CENTRAL QUEENSLAND SEISMOLOGY RESEARCH GROUP

# CQSRG Seismological Report 2017

Edition 1.00

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## Edition control

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Namaskar

Mike Turnbull

# Introduction

This report details earthquakes detected and located by the Central Queensland Seismology Research Group (CQSRG) during the 2017 calendar year. Technical summaries of earthquakes that occurred 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 February 2013, when, due to a divergence in academic focus of CQU and CQSRG, the researchers allowed their Adjunct appointments to lapse. From February 2013 until December 2016, CQSRG operated independently of CQU, with the same two people conducting the research. In mid-2016 Dr Andrew Hammond, Senior Lecturer in Geology at CQUniversity, joined CQSRG as a research collaborator. Mike Turnbull's and Kevin McCue's adjunct academic appointments with CQUniversity were re-established in October 2016.

During the 2017 calendar year CQSRG operated two seismic monitoring stations, designated FS03, and WOOW. Details of these stations, including location and equipment, are provided in Appendix A. This report contains information relating to earthquakes detected by the FS03, and WOOW seismic monitoring stations, as well as earthquakes of significance detected within Queensland, but outside the CQSRG catchment area, by Geoscience Australia (GA).

CQSRG locates and quantifies earthquakes using the methods detailed Appendices in D, E and F.

# CQSRG Station Reports

## FS03 Uptime 2017

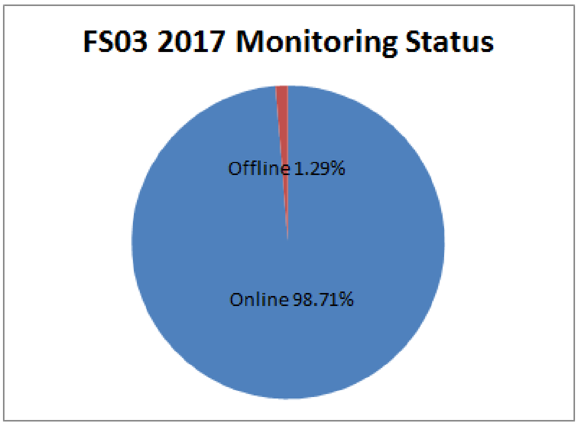


Figure 1: Percentage Uptime/Downtime of FS03 during 2017

The FS03 station has been in continuous operation since 2003-01-01 00:00:00.00 (UTC).

Technical details of the station are found at http://cqsrg.org/network/FS03technical/.

Throughout the 2017 calendar year the FS03 station was actively monitoring for seismic events greater than 98% of the year.

This high proportion of availability was due to automation of the data download process, and the provision of an RS232 serial data radio link to the station in April 2015.

Most of the down time was comprised of data download time.

The FS03 station itself had no downtime from power outages or any other equipment failures for the entire year.

## WOOW Uptime 2017

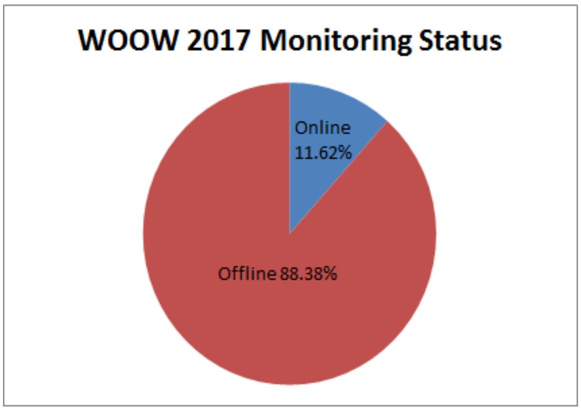


**Figure 2: Percentage Uptime/Downtime of WOOW during 2017.**

The WOOW station was installed in December 2016, and commissioned on 2017-01-10 03:10 (UTC).

Throughout the 2017 calendar year the WOOW station was actively monitoring for seismic events less than 12% of the year.

This high proportion of unavailability was due to two failures of the Telstra mobile data modem link from March to July, and then from July to the end of the year.

## WOOW Data Quality

Although pre-installation testing indicated that future data produced by the proposed WOOW site should be of usable quality, this expectation did not eventuate. The site was chosen for a number of reasons.

- It was situated on a slightly elevated rocky ridge.
- It was within 30 m of a residential house; providing security, and ready access to mains power that was being donated by the resident.
- It was located in the Biggenden area, thus covering the south-east extent of the Mt Perry seismicity zone.
- The site was within view of the Telstra mobile network transceiver on Mt Gananaman (less than 10 km away).

Unfortunately, the swimming pool pump used at the residential house was an unacceptable source of noise that triggered the monitoring recorder regularly. The vast majority of recordings were pool-pump triggers. When genuine seismic events did trigger they were mixed with local noise.

After the Telstra mobile data modem link went down for the second time a decision was made to not continue operation of the station until the technical problem was corrected. This situation produces a prolonged down-time of the station that persisted to the end of the calendar year.

# Significant Earthquake Events Detected During 2017

## Significant Event Sequences

Aftershock earthquakes associated with the **February 2015 Mt Perry**, the **July 2015 Rainbow Beach**, and the **August 2016 Bowen** sequences continued throughout 2017.

### The 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 named it the **2015 Mt Perry Earthquake**.

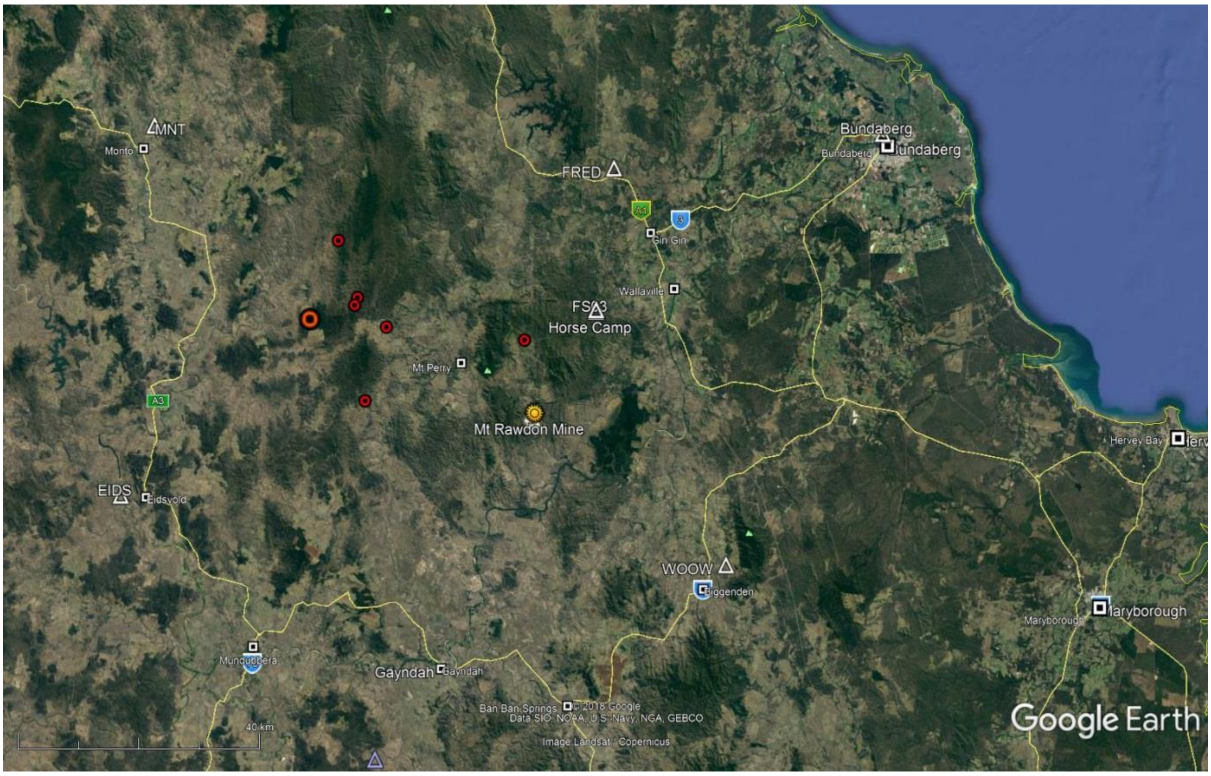


**Figure 3: Mt Perry sequence aftershocks during 2017.**

Aftershock earthquakes occurred throughout 2015, and 2016, and continued during 2017. Figure 3 shows the locations of the 2017 events (red markers), as well as the location of the 2015 main event (orange marker).

Only 6 aftershock events were detected and located in the Mt Perry sequence during 2017, ranging in magnitude from M 2.2 to M 0.6. This compares to a background average of 4.4 events per year recorded during the 11 years prior to the main earthquake in 2015 and is an indication that the seismicity of the area has reverted to its normal background level.

Background earthquakes continue to occur in the target area, but at a rate that indicates the aftershock sequence has terminated (Figure 4).

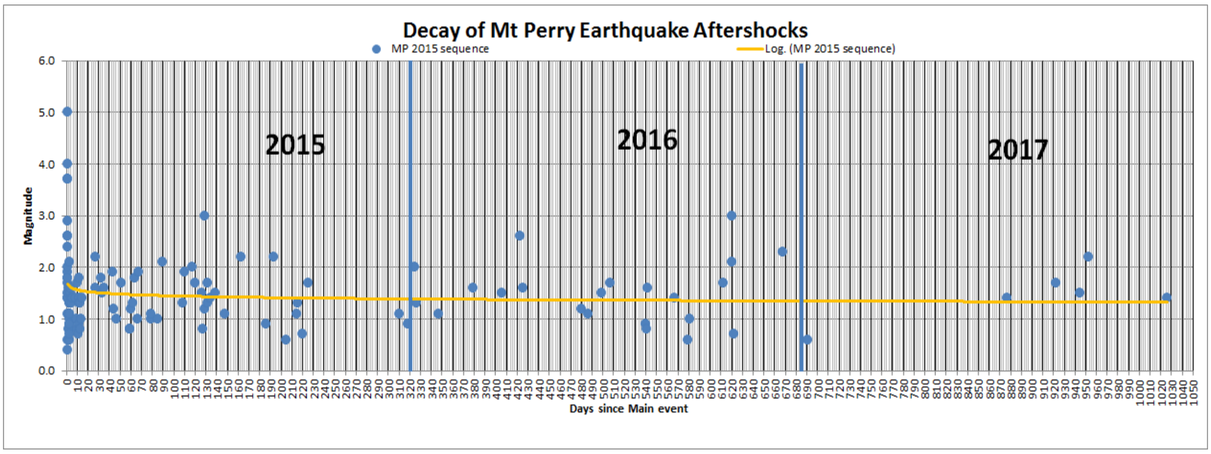


Figure 4: Logarithmic decay of the Mt Perry 2015 earthquake sequence.

## The 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 an 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 greater than ML 5.0 events were also reported as having been felt down to Brisbane.

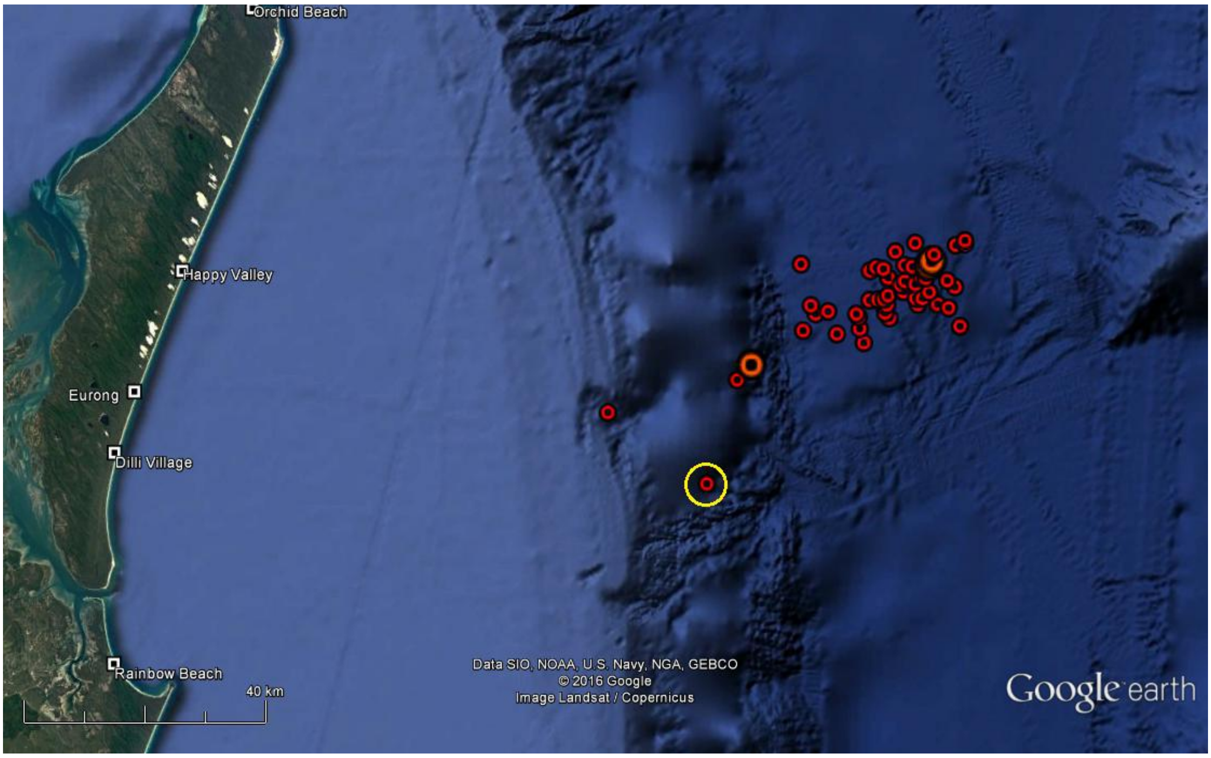


Figure 5: 2015 Rainbow Beach earthquake sequence as at the end of 2017.

Up to the end of 2017, 53 aftershocks had been recorded, including the two greater than ML 5.0 events. During 2016, and 2017 only one aftershock was recorded each year.

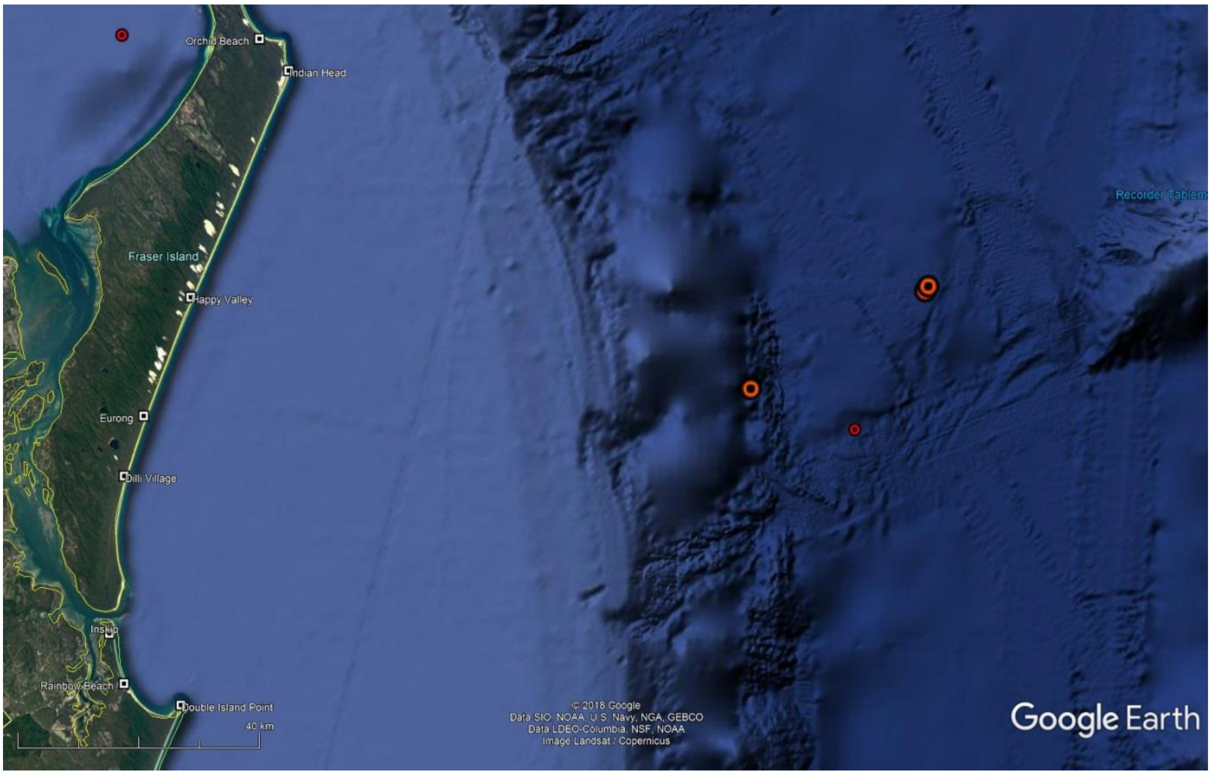


Figure 6: 2015 Rainbow Beach earthquakes and the 2017 aftershock.

During 2017 (as in 2016) only one aftershock was recorded, an M3.3 on 2017-09-30 at 08:29. The location of this aftershock (red marker) in relation to the 2015 main shocks (orange markers) is shown in Figure 22.

