CONTENTS

The story of severe tropical cyclone Larry 1
Monitoring the progress of Larry 3
The characteristics of Larry 6
Larry’s devastation 12
Learning from Larry 14
The warning process 16
Public access to tropical cyclone information 18
Acknowledgments 19
THE STORY OF SEVERE TROPICAL CYCLONE LARRY

Severe tropical cyclone Larry crossed the tropical north Queensland coast near Innisfail during the morning of Monday 20 March 2006. Fortunately, no lives were lost and no serious injuries were reported. However, between Babinda and Tully, damage to infrastructure and crops was extensive with the total estimated loss upwards of half a billion dollars. To a somewhat lesser extent, damage also occurred in areas north to Cairns, south to Cardwell and on the Atherton Tablelands.

Larry developed from a low pressure system over the eastern Coral Sea. The low became noticeable on Thursday 16 March and was then closely monitored by the Bureau of Meteorology. It developed into a tropical cyclone during the early hours of Saturday 18 March, and proceeded on a general westerly course towards the Queensland coast. Late in the morning of 18 March, Larry was classified as a severe Category 3 cyclone and continued to intensify to a marginal Category 5 cyclone as it approached the Queensland coast.

The eye of the cyclone made landfall near Innisfail around daybreak on Monday 20 March. Wind gusts were later estimated to have been up to 240 km/h (Category 4) in the area surveyed. A marked variation in wind gusts was observed, both in a spatial sense and across elevated terrain. This was clearly evidenced by varying levels of damage across relatively small distances. Larry began to weaken as it moved onto the Atherton Tablelands but did maintain cyclone strength into the early hours of Tuesday 21 March.

Larry was a small cyclone with very destructive winds occurring over a limited distance from its centre. Moreover, Larry moved relatively quickly at the time of landfall thereby restricting the time that any particular location experienced cyclonic winds, airborne debris and heavy rainfall. Heavy coastal rain between Ingham to just south of Cairns was not as severe as in other cyclonic events, and only a few river basins had any significant flooding. However the decaying cyclone did result in extensive flooding in northwest Queensland during the following week. Also, it was fortunate that tides were quite low at the time of Larry’s coastal crossing, so the impact of storm surge was not devastating.

Bureau forecasters conducted numerous radio and television interviews during the cyclone’s life, and regularly briefed disaster managers on the level of threat. The Bureau’s communication links to the Internet were subject to unprecedented demand with the estimated number of “hits” on the day of landfall being in excess of 60 million.

Overall, the Bureau’s warning service during Larry rated highly in community surveys with the new Tropical Cyclone Forecast Map being especially well received.
The complete track of severe tropical cyclone Larry.

Cyclone Larry's track with a more detailed view of the landfall phase.
MONITORING THE PROGRESS OF LARRY

The Bureau of Meteorology attaches very high priority to the Tropical Cyclone Warning System with protection of life and property being the main goal. The system is based on three Tropical Cyclone Warning Centres (TCWC) in Brisbane, Darwin and Perth. The Brisbane TCWC area of responsibility (Eastern Region) spans the western Coral Sea and eastern Gulf of Carpentaria. Senior forecasters and other specialist staff in the TCWC have access to a wide range of weather information from a variety of observational platforms.

High-resolution satellite images are received every hour from the Japanese geostationary meteorological satellite MTSAT-1R and are processed by the Bureau of Meteorology. These images are artificially enhanced with various colours or shades, corresponding to temperature ranges and vertical heights in the atmosphere. Meteorologists use the different patterns on the enhanced satellite images to help determine the intensity of the cyclone. If the cyclone is located off the coast, with no ship or aircraft nearby to provide observations, this technique may be the only one available to estimate its intensity.

When a cyclone approaches the coast, its progress can usually be closely monitored by weather watch radar. Radars detect the intensity of rain from the strength of the radar pulse returns (or echoes). The radar images are updated every 10 minutes and give a picture of the rainfall rates associated with the approaching cyclone. Weather radars at Cairns (Saddle Mountain), Cairns Airport, Townsville (Mt Stuart) and Willis Island provided the TCWC with valuable information during tropical cyclone Larry.
Infrared satellite image from MTSAT-1R satellite received and processed by Bureau of Meteorology courtesy of Japan Meteorological Agency. Queensland, 20/03/06, 7:30 am AEST.

