QUEENSLAND DEPARTMENT OF MINES

Seismic monitoring of the Burdekin Falls Dam. A preliminary report to February 1988

R. J. Cuthbertson

GEOPHYSICAL SERVICES
PROJECT REPORT GS2/1

SEISMIC MONITORING OF THE BURDEKIN FALLS DAM

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by

R.J. Cuthbertson

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ABSTRACT

The Burdekin Falls Dam has been monitored for the possibility of reservoir induced seismicity by the Mines Department since 1981. The original network consisted of three analogue recorders and these were supplemented in 1984 by seven digital recorders. The low level of the reservoir (less than 50% of full supply volume) up to February 1988 accounts for there being no induced activity. There exists a low level of natural seismicity in the area.

It is recommended that the monitoring continue at the existing level until the end of 1990, to include two years following filling of the reservoir, at which time the situation would be reviewed.

INTRODUCTION

The phenomenon of earthquake activity induced by the filling of large reservoirs has been well documented in Australia (eg Shirley, 1980) and overseas (eg Simpson, 1976). Simple calculations, comparing stress fields due to a reservoir with stress release in an earthquake, indicate that reservoir induced earthquakes greater than magnitude 4 can only occur in a crust with a significant existing stress field (Webb, 1981). Earthquakes below magnitude 3, however, can be induced directly by the reservoir without an existing near-critical stress.

The filling of a reservoir has two effects. The first is to increase the vertical stress field in the crust beneath the reservoir. The second is to increase the pore pressure in the crust immediately beneath and surrounding the reservoir. The former effect will have no time lag while the latter will be delayed by an amount (typically of the order of 1-2 years) dependent on the physical properties of the crust. An increase in pore pressure will reduce the strength of existing fractures while an increase in the vertical stress field may increase or decrease the stability of existing fractures depending upon the orientation of the principal stress direction in the crust. Induced activity is therefore dependent upon the existing state of stress in the crust, the permeability of the rocks of the crust, the orientation of existing fractures in the crust, the water level and volume of the reservoir, and even the rate of raising or lowering of the water level and volume of the reservoir.

Coordinated research into the problem of reservoir induced seismicity began in the 70's with the recommendation that reservoirs exceeding 100 m in depth or 10^9 m^3 in volume should be monitored. At a regional assembly of IASPEI in Hyderabad in 1984, these values were reduced to 60 m in depth and 0.5×10^9 m^3 in volume. Investigation requires the installation of seismographs well before the dam is constructed to determine the natural seismicity of the area. Pre- and post-impoundment seismicity is then compared to determine the effect of the reservoir.

The Burdekin Falls Dam is classified as a large reservoir and has been monitored for the possibility of reservoir induced seismicity by the Mines Department since 1981.

INSTRUMENTATION

Monitoring of the proposed Burdekin Falls Dam commenced in February 1981 with the installation of three Sprengnether MEQ-800 seismographs at BGRR, BGC and BMG (see Fig. 1 and Table 1). These instruments record continuously onto smoked paper charts and originally required changing twice per week by QWRC personnel from the damsite. A summary of the results of this network was presented by Cuthbertson (1982).

The network was extended in 1984 with the installation of seven PIT Yerilla recorders at BGRB, MCP, DNG, BSL, MHP, UKA and DLB. These instruments, which have a very large dynamic range, are triggered seismographs which record digitally onto a cassette. They are serviced on a weekly or fortnightly basis by local station owners.

In early 1985 the network was again altered with the moving of the analogue recorders from BGC to CVL and from BMG to BNG. The operation of one of the analogue recorders has caused some problems and it has been moved from BNG, to GVA, and finally to FGT. The currently operating network is indicated in Figure 1 by the solid symbols.

The instruments have been maintained by some local operators, inspections by a QWRC officer from Ayr (every 3 months) and by Mines Department personnel from Brisbane (once-twice a year).

