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PLAINS EXPLORATION & PRODUCTION COMPANY

VIC 1 330 HYDRAULIC FRACTURING
SURFACE GROUND MOTION MONITORING REPORT

September 15-16, 2011

Los Angeles County, California

SUMMARY

Matheson Mining Consultants, Inc. (MMC) was retained by Plains Exploration & Production Company (PXP) to provide surface peak particle velocity monitoring at four locations during hydraulic fracturing of the VIC 1 330 well in the Inglewood Field in Los Angeles, California.

Figure 1 - VIC 1 330 Well Site.

The purpose of the study was to ascertain if the surface locations experienced any ground motion generated at depth during hydraulic fracturing. Prior to hydraulic fracturing of the well, background ground motion data generated from oil field activities was collected to help differentiate between possible hydraulic fracturing ground motion generated at depth from oil field activity vibrations. In addition, Dr. Egill Hauksson, a Senior Research Associate in Geophysics with the California Institute of Technology downloaded and analyzed data from the sensitive seismometer in the Southern California Seismographic Network located near the PXP office at 5640 S. Fairfax, in Los Angeles.

MMC recorded background oil field activity surface vibrations for periods of up to seven hours at all four locations. MMC noted events caused by vehicles, pumping activity at the Vic 1 330 well site, and other oil field vibrations and compared the waveforms with events recorded during both the pumping test and hydraulic fracturing time periods. In addition, any potential vibrations produced at depth would be expected to be impulsive in nature and would exhibit much lower frequencies.

Based on the data, MMC concludes that no vibration events generated at depth were recorded at any of the four surface monitor locations as a result of either the pumping test on September 15, 2011 or hydraulic fracturing on September 16, 2011. If any of the vibrations measured during the pump test or hydraulic fracturing were sourced at depth, they would fall within background oil field vibration levels. None of the vibrations recorded were of a level sufficient for human perception or near the threshold that could cause damage to surrounding surface structures.

In addition, Dr. Hauksson concludes that the sensitive seismometer at the CI.BHP Baldwin Hills location did not register any signals above the local background levels.

Figure 2 - Typical Seismograph Setup.

INTRODUCTION

Ground motion is measured in terms of peak particle velocity and is comprised of a combination of body and surface waves (Figure 3)[1]. The body waves attenuate more rapidly with distance from the source than the surface waves. Body waves spread spherically, whereas the surface waves expand in two dimensions. In this case, body waves generated by hydraulic fracturing at an approximate depth of 8,000 feet result in body waves and converted surface waves as the body waves impinge on the surface. The principal cause of ground motion attenuation with distance is due to simple geometric spreading. As the ground motion wave train spreads outwards from the energy source, the medium's individual particles are set in retrograde elliptical motion about their rest positions. The wave is generated as each particle transmits energy to the next particle. Some energy loss occurs with each transmission of energy from one particle to the next, which is also a cause of ground motion attenuation with distance. The ground motion is a complex wave train consisting of many different wave types (Figure 4)[1]. As the body waves impinge upon the surface, they are converted to surface waves. Body waves may also be reflected and refracted to the surface to become converted to surface waves. As the surface wave spreads out, the various components of the wave train have different particle motions, travel at different velocities, and have different geometric constraints.

