January 5, 2018

Mr. Jim Griswold, Environmental Bureau Chief
New Mexico EMNRD
Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, NM 87505

Professional and Technical Services for the I&W Brine Cavern Project
Task 1: Site Monitoring
Monthly Site Monitoring Report – December 2017

Dear Mr. Griswold:

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) is pleased to provide the monthly instrumentation report to the New Mexico Energy, Minerals and Natural Resources Department Oil Conservation Division (OCD) summarizing the professional and technical services provided during the month of December 2017 at the I&W Brine Cavern (Site) located at 3005 South Canal Street, Carlsbad, New Mexico. A summary of the services provided during the month of December 2017 is presented below:

Alarm Notifications

Table 1 – Summary of Alarm Notifications

Alarm Type	Number of Alarms	Date	Sensor	Additional Information
Watchdog	16	12/19/17 12/20/17 12/21/17 12/25/17 12/28/17	L8260 L8536 L8292 L8898 L8292 Temp L8898 Temp CR1000 East Well E1_Tubing E1_Annulus Canal	• Watchdog alarms due to initiating maintenance and ongoing replacement of onsite instrumentation including the Instrumentation Computer, L8260, and L8536. • Additional information provided below.
Red Alarm	8	12/19/17	L8260	• Red alarms issued during December 2017 are not indicative of ground surface or subsurface instability. BTM L8260 and L8536 were removed on 12/19/17 and replaced with new tiltmeters. • Default values of -330 and 330 were issued during removal of the sensors. These values exceed red alarm criteria. • Prior to initiating maintenance, L8260 and L8536 were assigned a temporary alarm

				notification group. Red alarms were not issued to emergency response.

Prior to maintenance activities conducted on December 19-21, 2017, BTM L8260 and L8536 were removed from the emergency response notification group in ATLAS and reassigned to a maintenance notification group to prevent false alarms caused by the maintenance activities from notifying local emergency response.

Eight (8) Red alarms were issued during removal of BTM L8260. The Red alarm values of -330 and 330 microradians are maximum values which were exceeded during the removal of the sensors from the onsite boreholes and are not indicative of changes in the surface or subsurface stability in the vicinity of the Site.

Sixteen (16) Watchdog alarms were issued between December 19 and 28, 2017. The Watchdog alarms issued during this period are due to the instrumentation replacement activities conducted during December 19 – 21, 2017. Communication with the instrumentation computer and the majority of the sensors has been restored. Communication between the instrumentation computer and the onsite BTMs has not been restored. Troubleshooting activities are currently being conducted by the project team.

When communication with the onsite instrumentation is restored, the alarm notification levels will be reconfigured for BTM L8260 and L8536 based upon their current orientation. An updated Lily BTM Orientation map will be prepared and provided with the January 2018 Monitoring Report. BTM L8260 and L8536 will also be reassigned to the emergency response notification group.

Onsite Instrumentation

On December 19 – 21, 2017, Amec Foster Wheeler and RESPEC representatives mobilized to the Site to perform replacement of BTM L8260, BTM L8536, and the onsite instrumentation computer. Details of the field activities conducted during this period will be provided in the December 2017 Trip Report.

The Lily borehole tilt meters (BTMs) 8260, 8292, 8536, and 8898 did not respond to earthquakes during December 2017.

Hydrogeological Monitoring

Manual depth to water (DTW) measurements were collected for the two (2) monitoring wells installed at the Site. The manual DTW measurements were compared to DTW measurements reported by the Atlas Monitoring System. In the month of December 2017, the canal was turned off, therefore manual DTW measurements were not taken. The results are provided in Table 2 below.

Table 1 – Summary of Monitoring Well Water Levels

Date	Time	Monitoring Well	Manual DTW	Atlas DTW	Difference
12/01/17	09:23	East Well	-42.53	-42.508	-0.022
	09:25	West Well	-42.29	-42.2115	-0.0785
12/28/17	10:06	East Well	-43.19	-43.201	0.011

	10:03	West Well	-43.11	-43.0366	-0.0734

All measurements reported in feet below top of casing (BTOC).
DTW – Depth to Water

Table 2 – Summary of Canal Water Levels

Date	Staff Gauge	Atlas Recording	Difference
12/01/17	0.00	2.366	N/A
12/12/17	0.00	2.377	N/A
12/21/17	0.00	2.430	N/A
12/28/17	0.00	2.358	N/A

All measurements reported in feet below ground surface.

Fracture Monitoring

On December 1, 2017, the distance between pins on fractures at the church located to the east of the Site (Church) and feed store to the west of the Site (Circle S) were measured. Previous measurements were collected on September 29, 2017. The next fracture monitoring measurements will be collected in February 2018. Below is a list of the changes since the September 29, 2017 readings followed by cumulative change, all values are within historical ranges:Table 3 – Summary of Fracture Monitoring Changes

Location	Pin ID	Change Since Last Reading (inches)	Cumulative Change (inches)
Church	CM-1	+0.005	+0.032
	CM-2	+0.002	+0.006
	CM-3	+0.006	+0.021
	CM-4	+0.001	-0.003
	CM-5	+0.020	+0.031
Circle S	CM-1	+0.009	-0.030
	CM-2	+0.001	-0.022
	CM-3	+0.004	-0.006
	CM-4	+0.001	-0.005
	CM-5	+0.004	+0.001

All measurements reported in inches.

Microseismic Monitoring+

A Seismic Data Processing Results & Health Analysis Report was generated for the reporting period November 25, 2017 through December 24, 2017. Results of this report are summarized below

Table 4 – Microseismic Processing Summary

Event Types	Number of Triggers
Total Triggers	174
Type 1 Events	0
Type 2 Events	174
Type 3 Events	0

Type 1 Event – Short duration microseismic event located at depth. Clear P wave arrival on majority of sensors. Clear S wave arrival on 1 or more triaxial sensors. Dominant frequency content is around 50Hz. Typical 300-500ms signal length.
Type 2 Event – Located at surface, attributed to surface noise. Clear P wave arrival on majority of sensors. Low signal to noise S wave arrival on 1 or more triaxial sensors. Dominant frequency content 20-30Hz. 300-800ms signal length.

Type 3 Event – Long duration microseismic event located at depth. P wave arrival on over half of the sensors. Low signal to noise S wave arrival on 1 or more triaxial sensors. Dominant frequency content on triaxial sensors of 22-33Hz. >1000ms signal length.

During onsite inspections conducted during December 2017, onsite representatives reported that all four (4) microseismic stations were maintained, secured, and appear to be functioning normally.

Currently there are no errors being reported regarding the microseismic array maintained onsite.

Upcoming Site Visits

Weekly site inspections are anticipated to continue during the month of December 2017.

Weed removal and site maintenance activities are currently scheduled to be conducted during the week of January 8 – 12, 2018.

Attachments

Seismic Data Processing Results & Health Analysis Report November 25, 2017 through December 24, 2017

Amec Foster Wheeler appreciates the opportunity to work with OCD on this project. Please contact us if you have questions or require additional information regarding the information provided in the monthly monitoring report.

Sincerely,

Amec Foster Wheeler Environment & Infrastructure, Inc.