The area of particular interest to this study is depicted by the quadrilateral in Figure 1. This area is obtained by selecting a simple shape for the impounded area (ignoring the shallow upper reaches) and then doubling this shape in size. Any activity induced by the reservoir should occur within this area and any installed network should be designed to monitor this area specifically. The existing network is a compromise necessitated by the lack of people in the area who were both willing and able to operate the equipment. The current configuration of seismographs is capable of recording and locating all events in the "area of interest" above magnitude 1.0. Events with magnitudes less than 1.0 are recorded and located when they occur near several recorders. In the four years (1981 through 1984) when there were three analogue recorders (BGRR, BMG, BGC) in close proximity to Burdekin Falls, the detection threshold would have improved to include all events in the area of interest above magnitude 0.5.

DATA ANALYSIS

Records from the network are posted to Brisbane where they are analysed. All events on the analogue smoked-paper seismograms are read, tabulated and labelled as either local earthquakes (of interest to this project), teleseisms (distant, overseas earthquakes), regional earthquakes (generally interstate), or blasts. Attempts are usually made to attribute the recorded blasts to particular quarries or coal mines, although this is not always possible.

More detailed information (arrival times, amplitudes etc.) is obtained for all local earthquakes as well as for any blasts that do not fit "known" examples of blasts from particular quarries.

The computer analysis system, that was purchased primarily to analyse the digital data cassettes, is used to locate the events and to assign magnitudes. This information is then incorporated into a database of events (earthquakes and some blasts) for Queensland and northern New South Wales. The resultant file of events, containing all

the relevant information regarding those events, is then interrogated and processed for the desired purpose.

All locatable earthquakes up to the end of October 1987 have been processed and are included in the earthquake file. There are some events that have been recorded on one seismograph only (and are thus unlocatable) and these have not as yet been included in the earthquake file. These events will not affect the results presented below.

RESULTS

Located earthquakes in the Burdekin Falls Dam region up until the end of October 1987 are plotted in Figure 2 and listed in Table 2. The size of the symbol in Figure 2 relates to the earthquake magnitude. Symbols for earthquakes of magnitude 1, 3 and 5 are shown in the legend. Accuracy refers to the error in location and it depends on the number of stations recording the event and the network geometry. Events with accuracies denoted by the letters A, B and C (see Table 1) are located to within 5 km, while D indicates within 10 km and E and K within 50 km. The 13 events prior to 1981 have been located via intensity (felt) reports and in some cases via arrival times at Charters Towers seismograph (Rynn, 1987). The 77 events since 1981 located with the Burdekin Falls Dam Network range in magnitude from -1.5 to 3.0. Events in the vicinity of the Collinsville coal mines were carefully studied to ensure they were not blasts or indeed collapses in the underground workings. Most of the earthquake locations have been checked and revised if necessary to reduce errors.

Seismicity of the region can be broadly grouped as follows:

1. Collinsville area (-20.5°, 147.6°) - activity confined to the northern Bowen Basin.
2. Leichhardt Weir area (-20.5°, 147.2°) - activity confined to an area less than one kilometre square.
3. Western area - scattered activity confined by lines drawn roughly west and southwest from the dam.

The reservoir was impounded in November 1986 but up until January 1988 the reservoir had not exceeded 50% of the full supply volume. Preliminary analysis of seismograms up until February 1988 indicate no noticeable change in the seismic activity of the area. This is not significant given the low storage volume up to that date. Recent rain has filled the reservoir and QWRC will be notified in the event of any unusual activity.

Further analysis regarding the stress field existing in the area (via focal mechanism calculations), and the seismicity of a larger area around the dam, is continuing in an effort to better understand the seismicity of the region.

DISCUSSION AND RECOMMENDATIONS

Documented cases of induced activity show delays typically less than four years between reservoir impoundment and the occurrence of the **largest** induced earthquake (Simpson, 1976). However, the delay between impoundment (or at least 100% capacity) and the **onset of small induced activity** is typically less than one year. Instrumental monitoring of a reservoir for a two year period following filling would identify any induced activity. If there is no significant induced activity in the area, then the level

of monitoring should be reduced, leaving a basic network to continue monitoring the seismicity of the region.

Based on the results presented above the following actions are recommended:

1. That the monitoring network be maintained at the current level for a further two years (i.e. until the end of 1989) at which stage the situation should be reviewed.
2. That reports detailing the activity in the area be provided annually. QWRC will be notified immediately in the event of any unusual activity that may be reservoir induced.

