

## Attachment 1

### General Plan for Resumption of Hydraulic Fracturing Operations

As mentioned in the cover letter, our future hydraulic fracture design must be one that meets two key criteria. First, we are putting a top priority on designing a fracturing program that will allow us to conduct all of our work in a manner that will not produce seismicity at levels that will cause any concern to the local residents. Cuadrilla's team of seismic experts believe that seismic events with magnitudes less than  $M = +1.0$  will not be felt, given the depths at which we are working. And second, we need to design a multi-stage frac program that works, with respect to enabling us to produce gas at commercially viable flow rates from the shale. If both of those criteria are met we will be able to demonstrate that the Bowland Shale can be developed, with no seismic risks to personal safety or property, and minimal objections from the public.

At the point we are given the approval from DECC to resume fracturing & testing operations we plan to do the Beconsall -1 well first, followed by the Grange Hill -1. We fully appreciate that any seismicity induced by our future fracturing operations at either of those wells could cause concern to local residents. As such, when we resume operations we will be making major modifications to our frac job procedures (volumes, rates, flowback procedures), and will be very conservative with our traffic light system to eliminate seismicity at levels which would be of any concern to local residents.

But as we progress with our fracturing programs, we also have to have to find the right balance of seismic mitigation and post frac success. So while we will likely be over-conservative with our reduced job size and lower traffic light cut off when we resume, we will ultimately have to move in small steps toward optimization of our fracture treatment. That means that we may slowly increase our job size as we move through our fracturing program, providing we can do so without compromising our goal for producing no seismicity at levels that will cause concern to local residents. Recognizing that the induced seismicity at Preese Hall-1 was due to a particular set of circumstances, the confluence of which we can eliminate in future fracturing operations, we want to emphasize that the fracturing design that we propose here should be thought of as starting point, rather than a committed set of procedures for all future Bowland Shale fracture treatments.

These initial test wells in the basin should perhaps be viewed as science wells, in which we carefully monitor and control the fracturing process and learn progressively more about the nature of the formation response.

## Traffic Light System

The Traffic Light System we previously proposed in the geomechanical report was adequate for mitigating induced seismicity at magnitudes that would not give rise to any damage to property, namely  $M > 2.7$ . However, as mentioned above our stated goal is to keep any induced seismicity below  $M = 1.0$ , a level which will not be felt, given the average depth of the intervals to be fractured. Understanding that the magnitude of the induced seismicity may escalate after shut down of the pumping operation, we will initially make our maximum cutoff at  $M = 0.5$ , for the frac stages on the Beconsall and Grange Hill wells. We believe that because we will pump smaller jobs and start the flowback more quickly, the  $M = 0.5$  cut-off provides a sufficient safety factor to mitigate the risk of post-frac elevated seismicity that would reach or exceed  $M = 1.0$ .

During the Dec 16 meeting we discussed the various methods to measure the seismicity during the job. **Appendix A** provides a summary of the various methods that could be used to operate our traffic light system, including several methods to obtain full micro-seismic data for "fracture mapping". After careful consideration we are proposing to use a 4 geophone system, which is presented by Qcon in **Appendix B**. This will provide detection of events as low as  $M = -1.0$ , which is well within the detection range needed to operate our Traffic Light System effectively.

Cuadrilla's management and technical staff are well experienced in the use of microseismic monitoring and interpretation. And we fully recognize the cost to benefits ratio of using this for a field wide development program, where multiple well pads are being used (with access to multiple boreholes (monitor well) for deployment of downhole sensors). But microseismic analysis is designed for fracture mapping (fracture geometry and azimuth), not for mitigation against induced seismicity. And while it is capable of detecting events in the  $M = -2.0$  to  $-4.0$  range, observing events that small would not necessitate a pumping shut down, as they are in the range typically expected during fracturing treatments. Because our proposed real time 4 sensor system can detect events as small as  $M = -1.0$ , it will be every bit as effective as full microseismic monitoring, for mitigation of induced seismicity at  $M = 0.5$  or higher.

To conclude this discussion, we completely understand the benefits of microseismic monitoring and interpretations. And we have always intended to use it if we go to a full field development program with multi-well pads. But it is very expensive, and will not provide us with any additional margin of safety in our Traffic Light System. So in that regards we propose to use the system that is recommended by Qcon.

