.

The next warning was issued at 5.15pm by which time the North Johnstone and South Johnstone Rivers had started to fall upstream of Innisfail and the Johnstone River at Innisfail was expected to peak in the next few hours. This also referred to heavy rainfalls in the Babinda area. By the time the last warning was issued on Thursday 8 at 7.45pm, the river levels had generally peaked after the morning's heavy rainfall although renewed rises were predicted to occur overnight causing local to minor flooding.

The final warning for the Johnstone River was issued at 7.20am on 9 January. Heavy rainfall overnight had caused renewed rises, but river levels generally remained below minor flood level. Further rain was forecast and warnings would be re-issued if necessary. The local flooding of low lying areas and roads between Cairns and the Tully was forecast to continue.

6.3 Flood Warning - Tully River

A Preliminary Flood Warning was first issued for the Tully River at 1.35 pm on Thursday 8 January. This warning advised of heavy rainfall in the catchment over the previous 24 hours with further heavy falls predicted to result in stream rises and minor flooding.

The next warning, issued at 4.55 pm on that day, for the Tully River and adjacent coastal streams, advised of the commencement of minor flooding at Euramo with further rises expected.

RENEWAL OF FLOOD WARNING FOR THE TULLY RIVER AND ADJACENT COASTAL STREAMS
Issued at 6.55 am on Friday , 09/01/98
by the Bureau of Meteorology, Brisbane.

Rainfalls of up to 160 mm were recorded in the Tully catchment from 9am Thursday to 6 am Friday. Further rain with some heavy falls is forecast. Flooding of low lying areas and roads will continue during Friday along the coast from north of Cairns to the Cardwell area.

The Tully River at Euramo will continue to rise during Friday. At 6.30am, Euramo was 8.0 metres rising causing moderate flooding. A flood level of around 8.5 metres is expected late Friday. Minor to moderate flooding will continue in the lower Tully and Murray Rivers during Friday.

The next warning will be issued at about 10 am Friday.

Current flood warnings may be obtained from Infofax number 019725065 and the latest river heights from Infofax number 019725057.

Later at 7.55 pm, the Euramo height was reported as 6.9 metres rising and expected to reach at least 7.5 metres during Friday depending on further rain. Minor to moderate flooding in the lower Tully and Murray Rivers and flooding of low lying areas and roads along the coast from north of Cairns to the Cardwell area was expected to continue during Friday.

A renewal to the warning at 6.55 am on Friday 9, shown below, reported heavy rainfall overnight with further heavy rain predicted. The level at Euramo had reached 8.0 metres causing moderate flooding and was expected to be about 0.4 metres over the highway approaches late on Friday.

Further warnings at 10.15 am and 3.55 pm on Friday reiterated an expected flood level at Euramo of 8.5 metres later that day with possible further rises on Saturday. At 7.10 pm the flood level at Euramo was reported to be about 8.5 metres and nearing its peak. The level was predicted to stay at about this level til midday Saturday. Further rain was forecast with possible renewed river rises over the weekend.

The warning issued at 7.05 am on Saturday 10 January reported further heavy overnight rainfall and continued slow rises at Euramo to about 8.9 metres. The river was expected to peak at about 9 metres causing major flooding during Saturday night and Sunday morning. By this time, rainfalls had eased.

At 3.55 pm the level was reported as 8.95 metres and steady at its peak, about 1 metre above the Bruce Highway at Euramo.

Further warnings at 6.50 am, 10.25 am and 4.50 pm on Sunday 11 January reported river levels slowly falling at Euramo.

The warning issued at 8.20 am on Monday 12 reported a level at Euramo of 7.8 metres and falling fast and a Final Flood Warning was issued at 3.55 pm on 12 January with minor flood levels continuing to fall.

6.4 Flood Warning - Herbert River

A Priority Initial Flood Warning, shown below, was issued for the Herbert River at 5.00 am on Saturday 10 January, following the Severe Weather Warning of 4am. This warning advised of very heavy rainfall in the lower catchment since midnight and fast river rises in the lower Herbert River. It also advised of further heavy falls expected during the day. Major flooding was expected to develop in the Abergowrie Bridge and Ingham area during the day. A height of between 11.5 and 12 metres was predicted at Gairloch by 6 pm Saturday with further rises likely.

The next warning issued at 6.55 am on Saturday 10 reiterated the previous warning of fast rises in the Herbert River. Gairloch was forecast to reach a height of 11.5 metres by about 3 pm and 12 metres by 6 pm on that day.

The 10.30 am warning indicated that the height at Gairloch was reported as 11.55 metres and rising fast. A revised height of 12.3 metres was expected to be reached at Gairloch by 6 pm to 9 pm that evening. Heavy rain was expected to clear the southern part of the Herbert catchment in the next few hours.