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Project: **Seismic Data Processing Results & Health Analysis Report for AMEC Monitoring System**

Reporting Period: November 25, 2017 – December 24, 2017
Report Date: December 28, 2017
Reference Number: 2016-0116
Submitted to: AMEC-Carlsbad, USA

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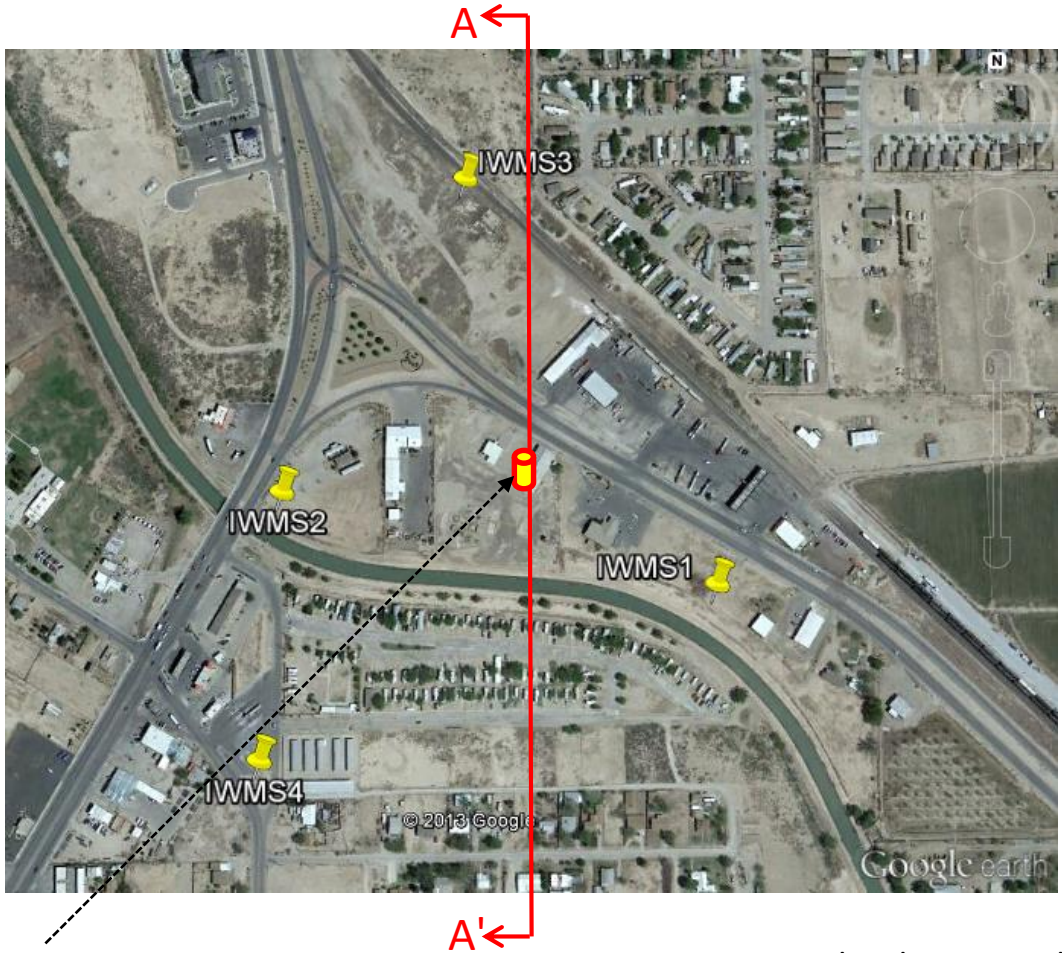
Introduction



Newly Installed Surface Sensor* (March 21, 2017)

- A microseismic monitoring system has been installed in Carlsbad, New Mexico with the aim of monitoring seismic activity around an underground cavern.
- A 24 channel system has been installed in 4 boreholes up to 700 ft in depth, consisting of:
  - 12 uniaxial 15 Hz geophones
  - 5 triaxial 15 Hz geophones
- AA‘ shows the section line

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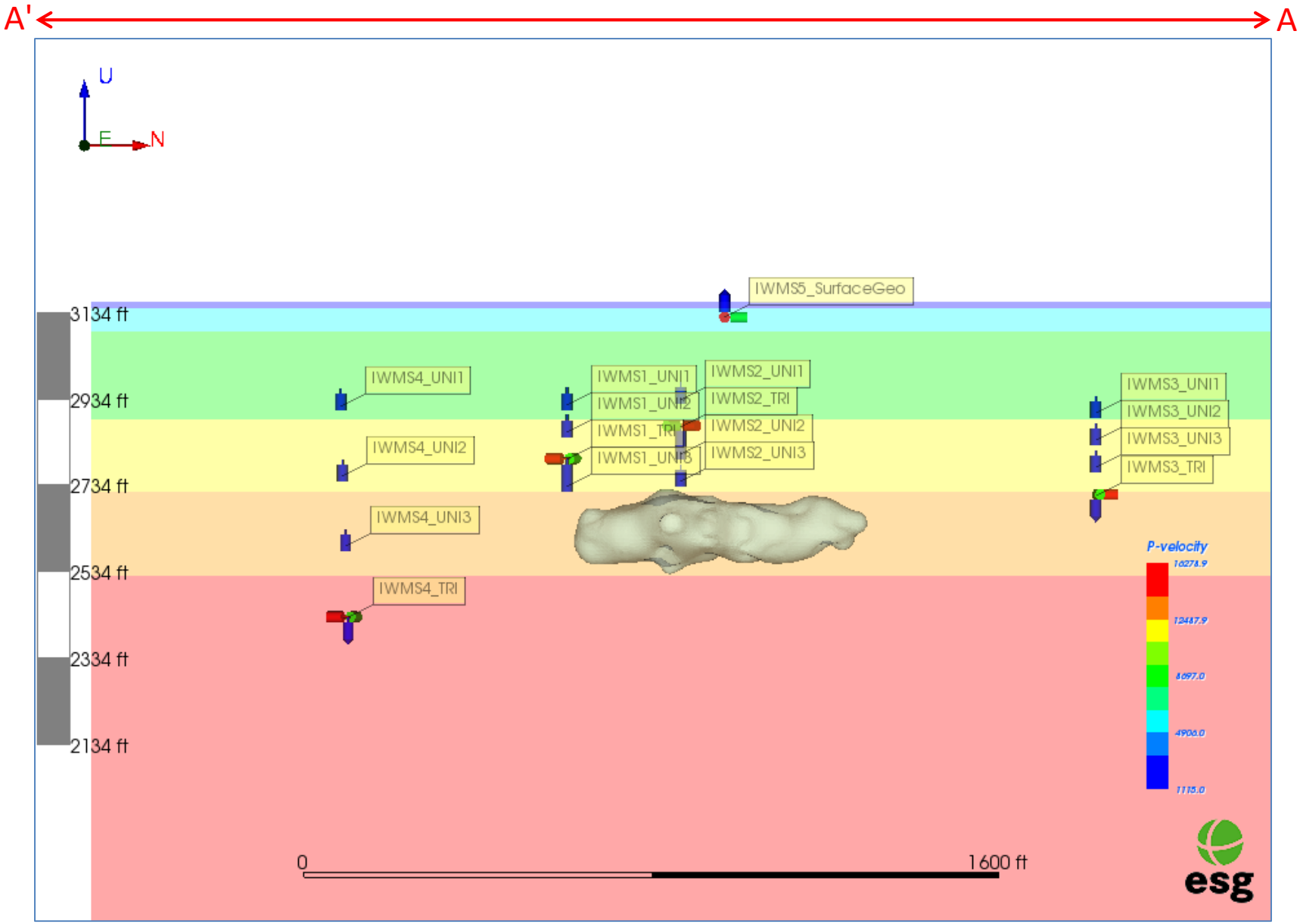
Cavern and Installed Sensors



- **View looking West showing Cavern and all installed sensors**

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Velocity Assumptions Used in Data Processing

- The event locations and magnitudes presented in this report were determined by implementing the 3D velocity model from ESG Solutions Calibration report “AMEC-Carlsbad Microseismic System Optimization (ref# 2018-0266-2.4)” that was completed in May 2017.

