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invertebrates. These habitats include sheltered lagoons with sandy floors, isolated patch reefs and coral lumps, reef crests with well-developed coral fauna exposed at low tide, spur and groove formations, shallow seagrass and algal beds in the lagoons or between reefs, and soft sand and live coral bottom areas in the deeper water between the reefs. The Great Barrier Reef Marine Park is the largest marine park in the world, covering 344,000 km², or 99% of the reef's area.⁷

CLIMATE AND WEATHER

Recording the weather

The Queensland Government appointed a meteorologist in 1866. A colonial weather service was established in 1887, headed by Clement Wragge. Highly influential in the development of weather services in the colony, Wragge held this position until 1903. He was succeeded by J. B. Henderson, a hydraulic engineer, who remained in the position until 1908 when the weather service became a federal responsibility and H. A. Hunt was appointed Commonwealth meteorologist.

The number of weather collection stations in Queensland grew rapidly in the 1880s and 1890s. In 1896 there were 504 stations throughout the colony. By 1901 there were 601 stations, and 803 by 1913.⁸ As Thornhill Weedon explained in 1897:

Queensland is intersected by a comprehensive system of climatic stations supplied with first-class instruments suited to the classification of each. The greater number of the observers are government officials—generally belonging to the Post and Telegraph Department—although some are private citizens. In most cases observations are taken thrice daily, and even more frequently (self-recording instruments being provided), and the results reported to the head office chiefly by wire.⁹

The *Commonwealth of Australia Constitution Act 1901* provided for the federal control of meteorological services. The *Meteorological Act 1906* (Cwlth) empowered the Commonwealth meteorologist to take and record meteorological observations; forecast the weather; issue storm warnings; display weather, flood, frost, and cold wave signals; and distribute weather information. The Act also empowered the Governor-General to enter into an arrangement with the Governor of any State in relation to matters such as the transfer to the Commonwealth of any observatory as well as instruments, books, registers, records and documents used in meteorological services, and the taking and recording of meteorological observations by State officers.¹⁰

In 1996 the Bureau of Meteorology had a network of about 6,000 weather recorders across Australia, including about 2,000 in Queensland. About a third provide data to the bureau daily. The bureau processes the data and produces weather reports for newspapers, television and radio.¹¹

Variations across the State

The climate in Queensland varies markedly, ranging from the hot arid south-west bordering on the Simpson Desert in central Australia to the warm wet tropical coastal belt and the more temperate southern inland agricultural areas where rainfall is moderate and occasional winter frost occurs.

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Table 2.3 Climatological summary by selected locations, Queensland, to 1996 (a)

Particulars	Brisbane	Toowoomba	Rockhampton	Cairns	Charleville	Mount Isa
Temperature						
Mean daily maximum (°C)	25.4	22.6	28.2	28.9	27.9	31.7
Mean daily minimum (°C)	15.7	11.4	16.5	20.7	13.5	17.5
Highest temperature (°C)	39.6	39.3	45.3	40.5	46.4	45.9
Highest in winter (°C)	29.6	29.5	33.3	30.1	33.5	36.1
Highest minimum (°C)	25.9	25.5	27.5	28.9	30.9	31.6
Highest minimum in winter (°C)	19.1	15.4	21.4	22.4	16.9	20.7
Lowest temperature (°C)	0.6	-4.4	-1.0	6.2	-5.2	-2.9
Lowest in summer (°C)	12.1	7.2	10.2	17.1	6.7	13.4
Lowest maximum (°C)	10.6	7.0	12.1	18.7	9.1	10.6
Lowest maximum in summer (°C)	20.2	15.7	21.7	23.9	19.3	23.0
Mean no. of days a year over 35°C	1.3	2.8	16.7	3.2	61.8	116.3
Mean no. of days a year over 30°C	36.6	28.2	130.4	138.9	153.3	224.4
Mean no. of days a year under 2.2°C	0.3	15.6	1.8	—	30.4	2.3
Mean no. of days a year under 0°C	—	4.6	0.1	—	12.0	0.5
Sunshine and cloud						
Mean daily sunshine (hours)	8.0	n.a.	n.a.	7.4	n.a.	9.6
Mean no. of clear days a year	109.8	103.9	106.9	72.2	164.9	178.9
Mean no. of cloudy days a year	90.8	95.2	70.4	110.3	65.5	53.3
Rainfall						
Mean annual rainfall (mm)	1,181.4	958.7	829.4	2,003.3	488.0	426.9
Highest monthly rainfall (mm)	803.6	735.6	660.2	1,417.4	307.2	479.4
Mean no. of days a year with rain	121.8	106.5	89.5	152.8	60.1	48.4
Highest no. of days in month with rain	30	25	25	27	19	29
Humidity (%)						
Mean 9 am relative humidity	65.6	71.5	69.5	72.9	51.3	43.0
Range of monthly averages at 9 am	59-71	65-79	62-74	66-78	37-71	29-59
Mean 3 pm relative humidity	53.4	52.0	46.7	61.1	29.3	25.9
Range of monthly averages at 3 pm	44-60	43-60	39-56	54-68	21-39	18-37
Wind						
Mean wind speed (km/h)	13.3	n.a.	12.0	16.3	11.6	11.3
Mean no. of days a year of strong wind	8.6	37.8	4.9	3.9	5.0	7.9
Mean no. of days a year of gales	0.4	0.7	0.3	0.1	0.2	0.4
Maximum wind gust (km/h)	185	n.a.	161	147	139	126
Other						
Mean no. of days a year with hail	1.0	1.9	0.5	—	0.7	0.1
Mean no. of days a year with frost	2.8	28.1	3.2	—	35.6	2.5
Mean no. of days a year with fog	7.9	59.3	30.2	0.3	3.3	0.3
Mean no. of days a year with thunder	23.7	30.1	22.9	16.4	33.0	33.7

(a) Current weather recording sites only, except Toowoomba. Post offices were often used as recording sites for major centres before airports became the sites. In this table, records for Brisbane are from 1949, Toowoomba from 1869, Rockhampton from 1939, Cairns from 1941, Charleville from 1942 and Mount Isa from 1966. Measurements of particulars such as mean daily sunshine and mean wind speed started more recently than particulars such as temperature and rainfall.

Source: Bureau of Meteorology, Queensland, Climatological Summaries.

Variations in Queensland's climate across the State are shown in table 2.3. Day temperatures are higher in the north and west, and night temperatures are lower inland at a particular latitude. Both extreme heat and cold are more common inland than near the coast. Rainfall is higher in coastal areas, although it can occasionally exceed 400 mm in a month inland. Humidity is

higher near the coast, but the range of monthly average readings is higher inland. While Cairns has higher average wind speed than other centres in table 2.3, Toowoomba has the highest number of days of strong wind. Hail and fog are most frequent in Toowoomba, frost in Charleville and thunder in Mount Isa.

Notwithstanding weather extremes the attractiveness of Queensland's climate, especially in the winter months, has been a strong promotional element for the tourism industry. Queensland is often known as the 'Sunshine State'. The State's climate has for many years been promoted as healthy and attractive. Weedon described the climate in 1897:

The climate of a country so extensive as Queensland varies, of necessity, according to locality, but on the whole may be described as a very healthy one. Although at each new settlement the miasmatic fevers common to all freshly opened up countries prevail for a time, especially in the north, giving trouble to those whose constitutions or whose callings cause them to be peculiarly liable to attack, yet as the country becomes more fully occupied, and drainage and clearing extend, the fever line is found to recede, and many places at one time deemed unhealthy are now found to possess a reputation for salubrity.¹²