(Below) Townsville (Mt Stuart) radar at 6:20 am AEST on 20 March 2006.
**TIMELINE OF THE LARRY WARNING PROCESS**

**TUESDAY 14 MARCH**
- 9 am Close monitoring of tropical low commenced

**SATURDAY 18 MARCH**
- 4 am Cyclone named Larry
- 8 am First Cyclone Watch issued
- 5 pm First Cyclone Warning issued
- 11 pm *Larry* becomes a Severe Tropical Cyclone (Category 3)

**SUNDAY 19 MARCH**
- 2.30 am First preliminary Storm Tide Warning issued to Emergency Services
- 11 am Standard Emergency Warning Signal (SEWS) commenced
- 11.30 am First quantitative advice of Storm Tide issued to Emergency Services
- 8 pm Hourly Cyclone Warnings commenced

**MONDAY 20 MARCH**
- 6 am to 7.20 am Cyclone eye crossed the coast
- 3 pm *Larry* no longer classified as a severe cyclone
- 5 pm Hourly Cyclone Warnings ceased

**TUESDAY 21 MARCH**
- 2 am Final Warning (Advice No.36) issued

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*Tropical Cyclone Forecast Track Map issued for cyclone Larry, 24 hours from landfall.*
Tropical cyclone Larry crossed the coast on the morning of 20 March 2006 on a westerly track with the centre of the eye passing over Innisfail. The eye of cyclone Larry extended from south of Babinda to north of Kurrimine Beach.

Pressure and wind data from Automatic Weather Stations (AWS) provided invaluable information during the passage of Larry. Data from the Flinders Reef AWS assisted with the tracking of Larry on Sunday 19 March. The closest official instrumented observation site to the coastal crossing, was the Bureau of Meteorology’s AWS at South Johnstone. The highest wind gust measured at this site was 181 km/h (98 knots) at 6.33 am and 6.38 am on Monday 20 March, whilst the lowest reported pressure was 959.3 hPa at 6.56 am on Monday 20 March. However, this was not the highest wind speed to occur in the impact area, and verified reports of lower pressures were also obtained closer to the coast.

The table on the right details maximum measured wind gusts associated with Larry. Bellenden Ker Tower (CSIRO) and Ravenshoe Wind Farm (Stanwell Corporation) are not official Bureau of Meteorology observation sites, and as such, the values measured at these two locations are not counted as official data.

![Pressure Data from South Johnstone AWS 19-20 March 2006](image)

*Pressure readings at South Johnstone AWS during severe tropical cyclone Larry.*
RAINFALL AND FLOODING

An active monsoon over northern Australia contributed to well above average March rainfall totals over northern Queensland and parts of western Queensland, with some

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum Measured Wind Gust (km/h)</th>
<th>Time of Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 March 2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flinders Reef</td>
<td>211</td>
<td>9.10 pm</td>
</tr>
<tr>
<td>Hamilton Island Airport</td>
<td>98</td>
<td>10.58 pm</td>
</tr>
<tr>
<td>20 March 2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alva Beach</td>
<td>80</td>
<td>5.31 am</td>
</tr>
<tr>
<td>Lucinda</td>
<td>109</td>
<td>5.32 am</td>
</tr>
<tr>
<td>South Johnstone</td>
<td>181</td>
<td>6.33 am</td>
</tr>
<tr>
<td>Green Island</td>
<td>109</td>
<td>7.04 am</td>
</tr>
<tr>
<td>Bellenden Ker Tower (elevation ~ 1450 m)</td>
<td>294</td>
<td>7.18 am</td>
</tr>
<tr>
<td>Cairns Airport</td>
<td>107</td>
<td>8.01 am</td>
</tr>
<tr>
<td>Mareeba</td>
<td>113</td>
<td>8.39 am</td>
</tr>
<tr>
<td>Ravenshoe Wind Farm</td>
<td>187</td>
<td>8.40 am</td>
</tr>
</tbody>
</table>

Floodwaters inundate the Leichhardt River crossing, Floraville station, Burketown. Photo courtesy of Burke Shire Council.
places breaking previous records for March. Rainfall associated with Larry resulted in flooding in the Mulgrave, Russell, Tully and Murray Rivers on the north tropical coast and in the gulf rivers. Road and rail access was disrupted for several days due to flooding and, at times, prevented road access to the Babinda-Innisfail area from both the north and south. Fortunately, the river rises in the Johnstone River at Innisfail remained below minor flood level.

Rapid river rises occurred in the Mulgrave and Russell Rivers on 20 March following heavy rainfall. The highest 3-hour rainfall total recorded was 139 mm in 3 hours to 9 am at The Boulders on Babinda Creek. Major flooding occurred in the Mulgrave River during the day with the river level at Gordonvale peaking at 15.2 metres, which was one metre over the Bruce Highway bridge.

