

CENTRAL QUEENSLAND SEISMOLOGY RESEARCH GROUP

CQSRG Seismological Report 2011

Edition: 2015-09-28

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Introduction

This report details earthquakes detected and located by the Central Queensland Seismology Research Group (CQSRG) in 2011. Detailed 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.

During the 2011 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 only 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 during 2011

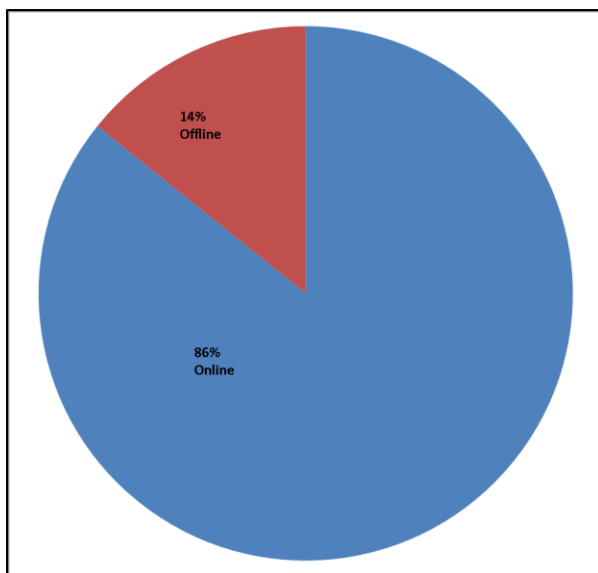


Figure 1: Percentage Uptime/Downtime of FS03.

During 2011 the FS03 Seismic Monitoring Station was actively on line and monitoring for events 86% of the overall year. This is depicted in Figure 1.

The main cause of downtime was the memory filling up and preventing further storage of triggered events. Downloading of triggered event files, and subsequent clearing of the FS03 storage memory has been conducted manually since it was installed in 2004. Consequently this operational procedure is dependent on the availability of trained personnel. Currently there is only one such person. The FS03 trigger settings are normally such that the available 6 MiB¹ of storage memory is exhausted in approximately 2 weeks, and takes about an

hour to download. This proves unsuitable for extended online periods.

During 2011 the operator needed to spend extended time away. To alleviate the filling of memory during these periods the sampling rate was reduced from 100 sps to 20 sps for most of the year. This

¹ The incorrect use of standard SI decade multiplier prefixes as binary multipliers has caused a great deal of confusion over a long period. For example, does a 6 megabyte file contain 6 000 000 (6×10^6) or 6 291 456 (6×2^{20}) bytes? This confusion has now been resolved - at least for those willing to adopt an international standard. In December 1998, the International Electrotechnical Commission (IEC) approved standard names and prefixes for binary multipliers. NIST (National Institute of Standards and Technology) has published the full set of standard names and prefixes for binary multipliers at <http://physics.nist.gov/cuu/Units/binary.html>.

did allow the memory to record for the extended periods. However, the reduced resolution of the records made interpretation of them difficult.

Downtime periods ranged from as short as 16 minutes, to as long as 36 days, during an extended absence of the operator.

Earthquake Events Detected during 2011

During 2011 seventeen earthquake events were detected by CQSRG, and locations were attempted for all events. Details of these events are provided in Table 1.

Table 1: Earthquake Events Detected by CQSRG during 2011.