Figure 7 is a graphic depiction of the aftershocks of the 2015 Rainbow Beach Earthquake up to the

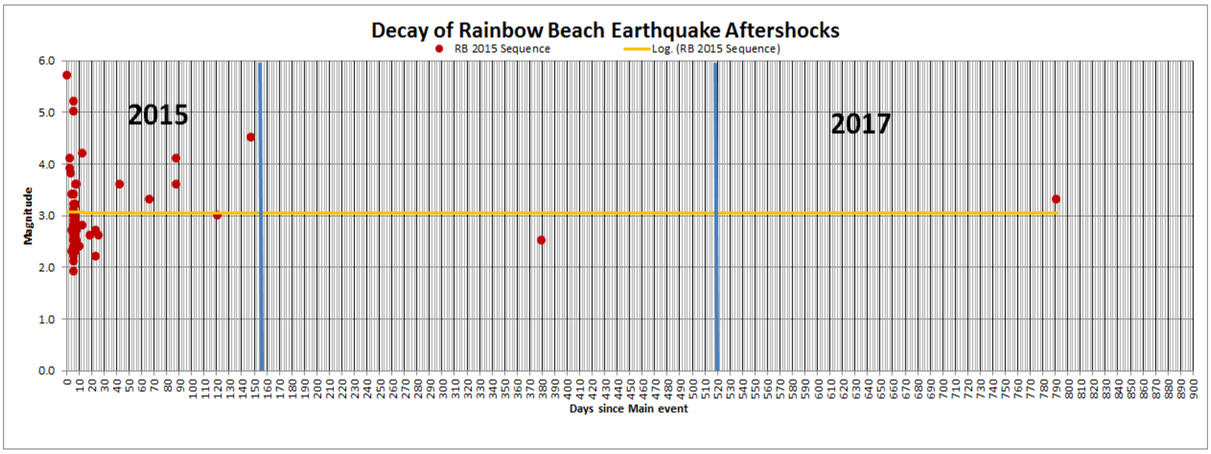


Figure 7: Logarithmic decay of the Rainbow Beach 2015 earthquake sequence.

end of 2017. 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**.

CQSRG regards the RB 2015 aftershock sequence as having terminated. However, it has to be noted that the paucity of seismic recording stations in the Central Queensland coastal region is so severe that the lowest magnitude event recorded by sufficient stations to achieve a location was M2.1. Comparison of this aftershock sequence with the MP 2015, and the BW 2016 aftershock sequences suggests that many more events of much lower magnitude would have occurred; and would have been recorded if sufficient monitoring stations were sited in proximity to the events.

## The Continuing Bowen Earthquake Sequence

On 2016-08-18 at 04:30 UTC an M5.8 earthquake[1] occurred 63 km north east of Bowen in the Whitsunday Passage. This was followed over the next three weeks by 77 aftershocks ranging from M1.6 to M4.2 that were located by CQSRG; however there were many more aftershocks of magnitudes below M 1.6 that have been identified by CQSRG in the Bowen Urban Monitoring (UM) network site (BW1H) seismic records but have not been located due to insufficient recordings. This sequence of events is known within CQSRG as the **2016 Bowen Earthquake** and Aftershock Sequence (BW 2016).

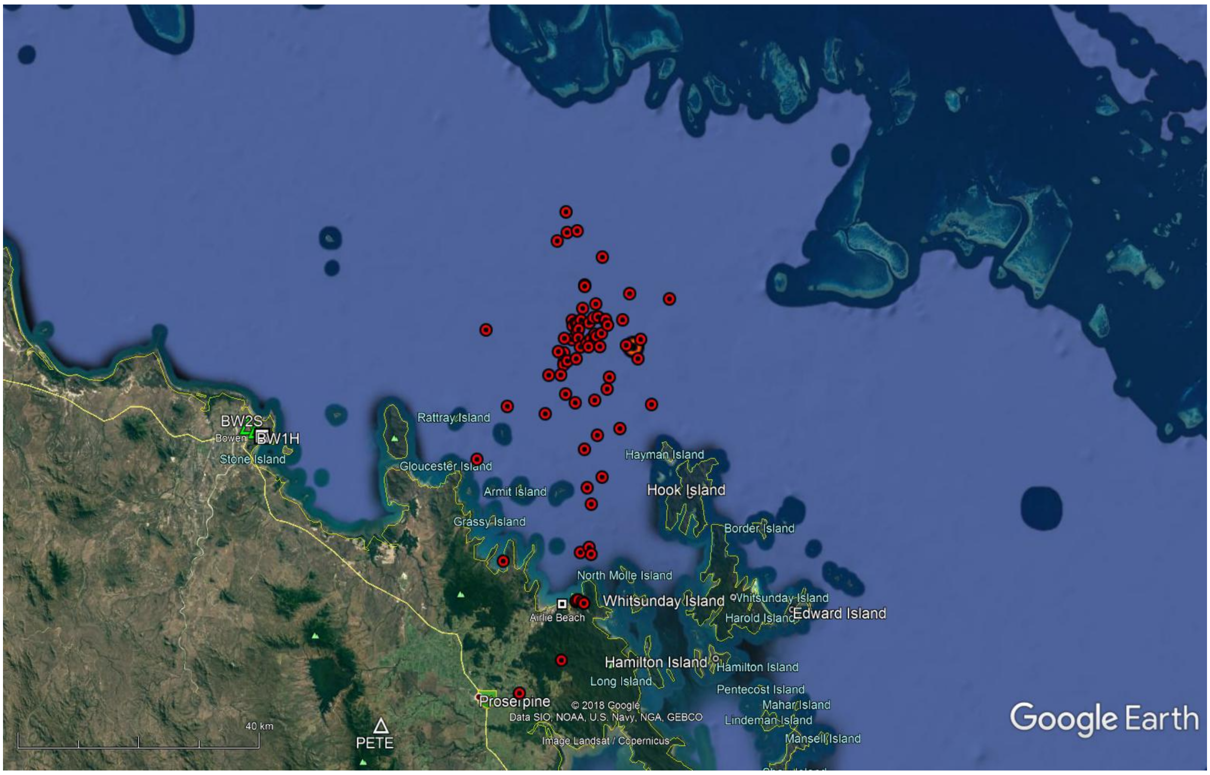


Figure 8: Bowen aftershocks, of M2.0 or greater, that occurred in 2017, and were located by CQSRG.

[1] The magnitude assigned by CQSRG is that assigned by Geoscience Australia.

During 2017 calendar year 258 aftershocks ranging in magnitude from M3.5 down to M1.3 were detected by CQSRG; not all of which, due to lack of sufficient instrumental records, were located. Of those events, 93 of M2.0 or greater provided sufficient recordings to be reliably located. A map showing locations of aftershocks that were located by CQSRG during 2017 is presented in Figure 8.

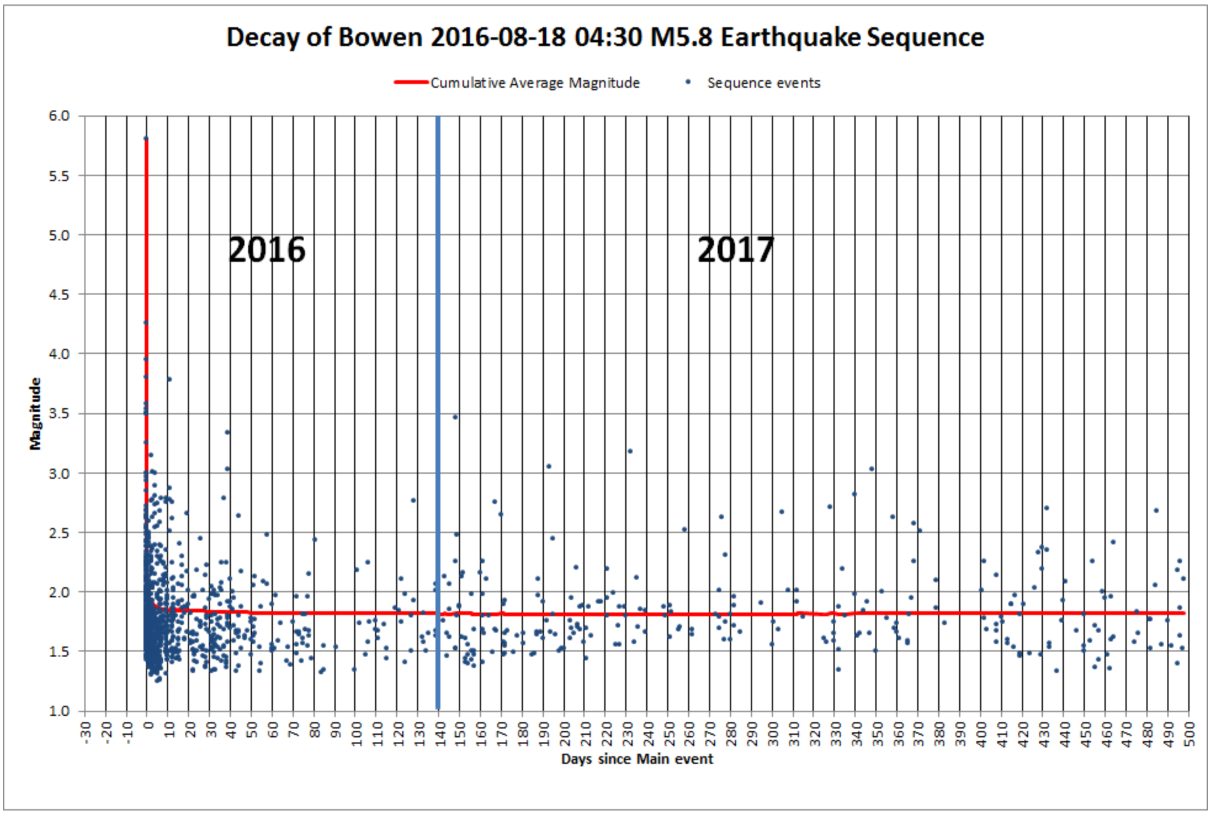


**Figure 9: Plot of the Bowen 2016 aftershock sequence with cumulative average magnitude indicated**

Figure 9 shows a graphical plot of the 2016 Bowen sequence up to the end of 2017. The red line indicates the cumulative average magnitude of the sequence, and shows that it has settled to an average magnitude of M1.8.

The hiatus of earthquake events shown in Figure 9 prior to the Main shock (at Day 0) is not an artefact – it is real. CQSRG staff have scanned the BW1H and BW2S records for a month prior to Day 0, and no events of M1.3 and above were observed. The previous most recent event in that area shown in the GA catalogue was an M3.6, a year earlier on 2015-11-18. Previous to that there was an M4.0, four years earlier, on 2011-09-17.

The available evidence indicates that the BW 2016 aftershock sequence is continuing, and will continue into the foreseeable future; indeed, what is currently being observed may well represent the initiation of a new long-term seismicity regime for the Bowen area.

## History of Earthquakes in the Bowen Region

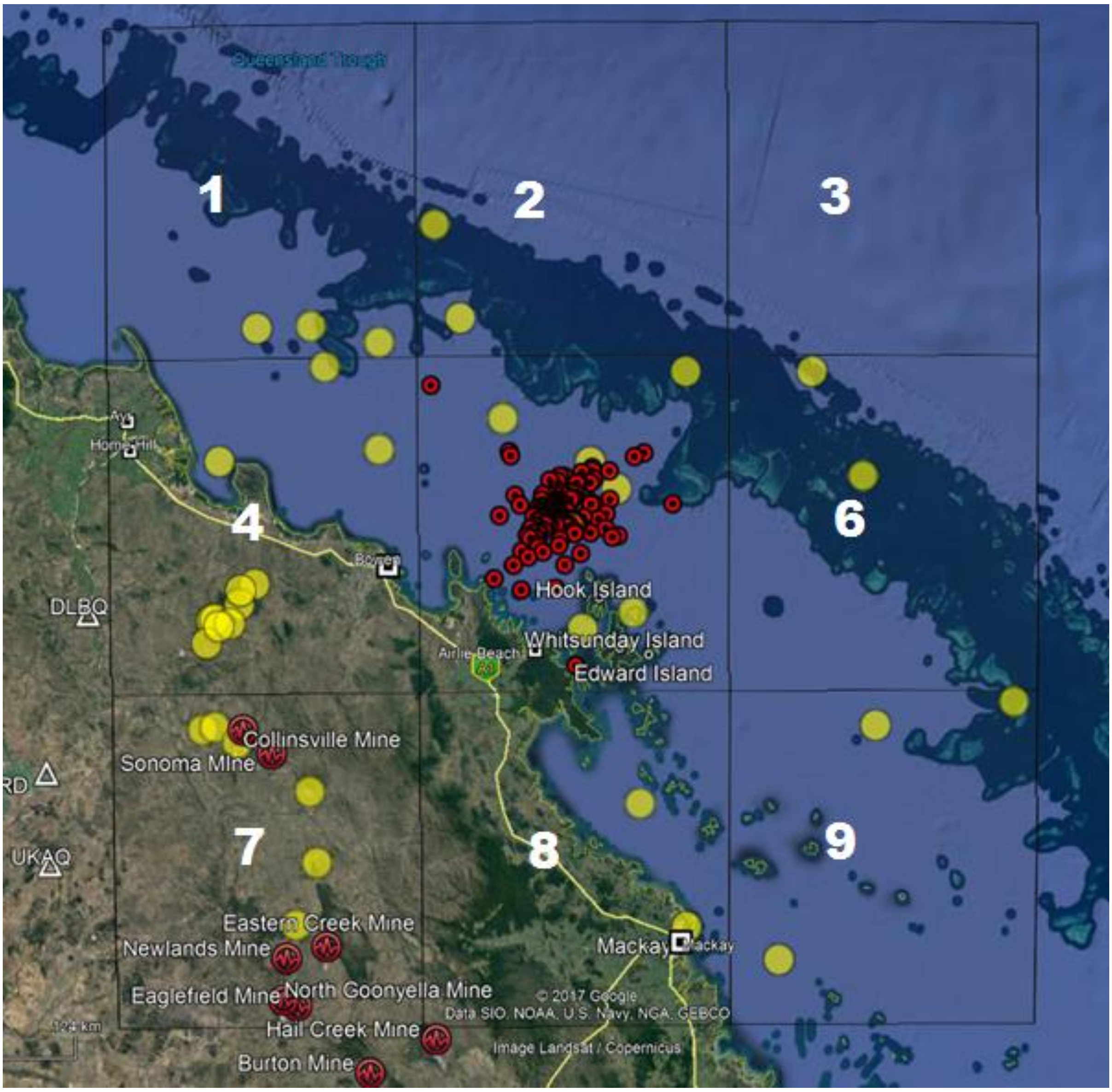


**Figure 10: Historical Earthquakes in the Bowen Region.**

Figure 10 shows all earthquakes listed in the Geoscience Earthquake Database[2] dating from the mid-1800s to the day before the August 2016 M5.8 earthquake – that is, up until 2016-08-17 24:00. The yellow dots are the historical events, and the red doughnuts are some of the August 2016 M5.8 aftershocks. The grid of nine squares is centred on the location of the M5.8, and each square delineates a 1° Latitude/Longitude region. For reference purposes the grid squares are numbered 1 to 9, from left to right and top to bottom.

[2] As a general rule it is not the practice within Geoscience Australia to actively seek to detect and locate earthquakes of magnitudes less than M3.5, except in instances where events are reported as being felt, or they are associated with ongoing sequences – and this seems to be especially true for Queensland events, probably due to the scarcity and spatial separation of GA monitoring stations in Queensland.

There are no entries in the GA Database, for the Bowen region shown in Figure 10, prior to April 1950. This is because, prior to that time, there were insufficient monitoring stations in the north of Queensland to detect the events that were occurring at those times. In particular, this implies that those historical events shown in Figure 10 and Figure 11 are a truncated representation of the actual seismic history of the Bowen region.