The heaviest rainfall in the Tully River catchment was over 500 mm recorded at Eumamo, near Tully, in the 72 hours to 9am 22 March. River levels rose slowly in both the Tully and Murray Rivers and major flood levels overtopped the Bruce Highway from 21 to 24 March.

As Larry moved westwards into the Gulf Country very heavy rain was reported in the Flinders and Leichhardt River in the 24 hours to 9 am Wednesday 22 March, with the highest total of 435 mm recorded at Gereta Station. Peak flood levels reached in the Leichhardt River during the week were the highest in thirty to forty years.

Kamilaroi Station (near Cloncurry) recorded 581.4 mm of rain during March 2006,
compared to an average of 86 mm, setting a new record March rainfall total (the highest in 108 years of record).

**WAVE IMPACT**

Large significant wave heights were recorded well to the south of the cyclone, at locations where the Great Barrier Reef is much further offshore. The nearest wave recorders were at Cairns and Townsville. During the event, a maximum individual wave height of 6.8 metres was recorded at Mackay (the fifth largest recorded at this site since records began in 1977). Corresponding figures for Townsville and Cairns were 5.3 metres and 2.7 metres respectively.

*Queensland rainfall map for March 2006.*
Wave impact and storm surge data was provided by the Queensland Environmental Protection Agency (EPA), in the publication “Fact Sheet Tropical Cyclone Larry,” FS 2006-03 Updated 30/03/2006.
STORM SURGE

Potentially, the most dangerous and destructive phenomenon associated with land falling cyclones is the storm surge. Storm surge is a rise above the normal water level along a shoreline that is the result of strong onshore winds and reduced atmospheric pressure. Storm surges accompany a tropical cyclone as it comes ashore. They may also be formed by intense low-pressure systems in non-tropical areas.

The combination of storm surge, waves and normal (astronomical) tide is known as a ‘storm tide’. The worst impacts occur when the storm surge arrives on top of a high tide. A gently sloping seabed can enhance the ability of the sea to move ashore, as can large waves if they are present.

In the worst case scenario, the area of sea water inundation may extend along the coast for over 100 kilometres, with water pushing several kilometres inland if the land is low lying.

Severe tropical cyclone Larry caused a significant storm surge. The largest recorded surge was 2.30 metres at Clump Point. Cardwell and Mourilyan recorded storm surges of 1.76 metres and 1.34 metres respectively. Unfortunately no gauges were located at the site of the maximum onshore winds, so the highest storm surge associated with Larry was not sampled. However, the highest inundation recorded was a very substantial 4.9 metres above the expected tide at Bingil Bay, and 4.2 metres at Etty Bay. There was no evidence of significant waves in the main impact area, indicating that the majority of the inundation was produced by the storm surge.

The situation would have been far worse, had Larry crossed the coast on the highest tide of the day, and not at the time of a relatively low tide. The same event a week later, and coincident with spring tides, would have been even more devastating.

Clump Point storm surge data.
LARRY’S DEVASTATION

Severe tropical cyclone Larry was the first severe tropical cyclone to cross near a populated section of the east coast of Queensland since Rona in 1999, and the effects of the winds on buildings were devastating. Townships affected by the northern and southern portions of the eye wall of the cyclone received the most damage, particularly Babinda, Innisfail and Silkwood. However, all townships in the region were severely affected by the cyclone.

Electricity transmission to the areas in the region (as well as Cairns) was severely disrupted. Road and rail access to the region was also disrupted for several days due to flooding. In the northwest of the State, heavy rainfall from ex-tropical cyclone Larry caused several townships to be isolated for a number of days due to flooding. Food drops were required. Emergency supplies had to be delivered by helicopter.

General Peter Cosgrove, was appointed by the Queensland Government to oversee the recovery mission in the cyclone-affected communities. Nearly 12 months on, General Cosgrove still regularly visited Innisfail, assisting locals to rebuild the community and coordinate the relief effort.

Innisfail – “Just Lar-ried”: The spirit of north Queensland’s residents is put on display.

School’s out: Innisfail State High School battered by Larry.
Tropical cyclone Larry

Cowley Beach: Trees uprooted by Larry.

Infrastructure Damaged: Snapped power pole along Mourilyan Harbour road.

Tree damage at Ella Bay, totally levelled by winds from the WSW.

The South Johnstone AWS looking S-SSW. Note the stripped vegetation on the hill.