FOR IMMEDIATE BROADCAST

PRIORITY INITIAL FLOOD WARNING FOR THE HERBERT RIVER
Issued at 5.00 am on Saturday, 10/01/98
by the Bureau of Meteorology, Brisbane.

Very heavy rains have fallen in the lower Herbert River catchment since midnight. Falls of 100 to 150 millimetres have been recorded in the Nash's Crossing and Zattas area, and 50 to 100 mm in the Abergowrie Bridge and Ingham area.

River levels along the lower Herbert River are rising very fast. Major flooding is expected to develop in the Abergowrie Bridge and Ingham area today. The Herbert River at Gairloch is expected to reach between 11.5 and and 12 metres by 6pm Saturday with further rises likely.

Continued heavy rainfall expected today is likely to cause high level major flooding at Ingham and Halifax tonight.

Motorists should avoid the area. Residents in low lying areas should monitor rising water levels closely and be prepared to move to higher ground.

Latest river heights at 4-00am include:

Nash's Crossing	*8.95 metres rising fast*
Zattas	*7.12 metres rising fast*

The next warning will be issued at 6-30am Saturday.

Current flood warnings may be obtained from Infofax number 019725065 and the latest river heights from Infofax number 019725057.

At 1.10 pm the recorded height for Gairloch at noon was reported in the warning as 12.10 metres and rising. The predicted height of 12.3 metres in the evening was unchanged. River levels at Abergowrie Bridge were expected to peak in the next few hours and major flooding was being experienced in the Stone River. Heavy rain had cleared southwards from the Ingham area.

A renewal warning for the Herbert River and Coastal Streams South to Townsville issued at 4.20 pm Saturday afternoon, shown below, reported major flood levels nearing their peak in the Abergowrie Bridge and Ingham area. Major flooding was still occurring in the

Stone River. Gairloch had reached a height of 12.3 metres near its peak and was rising slowly. Major flood levels downstream at Halifax were expected to peak during the next few hours.

The 4-20pm warning emphasized that a band of heavy rain was persisting between Ingham and Home Hill and that numerous small coastal streams, particularly in the Townsville district, would continue to cause flooding throughout the night. Advice was included for residents in low lying area to continue monitoring rising water levels, and for motorists to avoid the area.

RENEWAL OF FLOOD WARNING FOR THE HERBERT RIVER AND COASTAL STREAMS SOUTH TO TOWNSVILLE
Issued at 4.20 pm on Saturday, 10/01/98
by the Bureau of Meteorology, Brisbane.

Major flood levels are nearing their peak along the lower Herbert River in the Abergowrie Bridge and Ingham area.

Major flooding is also at a high level along the Stone River.

At 3pm, the Herbert River at Gairloch was 12.30 metres and rising slowly.

The Herbert River at Gairloch is expected to peak around the 12.3 metre level during the next few hours. Major flood levels downstream at Halifax will also peak during the next few hours.

The heavy rain has cleared southwards from the Ingham area.

A band of heavy rain persists between Ingham and Home Hill. Numerous small coastal streams, particularly in the Townsville district, will continue to cause flooding of low lying areas and roads throughout tonight. Residents in low lying areas should continue to monitor rising water levels closely. Motorists should avoid the area.

For detailed information on flooding in the Ingham and Halifax area, contact the Hinchinbrook Shire Council on 47 76 22 11.

Latest river heights include:

Gleneagle Homestead	*8.50 metres rising at 1-40pm*
Nash's Crossing	*6.75 metres falling at 3pm*
Abergowrie Bridge	*17.20 metres rising slowly at 3pm*
Gairloch	*12.30 metres rising slowly at 3pm*
Halifax	*5.37 metres rising slowly at 3pm*

The next warning will be issued at 7pm Saturday.

Current flood warnings may be obtained from Infofax number 019725065 and the latest river heights from Infofax number 019725057.

At 7.20 pm on 10 January, the flood level at Abergowrie Bridge was falling slowly after peaking at 17.2 metres at 3 pm. Major flood levels at Ingham, Gairloch and Halifax had peaked and were remaining steady. The general warning for small coastal streams remained.

The warnings was re-issued at 9.40 pm on Saturday 10 January, and subsequent warnings issued at 6.40 am, 10.10 am, 4.50 pm on Sunday 11 January and 7 am on 12 January reported the easing of flood levels. A Final Flood Warning was issued at 12.40 pm on Monday 12 January.

Heavy rain occurred again overnight on 12 January which resulted in an Initial Flood Warning being issued for the Herbert River at 8.05 am on Tuesday13. Moderate flood levels were expected to be reached from Abergowrie Bridge to Gairloch that afternoon. Further heavy rainfall was forecast.

