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CBM: Fracture Stimulation an Australian Experience

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Abstract
This paper reviews the fracture stimulation experience at the Dawson Valley CBM project situated in the Bowen Basin, Queensland, Australia. Multi stage water fracture stimulation was proven to be the most effective stimulation method. Stimulating multi-seam targets requires an aggressive fracture technique to ensure more than one seam is stimulated. Water volume, rather than sand volume, influences the Fracture Stimulation effectiveness.

Geological Setting
The Bowen Basin is a Permo-Triassic basin approximately 900 km long and 300km across at its widest point. The Dawson Valley project (Figure 1), located on the eastern boundary of the basin was deformed during a Triassic compressive event which caused extensive over thrusting from the east. This CBM project targeted high volatile bituminous coal seams of the Baralaba Coal Measures; in which there are up to 10 coal seams (Figure 2), some as thick as 4m, with an aggregate thickness of 25m and depths ranging from 250m to 1000m. Gas contents range from 8m3/t to 16 m3/t. The coal seams outcrop at an open cut coal mine and dip 3 to 8 degrees to the west and have low permeability. The dip of the coal seams led to surface to inseam techniques being applied in the shallower sections (ie to approximately 500m depth) and fracture stimulation in the deeper sections (i.e. from approximately 350m to 800m depth)

Project Background
The Dawson Valley project is located in petroleum lease 94 (PL94). Commercial production commenced November 1996. The project comprises four separate fields; (Dawson River, Nipan, Moura and Mungi).

Though an extensive resource, identifying areas of commercial flow rates, in the deeper section, has proved challenging. In the deeper section the average production flow was approximately 250 Mscfd and mean reserve was approximately 1 BCF per well on an 80 acre spacing.

The key production deliverability parameters were the geological structure and associated stress setting. Areas of high stress, thrust (reverse) faulting proved unproductive, whereas extensional areas such as half grabens or structural flexures were far more productive. Geological location was determined to be a primary and therefore commercial parameter in determining the effectiveness of the fracture stimulation type or method. The current method of fracture stimulation evolved through a trial and error process in testing a combination of gel, nitrogen foam and water fracture stimulations. Production and laboratory results confirmed that gels had an adverse affect on the coals and nitrogen stimulations had mixed results. Ultimately basic water fracture stimulation proved superior to the other stimulation methods. The focus of this paper is the performance of the water fracture stimulation method.

Completion
Each well comprised of up to 10 seams over a 300m interval. The seams were fracture stimulated in 4 or 5 stages. Coal seams, greater than 1.5m, were chosen to be stimulated. The stages were designed around the thickest seams. Staging was achieved by placing the baffle 3 to 5m below a target seam and 10 to 15m above the lower stage target seam. Ideally, these seams were stimulated individually when ever possible.

To be effective, water fractures require large pumping rates and, to minimise friction loss, the fracs are pumped down the casing. The wells are completed in 5 ½" L80 17# casing and aluminium ball and baffles used to isolate the stages. 5000 HHP pumping equipment, capable of delivering 60 lbs/min slurry, was required. Each stage comprised approximately 60,000 lbs of sand and 2,000 bbls of water.

The bottom most stage was perforated with casing guns and fracture stimulated. Generally, no flow-back post frac occurred and an aluminium ball was launched to isolate the first stage. The next stage was perforated, stimulated and isolated. This sequence continued until the final stage was completed. The well was flowed back to reduce wellhead pressure prior to the completion. A workover rig, utilising an air compressor and hammer bit, was used to drill out the balls and baffles and clean out the well bore prior to running the completion. The well was completed with a PCP pump on 2

3/8” tubing. The well design incorporated a 100m rat hole to prevent sanding in the PCP pump. Water production rates were generally less than 100 bwpd therefore slim-hole 2 3/8” pumps were utilized. Occasionally, pumps sanded in and the use of a macaroni string run in the annulus was required to remove sand from around the pump.

Fracture Stimulation

Fracture Stimulation modelling and theory is a difficult science as results are inferred not measured. Work presented endeavours to review the data objectively and determine the existence of correlations between frac delivery and production performance.

