CENTRAL QUEENSLAND SEISMOLOGY RESEARCH GROUP

CQSRG Seismological Report 2015

Compiled by: Michael Turnbull BAppSc(Distinction) QUT MAppSc CQU, January 2016.

Table of Contents

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Michael Turnbull may be contacted by email at: mike.turnbull@cqsrg.org

Introduction

This report details earthquakes detected and located by the Central Queensland Seismology Research Group (CQSRG) during the 2015 calendar year. Technical summaries of earthquakes that occurred or were felt in Central Queensland are provided. The date and time of earthquakes noted in this report are provided in Universal Coordinated Time (UTC).

CQSRG was established in 2002, under the auspices of the Faculty of Informatics and Communication of Central Queensland University (CQU), with Michael Turnbull (Lecturer, and later Adjunct Research Fellow) and Kevin McCue (Visiting Professor, and later Adjunct Professor) as the designated researchers. This affiliation with CQU continued until 2013, when, due to a divergence in academic focus of CQU and CQSRG, the researchers allowed their Adjunct appointments to lapse. Subsequently CQSRG continued independent of CQU, with the same two people conducting the research.

During the 2015 calendar year CQSRG operated one seismic monitoring station, designated FS03. Details of this station, including location and equipment, are provided in Appendix A. This report contains information relating to earthquakes detected by the FS03 seismic monitoring station.

CQSRG locates and quantifies earthquakes using the methods detailed in Appendices B and C.

FS03 Uptime 2015

During April 2015 an RS232 digital radio link was installed from Mike Turnbull's home to the FS03 station site. This allowed downloading of the station data without the need to travel down to the site; which was hitherto done on an irregular weekly basis. With the radio link in place and stable, Mike wrote a terminal emulation script that could interrogate the Kelunji Classic data logger, and download the data with no human intervention.

The addition of the radio transceiver at the FS03 site caused an increase in load current on the battery, causing it to fail after a couple of weeks. A larger capacity battery was installed, and an additional 100 W solar panel added, as well as a new voltage regulator.

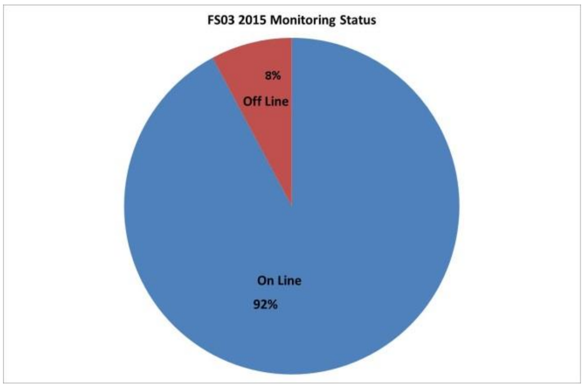

Figure 1: Percentage Uptime/Downtime of FS03.

On 2 June 2015 the download script was installed, and a regular 24 hour download session was scheduled on a computer at Mike's home. Since that date data has been downloaded automatically on a daily basis, with extra downloads performed as required.

In the period from 1 January to 31 December 2015 the FS03 Seismic Monitoring Station was actively on line and monitoring for events 92% of the overall year. This is depicted in Figure 1.

The main cause of downtime was the time taken to download data each day. However, from 1 January to 16 February there was 553 hours of downtime due to the absence of the operator, and subsequent filling of the memory. This problem should not occur in the future.

Earthquake Events Detected During 2015

Significant Event Sequences

During the year two significant earthquake sequences occurred – one 15 km north west of Mt Perry, and another 150 km north east of Rainbow Beach. Another minor earthquake sequence occurred about 5 km North West of Gin Gin. As a consequence of these aftershock sequences more earthquakes were recorded in 2015 than in the previous 13 years since CQSRG commenced operations.

Mount Perry Earthquake Sequence

At 2015-02-15 15:57:08.74 UTC, a local magnitude 5.0 event occurred about 26 km NW of Mt Perry. CQSRG has named it the **2015 Mt Perry Earthquake**.

The previous most recent Queensland earthquake of this magnitude was an ML 5.3 event, near Bowen, on 16 April 2011 @ 05:31:18 UTC.

The 2015 Mt Perry ML 5.0 earthquake was reported on ABC radio, and in Brisbane print media, as having been felt in Chermside, an inner northern suburb of Brisbane. It was strongly felt throughout the Wide Bay and Burnett regions, and up to Rockhampton. Mike Turnbull's wife, who was asleep at the time, 50 km from the event, was woken suddenly by the screen door at the end of the house rattling loudly, as if someone was trying to forcefully open it. Her pet dog jumped up onto the bed and got on top of her, seeking protection. This is a large Besser-block house on a 15 cm concrete slab.

Although no formal collection of felt reports was conducted, numerous residents from Gayndah to Bundaberg, Biggenden to Rockhampton, spoke with Mike Turnbull and described the noise like a truck running through the house. Many said they thought the roof was collapsing.

There was some minor structural damage to concrete slabs and masonry walls reported from the Eidsvold, Mundubbera, Gayndah, and Mt Perry areas.

On Wednesday 18 February, Geoscience Australia deployed four temporary monitoring stations in the immediate area of the epicentre. These were left in place for about a month. The data from these temporary stations was used by CQSRG to augment location of aftershocks that occurred over that period.

Up to the end of 2015, 96 aftershocks of this event have been recorded, and a higher than usual number of earthquake events have been recorded in the broader Mt Perry/Gin Gin region.

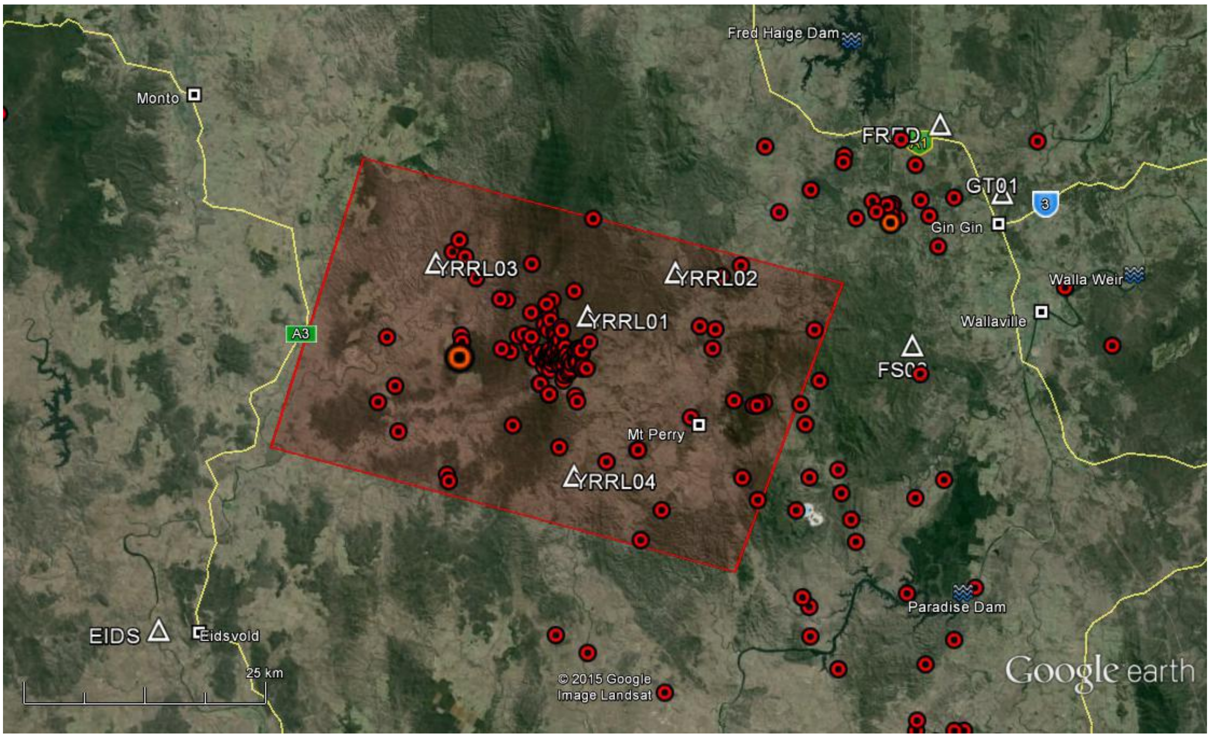

Figure 2: 2015 Mt Perry Earthquake and aftershocks.

Figure 2 is a map of the Mt Perry Earthquake sequence, as located by CQSRG. This map also shows the location of FS03, EIDS, and the four temporary GA stations, in relation to the earthquakes. The orange marker within the red zone shows the location of the main shock. (The orange marker to the west of Gin Gin is part of the Gin Gin sequence to be discussed below.) The red area is that used by CQSRG as the aftershock area. The choice of delineation area is arbitrary.

Although many pracitioners have attempted to deduce formulations to define aftershock bounds in time and physical area, such attempts are frawt with difficulties, particularly in Australia. There are many areas in Australia where significant earthquakes have occurred with no known previous seismic history. Subsequent to those *out-of-the-blue* events, aftershock sequences have continued for decades – even though many accepted aftershock time bounds formulations would have it that the sequences should have halted within a couple of months of the main event. Such would also seem to be the case with the 2015 Mt Perry Earthquake.

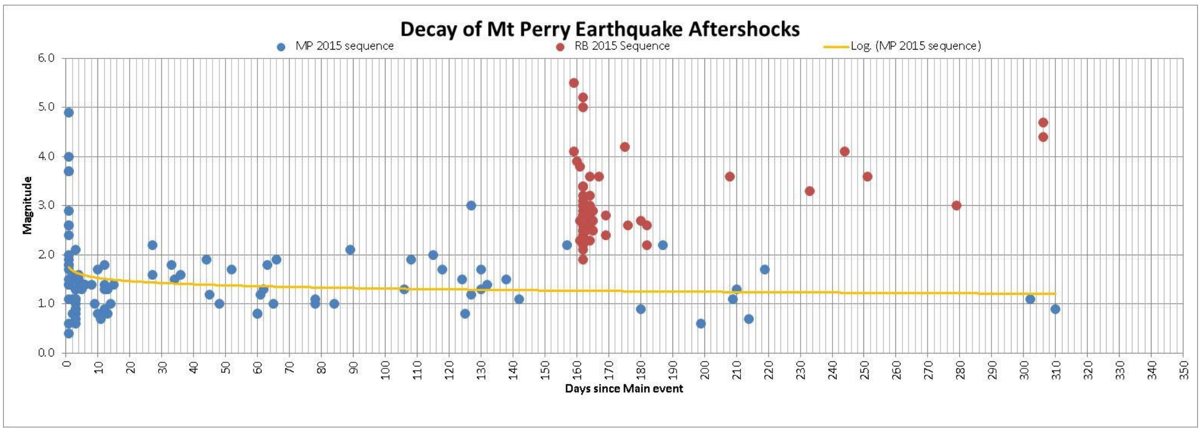

Figure 3: The MP 2015 Aftershock sequence.

Figure 3 is a depiction of the aftershocks of the 2015 Mt Perry Earthquake. The blue markers show the magnitudes of the individual events as a function of time in days after the main event. This aftershock sequence is referred to within CQSRG as the **MP 2015 sequence**.

The red markers relate to the Rainbow Beach aftershock sequence, which will be explained in the next sub-section. These markers have been added to the MP 2015 graph to show that the two sequences, although occuring concurrently, are in fact occuring independently of one another.

It is clear that the average event magnitude of the MP 2015 sequence is decaying as time proceeds, but the decay rate is very gradual. More than 10 months after the main ML 5.0 event, aftershocks of ML 1.0 are still occurring. Based on this evidence it is likely that aftershocks with magnitudes of the order of ML 0.5 to 1.0 will continue to occur throughout 2016.

Rainbow Beach Earthquake Sequence

At 2015-07-29 23:41:42.24 UTC a local magnitude 5.7 event occurred, out to sea, about 115 km NE of Rainbow Beach. CQSRG has named it the **2015 Rainbow Beach Earthquake**.

This event was followed two days later by an ML 5.2 event at 2015-08-01 03:38:44.06 UTC; and another ML 5.0 event at 2015-08-01 04:46:23.24 UTC. Although these two events could arguably be termed main events in their own right, CQSRG has chosen to classify them as aftershocks of the 2015 Rainbow Beach Earthquake.

The main ML 5.7 event was reported in the media as having been felt as far south as the New South Wales border, west to Gayndah, and north to Rockhampton. The following two > ML 5.0 events were also reported as having been felt down to Brisbane.

Up to the end of 2025, 56 aftershocks have been recorded, including the two > ML 5.0 events.