## Fracture Treatment Procedure

As mentioned, when we resume hydraulic fracturing operations we will make significant modifications to our procedure. In short, the changes include smaller frac intervals, smaller sand/fluid volumes, lower injection rates and faster turnaround to start flowback operations. Here is a summary of the main changes.

- (1) The mini-frac for each stage will be pumped on the day prior to the pumping of the actual injection period. This will give us enough time to study the results and make changes to the fracture design if needed. (NOTE: at Preese Hall we did the mini-frac on the same day as the main treatment, with only a few hours to look at the results). As we have done at Preese Hall, we will have a 3<sup>rd</sup> party consultant on-site during the mini-frac and main frac, to analyse the data and advise of any changes, if needed.
- (2) We will use a coil tubing unit and "Mongoose Frac System" (a hydro-jet tool) to place short slots in the 5-1/2" casing prior to injection of the fracture treatment. The slots will be placed in the center of the interval to be fractured. This method replaces perforating long intervals, as we have previously done. We believe this will enable us to provide adequate reservoir stimulation, but through the use of smaller fluid volumes and lower injection rates.
- (3) **Appendix C** shows the details of the treatment design that we would initially start with, including information about the Mongoose Frac System. For the first fracture treatment we plan to use fluid and sand volumes that are approximately 1/3 of what we used in Preese Hall. And we expect the injection rate to also be reduced proportionally. The frac fluid composition will be the same as we used previously (fresh water, sand and 0.4 gals/1000 of friction reducer). The frac design also provides for "pad sweeps" to be run intermittently during the job, to prevent excessive sand pack build up that could cause a screenout.
- (4) **Appendix D** was generated by Barree and Associates using the 3D grid oriented frac simulation software, GOHFER. It provides a simulation for the Stage 2 frac treatment that was pumped at Preese Hall. Additionally it provides a comparison run for the job size we plan to use at Becconsall- 1. From the work done by Barree it is evident that there is very little fracture height growth for the job size that we used during Stage 2 at Preese Hall. The predicted fracture length appears long, but it is important to note that with multiple fracture planes (which we expect in shale) the penetration length of our fracture treatment could be significantly reduced. For the smaller job, a much shorter frac length was predicted, however the height growth remains about the same. Barree's work suggests that we will not have any chance of excessive height growth issues with our proposed treatments, and as such there will definitely be no threat of the fracture growing in a height that would breach the Manchester Marl, and put the Sherwood Aquifer at risk. NOTE: The 3D simulated runs from Barree used information (stresses, leakoff, perm, etc.) derived from the Preese Hall logs and mini-frac data. We will update this model when we obtain values from the Becconsall logs and mini-frac data.

- (5) Following the injection shutdown for each fracturing stage we will allow a sufficient period to monitor the fall-off pressure response. We expect this to be a maximum of 1 hour, at which time we will start the flowback period. The flowback rates will be in the range of 1.5 to 3.5 bbls/min, which is a range sufficient to lift sand in 5-1/2" casing, but without drawing too much sand into the wellstream from the fracture. Chokes sizes will be selected so that the well flowback rate will start at around 3 to 3.5 bpm. Anytime the flow rates drop to 1.5 to 2 bpm, a larger choke will be installed that will put the rate back up to 3 to 3.5 bpm. We will continue to flowback within that range of rates (1.5 to 3.5 bpm) for at least 18 hours, and longer if we determine it is needed. When sufficient flowback has been achieved for a given stage, the well will be shut-in and preparations will be made to begin the next fracturing stage.
- (6) Throughout all mini-frac, main frac and post-frac flowback operations we will closely monitor all induced seismicity (if any). We will use the data to understand the impact of our operations on the seismicity, and to optimize our hydraulic fracturing process going forward, so that we can get good post-frac well performance but with focus on keeping induced seismicity at levels that will not cause any concern to local residents.
- (7) One of the deliverables raised from the December 16 meeting was for Cuadrilla to investigate the possibility of using a radioactive tracer during the fracture treatment, to provide information on the fracture height growth. We have contacted Protechnics UK to discuss this, and they have told us that there have been no tracers run in the UK at least since 2004. The Protechnics UK view was that it would be pretty difficult to obtain permission from the EA to run these, particularly for land based wells. It is our opinion that even if the EA would permit us to use radioactive tracers, we would advise against it for two reasons. First, they are not effective in determining fracture height growth, particularly if the fracture planes are inclined with respect to the wellbore, which is what we expect in our wells. And second, we think that the use of any radioactive additive in our fracturing fluid would cause concern for local residents.