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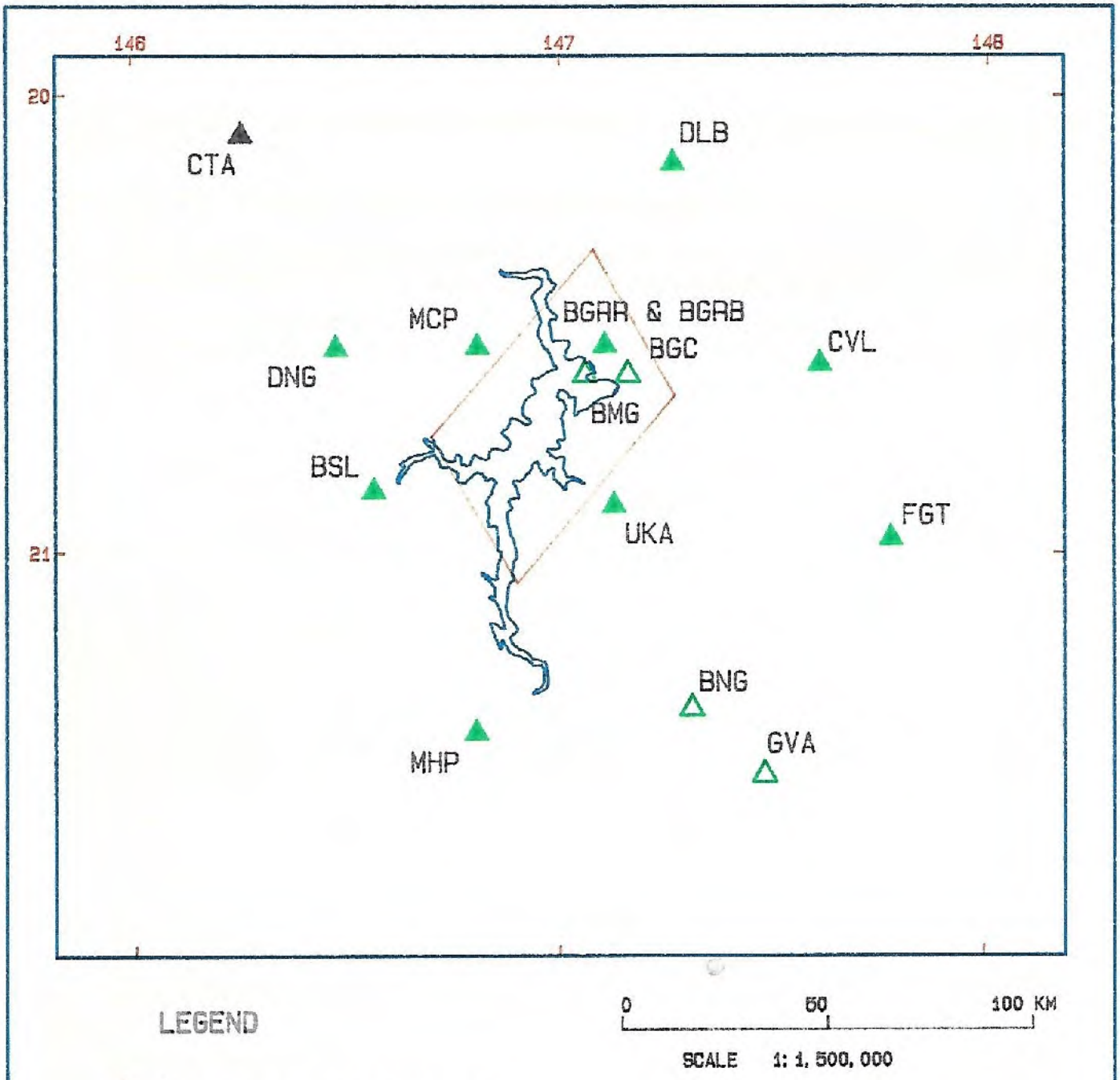
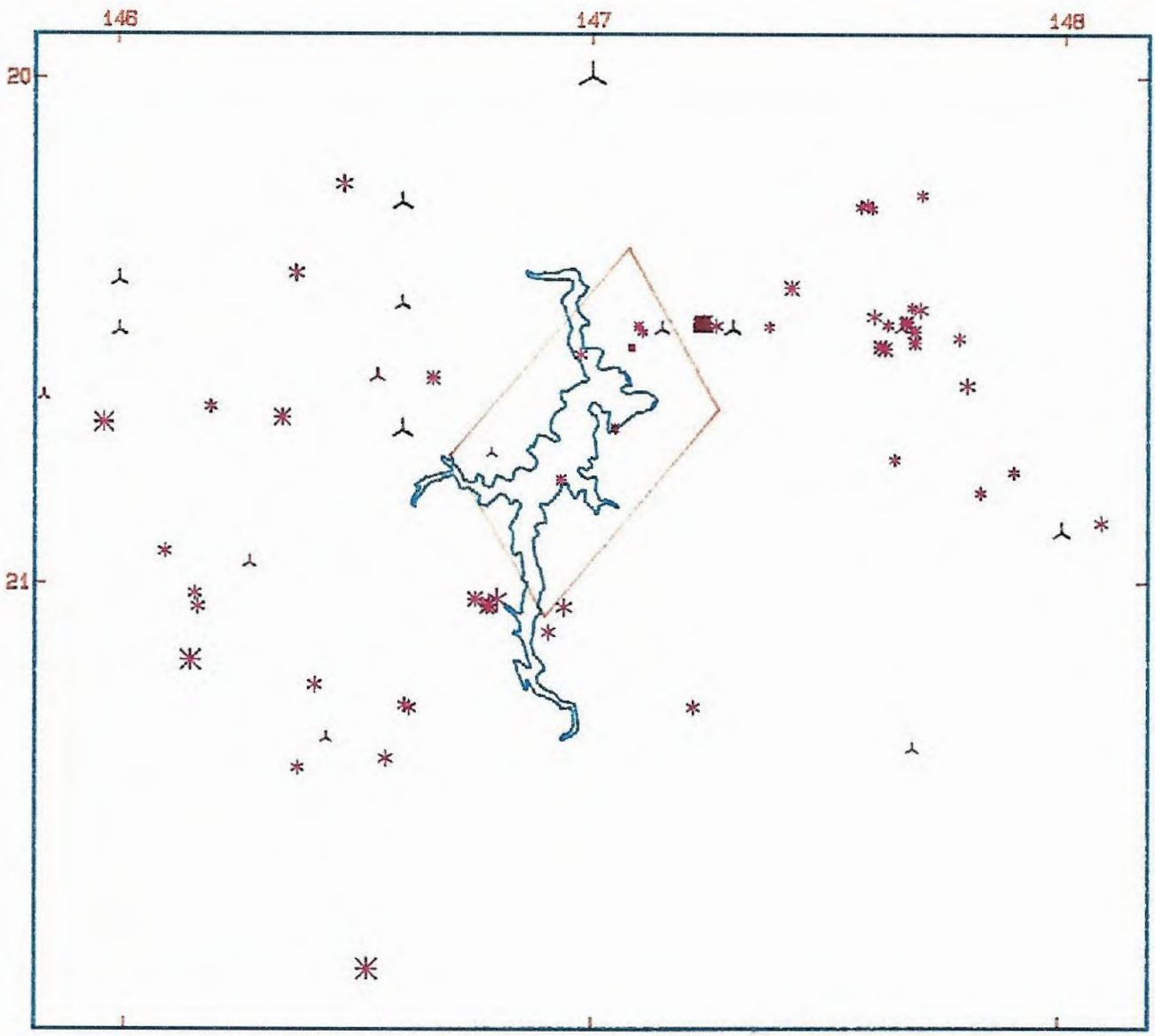


