Memo

To	Mark Miller
Cc	Eric Vaughan
From	Stefan Baisch
Date	30.12.2011
Subject	seismic monitoring in the Bowland Shale

Dear Mark,

Please find below a proposal for seismic monitoring of the next hydraulic stimulation in the Bowland Shale.

Kind regards,

Stefan

1. Overview

A main conclusion of the analysis of the seismicity induced during stimulation of the Preece Hall 1 well (DePater & Baisch, 2011. Geomechanical Study of Bowland Shale Seismicity. Synthesis Report, 29. Sept. 2011) is that future stimulations in the Bowland Shale most likely will not cause noticeable seismicity. Nevertheless, it has been recommended operating a seismic monitoring system in combination with a TLS (traffic light system) during future treatment operations in the Bowland Shale.

Here we propose operating a modified TLS for monitoring the next hydraulic stimulation in the Bowland Shale. The seismic monitoring system and the TLS have been modified by implementing an additional safety factor. The TLS proposed here is designed to avoid seismicity that could potentially be noticeable by human beings. Furthermore, the monitoring system consists of a sufficient number of seismic stations for determining hypocenter locations of reservoir seismicity.

2. Seismic Monitoring System

The seismic monitoring system consists of 4 stations located at horizontal distances of up to 3 km from the treatment well. The geometry of the monitoring system is optimized for hypocenter determination.

Each station is equipped with a three-component 1 Hz surface seismometer of type Lennartz LE3D. Data is recorded continuously at 100 Hz on a 24bit digitizer with a GPS clocked time stamp. Real-time data transfer from the monitoring stations to a central data acquisition office (located on the treatment lease) is implemented by WLAN or UMTS. The state-of-health (SOH) of all monitoring stations is automatically controlled every 5 minutes. A copy of the time-continuous data recordings is stored on the local hard drive at each monitoring station.

At the central acquisition office, data is automatically analysed in real-time using the QUBE software package (Q-con in-house software). Visual and audible alarm occurs when TLS threshold amplitudes are exceeded.

All triggered events are quality controlled by an experienced seismologist on site. For reservoir events, magnitude and absolute/relative hypocenter locations are determined in near-real time.

If required, seismic monitoring can be continued in 24/7 mode after the treatment (extra Q-con personnel is on-site).

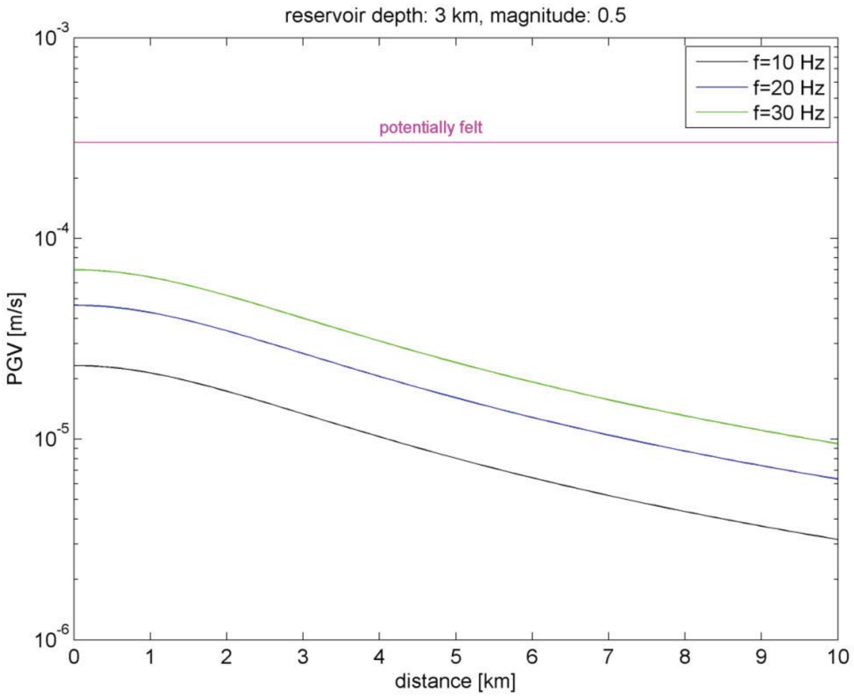
The seismic monitoring is documented by daily reports

1. summarizing the characteristics of detected reservoir events (occurrence time, magnitude, location),
2. showing a time-continuous display of measured ground velocities at all monitoring stations,
3. reporting all traffic light alarms and documenting follow-up actions,
4. showing a time-continuous display of SOH parameters for all monitoring stations and reporting all SOH incidents.

In addition, Q-con provides time-continuous records of ground vibrations in raw data format (cd1.1) and - if required - in a converted data format.

3. Traffic Light System

The TLS proposed by DePater & Baisch (2011) is designed to avoid material damage due to induced reservoir seismicity. Here, TLS threshold values are more conservative and are designed to avoid any noticeable seismicity. Following the modelling approach presented in Baisch & Vörös (Geomechanical study of Blackpool Seismicity. Q-con report CUA001, v6, 2011) we estimate a threshold level of approx. $M_L=1$ above which reservoir seismicity could potentially be felt by human beings near the epicentre (Figure 1). To account for a potential post-injection magnitude increase, we propose stopping pumping operations if a reservoir event with $M_L>0.5$ occurs. In this case, flow-back should be initiated which further reduces the probability of the occurrence of post-injection seismicity. The TLS is summarized in Figure 2.



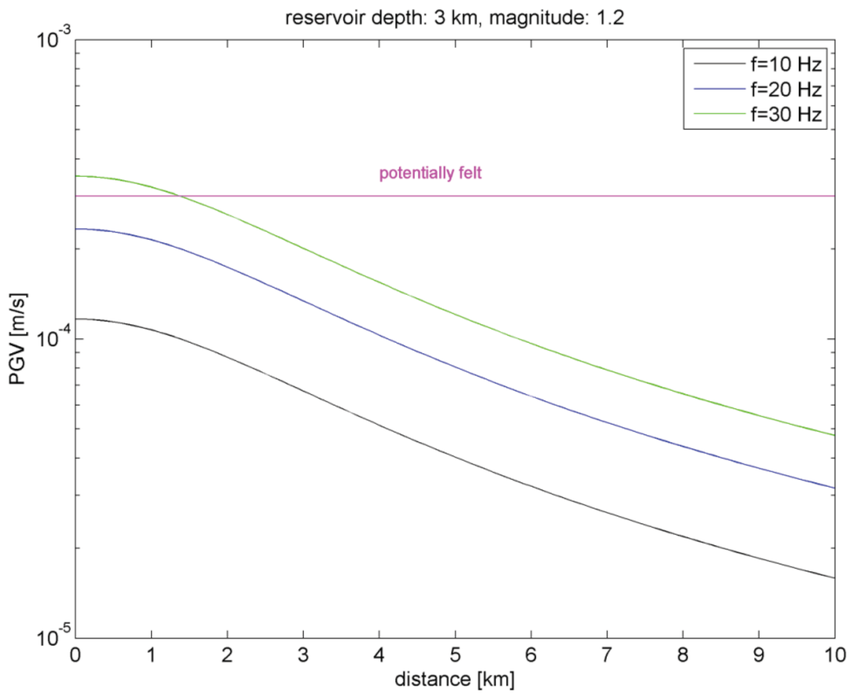


Figure 1: Modelled peak ground velocity as a function of epicentral distance for different seismic signal frequencies according to the legend. Straight line (magenta) indicates level above which signals could be felt by human beings (0.3 mm/s).