- The new 3D velocity model was developed using information gathered during the recent site-visit of March 14-15, 2017. During the visit, a new surface sensor was installed in the central region of the array, and also some additional calibration ‘drop-tests’ (generating calibration seismic signals from multiple impacts of a 3000lb block, dropped from a height of 10 ft) were performed.

- Optimization of the 3D seismic velocity model, with the new surface sensor.

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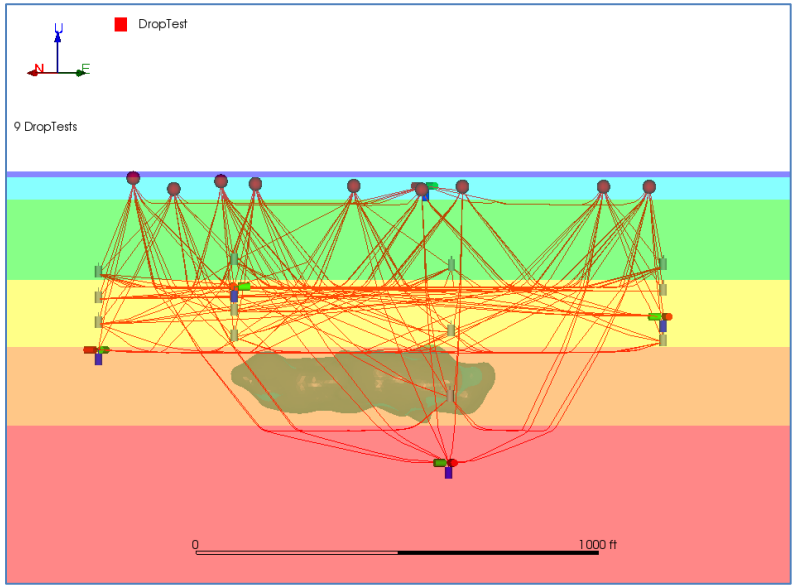
Results of P-wave Velocity Model Inversion

- P-wave ray paths from the 9 calibration seismic sources (drop-tests, with clear signal) to sensors are illustrated below.



Layer#	Elevation[1] (ft)	V_P velocity estimates (ft/sec)		
		Original[2]	New[3]	Difference
1	3130	5591.2	5792	200.8
2	3090	9013.4	8801	-212.4
3	3032	8612.2	8448	-164.2
4	2887	12731.1	12049	-682.1
5	2720	12790.1	12993	202.9
6	2523	14973.3	14799	-174.3

[1] Elevation of the layer top / the upper contact
[2] Based on the previous calibration analysis (Ref. 2014-0765-1)
[3] Updated values after the recent optimization done in May 2017.

- The 3D seismic velocity model has been optimized.

- In particular, the seismic velocities of the six sedimentary layers, where multiple ray-paths of the calibration events (drop-tests) have traveled, were optimized by minimizing the absolute location errors of the calibration events with known coordinates.

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Microseismic Processing Summary

Number of Triggers	174
Number of Event Type 1	0
Number of Event Type 3	0

Notes

- Please note that a few of the events/noise from the weekly reports may have been removed after the final processing/qcing of the data for the reporting period.

- Please also note that this report includes Event Type 1 and Type 3 events (if recorded). Type 2 events that are believed to be caused by surface activity at the site are not included in the report. The detailed explanation of the Trigger Classifications has been provided in the Appendix section of the report.

- Please also note that an event is located using sensors from 2 or more boreholes.
- No events were recorded in this reporting period.
- There is one disabled paladin (IWMS3).

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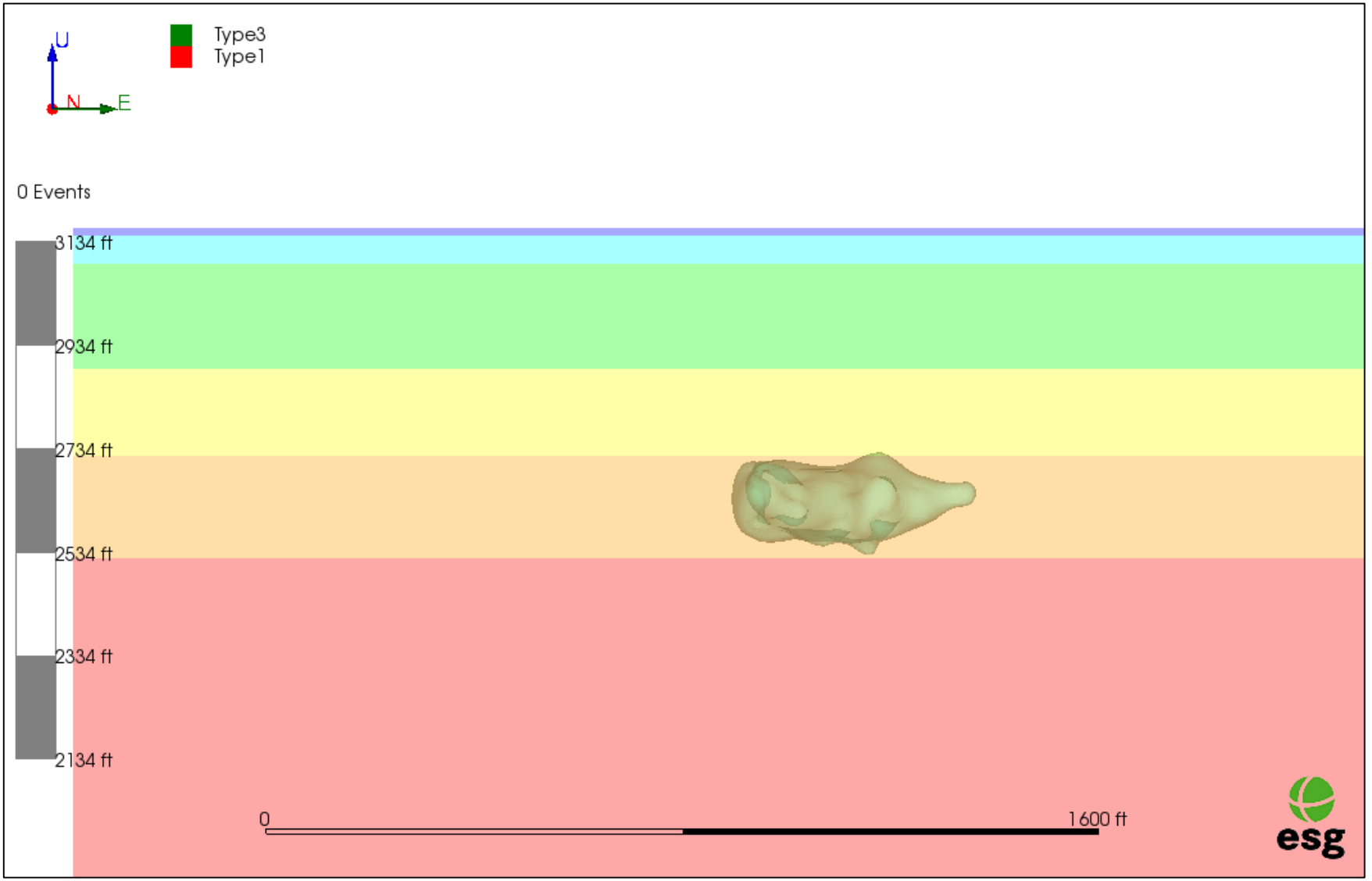
Seismicity: Processed Type 1 and/or Type 3 Events