Fig. 1 - SEISMOGRAPH LOCATIONS IN THE BURDEKIN FALLS DAM REGION (see also Table 1)



"AREA OF INTEREST"

EARTHQUAKES

Pre 1981

Post 1981 (Accuracy = 5 km)

Post 1981 (Accuracy = 10 km)

Post 1981 (Accuracy = 50 km)

1 3 5 Magnitude

Fig. 2 - EARTHQUAKE LOCATIONS IN THE BURDEKIN FALLS DAM REGION (see also Table 2)

Table 1 : Locations and operating periods of seismographs in the Burdekin Falls dam region

Code	Longitude	Latitude	Height	Start	End	Location
Analogue recorders						
BGC	147.1609	-20.6140	0.16	81-02-12	85-04-29	Glendon Crossing
BMG	147.0608	-20.6142	0.16	81-02-13	85-04-30	Mount Graham
BGRR	147.1052	-20.5492	0.16	81-02-16		Glenroy (Analog)
CVL	147.609	-20.590	0.102	85-04-30		Collinsville (Myuna)
BNG	147.3121	-21.3440	0.285	85-05-05	85-08-30	Bungobine
GVA	147.4827	-21.4890	0.200	86-03-18	87-06-01	Glen Eva
FGT	147.7765	-20.9701	0.220	87-08-13		Fig Tree
Digital recorders						
BGRB	147.1052	-20.5492	0.16	84-02-27		Glenroy (Digital)
BSL	146.564	-20.867	0.185	84-03-02		Bruslee
DLB	147.264	-20.151	0.070	84-04-09		Dalbeg
DNG	146.475	-20.555	0.280	84-02-29		Doongara
MCP	146.806	-20.552	0.300	84-02-23		Mt Cooper
MHP	146.802	-21.552	0.200	84-04-10		Mt Hope
UKA	147.127	-20.899	0.200	84-03-28		Ukalunda
University of Queensland recorder						
CTA	146.2550	-20.0883	0.357	62-00-00		Charters Towers (UQ)

Note: Height is in kilometres.
Start and end dates are in Year-Month-Day format.
No end date indicates the recorders are still operating.

Table 2 :- EARTHQUAKE LOCATIONS IN THE BURDEKIN FALLS DAM REGION

Catalogue QLD, format ECA, from start to 1987-10-31
Select events with:
Longitude greater than or equal to 145.80 and less than 148.20
Latitude greater than or equal to -21.90 and less than -19.90