Banana crops broken and flattened. Photo of banana farm about 10 km north of Innisfail.

Damage to homes in Mourilyan.

Cowley Beach: Trees uprooted by Larry.
LEARNING FROM LARRY

In an effort to gain a better understanding of the structure of Larry, and the underlying science, the Bureau of Meteorology coordinated a comprehensive survey of damage. Within two days of Larry hitting the coast, the Bureau’s Queensland TCWC sent a meteorologist to survey the impact zone. This survey involved:

- Ground based damage and storm tide assessment (in association with Engineers from Geoscience Australia and the James Cook University Cyclone Testing Station, and specialists from the Environmental Protection Agency's Coastal Services Unit).
- Helicopter-based reconnaissance of the coast from Cairns to Bedarra Island, and inland to the Tablelands.
- Collation of meteorological data from other agencies (e.g. Ravenshoe Wind Farm, CSIRO site at Bellenden Ker).
- Pressure readings, anecdotes and details of structural damage were recorded.
- Interviews with members of the community who experienced the eye of the cyclone.

Several major issues associated with Larry are the subject of ongoing research, including: (1) the complex nature of Larry's eye and inner core structure at landfall; (2) the related variation in observed wind gusts both spatially and across elevated terrain as evidenced by variable damage patterns; and (3) the complexities of storm tide modelling and prediction. Bureau studies on Larry are continuing in close collaboration with a number of other organisations.

COMMUNITY FEEDBACK

The community response to warnings issued by the Bureau of Meteorology was also assessed. Following the passage of severe tropical cyclone Larry, a team of five researchers from the James Cook University Centre for Disaster Studies carried out a post disaster household survey. The survey was conducted on a face-to-face interview basis, across eight communities that were impacted. The researchers interviewed representatives from about 150 participating households, and indicated a strong pattern of good preparation and protective behaviour.

There was a strong positive response to questions about the Bureau advice and messages to the public. The team of interviewers recorded the terms used by respondents such as "spot on" and "reliable". There was a greater than 90 per cent approval of the usefulness, ease of understanding, and technical appropriateness of the Bureau’s warning information. Thirty percent of those surveyed indicated that they would have liked more frequent updates of the Tropical Cyclone Advice, particularly as Larry moved closer to the coast.
SEVERE TROPICAL CYCLONES IN THE EASTERN AUSTRALIAN REGION
1990 to 2006

This table lists cyclones that reached Category 3 or higher (Severe Tropical Cyclones) at some stage of their life. Cyclones that are coded RED or BLUE were classified as Category 3 or higher at the time of their coastal crossing. Of the remainder, some crossed the Queensland coast, but were not classified as severe at that time (e.g. Fran).

1990-91   JOY
1991-92   BETSY DAMAN ESAU FRAN
1992-93   POLLY
1993-94   REWA THEODORE
1994-95   VIOLET WARREN AGNES
1995-96   BARRY CELESTE
1996-97   DRENA JUSTIN
1997-98   KATRINA
1998-99   RONA
1999-00
2000-01   ABIGAIL
2001-02   CLAUDIA
2002-03
2003-04
2004-05   KERRY HARVEY INGRID
2005-06   JIM LARRY WATI MONICA

RED – Queensland east coast landfalls
BLUE – Gulf of Carpentaria landfalls
THE WARNING PROCESS

During a cyclone event in the Eastern Australian Region, the Brisbane Tropical Cyclone Warning Centre provides the following services.

A Tropical Cyclone Information Bulletin is issued when a cyclone exists in the Region but is not threatening coastal and island communities.

The general name given to cyclone Watch and Warning messages is a Tropical Cyclone Advice.

A Tropical Cyclone Advice containing a Cyclone Watch is issued at 6 hourly intervals as soon as gales associated with a tropical cyclone are expected to affect any coastal or island communities within the next 24 to 48 hours.

A Tropical Cyclone Advice containing a Cyclone Warning is issued at 3 hourly intervals as soon as gales associated with a tropical cyclone are expected to affect any coastal or island community within 24 hours. Whenever a tropical cyclone, with the potential to produce destructive winds or greater on the coast or islands, can have its position confirmed with a high degree of confidence (e.g. by weather radar), Cyclone Warnings are issued at hourly intervals.

A Tropical Cyclone Advice is prefixed "Flash" when it is the first warning to a community not previously alerted by a Cyclone Watch, or if there is a significant change from the previous Tropical Cyclone Advice.