| Cell# | Magnitude | UTC Date | UTC Time | Latitude | Longitude | GA Approximate location and Comment | CQSRG Comment |
|---|---|---|---|---|---|---|---|
| 8 | 4.5 | 1950-04-05 | 19:50:52 | -21.100 | 149.200 | | 0 km Mackay. |
| 4 | 3.3 | 1959-11-25 | 04:31:02 | -19.700 | 147.700 | | 67 km NW Bowen. |
| 9 | 4.7 | 1960-10-19 | 11:37:06 | -21.200 | 149.500 | Mackay QLD | 34 km E Mackay. |
| 1 | 2.4 | 1962-12-28 | 12:50:22 | -19.300 | 148.000 | | 83 km NNW Bowen. |
| 2 | 2.5 | 1967-03-18 | 20:39:22 | -19.000 | 148.400 | | 110 km NNW 2016-08-18 04:30 M5.8. 113 km NNE Bowen. |
| 7 | 2.4 | 1969-01-11 | 21:05:17 | -20.900 | 148.000 | | 31 km N Eastern Creek. 36 km N Newlands. 36 km S Sonoma. 48 S Collinsville. May be blast. |
| 1 | 1.7 | 1982-01-27 | 16:24:08 | -19.350 | 148.219 | | 74 km N Bowen. |
| 4 | 1.6 | 1982-07-27 | 14:59:00 | -19.422 | 148.044 | | 68 km NNW Bowen. |
| 5 | 2.3 | 1982-11-16 | 15:34:21 | -19.581 | 148.615 | | 42 km NW 2016-08-18 04:30 M5.8. 62 km NE Bowen. |
| 8 | 2.0 | 1983-12-31 | 10:39:51 | -20.730 | 149.050 | | 48 km N Mackay. 95 km S 2016-08-18 04:30 M5.8. |
| 5 | 2.3 | 1985-06-07 | 22:13:35 | -20.160 | 149.030 | | 35 km SE 2016-08-18 04:30 M5.8. 83 km ESE Bowen. |
| 2 | 3.5 | 1985-07-27 | 16:43:46 | -19.280 | 148.480 | | 78 km NNW 2016-08-18 04:30 M5.8. 85 km NNE Bowen. |
| 5 | 4.7 | 1985-08-02 | 12:16:58 | -19.443 | 149.203 | Proserpine Qld - Felt Hayman Is and WhitSunday (Airlie) | 63 km NE 2016-08-18 04:30 M5.8. 119 km NE Bowen. |
| 4 | 1.7 | 1986-08-22 | 14:54:00 | -19.670 | 148.216 | | 38 km N Bowen. |
| 1 | 4.6 | 1987-09-27 | 16:01:26 | -19.304 | 147.825 | | 90 km NW Bowen. |
| 7 | 2.0 | 1990-12-27 | 08:47:32 | -20.541 | 147.746 | COLLINSVILLE ON MIRROR LINE | 0 km Collinsville Mine. 14 km NW Sonoma Mine. Possible blast. |
| 9 | 3.2 | 1991-04-06 | 01:44:45 | -20.499 | 149.814 | OFF WHITSUNDAYS ALL SITES IN A LINE | 97 km NE Mackay. 122 km SE 2016-08-18 04:30 M5.8. |
| 9 | 2.7 | 1991-04-13 | 03:28:29 | -20.429 | 150.264 | OFF WHITSUNDAYS MIIROR AT ALPHA - VERY POOR | 138 km NE Mackay. 160 km SE 2016-08-18 04:30 M5.8. |
| 7 | 1.9 | 1991-06-22 | 21:34:33 | -20.687 | 147.980 | COLLINSVILLE | 16 km SE Sonoma Mine. 28 km SE Collinsville Mine. Possible blast. |
| 5 | 3.2 | 1991-09-11 | 05:36:08 | -19.712 | 148.895 | OFF BOWEN | 21 km NE 2016-08-18 04:30 M5.8. 75 km NE Bowen. |
| 5 | 3.0 | 1991-09-11 | 07:13:36 | -19.792 | 148.979 | OFF BOWEN | 19 km NE 2016-08-18 04:30 M5.8. 81 km NE Bowen. |
| 7 | 2.2 | 1992-05-21 | 01:45:15 | -21.087 | 147.930 | NEWLANDS AREA NEWLANDS DID NOT BLAST | 15 km NW Eastern Creek Mine. 16 km N Newlands Mine. Possible blast |
| 6 | 3.1 | 1992-07-30 | 08:23:51 | -19.444 | 149.609 | OFF BOWEN ORIGINALLY THOUGHT TO BE A BLAST | 95 km NE 2016-08-18 04:30 M5.8. 157 km NE Bowen. |
| 7 | 2.5 | 1992-10-12 | 06:45:51 | -20.500 | 147.634 | COLLINSVILLE | 14 km NW Collinsville Mine. Possible blast. |
| 6 | 2.6 | 1993-02-23 | 21:12:36 | -19.755 | 149.773 | OFF TOWNSVILLE MIRROR AT 146 -23.5 | 99 km E 2016-08-18 04:30 M5.8. 162 km E Bowen. Mirror is 17 km NW Jerico. |
| 7 | 1.8 | 1994-04-26 | 03:13:19 | -20.492 | 147.675 | COLLINSVILLE | 10 km NW Collinsville Mine. Possible blast. |
| 5 | 3.4 | 1994-06-17 | 11:52:33 | -20.208 | 148.867 | HAMILTON ISLAND FELT WHITSUNDAYS | 35 km S 2016-08-18 04:30 M5.8. 17 km NE Airlie Beach. |
| 4 | 5.3 | 2011-04-16 | 05:31:18 | -20.085 | 147.764 | Near Bowen, QLD. | Main shock of an aftershock sequence. 50 km WSW Bowen. |
| 4 | 4.1 | 2011-04-16 | 07:06:52 | -20.170 | 147.679 | Near Bowen, QLD. | Aftershock of 2011-04-16 05:31 M5.3. 62 km WSW Bowen. |
| 4 | 3.2 | 2011-04-16 | 13:06:44 | -20.191 | 147.692 | Near Bowen, QLD. | Aftershock of 2011-04-16 05:31 M5.3. 61 km WSW Bowen. |
| 4 | 3.4 | 2011-04-16 | 15:33:19 | -20.128 | 147.759 | Near Bowen, QLD. | Aftershock of 2011-04-16 05:31 M5.3. 52 km WSW Bowen. |
| 4 | 3.2 | 2011-04-17 | 01:35:55 | -20.174 | 147.668 | Near Bowen, QLD. | Aftershock of 2011-04-16 05:31 M5.3. 62 km WSW Bowen. |
| 4 | 3.2 | 2011-04-19 | 07:38:05 | -20.067 | 147.810 | Near Bowen, QLD. | Aftershock of 2011-04-16 05:31 M5.3. 46 km WSW Bowen. |
| 4 | 3.1 | 2011-05-05 | 05:35:05 | -20.242 | 147.651 | SW of Bowen, Qld. | Aftershock of 2011-04-16 05:31 M5.3. 67 km WSW Bowen. |
| 4 | 4.0 | 2011-09-17 | 16:28:27 | -20.184 | 147.728 | SW of Bowen, QLD. | Aftershock of 2011-04-16 05:31 M5.3. 57 km WSW Bowen. |
| 5 | 3.6 | 2015-11-18 | 07:38:37 | -19.785 | 148.821 | N of Hayman Island, offshore QLD. | 13 km N 2016-08-18 04:30 M5.8. 65 km NE Bowen. |

**Figure 11: Table of Historical Seismic events in the Bowen area prior to the August 2016 M5.8 (Source: Geoscience Australia).**

It is worth noting at this stage that the SE to NE trending group of historical events shown in cell 4 are an M5.3 earthquake and associated aftershocks that commenced on 2011-04-16 (See Figure 10). Although only eight events are shown in this sequence, they are all of M3.1 or greater, and there will have undoubtedly have been many other aftershocks of lesser magnitude that were not detected at the time and therefore not entered into the GA Database. This suggests a side project to go back over the local station records to look for those events. Stations BW1H and BW2S in particular will have recorded them.

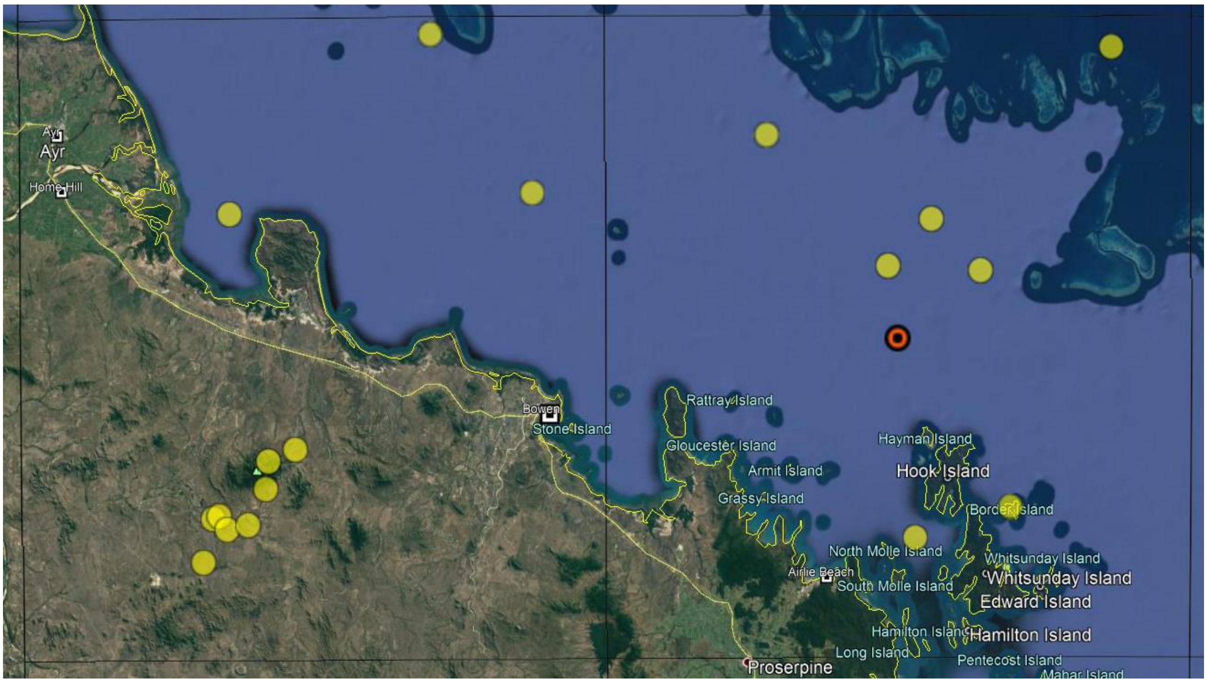


**Figure 12: Focused view of historical event locations in relation to the August 2016 main shock.**

Figure 12 shows a more focused view of cells 4 and 5, with the August 2016 aftershocks omitted, but showing the position of the main shock in relation to the historical events. In Figure 10, the historical event immediately north of the August 2016 event occurred in November 2015, and was magnitude 3.6. All other events shown in cell 5 occurred in June 1994, or earlier – the oldest being recorded in November 1982. The historical events in cell 5 range in magnitude from 2.3 to 4.7.

Due to locational errors caused by sparseness of records[3], any or all of the cell 5 events may or may not be associated with the same geological mechanism that caused the August 2016 M5.8 and subsequent aftershocks.

It should also be noted that any or all of the events shown in cell 7 of Figure 10 may or may not actually be extraction blasts conducted at one or more of the mines indicated in that figure.

## The Seismological Importance of the BW 2016 Event

The BW 2016 main event is arguably the second largest earthquake to have been recorded on the east coast of mainland Australia since the European arrivals. Consequently, in an Australian historical context, it is a very significant event.

The seismological history in Queensland from the late 1800s to the present time indicates that there are three principal seismogenic areas – the Mt Perry area, the Rainbow Beach to Lady Elliot Island area, and the Whitsunday Passage area. Although numerous other minor earthquakes have been recorded that sit outside the immediate core of these three areas, the historical record shows that

[3] The locational precision of offshore events anywhere along the Queensland coast is adversely affected by the fact that all recording stations are linearly positioned along the coast and nearby hinterlands. This linear placement is conducive to poor angular gap coverage and therefore poor locational errors due to linear overlapping of the station to event radial distance estimations.

these three areas have produced by far the largest number of earthquakes of greater than M 3.5 magnitude.

## CQSRG Earthquake catalogue 2017

During 2017, 133 earthquake events were detected, located, and catalogued by CQSRG. Details of these events are provided in Table 1. The online full version of the CQSRG catalogue can be accessed at http://cqsrg.org/catalogue/. The 133 located events listed in Table 1 include the 93 Bowen aftershock events that were sufficiently well recorded to have been located.

An additional 166 Bowen aftershock events were identified, but insufficient recordings of those events were available to allow for reliable locations. While the methodology used to identify BW 2016 aftershocks is considered reliable, it is possible that a small number of them (less than 3%) have been incorrectly assigned. For this reason, these 166 events have not yet been included in the main CQSRG Earthquake Catalogue. The dates, times, and magnitudes of these 166 events are listed in an auxiliary CQSRG catalogue, Table 2.

It should also be noted that, although the main M 5.8 Bowen event and some of the listed aftershocks were well recorded on the CQSRG FS03 station, numerous other aftershocks that are listed in the CQSRG main and supplementary catalogues were not principally detected on the CQSRG network. Most of those aftershock events were identified by manual inspection of the daily records obtained off the BW1H Urban Monitoring (UM) station at Bowen.

It is also noted that, where the EQLOCL algorithm could not calculate a depth due to lack of vertical resolution, the focal depths listed in the CQSRG Earthquake Catalogue have been constrained to the local norm (10 km).

### Table 1: Earthquake Events Detected, Located, and Catalogued by CQSRG during 2017.

| Date(UTC) | Time(UTC) | Longitude | Latitude | Depth | Magnitude | Event Type | Place | Comment |
|---|---|---|---|---|---|---|---|---|
| 2017-12-29 | 16:29:36.09 | 146.593 | -17.316 | 10.0 km | 2.2 ML | Mainshock | Innisfail | 64 km NE Innisfail. Reviewed 2017-12-30. |
| 2017-12-29 | 16:17:32.76 | 148.774 | -20.180 | 10.0 km | 2.1 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 11 km NE Airlie Beach. Reviewed 2017-12-30. |
| 2017-12-27 | 13:47:03.78 | 148.762 | -20.186 | 10.0 km | 2.2 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 58 km SE Bowen. Reviewed 2017-12-29. |
| 2017-12-26 | 12:39:56.55 | 148.739 | -20.264 | 10.0 km | 2.2 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 2 km E Airlie Beach. Reviewed 2017-12-29. |
| 2017-12-22 | 02:19:08.72 | 151.557 | -25.891 | 10.0 km | 1.8 ML | Mainshock | Proston | 30 km N Proston. 30 km S Gaydnah. Reviewed 2017-12-28. |
| 2017-12-16 | 22:27:04.81 | 147.804 | -19.995 | 10.0 km | 2.7 ML | Mainshock | Bowen | 46 km W Bowen near Mt Abbott National Forest. Same area as April 2011 M5.3. Reviewed 2018-09-24. |
| 2017-12-15 | 15:59:42.25 | 148.752 | -20.267 | 10.0 km | 2.1 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 4 km E Airlie Beach. Reviewed 2017-12-29. |
| 2017-12-06 | 09:18:36.56 | 151.523 | -25.127 | 10.0 km | 1.4 ML | Aftershock | Mt Perry | Aftershock of 2015-02-15 15:57 event. 14 km NW Mt Perry. Reviewed 2017-12-14. |
| 2017-12-04 | 01:26:07.79 | 152.930 | -24.743 | 10.0 km | 2.4 ML | Aftershock | Hervey Bay | 60 km E Bundaberg. 61 km N Hervey Bay. Aftershock of 2017-12-02 16:00 ML 3.2. Reviewed 2017-12-04. |
| 2017-12-02 | 16:00:12.30 | 153.083 | -24.955 | 10.0 km | 3.2 ML | Aftershock | Hervey Bay | 45 km NE Hervey Bay. 23 km W Orchid Beach. Reviewed 2017-12-04 |
| 2017-11-25 | 04:47:04.74 | 148.765 | -20.196 | 10.0 km | 2.4 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 9 km NE Airlie Beach. Reviewed 2017-12-29. |
| 2017-11-24 | 10:10:41.20 | 148.748 | -20.193 | 10.0 km | 2.0 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 9 km NE Airlie Beach. Reviewed 2017-12-29. |
| 2017-11-18 | 03:36:18.08 | 152.586 | -23.420 | 10.0 km | 3.0 ML | Mainshock | Gladstone | 143 km NE Gladstone. Reviewed 2017-11-18. |
| 2017-11-15 | 21:38:53.20 | 148.740 | -20.263 | 10.0 km | 2.3 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 2 km E Airlie Beach. Reviewed 2017-12-29. |
| 2017-11-02 | 17:08:51.93 | 148.767 | -20.123 | 10.0 km | 2.1 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 17 km NE Airlie Beach. Reviewed 2017-12-29. |
| 2017-10-31 | 16:47:05.32 | 151.723 | -25.180 | 10.0 km | 0.5 ML | Aftershock | Mt Perry | Aftershock of 14:28 event. 8 km E Mt Perry. Reviewed 2017-11-01. |
| 2017-10-31 | 15:20:04.22 | 151.752 | -25.219 | 10.0 km | 0.7 ML | Aftershock | Mt Perry | Aftershock of 14:28 event. 12 km SE Mt Perry. Reviewed 2017-11-01. |
| 2017-10-31 | 14:28:05.60 | 151.742 | -25.198 | 10.0 km | 0.8 ML | Mainshock | Mt Perry | 10 km ESE Mt Perry. Reviewed 2017-11-01. |
| 2017-10-27 | 18:22:21.00 | 151.746 | -17.651 | 10.0 km | 2.8 ML | Mainshock | Coral Sea | 600 km E Innisfail, 450 km NE Bowen. Reviewed 2017-10-30. |
| 2017-10-24 | 12:31:07.80 | 148.898 | -19.827 | 10.0 km | 2.9 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 71 km NE Bowen. Reviewed 2017-10-25. |
| 2017-10-24 | 08:30:02.79 | 148.800 | -19.939 | 10.0 km | 2.4 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 58 km NE Bowen. Reviewed 2017-10-25. |
| 2017-10-22 | 05:20:08.65 | 148.720 | -19.900 | 10.0 km | 2.5 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 51 km NE Bowen. Reviewed 2017-10-22. |
| 2017-10-22 | 02:50:20.36 | 148.743 | -20.262 | 10.0 km | 2.2 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 3 km E Airlie Beach. Reviewed 2017-12-29. |
| 2017-10-20 | 06:39:47.89 | 148.606 | -19.866 | 10.0 km | 2.4 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 41 km NE Bowen. Reviewed 2017-10-22. |
| 2017-10-18 | 10:46:44.29 | 148.760 | -19.838 | 10.0 km | 2.2 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 57 km NE Bowen. Reviewed 2017-10-25. |
| 2017-10-14 | 11:52:52.82 | 151.814 | -25.317 | 10.0 km | 1.2 ML | Aftershock | Mt Perry | 23 km SE Mt Perry. Aftershock of 2017-10-14 11:52:33 event. Reviewed 2017-10-15. |
| 2017-10-14 | 11:52:33.02 | 151.802 | -25.304 | 10.0 km | 1.3 ML | Mainshock | Mt Perry | 21 km SE Mt Perry. Reviewed 2017-10-15. |
| 2017-10-14 | 11:52:02.03 | 151.799 | -25.300 | 10.0 km | 1.0 ML | Foreshock | Mt Perry | 20 km SE Mt Perry. Foreshock |
| 2017-10-14 | 11:51:03.86 | 151.806 | -25.308 | 10.0 km | 0.4 ML | Foreshock | Mt Perry | 22 km SE Mt Perry. Foreshock |
| 2017-10-14 | 11:50:25.00 | 151.781 | -25.319 | 10.0 km | 0.2 ML | Foreshock | Mt Perry | 21 km SE Mt Perry. Foreshock |
| 2017-10-14 | 11:50:12.28 | 151.816 | -25.313 | 10.0 km | -0.2 ML | Foreshock | Mt Perry | 23 km SE Mt Perry. Foreshock |
| 2017-10-13 | 11:52:22.12 | 148.750 | -19.872 | 10.0 km | 1.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 55 km NE Bowen. Reviewed 2017-10-25. |
| 2017-10-11 | 15:56:56.89 | 148.729 | -19.914 | 10.0 km | 1.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 52 km NE Bowen. Reviewed 2017-11-28. |
| 2017-10-09 | 21:00:45.37 | 148.770 | -19.859 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 57 km NE Bowen. Reviewed 2017-10-25. |
| 2017-10-07 | 04:32:25.19 | 148.587 | -20.054 | 10.0 km | 1.9 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 36 km E Bowen. Reviewed 2017-10-25. |
| 2017-10-02 | 18:42:24.00 | 148.765 | -19.889 | 10.0 km | 1.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 56 km NE Bowen. Reviewed 2017-10-25. |
| 2017-09-30 | 12:14:35.94 | 148.866 | -19.980 | 10.0 km | 1.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 65 km E Bowen. Reviewed 2017-11-03. |
| 2017-09-30 | 12:11:47.63 | 148.730 | -19.962 | 10.0 km | 1.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 51 km NE Bowen. Reviewed 2017-11-03. |
| 2017-09-30 | 08:29:48.06 | 154.292 | -25.528 | 10.0 km | 3.3 ML | Aftershock | Rainbow Beach | 128 km NE Rainbow Beach. Aftershock of the 2015-07-29 events. Reviewed 2017-10-02. |
| 2017-09-30 | 01:51:16.92 | 148.742 | -19.883 | 10.0 km | 2.2 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 54 km NE Bowen. Reviewed 2017-11-03. |
| 2017-09-25 | 09:38:35.84 | 148.846 | -19.913 | 10.0 km | 1.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 64 km NE Bowen. Reviewed 2017-11-03. |
| 2017-09-24 | 22:41:17.65 | 148.778 | -19.876 | 10.0 km | 2.2 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 58 km NE Bowen. Reviewed 2017-11-03. |
| 2017-09-24 | 19:51:32.71 | 148.793 | -19.764 | 10.0 km | 1.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 63 km NE Bowen. Reviewed 2017-11-03. |
| 2017-09-24 | 10:01:12.50 | 151.750 | -25.147 | 10.0 km | 2.5 ML | Aftershock | Mt Perry | Aftershock of 2015-02-15 15:57 event. 12 km E Mt Perry. Reviewed 2017-09-30. Heard in Gin Gin. |
| 2017-09-23 | 10:41:21.38 | 148.728 | -19.919 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 52 km NE Bowen. Reviewed 2017-11-03. |