The warning issued at 1.05 pm reported that the Stone River had peaked that morning and that minor to moderate flood levels were expected to peak from Abergowrie Bridge to Gairloch that afternoon. At 4.20 pm the river levels between Abergowrie Bridge and Gairloch were reported near their peak with minor to moderate flooding. Moderate to major flooding was being maintained at Halifax with a peak expected to be reached overnight.

At 10.00 am on Wednesday 14, the level at Gairloch was falling after peaking at 7 pm the previous evening. Moderate to major flood levels in the Halifax area had commenced to fall.

Continued falls in the river levels were reported in the warning issued at 4.10 pm on the 14 January and a Final Flood Warning was issued at 9.40 am on Thursday 15 January.

6.5 Flood Warning - Haughton River

The initial flood warning for the Haughton River and adjacent coastal streams was issued at 6.55pm on Saturday, 10 January following the heavy rains in the headwaters of the Haughton River.

RENEWAL OF FLOOD WARNING FOR THE HAUGHTON RIVER & ADJACENT COASTAL STREAMS
Issued at 10.15 pm on Saturday, 10/01/98
by the Bureau of Meteorology, Brisbane.

A band of very heavy rain is moving down the coast into the Haughton River catchment. Falls of 50 to 150 millimetres have been recorded since 9am, and heavier rains are expected during the next few hours.

River rises to at least moderate flood levels are expected in the upper Haughton River and Major Creek tonight. The Haughton River at Giru is expected to reach moderate flood levels during Sunday morning, however the expected heavier rains may cause quicker rises to major flood level.

Exceptionally heavy rain has fallen in the Townsville area during the past few hours causing severe local flash flooding and high flood levels in coastal streams in the area.

The next warning will be issued at about 5am Sunday, or earlier if the situation deteriorates.

Current flood warnings may be obtained from Infofax number 019725065 and the latest river heights from Infofax number 019725056.

River rises to moderate flood levels were expected in the upper Haughton River and Major Creek that night and minor flooding at Giru on the Sunday. It was predicted that with further heavy falls overnight higher flood levels might be reached.

Deteriorating weather conditions resulted in a renewal warning being issued at 10.15pm that night, shown below, advising of continued heavy rainfall and the forecast of heavier rains in the next few hours. When the warning was issued at 5.35am on 11 January, the band of heavy rainfall had remained stationary over the Townsville area for the last 12 hours and heavy falls of 400 mm recorded overnight. River levels were rising and the

forecast for Giru was revised to moderate to major flooding. The level was predicted to reach 2.0 m by 9am and continue rising.

Subsequent warnings issued during the day advised of major flooding at Giru and Powerline that had peaked during the day. Giru reached 2.7 m and it was forecast that this level would be maintained and fall slowly overnight depending on any further rainfall. The last warning issued on 11 January at 4.40pm, noted that Giru had peaked and that the renewed rises that were being recorded in the upper reaches would not affect the flood levels at Giru.

> ***RENEWAL OF FLOOD WARNING FOR THE HAUGHTON RIVER & ADJACENT COASTAL STREAMS***
> *Issued at 10.15 pm on Saturday, 10/01/98*
> *by the Bureau of Meteorology, Brisbane.*
>
> *A band of very heavy rain is moving down the coast into the Haughton River catchment. Falls of 50 to 150 millimetres have been recorded since 9am, and heavier rains are expected during the next few hours.*
>
> *River rises to at least moderate flood levels are expected in the upper Haughton River and Major Creek tonight. The Haughton River at Giru is expected to reach moderate flood levels during Sunday morning, however the expected heavier rains may cause quicker rises to major flood level.*
>
> *Exceptionally heavy rain has fallen in the Townsville area during the past few hours causing severe local flash flooding and high flood levels in coastal streams in the area.*
>
> *The next warning will be issued at about 5am Sunday, or earlier if the situation deteriorates.*
>
> *Current flood warnings may be obtained from Infofax number 019725065 and the latest river heights from Infofax number 019725056.*

The warning issued at 8.05am on Monday 12 January reported the peak of 9.5 m at Powerline and the very slow easing of major flooding at Giru. Flood levels in the upper reaches of the Haughton River were all starting to fall. In the 4.25pm warning, river levels at Giru were remaining steady and further overnight rain with local heavy falls was expected to maintain the flooding at Giru.

As a result of overnight rain, the first warning for the Haughton River on 13 January reported the major flood levels at Giru as remaining steady and that the fluctuating river levels upstream would maintain at current levels. Moderate to heavy rainfall was forecast to ease during the day. The warning issued at 4.20pm finally advised of falling flood levels at Giru. Continued falling flood levels were reported in subsequent warnings and the final warning was issued at 9.40am on 14 January as minor flooding eased at Giru.