Temperature

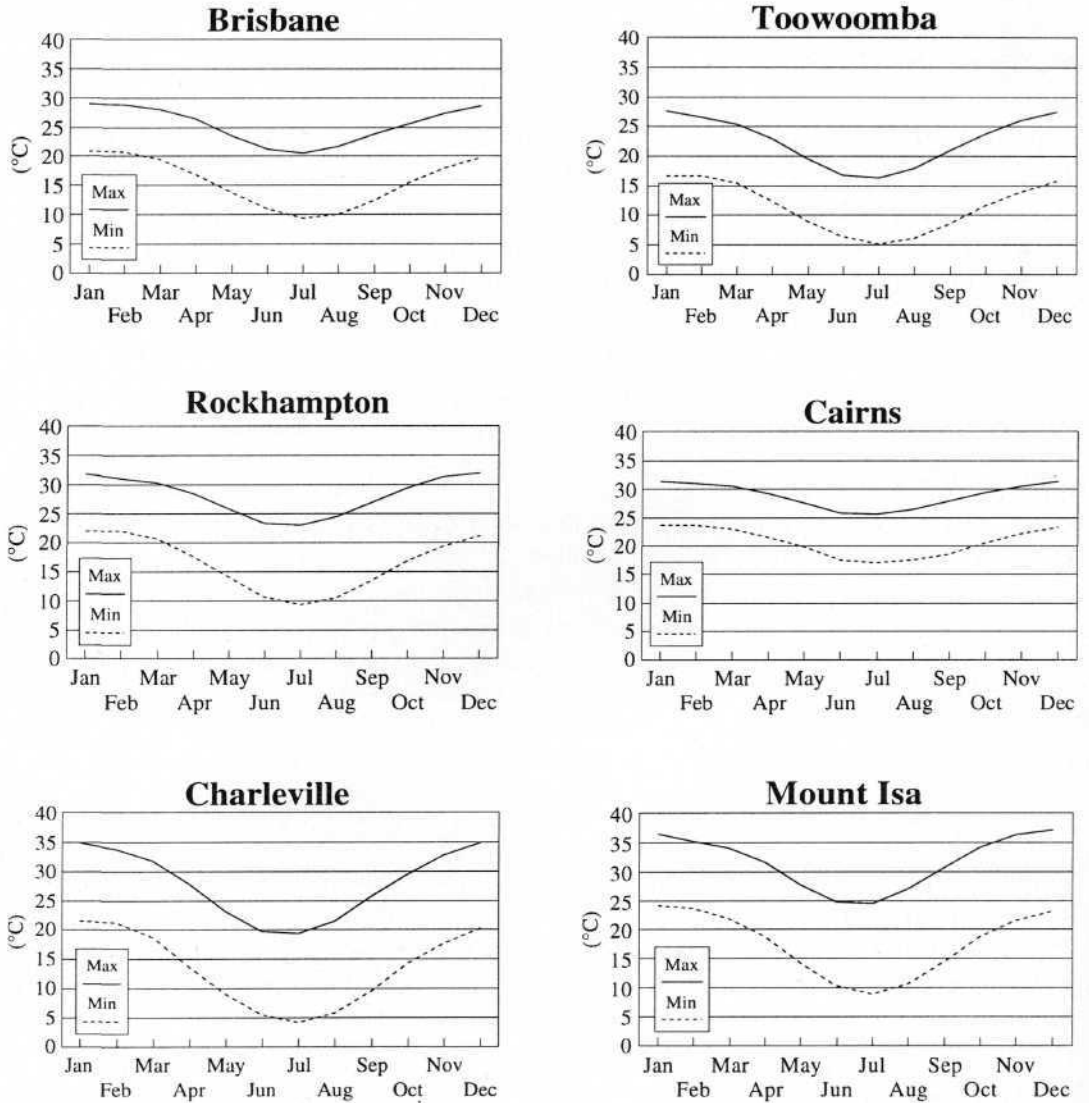
Queensland's climate is mainly subtropical and tropical, with day temperatures being warm to hot from November to April. Summers are long and spring and autumn short. Sea breezes can cool the coastal areas a little in the afternoon, although the tropical part of the coast (that is, from Rockhampton north) usually remains hot. In summer mean daily maximum temperatures range from high 20s in the south-east to low 30s along the central and northern coast and mid to high 30s in the far west where temperatures can exceed 37°C every day for weeks. Night temperatures in summer can be uncomfortable over a large area of the State due to high humidity. While in the south-east mean daily minimum temperatures in summer are around 18–22°C, in tropical areas the mean ranges from 22°C to 24°C and occasionally the night temperature does not fall below 26°C.¹³

In winter mean daily maximum temperatures range from mid teens on parts of the southern highlands to mid 20s along the northern coast. Few other settled areas of Australia experience such a mild winter. Only on the Darling Downs are mean daily maximum temperatures in winter under 18°C.¹⁴ Mean daily minimum temperatures in winter in southern coastal and northern inland areas are around 10°C, while coastal areas in the far north average about 17°C. The mean for southern and central inland areas is 4–8°C, and close to freezing point in some higher areas of the south-east. Sub-zero temperatures occur from time to time across southern and central Queensland away from the coast.¹⁵ Frosts are a regular feature in winter on the Darling Downs, and sometimes cause significant damage to crops.

Areas on or near the coast have a smaller daily and seasonal temperature range compared with those inland (figure 2.2). Brisbane has a January mean daily maximum temperature of 29.1°C and minimum of 20.9°C, a difference of 8.2°C. Charleville has a January mean daily maximum and minimum of 34.9°C and 21.6°C respectively, a difference of 13.3°C. In July in Brisbane the temperature ranges from a mean daily maximum of 20.6°C to a minimum of 9.4°C, while Charleville ranges from 19.4°C to 4.1°C. In Brisbane the mean daily maximum is highest in January, whereas December is the hottest month in most other centres in figure 2.2.

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Figure 2.2 Mean daily maximum and minimum temperatures by month, selected locations, Queensland, to 1996 (a)



(a) Current weather recording sites only, except Toowoomba. Post offices were often used as recording sites for major centres before airports became the sites. In this figure, records for Brisbane are from 1949, Toowoomba from 1869, Rockhampton from 1939, Cairns from 1941, Charleville from 1942 and Mount Isa from 1966.

Source: Bureau of Meteorology, Queensland, Climatological Summaries.

Details of major heatwaves in Queensland from 1896 to 1996 are shown in table 2.4. Many centres have experienced instances of extreme heat which may last for days or even weeks at a time. Some of these periods of high temperatures may coincide with periods of drought. Other higher than normal temperatures may occur after generally mild winters.

The record high temperature for Queensland was 49.5°C at Birdsville on 24 December 1972.

This compares with the Australian record of 50.7°C at Oodnadatta, South Australia, on 2 January 1960 and a world record of 58.0°C at Al'Aziziyah in Libya, Africa, in September 1922.¹⁶

Sunshine and cloud

Queensland and Western Australia have the highest mean daily sunshine in Australia. More than 99% of Queensland has a mean of more than eight hours of sunshine a day. While the south-west such as Birdsville, Boulia and Windorah has a mean of more than ten hours of sunshine a day, the Innisfail–Cairns–Atherton Tableland region has a daily mean of less than eight hours. The State's highest mean daily sunshine occurs in October due to clear skies and lengthening days.

July is the month of least sunshine, due to short days rather than cloud cover. The area of least sunshine in July is the Innisfail–Cairns–Atherton Tableland region with a mean of slightly less than seven hours a day. Camooweal, however, in the State's north-west enjoys a mean of more than ten hours of sunshine a day in July. Brisbane has a winter (that is, June to August) mean of 7.7 hours of sunshine a day. Compared with the other capital cities, only Darwin with a daily mean of 10.0 hours of sunshine has more than Brisbane in winter, while Sydney has 6.2 hours, Canberra 5.7 hours, Perth 5.6 hours, Adelaide 5.1 hours, Melbourne 4.6 hours and Hobart 4.4 hours.

Cloudiness over Brisbane is lowest from July to September when on average just over 30% of the sky is covered. Cloud cover is greatest in the warm, wet season when the average is over 60%. Although cloud cover varies considerably throughout the year, there is almost always greater cover in the afternoon than during the night.¹⁷

Snowfalls

The Granite Belt around Stanthorpe is the coldest area of Queensland. Stanthorpe had the State's lowest recorded temperature of -11.0°C on 4 July 1895.¹⁸ Snowfalls have been recorded on the Granite Belt and the Darling Downs on a number of occasions. In 1896 heavy snowfalls were recorded at Dalveen, Stanthorpe and Toowoomba. In July 1901 snow fell in Warwick, Toowoomba, Charleville, Longreach and Winton. In late August 1929 snowfall in Stanthorpe was regarded as one of the heaviest ever received. The Granite Belt received slight to moderate drifting snow in early June 1949 which was the heaviest in 20 years.

In July 1959 snow and sleet were reported from as far north as Biggenden (west of Maryborough), to Dalby, Crows Nest, Warwick and the Granite Belt, while the McPherson Range on the New South Wales border was snow-capped. In mid July 1965 light snow was reported over a wide area extending from the Clarke Range (west of Mackay), central highlands and northern Warrego to Maranoa and Darling Downs. In the first week of July 1984 snow and sleet fell on the Bunya Mountains, Toowoomba, the Granite Belt and Springbrook–Lamington Plateau.