The fracture stimulation design was based on coal thickness. Sand volumes were based on a rule of thumb 4000 lbs/ft. Design of the sand stages was done based on traditional fracture stimulation models but in practice the timing and size of each stage was done on the fly. The engineer would commence water pad and when all equipment was functioning, commence sand at 1/2 lb/gal and increase each stage when confident the formation could take an increase. Fortunately, if screen-outs occurred, flow-back was sufficient to enable the frac program to continue.

Production was the best indicator for the effectiveness of a drilling program, however, with the program targeting up to 10 seams from 4 to 5 stages, success or otherwise of an individual fracture stimulation was difficult to decipher.

To review the effectiveness of fracture stimulation, production performance from each production zone was necessary. Production logging tools, which measure flow rate and fluid density, were used in-situ to determine the breakdown of in-wellbore production. The difficulty in this technique was that the installation of PCP pumps prevented logging during production. Retrieving the completion and running the PLT logs generated inconclusive results because the time delay between ceasing pumping water and logging resulted in the well dynamics changing due to the influx of water into the wellbore. To overcome this problem, a procedure minimizing the time between cessation of pumping and PLT logging was developed.

A workover rig was required to remove the completion. A work string was lowered to TD (rat-hole) and an air compressor was used to remove fluid from the wellbore. Once stabilised, the air compressor was shut down, tubing raised to above the top coal seam and a memory PLT tool comprising a GR CCL and spinner was lowered into the wellbore. Timing was critical and the first log down was usually the only useful run. Subsequent logs were usually distorted due to water influx encroaching on production zones. This method may not be successful with wells producing excessive water rates. Maximum water rate was dependent on rat-hole dimensions and timing between completion of unloading the wellbore and logging. The resultant log can only indicate relative gas production from each seam. Though the sand line had a crude depth measurement, there was no speed control so the minimum gas flow required for the PLT to register would vary from job to job. For interpretative purposes, it was assumed the stimulation was successful if the flow was registered by the PLT spinner. The estimation of water production from each zone could not be interpreted with confidence and was ignored. An example of a production log from Well Number 33 is shown in Figure 3. This well has 7 coal seams which were fracture stimulated in 4 stages;

First Stage DL, Du;
Second stage C, B,
Third Stage A,
Fourth Stage Y,X &V

The production log indicated minor flow from the first stage, substantial flow from the second stage, negligible flow from the third and none from the fourth stage.

Production logs were run in ten wells covering 38 individual fracture stimulation stages, targeting 64 coal seams. These ten wells were chosen for production logging as they were low water producers (less than 15 bwpd) and required a workover.

The table below shows the 7 coal seams and resultant PLT flows.

Seam	Number	Flowing
V	6	1
X	9	4
Y	10	3
A	10	10
B	9	8
C	10	6
DL & Du	10	4

The table compares the number of target seams to PLT indicated flowing seams. Any flow indicated by the PLT was registered as a success. There are three possibilities for the lack of flow from the fracture stimulated coal seams.

- Geological (poor quality coal, stress environment etc).
- Not stimulated (if the staged frac included more than one seam).
- Ineffective fracture stimulation.

Geological environment did play a role as the thicker seams A, B and C were usually 2.5m or more thick compared with V, X and Y generally 1 to 2m thick. The V, X and Y seams were stimulated together whereas the A seam was quite often fraced by itself. Therefore, effectiveness of the fracture stimulation of multiple seams required further investigation. PLT logs showed some fracture stimulation stages failed to initiate production from their targeted coal seams. Comparing ineffective and effective stimulation jobs may indicate the key parameters for CBM stimulation.

Fracture Stimulation of Multiple Seams

Review of the pressure profile during fracture stimulation indicated that when near or total screen-out occurred PLT logs indicated production flow from multiple seams. Figure 4 shows an example of a fracture stimulation pressure profile exhibiting near screen-outs.

Reviewing PLT logs from ten wells enabled analysis of the effectiveness of fracture stimulation of multiple seams. Any indication of flow registered by the PLT's spinner was classified as a successful stimulation. Anecdotal evidence indicated that wells which experienced near or total screen-out during stimulation performed better than trouble free jobs. It was undeterminable whether the near or total screen-outs were based on leak-off characteristics or the aggressiveness of the delivery. Either way, the fracture stimulation delivery methods became aggressive.