6.6 Flood Warning - Burdekin River

The initial flood warning for the Upper Burdekin River was issued at 10.35am on Saturday 10 January following the heavy rain reported at Paluma and rapid river rises at Blue Range, just upstream from Mt Fullstop. Further heavy rainfall was forecast and significant river rises causing flooding expected in the upper Burdekin River. The next flood warning on the same day, restated rapid river rises as river levels started to rise downstream of Blue Range causing minor to moderate flooding.

The very rapid rise in river levels at Sellheim on the night of 10 January caused major flooding around the Sellheim area and a warning was issued at 4.45am on Sunday 11 advising of further rises. Further heavy rainfall was forecast and, although the river levels

upstream of Sellheim area were falling, further rises were considered possible depending on the rainfall. Subsequent warnings issued on 11 January advised of further rises at Sellheim with the flood levels peaking overnight. The outflow from Burdekin Dam was forecast to increase slowly over the next few days and peak late Tuesday 13 or early Wednesday 14. Possible minor flooding was also forecast downstream in the lower Burdekin River.

By the time the 7.25am warning was issued on Monday 12, river levels upstream of Sellheim were falling and minor flooding easing. The outflow from Burdekin Dam was forecast to increase over the next couple of days with possible minor flooding downstream. The warning issued at 12.35pm extended the warning to the whole Burdekin River. Further rises upstream of Sellheim at Mt Fullstop were also reported and that fluctuating water levels were expected to continue from the Mt Fullstop area to the Dam over the next 24 hours. Levels at the dam continued to rise and the Burdekin River at Inkerman Br was expected to reach a level of at least 8.5 m early morning, Tuesday 13. This level was revised to 9 m in the warning issued at 5pm.

The first warning issued at 7.05am on Tuesday 13, reported that the Burdekin Dam level was at or near its peak at 4.93 m. River levels downstream were forecast to continue to rise with the Burdekin River at Inkerman Bridge predicted to reach a level of at least 9.3 m later in the day. The warning issued at 11.45am indicated that the Burdekin Dam spillway level had peaked and the level at Inkerman Bridge was rising slowly at 9.1 m and near its peak. The level at Inkerman Bridge was considered to have peaked at 9.15 m in the warning issued at 4.25pm. Subsequent warnings issued on 14 to 16 January referred to falling river levels and minor flooding easing. The final flood warning was issued at 9.45am on Friday 16 January.

7.0 CONCLUDING REMARKS

An event of this extreme nature provides the Bureau with an opportunity to review performance and identify improvements in the design and operation of its severe weather and flood warning systems and services, and their integration and interaction with a wide range of agencies and the community.

This process of review and improvement is ongoing at the time of writing this report, and includes Bureau involvement in short and long term activities such as:

* Participation in formal and informal emergency service debriefs and discussions, and development of recommendations with relevant agencies;

* Addressing of issues identified in general agency and community feedback including that from the post-event survey (to which the Bureau contributed) of Townsville & Thuringowa residents conducted by the James Cook University Centre for Disaster Studies;

* With Townsville and Thuringowa City Councils and their Water Board, the development of proposals for an integrated flood warning system for the Ross River, and consideration of possible flash-flood warning measures for smaller streams;

* Continuation of projects to improve the forecasting of heavy rainfall, including real-time analysis of rainfall from radar and the ground-based networks;

* Re-analysis and refinement of existing real-time flood forecasting catchment models, and the development of new models for other river systems including the Ross River.

* Investigation of improved methods for alerting Bureau, Local Government personnel and the community to the potential for, and occurrence of, flood-producing rainfall;

* Fault maintenance visits to field equipment, and the identification of future preventative and upgrade measures to improve reliability;

* Review of adequacy of monitoring networks and communication methods, and identification of upgrade measures.

It is anticipated that further interactions will take place with relevant agencies, including Emergency Services and Local Government, aimed at improving warning services associated with such extreme events.

The outcomes of this ongoing review and improvement process will apply to both the immediate North Queensland situation, and the broader Queensland and Australian weather and flood warning context.

SEVERE WEATHER AND FLOODING

NORTH QUEENSLAND

JANUARY 1998

Queensland Regional Office
Bureau of Meteorology

April 1998

APPENDIX A

TOWNSVILLE/THURINGOWA AREA RAINFALL

A.1 Rainfall Totals

Daily rainfall totals from Saturday 10 to Wednesday 14 January in the Townsville area are given for the official and unofficial stations in Table A1. Official stations have a standard 203mm rain gauge, conform to Bureau standards and are recorded for the Bureau by volunteer observers. The gauges at unofficial stations are of unknown types and may not conform to Bureau standards.