Rainfall

Queensland's mean annual rainfall varies from 150 mm in the far south-west near Birdsville to more than 4,000 mm in certain localities between Cardwell and Cairns. Australia's highest mean annual rainfall is 4,446 mm at Happy Valley near Babinda.¹⁹ The wettest areas of the tropical

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Table 2.4 Major heatwaves, Queensland, 1896–1996

Date	Location	Comments
Dec 1901	Rockhampton	Great heat: 42.6°C.
Feb 1902	Central Queensland	Temperature of 41°C recorded at Hughenden, 43°C at Maryborough, 41°C at Boulia.
Nov 1908	South-western Queensland	Extreme heat with Thargomindah recording 44°C.
Jan 1909	South-western Queensland	Intense heatwave affected the whole of the interior with Thargomindah registering 48°C.
Jan 1912	Queensland	Great heat experienced through most of the month owing to the continuous influence of the monsoon. Temperatures over 43°C at Urandangie, Boulia, Windorah, Thargomindah, Cunnamulla, Cloncurry, Camooweal, Richmond, Winton and Longreach. Charleville reported longest spell of continuous heat: over 38°C for 17 days.
Jan 1913	Queensland	A heatwave affected most of the state, with a maximum of 46°C at Urandangie on 26 January.
Nov 1913	Southern Queensland	Heatwave over southern Queensland. Maximum temperature at Brisbane on 18 November was 41.2°C.
Nov 1913	North-western Queensland	Extreme heat: Urandangie 47°C and Camooweal 44°C.
Dec 1913	North-western Queensland	Great heat and exceedingly dry. At Urandangie maximum exceeded 42°C from 1 to 14 December, including 47°C on 7 December.
Jan 1940	Southern and central Queensland	Many maximums exceeded 46°C, including Winton 47.2°C, Longreach 47.2°C, Eulo 46.7°C and Roma 46.7°C. Brisbane had nine consecutive days of extreme heat, with maximum of 43.2°C, its highest ever temperature.
Feb 1956	Cairns; Townsville	Heatwave conditions from 18 to 24 February.
Nov 1962	Croydon	Ten days of heatwave from 9 to 19 November.
Dec 1972	Central and southern inland Queensland	Longreach, Mitchell, Mount Isa and Emerald experienced seven consecutive days of heatwave, commencing on 21 December. Birdsville had 49.5°C on 24 December.
Jan 1979	South-western Queensland	Heatwave from 9 to 17 January. Thargomindah had eight consecutive days with maximum over 41.5°C.
Dec 1981– Jan 1982	Longreach; Mount Isa	Nine consecutive days of extreme heat.
Oct 1987	Far northern Queensland	Heatwave on Atherton Tableland and Cape York Peninsula. Herberton experienced highest maximum October temperature for 80 years.
Dec 1990	Mount Isa	Eleven consecutive days with temperatures in excess of 41.0°C.
Dec 1993– Jan 1994	Eastern Queensland	Many centres experienced more than a week of heatwave, including Toowoomba, Emerald, Townsville, Gayndah, Kingaroy and Georgetown.

Source: Bureau of Meteorology, Queensland, unpublished data.

northern coast often record annual rainfall of more than 5,000 mm, with a Queensland and Australian record of 11,251 mm at Bellenden Ker (top station) in 1979. This station also has the Australian record for the highest rainfall in a month with 5,387 mm in January 1979. Australia's highest rainfall in a day is 907 mm at Crohamhurst near Beerwah on 3 February 1893. The Queensland record for the highest number of rain days in a year is 313 at Borgu in 1942.²⁰

The driest parts in south-western Queensland record annual falls of less than 50 mm in one in about five years. A dry inland means that the State's agricultural belt is restricted mainly to coastal areas except in the south where the Darling Downs receives mean annual rainfall in excess of 600 mm. The pastoral country to the west of the Darling Downs receives an average of 400–600 mm a year, and the Gulf Country in the north-west of the State 600–1,000 mm.

Northern Queensland usually experiences reliable summer rains with little significant rainfall in the winter months. The highest proportion of rain falling in the warmer months (that is, November to April) occurs in the north and west of the State, reaching a maximum in the Gulf of Carpentaria which receives about 95% of its average annual total in these six months and only 25–40 mm in the cooler months (that is, May to October). South of the Tropic of Capricorn summer rains are less reliable except for the southern coastal fringes which usually have good summer rain. Winter rain is quite reliable in southern Queensland. Rain in the cooler months averages about 30% of the annual total, and about 40% along the border with New South Wales.²¹

Rainfall is concentrated in the warmer months for all six centres in figure 2.3. Toowoomba's rainfall is spread more evenly through the year compared with the other centres. Brisbane's mean monthly rainfall is highest in December–March, and lowest in August–September. Mean monthly rainfall in Cairns exceeds 400 mm in January–March, but declines to below 50 mm in June–October. In Mount Isa the mean monthly rainfall is below 10 mm in June–September.

Rainfall can vary greatly from monthly averages. In Brisbane in June, for example, the highest and lowest recordings are 701.1 mm and 1.1 mm respectively while the mean is 69.7 mm. Similarly, rainfall can vary markedly from year to year, increasing in variability the further from the coast. Tropical cyclones are partly responsible for the high variability in rainfall in much of the State. In Brisbane, for example, in about half the years for which data is available, the annual rainfall differs from the mean by more than 20%, and in one in about 10 years by more than 50%.²² The driest period on record in Queensland was between 1898 and 1903 when there was little rain over most of the State and when widespread drought caused considerable damage. There have also been numerous wet years with repeated flooding and where annual rainfall totals were more than twice the mean. Flooding has occurred somewhere in the State in most years since records have been kept.

Compared with averages, rainfall in Queensland can vary significantly across the State in certain years. In 1977 Innisfail, for example, received over 7,000 mm of rain which resulted in severe flooding, while Brisbane received only 660 mm, one of the lowest figures on record.²³