A message to the media to activate the Standard Emergency Warning Signal (SEWS) is included any time a cyclone is expected to produce one or more of the following phenomena within the warning area in the next 12 hours:

- Wind gusts of 125 km/h or more (destructive winds)
- Intense rainfall leading to major flash flooding
- A storm tide at least 0.5 metres above highest astronomical tide (HAT).

To provide communities with a general idea of the expected worst conditions, an estimate of cyclone severity is included in all Tropical Cyclone Advices. Cyclone categories range from 1 for a relatively weak cyclone to 5 for the most severe. Category 3, 4 and 5 cyclones are classified as severe with hurricane force winds.

The Tropical Cyclone Forecast Track Map was introduced in the 2005-06 Tropical Cyclone Season on a trial basis. This graphical product provides the current position of the cyclone plus the forecast movement (with uncertainty indicated by a grey cone) 24 hours hence. The grey cone indicates the area within which the cyclone centre is expected to be in the 24 hours after the latest observed time.

The graphic also shows the extent of damaging winds, both current and forecast, and a graphical representation of the areas affected by current cyclone watch and cyclone warning.
The Tropical Cyclone Forecast Track Maps are issued at least 6-hourly whenever Tropical Cyclone Information Bulletins, Watches or Warnings are current.

A modified version of the Tropical Cyclone Forecast Track Map was introduced for the 2006-07 cyclone season, following the success of the trial. This gives forecast movement out to 48 hours.

<table>
<thead>
<tr>
<th>Category</th>
<th>Strongest Gust (km/h)</th>
<th>Typical Effects (Indicative only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Tropical cyclone)</td>
<td>Less than 125 (Gales)</td>
<td>Negligible house damage. Damage to some crops, trees and caravans. Craft may drag moorings.</td>
</tr>
<tr>
<td>2 (Tropical cyclone)</td>
<td>125-169 (Destructive winds)</td>
<td>Minor house damage. Significant damage to signs, trees and caravans. Heavy damage to some crops. Risk of power failure. All craft may break moorings.</td>
</tr>
<tr>
<td>3 (Severe tropical cyclone, e.g. Rona)</td>
<td>170-224 (Very destructive winds)</td>
<td>Some roof and structural damage. Some caravans destroyed. Power failure likely.</td>
</tr>
<tr>
<td>4 (Severe tropical cyclone, e.g. Larry)</td>
<td>225-279 (Very destructive winds)</td>
<td>Significant roofing loss and structural damage. Many caravans destroyed and blown away. Dangerous airborne debris. Widespread power failures.</td>
</tr>
<tr>
<td>5 (Severe tropical cyclone)</td>
<td>More than 280 (Very Destructive Winds)</td>
<td>Extremely dangerous with widespread destruction.</td>
</tr>
</tbody>
</table>
PUBLIC ACCESS TO TROPICAL CYCLONE INFORMATION

Tropical Cyclone Advices are broadcast at regular intervals by the local media (both radio and television) when a cyclone is threatening nearby coastal and island communities.

Information Bulletins, Advices and Tropical Cyclone Forecast Track Maps are available on the Bureau’s web page www.bom.gov.au.

At any time, the latest update on a current cyclone can be heard on a recorded telephone service, for the cost of a local call (more from international, satellite, Mobile or public phones).

Queensland Tropical Cyclone Warnings: 1300 659 212

This number is also listed in the White Pages, under Bureau of Meteorology, Tropical Cyclone Information.

If a cyclone is threatening your area, take appropriate action to protect yourself and the people around you. Some common sense guidelines include:

• Learn as much as you can about cyclones and the risk to your area;
• Be prepared and take precautions as recommended in cyclone brochures;
• Stay tuned for the latest information from the Bureau on a cyclone threat;
• Seek shelter if you find yourself in the path of a cyclone; and
• Carefully follow instructions if evacuation becomes necessary.
ACKNOWLEDGMENTS

Inside front cover image courtesy of Chris Velden, Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison. The Bureau of Meteorology also gratefully acknowledges: the Queensland Environmental Protection Agency for granting permission to reproduce wave height and storm surge data from its observational network and for supply of wave and tide plots; Director and staff from the Centre for Disaster Studies, James Cook University, for providing the Bureau with data from the community surveys; and Burke Shire Council for permission to include photos of flooding in northwest Queensland. Mr Peter Otto of the Queensland Severe Weather Section provided images of damage in and around Innisfail.
Research has shown that cyclones in the Australian region exhibit more erratic paths than cyclones in other parts of the world. A tropical cyclone can last for a few days or up to two or three weeks. Movement in any direction is possible including sharp turns and even loops.