For the 5 day period, Paluma recorded the highest total of 1,374 millimetres, Rangeview Ranch recorded 1,042 millimetres, and the unofficial station at Vincent recorded 1,199mm.

The Townsville Airport Meteorological Office (AMO) recorded 549 millimetres for the 24 hour period ending 9am Sunday 11 January. The previous 24 hour record rainfall for Townsville at this location which commenced in 1940, was 366 millimetres for the 24 hours ending 3 March 1946.

At Magnetic Island, a total of 774mm was recorded in the period.

In the Townsville area itself, the highest rainfalls appear to have been reported around the CBD where unofficial totals were up to 742mm at Railway Estate. Other significant totals in the Townsville include Vincent 735mm, Cranbrook 678 mm and Mundingburra 600mm.

TABLE A.1 Daily Rainfall (mm)

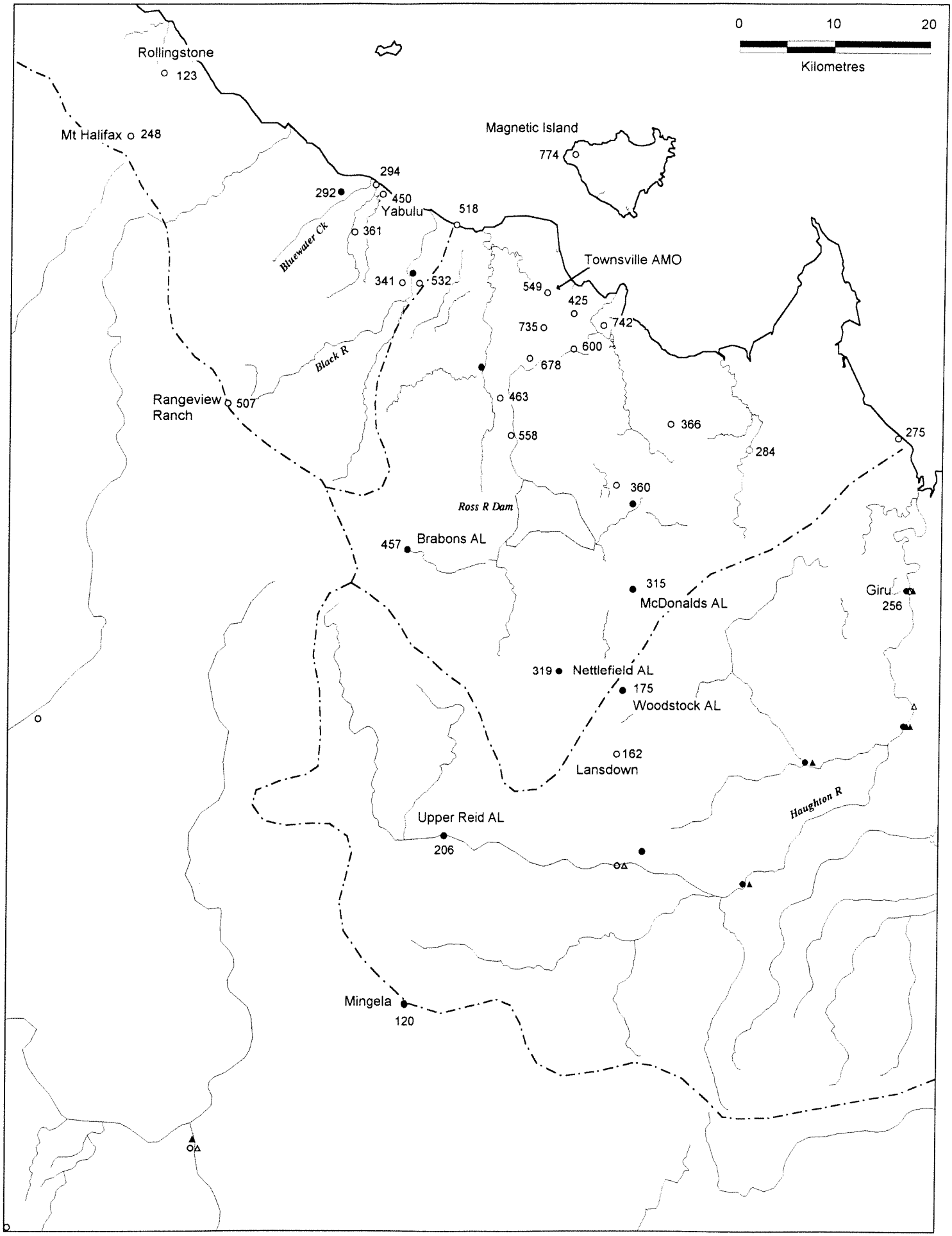
(a) Official Stations

Station Name	CBM Number	January 1998					Total
		Sat 10	11 Sun	12 Mon	13 Tue	14 Wed	
Townsville AMO	032040	46	549	82	163	30	870
Yabulu	032157	66	341	69	146	27	649
Yabulu Refinery	032050	71	450	117	123	N/A	761
Paluma	032064	307	340	163	281	283	1374
Rangeview Ranch	032175	110	507	239	149	37	1042
Lansdown	033226	40	162	110	59	10	381
Giru	033028	41	256	77	13	22	409
Mingela	033051	N/A	120	111	35	8	274
Paynes Lagoon	033139	18	273	40	18	14	363
Bluewater TM	-	69	292	69	87	N/A	517
Brabons AL	533007	41	457	165	118	14	795
Cormacks AL	533045	19	155	91	50	8	323