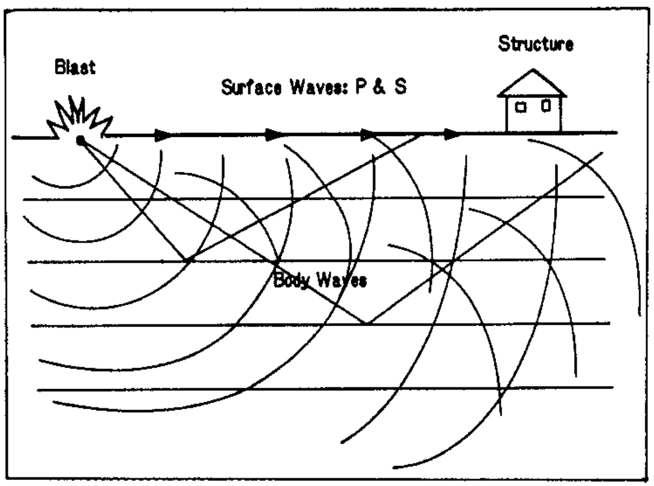


Figure 3 - Surface and Body Waves

Particle velocity has been determined to be the most significant single parameter, in terms of the potential for damage (as opposed to acceleration or displacement). Furthermore, the peak particle velocity found on any of the three geophone channels is the parameter used, rather than the resultant vector sum particle velocity. All research has been done and all regulations have been written in terms of peak particle velocity (PPV). Using the PPV instead of the vector sum allows for easier, more consistent comparison of values. A true resultant velocity could be calculated from the peak measurements for all three components if they occurred at the same instant of time. In addition, there is variability in how different seismograph manufacturers calculate the vector sum. Some actually calculate a pseudo resultant sum. These models take the peak levels on all three channels, regardless of where they individually occurred in time, to calculate the vector sum.

[1] Rosenthal, M.F., and G.L. Morlock. Blasting Guidance Manual. U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, March, 1987, p.11.
[1] Ibid., p. 12.

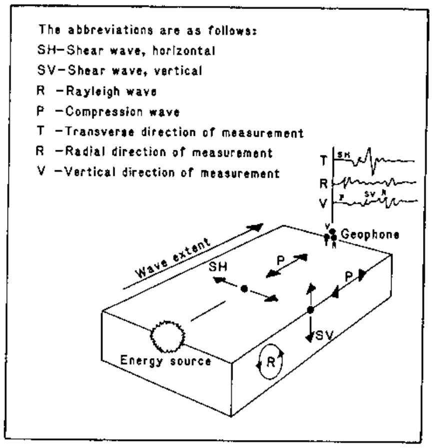


Figure 4- Types of Ground Motion Waves

Since the 1920's or earlier, ground vibrations have been studied extensively to determine their potential for damage to various structures and construction materials. Blasting activities are among the most common sources of ground motion, have therefore been studied the most, and have thus prompted the ordinances and regulations that are in place. At the present time, the only federal regulation that pertains to ground motion is from the federal Office of Surface Mining Reclamation and Enforcement (OSMRE). This regulation was written to protect residential structures.

INSTRUMENTATION

Vibration records were collected using Instantel Minimate Plus seismographs. Each seismograph records particle velocity digitally in the frequency range of 1.5 to 250 Hertz. Each sweep is measured in three orthogonal channels of ground motion: vertical, longitudinal, and transverse. Zero-crossings of each of the three waveform components are calculated to determine frequency response.

An excerpt from the Blastmate III User's Manual is attached as part of Appendix I and describes the specifications and function of the instrumentation, and record processing.

An independent party using shake table, piston phone, and electronics traceable to the National Institute of Science and Technology has calibrated the instruments within the past year. Copies of the Calibration Certificates for each instrument and geophone are also included in Appendix I.

The microphone measures air overpressure in dBL. Air overpressures are typically produced from blasting activities. Therefore the microphone channel was turned off for hydraulic fracturing measurements.

It is not possible to alter the vibration recordings or file names in any way, other than the ability to add post event notes. For security reasons, the instrument and software manufacturer (Instantel) will not release any of the programming code to any outside interests for any reason.

A self-test (on board calibration) was performed at each monitor location after setting up the instrument. The instrument also performs a self-test when it is put into monitor mode.

METHOD

The energy source consisted of hydraulic fracturing at depths of 8,030 to 8,050 feet using a maximum treatment pressure of 3,526 psi.

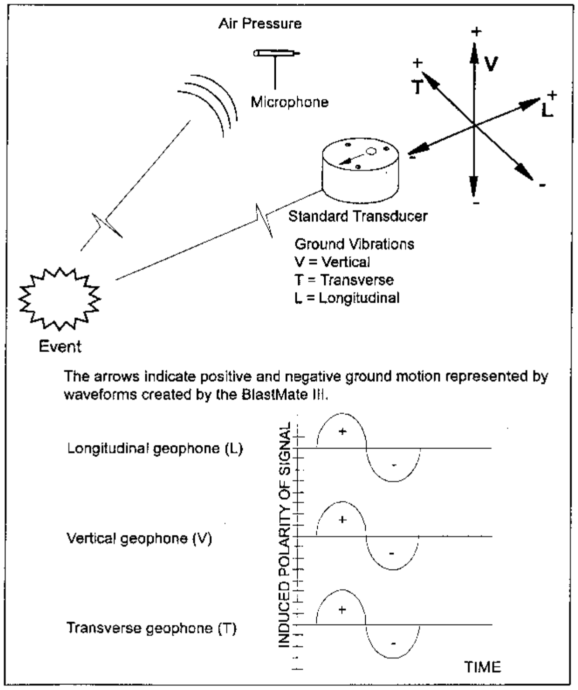


Figure 5 - Event Monitoring

Figure 5 shows an excerpt from the Blastmate III user's manual and illustrates how the geophone was oriented relative to the energy source. The longitudinal channel of each seismograph was aimed at the surface location of the VIC 1 330 well. Surface material was removed as necessary to get a good solid geophone plant at all recording locations.