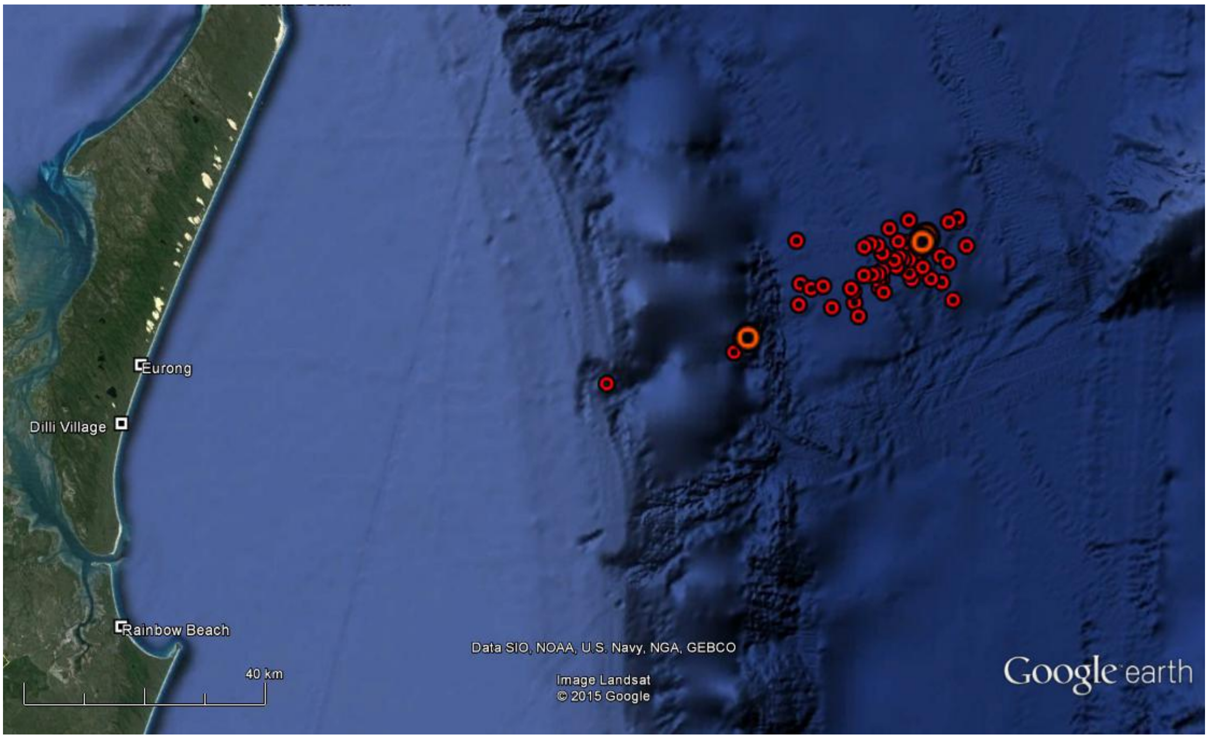

Figure 4: 2015 Rainbow Beach Earthquake and aftershocks.

Figure 4 is a map of the 2015 Rainbow Beach Earthquake sequence, as located by CQSRG. The orange marker at the south west end of the sequence is the main event. The two orange markers at the north east end are the other two > ML 5.0 events.

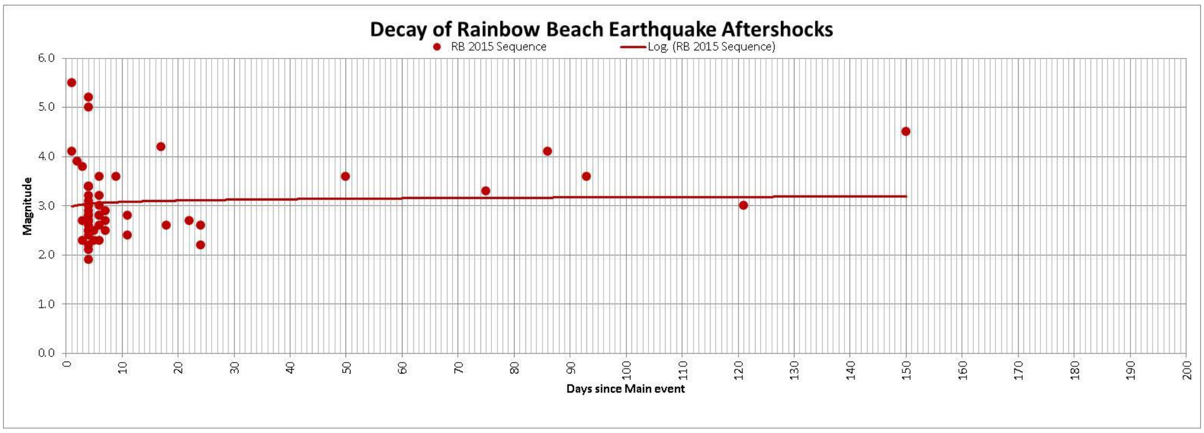

Figure 5: The RB 2015 Aftershock sequence.

Figure 5 is a depiction of the aftershocks of the 2015 Rainbow Beach Earthquake. The red markers show the magnitudes of the individual events as a function of time in days after the main event. This aftershock sequence is referred to within CQSRG as the **RB 2015 sequence**.

It is noted that, unlike the MP 2015 sequence, which is slowly decaying, the average magnitude of aftershock events in the RB 2015 sequence is increasing! Placing a scientific interpretation on this observation is difficult. The inference would seem to be that the RB 2015 Earthquake may be succeeded by more significant events such as the two previous main aftershocks – or even that a larger event may occur in the coming months. However, such an interpretation would be a brave speculation, based on intuition rather than scientific knowledge. Only time will decide the actual outcome; and this should be evident within the next six months.

The RB 2015 sequence is a typical example of an area in Australia where significant earthquake events and aftershock sequences have occurred despite there having been no clear record of earthquakes in that area in previous history. In 1918 there was a magnitude 6.0 earthquake, reported to have occurred in the vicinity of Lady Elliot Island. The dubious location of that 1918 event was made from seismograms recorded as far away as Egypt and Java. The nearest recording was made in Sydney. It may well be that the 1918 event occurred in the same area as the 2015 events; however, that may never be known for sure.

Gin Gin Earthquake Sequence

At 2015-11-24 20:46:33.12 UTC a local magnitude 1.2 event occurred, 11 km west of Gin Gin. This event was preceded within two minutes by two micro-earthquakes of ML 0.4 and 0.6 respectively, and followed by 19 aftershocks over the next 18 days, ranging in magnitude from ML 0.1 to ML 1.2. CQSRG has named it the **GG 2015 sequence**.

The most recent aftershock occurred on 2015-12-11, 20 days ago from the time of writing, and the sequence appears to have halted.

Figure 6 shows a map of the sequence, with the main ML 1.2 event shown as an orange marker.

The red line to the east of Gin Gin, extending through Lake Monduran to the north and east of Wallaville to the south, is the Electra Fault (documented in the Bundaberg Geology Sheet and accompanying notes). The red line to the west of Gin Gin, extending to the south and converging with the Electra fault, is an undocumented fault, inferred from the locations of the earthquakes in conjunction with geological features observed during the analysis of the earthquake locations.

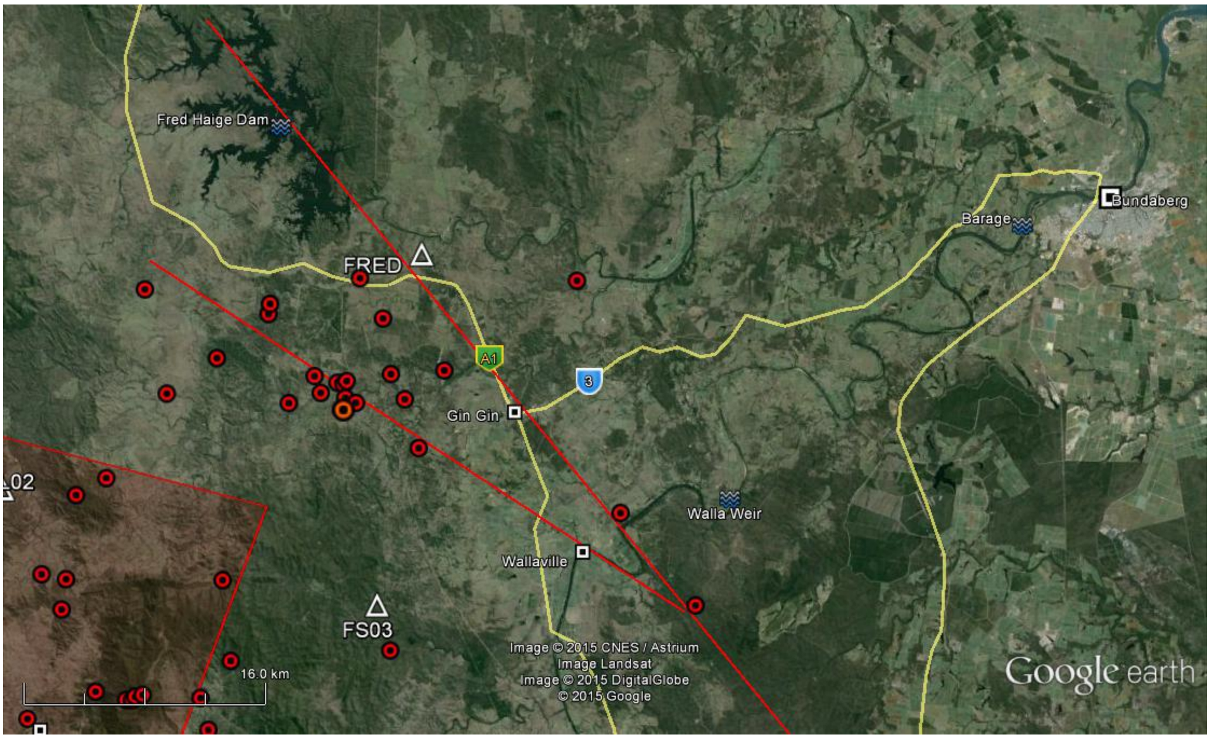

Figure 6: 2015 Gin Gin Earthquake and aftershocks.

CQSRG has nominally named the inferred fault the **Gin Gin Fault**.

In Figure 6 it can be seen that the Electra fault crosses the Burnett River at a distinct right-angle southern deviation of the river. This deviation is paired some 2 km to its south west by a similar right-angle southern deviation, which indicates the location of a second fault.

Figure 7 shows the inferred Gin Gin Fault where it crosses the Gin Gin Creek west of Gin Gin. Here there is a distinct double right-angle deviation in Gin Gin Creek at the location of the inferred Gin Gin Fault.

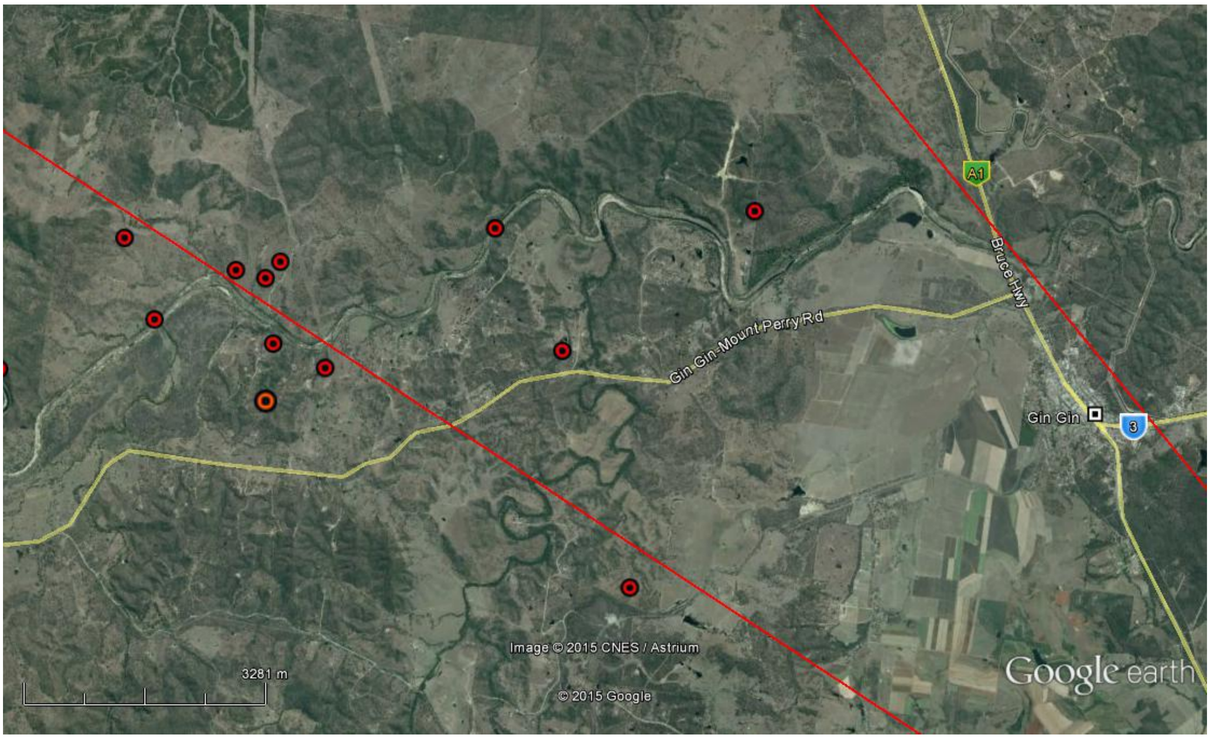

Figure 7: The Gin Gin Fault at Gin Gin Creek.

Although the magnitudes of the GG 2015 sequence events are very small (none of them, including the main event are greater than ML 1.2) the fact that the detection and subsequent location of them has revealed an important geological feature such as the Gin Gin Fault is an indication that monitoring for similar events is an important tool for seismological research in the Central Queensland region (as, indeed, it is for all regions of Australia). Not only, in this particular case, does this small earthquake sequence reveal the presence of the inferred Gin Gin Fault, it also attests to the fact that either the Electra Fault or the Gin Gin Fault, or both of them, are seismically active. This is important information on the social level, as it indicates that this area **will** generate earthquakes in the future. Interpreted in conjunction with knowledge of the other significant events concurrently occurring throughout the immediate region, it may be inferred that **any of the currently active zones are capable of generating large and potentially damaging earthquake events at any time**.

CQSRG Earthquake catalogue 2015

During 2015, 205 earthquake events were detected by CQSRG, and locations were attempted for all events. Details of these events are provided in Table 1. The online full version of the CQSRG catalogue can be accessed at http://www.cqsrg.org.

It is noted that the depth has been constrained to the local norm where the EQLOCL algorithm could not calculate a depth, due to lack of vertical resolution. Due to FS03 being off line at the time, magnitudes of the Mt Perry earthquake and aftershocks occurring on 2015-02-15 and 16 were determined using EIDS records, according to the method described in Appendix D.