McDonalds AL	533044	12	315	136	53	17	533
Nettlefield AL	533043	14	319	145	62	7	547
Woodstock AL	533054	38	175	97	49	5	364
Upper Reid AL	533053	15	206	109	33	1	364

(b) Unofficial Stations

Station Name	January 1998					Total
	10 Sat	11 Sun	12 Mon	13 Tue	14 Wed	
Alligator Ck	18	284	171	47	27	547
Bushland Beach	64	518	100	155	37	874
Cranbrook	38	678	108	193	23	1040
Cungulla	43	275	98	11	22	449
Herveys Range	84	452	161	181	45	923
Jensen	N/A	532	108	175	31	846
Kelso	N/A	558	183	N/A	N/A	741
Magnetic Island	66	774	94	160	N/A	1094
Mt Halifax	217	248	109	144	82	800
Mundingburra	43	600	131	160	N/A	934
Oak Valley	20	360	189	96	24	689
Pangola Park	39	264	93	N/A	N/A	396
Railway Estate	34	742	123	178	28	1105
Rasmussen	23	463	111	207	N/A	804
Rollingstone	153	123	51	65	150	542
Saunders Beach	50	294	N/A	N/A	N/A	344
Serene Valley	33	366	239	80	40	758
West End	29	425	91	171	32	748
Vincent	40	735	165	237	22	1199

The map of the Townsville area shows the rainfall totals in millimetres which fell in the 24 hour period from 9am Saturday 10 January to 9am Sunday 11 January. The highest totals exceeding 700 millimetres were centred over Townsville and Magnetic Island. Lesser 24 hour falls of 300 to 500 millimetres were recorded in the immediate area surrounding Townsville.



- Manual Heavy Rainfall Station
- Daily Reporting Rainfall Station
- Manual River Station
- Telemetry Rainfall Station
- Telemetry River Station