| Date (UTC) | Time (UTC) | Longitude | Latitude | Depth (km) | Depth Status | Mag (ML) | Event Type | Place | Comment |
|------------|-------------|-----------|----------|------------|---------------------------|----------|-----------------------|----------------------|--|
| 2011-11-08 | 04:12:46.83 | 151.803 | -25.27 | 10.0 | Constrained to local norm | 1.3 | Earthquake Mainshock | Mt Perry | 19 km SW Mt Perry. Reviewed 2015-09-28. |
| 2011-11-07 | 03:25:30.20 | 151.415 | -25.04 | 10.0 | Constrained to local norm | 0.8 | Earthquake Mainshock | Mt Perry | 28 km NW Mt Perry. Reviewed 2015-09-28. |
| 2011-11-07 | 01:15:00.31 | 151.871 | -25.46 | 10.0 | Constrained to local norm | 0.6 | Earthquake Mainshock | Biggenden | 18 km NW Biggenden. Reviewed 2015-09-28. |
| 2011-11-06 | 21:02:54.06 | 151.404 | -25.02 | 10.0 | Constrained to local norm | 0.8 | Earthquake Mainshock | Mt Perry | 30 km NW Mt Perry. Reviewed 2015-09-28. |
| 2011-11-02 | 16:33:57.08 | 152.26 | -23.768 | 10.0 | Constrained to local norm | 4.0 | Earthquake Mainshock | Lady Musgrave Island | 20 km NW Lady Musgrave Island. Reviewed 2015-09-28. |
| 2011-07-15 | 03:02:45.94 | 152.607 | -24.557 | 10.0 | Constrained to local norm | 2.0 | Earthquake Aftershock | Bundaberg | Aftershock of 2011-07-14. 31 km W Mt Perry. Reviewed 2015-09-28. |
| 2011-07-14 | 04:52:31.61 | 152.557 | -24.666 | 10.0 | Constrained to local norm | 2.2 | Earthquake Mainshock | Bundaberg | Mainshock of sequence. 30 km NE Bundaberg. Reviewed 2015-09-27. |
| 2011-07-09 | 18:26:40.41 | 151.333 | -25.184 | 10.0 | Constrained to local norm | 1.0 | Earthquake Aftershock | Mt Perry | Aftershock of 18:12:34. 31 km W Mt Perry. Reviewed 2015-09-27. |
| 2011-07-09 | 18:12:34.15 | 151.33 | -25.151 | 10.0 | Constrained to local norm | 1.7 | Earthquake Mainshock | Mt Perry | Main shock of sequence. 32 km W Mt Perry. Reviewed 2015-09-27. |
| 2011-07-09 | 16:48:45.38 | 151.312 | -25.156 | 10.0 | Constrained to local norm | 1.6 | Earthquake Foreshock | Mt Perry | Foreshock of 18:12:34. 34 km W Mt Perry. Reviewed 2015-09-27. |
| 2011-06-26 | 20:32:17.27 | 152.464 | -27.167 | 6.0 | Unconstrained | 2.9 | Earthquake Mainshock | Esk | 9 km NNE Esk. Reviewed 2015-09-27. |
| 2011-04-30 | 14:28:37.55 | 151.345 | -25.546 | 10.0 | Constrained to local norm | 1.0 | Earthquake Mainshock | Mundubbera | 7 km NE Mundubbera. Reviewed 2015-09-27. |

| Date (UTC) | Time (UTC) | Longitude | Latitude | Depth (km) | Depth Status | Mag (ML) | Event Type | Place | Comment |
|------------|-------------|-----------|----------|------------|---------------------------|----------|----------------------|----------------------|---|
| 2011-03-13 | 03:33:01.47 | 152.512 | -24.032 | 10.0 | Constrained to local norm | 3.2 | Earthquake Mainshock | Lady Musgrave Island | 18 km SE Lady Musgrave Island. Reviewed 2015-09-27. |
| 2011-02-21 | 22:43:42.65 | 152.96 | -24.235 | 10.0 | Constrained to local norm | 3.3 | Earthquake Mainshock | Lady Elliot Island | 28 km SE Lady Elliot Island. Reviewed 2015-09-27. |
| 2011-02-20 | 14:53:15.97 | 151.756 | -25.18 | 10.0 | Constrained to local norm | 0.5 | Earthquake Mainshock | Mt Perry | 11 km E Mt Perry. Reviewed 2015-09-27. |
| 2011-02-16 | 21:25:20.49 | 151.528 | -25.394 | 10.0 | Constrained to local norm | 1.8 | Earthquake Mainshock | Mt Perry | 27 km SW Mt Perry. Reviewed 2015-09-27. |
| 2011-02-10 | 07:12:06.81 | 151.66 | -25.108 | 10.0 | Constrained to local norm | 2.0 | Earthquake Mainshock | Mt Perry | 8 km N Mt Perry. Reviewed 2015-09-27. |