Table 1: Earthquake Events Detected by CQSRG during 2015.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-02-15	15:57:08.74	151.398	-25.114	10.0 km	Constrained to Local norm	5.0 ML	Earthquake Mainshock	Mt Perry	26 km NW Mt Perry. Felt strongly in CQ. Felt in Chermside, Brisbane. Numerous aftershocks during following months.
2015-02-15	15:59:04.34	151.500	-25.120	10.0 km	Constrained to Local norm	3.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:03:10.88	151.490	-25.140	10.0 km	Constrained to Local norm	1.8 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:04:42.78	151.490	-25.110	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 18 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:14:38.09	151.520	-25.120	10.0 km	Constrained to Local norm	2.4 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 14 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:19:59.14	151.490	-25.150	10.0 km	Constrained to Local norm	2.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km WNW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:20:16.91	151.480	-25.140	10.0 km	Constrained to Local norm	2.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:25:44.92	151.510	-25.130	10.0 km	Constrained to Local norm	1.4 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km WNW Mt Perry. Reviewed 2015-09-03.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-02-15	16:37:51.72	151.452	-25.179	10.0 km	Constrained to Local norm	2.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 19 km W Mt Perry. Reviewed 2015-09-03.
2015-02-15	17:37:04.43	151.509	-25.113	10.0 km	Constrained to Local norm	3.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km W Mt Perry. Reviewed 2015-09-03.
2015-02-15	18:06:06.03	151.491	-25.108	10.0 km	Constrained to Local norm	2.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	19:00:25.08	151.517	-25.152	10.0 km	Constrained to Local norm	1.4 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 9 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	19:04:38	151.500	-25.200	10.0 km	Constrained to Local norm	0.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km W Mt Perry. Reviewed 2015-09-03.
2015-02-15	20:21:29.38	151.441	-25.107	10.0 km	Constrained to Local norm	1.5 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 22 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	22:56:57.09	151.472	-25.096	10.0 km	Constrained to Local norm	1.8 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 20 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:30:57:05	151.490	-25.150	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km WNW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:40.04.69	151.450	-25.110	10.0 km	Constrained to Local norm	1.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 21 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-15	16:40.35.87	151.322	-25.095	10.0 km	Constrained to Local norm	3.3 ML	Earthquake Mainshock	Mt Perry	34 km NW Mt Perry. Reviewed 2015-09-03.
2015-02-16	05:56:50.68	151.399	-25.094	10.0 km	Constrained to Local norm	4.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 27 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-16	06:02:11.39	151.400	-25.100	10.0 km	Constrained to Local norm	0.4 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 27 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-16	23:05:12.42	151.502	-25.123	10.0 km	Constrained to Local norm	0.5 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-17	00:47:10.01	151.524	-25.108	10.0 km	Constrained to Local norm	1.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-09-02.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-02-17	00:54:54.72	151.524	-25.112	10.0 km	Constrained to Local norm	1.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 14 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-17	02:21:04.81	151.518	-25.109	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-17	03:34:48.69	151.518	-25.114	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-17	06:02:15.81	151.532	-25.101	10.0 km	Constrained to Local norm	2.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 14 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-17	08:22:37.10	151.505	-25.116	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-17	08:27:20.35	151.476	-25.117	10.0 km	Constrained to Local norm	1.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 18 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-17	10:00:54.29	151.501	-25.113	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-02.
2015-02-17	10:03:20	151.501	-25.113	10.0 km	Constrained to Local norm	0.8 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Only recorded on EIDS. Loc stated is that of event 2 minutes earlier. Reviewed 2015-09-02.
2015-02-17	13:35:35.00	151.489	-25.117	10.0 km	Constrained to Local norm	1.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-17	15:47:13.84	151.498	-25.117	10.0 km	Constrained to Local norm	1.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-17	15:58:33.23	151.507	-25.113	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-17	18:50:40.19	151.493	-25.116	10.0 km	Constrained to Local norm	0.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-17	19:39:58.94	151.508	-25.116	10.0 km	Constrained to Local norm	0.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-01.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-02-18	12:38:13.88	151.521	-25.107	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 14 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-18	21:39:15.72	151.490	-25.113	10.0 km	Constrained to Local norm	1.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-19	04:41:49.87	151.702	-25.162	10.0 km	Constrained to Local norm	0.6 ML	Earthquake Mainshock	Mt Perry	6 km ENE Mt Perry. Reviewed 2015-09-01.
2015-02-19	06:30:55.93	151.900	-25.233	10.0 km	Constrained to Local norm	1.6 ML	Earthquake Foreshock	Goodnight Scrub	26 km ESE Mt Perry. 12 km N Paradise dam. Reviewed 2015-09-01.
2015-02-19	06:32:14.37	151.999	-24.914	10.0 km	Constrained to Local norm	0.7 ML	Earthquake Foreshock	Bullyard	8 km NW Bullyard. Reviewed 2015-09-01
2015-02-19	07:17:19.74	151.490	-25.110	10.0 km	Constrained to Local norm	1.4 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-19	21:57:56.19	151.489	-25.111	10.0 km	Constrained to Local norm	1.5 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 18 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-20	07:58:10.06	151.513	-25.126	10.0 km	Constrained to Local norm	1.5 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 14 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-20	18:51:39.17	151.470	-25.104	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 19 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-21	12:37:02	151.730	-24.980	10.0 km	Constrained to Local norm	0.8 ML	Earthquake Mainshock	Mt Perry	20 km NE of FS03.
2015-02-22	23:11:08.71	151.498	-25.103	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-23	18:10:02.89	151.507	-25.113	10.0 km	Constrained to Local norm	0.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-24	14:02:41.30	151.505	-25.109	10.0 km	Constrained to Local norm	1.8 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-24	14:15:45.08	151.464	-25.093	10.0 km	Constrained to Local norm	0.8 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 21 km NW Mt Perry. Reviewed 2015-09-01.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-02-25	17:34:56.67	151.525	-25.109	10.0 km	Constrained to Local norm	0.8 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 14 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-26	02:08:15.83	151.502	-24.124	10.0 km	Constrained to Local norm	1.5 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-26	20:45:04.27	151.501	-25.114	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-26	22:06:08.70	151.458	-25.095	10.0 km	Constrained to Local norm	0.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 21 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-26	23:21:55.52	151.496	-25.111	10.0 km	Constrained to Local norm	1.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-27	07:23:19.50	151.524	-25.126	10.0 km	Constrained to Local norm	0.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-27	16:18:02.26	151.508	-25.111	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-09-01.
2015-02-28	17:57:08.05	151.529	-25.126	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 13 km NW Mt Perry. Reviewed 2015-09-01.
2015-03-01	00:46:42.06	151.523	-25.109	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-09-01.
2015-03-13	02:19:13.92	151.506	-25.132	10.0 km	Constrained to Local norm	2.3 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-09-01.
2015-03-13	18:48:22.91	151.485	-25.124	10.0 km	Constrained to Local norm	1.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-09-01.
2015-03-18	14:41:32.84	151.482	-25.111	10.0 km	Constrained to Local norm	2.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 18 km NW Mt Perry. Reviewed 2015-09-01.
2015-03-19	02:28:42.98	151.910	-25.384	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Mainshock	Biggenden	19 km NW Biggenden. Reviewed 2015-09-01.
2015-03-19	16:50:13.36	151.766	-25.091	10.0 km	Constrained to Local norm	0.7 ML	Earthquake Mainshock	Mt Perry	15 km NE Mt Perry. Reviewed 2015-08-31.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-03-19	18:48:28.48	151.517	-25.053	10.0 km	Constrained to Local norm	1.4 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 19 km NW Mt Perry. Reviewed 2015-08-31.
2015-03-21	01:56:04.95	151.474	-25.115	10.0 km	Constrained to Local norm	1.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 19 km NW Mt Perry. Reviewed 2015-08-31.
2015-03-29	22:12:27.71	151.491	-25.127	10.0 km	Constrained to Local norm	2.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-08-31.
2015-03-30	01:41:51.25	151.488	-25.065	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 20 km NW Mt Perry. Reviewed 2015-08-31.
2015-04-06	17:41:44.60	151.507	-25.106	10.0 km	Constrained to Local norm	1.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-08-31.
2015-04-13	20:14:49.44	151.870	-25.250	10.0 km	Constrained to Local norm	0.8 ML	Earthquake Mainshock	Mt Perry	16 km S FS03. Reviewed 2015-08-31.
2015-04-14	12:56:24.00	151.518	-25.119	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-08-31.
2015-04-14	17:35:06.16	151.505	-25.121	10.0 km	Constrained to Local norm	1.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-08-31.
2015-04-15	11:14:33.21	151.502	-25.119	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-08-31.
2015-04-17	11:19:27.25	151.520	-25.115	10.0 km	Constrained to Local norm	1.5 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 14 km NW Mt Perry. Reviewed 2015-08-31.
2015-04-19	16:41:32.41	151.493	-25.121	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-08-31.
2015-04-21	04:20:39.38	151.760	-25.380	10.0 km	Constrained to Local norm	1.7 ML	Earthquake Mainshock	Mt Perry	25 km SW Mt Perry. Reviewed 2015-08-31.
2015-04-21	10:11:14.12	151.385	-25.231	10.0 km	Constrained to Local norm	2.1 ML	Earthquake Mainshock	Mt Perry	27 km WSW Mt Perry. Reviewed 2015-06-04.
2015-04-21	16:21:19.35	151.506	-25.122	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 15 km NW Mt Perry. Reviewed 2015-08-31.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-04-22	08:35:34.23	151.501	-25.116	10.0 km	Constrained to Local norm	2.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-08-31.
2015-05-04	18:24:54.97	151.473	-25.027	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 24 km NW Mt Perry. Reviewed 2015-08-10.
2015-05-04	18:35:03.68	151.492	-25.080	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 19 km NW Mt Perry. Reviewed 2015-08-31.
2015-05-09	06:39	151.867	-25.107	10.0 km	Constrained to Local norm	0.7 ML	Earthquake Mainshock	Horse Camp	8 km from FS03. Location given is that of FS03. Time is to the nearest minute.
2015-05-10	13:05:52.60	151.500	-25.100	10.0 km	Constrained to Local norm	0.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-08-30.
2015-05-15	06:04:13.99	151.503	-25.087	10.0 km	Constrained to Local norm	2.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 18 km NW Mt Perry. Reviewed 2015-08-30.
2015-05-22	08:09:01.32	151.383	-25.225	10.0 km	Constrained to Local norm	1.7 ML	Earthquake Mainshock	Mt Perry	27 km WSW Mt Perry. Reviewed 2015-08-30.
2015-05-24	02:42:22.73	151.805	-25.485	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Mainshock	Biggenden	24 km WNW Biggenden. Reviewed 2015-08-30.
2015-06-02	23:53:00.98	151.526	-25.124	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 13 km NW Mt Perry. Reviewed 2015-09-07.
2015-06-04	22:48:28.09	151.498	-25.095	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 18 km NW Mt Perry. Reviewed 2015-08-30.
2015-06-05	10:13:50.27	151.608	-25.432	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Aftershock	Mt Perry	28 km S Mt Perry. Reviewed 2015-08-30.
2015-06-11	16:33:34.90	151.543	-25.146	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Mainshock	Mt Perry	Aftershock of 2015-02-15. 13 km WNW Mt Perry. Reviewed 2015-08-30.
2015-06-14	03:50:34.47	151.491	-25.073	10.0 km	Constrained to Local norm	1.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 20 km NW Mt Perry. Reviewed 2015-06-20.
2015-06-14	04:02:03.55	151.746	-25.261	10.0 km	Constrained to Local norm	2.6 ML	Earthquake Mainshock	Mt Perry	14 km SE Mt Perry. Reviewed 2015-08-30.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-06-18	23:08:53.65	151.759	-25.352	10.0 km	Unconstrained	1.2 ML	Earthquake Mainshock	Mt Perry	38 km SE Mt Perry. Reviewed 2015-08-29.
2015-06-20	10:06:56.50	151.493	-25.093	10.0 km	Constrained to Local norm	1.5 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 18 km NW Mt Perry. Reviewed 2015-08-30.
2015-06-21	19:03:55.88	151.584	-25.287	10.0 km	Constrained to Local norm	1.0 ML	Earthquake Mainshock	Mt Perry	Aftershock of 2015-02-15. 13 km SSW Mt Perry. Reviewed 2015-08-30.
2015-06-23	07:10:18.02	151.487	-25.119	10.0 km	Constrained to Local norm	2.8 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km NW Mt Perry. Reviewed 2015-08-09.
2015-06-23	07:29:46.54	151.501	-25.107	11.0 km	Unconstrained	1.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 16 km NW Mt Perry. Reviewed 2015-08-09.
2015-06-25	07:29:33.36	152.371	-27.055	7.0 km	Unconstrained	3.3 ML	Earthquake Mainshock	Toogoolawah	3 km N Toogoolawah. Reviewed 2015-08-30.
2015-06-26	08:28:59.95	151.499	-25.158	10.0 km	Constrained to Local norm	1.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 17 km WNW Mt Perry. Reviewed 2015-08-30.
2015-06-26	23:11:46.47	151.537	-24.985	10.0 km	Constrained to Local norm	1.5 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 24 km NW Mt Perry. Reviewed 2015-08-09.
2015-06-28	03:55:07.57	151.706	-25.162	10.0 km	Constrained to Local norm	1.6 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15.60 km ENE Mt Perry. Reviewed 2015-08-30.
2015-07-03	18:12:28.98	151.664	-25.090	10.0 km	Constrained to Local norm	1.8 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 10 km N Mt Perry. Reviewed 2015-08-30.
2015-07-12	20:00:37.95	151.447	-25.061	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 24 km N Mt Perry. Reviewed 2015-08-30.
2015-07-15	20:57:19.58	152.784	-24.555	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Mainshock	Bundaberg	56 km NE Bundaberg. Reviewed 2015-08-13.
2015-07-21	05:03	151.876	-25.133	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Mainshock	Horse Camp	3 km SE FS03. Located using FS03 first motion azimuth and EIDS. Time is to the nearest minute. Reviewed 2015-08-09.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-07-21	05:05:54.17	151.913	-28.794	4.0 km	Unconstrained	3.1 ML	Earthquake Aftershock	Stanthorpe	16 km S Stanthorpe. Reviewed 2015-09-06.
2015-07-27	12:52:00.44	151.496	-25.093	10.0 km	Constrained to Local norm	2.2 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15. 18 km NW Mt Perry. Reviewed 2015-08-09.
2015-07-29	23:41:42.24	154.128	-25.462	10.0 km	Constrained to Local norm	5.4 ML	Earthquake Mainshock	Rainbow Beach	115 km NE Rainbow Beach. Felt in Gayndah and on the Gold Coast (300 km). Reviewed 2015-08-28.
2015-07-29	23:44:58.42	154.390	-25.285	10.0 km	Constrained to Local norm	4.3 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 147 kmNE Rainbow Beach. Reviewed 2015-08-29.
2015-07-30	01:59:00.33	154.358	-25.298	10.0 km	Constrained to Local norm	4.0 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 143 km NE Rainbow Beach. Reviewed 2015-08-29.
2015-07-31	04:11:53.19	154.265	-25.417	10.0 km	Constrained to Local norm	3.8 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 129 km NE Rainbow Beach. Reviewed 2015-08-04.
2015-07-31	04:31:47.46	154.403	-25.364	10.0 km	Constrained to Local norm	2.4 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 143 kmN E Rainbow Beach. Reviewed 2015-08-08.
2015-07-31	22:05:11.27	154.210	-25.413	10.0 km	Constrained to Local norm	2.2 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 123 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-01	01:18:20.95	154.374	-25.340	10.0 km	Constrained to Local norm	3.5 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 143 km NE Rainbow Beach. Reviewed 2015-08-21.
2015-08-01	03:38:44.06	154.414	-25.316	10.0 km	Constrained to Local norm	5.3 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 146 km NE Rainbow Beach. Reviewed 2015-08-21.
2015-08-01	03:43:15.75	154.443	-25.338	10.0 km	Constrained to Local norm	3.4 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 150 km NE Rainbow Beach. Reviewed 2015-08-06.
2015-08-01	03:48:21.66	154.343	-25.386	10.0 km	Constrained to Local norm	2.8 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 137 km NE Rainbow Beach. Reviewed 2015-08-07.
2015-08-01	04:10:22.89	154.370	-25.354	10.0 km	Constrained to Local norm	2.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 141 km NE Rainbow Beach. Reviewed 2015-08-21.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-08-01	04:29:33.90	154.465	-25.403	10.0 km	Constrained to Local norm	2.3 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 147 km NE Rainbow Beach. Reviewed 2015-08-07.
2015-08-01	04:46:23.24	154.419	-25.309	10.0 km	Constrained to Local norm	5.1 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 149 km NE Rainbow Beach. Reviewed 2015-08-28.
2015-08-01	04:51:39.28	154.446	-25.377	10.0 km	Constrained to Local norm	3.0 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 146 km NE Rainbow Beach. Reviewed 2015-08-07.
2015-08-01	04:57:20.15	153.895	-25.534	10.0 km	Constrained to Local norm	2.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 90 km NE Rainbow Beach. Reviewed 2015-08-07.
2015-08-01	05:08:32.06	154.317	-25.326	10.0 km	Constrained to Local norm	3.2 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 139 km NE Rainbow Beach. Reviewed 2015-08-04.
2015-08-01	05:54:14.32	154.381	-25.344	10.0 km	Constrained to Local norm	2.8 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 143 km NE Rainbow Beach. Reviewed 2015-08-04.
2015-08-01	06:29:05.56	154.230	-25.389	10.0 km	Constrained to Local norm	2.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 128 km NE Rainbow Beach. Reviewed 2015-08-04.
2015-08-01	06:53:43.98	154.367	-25.345	10.0 km	Constrained to Local norm	2.9 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 141 km SE Rainbow Beach. Reviewed 2015-08-07.
2015-08-01	06:56:48.53	154.348	-25.337	10.0 km	Constrained to Local norm	3.1 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 140 km NE Rainbow Beach. Reviewed 2015-08-07.
2015-08-01	07:06:48.85	154.373	-25.317	10.0 km	Constrained to Local norm	2.5 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 144 km NE Rainbow Beach. Reviewed 2015-08-04.
2015-08-01	07:15:18.06	154.386	-25.319	10.0 km	Constrained to Local norm	3.2 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 144 km NE Rainbow Beach. Reviewed 2015-08-04.
2015-08-01	07:28:19.74	154.350	-25.393	10.0 km	Constrained to Local norm	2.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 136 km NE Rainbow Beach. Reviewed 2015-08-04.
2015-08-01	11:10:59.64	154.296	-25.388	10.0 km	Constrained to Local norm	2.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 133 km NE Rainbow Beach. Reviewed 2015-08-06.
2015-08-01	11:17:42.32	154.327	-25.321	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 139 km NE Rainbow Beach. Reviewed 2015-08-06.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-08-01	13:34:19.87	154.339	-25.323	10.0 km	Constrained to Local norm	2.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 139 km NE Rainbow Beach. Reviewed 2015-08-06.
2015-08-01	13:51:16.24	154.410	-25.319	10.0 km	Constrained to Local norm	2.6 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 147 km NE Rainbow Beach. Reviewed 2015-08-06.
2015-08-01	14:20:42.51	154.414	-25.355	10.0 km	Constrained to Local norm	3.2 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 145 km NE Rainbow Beach. Reviewed 2015-08-06.
2015-08-01	14:51:09.55	154.421	-25.301	10.0 km	Constrained to Local norm	2.6 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 149 km NE Rainbow Beach. Reviewed 2015-08-06.
2015-08-01	18:56:03.99	154.347	-25.335	10.0 km	Constrained to Local norm	2.2 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 140 km NE Rainbow Beach. Reviewed 2015-08-06.
2015-08-02	00:27:22.60	154.340	-25.366	10.0 km	Constrained to Local norm	2.5 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 138 km NE Rainbow Beach. Reviewed 2015-08-06.
2015-08-02	12:03:20	151.870	-25.110	10.0 km	Constrained to Local norm	0.8 ML	Earthquake Mainshock	Horse Camp	Within 22 km of FS03. Location is that of FS03. Reviewed 2015-08-02.
2015-08-02	14:35:06.29	154.456	-25.347	10.0 km	Constrained to Local norm	2.3 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 150 km NE Rainbow Beach. Reviewed 2015-08-07.
2015-08-03	01:52:51.61	154.409	-25.314	10.0 km	Constrained to Local norm	3.0 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 148 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-03	01:55:00.76	154.408	-25.335	10.0 km	Constrained to Local norm	2.8 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 145 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-03	06:55:52.08	154.471	-25.280	10.0 km	Constrained to Local norm	2.5 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 153 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-03	15:07:38.48	154.205	-25.318	10.0 km	Constrained to Local norm	2.2 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 129 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-03	16:42:49.02	154.456	-25.287	10.0 km	Constrained to Local norm	3.3 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 152 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-03	19:18:57.67	154.396	-25.373	10.0 km	Constrained to Local norm	3.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 142 km NE Rainbow Beach. Reviewed 2015-08-08.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-08-03	19:20:30.24	154.346	-25.374	10.0 km	Constrained to Local norm	2.9 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 111 km NE Rainbow Beach. Reviewed 2015-08-03.
2015-08-04	05:16:03.13	154.402	-25.335	10.0 km	Constrained to Local norm	2.9 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 145 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-04	08:36:37.46	154.373	-25.355	10.0 km	Constrained to Local norm	2.5 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 141 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-04	11:56:55.29	154.341	-25.375	10.0 km	Constrained to Local norm	2.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 136 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-06	05:36:53.88	154.391	-25.344	10.0 km	Constrained to Local norm	3.6 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 143 km NE Rainbow Beach. Reviewed 2015-08-08.
2015-08-08	09:09:04.93	154.392	-25.364	10.0 km	Constrained to Local norm	2.9 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 141 km ENE Rainbow Beach. Reviewed 2015-08-09.
2015-08-14	01:06:57.11	154.250	-25.385	10.0 km	Constrained to Local norm	4.2 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 129 km NE Rainbow Beach. Reviewed 2015-08-014.
2015-08-15	16:22:58.73	154.331	-25.367	10.0 km	Constrained to Local norm	2.6 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 136 km NE Rainbow Beach. Reviewed 2015-08-16.
2015-08-16	03:05:11.13	151.606	-25.263	10.0 km	Constrained to Local norm	1.5 ML	Earthquake Mainshock	Mt Perry	10 KM SSW Mt Perry. Reviewed 2015-08-16.
2015-08-19	02:39:09.60	151.511	-25.128	10.0 km	Constrained to Local norm	0.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 15 km WNW Mt Perry. Reviewed 2015-08-19.
2015-08-19	23:04:55.84	154.317	-25.368	10.0 km	Constrained to Local norm	2.8 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 136 km NE Rainbow Beach. Reviewed 2015-08-20.
2015-08-21	13:37:44.83	154.300	-25.392	10.0 km	Constrained to Local norm	2.2 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 133 km NE Rainbow Beach. Reviewed 2015-08-22.
2015-08-21	16:09:37.17	154.347	-25.361	10.0 km	Constrained to Local norm	2.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 139 km NE Rainbow Beach. Reviewed 2015-08-22.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-08-26	01:29:28.11	151.505	-25.137	10.0 km	Constrained to Local norm	2.0 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 15 km NW Mt Perry. Reviewed 2015-08-27.
2015-08-28	06:17:25.00	151.932	-25.335	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Mainshock	Paradise Dam	2 km NE Paradise dam. Reviewed 2015-09-04.
2015-09-03	19:34:46.47	151.810	-24.986	10.0 km	Constrained to Local norm	1.0 ML	Earthquake Mainshock	Gin Gin	15 Km W Gin Gin. Reviewed 2015-09-04.
2015-09-04	15:23:17.72	152.952	-24.152	10.0 km	Constrained to Local norm	2.1 ML	Earthquake Mainshock	Lady Elliot Island	24 km E Lady Elliot Island. Reviewed 2015-09-05.
2015-09-05	03:08:18.93	150.466	-25.625	10.0 km	Constrained to Local norm	1.7 ML	Earthquake Mainshock	Cracow	40 km SSE Cracow. Reviewed 2015-09-05.
2015-09-07	20:02:34.17	151.502	-25.099	10.0 km	Constrained to Local norm	0.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 17 km NW Mt Perry. Reviewed 2015-09-08.
2015-09-16	23:37:28.62	154.469	-25.284	10.0 km	Constrained to Local norm	3.6 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 154 km NE Rainbow Beach. Reviewed 2015-09-17.
2015-09-17	21:08:16.77	151.520	-25.122	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 14 km NW Mt Perry. Reviewed 2015-09-19.
2015-09-18	22:04:04.39	151.514	-25.121	10.0 km	Constrained to Local norm	1.4 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 15 km NW Mt Perry. Reviewed 2015-09-19.
2015-09-22	15:25:26.93	151.486	-25.084	10.0 km	Constrained to Local norm	0.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 19 km NW Mt Perry. Reviewed 2015-09-23.
2015-09-27	15:59:24.82	151.504	-25.090	10.0 km	Constrained to Local norm	1.7 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 17 km NW Mt Perry. Reviewed 2015-09-28.
2015-10-01	20:11:32.59	152.623	-24.745	10.0 km	Constrained to Local norm	1.6 ML	Earthquake Mainshock	Bundaberg	31 km NE Bundaberg. Reviewed 2015-10-02.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-10-11	03:24:40.19	154.115	-25.470	10.0 km	Constrained to Local norm	3.4 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 112 km NE Rainbow Beach. Reviewed 2015-10-15.
2015-10-22	20:45:12.25	154.428	-25.372	10.0 km	Constrained to Local norm	4.1 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 146 km NE Rainbow Beach. Reviewed 2015-10-23.
2015-10-29	08:13:29.14	154.302	-25.409	10.0 km	Constrained to Local norm	3.6 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 132 km NE Rainbow Beach. Reviewed 2015-10-30.
2015-11-18	07:38:39.29	148.815	-20.014	10.0 km	Constrained to Local norm	3.6 ML	Earthquake Mainshock	Hook Island	15 km NW Hook Island. Reviewed 2015-11-19. Mag assigned by GA.
2015-11-18	23:47:13.24	151.752	-25.343	10.0 km	Constrained to Local norm	2.1 ML	Earthquake Mainshock	Mt Perry	21 km SE Mt Perry. Reviewed 2015-11-19.
2015-11-24	20:45:30.25	151.827	-24.970	10.0 km	Constrained to Local norm	0.4 ML	Earthquake Foreshock	Gin Gin	13 km WNW Gin Gin. Reviewed 2015-11-26.
2015-11-24	20:46:17.56	151.857	-24.912	10.0 km	Constrained to Local norm	0.6 ML	Earthquake Foreshock	Gin Gin	13 km NW Gin Gin. Reviewed 2015-11-26.
2015-11-24	20:46:33.12	151.846	-24.990	10.0 km	Constrained to Local norm	1.2 ML	Earthquake Mainshock	Gin Gin	11 km W Gin Gin. Reviewed 2015-11-26.
2015-11-24	20:48:39.52	151.895	-25.013	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Gin Gin	7 km WSW Gin Gin. Reviewed 2015-11-26.
2015-11-24	21:02:09.12	151.763	-24.959	10.0 km	Constrained to Local norm	0.1 ML	Earthquake Aftershock	Gin Gin	20 km W Gin Gin. Reviewed 2015-11-26.
2015-11-24	21:02:30.53	151.798	-24.927	10.0 km	Constrained to Local norm	0.1 ML	Earthquake Aftershock	Gin Gin	18 km WNW Gin Gin. Reviewed 2015-11-25.
2015-11-24	21:03:18.60	151.842	-24.974	10.0 km	Constrained to Local norm	0.9 ML	Earthquake Aftershock	Gin Gin	12 km W Gin Gin. Reviewed 2015-11-25.
2015-11-24	21:20:22.87	151.846	-24.975	10.0 km	Constrained to Local norm	1.0 ML	Earthquake Aftershock	Gin Gin	11 km W Gin Gin. Reviewed 2015-11-25.
2015-11-24	21:01:55:01	151.716	-24.918	10.0 km	Constrained to Local norm	0.2 ML	Earthquake Aftershock	Gin Gin	18 km NW Gin Gin. Reviewed 2015-11-26.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-11-24	21:13;01.06	151.854	-24.986	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Gin Gin	11 km W Gin Gin. Reviewed 2015-11-25.
2015-11-26	15:09:08.95	154.309	-25.429	10.0 km	Constrained to Local norm	3.0 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 134 km NE Rainbow Beach. Reviewed 2015-11-27.
2015-11-30	02:33:43.93	151.872	-24.936	10.0 km	Constrained to Local norm	0.9 ML	Earthquake Aftershock	Gin Gin	11 km NW Gin Gin. Reviewed 2015-11-30.
2015-11-30	17:35:58.70	151.797	-24.933	10.0 km	Constrained to Local norm	0.5 ML	Earthquake Aftershock	Gin Gin	17 km NW Gin Gin. Reviewed 2015-12-01.
2015-12-01	04:24:05.56	151.831	-24.980	10.0 km	Constrained to Local norm	0.8 ML	Earthquake Aftershock	Gin Gin	13 km W Gin Gin. Reviewed 2015-11-01.
2015-12-01	09:07:51.82	150.738	-24.816	10.0 km	Constrained to Local norm	3.3 ML	Earthquake Mainshock	Monto	40 km WNW Monto. Reviewed 2012-12-02.
2015-12-01	17:09:11.62	151.877	-24.969	18.0 km	Unconstrained	0.6 ML	Earthquake Aftershock	Gin Gin	9 km WNW Gin Gin. Reviewed 2015-12-02.
2015-12-01	21:37:19.35	151.912	-24.967	21.0 km	Unconstrained	0.9 ML	Earthquake Aftershock	Gin Gin	5 km NW Gin Gin. Reviewed 2015-12-02.
2015-12-02	12:00:59.98	151.847	-24.983	11.0 km	Unconstrained	0.6 ML	Earthquake Aftershock	Gin Gin	11 km W Gin Gin. Reviewed 2015-11-03.
2015-12-02	14:37:57.81	152.638	-24.382	10.0 km	Constrained to Local norm	1.9 ML	Earthquake Foreshock	Bundaberg	Foreshock of 15:10 event. 60 km NE Bundaberg. Reviewed 2015-12-03.
2015-12-02	14:52:57.97	151.848	-24.973	17.0 km	Unconstrained	0.4 ML	Earthquake Aftershock	Gin Gin	11 km W Gin Gin. Reviewed 2015-11-03.
2015-12-02	15:10:04.89	152.562	-24.369	10.0 km	Constrained to Local norm	2.1 ML	Earthquake Mainshock	Bundaberg	59 km NE Bundaberg. Reviewed 2015-12-03.
2015-12-04	18:53:06.93	151.886	-24.984	18.0 km	Unconstrained	0.8 ML	Earthquake Aftershock	Gin Gin	7 km W Gin Gin.
2015-12-05	20:12:32.51	151.880	-25.407	9.0 km	Unconstrained	1.5 ML	Earthquake Mainshock	Biggenden	20 km NW Biggenden. Reviewed 2015-12-06.