TOWNSVILLE AREA

Daily Rainfall 0900 10/1/98 to 0900 11/1/98

Figure A1

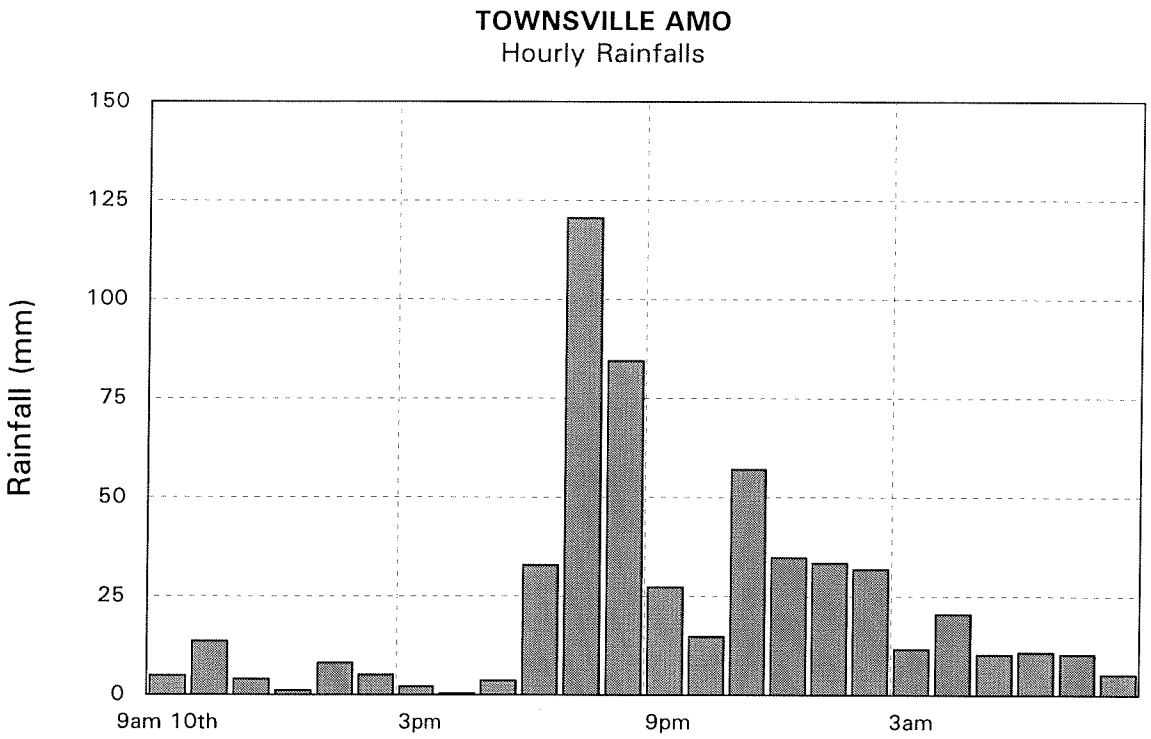
A.2 Rainfall Temporal Patterns

One hourly rainfalls for selected stations in the Townsville area are given in Table A.2 while the Townsville AMO rainfall is shown in graphical form.

The highest one hourly totals for each station are highlighted, indicating that for most areas around Townsville, the heaviest rainfall occurred between 6 and 9pm 10 January. At Yabulu and Bluewater, the heaviest rain was recorded in the hour before it occurred at Townsville.

TABLE A.2 Hourly Rainfalls

Time	Townsville AMO	Yabulu Refinery	Bluewater TM	Nettlefield AL	Brabons AL	McDonalds AL	Woodstock AL
1000	5.0	12	19	2.8	9.0	1.4	3.2
1100	13.6	10	9	7.6	17.2	6.4	3.0
1200	4.0	13	14	16.0	17.2	9.2	6.6
1300	1.0	8	11	13.4	13.8	4.2	7.6
1400	8.0	2	4	**30.2**	11.4	6.0	6.6
1500	5.0	3	3	**30.2**	4.2	4.8	6.6
1600	2.0	2	3	28.0	6.2	3.6	4.4
1700	0.4	8	12	2.4	1.8	1.2	3.8
1800	3.6	53	72	5.4	15.2	5.2	10.4
1900	32.8	**128**	**73**	14.2	**67.0**	4.0	13.2
2000	**120.6**	96	28	**24.6**	48.6	28.4	**17.8**
2100	84.6	52	16	13.6	46.4	**46.0**	14.2
2200	27.2	4	3	14.0	22.2	38.8	10.0
2300	14.8	5	2	19.4	14.4	25.8	13.0
0000	57.2	17	3	7.2	4.8	10.8	7.6
0100	34.8	5	0	8.4	4.0	19.8	5.6
0200	33.4	3	1	6.0	12.8	24.8	8.4
0300	31.8	1	0	8.0	24.6	21.8	5.2
0400	11.8	0	0	9.2	14.6	18.4	5.4
0500	20.6	12	0	11.2	15.4	5.2	3.2
0600	10.2	5	0	13.0	20.6	2.6	3.4
0700	10.8	1	18	5.4	12.6	6.6	2.4
0800	10.4	1	0	19.6	25.2	18.0	5.8
0900	5.2	0	0	9.6	27.8	3.0	8.0
Total	548.8	441	291	319.4	457.0	316.0	175.4



Both the table and graph clearly show the onset of the heavy rainfall at Townsville in the hour between 6 and 7pm on Saturday 10 January. Between 6pm Saturday and 3am Sunday morning, the rainfall for every hour, with the exception of the hour between 11 and midnight on Saturday, exceeded 25 millimetres.

The heaviest hourly rainfall (constrained "clock hour" value) occurred between 7 and 8 pm Saturday night when over 120mm was recorded at Townsville AMO. Given that higher 24 hour totals were recorded in other areas of Townsville, it is likely that the maximum hourly rainfall was greater than 120mm.

A.3 Rainfall Records

Table A.3 Comparison of Record Townsville Daily Rainfall Totals

Station	Rainfall and Date			
	Record	2nd Highest	3rd Highest	Jan 1998
032047 Townsville Pilot 1871-1951	488 21/01/1892	381 28/12/1903	356 03/03/1946	-
032040 Townsville AMO 1940-	549 11/01/1998	366 03/03/1946	346 16/01/1953	549 11/01/1998

The records at the current Townsville station at the Airport Meteorological Office only commence in 1940 and, for this station, the previous record was 366 mm in March 1946.