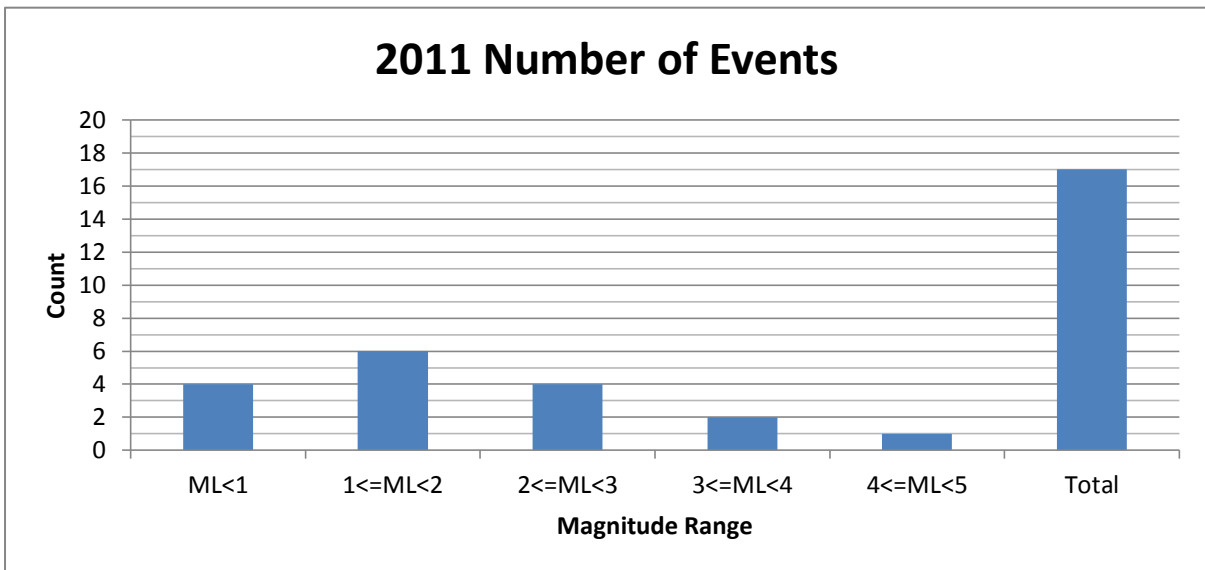


Figure 2: 2011 Earthquake Magnitude Frequencies.

Figure 2 provides a graphical representation of the frequency of magnitude spread, while Figure 3 is a map of the event locations.

The red circle in Figure 3 indicates that, during 2011, the most distant earthquake event detected by CQSRG was ML 2.9, approximately 350 km from FS03.