| Date(UTC) | Time(UTC) | Longitude | Latitude | Depth | Magnitude | Event Type | Place | Comment |
|---|---|---|---|---|---|---|---|---|
| 2017-09-16 | 01:32:21.62 | 151.476 | -25.084 | 10.0 km | 1.5 ML | Aftershock | Mt Perry | Aftershock of 2015-02-15 15:57 event. 20 km NW Mt Perry. Reviewed 2017-09-18. |
| 2017-09-12 | 11:52:45.51 | 151.700 | -24.958 | 10.0 km | 0.9 ML | Mainshock | Mt Perry | 25 km N Mt Perry. Reviewed 2017-09-13. |
| 2017-09-05 | 10:07:42.21 | 148.777 | -19.852 | 10.0 km | 1.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 58 km NE Bowen. Reviewed 2017-11-03. |
| 2017-09-01 | 06:08:59.74 | 148.745 | -19.975 | 10.0 km | 2.1 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 52 km NE Bowen. Reviewed 2017-11-03. |
| 2017-09-01 | 02:36:03.29 | 148.185 | -27.738 | 10.0 km | 3.6 ML | Mainshock | St George | 52 km NW St George. Reviewed 2017-09-01. |
| 2017-09-01 | 02:27:44.64 | 148.704 | -19.934 | 10.0 km | 1.9 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 49 km NE Bowen. Reviewed 2017-11-03. |
| 2017-08-26 | 09:30:08.87 | 154.723 | -23.777 | 10.0 km | 3.0 ML | Mainshock | Bundaberg | 270 km NE Bundaberg. Reviewed 2017-08-27. |
| 2017-08-24 | 17:49:03.28 | 151.445 | -25.001 | 10.0 km | 1.7 ML | Aftershock | Mt Perry | Aftershock of 2015-02-15 15:57 event. 28 km NW Mt Perry. Reviewed 2017-08-25. |
| 2017-08-24 | 12:40:41:43 | 148.752 | -19.881 | 10.0 km | 2.5 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 55 km NE Bowen. Reviewed 2017-11-05. |
| 2017-08-21 | 16:43:09.42 | 148.753 | -19.868 | 10.0 km | 2.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 55 km NE Bowen. Reviewed 2017-11-05. |
| 2017-08-21 | 11:35:05.65 | 148.744 | -19.863 | 10.0 km | 2.3 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 55 km NE Bowen. Reviewed 2017-11-05. |
| 2017-08-20 | 09:50:36.49 | 148.796 | -19.855 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 60 km NE Bowen. Reviewed 2017-11-05. |
| 2017-08-19 | 12:43:06.76 | 148.755 | -19.894 | 10.0 km | 1.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 55 km NE Bowen. Reviewed 2017-11-05. |
| 2017-08-18 | 00:42:52.87 | 148.749 | -19.859 | 10.0 km | 1.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 55 km NE Bowen. Reviewed 2017-11-05. |
| 2017-08-14 | 19:33:46.39 | 151.730 | -25.003 | 10.0 km | 1.0 ML | Mainshock | Gin Gin | 23 km W Gin Gin in the New Moonta area. Reviewed 2017-08-15. |
| 2017-08-14 | 17:17:29.67 | 148.757 | -19.855 | 10.0 km | 1.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 56 km NE Bowen. Reviewed 2017-11-05. |
| 2017-08-13 | 17:03:59.09 | 148.752 | -19.860 | 10.0 km | 1.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 55 km NE Bowen. Reviewed 2017-11-04. |
| 2017-08-13 | 02:28:30.49 | 148.796 | -19.956 | 10.0 km | 1.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 58 km NE Bowen. Reviewed 2017-11-04. |
| 2017-08-12 | 15:50:54.65 | 148.743 | -19.855 | 10.0 km | 1.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 55 km NE Bowen. Reviewed 2017-11-04. |
| 2017-08-11 | 07:00:02.94 | 148.748 | -19.911 | 10.0 km | 2.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 54 km NE Bowen. Reviewed 2017-11-04. |
| 2017-08-08 | 19:08:52.74 | 148.729 | -19.902 | 10.0 km | 1.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 52 km NE Bowen. Reviewed 2017-11-04. |
| 2017-08-06 | 20:30:42.24 | 148.730 | -19.881 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 53 km NE Bowen. Reviewed 2017-11-04. |
| 2017-08-03 | 20:20:01.34 | 152.755 | -24.541 | 10.0 km | 2.1 ML | Mainshock | Bundaberg | 55 km NE Bundaberg. Reviewed 2017-08-04. |
| 2017-08-03 | 19:44:42.51 | 148.799 | -19.863 | 10.0 km | 1.5 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 60 km NE Bowen. Reviewed 2017-11-04. |
| 2017-08-01 | 23:43:54.05 | 148.789 | -19.875 | 10.0 km | 3.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 59 km NE Bowen. Reviewed 2017-11-04. |
| 2017-07-27 | 23:36:41.59 | 150.699 | -25.623 | 10.0 km | 2.2 ML | Mainshock | Eidsvold | 51 km SW Eidsvold. 9 km NW Nerangy Homestead. Reviewed 2017-07-30. |
| 2017-07-24 | 22:58:55.76 | 148.772 | -19.883 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 57 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-24 | 02:19:02.61 | 148.734 | -19.914 | 10.0 km | 2.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 52 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-21 | 10:20:24.77 | 151.831 | -25.365 | 10.0 km | 2.2 ML | Mainshock | Biggenden | 27 km NW Biggenden. 9 km W Paradise Dam. Reviewed 2017-07-21. |
| 2017-07-19 | 08:27:48.15 | 148.795 | -19.856 | 10.0 km | 1.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 60 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-18 | 19:19:32.42 | 148.723 | -19.934 | 10.0 km | 2.2 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 51 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-16 | 19:53:24.43 | 148.784 | -19.851 | 10.0 km | 1.9 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 59 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-16 | 12:01:17.95 | 148.823 | -19.856 | 10.0 km | 1.3 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 63 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-16 | 10:58:35.72 | 151.835 | -27.096 | 10.0 km | 2.1 ML | Mainshock | Cooya | 13 km S Cooya. Reviewed 2017-10-15. |
| 2017-07-16 | 07:49:37.79 | 148.828 | -19.893 | 10.0 km | 1.5 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 62 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-14 | 14:59:12.33 | 148.768 | -19.894 | 10.0 km | 1.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 56 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-14 | 10:38:14.73 | 148.786 | -19.894 | 10.0 km | 1.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 58 km NE Bowen. Reviewed 2017-11-08. |
| 2017-07-14 | 01:13:02.30 | 148.781 | -19.879 | 10.0 km | 1.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 58 km NE Bowen. Reviewed 2017-11-07. |
| 2017-07-12 | 00:02:06.67 | 148.764 | -19.806 | 10.0 km | 2.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 59 km NE Bowen. Reviewed 2017-11-07. |
| 2017-07-10 | 21:32:30.64 | 151.471 | -25.095 | 10.0 km | 1.4 ML | Aftershock | Mt Perry | Aftershock of 2015-02-15 15:57 event. 20 km NW Mt Perry. Reviewed 2017-07-11. |
| 2017-07-10 | 14:53:29.92 | 148.781 | -19.832 | 10.0 km | 1.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 59 km NE Bowen. Reviewed 2017-11-07. |
| 2017-07-09 | 14:55:34.91 | 148.697 | -19.990 | 10.0 km | 1.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 47 km E Bowen. Reviewed 2017-11-07. |
| 2017-06-26 | 21:57:28.34 | 148.758 | -20.043 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 54 km E Bowen. Reviewed 2017-12-29. |
| 2017-06-26 | 19:22:41.72 | 148.755 | -20.222 | 10.0 km | 2.0 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 6 km NE Airlie Beach. Reviewed 2018-09-24. |
| 2017-06-22 | 16:55:43.70 | 148.776 | -19.972 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 56 km E Bowen. Reviewed 2017-12-29. |
| 2017-06-19 | 08:21:49.39 | 148.764 | -19.804 | 10.0 km | 2.7 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 59 km NE Bowen. Reviewed 2017-12-29. |
| 2017-05-27 | 02:49:25.88 | 148.761 | -20.099 | 10.0 km | 2.0 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 19 km N Airlie Beach. Reviewed 2017-12-29. |

| Date(UTC) | Time(UTC) | Longitude | Latitude | Depth | Magnitude | Event Type | Place | Comment |
|---|---|---|---|---|---|---|---|---|
| 2017-05-23 | 08:06:45.31 | 148.754 | -19.725 | 10.0 km | 2.3 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 62 km NE Bowen. Reviewed 2017-12-29. |
| 2017-05-21 | 23:01:26.12 | 148.711 | -19.719 | 10.0 km | 2.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 59 km NE Bowen. Reviewed 2017-12-30. |
| 2017-05-20 | 16:58:44.64 | 148.767 | -19.767 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 61 km NE Bowen. Reviewed 2017-12-30. |
| 2017-05-06 | 19:00:25.73 | 154.927 | -26.288 | 10.0 km | 2.8 ML | Mainshock | Noosaville | 186 km E Noosaville. Reviewed 2017-05-07. |
| 2017-05-03 | 18:02:18.70 | 148.800 | -19.859 | 10.0 km | 2.5 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 60 km NE Bowen. Reviewed 2017-12-30. |
| 2017-04-26 | 17:50:05.63 | 151.391 | -26.493 | 10.0 km | 2.3 ML | Mainshock | Durong | 18 km SE Durong. Reviewed 2017-04-27. |
| 2017-04-13 | 21:57:27.86 | 150.716 | -25.724 | 10.0 km | 1.4 ML | Mainshock | Monogorilby | 45 km NW Monogorilby. Reviewed 2017-04-17. |
| 2017-04-10 | 11:47:40.70 | 148.750 | -20.194 | 10.0 km | 2.1 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 9 km NE Airlie Beach. Reviewed 2017-12-30. |
| 2017-04-07 | 11:31:17.61 | 148.871 | -19.851 | 10.0 km | 3.2 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 68 km NE Bowen. Reviewed 2017-12-30. |
| 2017-04-02 | 03:03:31.91 | 148.673 | -19.978 | 10.0 km | 1.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 41 km E Bowen. Reviewed 2017-12-05. |
| 2017-03-30 | 02:33:02.73 | 148.818 | -19.814 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 64 km NE Bowen. Reviewed 2017-12-30. |
| 2017-03-27 | 11:57:47.02 | 148.721 | -20.003 | 10.0 km | 2.0 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 50 km E Bowen. Reviewed 2017-12-30. |
| 2017-03-27 | 02:12:57.95 | 148.759 | -20.071 | 10.0 km | 2.2 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 22 km N Airlie Beach. Reviewed 2017-12-30. |
| 2017-03-24 | 13:32.01.23 | 150.667 | -28.933 | 10.0 km | 2.7 ML | Mainshock | Goondiwindi | 57 km SE Goondiwindi Reviewed 2017-03-25. |
| 2017-03-23 | 04:19:15.37 | 151.452 | -26.167 | 10.0 km | 1.3 ML | Mainshock | Proston | 15 km W Proston. Reviewed 2017-03-31. |
| 2017-03-19 | 07:50:42.69 | 151.653 | -24.323 | 10.0 km | 1.6 ML | Mainshock | Miriam Vale | 9 km E Miriam Vale. Reviewed 2017-03-23. |
| 2017-03-15 | 17:33:22.83 | 151.830 | -25.027 | 10.0 km | 0.6 ML | Mainshock | Gin Gin | 14 kmWSW Gin Gin. Reviewed 2017-03-16. |
| 2017-03-12 | 10:39:30.04 | 148.769 | -20.186 | 10.0 km | 2.2 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 11 km NE Airlie Beach. Reviewed 2017-12-30. |
| 2017-03-10 | 02:11:39.45 | 151.419 | -26.179 | 10.0 km | 1.0 ML | Mainshock | Proston | 18 km W Proston. Reviewed 2017-03-10. |
| 2017-03-05 | 14:36:46.50 | 152.560 | -24.361 | 10.0 km | 2.6 ML | Mainshock | Bundaberg | 60 km NNE Bundaberg. Reviewed 2017-03-09. |
| 2017-03-01 | 14:37:19.47 | 148.749 | -20.183 | 10.0 km | 2.4 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 10 km N Airlie Beach. Reviewed 2017-12-30. |
| 2017-02-27 | 19:55:07.73 | 148.851 | -19.885 | 10.0 km | 3.1 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 65 km E Bowen. 44 km N Airlie Beach. Reviewed 2017-02-27. |
| 2017-02-22 | 17:54:04.27 | 148.747 | -20.265 | 10.0 km | 2.0 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 3 km E Airlie Beach. Reviewed 2017-12-31. |
| 2017-02-22 | 03:48:07.02 | 148.822 | -20.079 | 10.0 km | 2.1 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 24 km NE Airlie Beach. Reviewed 2017-12-31. |
| 2017-02-04 | 15:03:21.29 | 148.837 | -19.826 | 10.0 km | 2.6 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 65 km NE Bowen. Reviewed 2017-12-31. |
| 2017-02-01 | 11:56:29.91 | 148.785 | -20.084 | 10.0 km | 2.8 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 57 km E Bowen. 21 km N Airlie Beach. Reviewed 2017-02-02. |
| 2017-01-28 | 22:20:31.22 | 148.767 | -20.079 | 10.0 km | 2.1 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 22 km NE Airlie Beach. Reviewed 2017-12-31. |
| 2017-01-26 | 23:16:08.87 | 148.763 | -20.186 | 10.0 km | 2.3 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 10 km NE Airlie Beach. Reviewed 2017-12-31. |
| 2017-01-26 | 13:21:44.73 | 148.761 | -20.036 | 10.0 km | 2.0 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 26 km N Airlie Beach. Reviewed 2017-12-31. |
| 2017-01-25 | 22:55:02.66 | 148.625 | -20.203 | 10.0 km | 2.2 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 12 km NW Airlie Beach. Reviewed 2017-12-31. |
| 2017-01-22 | 15:34:04.06 | 142.915 | -28.234 | 10.0 km | 3.2 ML | Mainshock | Bulloo Downs | 93 km SW Thargomindah. 33 km NNW Bulloo Downs, not felt at Bulloo Downs nor Thargomindah. Reviewed 2017-01-23. |
| 2017-01-21 | 02:46:44.33 | 148.749 | -20.265 | 10.0 km | 2.0 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event. 3 km E Airlie Beach. Reviewed 2017-12-31. |
| 2017-01-17 | 23:40:41.09 | 148.779 | -20.023 | 10.0 km | 2.2 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event.28 km N Airlie Beach. Reviewed 2018-01-09. |
| 2017-01-16 | 22:06:20.12 | 148.646 | -20.396 | 10.0 km | 2.1 ML | Aftershock | Proserpine | Aftershock of 2016-08-18 04:30 event.7 km E Proserpine. Reviewed 2018-01-09. |
| 2017-01-14 | 02:07:31.72 | 148.738 | -19.727 | 10.0 km | 2.5 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 60 km NE Bowen. Reviewed 2018-01-09. |
| 2017-01-13 | 19:29:10.17 | 148.722 | -19.739 | 10.0 km | 2.3 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 58 km NE Bowen. Reviewed 2018-01-09. |
| 2017-01-13 | 18:13:33.47 | 148.835 | -19.818 | 10.0 km | 3.5 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 65 km NE Bowen. Reviewed 2017-01-14. |
| 2017-01-10 | 11:40:33.40 | 148.714 | -20.349 | 10.0 km | 1.9 ML | Aftershock | Airlie Beach | Aftershock of 2016-08-18 04:30 event.9 km S Airlie Beach. Reviewed 2018-01-09. |
| 2017-01-10 | 11:39:06.88 | 148.737 | -19.697 | 10.0 km | 2.1 ML | Aftershock | Bowen | Aftershock of 2016-08-18 04:30 event. 62 km NE Bowen. Reviewed 2017-01-14. |
| 2017-01-05 | 16:31:51.40 | 151.487 | -25.234 | 10.0 km | 0.5 ML | Aftershock | Mt Perry | Aftershock of 2015-02-15 15:57 event. 17 km SW Mt Perry. Reviewed 2017-01-06. |
| 2017-01-05 | 16:31:41.39 | 151.487 | -25.234 | 10.0 km | 0.6 ML | Aftershock | Mt Perry | Aftershock of 2015-02-15 15:57 event. 17 km SW Mt Perry. Reviewed 2017-01-06. |