Surface monitor locations were chosen by MMC and PXP representatives in an approximate east-west line extending both east and west from the well site (Figure 6). Because of the high degree of activity in the oil field (truck traffic, construction activity, pump jacks, and the activity around the VIC 1 330 hydraulic fracturing site), the seismographs were placed in as seismically quiet areas as possible in order not to fill up instrument memory. This often meant placing them away from main roads in vegetated areas. The seismographs were placed in the soil at locations with no apparent ground disturbance such as cut or fill.

Instrument location #1 was placed 142 feet east of the VIC 1 330 hydraulic fracture well site.

Instrument location #2 was placed 265 feet northwest of the VIC 1 330 hydraulic fracture well site and was approximately 30 feet north of the VIC 734 well.

Instrument location #3 was placed 1081 feet west of the VIC 1 330 hydraulic fracture well site near the west side of Inglewood field in a direction towards the closest inhabited residences. The closest residences are approximately 2,725 feet away to the west northwest and the closest businesses/warehouses are approximately 1,790 feet away to the west.

Instrument location #4 was placed 847 feet east northeast of the VIC 1 330 hydraulic fracture well site in order to monitor possible vibrations to the east of the bottom hole location.

Waypoints were collected at each monitor location using a handheld Garmin GPS. A list of waypoints with location coordinates is included in Appendix II.