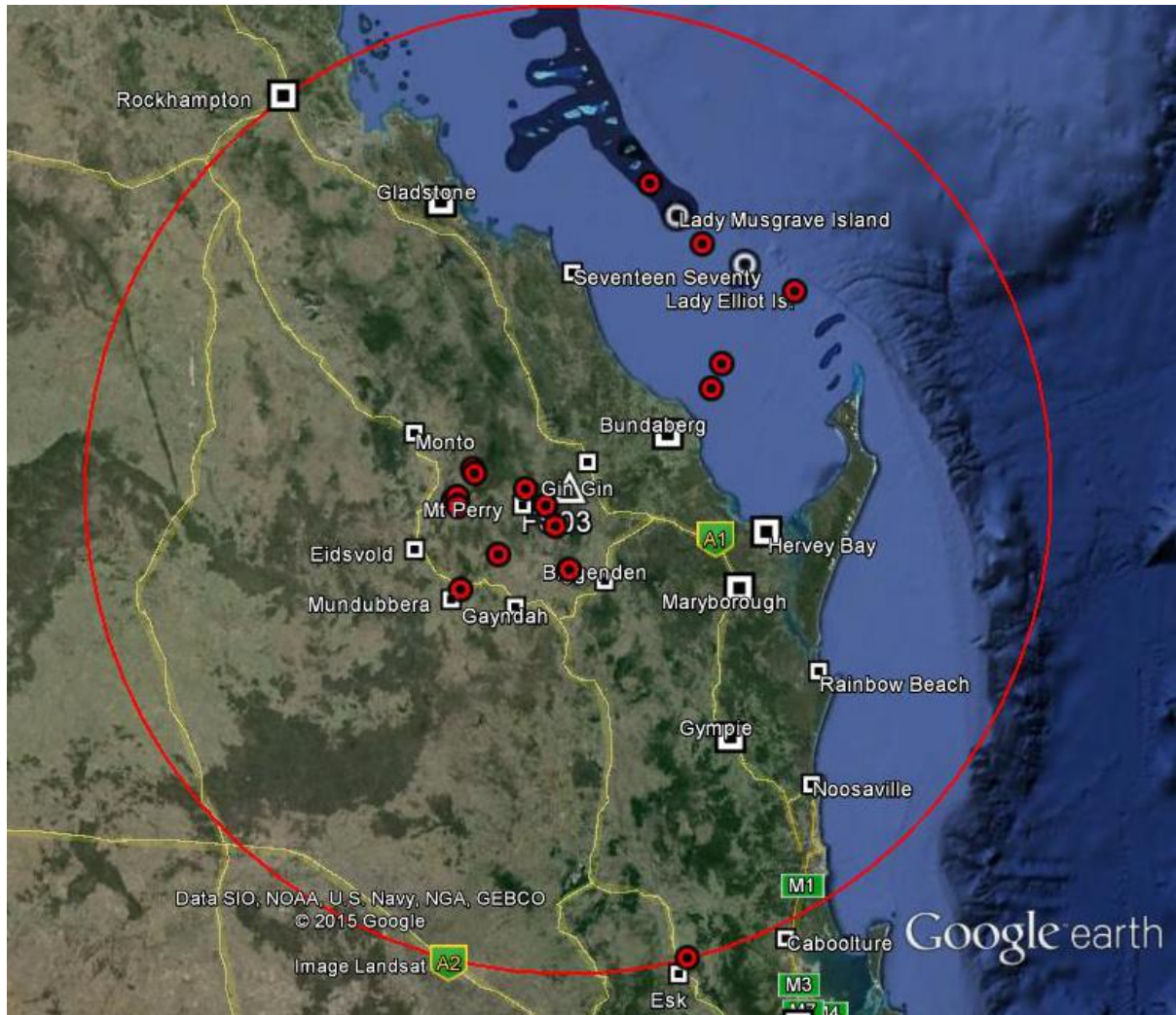


Figure 3: 2011 Earthquake Locations.

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/>).

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

From 2011-01-01 00:00 to 2011-04-24 02:04

Sampling of ground velocity at 100 sample/sec, full scale 4194304 counts

From 2011-04-24 02:04 to 2011-10-28 22:55.

Sampling At 20 sample/sec, full scale 4194304

From 2011-10-28 22:55 to 2011-12-31 24:00

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

From 2011-01-01 00:00 to 2011-04-24 02:04

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.

From 2011-04-24 02:04 to 2011-10-28 22:55.

STA/LTA Channel 3, filter 0.20 to 1.50 Hz

Time const 1.02, 10.0, 100.0, 1000.0 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

From 2011-10-28 22:55to 2011-12-31 24:00

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.

Appendix C – CQSRG Method of Magnitude Quantification

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 in August 2008, it was replaced with a Mark Products L43D seismometer sensor on 2 September 2009. 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.

This method has been used to calculate the magnitudes of the 2013 events, and it is those recalculated magnitudes that are listed in Table 1.

Background Information

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

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

Where:

A is the maximum amplitude of the seismic record of the earthquake, 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 as given in Eq. 2 (**NOTE: This assumed relationship has yet to be confirmed as being valid**).

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

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.

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

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 4 shows the graph of $\log_{10}A_0$ plotted against the associated S-P time difference (extracted from Table 1).