Date (UTC)	Time (UTC)	Longitude	Latitude	Depth	Depth Status	Magnitude	Event Type	Place	Comment
2015-12-11	09:40:07.73	151.647	-25.087	11.0 km	Unconstrained	1.4 ML	Earthquake Mainshock	Mt Perry	10 km N Mt Perry. Reviewed 2012-12-11.
2015-12-17	10:23	151.400	-26.051	10.0 km	Constrained to Local norm	1.3 ML	Earthquake Foreshock	Boondooma Dam	Foreshock of 2015-12-21 Boondooma Dam event. Reviewed 2015-12-22.
2015-12-21	16:00:35.13	151.400	-26.051	9.0 km	Unconstrained	2.9 ML	Earthquake Mainshock	Boondooma Dam	6 km NW Boondooma Dam. Reviewed 2015-12-22.
2015-12-21	17:06:55.59	151.518	-25.109	10.0 km	Constrained to Local norm	1.1 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 15 km NW Mt Perry. Reviewed 2015-12-22.
2015-12-25	18:40:07.06	154.212	-25.382	10.0 km	Constrained to Local norm	4.4 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 126 km NE Rainbow Beach. Reviewed 2015-12-26.
2015-12-25	18:40:09.35	154.486	-25.322	10.0 km	Constrained to Local norm	4.7 ML	Earthquake Aftershock	Rainbow Beach	Aftershock of 2015-07-29. 153 km NE Rainbow Beach. Reviewed 2015-12-26.
2015-12-29	17:49:38.54	151.494	-25.114	10.0 km	Constrained to Local norm	0.9 ML	Earthquake Aftershock	Mt Perry	Aftershock of 2015-02-15 15:57 event. 17 km NW Mt Perry. Reviewed 2015-12-30.