UT Date	Time	Lat	Long	Dep	Mag	Imx	Acc	Place
1913-12-18	1353 40.0	-20.000	147.000	35	ML 5.5	5	E	RAVENSWOOD
1957-11- 9	2123 19.0	-20.500	147.300	10	ML 1.8		E	LEICHHARDT WEIR
1958- 7-30	0211 50.5	-20.500	147.300	10	ML 1.9		E	LEICHHARDT WEIR
1958-11-30	1020 13.0	-20.500	147.150	10	ML 1.5		E	LEICHHARDT WEIR
1963- 2-12	1602 51.2	-20.250	146.600	10	ML 3.0	3	E	BRITTANIA DOWNS
1966- 7-30	1610 3.8	-20.500	146.000	10	ML 1.8		E	S CHARTERS TOWERS
1969- 1-11	2105 17.0	-20.900	148.000	10	ML 2.4		E	SE CHARTERS TOWERS
1972-11- 9	1610 13.6	-20.450	146.600	10	ML 1.5	2	E	SE CHARTERS TOWERS
1973- 4- 2	0901 13.7	-20.700	146.600	10	ML 1.7	2	E	CHARTERS TOWERS
1974- 8-21	0505 3.4	-20.250	146.600	10	ML 1.9	2	E	SE CHARTERS TOWERS
1977- 9-23	1530 0.0	-20.400	146.000	10	MP 2.2	3	K	S CHARTERS TOWERS
1978- 5-24	1737 59.5	-20.700	146.600	10	ML 3.2	4	E	HARVEST HOME
1978- 5-24	2345 42.4	-20.700	146.600	0	ML 1.3		E	HARVEST HOME
1981- 3-21	0813 43.9	-20.212	146.476	11	ML 2.0		D	CAMERON STATION
1981- 5-22	1013 22.9	-20.695	147.050	5	ML-0.8		C	MT. MC.CONNELL
1981- 5-22	1200 51.1	-20.700	147.051	4	ML-1.5		D	MT. MC.CONNELL
1981- 6- 4	0359 44.2	-20.745	146.788	10	ML 0.1		E	HARVEST HOME STATION ?
1981- 6-28	2141 13.8	-20.674	146.344	8	ML 1.4		C	MT. BELLEVUE
1981- 7- 4	1343 26.5	-20.258	147.570	17	ML 0.5		D	MT. CASTOR
1981- 7-10	1544 50.0	-20.822	147.827	14	ML 0.5		D	MT. ST. MARTIN
1981- 7-14	2229 9.1	-21.049	146.777	17	ML 0.7		C	SCARTWATER
1981- 7-14	2229 28.2	-21.046	146.782	17	ML 1.1		C	SCARTWATER
1981- 7-14	2231 44.1	-21.035	146.752	18	ML 0.8		C	SCARTWATER
1981- 7-18	0058 30.0	-20.253	147.583	4	ML 0.2		D	MT. CASTOR
1981- 7-20	2153 56.9	-20.781	147.898	14	ML 0.3		D	MT. ST. MARTIN
1981- 8-13	0634 13.8	-20.460	147.697	5	ML 1.3		D	COLLINSVILLE
1981- 8-31	0601 35.6	-20.881	148.084	19	ML 1.1		D	MT. SUGARLOAF
1981- 9-10	1158 10.3	-20.534	147.612	16	ML 0.6		C	RED HILL
1981- 9-10	1158 54.0	-20.538	147.622	15	ML 0.6		C	RED HILL
1981- 9-12	1849 13.8	-20.517	147.780	15	ML 0.4		D	COLLINSVILLE
1981-10- 3	1627 36.4	-20.484	147.668	16	ML 0.2		C	RED HILL
1981-10- 3	1818 13.7	-20.504	147.685	8	ML 0.4		C	COLLINSVILLE
1981-10- 3	1818 48.0	-20.487	147.666	16	ML 0.4		C	COLLINSVILLE
1981-10- 8	0339 14.1	-20.488	147.233	4	ML 0.6		C	LEICHHARDT WEIR
1981-10- 8	2142 49.5	-20.493	147.231	3	ML-0.4		B	LEICHHARDT WEIR
1981-10- 9	0008 2.0	-20.526	147.686	4	ML 0.1		C	COLLINSVILLE
1981-10-11	1002 6.1	-20.488	147.238	4	ML 1.5		C	LEICHHARDT WEIR
1981-10-11	1126 35.0	-20.487	147.229	4	ML-0.6		C	LEICHHARDT WEIR
1981-10-11	1741 52.3	-20.489	147.233	4	ML-0.8		C	LEICHHARDT WEIR
1981-10-12	0711 57.2	-20.491	147.231	4	ML 0.6		C	LEICHHARDT WEIR
1981-10-12	1921 2.0	-20.489	147.228	4	ML-0.6		C	LEICHHARDT WEIR
1981-10-21	1024 3.4	-20.234	147.699	4	ML 0.0		D	BRIABA
1981-10-26	2335 12.5	-20.490	147.235	4	ML 0.1		C	LEICHHARDT WEIR
1981-10-29	0601 6.6	-20.261	147.593	0	ML 0.0		D	MT. CASTOR
1981-10-29	1717 22.8	-20.486	147.237	5	ML-0.1		C	LEICHHARDT WEIR
1981-11- 1	1136 14.4	-20.495	147.233	3	ML-0.8		B	LEICHHARDT WEIR
1981-11- 5	1112 27.4	-20.491	147.235	4	ML 0.1		C	LEICHHARDT WEIR
1981-11-11	0638 37.2	-20.611	147.797	4	MD 1.3		D	COLLINSVILLE
1982- 2-21	1757 58.4	-21.329	147.684	19	ML 0.9		E	BULGONUNNA PEAK
1982- 3- 1	1930 25.1	-20.937	146.093	16	ML 0.8		D	EGERA STATION

Table 2 :- Continued

Catalogue QLD, format ECA, from start to 1987-10-31
Select events with:
Longitude greater than or equal to 145.80 and less than 148.20
Latitude greater than or equal to -21.90 and less than -19.90