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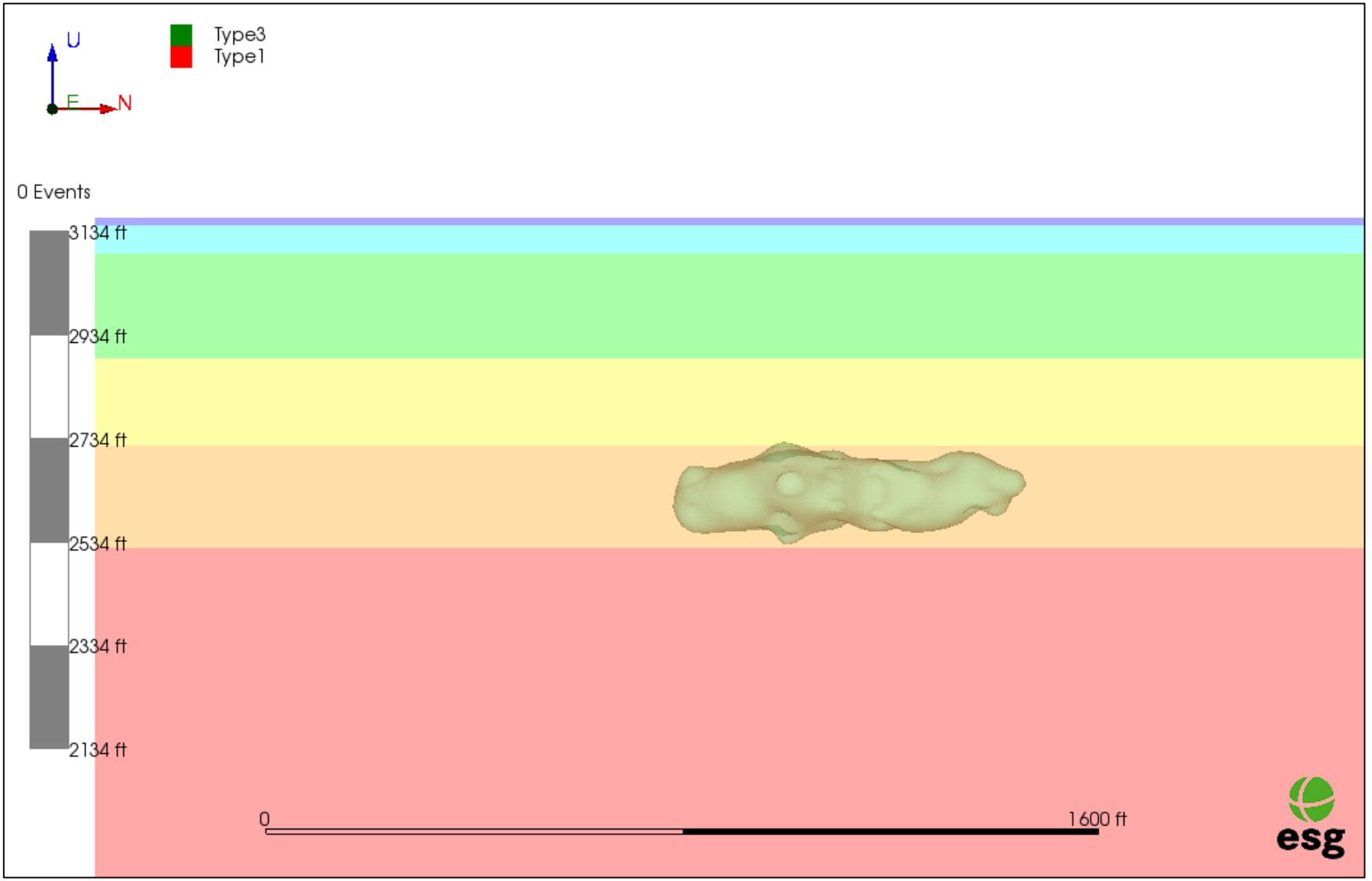
- **Northing view**

Seismicity: Processed Type 1 and/or Type 3 Events



- **East view**

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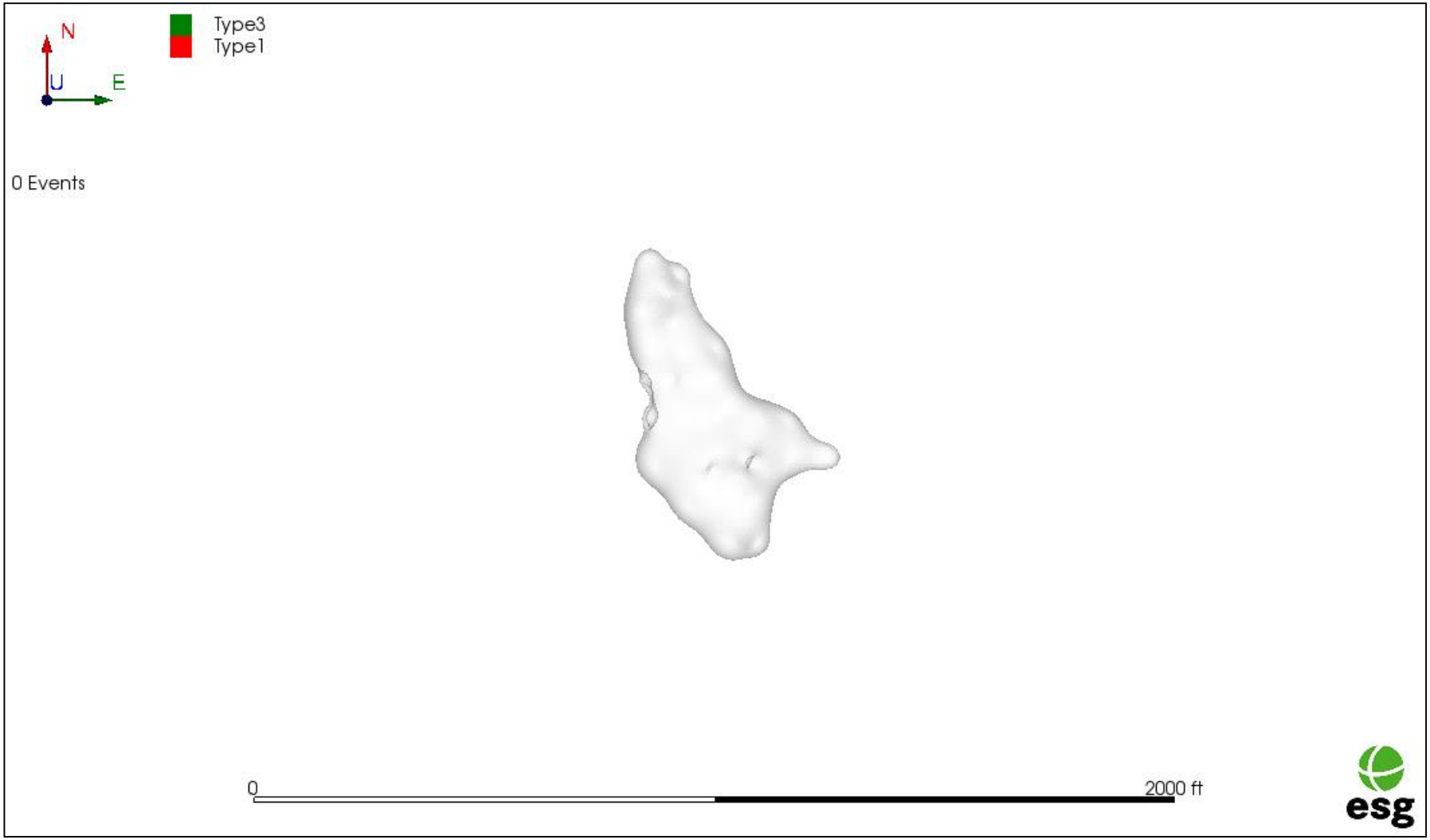
Seismicity: Processed Type 1 and/or Type 3 Events