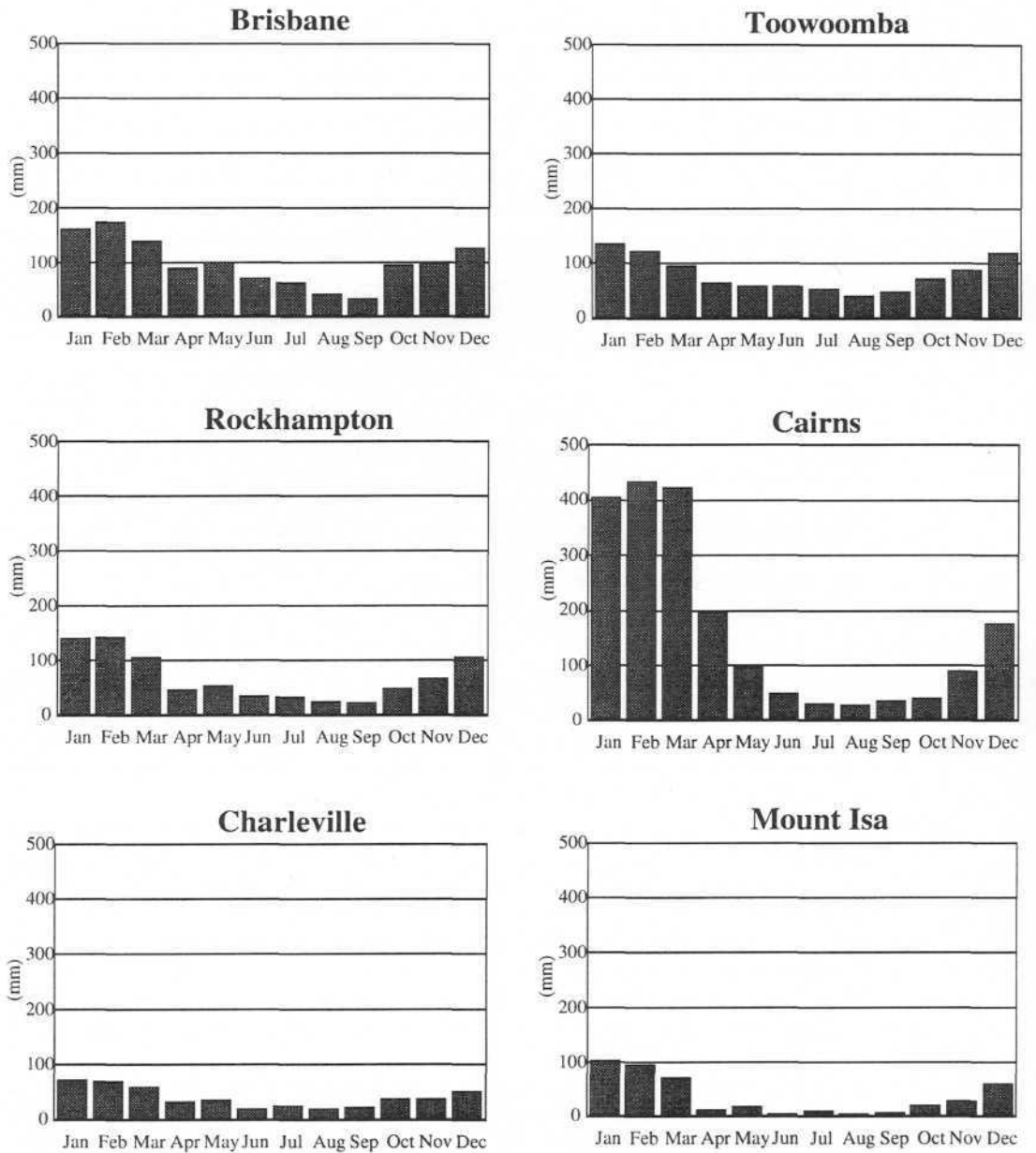
Droughts

Drought has been an ever-present threat to agricultural production since the earliest days of European settlement in Queensland. The most significant drought in Australia's history in terms of both severity and the area affected was from 1898 to 1903 (table 2.5). This drought covered practically the whole of Australia at various times. Other periods of severe drought in Queensland were 1925–26, 1927–36, 1951–54, 1964–66, 1969–70, 1979–83 and 1990–96. A severe drought is defined as one in which ten or more rainfall districts are substantially affected by rainfall deficiencies for eight or more months.²⁴

Drought occurrence is dependent on land use as well as rainfall. The extent of droughts and their frequency have been studied for the planning of agricultural, pastoral, industrial and

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Figure 2.3 Mean monthly rainfall, selected locations, Queensland, to 1996 (a)



(a) Current weather recording sites only, except Toowoomba. Post offices were often used as recording sites for major centres before airports became the sites. In this figure, records for Brisbane are from 1949, Toowoomba from 1869, Rockhampton from 1939, Cairns from 1941, Charleville from 1942 and Mount Isa from 1966.

Source: Bureau of Meteorology, Queensland, Climatological Summaries.

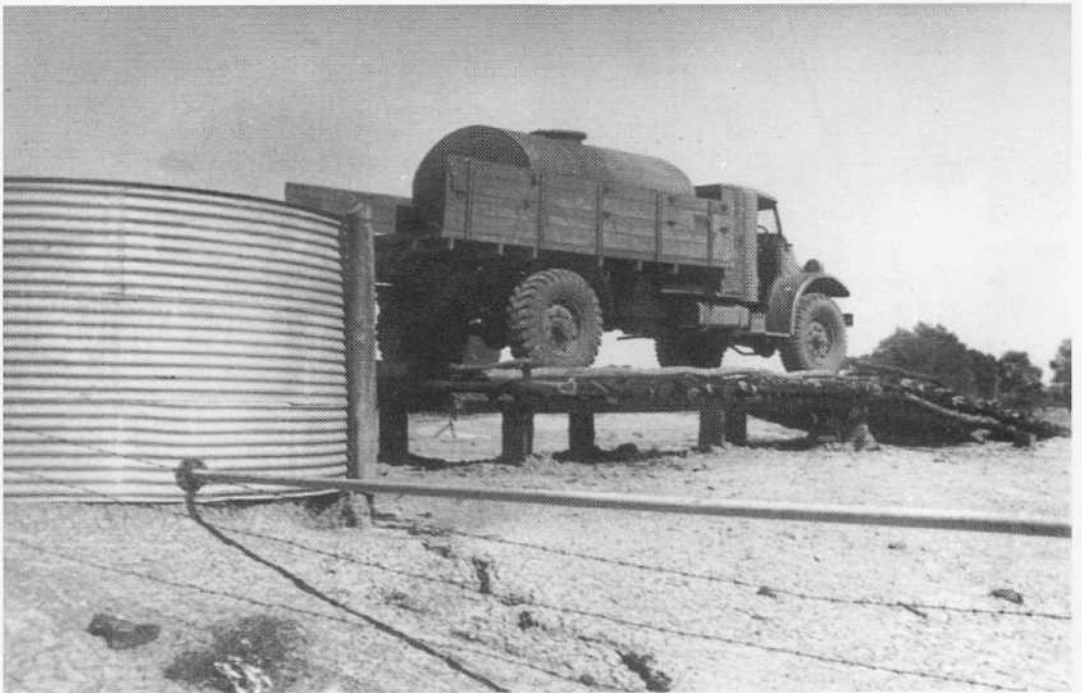
Table 2.5 Major droughts, Queensland, 1896–1996

Years	Comments
1898–1903	This five-year drought was one of the most severe ever experienced. It affected practically the whole of Australia but most persistently the coast of Queensland and inland areas of New South Wales and South Australia and extended to central Australia. The drought consisted of a series of very dry years with only some areas receiving good rains. In 1901–02 dry conditions throughout Queensland resulted in a severe drought that had a devastating effect on stock, crops, and pastures which had survived the dry conditions of previous years. Sheep numbers were reduced by about half, and cattle numbers by more than 40%. Average wheat yields per hectare were reduced to a quarter of their usual levels and sugar production was significantly reduced.
1925–1926	One of the harshest droughts in Queensland occurred in 1925–1926. In some areas this drought was more severe than that of 1898–1903. It began with the failure of the 1925–26 summer rains. Most of Queensland had heavy stock and crop losses. Some temporary relief rains fell in September 1926, but drought conditions quickly returned until substantial rain fell in December 1926.
1927–1936	This was a period of almost continuous rain deficiency in the central and southern interior with short breaks occurring in 1930, 1931, 1932 and 1933. In south-western Queensland severe drought conditions prevailed from 1927 to 1930. In July 1927 press reports stated that large areas in central and south-western Queensland were still in the grip of drought. In 1932 a dry cold winter followed poor summer rains, bringing hardship to the agricultural and dairying industries. Good spring rains in some districts restored conditions. By the end of 1933 inland Queensland was very dry. Three very dry months ended 1934, and 1935 opened with drought conditions. Devastating losses continued. In south-eastern Queensland drought continued through 1936, resulting in the failure of the wheat crop.
1951–1954	After record heavy rains over most of the state in 1950, a severe dry spell set in from February 1951. Low rainfall, grass fires and bushfires over an area of about 6 million ha and cold winters caused one of the worst droughts in Queensland. Heavy losses occurred in the pastoral and dairying industries, with some of the worst affected parts being the southern coast to Port Curtis and the tropical interior. Crop and dairy production were the lowest since 1926. These conditions continued until April 1952. Another short period of dry weather followed in some areas in 1953. By January 1954 the drought extended from the Gulf of Carpentaria to the Darling Downs and west to the border with South Australia.
1964–1966	Drought conditions prevailed mainly in the south-west and south of Queensland from late 1964 to late 1965. In 1965 areas around the central coast, central highlands, and the Curtis districts were also affected. Good rains in December 1965 and January 1966 brought some relief, but dry conditions persisted in the far south-west and certain coastal areas as late as August 1966.
1969–1970	Drought was widespread throughout Queensland, and was harshest in the western border districts and on the central coast.
1979–1983	This extensive drought affected nearly all of eastern Australia. Drought had been severe through the south-west of Queensland from 1979 and some areas of Queensland recorded their record lowest rainfall.
1990–1996	The drought that gripped most of Queensland in 1991 was quite severe. The initial onset of dry conditions commenced in mid 1990, and the partial failure of the 1990–91 summer rains in the south of the state resulted in serious deficiencies in a number of areas. From March 1991 rain declined across the state, and by November 1991 the area from Bundaberg to the New South Wales border and west to Charleville was in the grip of drought. Although the tropical areas had received above average rainfall during the summer of 1990–91, by October 1991 this area had suffered eight consecutive months of below average rainfall. The first area to receive drought relief was the Proserpine–Sarina district. This drought continued to affect many areas of Queensland into 1996.

Source: Foley, *Droughts in Australia: Review of Records from Earliest Years of Settlement to 1955*; ABS, *Queensland Year Book*, 1991, p. 19; ABS, *Queensland Year Book*, 1986, pp. 38–40; ABS, *Year Book, Australia*, various years.



Period of drought, Whetstone station, Inglewood district, c. 1910.



Carting water during a drought, Strathalleyn station, Tara district, 1946.

economic activities. These studies have provided an assessment of drought risk and have assisted the planning of short-term action such as the declaration of drought occurrence and the choice of areas to which stock can be moved.

The physical causes of drought have their origins in the fluctuations of the global climatic system. Variability in time and space is an inherent characteristic of global climate and therefore droughts are of varying extent and severity. An improved understanding of how various parts of the climatic system fit together and interact with one another has extended to causes of large-scale droughts. An important cause of drought is the so-called El Niño effect.