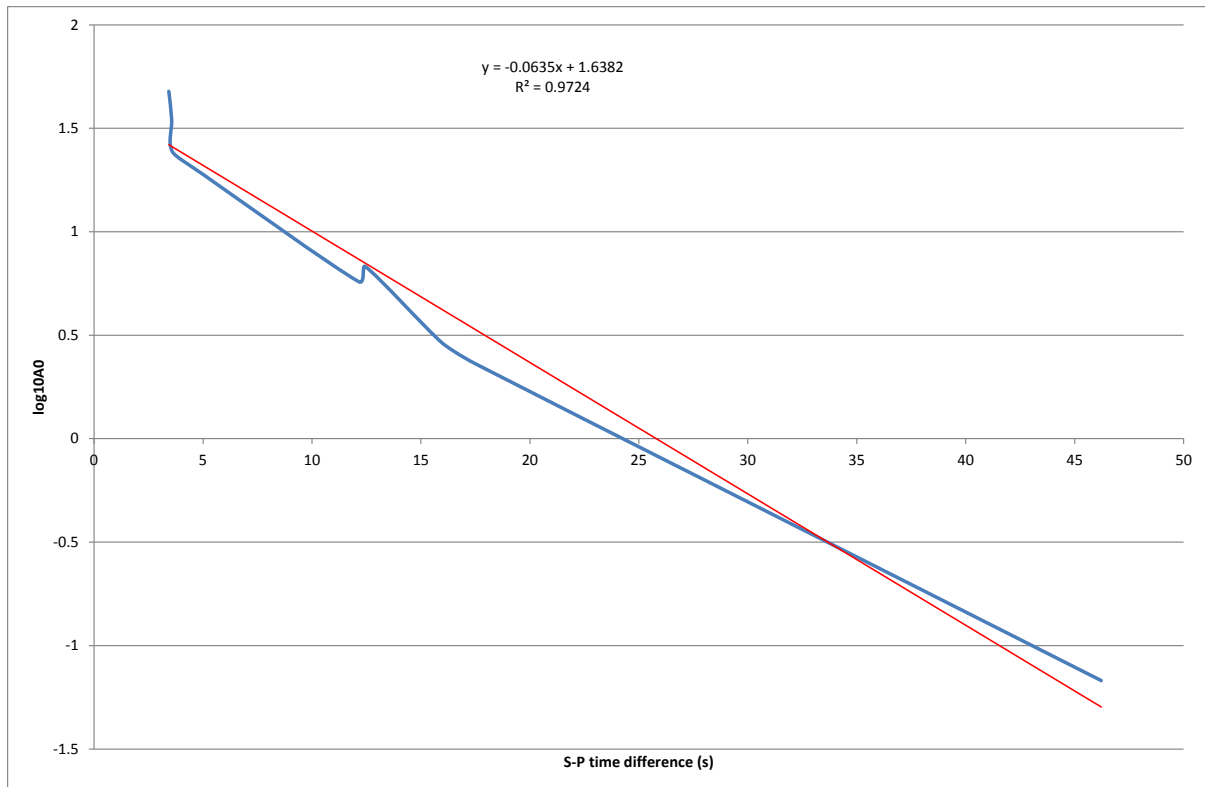


Figure 4: $\log_{10}A_0$ Vs S-P

Figure 4 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 4, 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 2 shows the seismogram of an earthquake that was recorded on station FS03 on 26 October 2012.