- **Plan view**

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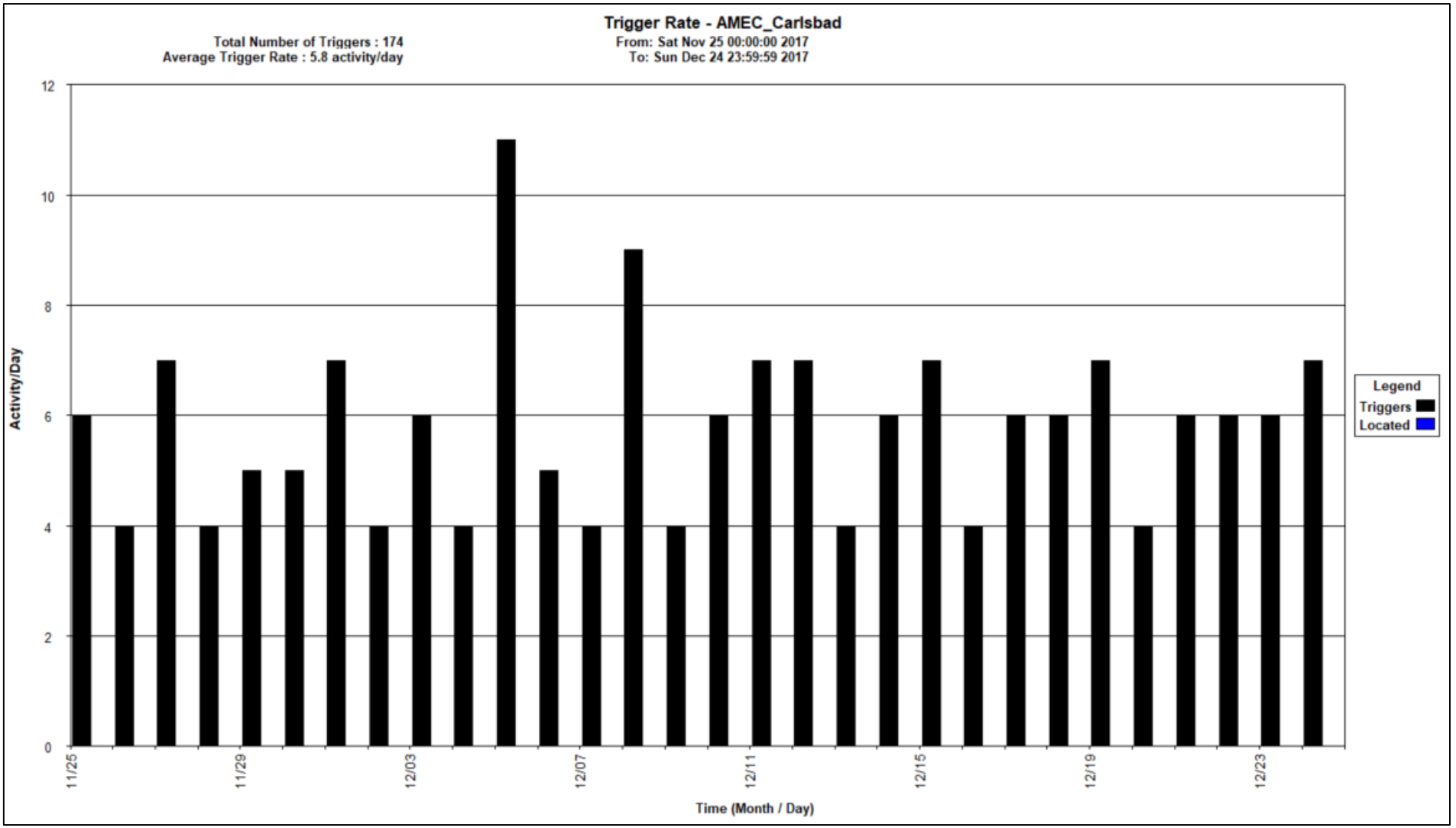
Trigger Rate Graph



- **Trigger rate graph**

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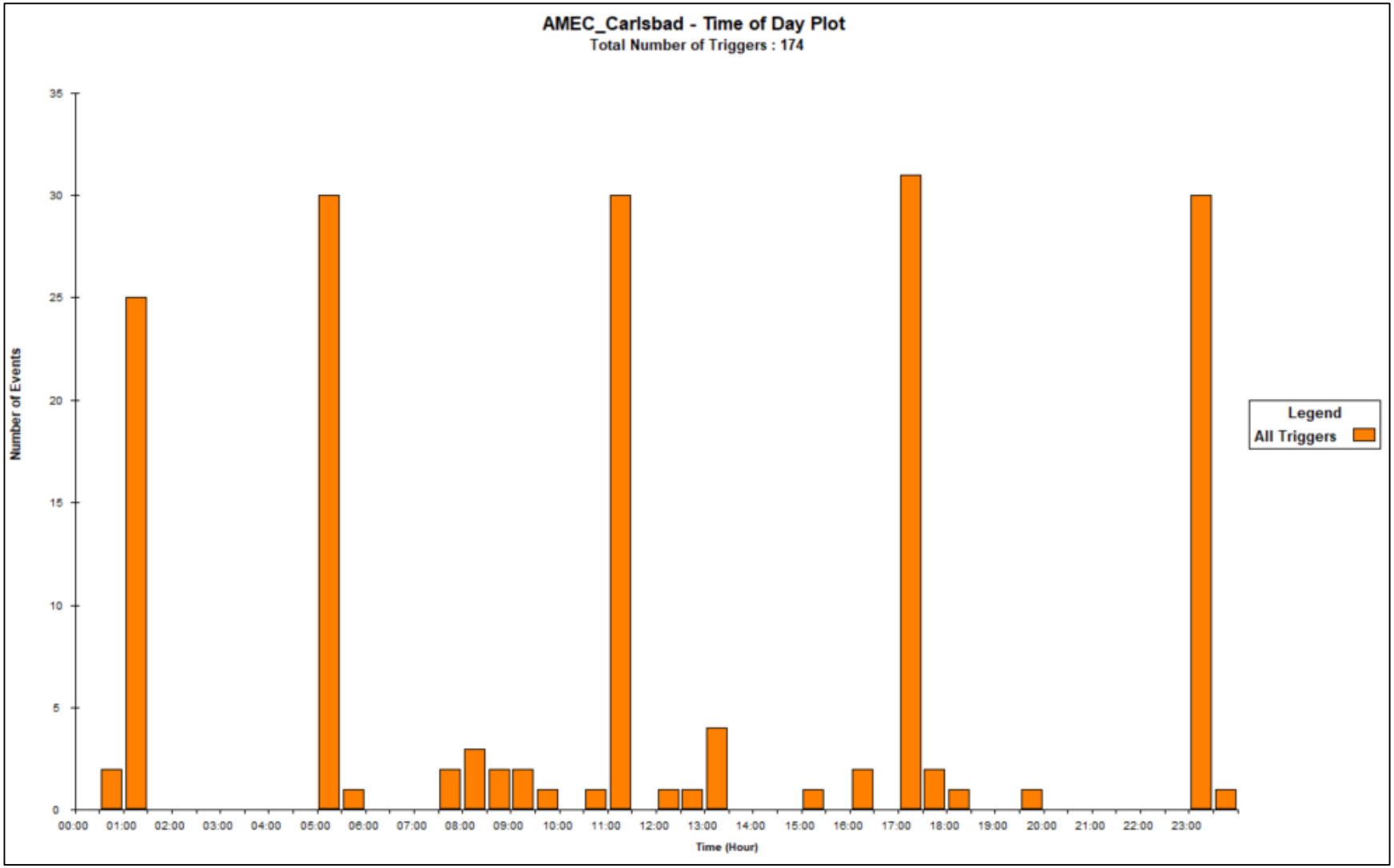
Time of Day Plot