Southern Oscillation and the El Niño effect

The climate of eastern and northern Australia is influenced by the Southern Oscillation. This is a major air pressure shift between Asia and the eastern Pacific region. The Southern Oscillation has also been described as a see-sawing of atmospheric pressure between the South Pacific and Indian oceans. When the atmospheric pressure is abnormally high over the Indian Ocean it is usually abnormally low over the South Pacific and vice versa. For Queensland the Southern Oscillation is the second most important cause of climatic variation after the annual seasonal cycle. The Southern Oscillation Index measures the difference in sea level atmospheric pressure between Tahiti and Darwin. When the index is positive the trade winds blow strongly westward across the Pacific, feeding moisture into and converging with the monsoons of Asia and Australia. When the index is negative, the trade winds are weak or even reversed, depriving the monsoons of their energy source.

When the westerly trade winds weaken a mass of warm water forms off north-eastern Australia and is pushed eastward to South America. This mound of water can be 20 cm high and cover an area larger than Australia. The warmth of this water compared with surrounding water means it can be detected by radar from satellites. The phenomenon is known as the El Niño effect which can bring heavy rain to South America but cause a delay in the arrival of the north-western monsoon and a late start to the wet season in Australia. Rainfall is below average and tropical cyclones are fewer, and eventually widespread drought occurs over eastern and northern Australia. These conditions usually commence early in the year, last for about 12 months, and recur at intervals of 2–7 years. The opposite effect is called La Niña.

El Niño and the Southern Oscillation are components of a broader set of interrelated processes in the atmosphere and ocean, which have their origins in the tropics, but which can result in unusual weather and climatic conditions over much larger areas. The drought of 1990–91, for example, is linked to an El Niño that affected the whole Pacific region. Previous droughts over eastern Australia such as those of 1969–70 and 1979–83 were also associated with El Niño.

Floods

Flooding occurs frequently in Queensland. Since the early days of settlement, floods have brought loss of life and considerable damage to property. Towns such as Adavale and parts of Clermont have been relocated to minimise damage caused by floods. In 1841 severe floods affected Brisbane and Ipswich, and in 1890 and 1893 extensive flooding occurred throughout Queensland. More recently, there was serious flooding throughout the State in 1974 and 1996. Details of major floods in Queensland from 1896 to 1996 are shown in table 2.6.

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Table 2.6 Major floods, Queensland, 1896–1996

Date	Comments
Mar 1903	Heavy flooding in Camooweal and Urandangie.
Jan 1908	Floods throughout the Burketown district. The Leichhardt River between Floraville and Donaldson in high flood. Serious flooding in southern Queensland. Brisbane River at the Port Office rose to 4.5 m.
Dec 1916	Highest floods on record in Theresa Creek, and the Comet, Nogoia and Mackenzie rivers. The headwaters of Theresa Creek submerged the lower part of Clermont with great damage. Sixty-one persons drowned. Great damage at Sapphiretown.
Jan 1917	Unprecedented flooding of the Flinders River. Great damage to property. Considerable stock losses.
Mar 1917	Highest floods at Charleville and Adavale since 1897.
Jan 1918	Streets of Emerald submerged. Flooding between Emerald and Clermont and between Emerald and Longreach. Most severe flooding at Mackay associated with a devastating cyclone; great damage to property; 20 lives lost. Unprecedented flooding in the Burdekin and Fitzroy rivers; severe flooding at Rockhampton.
Feb 1922	Floods in all rivers draining from central Queensland towards Lake Eyre and the Darling River. Parts of Rockhampton inundated. Longreach and Winton streets submerged.
Feb 1925	Heavy flooding in the Burdekin, Herbert, Johnston, Proserpine and Tully rivers. Bridge over the Burdekin at Inkerman collapsed. Flooding in the Innisfail district disrupted the cane-cutting season.
Jan 1927	Stanley and upper Brisbane rivers flooded; many metropolitan districts submerged. Low lying parts of Ipswich submerged. Gympie district seriously affected and low lying parts of Maryborough submerged. Drownings at Townsville, Mackay and Maryborough. Part of Surat under water. Flooding at Tully, Cardwell and Charters Towers; Halifax, Ingham, Innisfail and Tully partly submerged. Thirty-nine persons drowned. Many houses washed away with considerable property loss.
Jan 1936	Major flood in the Burke River. Homes at Boulia partly submerged. Heavy stock losses.
Mar 1936	Severe flooding at Longreach, Barcaldine, Blackall, Normanton, Burketown, Cunnamulla, Quilpie and Thargomindah. Water covered main streets of Longreach and Barcaldine and houses submerged.
Feb 1939	Low lying parts of Innisfail submerged. Drownings at Cairns and South Johnstone.
Mar 1939	General flooding between Bundaberg and Coolangatta. Extensive flooding of low lying suburbs of Brisbane. Lower parts of Gympie and Maryborough submerged. Streets of Southport submerged.
Apr 1940	Heavy flooding between Townsville and St Lawrence, especially Ayr–Home Hill area where several lives were lost.
Mar 1955	Serious flooding in the Mary River caused damage to property, stock and crops. Some streets in Gympie were under 3 m of water. Flooding in parts of Brisbane.
Jan 1974	Severe flooding in south-eastern Queensland brought about by cyclone <i>Wanda</i> . Much of Brisbane, Ipswich and south-east inundated, with very considerable damage to property. Gympie and Maryborough flooded.
May 1983	Extensive flooding throughout south-eastern Queensland. Damage to property at Ipswich, Sunshine Coast to Gympie, Toowoomba to Dalby and in western Queensland.
Mar–Apr 1988	Flooding in central Queensland from cyclone <i>Charles</i> . Floods in south-eastern Queensland caused an estimated \$60m damage to areas from Brisbane, through Fassifern and Brisbane valleys to Warwick.
Apr 1989	Flooding from cyclone <i>Aivu</i> extensive in south-eastern Queensland, including Gympie, Sunshine Coast and Gold Coast, and in the Channel Country.
Apr 1990	Widespread flooding in central and south-western Queensland especially at Alpha, Augathalla, Blackall and Jericho. Severe and extensive flooding at Charleville.
Jan 1991	Severe flooding in northern and central Queensland as a result of cyclone <i>Joy</i> . Flooding occurred at Richmond, Julia Creek and Normanton, and throughout western Queensland.
Mar 1996	Flooding in far northern Queensland, especially of the Daintree River.

Source: Bureau of Meteorology, Queensland, in GSO/ABS, *Queensland Year Book*, various years.

Flooding may be confined to a locality or it may be widespread. There was extensive flooding throughout Queensland in 1908, for example, encompassing rivers from Cooktown to Birdsville. One of the wettest years on record in Queensland was 1950, with flooding occurring every month, most markedly in the central and western parts of the State where many new records were set. Some western towns were flooded badly in April 1990 with rivers exceeding their previous record levels by more than a metre. Record flooding occurred in the Barcoo, Alice, Warrego and Maranoa rivers and Alpha Creek, while major flooding occurred in the Thomson River, Cooper Creek and the Bulloo, Paroo and Balonne rivers. The Belyando, Nogoa, Comet and Dawson rivers also experienced flooding at this time. Charleville and Alpha were devastated while centres such as Augathella, Jericho and Blackall were seriously flooded.

Serious flooding mainly occurs between November and April, a period that coincides with the cyclone season. South-east Queensland has had major floods in most months, with only August and September always being flood free. In summer, flooding of the interior rivers can last for more than a month at a time as the flood wave moves downstream. Frequently in the western rivers there are several flood peaks in a river basin as a result of the same rain period, and peaks can sometimes be two or more weeks apart. The effect of these floods, combined with the large network of unsealed roads and flat terrain in western Queensland, is to bring land transport to a standstill, isolating towns and homesteads for long periods. By contrast, floodwaters in coastal regions usually rise and fall within quite short periods.

The Bureau of Meteorology maintains a flood warning service, issuing warnings for all rivers in Queensland and flood forecasts for certain river basins in the highly populated areas of the State. The warnings aim to reduce flood damage and loss of life, allowing time to evacuate people and remove livestock and equipment. General flood warnings are applicable to river basins in which rural and urban communities could be affected by over-bank flows that cause economic loss.

The warnings usually include a summary of the rainfall over the catchment area, key river heights, the location of the flood crest and the expected severity of flooding in terms of minor, moderate or major flooding. Minor flooding causes inconvenience such as closure of minor roads and submergence of low level bridges. Major flooding is where large areas are inundated, isolating towns and cities, and may include evacuation of many houses and business premises. Specific flood warnings provide a forecast height in a key river gauge, the time of the flood peak and the time of critical occurrences such as over-bank flow, bridge inundation, and the commencement of flooding in urban streets. These forecasts are disseminated to the public up to 48 hours in advance.