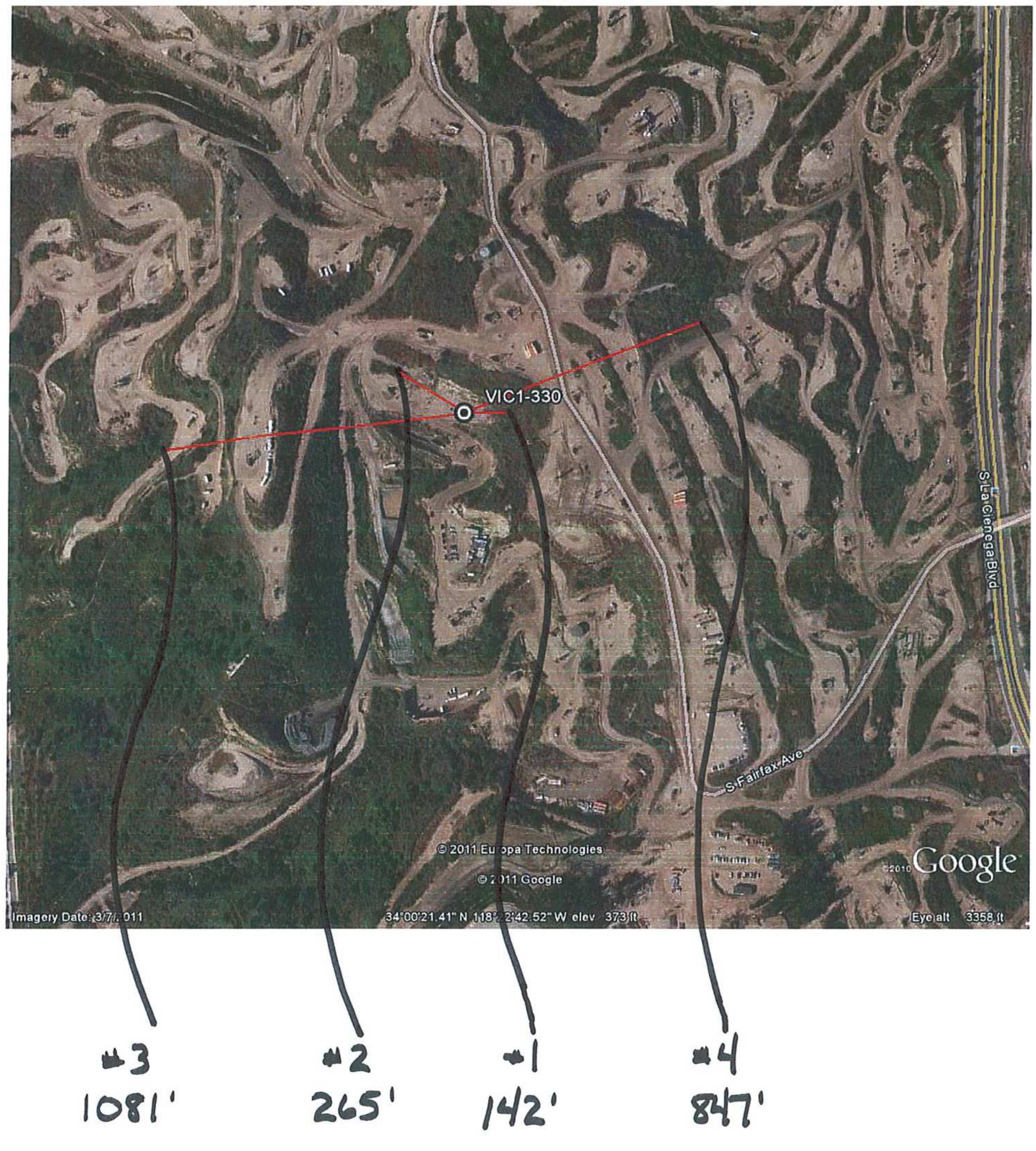


Figure 6 – Surface Monitor Locations

Distances were obtained from Google Earth and are straight-line distances. Google Earth images showing surface monitor locations, as well as the location of the Baldwin Hills accelerometer are found in Appendix III. Photographs of all four recording locations and instrument setups are found in Appendix IV.

The lowest trigger levels possible were used in all four instruments (0.005 ips). The seismographs are extremely sensitive at this level; therefore it was necessary to place them in areas where they would not rapidly fill up with surface oil field vibrations. After setup and calibration check at each surface monitor location, an event intentionally induced by MMC (a foot stomp immediately adjacent to the geophone) was placed on each instrument to ensure the geophones were properly recording events. These intentionally induced events could result in approaching or exceeding the plaster limit (described in Results; Recommended Vibration Limits) despite the minimal energy released, and the impossibility that the foot stomp would cause damage to any nearby points of concern and could not be felt by any people in the immediate vicinity.

The geophones record these events at or near the plaster limits since the geophone sensitivity level is set to record events much further from the geophone – at depth. When an event occurs at the surface and near the geophone, the geophone will record the event at much higher levels than actually occur at distances of over a few inches to a few feet in the surrounding area due to this sensitivity setting. Therefore, the geophones were set in place and operational approximately 7-hours prior to the hydraulic fracturing at VIC1-330 on September 15, 2011 to record background data caused by surface activities such as vehicles, pump jacks, and activity around the hydraulic fracturing site. Background oil field vibration are dependent on the distance away from the source, but in general, vary from non-detectable (<0.005 ips) to levels that are beneath human perception (<0.030 ips). This background data could then be compared to ground motion events recorded during the pump test and hydraulic fracturing to determine if any vibrations were coming from depth.

Surface monitoring was performed at the 4 different locations on September 15-16, 2011. The pump test was monitored from 4:40 pm until 5:05 pm on September 15, 2011. Hydraulic fracturing was monitored from 8:35 am until 10:28 am on September 16, 2011.

California Institute of Technology Accelerometer

An accelerometer and velocity transducer (station CI.BHP, Baldwin Hills) in the Southern California Seismographic Network is located near the northwest corner of the picnic ground northwest of the PXP office at 5640 S. Fairfax in Los Angeles.

The Baldwin Hills seismograph station consists of an accelerometer, a velocity transducer, and a station data logger. The sensors measure the ground motions, which are then digitized, recorded and transmitted in real-time to Caltech by the data logger.