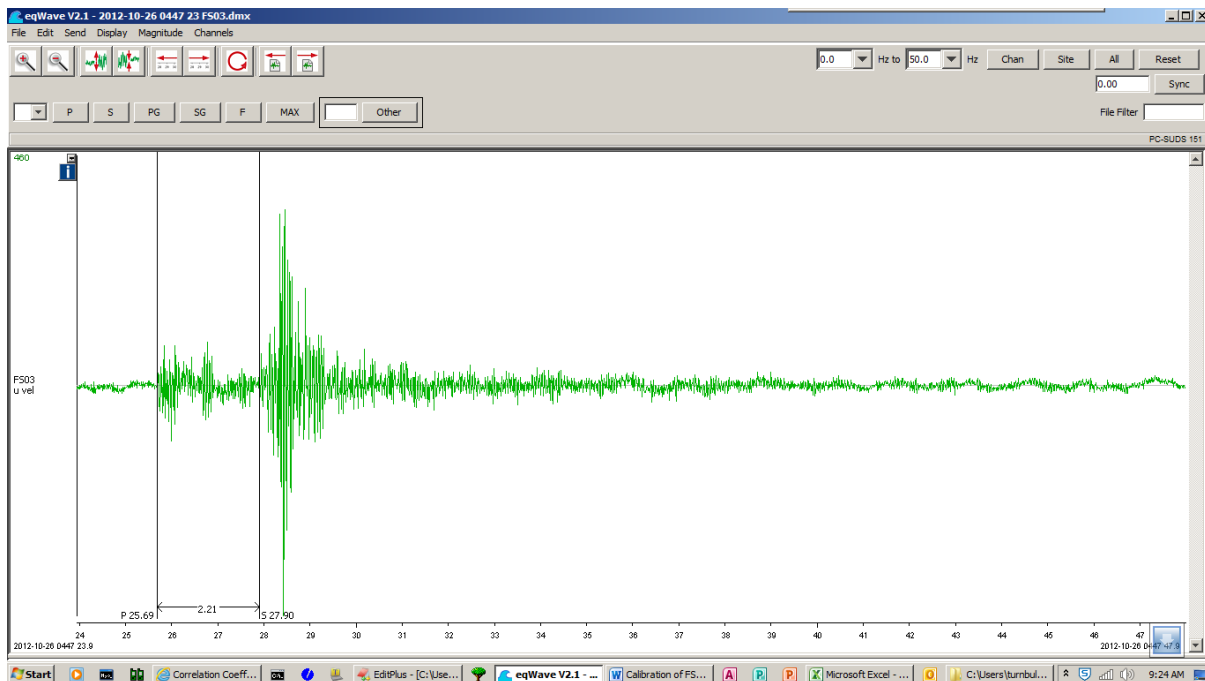


Figure 5: FS03 record of an earthquake.

From Figure 2 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 2 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 6, 7, 8 and 9 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.