**Table 2: Bowen sequence events detected in 2017, but not located due to lack of instrumental records.**

| Date | Time | ML | Date | Time | ML | Date | Time | ML | Date | Time | ML |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2017-01-04 | 05:06 | 2.0 | 2017-02-01 | 02:14 | 1.6 | 2017-04-01 | 05:56 | 1.6 | 2017-09-30 | 02:17 | 1.6 |
| 2017-01-04 | 06:32 | 1.8 | 2017-02-02 | 14:22 | 1.8 | 2017-04-02 | 03:55 | 1.9 | 2017-10-05 | 02:31 | 1.5 |
| 2017-01-04 | 06:34 | 1.9 | 2017-02-05 | 00:24 | 1.9 | 2017-04-04 | 16:39 | 1.8 | 2017-10-05 | 16:12 | 1.5 |
| 2017-01-04 | 13:55 | 1.6 | 2017-02-05 | 15:35 | 1.5 | 2017-04-05 | 20:46 | 1.8 | 2017-10-07 | 04:32 | 1.8 |
| 2017-01-05 | 16:19 | 1.7 | 2017-02-05 | 19:01 | 1.5 | 2017-04-09 | 13:41 | 1.6 | 2017-10-08 | 21:09 | 1.4 |
| 2017-01-05 | 20:48 | 1.5 | 2017-02-06 | 02:17 | 1.6 | 2017-04-11 | 11:36 | 1.7 | 2017-10-08 | 21:11 | 1.5 |
| 2017-01-07 | 04:19 | 1.8 | 2017-02-06 | 14:38 | 1.8 | 2017-04-12 | 08:16 | 1.8 | 2017-10-11 | 12:57 | 1.4 |
| 2017-01-08 | 09:37 | 2.2 | 2017-02-06 | 15:26 | 1.4 | 2017-04-14 | 10:06 | 1.9 | 2017-10-11 | 21:40 | 1.6 |
| 2017-01-09 | 21:16 | 1.8 | 2017-02-06 | 18:31 | 1.4 | 2017-04-14 | 16:40 | 1.7 | 2017-10-11 | 21:44 | 1.5 |
| 2017-01-09 | 22:31 | 1.5 | 2017-02-06 | 18:36 | 1.6 | 2017-04-23 | 22:48 | 1.8 | 2017-10-16 | 17:59 | 1.4 |
| 2017-01-10 | 07:51 | 1.8 | 2017-02-07 | 22:44 | 1.6 | 2017-04-24 | 10:58 | 1.8 | 2017-10-21 | 14:58 | 1.4 |
| 2017-01-13 | 19:15 | 1.5 | 2017-02-10 | 22:20 | 1.6 | 2017-04-26 | 01:05 | 1.8 | 2017-10-25 | 00:33 | 1.7 |
| 2017-01-13 | 23:29 | 1.6 | 2017-02-15 | 13:29 | 1.6 | 2017-04-26 | 13:39 | 1.7 | 2017-10-25 | 15:25 | 1.5 |
| 2017-01-14 | 14:20 | 1.8 | 2017-02-15 | 23:05 | 1.7 | 2017-04-27 | 15:46 | 1.7 | 2017-10-29 | 11:30 | 1.3 |
| 2017-01-15 | 06:19 | 1.9 | 2017-02-19 | 17:03 | 1.5 | 2017-04-30 | 09:50 | 1.7 | 2017-10-31 | 06:56 | 1.8 |
| 2017-01-15 | 22:50 | 1.9 | 2017-02-20 | 08:52 | 1.4 | 2017-05-01 | 09:31 | 1.6 | 2017-11-01 | 04:18 | 1.8 |
| 2017-01-16 | 13:25 | 1.6 | 2017-02-21 | 14:59 | 1.6 | 2017-05-07 | 05:17 | 1.7 | 2017-11-07 | 13:27 | 1.6 |
| 2017-01-18 | 12:53 | 1.6 | 2017-02-21 | 19:03 | 1.6 | 2017-05-07 | 10:07 | 1.7 | 2017-11-11 | 06:36 | 1.8 |
| 2017-01-18 | 16:48 | 1.7 | 2017-02-23 | 10:53 | 1.6 | 2017-05-18 | 01:15 | 1.8 | 2017-11-11 | 16:41 | 1.5 |
| 2017-01-18 | 18:33 | 1.4 | 2017-02-24 | 02:40 | 1.9 | 2017-05-20 | 05:12 | 1.8 | 2017-11-11 | 21:03 | 1.4 |
| 2017-01-19 | 07:48 | 1.4 | 2017-02-24 | 11:19 | 1.6 | 2017-05-20 | 09:51 | 1.7 | 2017-11-14 | 12:17 | 1.5 |
| 2017-01-19 | 12:32 | 1.6 | 2017-02-26 | 22:06 | 1.6 | 2017-05-22 | 15:48 | 1.7 | 2017-11-16 | 15:21 | 1.7 |
| 2017-01-19 | 22:56 | 1.5 | 2017-02-28 | 22:45 | 1.7 | 2017-05-23 | 10:57 | 1.7 | 2017-11-16 | 16:17 | 1.4 |
| 2017-01-21 | 11:16 | 1.5 | 2017-03-01 | 20:34 | 1.8 | 2017-05-25 | 02:29 | 1.8 | 2017-11-18 | 07:04 | 1.6 |
| 2017-01-21 | 16:44 | 1.5 | 2017-03-02 | 22:19 | 1.7 | 2017-05-25 | 17:44 | 1.7 | 2017-11-18 | 14:06 | 1.4 |
| 2017-01-22 | 00:17 | 1.7 | 2017-03-04 | 05:22 | 1.5 | 2017-05-27 | 04:40 | 1.9 | 2017-11-20 | 18:46 | 1.8 |
| 2017-01-22 | 16:23 | 1.4 | 2017-03-05 | 00:09 | 1.5 | 2017-05-27 | 06:47 | 1.7 | 2017-11-21 | 02:04 | 1.9 |
| 2017-01-22 | 21:00 | 1.6 | 2017-03-06 | 19:06 | 1.5 | 2017-05-30 | 11:52 | 1.7 | 2017-11-22 | 20:07 | 1.6 |
| 2017-01-22 | 23:38 | 1.4 | 2017-03-09 | 02:05 | 1.8 | 2017-06-09 | 23:33 | 1.9 | 2017-11-23 | 11:43 | 1.4 |
| 2017-01-26 | 01:17 | 1.8 | 2017-03-09 | 15:27 | 1.6 | 2017-06-14 | 07:16 | 1.7 | 2017-11-24 | 14:20 | 1.5 |
| 2017-01-26 | 14:46 | 1.4 | 2017-03-10 | 08:06 | 1.6 | 2017-06-15 | 08:50 | 1.7 | 2017-11-25 | 02:52 | 1.6 |
| 2017-01-26 | 21:38 | 1.7 | 2017-03-10 | 18:40 | 1.8 | 2017-06-17 | 16:11 | 1.7 | 2017-12-05 | 17:01 | 1.7 |
| 2017-01-27 | 21:38 | 1.6 | 2017-03-11 | 14:47 | 1.7 | 2017-06-29 | 16:12 | 1.8 | 2017-12-06 | 20:50 | 1.9 |
| 2017-01-29 | 16:37 | 1.8 | 2017-03-13 | 02:37 | 1.7 | 2017-07-25 | 19:54 | 1.6 | 2017-12-07 | 12:03 | 1.6 |
| 2017-01-31 | 03:00 | 1.5 | 2017-03-13 | 21:09 | 1.7 | 2017-07-26 | 09:32 | 1.6 | 2017-12-12 | 05:53 | 1.9 |
| | | | 2017-03-14 | 01:36 | 1.7 | 2017-07-28 | 04:34 | 1.8 | 2017-12-13 | 13:45 | 1.9 |
| | | | 2017-03-14 | 15:25 | 1.8 | 2017-07-30 | 04:24 | 1.9 | 2017-12-13 | 17:15 | 1.5 |
| | | | 2017-03-15 | 02:39 | 1.9 | 2017-07-31 | 21:59 | 1.6 | 2017-12-18 | 13:08 | 1.5 |
| | | | 2017-03-16 | 21:42 | 1.5 | 2017-08-18 | 16:47 | 1.5 | 2017-12-21 | 19:25 | 1.8 |
| | | | 2017-03-17 | 03:56 | 1.8 | | | | 2017-12-23 | 22:43 | 1.5 |
| | | | 2017-03-17 | 17:56 | 1.4 | | | | 2017-12-26 | 12:55 | 1.4 |
| | | | 2017-03-18 | 15:00 | 1.7 | | | | 2017-12-27 | 06:13 | 1.8 |
| | | | 2017-03-19 | 09:09 | 1.7 | | | | 2017-12-27 | 09:29 | 1.7 |
| | | | 2017-03-23 | 18:24 | 1.9 | | | | 2017-12-28 | 09:08 | 1.5 |
| | | | 2017-03-24 | 21:24 | 1.9 | | | | 2017-12-31 | 13:37 | 1.5 |
| | | | 2017-03-27 | 07:23 | 1.7 | | | | | | |
| | | | 2017-03-31 | 18:36 | 1.6 | | | | | | |

# 2017 Statistical Summary

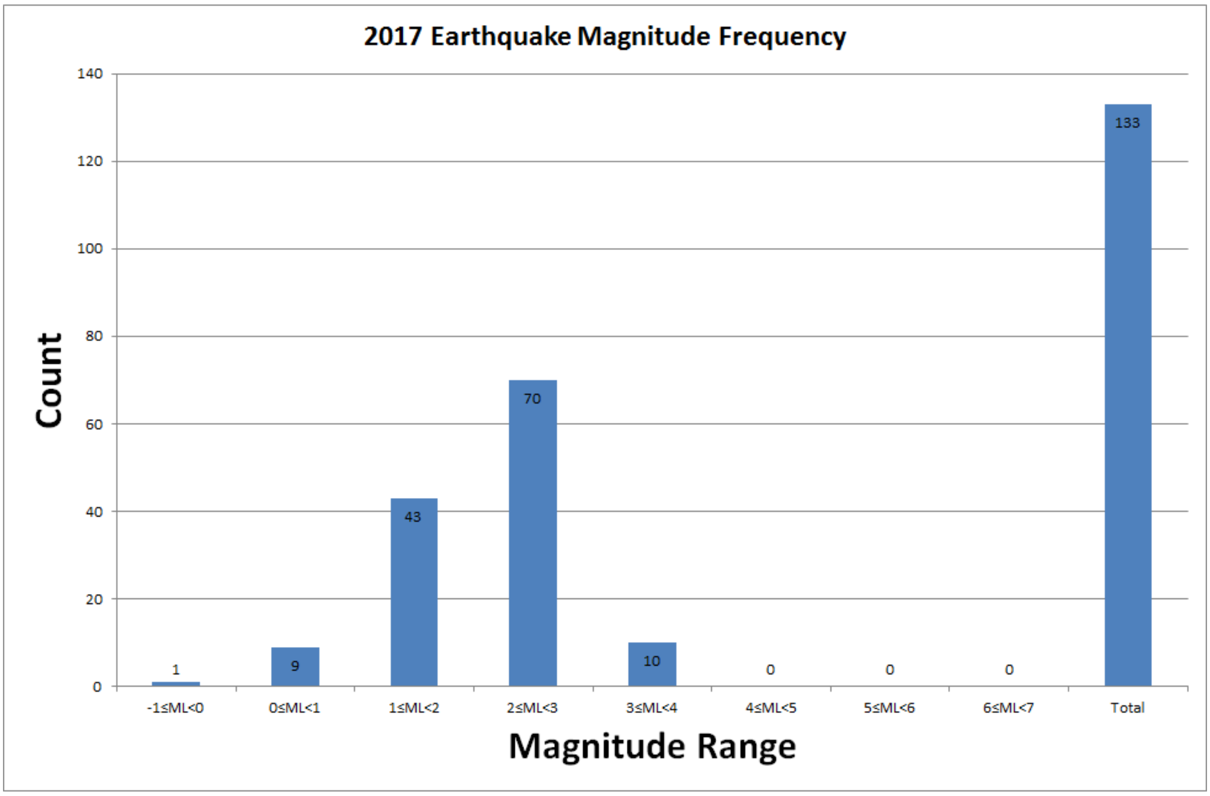


Figure 13: Frequency of earthquake magnitudes during 2017.

Figure 13 provides a graphical representation of the frequency of magnitude spread for earthquake events listed in the main CQSRG Catalogue (**Error! Reference source not found.**).

Figure 14 puts into context the extraordinary number of earthquakes detected during 2015, 2016, and 2017 when compared to the numbers detected in previous years.

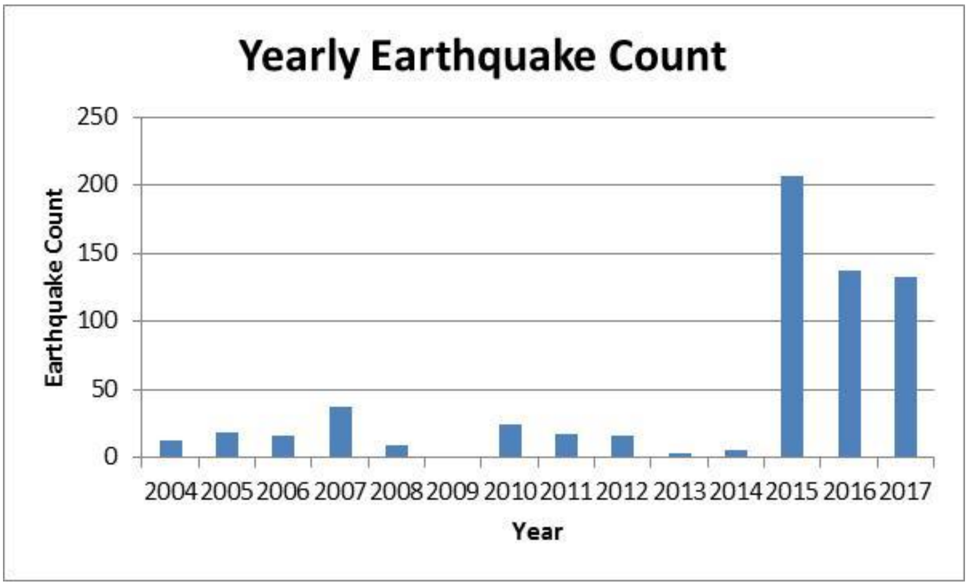


Figure 14: Yearly count of earthquakes detected by CQSRG.

The three years 2015, 2016, and 2017 have each exhibited a significantly greater number of earthquake events than all previous years – certainly since 2004, when CQSRG began monitoring. The M 5.8 Bowen event is probably the second largest earthquake to have been recorded on the East coast of Mainland Australia in modern times.

Figure 15 is a broad-view map of the earthquakes location in the southern coastal part of Queensland by CQSRG in 2017. This does not include any of the 2017 Bowen earthquakes.