2015 Statistical Summary

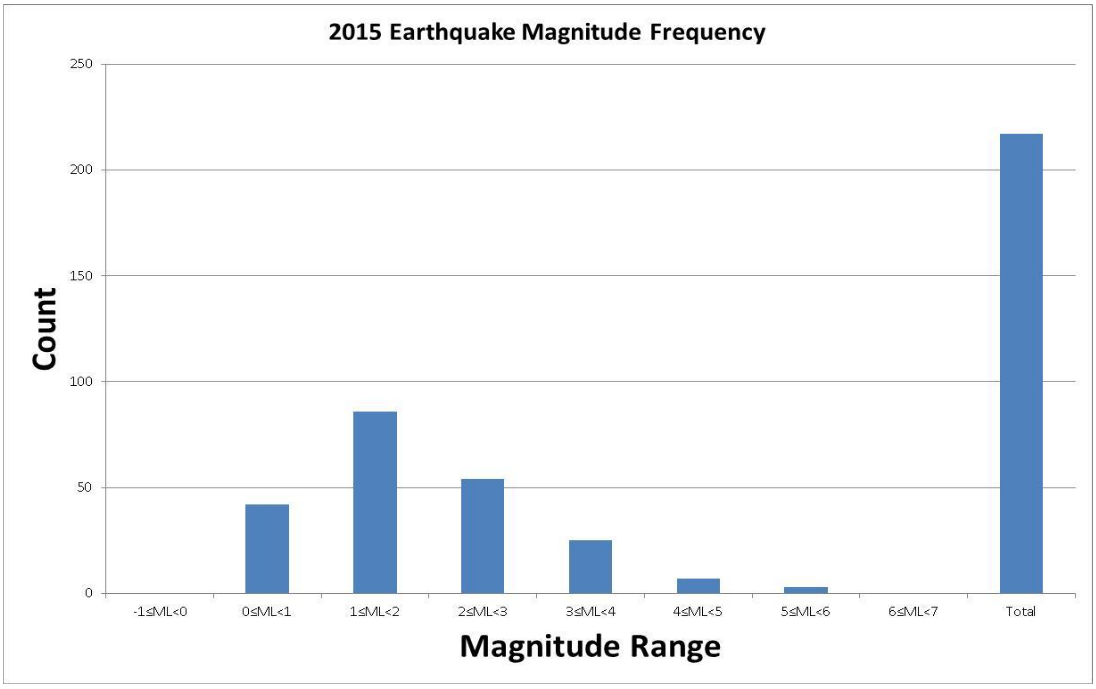

Figure 8: Earthquake magnitude Frequency 2015.

Figure 8 provides a graphical representation of the frequency of magnitude spread. 2015 exhibited a significantly greater number of earthquake events than previous years; producing four events of magnitude greater than or equal to ML 5.0.

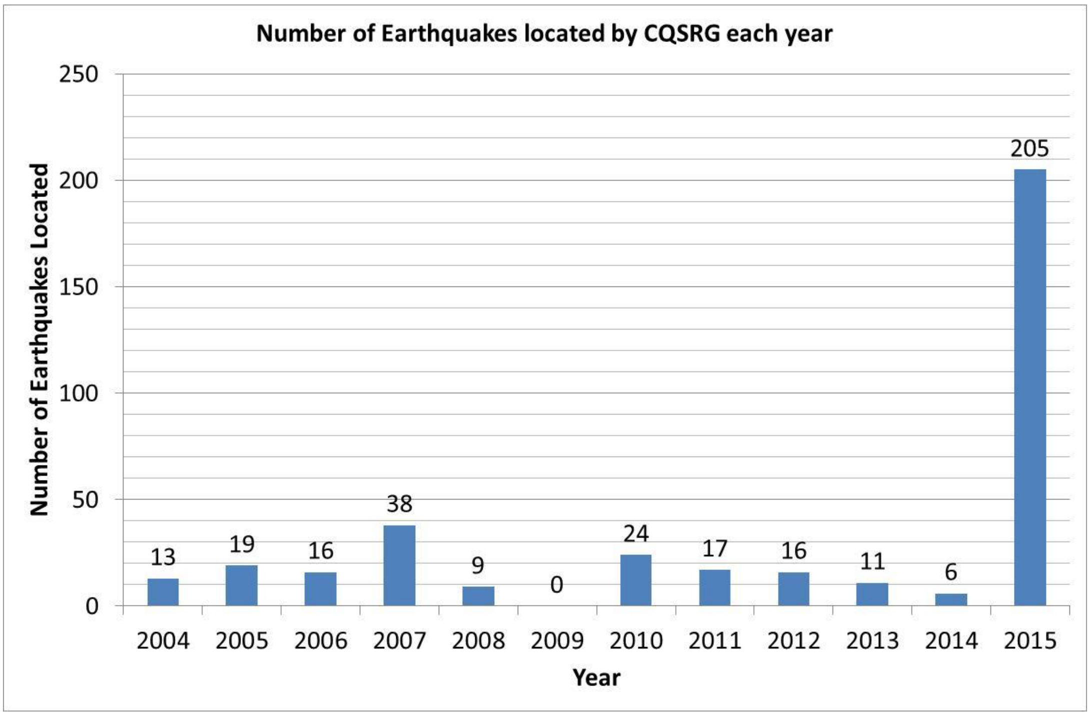

Figure 9: Yearly count of earthquakes detected by CQSRG.

Figure 9 puts into context the extraordinary number of earthquakes detected during 2015 when compared to the numbers detected in previous years.

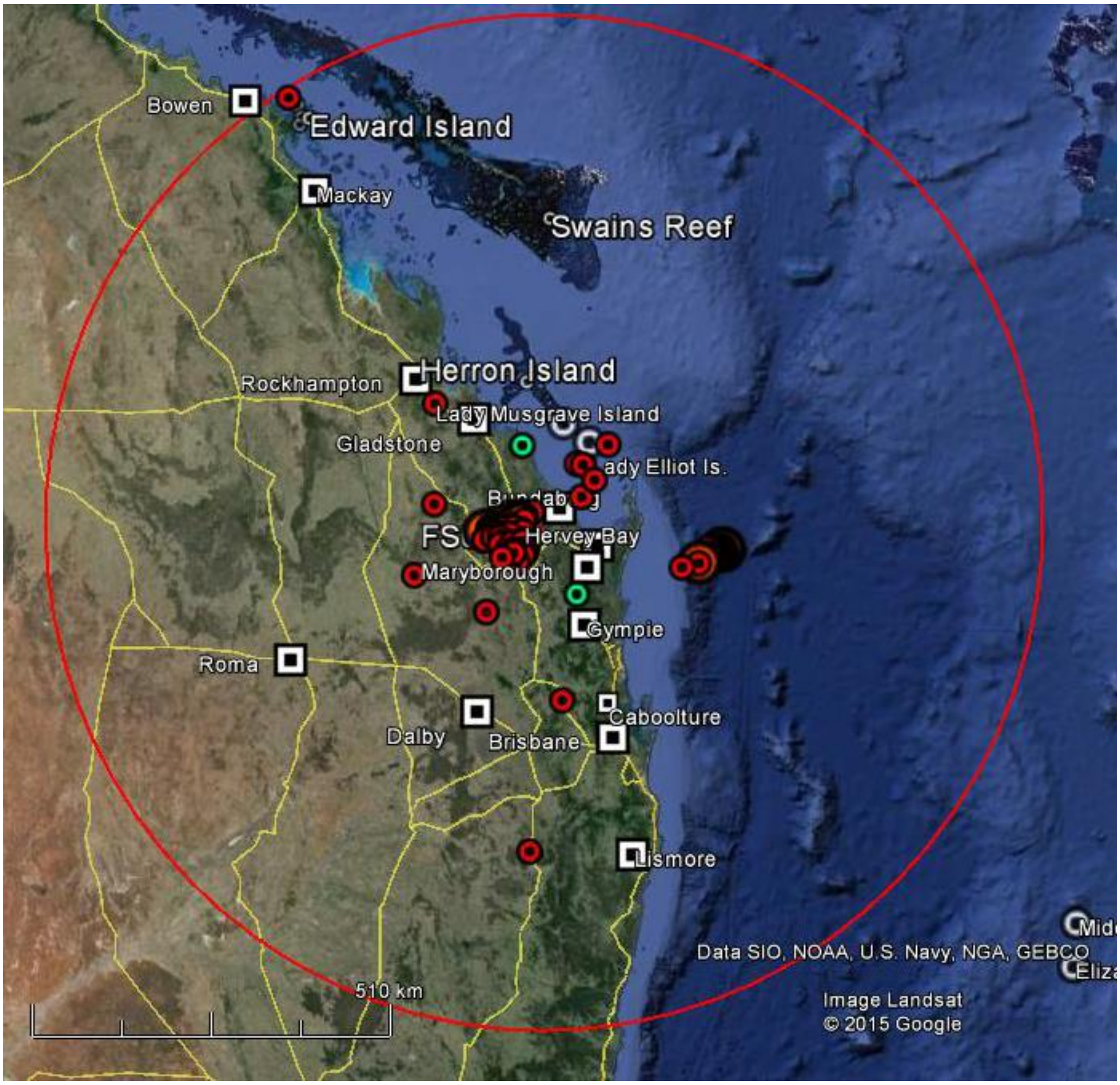

Figure 10: Broad view of 2015 earthquake locations.