Aggressive stimulations endeavour to continually increase the treating pressure as this ensured that the induced fracture was continually increasing. In the case of "trouble free" jobs, see Figure 5, the treating pressure was decreasing indicating either fracture height or width growth. Previous tracer work indicated that the Dawson Valley fracture stimulations were confined to the coal seams and, therefore, it was probable that width growth through sand erosion was occurring.

In the case of fracture stimulating multi-seams, an aggressive approach during stimulation improved the chance that more than one seam was stimulated. The following table shows the statistical results of fracture stimulating multiple coal seams. Inducing near screen-outs during fracture stimulating multiple seams resulted in a greater chance of propagating a frac in the secondary seam. Even with fracture stimulating three seams, there was a 50% chance of propagating a fracture in all seams.

There was no evidence that limited entry perforating had any effect to the extent that when this practice was ceased there was no noticeable change in the wells production performance.

Review of treating pressures was inconclusive though successful fracture stimulated jobs starting at as low as possible treating pressure gave the engineer greater flexibility. Figure 3 (Well Number 19) shows a fracture stimulation from one of the best producing wells. The pumping rate 50 bpm remained constant and sand concentration varied to increase pressure throughout the job.

Number of Seams per stage	All seams	Fracs with near or total screen-outs	Fracs- trouble free
	Percentage of Seams that flowed (%)	All Seams in each stage that flowed (%)	All Seams in each stage that flowed (%)
one seam	100	100	100
two seams	55	71	25
three seams	25	50	0

Water and Sand Volumes

The design of Dawson Valley fracture stimulation was based on 4000 lbs per foot of coal and water volumes based on the sand volume. Figure 6 shows the sand volumes per stage versus the wells' reserves. There was no correlation between sand volume and reserves. Comparing stages which registered gas flow and no gas flow showed no obvious sand volumes correlation.

Figure 7 shows the water volumes per stage compared with reserves. There were no obvious trends except that higher water volume fracs were more likely to register gas flow i.e. 85% of stages registered flows where water volumes exceeded 75,000 gallons, however, only 35% of stages flowed where water volumes were less than 75,000 gallons. The Dawson project low permeable coals have a low leakoff and therefore the higher water volume fracs with increasing treating pressures should generate fracture length. Fracture stimulations have subsequently been performed varing the slurry rate and sand concentration while endeavouring to continually increase bottomhole pressure. Though only few stages have been fraced using this method, their respective well production results have been encouraging.

Future Directions

CBM fracture stimulation at Dawson Valley continues to evolve. Production logs have proved a useful diagnostic tool. PLT logs have shown that not all seams have been effectively stimulated, opening re-fracture stimulation as a further opportunity. Fracture stimulating multiple coal seams requires an aggressive approach to ensure more than seam is stimulated. Future stimulation programmes will be designed around water volumes and delivery techniques to ensure increasing treating pressure by manipulation of slurry rate. Water fracture stimulation of low permeable CBM reservoirs is an evolving science which requires continuous evaluation and experimentation.

Acknowledgements

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Nomenclature

CBM	Coalbed Methane
Mscfd	Thousand standard cubic feet per day
bbls	barrels
PCP	Progressing Cavity Pumps
PLT	Production Logging Tool