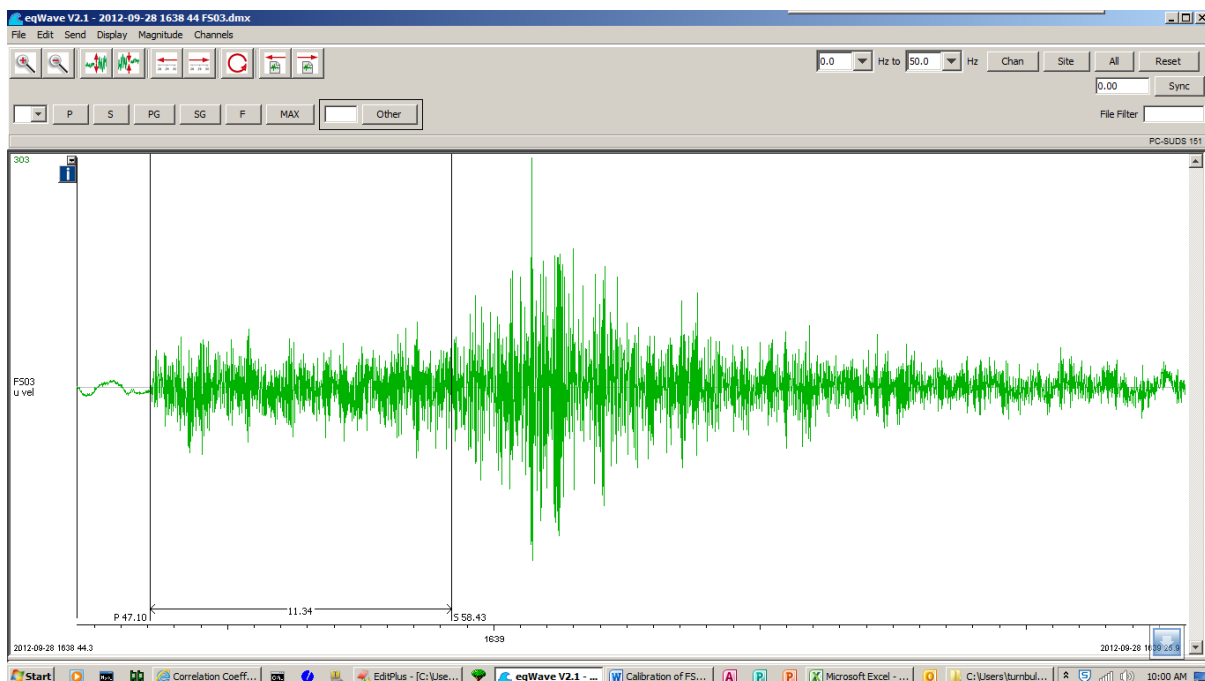


Figure 6: Earthquake recorded on FS03 on 28 September 2012

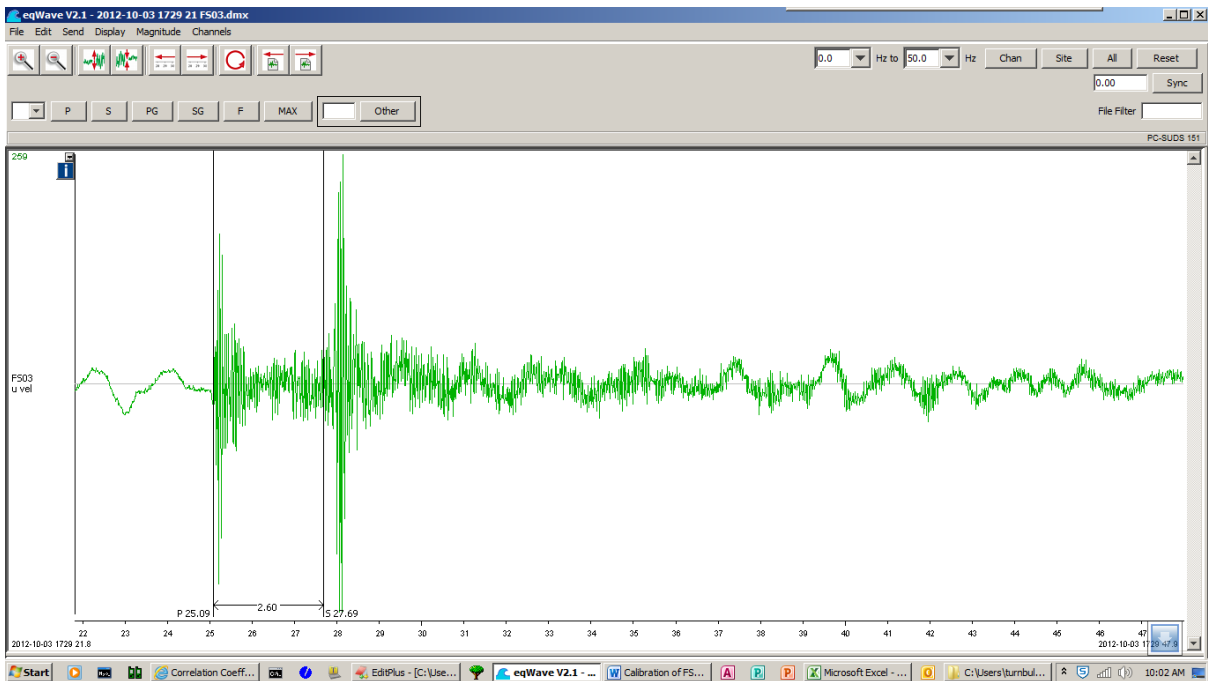


Figure 7: Earthquake recorded on FS03 on 3 October 2012