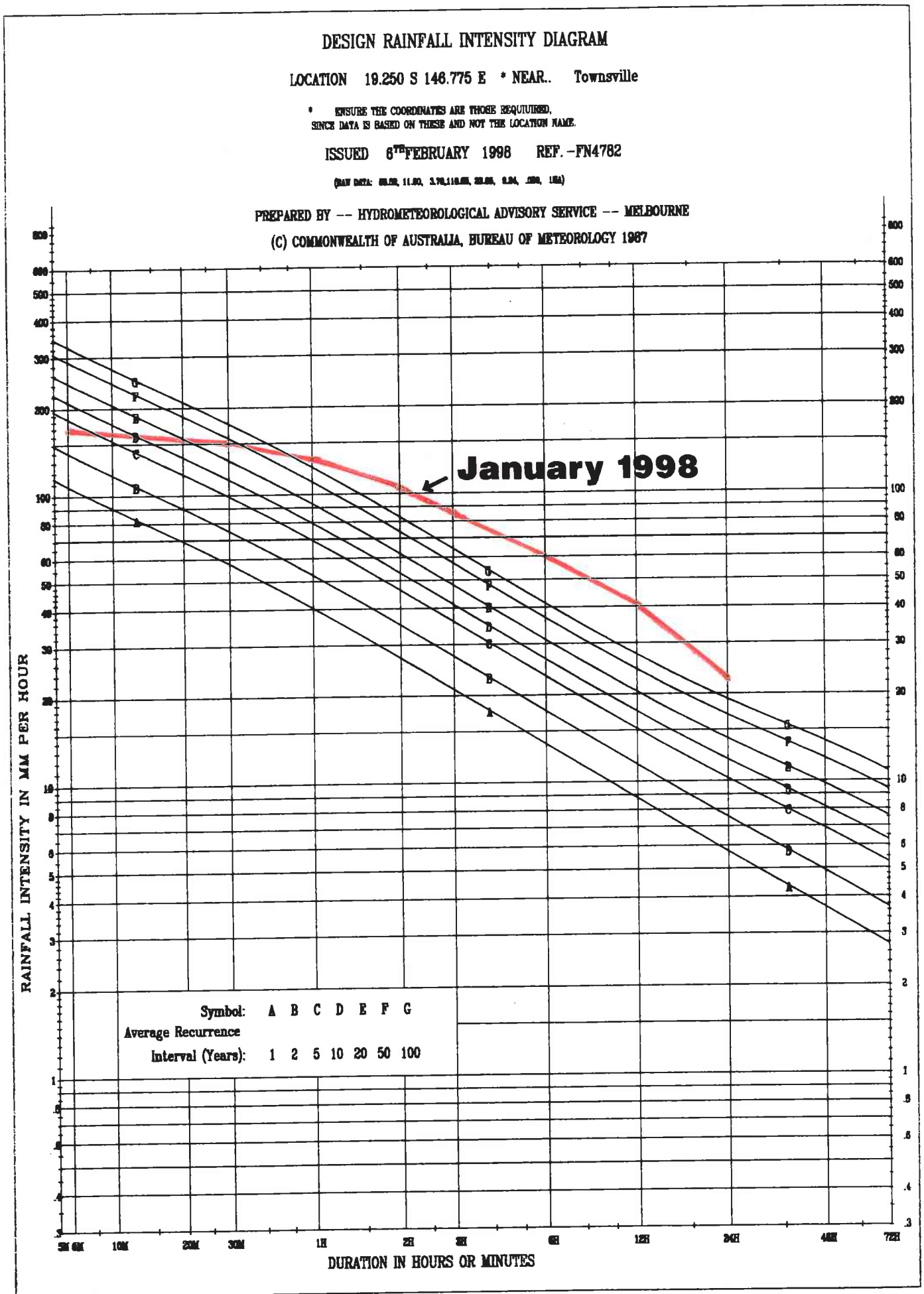

DESIGN RAINFALL INTENSITY DIAGRAM
LOCATION 19.250 S 146.775 E * NEAR.. Townsville
* ENSURE THE COORDINATES ARE THOSE REQUIURED,
SINCE DATA IS BASED ON THESE AND NOT THE LOCATION NAME.
ISSUED 6TH FEBRUARY 1998 REF.-FN4782
PREPARED BY -- HYDROMETEOROLOGICAL ADVISORY SERVICE -- MELBOURNE
(C) COMMONWEALTH OF AUSTRALIA, BUREAU OF METEOROLOGY 1987
January 1998
RAINFALL INTENSITY IN MM PER HOUR
DURATION IN HOURS OR MINUTES
Symbol: A B C D E F G
Average Recurrence
Interval (Years): 1 2 5 10 20 50 100

Figure A2