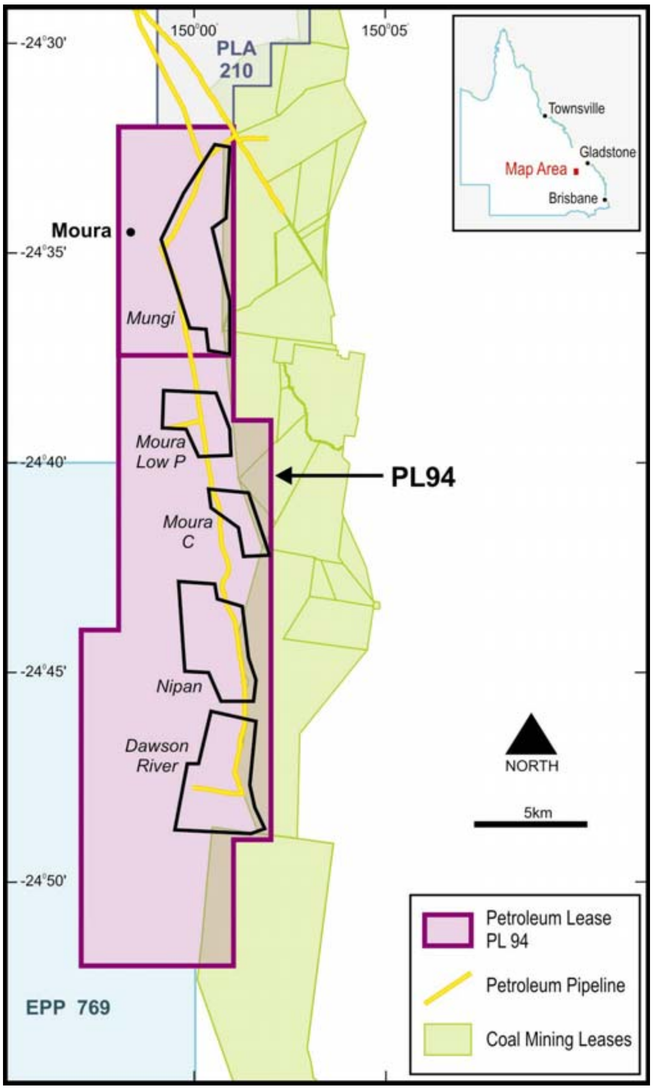

Figure 1 Dawson Valley Project Location

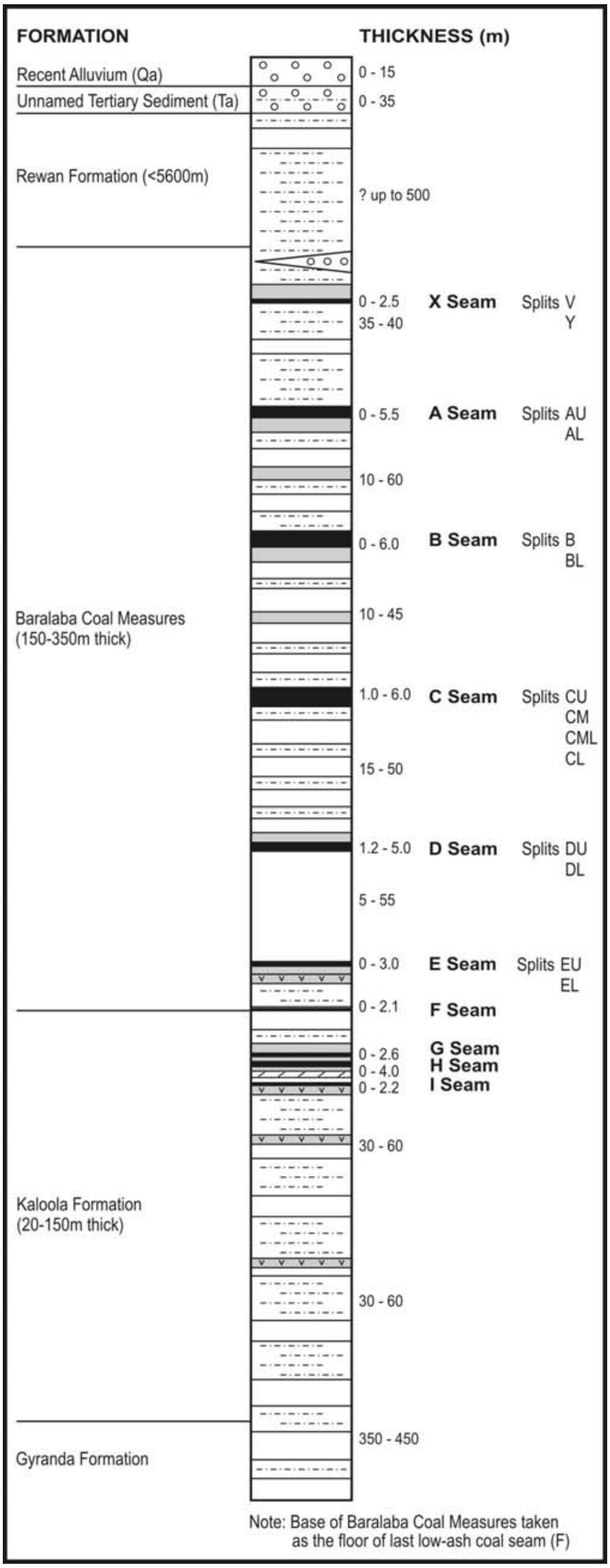

Figure 2 Stratagraphic Column