- **Please note that the system generates a background auto trigger every six hours each day at 06:00:00 am/pm and 12:00:00 am/pm. The graph shows these auto triggers.**
- **The graph also includes daily sensor pulse tests which occur at 01:00.**

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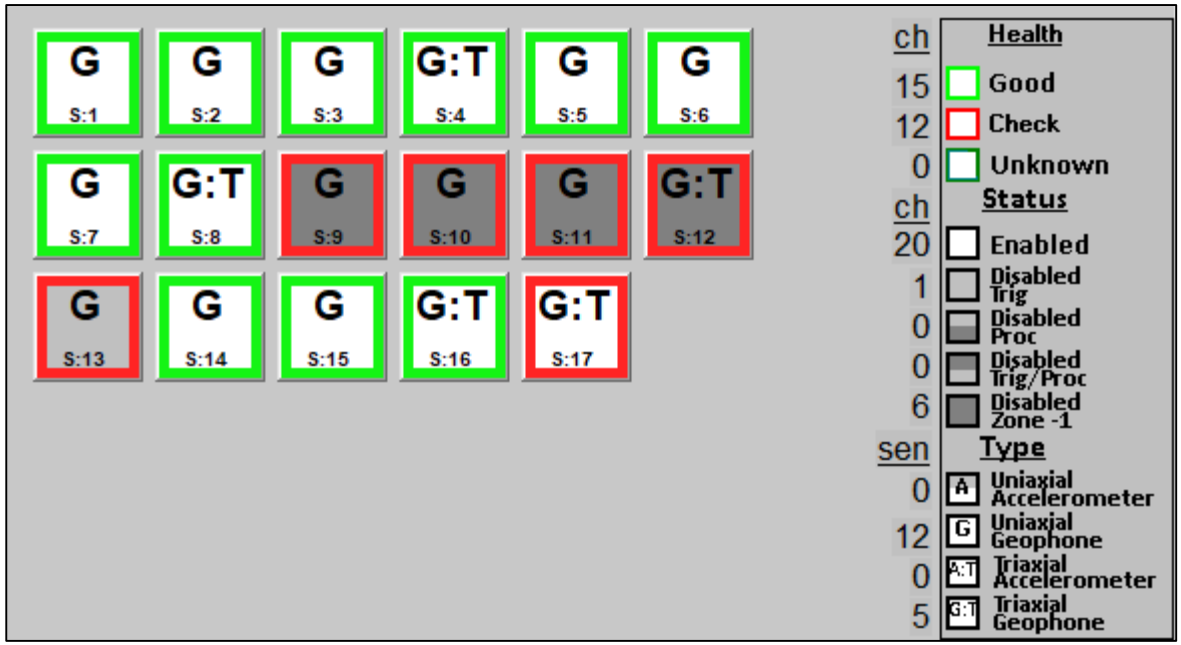
System Health Status

Changes to the system status

Date	# of Sensors			
	Functioning Normally	Functioning but Possible Problem	Not Working	Disabled
Start of the Reporting period	11	0	6	5
End of the Reporting period	11	0	6	5
Change	0	0	0	0



Details of the diagnostics information on December 24th, 2017

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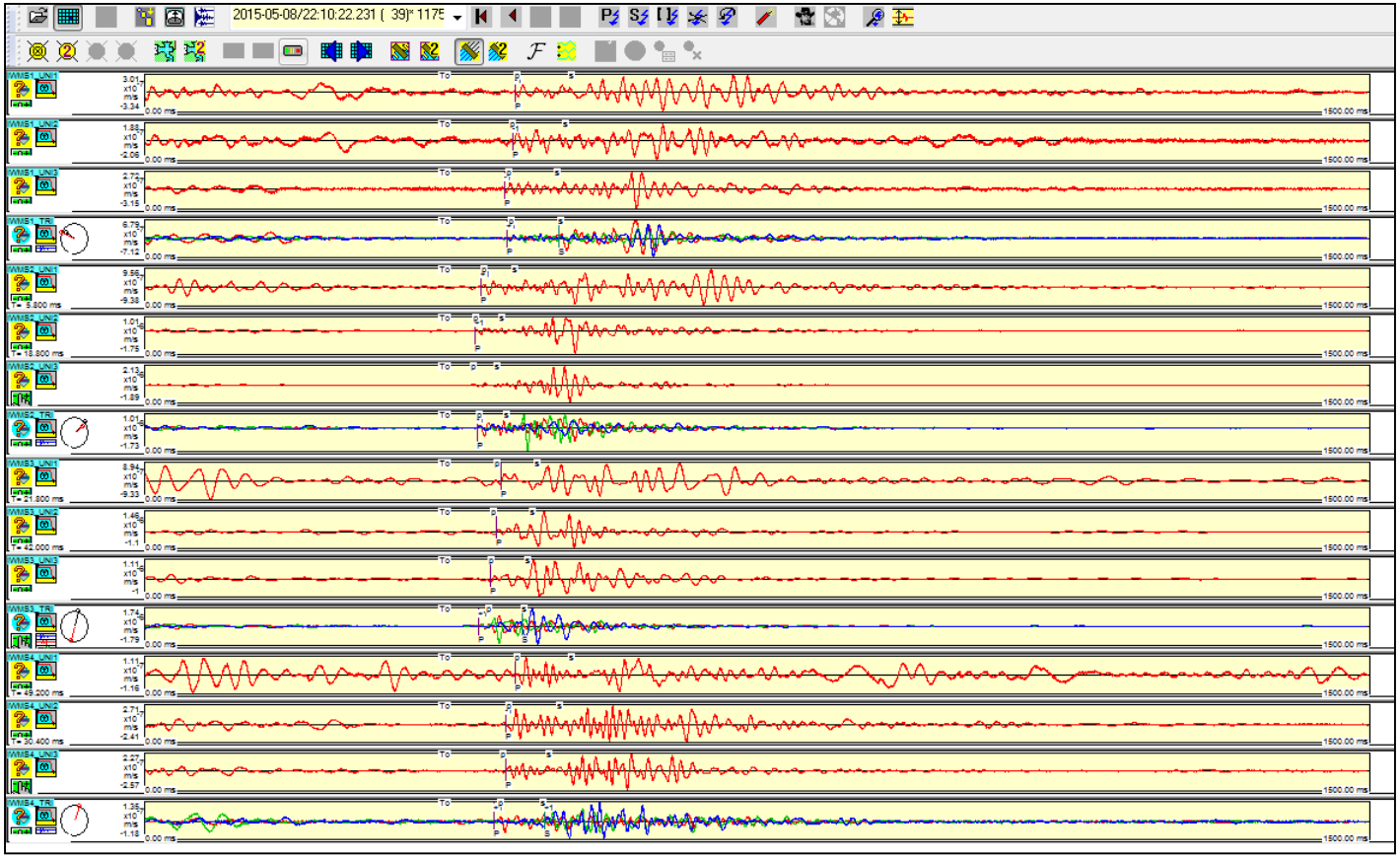
Appendix A: Trigger Classification – Event Type 1