Flood mitigation has reduced the extent of flooding in many populated areas, resulting in less damage and fewer drownings.

Tornadoes and cyclones

In 1914 the Bureau of Meteorology began to distinguish different sorts of destructive windstorms. These storms included squall winds that normally occur in violent thunderstorms, tornadoes, hurricanes and related tropical cyclonic storms. In addition, there are innumerable dust whirlwinds that rarely cause serious damage.

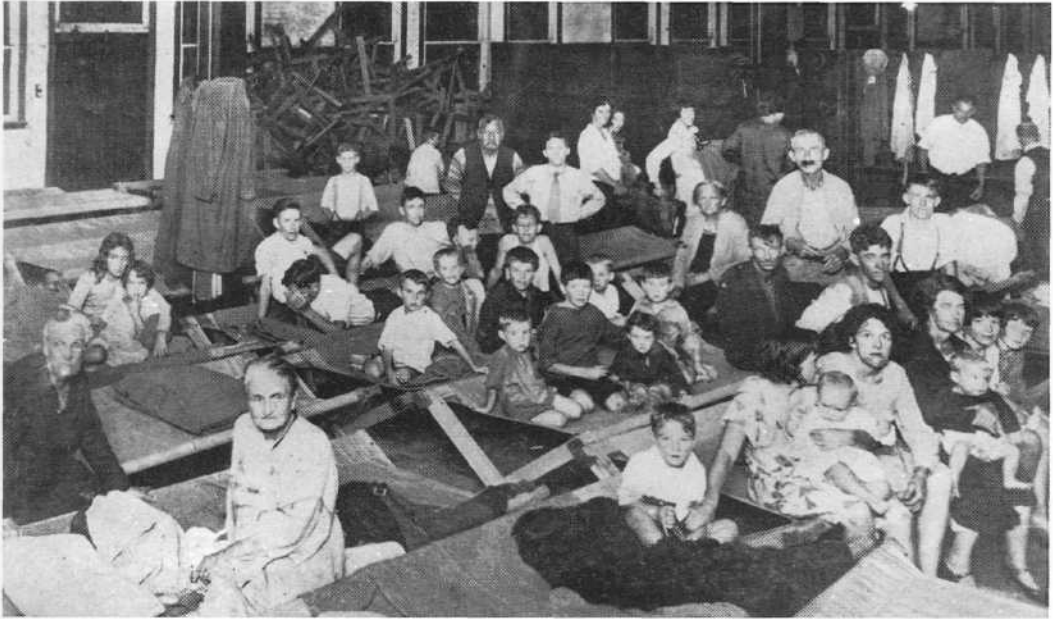
Tornadoes are fairly frequent in Queensland, although most of them cause little or no damage. A few tornadoes can be very damaging, despite their narrow path and destructive forces that



Flooding, East Street, Rockhampton, 1918.



Flooding, Wills Street, Charleville, 1934.



Refugees from flooded areas in the accommodation provided at the Exhibition Grounds.
Brisbane floods, 1931.



Flooding outside the Empire Hotel, Plume Street, South Townsville, 1946.

are usually limited to a few minutes. Tornadoes mostly occur in summer and frequently accompany tropical disturbances or low pressure systems. One such tornado struck Brisbane during November 1973.

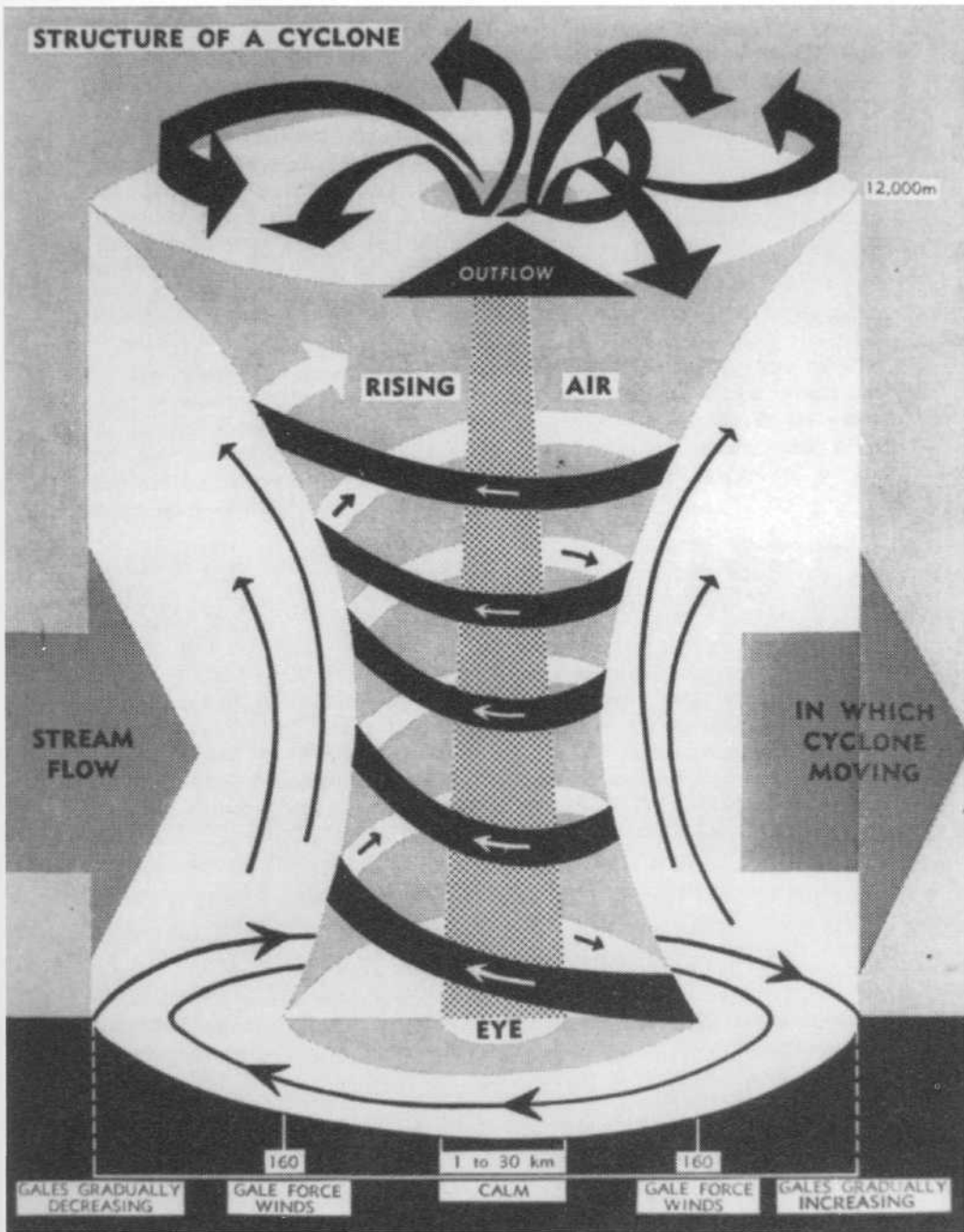
Tropical cyclones or hurricanes, unlike tornadoes, affect a much greater area. Cyclones have a diameter of 80–1,000 km. They often produce gales throughout a belt 300 km wide and travel for hundreds and sometimes thousands of kilometres, usually at less than 10 km/h. Because of the large area affected, cyclones are usually far more destructive than tornadoes. Cyclones take several hours and sometimes, in the case of slow-moving storms, days to pass. The life cycle of tropical cyclones varies from a few hours to 2–3 weeks. The path taken by a tropical cyclone is the result of large-scale interaction with the environment and can range from a smooth regular course to a complex zig-zagging one. Some cyclones move inland where they lose intensity but still produce widespread heavy rain. The frequency of cyclones can vary greatly.

Cyclones are intense low pressure systems that develop in many tropical areas of the world and are also known as hurricanes and typhoons. The structure of a cyclone is shown in figure 2.4. Cyclones are circular systems with gale force wind of 65 km/h or stronger, whirling clockwise in the southern hemisphere (anticlockwise in the northern hemisphere) around a centre of very low pressure called an eye. The force of the wind depends on the intensity of the low pressure system. The eye is an area of calm or light wind with only a small amount of overhead cloud. Cyclones develop over the sea within about 15° of the equator from November to April, when abundant moisture is available from the evaporation of warm water. The movement of warm air around a low pressure system can give rise to a rapid ascent of air around the centre. A deep cumulo-nimbus cloud structure with heights of up to 12 km can develop and result in heavy rain.