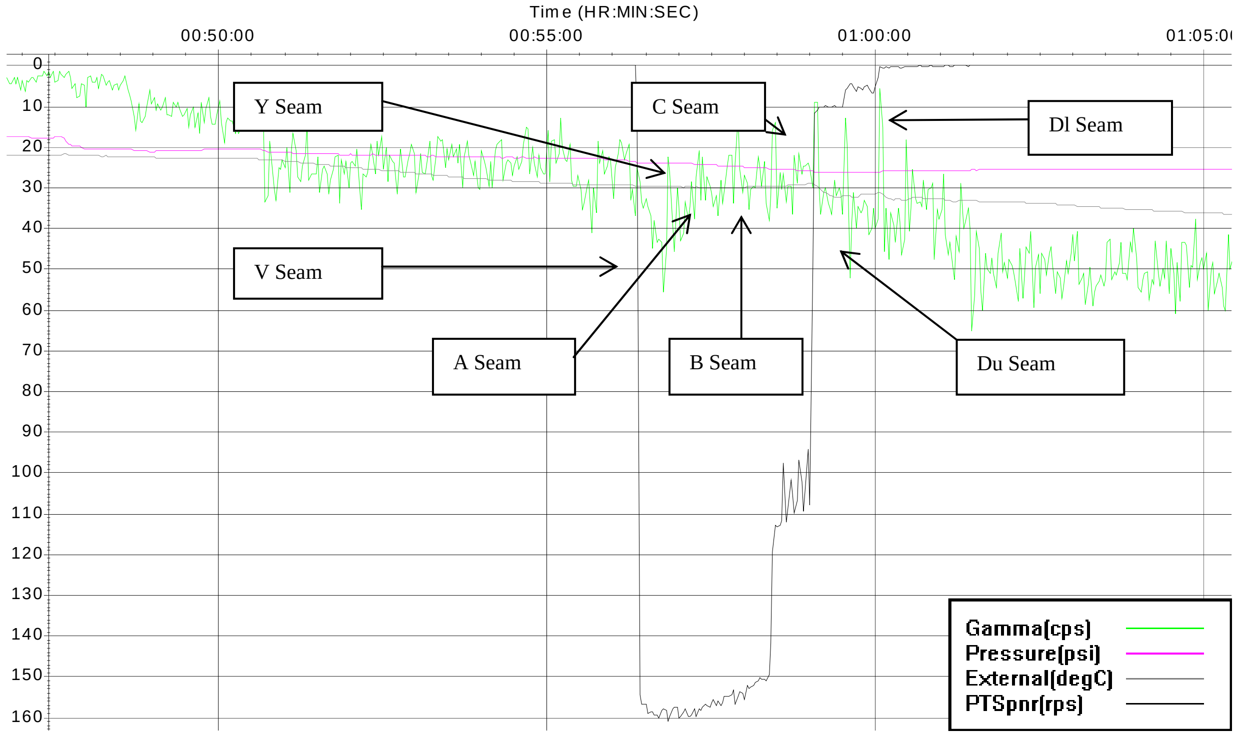

Figure 3 - Well Number 33 PLT Log

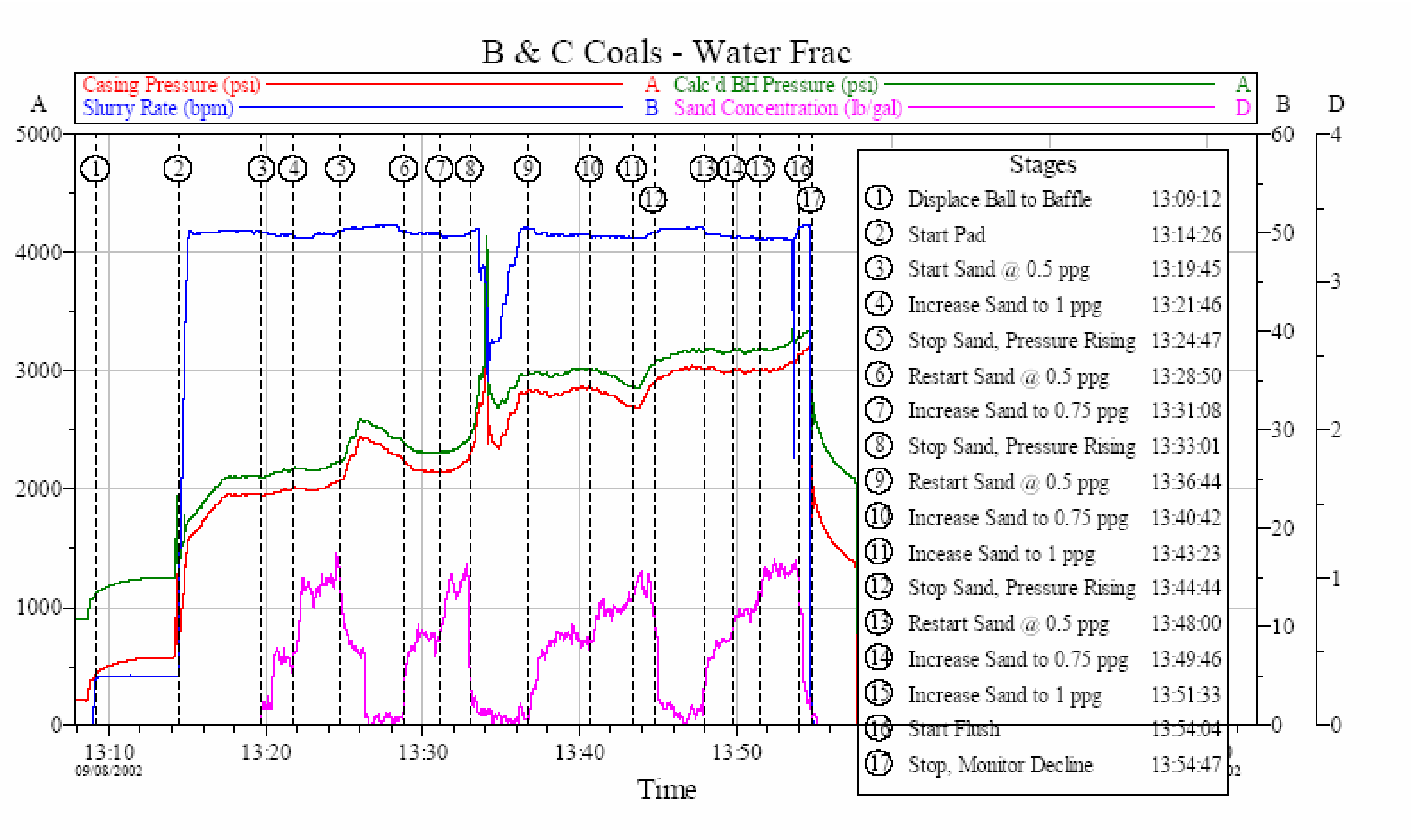

Figure 4 Well Number 19 Stage 2 Fracture