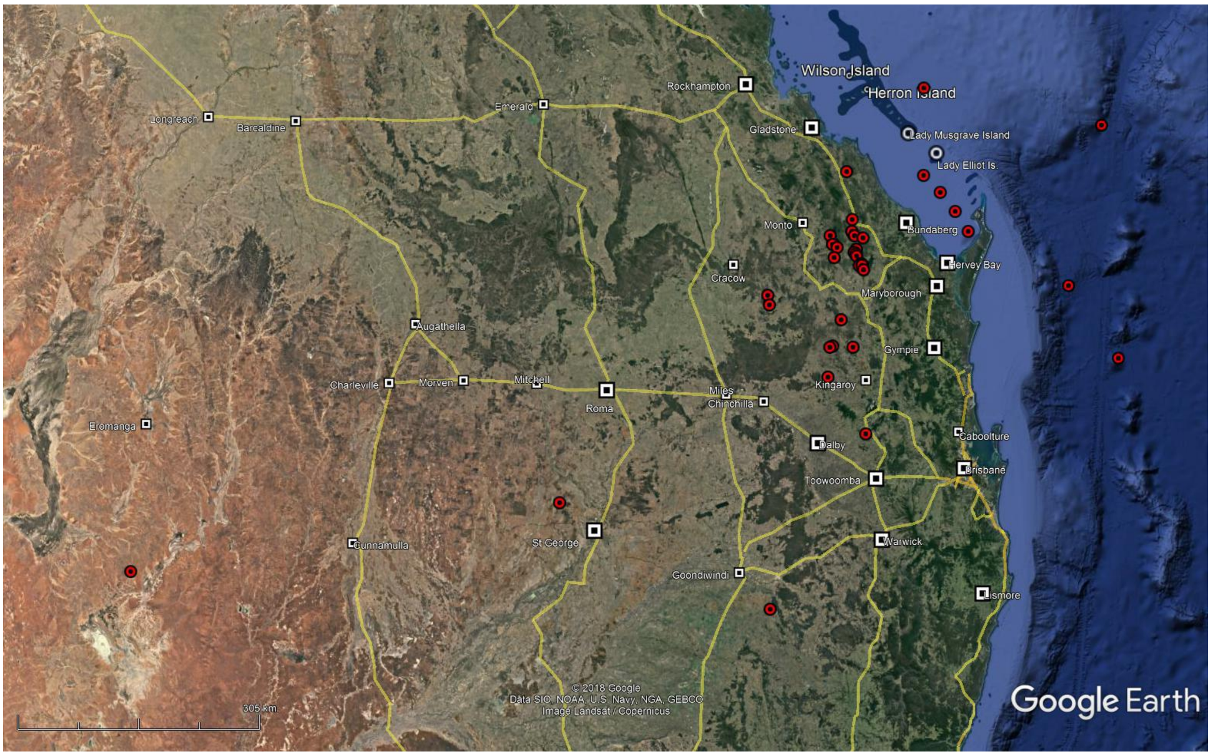


**Figure 15: Broad view of earthquakes located in 2017 by CQSRG in Southern coastal Queensland.**

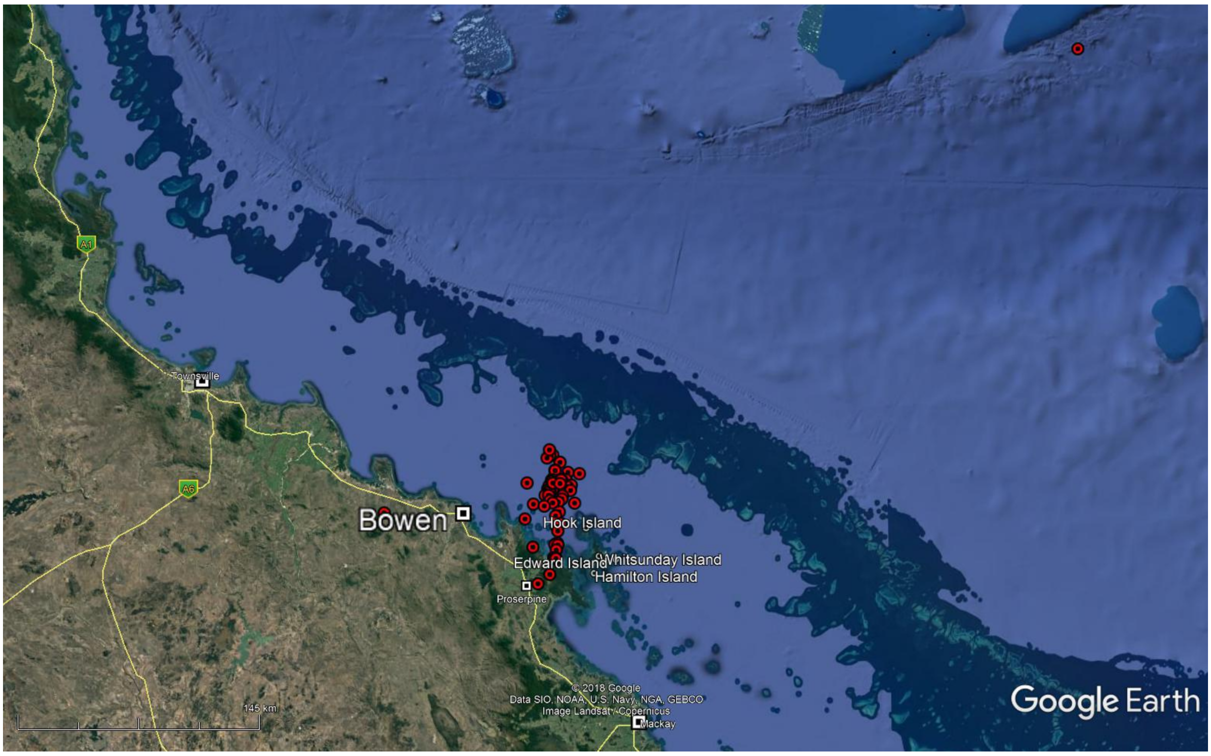


Figure 16: Broad view of earthquakes located in 2017 by CQSRG in Northern coastal Queensland.

Figure 16 is a broad-view map of the earthquakes location in the northern coastal part of Queensland by CQSRG in 2017. This includes the 2017 Bowen earthquakes.

## 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 , 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 ).

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

Station FS03 is registered with the International Registry of Seismograph Stations maintained jointly by International Seismological Centre & World Data Centre for Seismology.

### 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.

| 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 – Details of WOOW

Station WOOW is registered with the International Registry of Seismograph Stations maintained jointly by International Seismological Centre & World Data Centre for Seismology.

### LOCATION

Latitude 25.4755, Longitude 152.0799, Height above sea level 128 m. 5 km NE of Biggenden, Queensland, Australia.

### SITE AND SAMPLING

Sampling At 100 sample/sec, full scale 4194304

| Ch | Type | Serial | Name | Direction | Gain | Filters | |
|---|---|---|---|---|---|---|---|
| 1 | S6000 | #10509 | East | 90 deg mag | 1.00 | DC | 25.0 |
| 2 | S6000 | #10509 | North | 0 deg mag | 1.00 | DC | 25.0 |
| 3 | S6000 | #10509 | Up | Positive up | 1.00 | DC | 25.0 |

### 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

TA/LTA Channel 3, filter 2.00 to 7.50 Hz
Time const 0.20, 2.0, 20.0, 200.0 seconds
Ratios Fast 2.50, slow 1.75, squelch 5, 7 days
Length 150 to 230 secs, 99.00 sec pre-trigger, 1.10 cutoff.

# Appendix C – 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 CQSRG network 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.

# Appendix D – 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 ($\mathrm{M}$) is calculated using the formula given in Eq. 1.

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

Where:

$\mathrm{A}$ 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:

$\delta$ 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 $\delta$, providing that sufficient data is available

The epicentral distance $\delta$ 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.

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

Table 3 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 3: 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 17 shows the graph of $\log_{10}A_0$ plotted against the associated S-P time difference (extracted from Table 3).

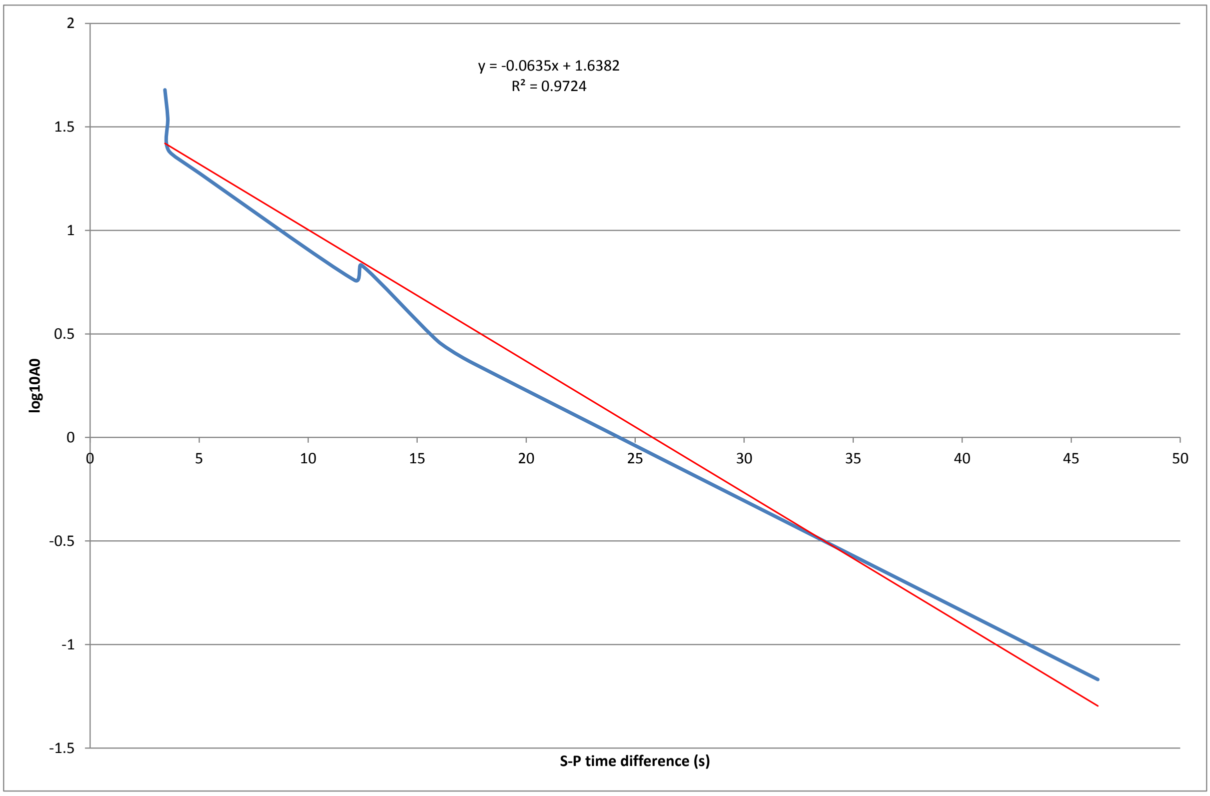


Figure 17: $\log_{10}A_0$ Vs S-P

Figure 17 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.

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

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 3, Figure 17, 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 4.

**Table 4: 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 4 are those used at CQSRG to calculate local magnitudes of events recorded by station FS03.

## Example Usage

Figure 18 shows the seismogram of an earthquake that was recorded on station FS03 on 26 October 2012.

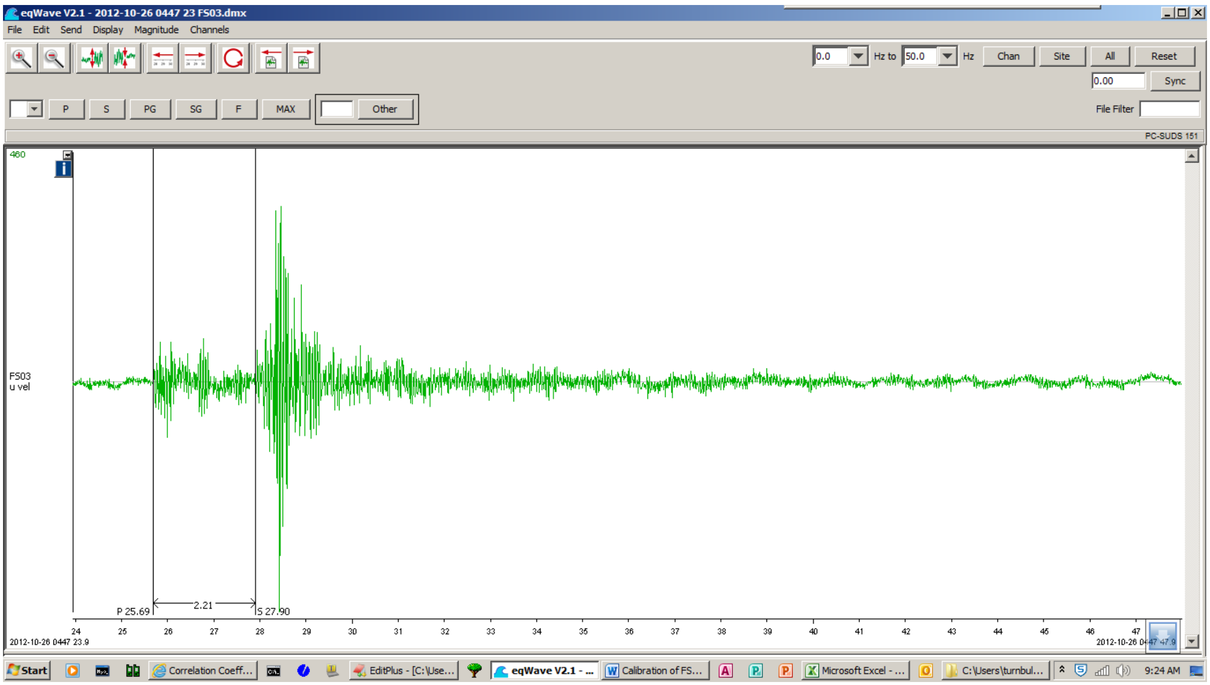


**Figure 18: FS03 record of an earthquake.**

From Figure 18 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 5 shows the results of some other similar calculations, for different earthquakes.

**Table 5: 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

Figure 19, Figure 20, Figure 21, and Figure 22 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.