The key function of a seismic network is to record as much ground motion on-scale and with as good resolution as possible. Signals generated by the earth vary hugely, with energy varying over 10 orders of magnitude from the local background noise of the site and signals associated with ocean tides to the most violent earthquake ground motions. There are various types of both sensor and data logger available, which have different sensitivity and range. In the case of the Baldwin Hills seismograph station, two sensors are used to cover the entire region of seismic interest. The accelerometer is designed to measure the strongest motion in the near source region from the largest earthquakes to small events at close distances, and regional events at moderate distances. The more sensitive seismometer is a broadband velocity sensor and is sensitive to motions from below the background noise of almost every site on earth to small events at close distances, and regional events at moderate distances.

Dr. Egill Hauksson, a Senior Research Associate in Geophysics with The California Institute of Technology Seismological Laboratory downloaded and analyzed data from the more sensitive seismometer CI.BHP from 4 pm to 5 pm on September 15th, from 5 pm to 6 pm on September 15th, and from 8 am to 11 am on September 16, 2011. The Baldwin Hills accelerometer is located 7,806 feet southeast of the VIC 1 330 hydraulic fracture well site (Appendix III).

RESULTS

Recommended Vibration Limits

The U.S. Bureau of Mines (USBM) Report of Investigations 8507 (November 1980) recommends a Variable Particle Velocity versus Frequency standard for assuring non-damage to all structures (see Figure 7). The federal Office of Surface Mining and Reclamation Enforcement (OSMRE) regulations, as outlined in their Blasting Guidance Manual, employ a similar variable particle velocity versus frequency limit. These two standards are the most often quoted limits for ground vibration from blasting operations in the United States and are very conservative. Under typical circumstances ground vibrations need to exceed the USBM recommendations or the OSMRE regulations by a considerable amount in order to observe threshold damage such as plaster or drywall cracking or paint flaking.

MMC recommends adherence to the USBM and the OSMRE variable particle velocity vs. frequency criteria for non-damage to plaster-on-lath, considered the most fragile of construction materials The government regulations are designed to provide positive protection against damage to private and public property, and therefore, these regulations are as conservative as possible. Documented cases of structural damage have never been observed in any structure, historic, exceptionally fragile, residential, or commercial, at particle velocities less than those recommended in the USBM and OSMRE standards.

Residential structures are most prone to damage as a result of vibration energy within the frequency range of 4-12 hertz. Within this range, a 0.50 inch per second maximum particle velocity is recommended to preclude “threshold” damage to the plaster-on-wood lath interior portions of older structures.

Above 12 hertz, the allowable vibration increases as the frequency increases, up to 40 hertz. Above 40 hertz, a constant 2.0 ips is recommended to protect the interior walls and ceilings of structures, regardless of construction material. A graphic representation of the USBM recommended criteria is shown in Figure 7