- Example of Event Type 1.



Definition :

- Clear P wave arrival on majority of sensors. Clear S wave arrival on 1 or more triaxial sensors. Dominant frequency content is around 50Hz. Typical 300-500ms signal length.
- Locates at depth (not surface source). Believed to be due to a real event such as fracturing in competent rock. Higher confidence in source location accuracy compared to Event Type 2 and 3.

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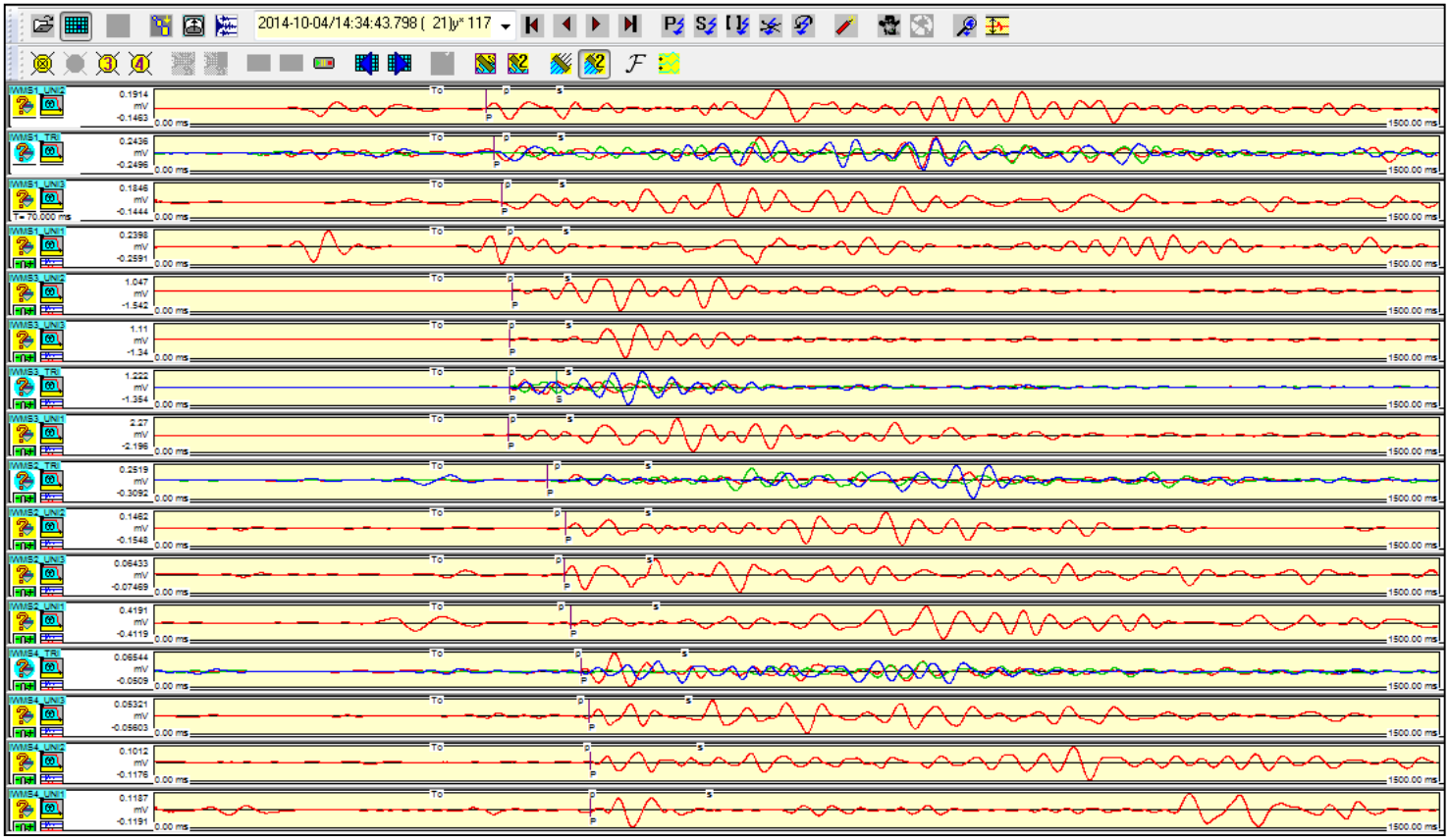
Appendix A: Trigger Classification – Event Type 2

- Example of Event Type 2.



Definition :

- Clear P wave arrival on majority of sensors. Low signal to noise S wave arrival on 1 or more triaxial sensors. Dominant frequency content 20-30Hz. 300-800ms signal length.
- Generally occurs during daytime (08:00-17:00). Believed to be due to a surface noise source.
- Lower confidence in source location accuracy compared to Event Type 1.