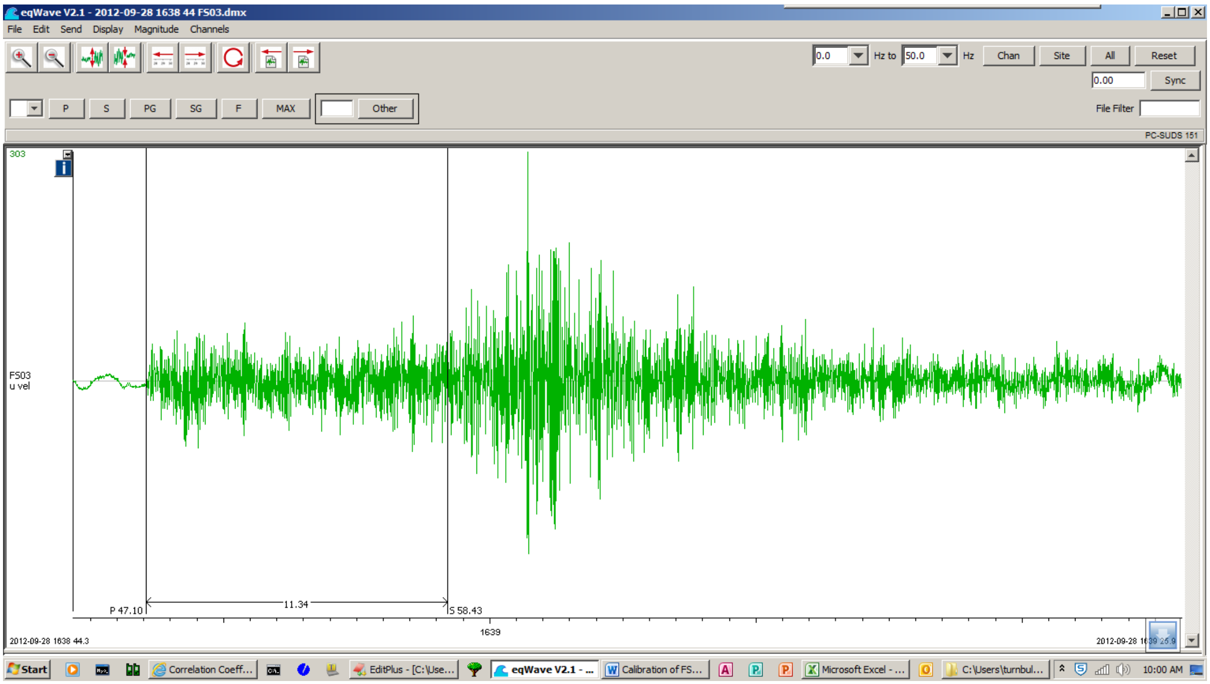


**Figure 19: Earthquake recorded on FS03 on 28 September 2012**

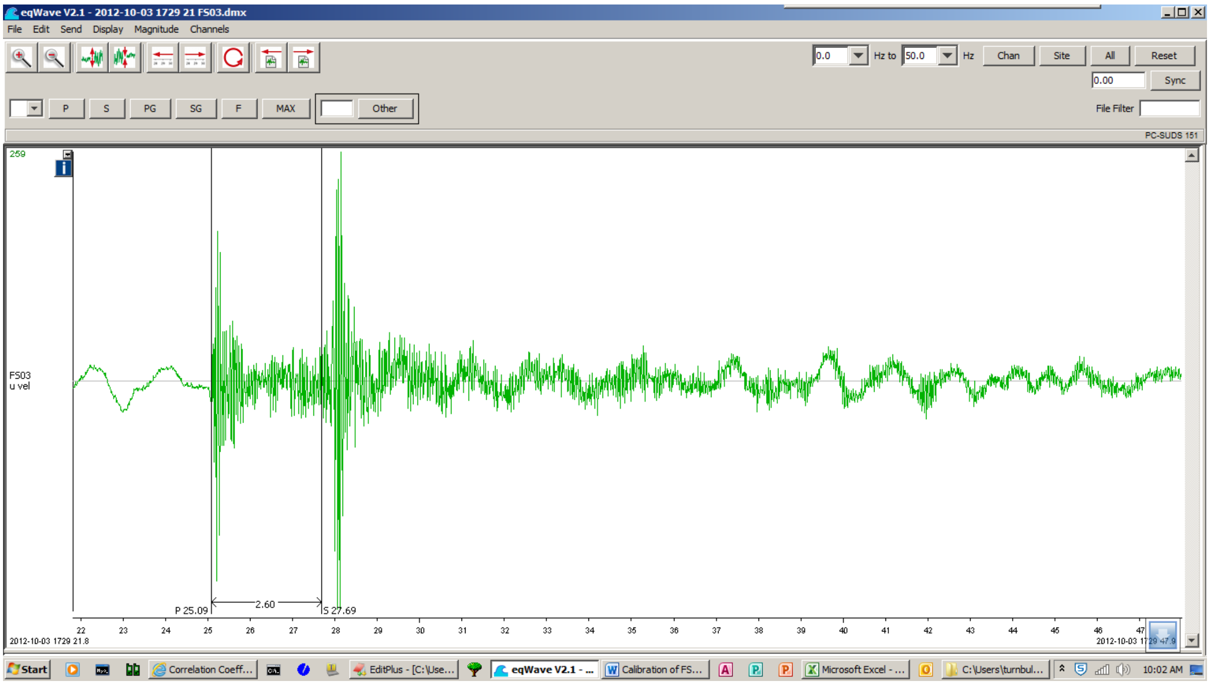


Figure 20: Earthquake recorded on FS03 on 3 October 2012

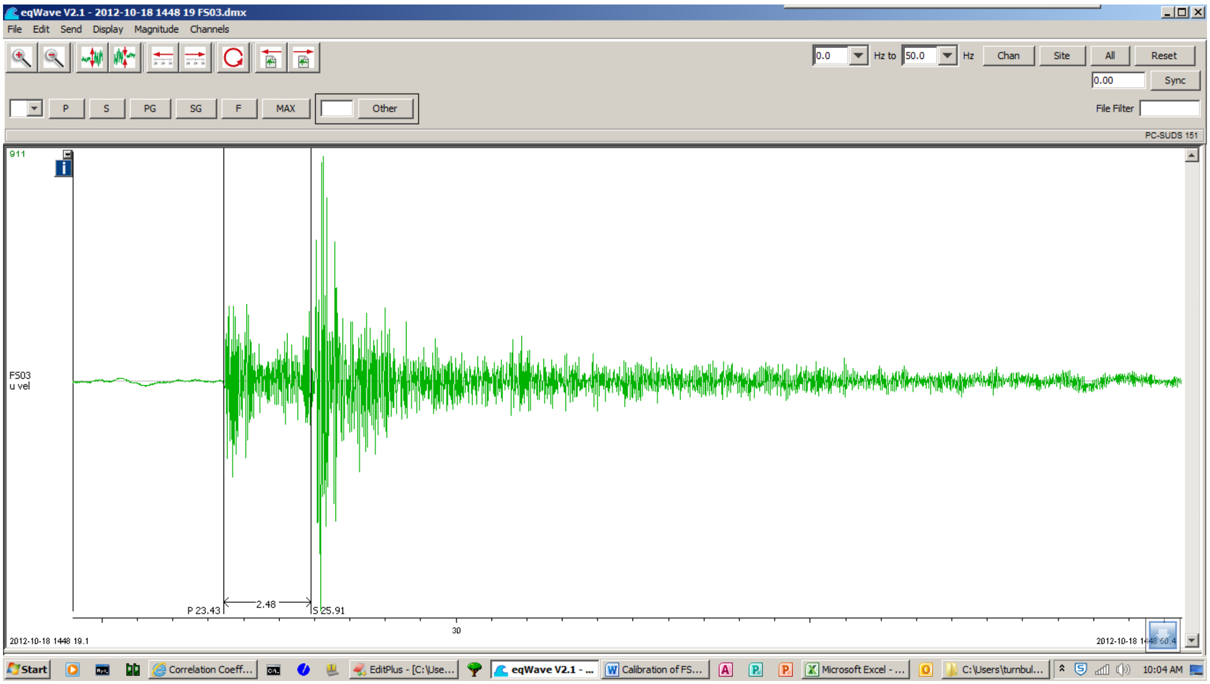


Figure 21: Earthquake recorded on FS03 on 18 October 2012

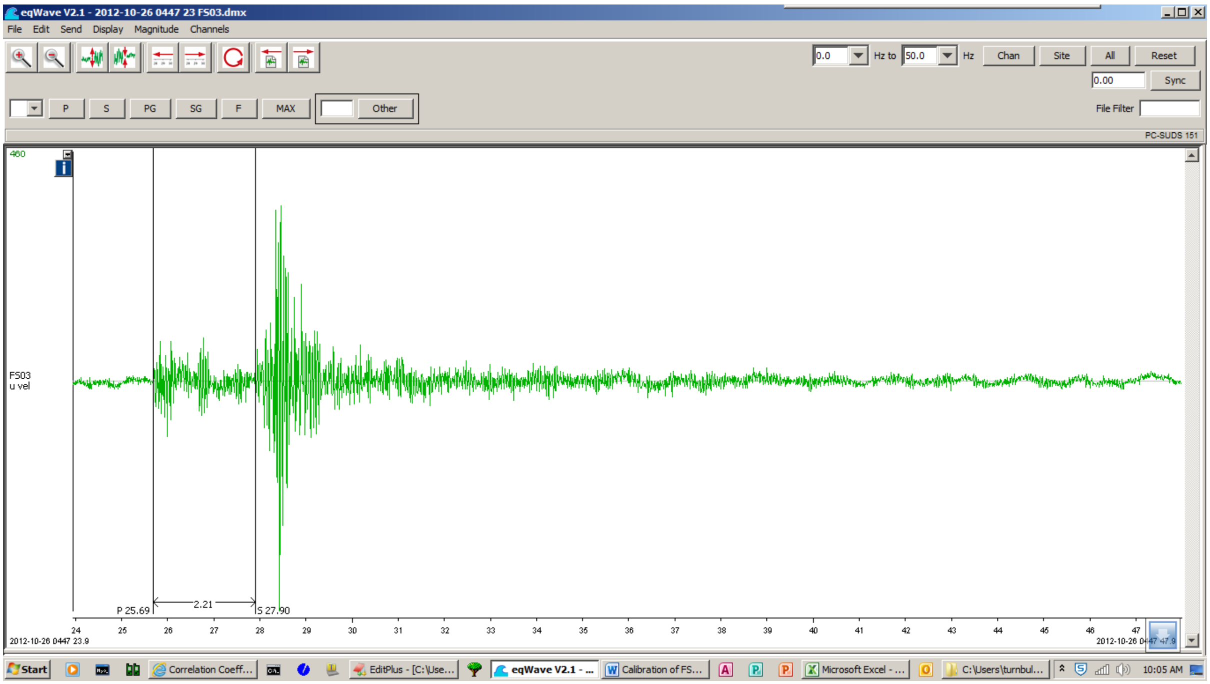


Figure 22: Earthquake recorded on FS03 on 26 October 2012

# Appendix E - 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.

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

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:

$\delta$ 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 $\delta$, 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.

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

Table 6 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 6: Determination of $\log_{10}A_0$ 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 23 shows the graph of $\log_{10}A_0$ plotted against the associated S-P time difference (extracted from Table 6: Determination of $\log_{10}A_0$ from past events recorded on the EIDS seismograph.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**

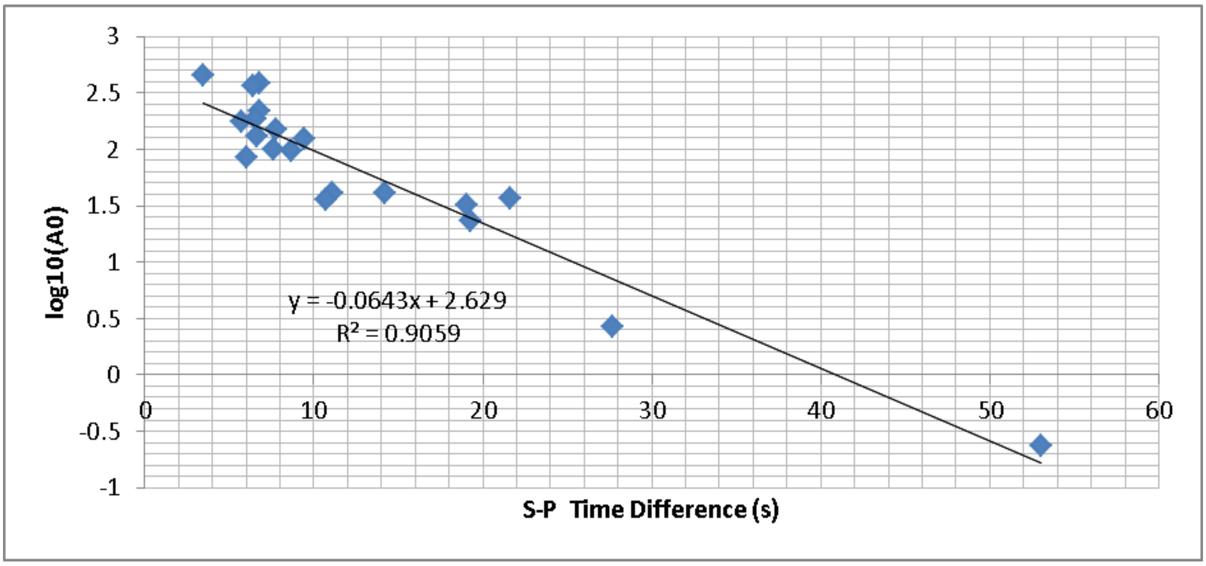


Figure 23: 23: $\log_{10}A_0$ Vs S-P

**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.

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

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

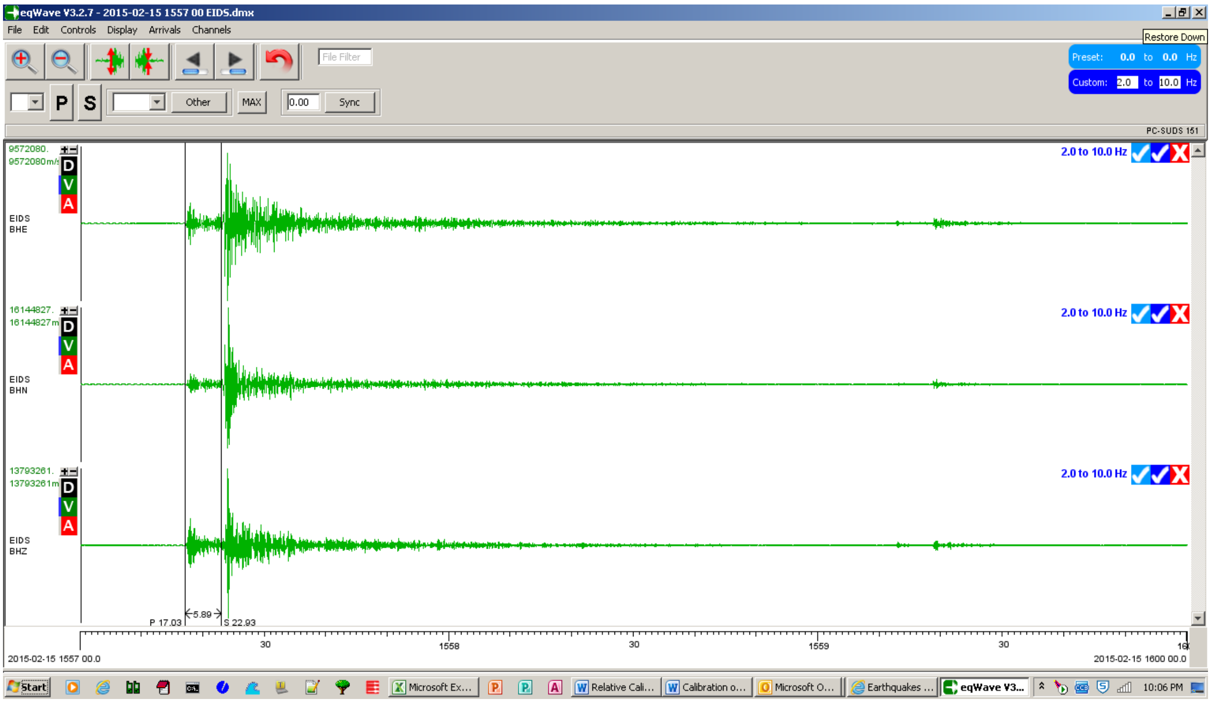


Figure 24: EIDS record of an earthquake.

From Figure 24 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 7 shows the results of some other similar calculations, for different earthquakes, along with the GA published magnitudes for the same events.

Table 7: 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 |

# Appendix F - Magnitude Calibration of BW1H for the Bowen 2016 Earthquake Sequence.

## Introduction

In August 2016 a magnitude 5.8 earthquake occurred in the Whitsunday Passage east of Bowen and North of Airlie Beach. This was followed by many aftershocks over the next few months. The nearest seismic monitoring stations were the Urban Monitoring (UM) network stations in Bowen. There are two stations: one on soft basement (BW2S); and one on hard basement (BW1H).

The BW1H station provided relatively clean records of the main and aftershocks.

The locations of the earthquakes in the sequence formed a relatively tight group around the main event. Figure 25 shows the grouping pattern.

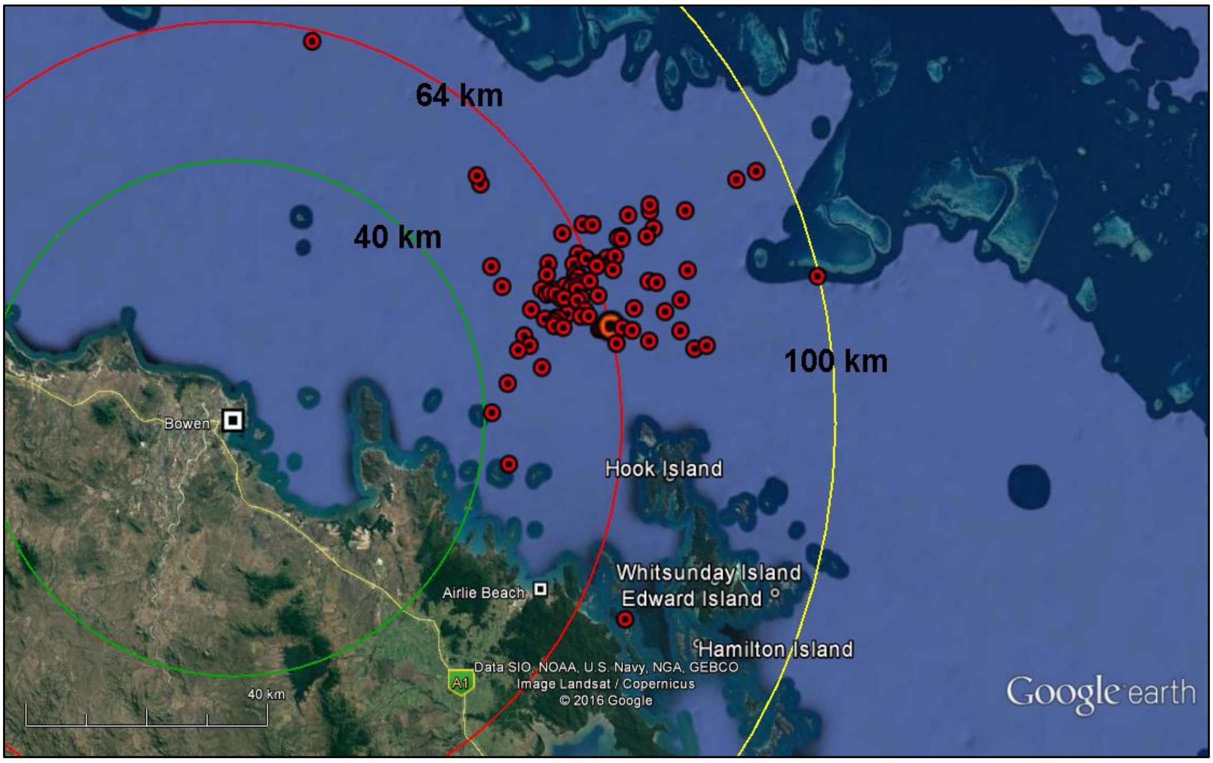


Figure 25: The grouping of the 2016 Bowen earthquake sequence.

The main event was located 64 km NNE of Bowen, with the other earthquakes ranging from 40 km to 100 km radial distance from Bowen.

The relative proximity of all earthquakes to Bowen meant that the radial attenuation of the seismic energy over that distance would vary only slightly; and it was assumed that any such slight attenuation would not adversely affect any logarithmic magnitude values determined within the 40 to 100 km range. It was therefore decided to calibrate the BW1H records against the Geoscience Australia (GA) published magnitudes, so that those records could be used to determine the magnitudes of those smaller events not analysed by GA.

The method of calibration was as follows.

## Method of Calibration

Thirty three earthquakes with published GA magnitudes in the range from M 2.1 to M 5.8 were selected (See Table 8).

**Table 8: List of earthquake magnitudes published by GA.**

| Date | Time | P | S | S-P | Amplitude 2-10 Hz | Published GA Mag | Calculated BW1H M |
|---|---|---|---|---|---|---|---|
| 2016-08-20 | 01:17 | 4654.46 | 4662.07 | 7.61 | 669 | 2.2 | 2.2 |
| 2016-08-19 | 17:03 | 61422.39 | 61430.16 | 7.77 | 697 | 2.1 | 2.2 |
| 2016-08-18 | 15:47 | 56863.64 | 56871.33 | 7.69 | 753 | 2.3 | 2.2 |
| 2016-08-19 | 22:41 | 81707.73 | 81715.41 | 7.68 | 1205 | 2.5 | 2.4 |
| 2016-08-18 | 17:17 | 62271.91 | 62279.60 | 7.69 | 1324 | 2.4 | 2.4 |
| 2016-08-19 | 11:15 | 40552.57 | 40560.20 | 7.63 | 1574 | 2.2 | 2.4 |
| 2016-08-20 | 20:11 | 72668.06 | 72675.76 | 7.70 | 1794 | 2.3 | 2.5 |
| 2016-08-18 | 15:05 | 54340.74 | 54348.38 | 7.64 | 1810 | 2.6 | 2.5 |
| 2016-08-20 | 00:53 | 3224.43 | 3232.12 | 7.69 | 1857 | 2.1 | 2.5 |
| 2016-08-18 | 13:57 | 50252.43 | 50260.39 | 7.96 | 2159 | 2.3 | 2.5 |
| 2016-08-19 | 23:56 | 86213.38 | 86220.91 | 7.53 | 2349 | 2.4 | 2.6 |
| 2016-08-18 | 16:23 | 58987.97 | 58995.55 | 7.58 | 2387 | 2.8 | 2.6 |
| 2016-08-18 | 05:54 | 21249.73 | 21257.29 | 7.56 | 2430 | 2.7 | 2.6 |
| 2016-08-18 | 10:06 | 36414.70 | 36422.36 | 7.66 | 2653 | 2.7 | 2.6 |
| 2016-08-19 | 20:40 | 74439.78 | 74447.37 | 7.59 | 2715 | 2.4 | 2.6 |
| 2016-08-18 | 15:52 | 57131.48 | 57138.86 | 7.38 | 2928 | 2.5 | 2.7 |
| 2016-08-18 | 07:35 | 27311.40 | 27319.08 | 7.68 | 2940 | 2.6 | 2.7 |
| 2016-08-18 | 09:23 | 33823.41 | 33830.84 | 7.43 | 2965 | 2.8 | 2.7 |
| 2016-08-18 | 05:57 | 21467.21 | 21474.69 | 7.48 | 3240 | 2.6 | 2.7 |
| 2016-08-18 | 05:36 | 20196.43 | 20203.14 | 6.71 | 3561 | 3.3 | 2.7 |
| 2016-08-20 | 07:10 | 25849.39 | 25857.21 | 7.82 | 3832 | 2.8 | 2.8 |
| 2016-08-18 | 21:38 | 77887.80 | 77895.31 | 7.51 | 4140 | 3.1 | 2.8 |
| 2016-08-20 | 16:46 | 60410.48 | 60418.09 | 7.61 | 9503 | 3.2 | 3.1 |
| 2016-08-18 | 05:09 | 18579.10 | 18586.66 | 7.56 | 9553 | 2.9 | 3.1 |
| 2016-08-18 | 14:03 | 50598.61 | 50606.19 | 7.58 | 9780 | 3.4 | 3.1 |
| 2016-08-18 | 04:36:53.28 | 16622.15 | 16629.53 | 7.38 | 10228 | 3.9 | 3.1 |
| 2016-08-18 | 05:23 | 19445.18 | 19452.59 | 7.41 | 22102 | 3.6 | 3.5 |
| 2016-08-18 | 09:30 | 34261.85 | 34269.63 | 7.78 | 22753 | 3.5 | 3.5 |
| 2016-08-18 | 08:56 | 32219.57 | 32227.10 | 7.53 | 40768 | 3.4 | 3.8 |
| 2016-08-18 | 04:39:52.05 | 16740.36 | 16747.92 | 7.56 | 42854 | 3.8 | 3.8 |
| 2016-08-18 | 05:30 | 19847.18 | 19854.69 | 7.51 | 52254 | 4.0 | 3.9 |
| 2016-08-18 | 18:27 | 66467.63 | 66474.96 | 7.33 | 128115 | 4.1 | 4.4 |
| 2016-08-18 | 04:30:08.43 | 16219.32 | 16227.00 | 7.68 | 973331 | 5.8 | 5.8 |

The amplitudes stated in Table 8 are those of the associated earthquake's S phase maximum, with a bandpass filter of 2 Hz to 10 Hz applied to the time series data.