stimulation of the B and C Seam

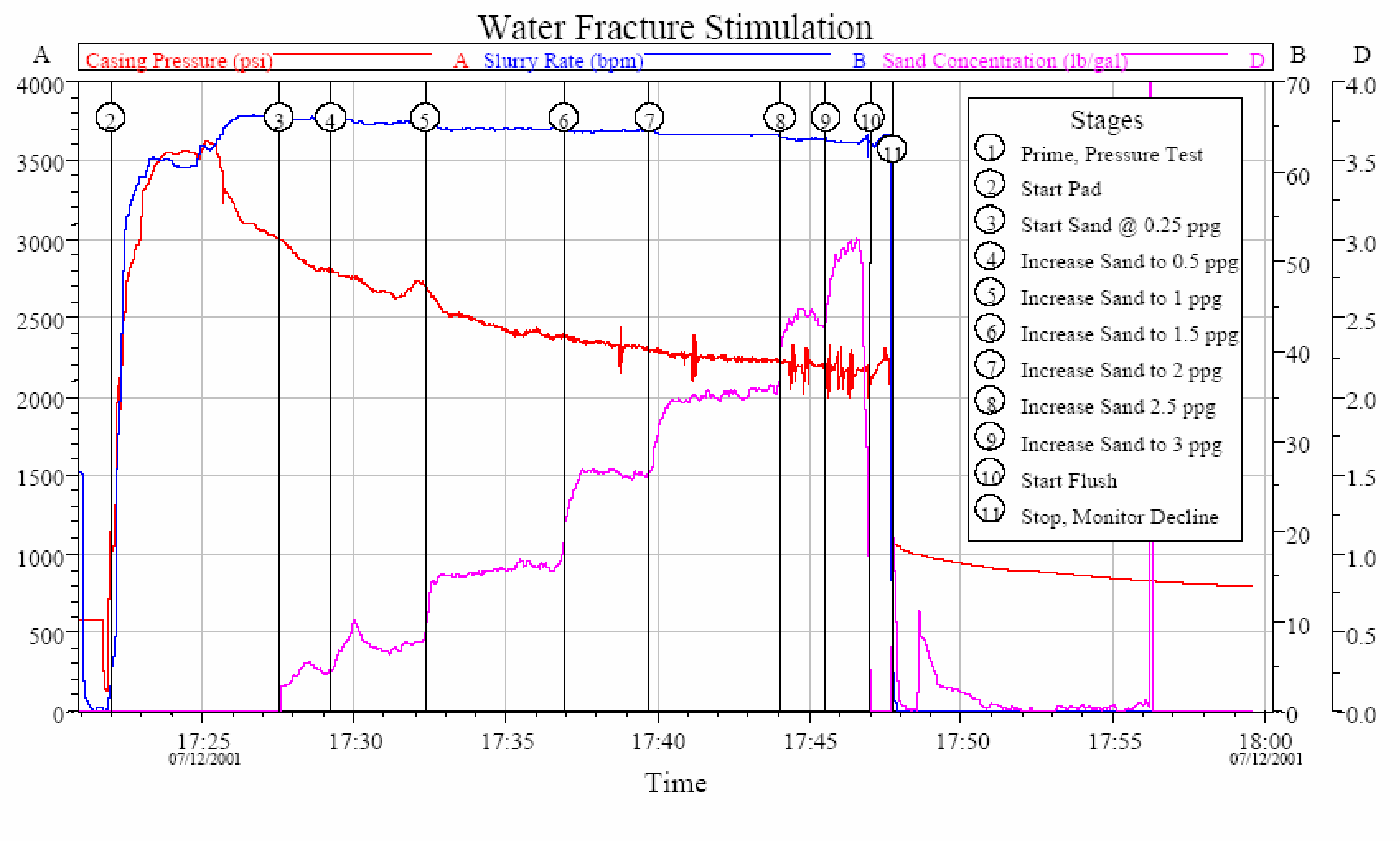

Figure 5 Well Number 30 Stage 1 Fracture stimulation of the Dl and Du Seam