The cyclones that affect Queensland develop over the waters to the continent's east (Coral Sea, Solomon Sea and South Pacific Ocean) and to the north (Gulf of Carpentaria and Arafura Sea). Many cyclones approach the eastern coast of northern Queensland. They often recurve near the coast and pass southward, frequently as far as Brisbane, and then move off the coast to the east and the south-east. Other cyclones recurve some distance east of the coast, near the Great Barrier Reef, and pass south and then east without causing much damage. Still others, especially those that strike the northern part of Cape York, pass inland. These cyclones can recurve in the State's interior and pass back out to sea. Some cyclones cross the continent to Western Australia, while others cross the land from the west to Queensland and regenerate when they reach the Pacific Ocean. While most cyclones lose force shortly after crossing land and become rain depressions, some strengthen considerably if they reach the coast again.

The Bureau of Meteorology in Brisbane monitors cyclonic developments and the progress of cyclones along the Queensland and northern New South Wales coasts. The bureau provides a weather warning service to communities likely to be affected by any approaching cyclone. Before sophisticated technology was introduced, tropical cyclones were detected and tracked solely through the use of weather charts based on wind and pressure observations from a network of surface stations throughout the State. While these charts still provide basic reference points, upper atmospheric conditions are now analysed too. Most cyclones are initially detected by satellites that provide hourly coverage of cloud patterns. Upper level measurements of wind, air pressure, temperature and humidity are obtained by radar tracking of hydrogen filled balloons with attached radio transmitters and sensing equipment.

Figure 2.4 Structure of a cyclone



Source: Bureau of Meteorology, Queensland, in ABS, *Queensland Year Book 1975*, Cat. No. 1301.3, p. 56.

Weather systems were first named in 1894 when Clement Wragge gave the name *Zeta* to a tropical cyclone. Wragge's system was used for some years, but was discontinued. In the mid 1950s the news media often selected names for cyclones. This practice was formalised in the 1964–65 cyclone season when, by international agreement, female names were selected. From



Flooding, Albert Street, Brisbane, 1974.



St James Rectory, Townsville, after cyclone *Leonta*, 1903. Back view showing the remains of the kitchen and outbuilding.

1975 the prepared list was extended to include male names. Male and female names are now used alternately. Cyclones are named by the region in which they form. Cyclone *Aivu*, for example, was named by Papua New Guinea as it began in that region.

Some sections of the Queensland coast are more prone to cyclones than other sections. The number of cyclones along each section of the coast from the Northern Territory border to the New South Wales border from 1909 to 1989 is shown in table 2.7. Over the 81-year period, the Queensland coast had 162 cyclones at an average of two a year. The occurrence of cyclones is greatest between Cooktown and Cairns with 10 cyclones per 100 km over this period.

The severity of cyclones is measured on a scale from category 1 to category 5. Category 1 describes weak cyclones with air pressure above 985 hectopascals and category 5 describes the most severe cyclones with pressure below 920 hectopascals. These categories apply to the zone of maximum wind which is near the eye of the cyclone. Impact by severe tropical cyclones is relatively infrequent, occurring on average once every 5–6 years. Details of major cyclones and severe storms that have affected Queensland from 1896 to 1996 are shown in table 2.8.

Cyclones produce extreme winds that can exceed 200 km/h. Such winds can result in extensive property damage both directly and from airborne debris. The highest wind gusts ever recorded in Queensland were 200 km/h at Willis Island in the Coral Sea, 195 km/h at Townsville and 186 km/h at Bowen.²⁵ Winds produced by cyclones can cause rough seas that are dangerous for vessels at sea or moored in harbours. Serious erosion of the foreshore can occur, such as along the Sunshine Coast and Gold Coast from time to time. Even where a cyclone remains well out to sea, the swells generated can cause considerable erosion.

Rainfall during cyclones is usually widespread and heavy. The heaviest rain is concentrated around the eye of the cyclone and in the area of strongest onshore winds. If the system is slow moving, particular localities can be deluged, producing further damage. If the cyclone moves rapidly, falls will generally be less. Many falls of over 450 mm in 24 hours in a locality have occurred due to cyclones. Incidents of high rainfall readings over short periods during cyclones are shown in table 2.9. Queensland's 24-hour record is 1,140 mm near Cairns on 4 January 1979, almost equal to Brisbane's mean annual rainfall of 1,181 mm (table 2.3).

Table 2.7 Cyclones by section of coast, Queensland, 1909–1989

Section of coast	Cyclones number	Direct distance km	Cyclones per 100 km number
Northern Territory border to Karumba	19	320	5.9
Karumba to Edward River	11	310	3.5
Edward River to Thursday Island	23	470	4.9
Thursday Island to Cooktown	17	640	2.7
Cooktown to Cairns	17	170	10.0
Cairns to Townsville	14	300	4.7
Townsville to Bowen	10	170	5.9
Bowen to Mackay	8	160	5.0
Mackay to Yeppoon	14	270	5.2
Yeppoon to Maryborough	13	330	3.9
Maryborough to New South Wales border	16	300	5.3
Total	162	3,440	4.7

Source: ABS, *Queensland Year Book*, 1991, p. 15.

QUEENSLAND PAST AND PRESENT

Table 2.8 Major cyclones and severe storms, Queensland, 1896–1996

Date	Location	Name	Comments
5 Mar 1899	Northern Queensland	Bathurst Bay cyclone	Pearling fleet destroyed; over 300 lives lost; barometer reading of 914 hectopascals is state's lowest on record.
9 Mar 1903	Townsville; Bowen	<i>Leonta</i>	Severe damage to Townsville; 10 lives lost.
16 Mar 1911	Port Douglas to Innisfail	—	Severe damage at Cairns; practically all buildings were damaged and 2 lives lost at Port Douglas.
27–28 Dec 1916	Mackay to Clermont	—	Passed inland between Bowen and Mackay; widespread flooding in Clermont where 62 lives lost.
20–22 Jan 1918	Mackay; Rockhampton	—	30 lives lost and estimated \$3m of property destroyed at Mackay; 3 m storm surge at Mackay; barometric pressure of 933 hectopascals recorded; unprecedented flooding in the Burdekin and Fitzroy rivers.
23 Mar – 9 Apr 1923	Gulf of Carpentaria	—	7 m storm surge (combined with high tide) recorded in the west of the Gulf of Carpentaria.
11–13 Mar 1934	Port Douglas	—	Crossed the coast north of Port Douglas; huge seas wrecked pearling luggers; 75 lives lost; significant damage in Mossman and Daintree districts.
1–4 Mar 1949	Rockhampton	—	While passing over Cape Capricorn and Rockhampton, wind gusts of 160 km/h; great property damage at Rockhampton and Bundaberg; 4 lives lost.
6 Mar 1956	Townsville; Cairns; Mackay	<i>Agnes</i>	Some localities between Cairns and Mackay suffered severe damage; 4 lives lost in inland flooding; \$5m damage.
4 Feb 1964	Gulf of Carpentaria	<i>Dora</i>	Extensive flooding in gulf rivers; winds of 160 km/h.
17–19 Jan 1970	Whitsunday Islands; Proserpine	<i>Ada</i>	\$12m damage; 13 lives lost; wind gusts of 130 km/h.

... contd

A maritime phenomenon related to cyclones, which can cause serious damage due to inundation of low lying coastal areas, is a storm surge. This is a raised dome of water 60–80 km across, which in extreme cases can be about 3 m higher than the normal tide level. A storm surge is mostly produced by winds driving the seawater shorewards but partly by the low atmospheric pressure at the centre of the storm, and can penetrate several kilometres into low lying coastal areas causing extensive damage. When cyclone *Althea* hit Townsville in December 1971, a storm surge added 3 m to the height of the tide at the time it arrived, making a total of 4 m. Had the surge occurred five hours later at high water, the storm tide would have been 5 m and caused far greater damage.²⁶ In the Gulf of Carpentaria in January 1996 a storm surge was estimated at more than 3 m during the passage of tropical cyclone *Barry* across a remote section of the coastline about 130 km north of Karumba.²⁷

The Department of Environment has established a storm gauge network that comprises 21 sites along the Queensland coast. The network provides information for determining the extent of coastal land vulnerable to tidal inundation from the combined effects of a storm surge and a high tide. Information on storm surges and water levels during cyclones is vital for State

Table 2.8 Major cyclones and severe storms, Queensland, 1896–1996 (contd)