The filtered amplitudes were then plotted against the published GA magnitudes as shown in Figure 26.

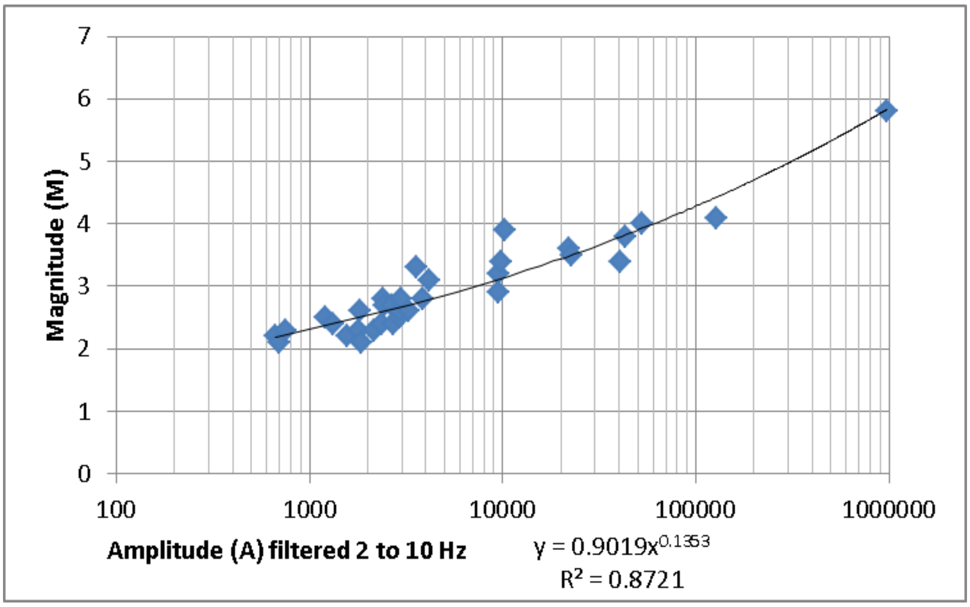


Figure 26: Filtered Amplitudes Vs Published Magnitudes.

A power curve was then fitted to the plotted data to determine the following relation.

$$M_{BW1H} = 0.9019 {A_{BW1H}}^{0.1353}$$

This relation has a correlation coefficient of 87%.

Although the use of the power relation parameters to four decimal places is not warranted (two decimal places would probably suffice), the full precision was maintained when determining the magnitudes of 2016 Bowen aftershocks not published by GA.

## Verification of Calibration

The right hand column of Table 8 lists the $M_{BW1H}$ values calculated using the power relation. This shows that the calculated magnitudes are typically accurate to one decimal place ±0.1, in the range from M2.0 up to M 5.8, with occasional inaccuracies up to ±0.8.

## Calibration Saturation

Inspection of Figure 26 indicates that the power relation is flattening out at the bottom end to become asymptotic between M 2.0 and M 1.5.

Therefore $M_{BW1H}$ values in the range M 1.5 to M 2.0 will be overestimated, and values below that range should be ignored.

# Appendix G - Method Used to Identify Bowen August 2016 M5.8 Aftershocks

As state in the CQSRG web page at ,  CQSRG's primary research aim is to monitor for, and catalogue, earthquakes in Eastern Central Queensland; in the region bounded (approximately) north to Mackay, South to the Sunshine Coast, west to Roma, and out to sea some hundreds of kilometres. The main reason for generally restricting research to that broad region is that it encompasses the earthquake detection capability of the main recording station operated by CQSRG – that is, the FS03 seismic monitoring station just west of Gin Gin, in the Bundaberg Regional area. When the Bowen August 2016 M5.8 event occurred it triggered the FS03 recorder, as did several of the aftershocks that occurred in the following weeks.

As the aftershock sequence progressed, the average magnitude of the events reduced. Consequently, after a short time, the aftershocks were no longer triggering on the CQSRG network. However, experience gained during analysis of the earlier, larger magnitude aftershocks indicated that the lesser magnitude aftershocks, of about M1.3 and above, could be unambiguously identified by visual inspection of the BW1H and BW2s station seismograms with a very high degree of reliability.

The key diagnostic features used to visually identify the aftershock recordings were:

- The consistent S-P times being confined to a precise spread within three standard deviations of the sequence average.
- The characteristic shape of the wave form (the wave form *signature*).
- Suitable and consistent choice of amplitude and time-scale gain settings on the seismogram viewer being used to visually inspect the seismogram records.

## Analysis of S-P Times

In the first two days following the main earthquake Geoscience Australia published location solutions for 34 events (including the main event and aftershocks). The closest station to the events was BW1H, the Bowen hard site Queensland UMP station. Using the S and P arrival times picked from the BW1H records of the 34 published events the S-P times were obtained, averaged, and the sample standard deviation was derived. The results of this analysis are provided in Table 9.

**Table 9: Statistical Analysis of Main event and aftershock S-P Times.**

| S-P Time | Statistic Description |
|---|---|
| 7.6 | Average S-P time for 34 events recorded on BW1H and verified by Geoscience Australia. |
| 0.2 | Sample standard deviation of the aftershock S-P times. |
| 8.2 | Upper S-P time expected for valid aftershocks. |
| 6.9 | Lower S-P time expected for valid aftershocks. |

Based on the statistics listed in Table 9, individual events with S-P times greater than 8.2 s were treated with suspicion as being non-aftershock events. Extra analysis and inspection of the vast majority of these suspect events proved them to be exclusively extraction blasts from the Collinsville and Sonoma Coal Mines, 70 km south west of Bowen.

Many of the prospective "events" with S-P times less than 6.9 s, especially those with dramatically short S-P times, turned out on further inspection and analysis to be local social noise – as shown by not being present on the BW2S records. However, valid aftershock events were recorded with S-P times as low as 5.59 s.

## The characteristic shape of the wave form

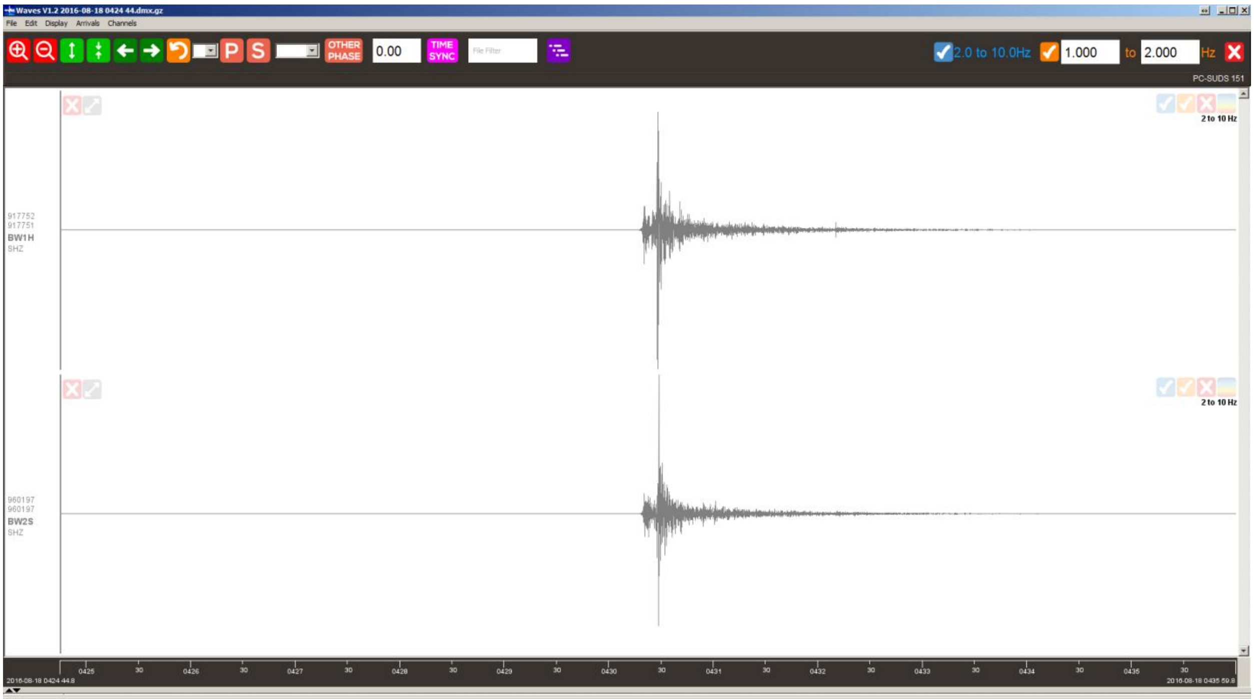


Figure 27: BW1H and BW2S Recordings of the Main M5.8 event.

Figure 27 is the seismographic record of the main M5.8 earthquake event, as recorded on the BW1H and BW2S stations' vertical sensors, and as viewed on the Seismology Research Centre's (SRC) Waves V1.2 Seismic Waveform Analysis Software. The visual characteristics to note are:

- The S-P time, as previously mentioned.
- The impulsive nature of both the S and P arrivals.
- The rapid decay of the P train resulting in a single maximum amplitude P peak, and clean distinction of the subsequent S arrival.
- The rapid decay of the S train resulting in a single vertical line maximum S amplitude feature.

Observation of numerous verified aftershock records showed that these visual characteristics were invariably present in all valid aftershock records – even those of magnitudes less than M1.5; as can be seen in Figure 28, a BW1H/BW2S recording of an M1.3 aftershock.


Figure 28: Record of an M1.3 Aftershock on BW1H and BW2S.

Despite the signature of the P and S arrivals on both BW1H and BW2S stations being only just proud of the ambient noise, they can be readily distinguished on both stations (indicating that it is not a local noise event), and the S-P times for both stations are consistent with the expectation statistics.

The magnitude of M1.3 was observed to be the lowest magnitude aftershock recording that could be reliably discriminated from the ambient background noise. However, it is considered that even the M1.3 events would only have been detected under ideal conditions, and that many valid aftershock events of this magnitude would have not been detected by this observational method.

While Figure 27and Figure 28 represent the two extremes of the magnitude range, the following Figure 29 and Figure 30 provide examples of mid-range aftershocks of M1.8, 2.2 and 2.6.

All three of the events in Figure 29 and Figure 30 have been located using data from multiple stations and verified as being valid aftershocks.

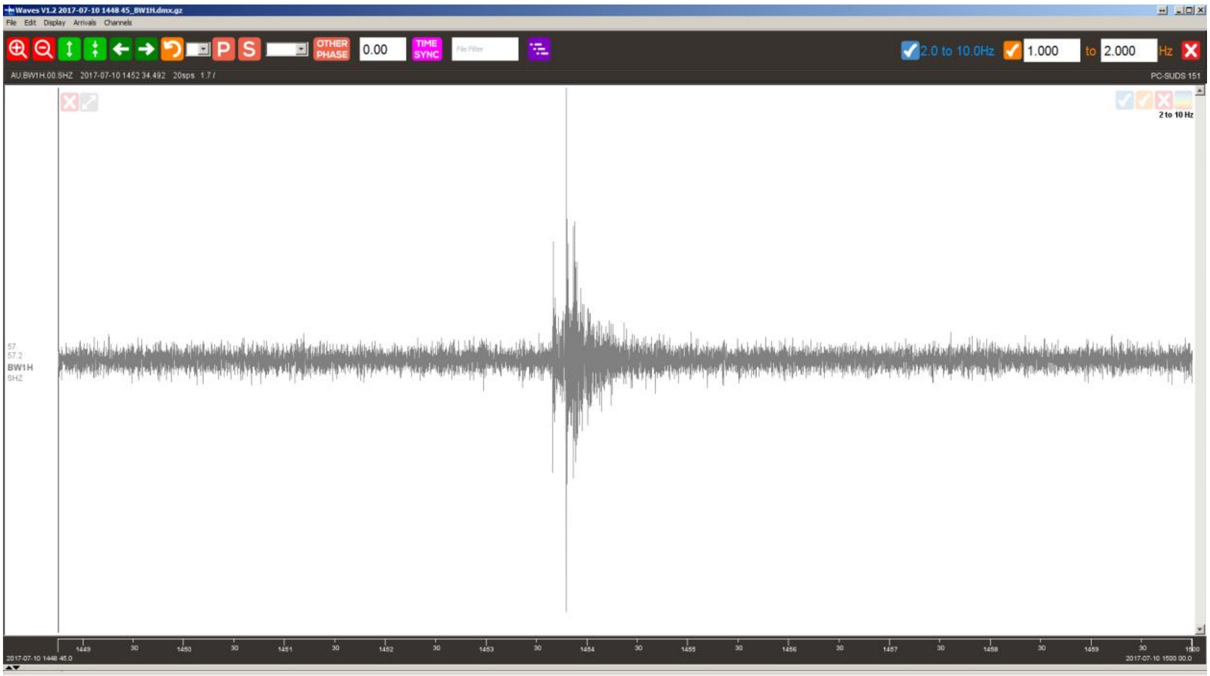


Figure 29: Example of an M1.8 aftershock

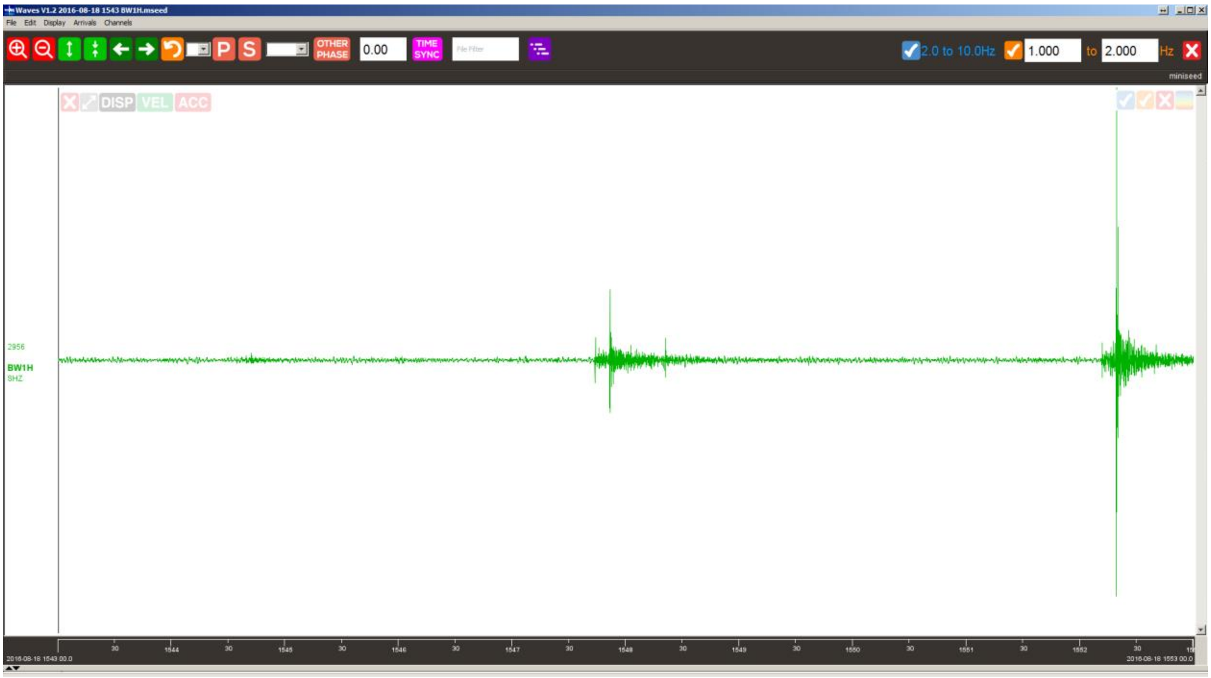


Figure 30: Example of M2.2 and M2.6 aftershocks.