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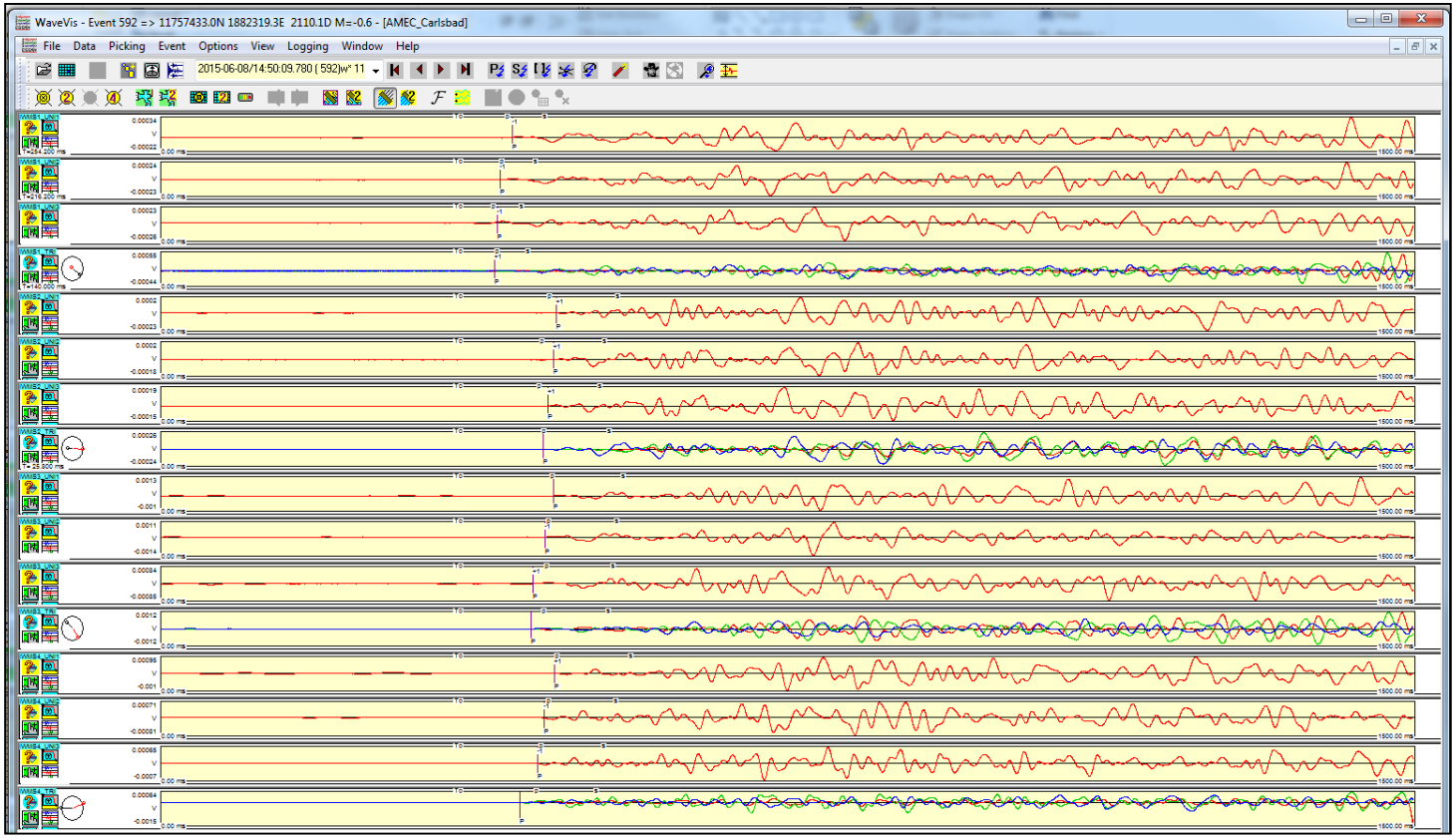
Appendix A: Trigger Classification – Event Type 3

- Example of Event Type 3.



Definition :

- P wave arrival on over half of the sensors. Low signal to noise S wave arrival on 1 or more triaxial sensors. Dominant frequency content on triaxial sensors of 22-33Hz. More emergent signal than Type 1. >1000ms signal length. May be a long duration microseismic event occurring underground.
- Lower confidence in source location accuracy compared to Event Type 1.

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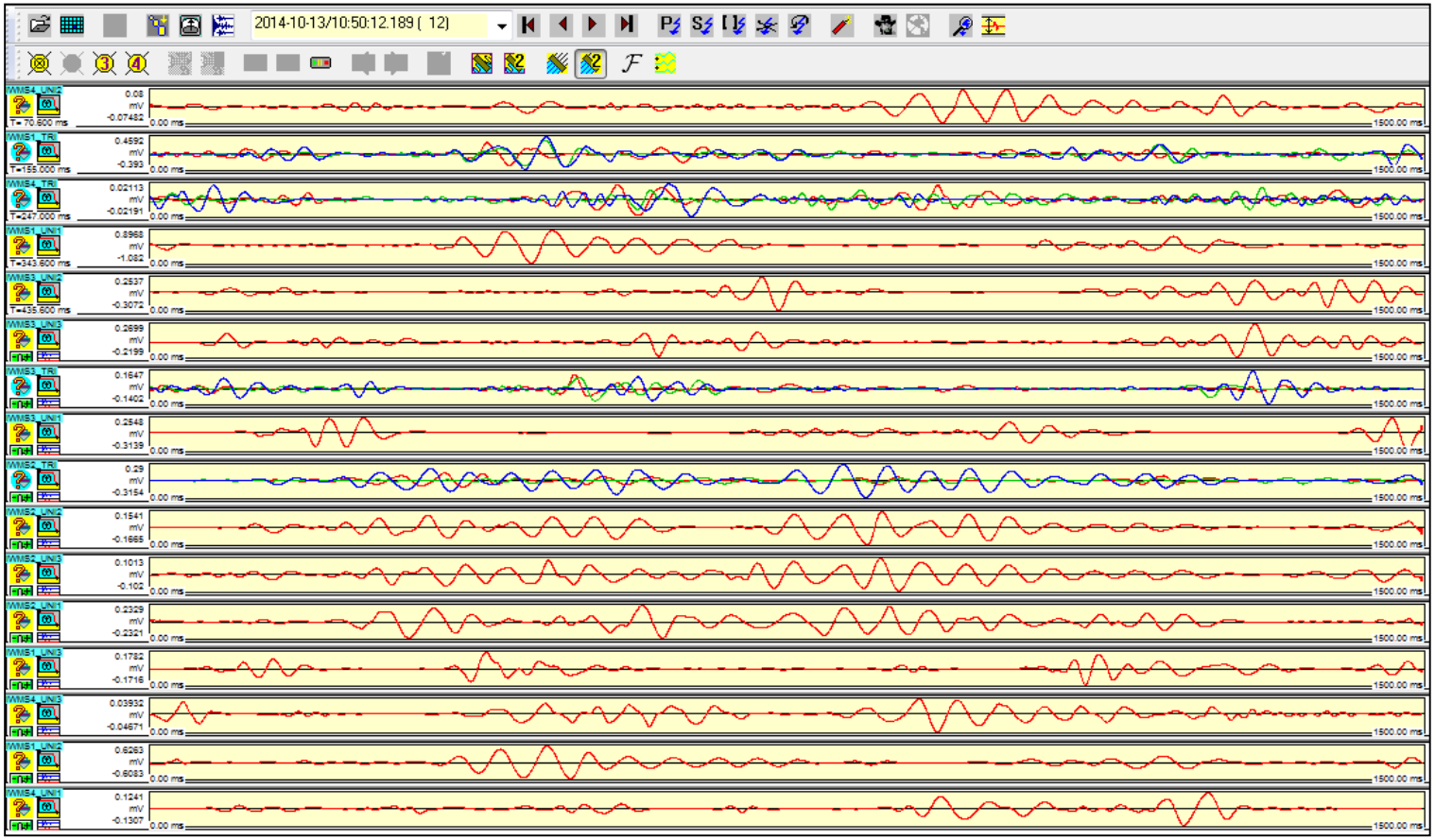
Appendix A: Trigger Classification – Noise Trigger

- Example of Noise Trigger



Definition :

- Uncharacteristic seismic signal or elevated background noise resulting in a trigger.
- Examples include electrical spikes and mono frequency pulses.
- Cannot be source located.

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Thank You

Thank you for your business

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