Figure 10 is a broad-view map of the 2015 earthquake locations. The red circle in Figure 10 indicates that, during 2015, the most distant earthquake event detected by CQSRG was ML 3.6, approximately 660 km from FS03. The two green place markers are alternative positions of the same event that gave an ambiguous location due to the availability of data from only two stations.

Public Seismic Network (PSN)

Since 2011-08-05 CQSRG has hosted a PSN seismograph station, known to the Australian PSN community as the Gin Gin or the Horse Camp station. Vic Dent and Mike Turnbull originally installed the station with a rudimentary setup consisting of a 3D geophone attached to a PSN A/D board, in a vacant brick shed on Mike Turnbull's property at Horse Camp, 16 km SW of Gin Gin. Mike provided a desktop computer onto which the PSN software was installed. Since then the station has been regularly uploading GIF pictures of the daily seismogram traces to the Regional Seismic Users web site at http://www.rsuw.daleh.id.au/, operated by Dale Hardy. The station also uploads continuous data to the Regional Seismic Network (RSN), operated by the Australian Centre for Geomechanics (AGC) (Information at http://www.acg.uwa.edu.au/).

In 2013 the geophone was replaced with a Sprengnether S6000 seismometer, and the PSN A/D board was housed in a respectable electronics housing, along with custom made adaptor electronics to accommodate the sensor and GPS interface.

Since the PSN station is located only 300 m from FS03, data from the PSN station is not used in locating events detected by CQSRG.

Appendix A – Details of FS03

LOCATION

Latitude -25.1068, Longitude 151.8667, Height above sea level 180 m. Approximately 16 km SW Gin Gin, Queensland, Australia.

SITE AND SAMPLING

Sampling of ground velocity at 100 sample/sec, full scale 4194304 counts (for about a month after the Mt Perry earthquake the sample rate was increased to 200 sample/second)

Ch	Type	Serial	Name	Direction	Gain	Filters	
1	L43D	#1482	East	90 deg true	0.00	DC	50.0
2	L43D	#1482	North	0 deg true	0.00	DC	50.0
3	L43D	#1482	Up	Positive up	0.00	DC	50.0

DATA LOGGER

Kelunji Classic #153, GURIA V4.16A Operating System.

TIME SYNC

Sync every day at 1400 UCT, using GPS. Wait for up to 80 seconds
Wait up to 120 seconds for a position
Auto-correct clock after sync

TRIGGER SETTINGS

STA/LTA Channel 3, filter 1.00 to 7.50 Hz
Time const 0.20, 2.0, 20.0, 200.0 seconds
Ratios Fast 3.50, slow 1.75, squelch 5, 15 days
Length 100 to 200 secs, 80.00 sec pre-trigger, 1.10 cutoff.

Appendix B – CQSRG Method of Earthquake Location

In general, CQSRG only catalogues earthquake events that are detected by its seismic monitoring station(s). However, in the event of significant local events that, for reasons of station downtime, are not recorded by CQSRG stations, locations are conducted by obtaining data from other agencies.

The general process for earthquake event location at CQSRG is as follows.

1. Identify local earthquake events from visual inspection of FS03 seismograms.

2. Download extra seismograms from other agencies; typically, University of Queensland, Geoscience Australia, and the Australian National University (ANU) Australian Seismometers in Schools (AuSIS) project.

3. Send email requests to other agencies; typically, the Seismology Research Centre (SRC), and the South East Queensland Water Company (SeqWater).

4. Collect all available seismogram records and pick P and S phase arrival times using EqWave (SRC sourced software).

5. Enter the picked P and S times into EQLOCL (SRC sourced software).

6. Use the location calculated by EQLOCL.

In the not so rare cases where the only record available is that from FS03, an attempt is made to locate the event using first motion polarity and near field trigonometry. This can only be done when the first motions are sufficiently impulsive to give an unambiguous indication of the arrival azimuth.

In cases where only two records are available (invariably FS03 and EIDS), and the S-P derived radial distance circles meet, but do not over extend, the touch point is used as a seed to the EQLOCL algorithm.

In cases where only two records are available (invariably FS03 and EIDS), and the S-P derived radial distance circles over extend, but the first motions are sufficiently impulsive to derive an unambiguous azimuth, the radial touch point indicated by the azimuth direction is used as a seed to the EQLOCL algorithm.

In cases where only two records are available (invariably FS03 and EIDS), and the S-P derived radial distance circles over extend, but the first motions are insufficiently impulsive to derive an unambiguous azimuth, the locations of both the radial touch points are used as seeds to the EQLOCL algorithm, and the resulting ambiguous locations are noted in the catalogue entry comments.

In cases where the only information that can be gleaned is the radial distance from FS03, that distance may be noted in the catalogue listing comments.

Appendic C – CQSRG Method of Magnitude Quantification from FS03 Records

Calibration of FS03 Seismometer for Earthquake Magnitude Determination.

Mike Turnbull, 7 November, 2012.

Introduction

FS03 is the designation of a seismic monitoring station operated by the Central Queensland Seismology Research Group (CQSRG). It is located about 16 km south-west of Gin Gin.

When the FS03 station was first installed it had a Sprengnether S6000 seismometer attached to a data logger manufactured by the Seismology Research Centre (SRC). The characteristics of this sensor and the amplification factors of the data logger section of the seismograph were used as input to the SRC software used to locate and quantify earthquakes recorded on the seismograph. When the S6000 sensor failed it was replaced with a Mark Products L43D seismometer sensor. By comparison of the calibration waveform amplitudes of the S6000 against the L43D, a correction factor of 1.7 was calculated and used to adjust the amplitude value input to the SRC software to determine earthquake magnitudes using the new sensor – and this provided a temporary solution.

In order for the SRC software to be able to calculate an earthquake magnitude, it first must be able to calculate the earthquake's epicentral location. This can only be done if seismographic records from at least three different stations are available. In situations where only one or two records are available the software cannot locate the epicentre. Consequently, in cases where an earthquake cannot be located, determination of its magnitude using EQLOCL has always been problematic.

This appendix describes a method of extracting parametric information from past earthquake magnitudes, located with the SRC software using FS03 seismograms, that can be used in a suitable mathematical formula to determine the magnitude of other earthquakes recorded on the FS03 seismograph, using information from the single station data. This allows the magnitude determination to be done independent of the SRC software.

Background Information

The Richter local earthquake magnitude (M) is calculated using the formula given in Eq. 1.

$$M = log_{10}A - log_{10}A_0 \qquad \text{(Eq. 1)}$$

Where:

A is the maximum amplitude of the seismic record of the earthquake, and

$\mathrm{A_0}$ is the maximum amplitude that would be produced on the same sensor by an earthquake of magnitude zero, occurring at the same location as the earthquake under consideration.

The value of $\log_{10}\mathrm{A_0}$ is dependent only on the epicentral distance of the earthquake from the sensor, and the response characteristics of the sensor itself. It is assumed that the relationship is as given in Eq. 2 **(NOTE: This assumed relationship has yet to be confirmed as being valid)**.

$$log_{10}A_0 = a\delta + b \qquad \text{(Eq. 2)}$$

Where:

δ is the epicentral distance, and

a and b are parameters yet to be determined, characteristic of the sensor.

Method

It is clear that Eq.2 is linear. Therefore the sensor parameters a and b can be determined from the slope and intercept, respectively, of the graph of $\log_{10}A_0$ plotted against δ, providing that sufficient data is available

The epicentral distance δ can be expressed in any value that provides a valid determination of the distance from the sensor to the epicentre. This could be (for example):

- the difference in arrival times of the P and S waves (in seconds for example); or,
- the surface distance from sensor to epicentre (in km for example); or,
- the Earth centric angle of arc from sensor to epicentre (in degrees for example).

The values for $\log_{10}A_0$ can be calculated from past earthquake events, the magnitudes of which have been determined with the SRC software using FS03 seismograms.

Transformation of Eq.1 gives Eq. 3.

$$log_{10}A_0 = log_{10}A - M \qquad \text{(Eq.3)}$$

Table 2 presents the calculations of $\log_{10}A_0$ based on nine past events that were quantified with the SRC software, showing the S-P time differences used to measure epicentral distances.

Table 2: Determination of $\log_{10}A_0$ from past events recorded on the FS03 seismograph.

Earthquake Date	Measured P arrival in relative seconds	Measured S arrival in relative seconds	S-P time (s)	Measured Amplitude A	Magnitude estimated using ES&S algorithm M	Calculated $\log_{10}(A_0)$
2012-09-19 06:14	11.54	14.97	3.43	1900	1.6	1.6787536
2012-05-20 17:58	42.23	45.79	3.56	1103	1.5	1.5425755
2012-09-22 23:59	38.31	41.91	3.6	243	1.0	1.3856063
2012-04-10 01:51	37.54	42.57	5.03	473.2	1.4	1.2750447
2012-09-25 03:06	10.56	22.7	12.14	456	1.9	0.7589648
2012-08-19 22:37	29.38	41.82	12.44	215	1.5	0.8324385
2012-09-03 15:04	10.86	26.84	15.98	1828	2.8	0.4619762
2012-09-23 16:29	36.21	53.77	17.56	3620	3.2	0.3587086
2012-01-05 14:05	9.96	56.18	46.22	1352	4.3	-1.1690233

Figure 8 shows the graph of $\log_{10}A_0$ plotted against the associated S-P time difference (extracted from Table 2).

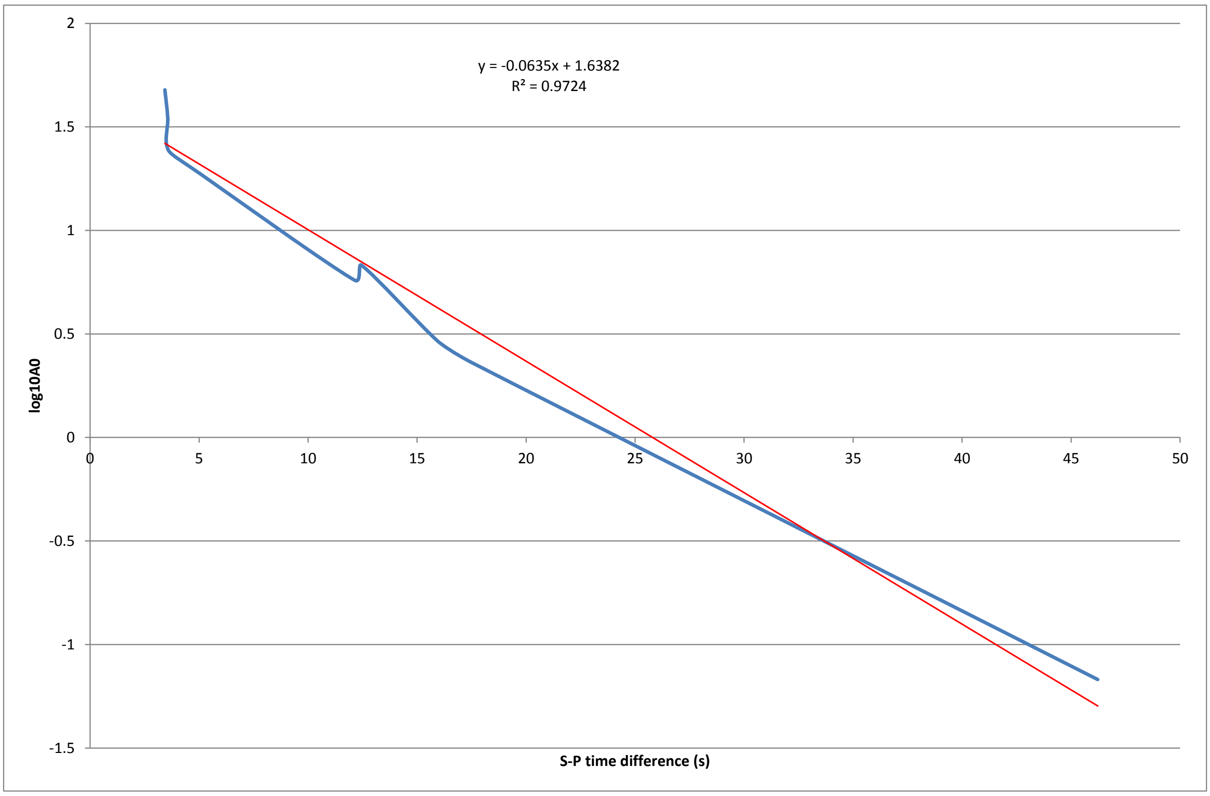

Figure 11: $\log_{10}A_0$ Vs S-P

Figure 8 also displays the line of best fit, calculated using linear regression of the plotting data, along with the slope, intercept, and correlation coefficient (R^2). **The R^2 value of 0.97 confirms that the assumed linear relationship is valid.**

By substituting the slope and intercept values into Eq.1 and Eq.2 we arrive at the formula for FS03 magnitudes given in Eq.4.

$$M_{FS03} = log_{10}A - (-0.064(S-P) + 1.64) \quad \text{(Eq.4)}$$

Where:

M_{FS03} is the Richter magnitude determined from an FS03 seismogram record;

A is the maximum amplitude of the unfiltered FS03 seismogram record;

S is the arrival time of the S wave in seconds, and;

P is the arrival time of the P wave in seconds.

Important Note Concerning Accuracy and Precision

Table 2, Figure 8, and Equation 4, show a shortened calculation using only 9 historical events, to demonstrate the method. A consequence of using so few input values is that the resulting error ranges will suffer. Consequently, in order to reduce the standard errors in magnitude calculations based on this method, and extend the accuracy to at least one decimal point, many more input data are required.