Date	Location	Name	Comments
24 Dec 1971	Townsville	<i>Althea</i>	\$25m damage; 3 lives lost; 3 m storm surge; wind gusts of nearly 200 km/h; flooding of inland rivers; weakened, but re-crossed the coast near Maryborough on 27 December with gale force winds between Pialba and Noosa Heads.
24–27 Jan 1974	South-eastern Queensland	<i>Wanda</i>	\$200m damage in Brisbane alone; 15 lives lost; wind gusts of 130 km/h; in Brisbane some 6,700 householders had their dwellings wholly or partially submerged; in Ipswich 40 houses washed away and 1,800 severely damaged.
19 Dec 1976	Gulf of Carpentaria	<i>Ted</i>	Crossed the coast north of Burketown causing extensive damage to Burketown and Mornington Island.
13 Feb – 6 Mar 1979	Mackay district	<i>Kerry</i>	Began near the Solomon Islands; crossed the Queensland coast near Mackay on 1 March; first cyclone to be penetrated by research aircraft of the US National Oceanic Atmosphere Administration; maximum wind 252 km/h over ocean; longest lived cyclone in the Australian region.
Feb 1988	Burdekin River district	<i>Charlie</i>	Caused damage in the Ayr–Home Hill district; damage to sugar crop estimated at \$15m.
31 Mar – 5 Apr 1989	Burdekin River district	<i>Aivu</i>	Began in Papua New Guinea and crossed the Queensland coast near the Burdekin delta; on 4 April wind gusts of nearly 200 km/h recorded together with a storm surge of 3 m; greatest damage near Upstart Bay; damage estimated at \$80m.
Mar 1991	Cairns to Rockhampton	<i>Joy</i>	Cyclone affected a 1,200 km stretch of the Queensland coast from Cairns to Rockhampton; flood rains to much of Queensland, causing extensive damage to crops.
Jan 1996	Northern Queensland	<i>Celeste</i>	Heavy rain; winds of 180 km/h in the Bowen district.

Source: Bureau of Meteorology, Queensland, unpublished data.

Counter Disaster Organisation consideration of the evacuation of communities before a cyclone crosses the coast.

Storms

Thunderstorms and hailstorms occur more frequently in the warm wet season than in winter, and usually occur in the afternoon. Hail is always associated with the thunderstorm type cloud, but often melts before it reaches the ground. Cyclones are often accompanied by thunderstorms and hailstorms. Brisbane averages about 24 days a year with thunderstorms (table 2.3).

Thunderstorms with associated lightning are relatively common throughout Queensland from late spring to early autumn. The negatively charged area at the bottom of a cumulo-nimbus cloud induces a positive charge on the ground. The electrical charge builds up and results in lightning. The lightning heats the air in its path to about 30,000°C, causing an expansion of air and a loud soundwave that travels at about 330 m a second. A six-second delay, for example, between lightning and thunder means the lightning is about 2 km away. Lightning strikes, which have their greatest impact in the more densely populated south-east of the State, have caused death to humans and livestock and damage and destruction to buildings. In October

Table 2.9 Heavy rainfall recorded during cyclones, Queensland, 1893–1990

Date	Rainfall	Period	Location	Cyclone
3 Feb 1893	907 mm	24 hours	Crohamhurst, west of Landsborough	—
3 Mar 1946	305 mm	2 hours	Upper Ross, near Townsville	—
19–20 Feb 1954	1,044 mm	36 hours	Springbrook, in the Gold Coast hinterland	—
20 Jan 1970	869 mm	24 hours	Mount Dangar, south of Bowen	<i>Ada</i>
8–12 Jan 1972	1,864 mm	5 days	Paluma, south of Ingham	<i>Bronwyn</i>
4 Jan 1979	1,140 mm	24 hours	Bellenden Ker top station, south of Cairns	<i>Peter</i>

Source: ABS, *Queensland Year Book*, 1991, p. 15.

1909, for example, severe thunderstorms with light to moderate rain, strong winds and some hail occurred on the eastern Darling Downs. Lightning strikes were reported, including one to a passenger travelling on the mixed goods and passenger train from Toowoomba to Roma.

Examples of more recent severe thunderstorms follow:

- In November 1973 a thunderstorm with an associated tornado caused damage to more than 1,300 buildings in western and southern Brisbane.
- In January 1976 a thunderstorm with large hail damaged more than 1,000 buildings in the eastern suburbs of Toowoomba.
- In December 1980 a thunderstorm caused extensive damage to 5,000 homes in Brighton and Bracken Ridge, in northern Brisbane.
- In January 1985 severe wind and a hailstorm passed over Brisbane and produced the strongest wind gust ever recorded at Brisbane Airport of 185 km/h. An estimated \$307m in damage was caused within 30 minutes.²⁸

Destructive hailstorms have occurred in various centres throughout Queensland. In December 1912, for example, a severe hailstorm with strong squalls passed over Brisbane, producing 36 mm of rain in 30 minutes. Hail caused damage to windows, trees and gardens, mainly between Indooroopilly and East Brisbane. An accumulation of hail in gutters caused local flooding. In December 1946 a severe thunderstorm was accompanied by heavy rain and large hailstones measuring up to 5 cm by 7 cm. Wind reached gusts of 125 km/h and damage was widespread.²⁹

Greenhouse effect

The greenhouse effect, which was so named because the earth's atmosphere acts much like the glass roof and walls of a greenhouse, is the warming that occurs near the earth's surface when the atmosphere traps the heat of the sun. The warmed surface of the earth re-emits the heat energy back into the atmosphere as infrared radiation. Certain gases in the atmosphere contribute to this warming by absorbing this infrared radiation. These gases, which include carbon dioxide, tropospheric ozone and water vapour, are transparent to incoming solar radiation but opaque to outgoing terrestrial radiation which has a longer wavelength. Thus, heat is trapped and the warmed gases send infrared radiation back toward earth, adding to the warming of the earth's surface. This is a natural phenomenon responsible for the maintenance of temperatures on the earth.

Since the industrial revolution and the rapid expansion of the world's population, the concentrations of carbon dioxide and other greenhouse gases such as methane, nitrous oxide, and the chlorofluorocarbons have increased, and the atmosphere is becoming more opaque to outgoing radiation. As a result the mean temperature of the atmosphere is expected to increase.

The burning of fossil fuels such as coal, oil and natural gas is a major factor giving rise to the greenhouse effect.

Expected increases in carbon dioxide concentration in the atmosphere during the twenty-first century may raise the mean global temperature by up to 3.5°C. The rate of emission of all greenhouse gases is such that a doubling of carbon dioxide concentration is likely to be experienced by 2030. One of the consequences of the greenhouse effect has been a serious decline in ozone concentrations over Antarctica. Less significant declines have occurred in all regions apart from the tropics between the mid 1980s and mid 1990s.³⁰ Climate models suggest that by 2100 global mean temperature will have risen by 1–3.5°C and global sea level by 15–95 cm. Uncertainties exist regarding the timing, magnitude and regional patterns of climatic change.³¹

The greenhouse effect has implications for rural industries, especially in the impact of climatic change on soils, water, plants and animals, and for engineering and public works including road, railway and airport construction, drainage, and flood mitigation. For the energy and mining sectors, there would be an impact on the State's exports of steaming coal should countries decide to use 'cleaner' sources of energy, including solar, wind and nuclear sources for their electricity generators.

ENVIRONMENT

The environment is the aggregate of surrounding things—physical, chemical and biological—as well as conditions and influences. People often regard the environment as the air, water, land, plants, animals, structures, etc. that influence their lifestyle. Responsibility for the administration of the environment is spread across several Commonwealth and State Government departments and agencies, and all local government authorities. Landholders and other individuals are involved directly and through industrial, commercial and community organisations. Conservation of the environment includes research, recording, monitoring, legislation, planning, management and education.

Meteors

Numerous appearances of meteors and shooting stars have been reported in Queensland since 1896. Most reports of meteors include a rumbling noise like thunder, heard after the meteors have passed overhead. Findings of meteoric material are few, and the largest collection is held by the Queensland Museum. Virtually all the material was found in the south-west of the State where sparser vegetation enabled the findings to be made. Some of the more notable finds of meteoric material held by the museum include the following stones:

- Glenormiston meteorite, found near Boulia (22°54' S, 138°43' E). The mass of the main stone is 38.8 kg.
- Tenham meteorites, found near Ingella (25°44' S, 142°57' E). There are more than 130 individual stones with a total mass in excess of 41 kg.
- Thunda meteorite, found at Windorah (25°42' S, 143°03' E). The museum holds a 43 g slice.
- Gladstone meteorite, found 7 km south of Gladstone (23°54' 30" S, 151°15' 30" E). The mass of the main stone is 17.6 kg.³²