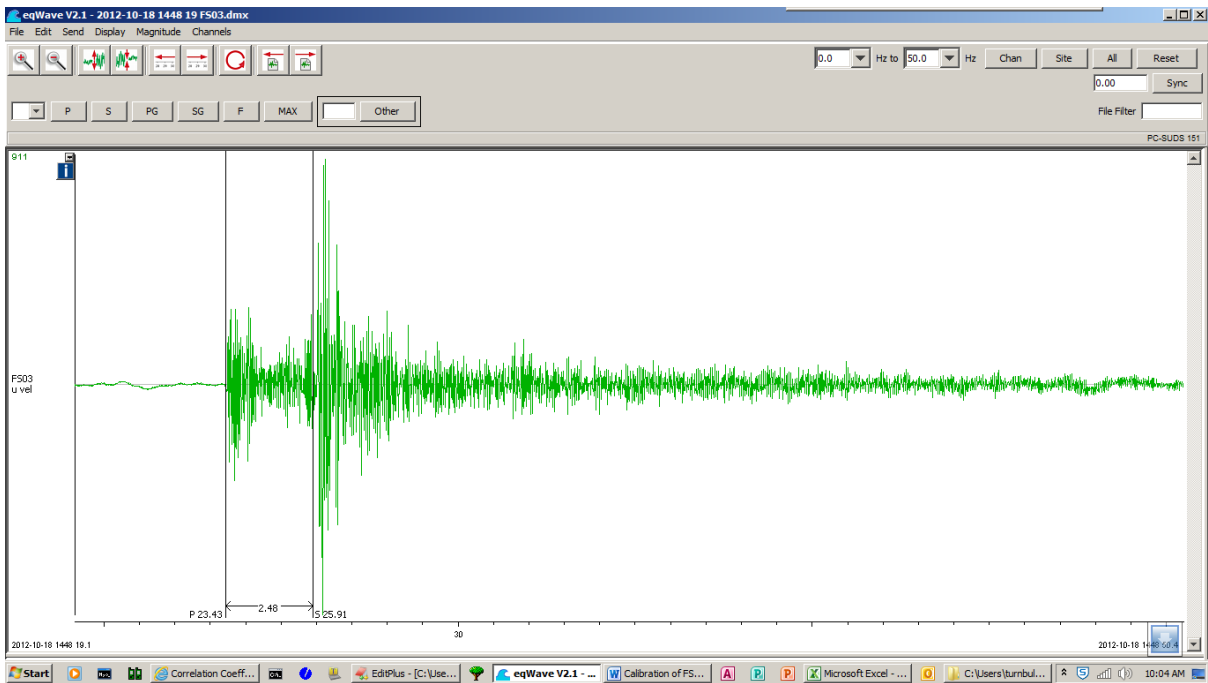


Figure 8: Earthquake recorded on FS03 on 18 October 2012

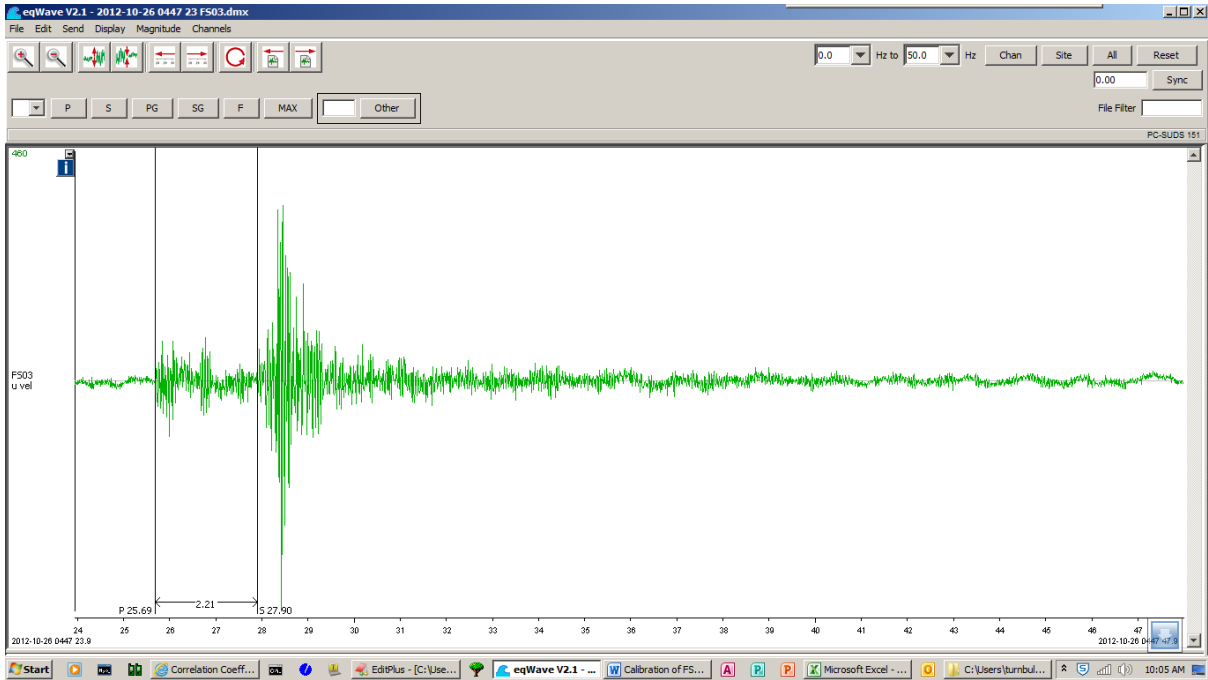


Figure 9: Earthquake recorded on FS03 on 26 October 2012