UT Date	Time	Lat	Long	Dep	Mag	Imx	Acc	Place
1982- 6-10	0846 31.5	-20.418	147.424	4	ML 1.0		C	MT. WICKHAM
1982- 8-15	0109 28.3	-20.798	146.934	7	ML-0.4		C	MT. MC.CONNELL STATION
1982-11-23	2129 15.9	-21.367	146.374	19	ML 0.7		D	DAWSON VALE STATION
1982-11-23	2130 32.6	-21.048	146.162	15	ML 1.0		D	NATAL DOWNS STATION
1982-11-23	2141 0.1	-21.153	146.146	18	ML 2.5		C	MIRTNA STATION
1982-12-17	1225 51.7	-21.021	146.156	18	ML 0.7		D	NATAL DOWNS STATION
1982-12-31	0919 45.7	-20.488	147.235	4	ML 0.8		C	LEICHHARDT WEIR
1983- 2-15	1508 0.0	-21.309	146.435	18	ML 0.5		E	MT. BINGERINGO
1983- 2-22	0903 0.6	-21.248	147.218	14	ML 0.9		D	MT. CARMEL
1983- 8-16	1830 36.0	-20.493	147.100	8	ML-0.7		B	GLENROY
1983- 8-20	0324 20.9	-21.202	146.411	6	ML 1.2		D	DAWSON-VALE STATION
1983- 8-27	2008 58.0	-20.491	147.234	5	ML 0.7		C	LEICHHARDT WEIR
1983- 8-27	2016 31.4	-20.491	147.235	4	ML 0.0		C	LEICHHARDT WEIR
1983- 8-27	2024 11.6	-20.490	147.233	5	ML 0.5		C	LEICHHARDT WEIR
1983-10-26	1344 46.3	-20.488	147.234	4	ML 0.1		C	LEICHHARDT WEIR
1983-11-13	0642 12.2	-21.035	146.799	5	MD 3.0		D	SCARTWATER
1983-12- 1	0048 59.3	-20.652	146.192	13	ML 0.7		D	EGERA STATION
1983-12-20	1839 48.5	-20.388	146.374	11	ML 1.5		D	BRITTANIA STATION
1983-12-25	0837 27.3	-20.474	147.599	4	ML 1.1		D	COLLINSVILLE
1984- 4- 2	0603 50.9	-20.484	147.240	5	ML 0.1		C	LEICHHARDT WEIR
1984- 4-19	0650 18.1	-21.766	146.521	14	ML 2.8		C	HYDE PARK STATION
1984- 5-18	1509 8.7	-20.596	146.664	4	ML 0.4		C	MT. ALMA
1984- 5-31	2309 52.3	-20.495	147.377	10	ML-0.1		D	MT. WICKHAM
1984- 7- 4	2111 36.9	-20.505	147.108	10	ML-0.3		D	GLENROY
1984- 8-14	1605 56.1	-20.536	147.086	1	ML-1.5		C	GLENROY
1985- 3-18	2148 40.0	-20.758	147.644	11	ML 0.1		D	HAVILAH
1985- 5-19	1626 8.8	-20.682	145.965	19	ML 2.1	2	B	LASCELLES STATION
1985- 6-14	1522 57.6	-20.456	147.678	10	ML-0.2		D	COLLINSVILLE AREA
1985- 6-25	1457 59.0	-20.629	145.838	3	ML 0.8		E	LASCELLES STATION
1985-10-29	0140 50.2	-20.491	147.628	6	ML 0.2		D	RED HILL
1985-12- 9	1246 23.0	-21.243	146.602	10	ML 0.8		D	DAWSON VALE STATION
1985-12- 9	1246 41.3	-21.349	146.562	9	ML 1.4		D	DAWSON VALE STATION
1985-12- 9	1250 52.4	-21.248	146.612	10	ML 1.1		D	DAWSON VALE STATION
1985-12-20	2010 10.7	-20.593	146.547	19	ML 1.6		E	PALLAMANA STATION
1985-12-26	1809 59.9	-20.497	147.657	9	ML 1.1		E	COLLINSVILLE
1986- 2-14	1803 30.2	-20.550	146.977	5	ML 0.6		D	MT MCCONNELL
1987- 1-21	0439 58.5	-21.051	146.941	8	ML 1.8		D	SCARTWATER
1987- 1-21	0440 53.1	-21.100	146.908	6	ML 1.1		D	SCARTWATER
1987- 5-22	1624 49.2	-20.962	146.273	9	ML 1.2		E	MIRTNA
1987- 8-19	1821 51.6	-20.493	147.264	4	ML 0.9		D	LEICHHARDT WEIR

90 events listed

Note :- Dep is earthquake depth in kilometres
Date and time are Universal Date and time
Imx is maximum reported intensity on the Modified Mercalli Scale
Acc is location accuracy