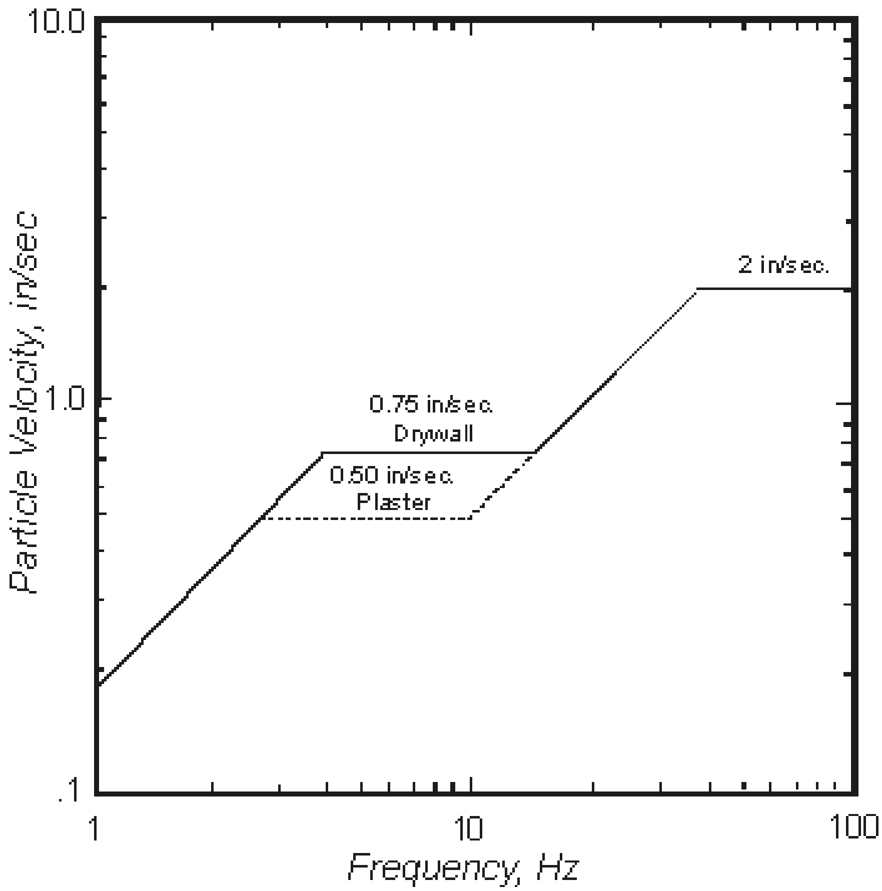


Figure 7 - USBM Criteria from RI-8507, November 1980

Oil and gas wells, pipelines, and fiber optic cables can withstand significantly higher levels. Bell Labs states that a limit of 4.00 ips is safe for their fiber optic cable and the USBM states that a limit of 4.92 ips is safe for a pipeline of any age or construction material and that this limit is also safe for wells.

The highest level of non-MMC induced ground motion recorded at any of the four recording locations was 0.0119 ips, which is 2.4% of the 0.50 ips plaster limit.

<u>Surface Monitoring</u>

The USBM and OSMRE variable particle velocity vs. frequency criteria is plotted on each vibration event report. The upper line represents the threshold level for possible sheetrock damage, while the lower, dashed line represents the threshold level for possible plaster-on-lath damage.

The monitor log (shows when the instrument was armed, disarmed, what the trigger level was, and when each ground motion event was recorded), an event summary and vibration recordings for Location #1 are found in Appendix V, for Location #2 are found in Appendix VI, for Location #3 is found in Appendix VII, and for Location #4 is found in Appendix VIII.

Location #1 – 142 feet east of the Vic 1 330 site

On September 15, 2011, five vibration events were recorded. One event was intentionally induced by MMC to test geophone functionality as described in the Method section of this report and four other events were recorded. The event that was intentionally induced by MMC was 0.0119 ips, which is 2.4% of the plaster limit. The one event that was recorded during the pump test was caused by a surface source of vibration at the Vic 1 330 well site which happened to be captured during the same time the pump test was running. The highest level recorded during the pump test was 0.0056 ips, which is 1.1% of the 0.50 ips plaster limit. The highest level recorded outside of the pump test time was 0.0050 ips, which is 1% of the plaster limit. All four of these events appear to be induced by sand mixing, diesel engines and pumps, or other Vic 1 330 well site activity on the surface and were not sourced at depth.

On September 16, 2011, two vibration events were recorded. One event was intentionally induced by MMC and one event was recorded during hydraulic fracturing. The event that was intentionally induced by MMC was 0.101 ips, which is 20.0% of the plaster limit. The event that was recorded during hydraulic fracturing appears to be induced from diesel engines and pumping on the surface at the Vic 1 330 site and was not sourced at depth. This event measured 0.0050 ips, which is 1% of the 0.50 ips plaster limit.

Location #2 – 265 feet northwest of the Vic 1 330 site

On September 15, 2011, thirty one vibration events were recorded. Two events were induced intentionally by MMC to test geophone functionality as described in the Method section of this report. One MMC intentionally induced event was 0.0112 ips, which is 2.2% of the plaster limit and the other MMC intentionally induced event was 0.0125 ips, which is 2.5% if the plaster limit. One event was unintentionally induced by MMC and was 0.00812 ips, which is 1.6% of the plaster limit. Twenty-eight events attributable to diesel engines and pumps, sand mixing, or other Vic 1 330 well site activity were recorded. Seven of these events occurred during the pumping test and were caused by surface sources of vibration at the Vic 1 330 well site. The highest level recorded during the pump test was 0.00625 ips, which is 1.25% of the plaster limit. The highest level recorded outside of the pump test time was 0.00625 ips, which is 1.25% of the plaster limit. All 28 of these events appear to be induced by sand mixing, diesel engines and pumps, or other Vic 1 330 well site activity on the surface and were not sourced at depth.