The calculations used to determine the actual $\log_{10}A_0$ values for FS03, used in quantifying earthquake magnitudes, used 34 historical events. This resulted in parameter **a** and **b** values for Equation 2, as shown in Table 3.

Table 3: Equation 2, a and b Parameter values and Standard Errors.

	a	b
Estimation	-0.088	1.81
Standard Error	±0.004	±0.05
Correlation	0.94	

This implies that magnitudes determined using this method will be accurate to at least one decimal place. The a and b values shown in Table 3 are those used at CQSRG to calculate local magnitudes of events recorded by station FS03.

Example Usage

Figure 9 shows the seismogram of an earthquake that was recorded on station FS03 on 26 October 2012.

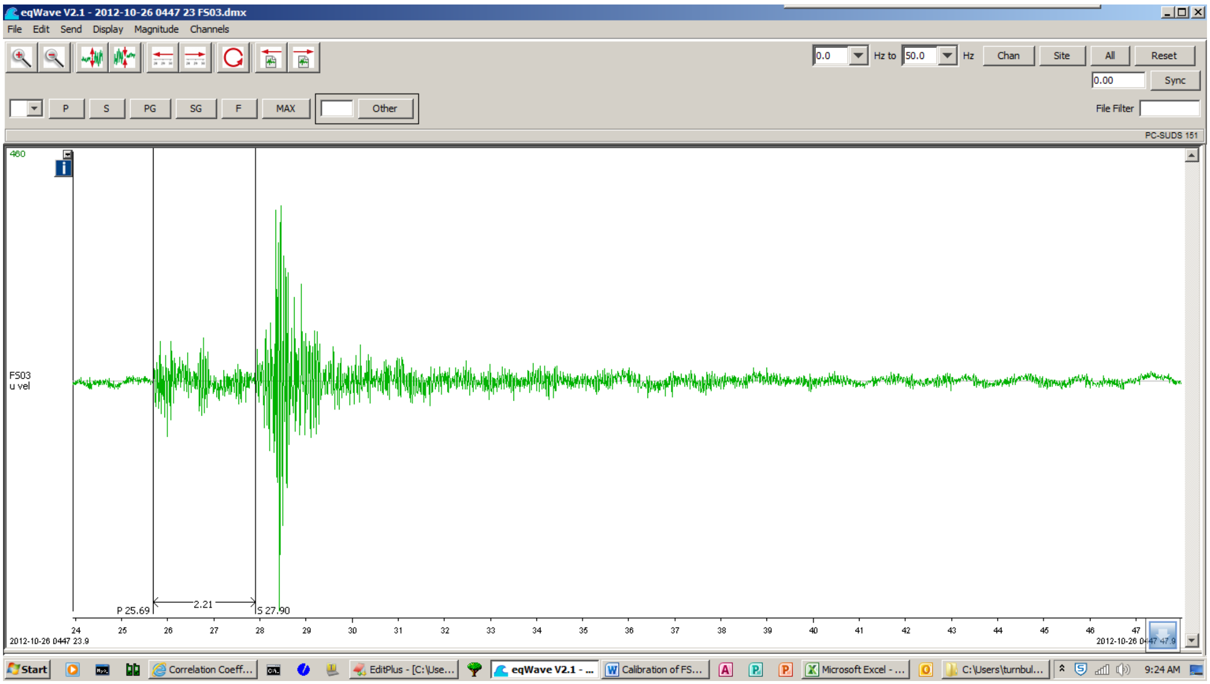

Figure 12: FS03 record of an earthquake.

From Figure 9 we can obtain the maximum amplitude (A = 460), the P wave arrival time (P = 25.69 s) and the S wave arrival time (S = 27.90 s); from which the time difference (S – P = 2.21 s) can be determined.

Inserting these values into Eq.4 we calculate a Richter magnitude of 1.2 (rounded to one decimal place).

Table 4 shows the results of some other similar calculations, for different earthquakes.

Table 4: Calculations of FS03 Richter magnitudes for some earthquakes.

Earthquake Date	Measured P arrival in relative seconds	Measured S arrival in relative seconds	S-P time (s)	Measured Amplitude A	Calculated M_{FS03} Magnitude
2012-09-28 16:38	10.56	22.7	12.14	304	1.6
2012-10-03 17:29	25.09	27.69	2.6	259	0.9
2012-10-18 14:48	23.43	25.91	2.48	911	1.5
2012-10-26 04:47	25.69	27.9	2.21	460	1.2

Student Resources

Figures 10, 11, 12 and 13 are images of earthquake seismograms recorded by FS03. They are included here for the reader to use as practice on the CQSRG magnitude determination method. They can also be used as a resource for High School science teachers who may want to use the formulae presented here as real-world examples of applied mathematics.

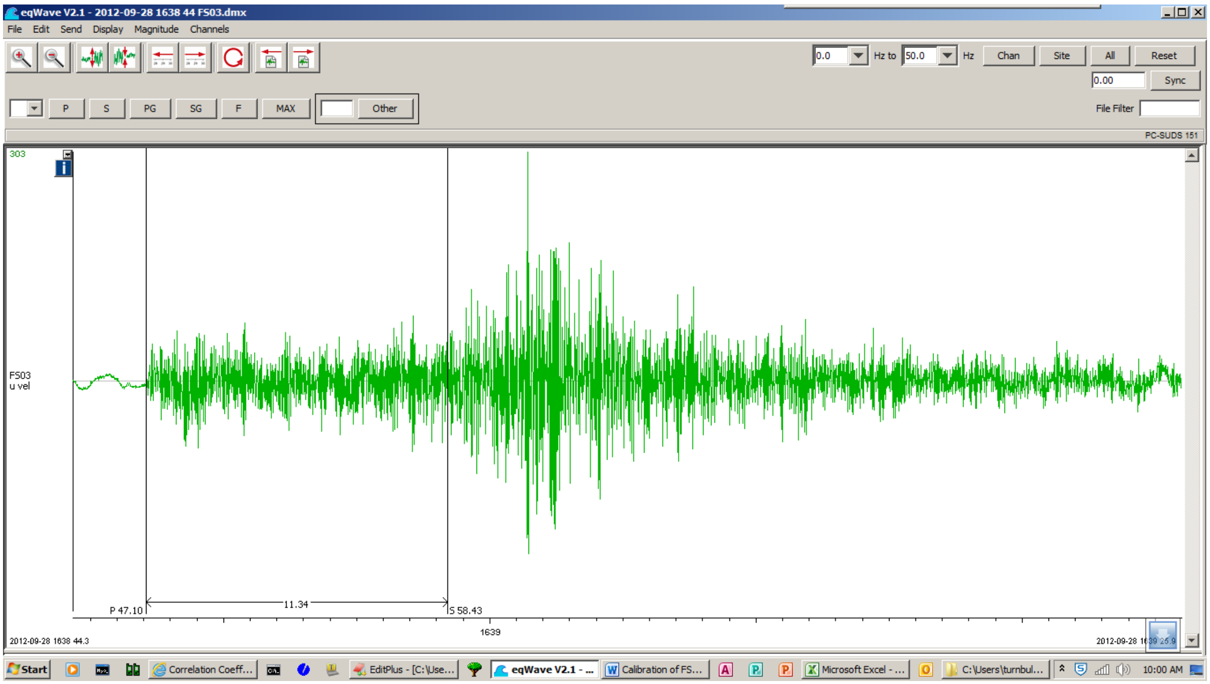

Figure 13: Earthquake recorded on FS03 on 28 September 2012

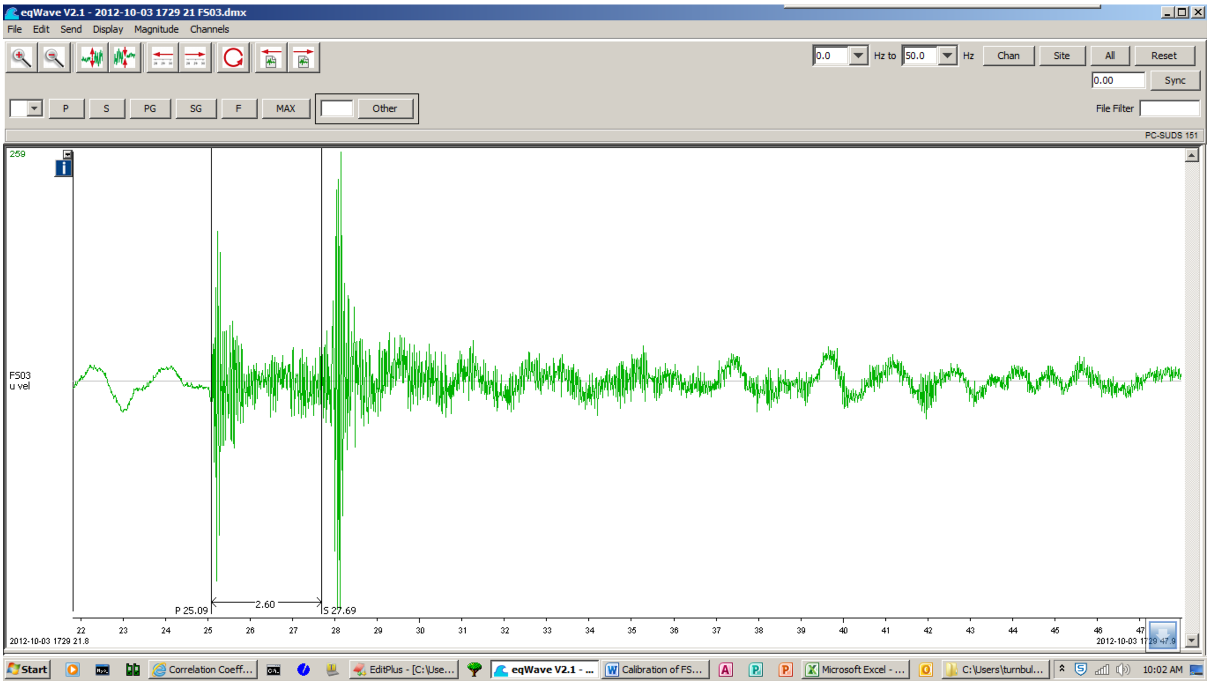

Figure 14: Earthquake recorded on FS03 on 3 October 2012

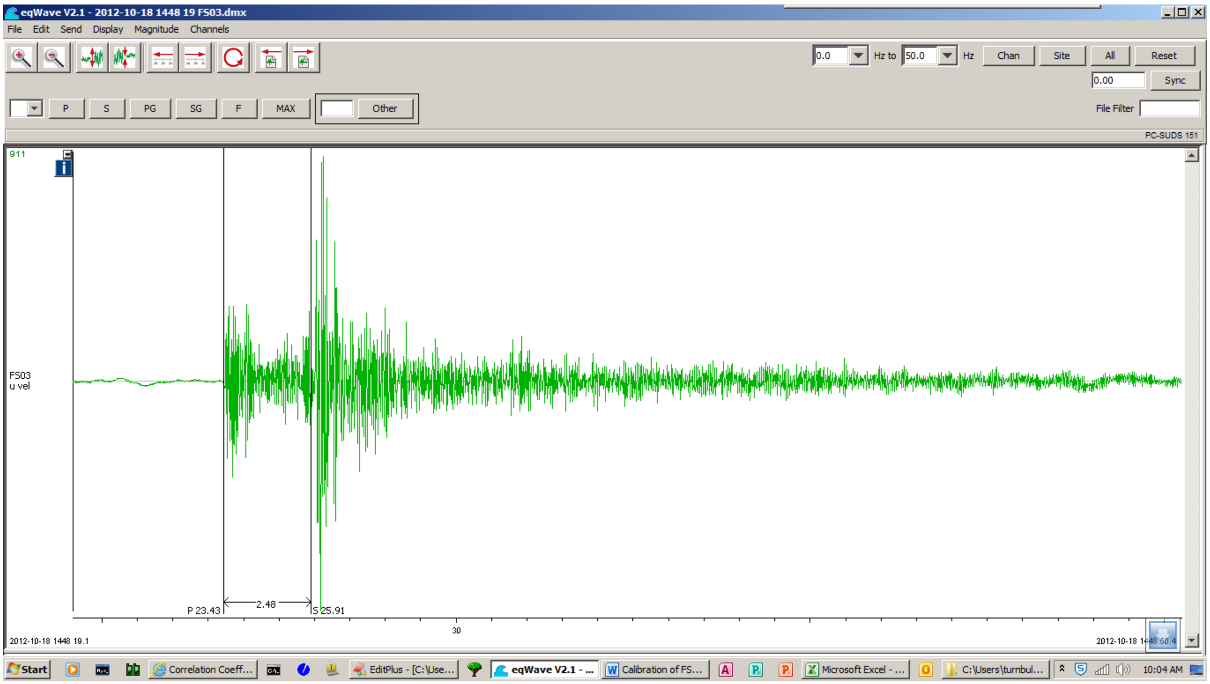

Figure 15: Earthquake recorded on FS03 on 18 October 2012

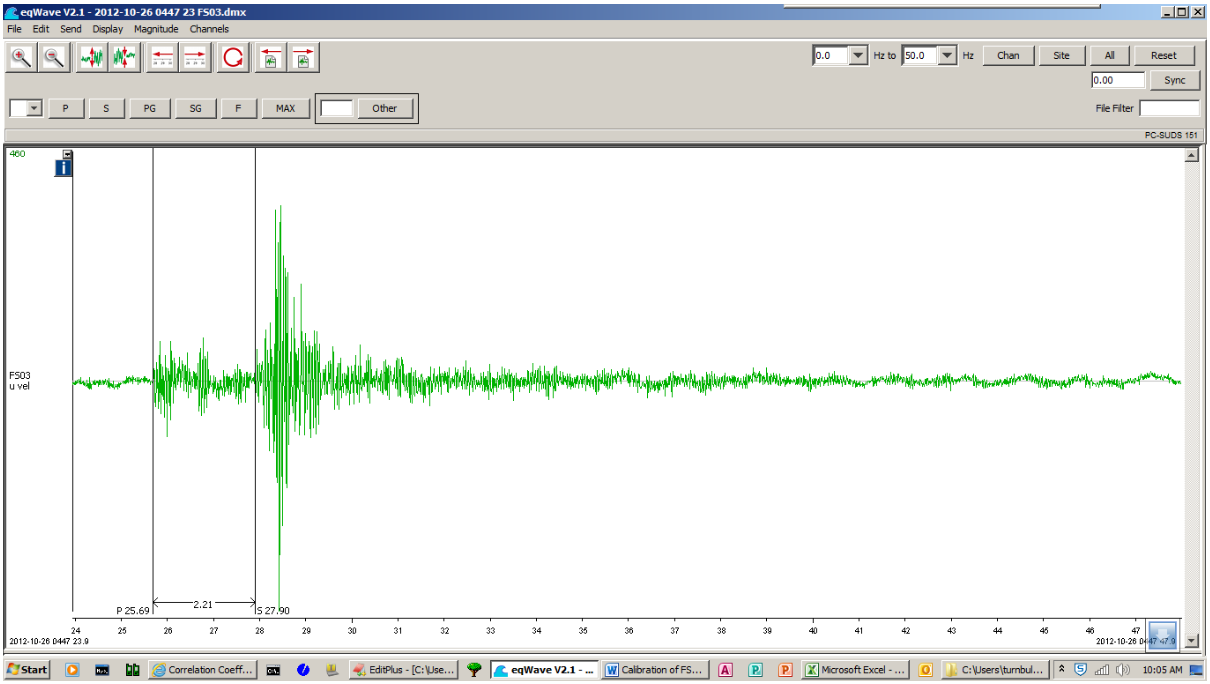

Figure 16: Earthquake recorded on FS03 on 26 October 2012

Appendix D - CQSRG Method of Magnitude Quantification from EIDS Records

Relative Calibration of EIDS Seismometer for Earthquake Magnitude Determination Based on FS03 Past events.