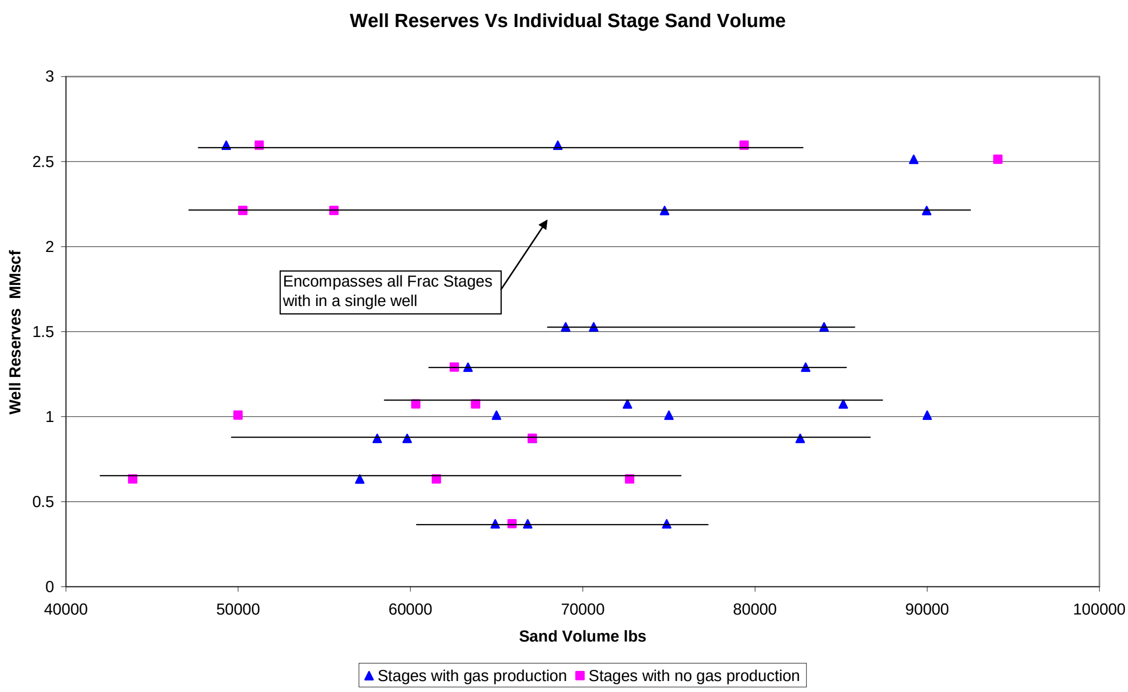

Figure 6

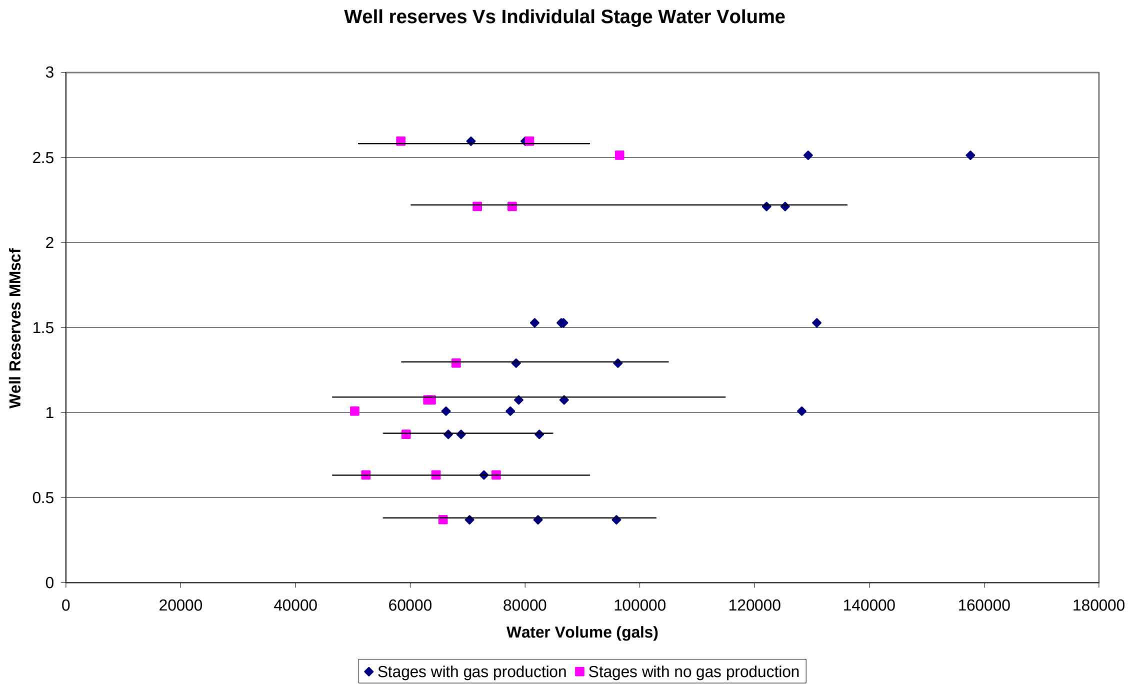
Well reserves Vs Individual Stage Water Volume
Well Reserves MMscf
3
2.5
2
1.5
1
0.5
0
0
20000
40000
60000
80000
100000
120000
140000
160000
180000
Water Volume (gals)
Stages with gas production
Stages with no gas production

Figure 7