On September 16, 2011, one MMC intentionally induced vibration event to test geophone functionality as described in the Method section of this report and 21 events attributable to diesel engines and pumps, sand mixing, or other Vic 1 330 well site activity were recorded. The MMC intentionally induced event was 0.185 ips, which is 37% of the plaster limit. Twelve of the non-MMC induced vibration events were recorded during hydraulic fracturing and were caused by surface sources of vibration at the Vic 1 330 well site. The highest level recorded during hydraulic fracturing was 0.00875 ips, which is 1.75% of the plaster limit The highest level recorded outside of the hydraulic fracturing time was 0.00625 ips, which is 1.25% of the plaster limit. All 21 events appear to be induced by sand mixing, diesel engines and pumps, or other Vic 1 330 well site activity on the surface and were not sourced at depth.

Location #3 – 1,081 feet west of the Vic 1 330 site

On September 15, 2011, two MMC induced vibration events were recorded, one intentionally induced to test geophone functionality as described in the Method section of this report and one unintentionally induced. The intentionally induced event was 0.0156 ips, which is 3.1% of the plaster limit and the unintentionally induced event was 0.0162 ips, which is 3.2% of the plaster limit. On September 16, 2011, one MMC intentionally induced event to test geophone functionality as described in the Method section of this report was recorded and was 0.154 ips, which is 30.8% of the plaster limit. No other events were recorded.

Location #4 – 847 feet east northeast of the Vic 1 330 site

On September 15, 2011, one MMC intentionally induced event to test geophone functionality as described in the Method section of this report and seven events induced by field operations outside of the Vic 1 330 hydraulic fracture well site were recorded. The MMC intentionally induced event was 0.0125 ips, which is 2.5% of the plaster limit. The non-MMC induced events appear to be caused by surface sources of vehicular traffic near the recording location #4. No events were recorded during the pumping test. The highest level of traffic recorded was 0.00625 ips, which is 1.25% of the plaster limit.

On September 16, 2011, one vibration event was intentionally induced by MMC to test geophone functionality as described in the Method section of this report and 18 events generated by vehicles were recorded. The MMC intentionally induced event was 0.180 ips, which is 36% of the plaster limit. Eight events were recorded during hydraulic fracturing and were caused by surface sources of vibration (vehicle traffic). The highest level recorded during hydraulic fracturing was 0.0119 ips, which is 2.4% of the plaster limit. Ten vibration events were recorded outside of the hydraulic fracturing time period and were caused by surface sources of vibration near to the Location #4 recording site. The highest level recorded outside of the hydraulic fracturing period was 0.00562 ips, which is 1.1% of the plaster limit. All 18 vibration events appear to be induced by vehicles near the Location #4 recording site and were not sourced at depth.

California Institute of Technology Accelerometer

Plots for all three time periods from the more sensitive seismometer at the station BHP are found in Appendix IX.

The times on the plots are in Greenwich Mean Time (GMT). This clock is seven hours ahead of Pacific Daylight Time. The vertical axis is velocity, in centimeters per second. Dr. Hauksson's analysis yielded the conclusion that there were no noise signals above the local background during the pumping test on September 15' 2011 and the hydraulic fracturing on September 16' 2011." Local background levels range from 0.0003 to 0.0006 ips.

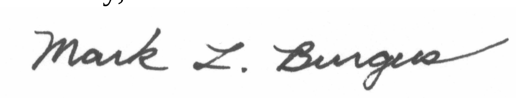
CONCLUSIONS

MMC concludes that no vibration events were recorded at any of the four surface monitor locations as a result of either the pumping test on September 15, 2011 or hydraulic fracturing on September 16, 2011.

As a result of the comparison of background data waveforms (truck traffic, diesel engines, pumping, and sand mixing) with ground motion events that occurred during the pump test or hydraulic fracturing, MMC concludes all recorded events are a result of surface sources caused by operator, construction, pumping and sand mixing at the hydraulic fracture site, or traffic induced vibrations and were not sourced at depth. Any potential vibrations sourced at depth would be expected to be more impulsive in nature and would be expected to exhibit lower frequencies. The highest level of ground motion caused by surface sources was 0.0119 ips, which is 2.4% of the recommended plaster limit. None of the vibrations measured were at a level sufficient for human perception (the typical human can feel vibrations down to about 0.030 ips).

In addition, Dr. Hauksson's analysis of the BHP accelerometer data yielded the conclusion that there were no noise signals above the local background during the pumping test on September 15, 2011 and the hydraulic fracturing on September 16, 2011.

Sincerely,



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