Mike Turnbull, 17 Feb, 2015.

Introduction

FS03 is the designation of a seismic monitoring station operated by the Central Queensland Seismology Research Group (CQSRG). It is located about 24 km south-west of Gin Gin.

EIDS is the Geoscience Australia station located near Eidsvold. The characteristics of the EIDS sensor and associated equipment are unknown (to the author); however, it would be useful to be able to estimate event magnitudes using records from EIDS.

This paper describes a method of extracting parametric information from past earthquakes recorded by both FS03 and EIDS, and quantified using the FS03 seismograms or some other reliable method, that can be used in a suitable mathematical formula to determine the magnitude of earthquakes recorded on the EIDS seismograph.

Background Information

The Richter local earthquake magnitude (M) is calculated using the formula given in Eq. 1.

$$M = log_{10}A - log_{10}A_0 \qquad \text{(Eq. 1)}$$

Where:

A is the maximum amplitude of the seismic record of the earthquake on a given sensor, and

A_0 is the maximum amplitude that would be produced on the same sensor by an earthquake of magnitude zero, occurring at the same location as the earthquake under consideration.

The value of $\log_{10}A_0$ is dependent only on the epicentral distance of the earthquake from the sensor, and the response characteristics of the sensor itself. It is assumed that the relationship is linear as given in Eq. 2 **(NOTE: This assumed relationship has yet to be confirmed as being reasonable)**.

$$log_{10}A_0 = a\delta + b \qquad \text{(Eq. 2)}$$

Where:

δ is the epicentral distance from the sensor under consideration, and

a and b are parameters yet to be determined, characteristic of the sensor under consideration.

Method

Eq.2 is linear, therefore the sensor parameters a and b can be determined from the slope and intercept, respectively, of the graph of $\log_{10}A_0$ plotted against δ, using linear regression, providing that sufficient data is available for the sensor being considered.

The epicentral distance δ can be expressed in any value that provides a valid determination of the distance from the sensor to the epicentre. This could be (for example):

- the difference in arrival times of the P and S waves (in seconds for example); or,
- the surface distance from sensor to epicentre (in km for example); or,
- the Earth centric angle of arc from sensor to epicentre (in degrees for example).

The values for $\log_{10}A_0$, for the sensor under consideration, can be calculated from the amplitudes and S-P times of records of past earthquake events, the magnitudes of which events have been determined by some other reliable method – in this case, from magnitudes determined from FS03 records, or as published by Geoscience Australia.

Transformation of Eq.1 gives Eq. 3.

$$log_{10}A_0 = log_{10}A - M \qquad \text{(Eq.3)}$$

Table 5 presents the calculations of $\log_{10}A_0$ values for EIDS based on past events that were quantified with FS03 seismograms, showing the S-P time differences used to measure epicentral distances from the EIDS sensor. The EIDS seismograms were all similarly conditioned using a 2 Hz to 10 Hz band-pass filter.

Table 5: Determination of log10A0 from past events recorded on the EIDS seismograph.

Earthquake Date	Measured EIDS P arrival	Measured EIDS S arrival	EIDS S-P	Measured EIDS Amplitude A	Magnitude Estimated using FS03 M	Calculated EIDS $\log_{10}(A_0)$
14/06/2014 14:19	17.82	25.48	7.66	99198	3	1.996503
26/06/2014 11:02	17.63	45.34	27.71	678	2.4	0.43123
22/08/2014 08:34	37.56	43.62	6.06	6649	1.9	1.922756
22/08/2014 08:35	27.14	33.69	6.55	92100	2.7	2.26426
22/08/2014 08:38	21.63	28.42	6.79	137217	2.8	2.337408
03/01/2013 19:11	55.16	65.87	10.71	1422	1.6	1.5529
07/01/2013 18:41	60.16	71.28	11.12	822	1.3	1.614872
14/02/2013 23:03	15.7	34.76	19.06	3992	2.1	1.501191
05/01/2012 14:05	75.3	128.37	53.07	4691	4.3	-0.62873
10/04/2012 01:51	43.44	52.12	8.68	2440	1.4	1.98739
20/05/2012 17:58	50.12	59.56	9.44	3879	1.5	2.08872
19/08/2012 22:37	16.48	19.93	3.45	14340	1.5	2.656549
03/09/2012 15:03	15.13	34.44	19.31	14467	2.8	1.360378
19/09/2012 06:14	17.89	25.65	7.76	5905	1.6	2.17122
22/09/2012 23:59	40.45	46.17	5.72	1761	1	2.245759
23/09/2012 16:29	32.05	46.23	14.18	65547	3.2	1.616553
25/09/2012 03:05	22.88	44.51	21.63	2944	1.9	1.568938
03/12/2012 07:41	44.89	51.7	2447	9544	1.4	2.57973
04/12/2012 20:17	55.01	61.41	6.4	570212	3.2	2.556036
12/12/2012 10:36	53.69	60.33	6.64	20513	2.2	2.112029

Figure 14 shows the graph of $\log_{10}A_0$ plotted against the associated S-P time difference (extracted from Table 5).

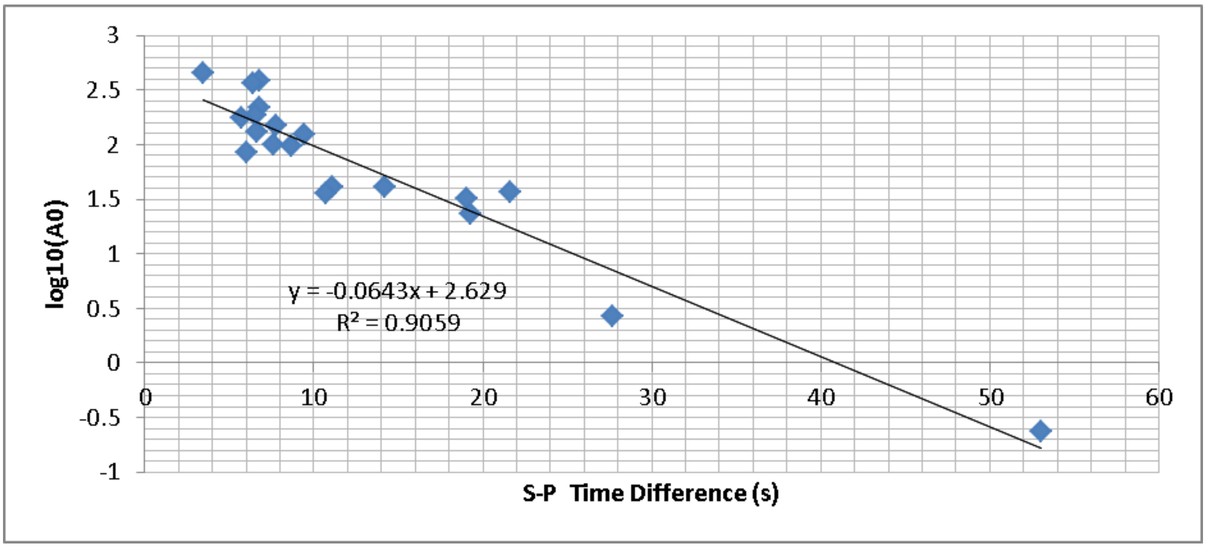

Figure 17: log10A0 Vs S-P

Figure 1 also displays the line of best fit, calculated using linear regression of the plotting data, along with the slope, intercept, and correlation coefficient (R^2). **The R^2 value of 0.91 confirms that the assumed linear relationship is reasonably valid.**

By substituting the slope and intercept values into Eq.1 and Eq.2 we arrive at the formula for EIDS magnitudes given in Eq.4.

$$M_{EIDS} = log_{10}A - (-0.064(S - P) + 2.63) \quad \text{(Eq.4)}$$

Where:

M_{EIDS} is the Richter magnitude determined from an EIDS seismogram record;

A is the maximum amplitude of the EIDS seismogram record;

S is the arrival time of the S wave in seconds, and;

P is the arrival time of the P wave in seconds.

Example Usage

Figure 15 shows the seismogram of an earthquake that was recorded on station EIDS on 15 February 2015.

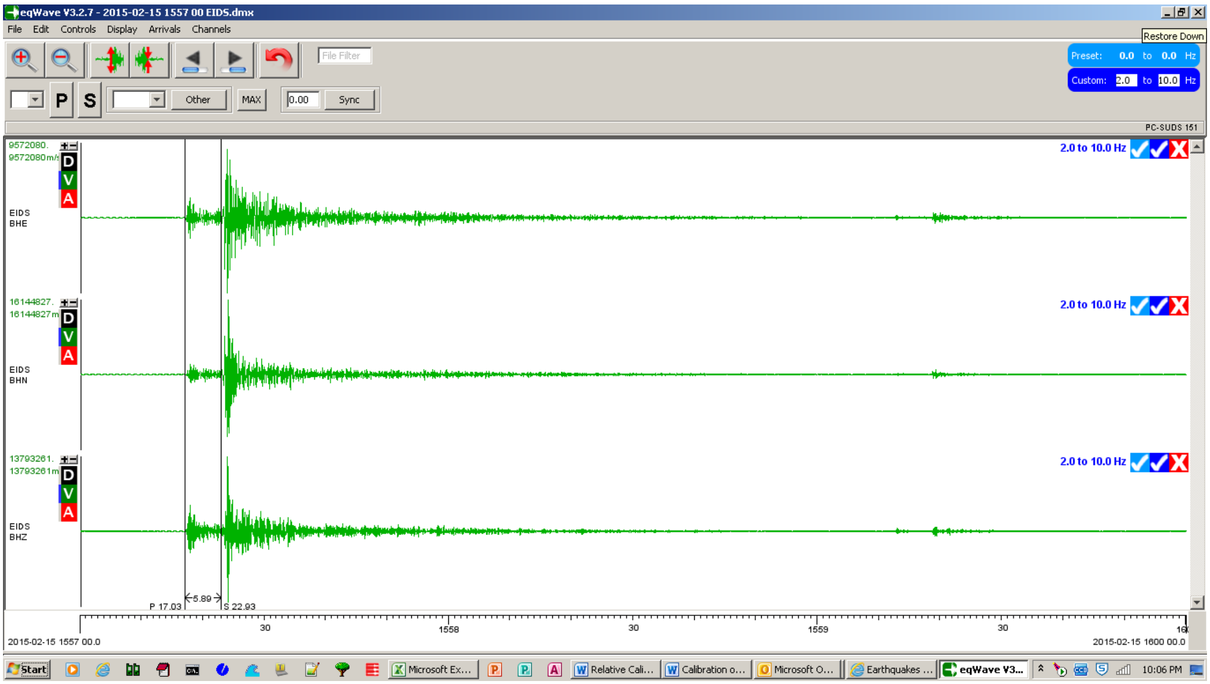

Figure 18: EIDS record of an earthquake.

From Figure 15 we can obtain the maximum amplitude (A = 13793261), the P wave arrival time (P = 17.03 s) and the S wave arrival time (S = 22.93 s); from which the time difference (S – P = 22.93 s) can be determined.

Inserting these values into Eq.4 we calculate a Richter magnitude of 4.9 (rounded to one decimal place).

Table 6 shows the results of some other similar calculations, for different earthquakes, along with the GA published magnitudes for the same events.

Table 6: Calculations of EIDS Richter magnitudes for some earthquakes.

Earthquake Date	Measured P arrival	Measured S arrival	S-P	EIDS Amplitude A	Calculated M_{EIDS} Magnitude	GA Published Magnitude
15/02/2015 15:57	17.03	22.93	5.9	13793261	4.9	5.1
15/02/2015 15:58	12.58	18.56	5.98	869195	3.7	
15/02/2015 16:40	43.7	49.25	5.55	278525	3.2	3.2
15/02/2015 17:37	13.18	19.15	5.97	907859	3.7	3.4
15/02/2015 18:06	14.56	20.54	5.98	125151	2.9	2.5
16/02/2015 05:56	58.18	64.14	5.96	1703875	4.0	4.0