## Further Analysis at Preese Hall

At the December 16 meeting there were 2 additional items identified for further analysis at the Preese Hall -1 well. The first was to rerun a casing calliper and the second was to provide discussion and interpretation of the 2 additional seismic events that occurred near the Preese Hall site in August 2011.

**Casing Calliper Run** -- The purpose of the upcoming casing calliper run is to log down to and through the interval of deformed casing, and down to the maximum depth that the tool can be run. The data from the calliper run will provide the following information:

- (1) Verify the profile across the deformed interval that was shown on the first run in April 2011, and provide calliper information below the perforated interval for the 2<sup>nd</sup> frac stage.
- (2) Allow us to see if any additional deformation has occurred as a result of the seismic event on May 27, 2011, either in the deformed interval or above it.
- (3) Following the calliper run, our plan is to plug and abandon the bottom part of the Preese Hall well from TD up to a depth above our uppermost perforated interval in Stage 6. The condition of the wellbore as provided from the calliper run will be used to design the plugging operation.

In November we conducted a cement squeeze operation in the upper part of the wellbore to repair several areas of poor bond across the Sabden Shale. This was done to prepare the well for a possible stimulation treatment in the Sabden at some point in the future. Testing the Sabden Shale is not a priority for now, so we will not go into detail about how that procedure may be carried out. But we want to keep that part of the well in a state of readiness, should we decided to give it a test in the future.

Because of the cement squeeze operations, before we can run our calliper we will first have to drill out a bridge plug and cement retainer, plus any cement that lies between the two of them. The following is a summary of the program to be used for this.

- (1) Move in rig up workover rig, install and test BOP's.
- (2) Run in hole with 2-7/8" tubing and flat bottom mill to drill through the cement retainer, bridge plug and any cement left in the hole.
- (3) Pullout mill, rerun into well with 2-3/8" tubing to clean out the well as far down as we can.
- (4) Pull out the 2-3/8 tubing, run in well with slickline and 4.5 inch OD gauge ring. Run it down to the top of the deformed casing to ensure there is no casing new casing deformation above where it was previously found.

- (5) Pull out with slickline, and rerun with a 2 inch gauge ring to the greatest depth it will go. This will ensure that we can run the calliper tool (1.75 inch OD) without risk of sticking it.
- (6) If the 2 in. gauge ring run shows that we cannot get to TD, pull out, then rerun a sand bailer to remove any debris that may be blocking the hole (exs. Sand, cement, small plug parts).
- (7) Mobilize a 3<sup>rd</sup> party multi-finger casing calliper tool and operator to perform the job. The tool will run on slickline so that wireline jars can be used to free the tool should it get stuck in the casing or sand during the operation.

As per HSE requirements, we are currently working with our independent well examiner to finalize this well entry program. We will then prepare the BSOR notification form and submit it to the HSE for approval to begin the work.

**Analysis of August Seismic Events** --- The seismic monitoring equipment installed by Cuadrilla observed three small (minor) seismic events near the Preese Hall well in July and August 2011 (M= -1.2 on 30 July, M= -0.2 on 2 August and M=-1.0 on 8 August, 2011). Accordingly we asked Dr. Leo Eisner to perform an analysis of these three events. He determined that the M= -1.2 was a false event. He has also determined that the other events were found to be located within 300 to 400 meters of the Preese Hall wellbore, and that they occurred at a time when we were performing swabbing and testing operations at the well. While it is apparent that these events were connected to the previous seismic events in April and May 2011, it is not clear whether they were related to the swabbing and testing operations being carried out at that time. These same well testing operations were being conducted through much of the time period from June to October, and no other similar events were observed. The report prepared by Dr. Eisner can be found in **Appendix E**. The work from Leo Eisner, suggests that the location of the earthquakes at Preese Hall is below the bottom of the well, in the Clitheroe Limestone.