

Pump III Program

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“Development Practices for Optimized MEOR in Shallow Heavy Oil Reservoirs”

First Year Annual Report, Technical Progress Report

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Abstract

The objective of this research project is to demonstrate an economically viable and sustainable method of producing shallow heavy oil reserves in western Missouri and southeastern Kansas, using an integrated approach including surface geochemical surveys, conventional MEOR treatments, horizontal fracturing in vertical wells, electrical resistivity tomography (ERT), and reservoir simulation to optimize the recovery process. The objective also includes transferring the knowledge gained from the project to other local landowners, to demonstrate how they may identify and develop their own heavy oil resources with little capital investment.

The first year period was divided into two phases – Phase I and Phase II. Each phase was 6 months in duration.

Tasks completed in first six month period included soil sampling, geochemical analysis, construction of ERT arrays, collection of background ERT surveys, and analysis of core samples to develop a geomechanical model for designing the hydraulic fracturing treatment. Five wells were to be drilled in phase I. However, weather and funding delays resulted in drilling shifting to the second phase of the project.

During the second six month period, five vertical wells were drilled through the Bluejacket and Warner Sands. These wells were drilled with air and logged openhole. Drilling locations were selected after reviewing results of background ERT and geochemical surveys. Three ERT wells (2,3,4) were arranged in an equilateral triangle, spaced 70 feet apart and these wells were completed open hole. ERT arrays constructed during Phase I, were installed and background surveys were taken.

Two wells (1,5) were drilled, cased, cemented and perforated. These wells were located north and south of the three ERT wells. Each well was stimulated with a linear guar gel and 20/40 mesh Brady sand. Tiltmeters were used with one fracture treatment to verify fracture morphology.

Work performed during the first year of this research project demonstrates that surface geochemical methods can be used to differentiate between productive and non-productive areas of the Warner Sand and that ERT can be used to successfully image through the Warner Sand.

ERT work also provided a background image for future MEOR treatments. Well logs from the five wells drilled were consistent with previous logs from historical coreholes, and the quality of the formation was found to be as expected. Hydraulic fracturing results demonstrated that fluid leakoff is inadequate for tip screenout (TSO) and that a horizontal fracture was generated. At this point it is not clear if the induced fracture remained in the Warner Sand, or propagated into another formation.

MEOR treatments were originally expected to commence during Phase II. Due to weather delays, drilling and stimulation work was not completed until September, 2003. Microbial treatments therefore will commence in October, 2003. Phase III, the first 10 months of the second project year, will focus primarily on repeated cycles of MEOR treatments, ERT measurements and well pumping.

Table of Contents

1.0 Executive Summary	8
2.0 First Year Objectives and Results.....	11
Phase I, Task 1 – Develop Surface Geochemical Sampling Plan and Grid.....	11
Modeling.....	11
Grid	11
Phase I, Task 2 – Collect Soil Samples for Surface Geochemistry	12
Phase I, Task 3. Construct Plastic Tubing with Electrodes for ERT Work.....	13
Phase I, Task 4. Record A Baseline ERT Survey	14
Phase I, Task 5. Preliminary Fracturing Review and Design	15
Phase I, Task 6. Technology Transfer/Publicity	15
Phase II, Task 1 – Drill Five Wells.....	16
Phase II, Task 2 – Fracture Stimulate Two Wells	17
Hydraulic Fracturing Analysis.....	17
Titltmeters and Tilt Analysis	19
Phase II, Task 3 – MEOR Treatments and ERT Monitoring.....	20
3.0 Phase III Future Plans	20
4.0 Results and Discussion	21
6.0 Conclusions.....	22
Appendix.....	45

List of Figures and Tables

<u>Figure</u>	<u>Title</u>
Figure 1	Leasehold in Vernon County
Figure 2	Arrangement of Wells Drilled (Fauvergue #1-5)
Figure 3	Student Collecting Soil Samples over Leasehold
Figure 4	Leasehold Base Map Showing Locations of Soil Samples
Figure 5	C ₁ -C ₆ Composition
Figure 6	C ₁ -C ₆ Discrimination
Figure 7	Percentage Pentane
Figure 8	Fluorescence Hydrocarbon Analysis SSF 1
Figure 9	Fluorescence Hydrocarbon Analysis SSF 410
Figure 10	SSF Intensity by Well
Figure 11	Wetness Ratio
Figure 12	Schematic of Electrode Arrays Constructed for Project
Figure 13	Electrical Resistivity Tomography Sample
Figure 14	Corehole #1 Well Log
Figure 15	Geomechanical Dataset
Figure 16	Fauvergue #1 Resistivity Log
Figure 17	Fauvergue #1 Porosity Log
Figure 18	Fauvergue #5 Resistivity Log
Figure 19	Fauvergue #5 Porosity Log
Figure 20	Drilling Operation
Figure 21	Cementing Operation
Figure 22	Well #1 Frac Treatment Data Collection Summary
Figure 23	Well #1 Surface Pressure and Rate vs. Time
Figure 24	Well #1 Mini Frac Pressure Decline
Figure 25	Well #1 Mini Frac Net Pressure History Match
Figure 26	Well #1 Propped Fracture Treatment Summary
Figure 27	Well #5 Propped Fracture Treatment Summary

Figure 28	Photograph of Hydraulic Fracturing Treatment
Figure 29	Surface Hole Equipped with Tiltmeter
Figure 30	Tiltmeter Array and Results
Figure 31	Faculty and Students On-site During Frac Treatment

<u>Table</u>	<u>Title</u>
Table 1	Triaxial Stress Analysis of Core Samples
Table 2	Hydraulic Fracturing Design

1.0 Executive Summary

The first year time period covers 1 October 2002, to 30 September 2003. This period was divided into two phases – Phase I and Phase II. Each phase was 6 months in duration.

The objectives of phase I work included in the original proposal were to initiate surface geochemical analysis and collect soil samples over the leasehold according to defined grid(s); to construct electrodes to allow ERT methods to be used in tracking microbial movement within the reservoir; to drill five vertical wells; to incorporate geochemical results in selecting well locations if data are available; to complete/equip the wells for subsequent MEOR treatments; and to prepare a detailed fracturing design. Phase II objectives were to commence MEOR treatments in all wells; to apply ERT monitoring to track microbial movement in the subsurface; to hydraulically fracture stimulate two wells according to the design developed; to analyze soil samples collected; and to prepare an annual report of progress.

Due to funding and weather delays, drilling and hydraulic fracturing were delayed until August and September 2003. This, in turn, delayed the start of MEOR treatments beyond the first project year. All other objectives of the first year of work were met.

Preliminary meetings were conducted with project participants, and all participants were sub-contracted. Participants include Direct Geochemical (surface geochemistry), Nolte Smith, Inc. (hydraulic fracturing design), J-Environmental (MEOR treatments), Mr. Jim Long (consultant), Garland Oil and Gas (operator), and Dr. Lee Slater (ERT support). It should be noted that, at the time of the initial project award, Dr. Slater was located at the University of Missouri, but has subsequently moved to Rutgers University in New Jersey.

Soil samples were collected over several areas of the leasehold, to evaluate the use of geochemical analysis in identifying productive and non-productive areas of the Warner Sand, and also for differentiating the quality of the productive area throughout the leasehold. Soil samples and corresponding GPS data were collected over several areas and provided to Direct Geochemical for analysis. Results from this work demonstrate that the surface geochemistry across the leasehold, and over two known dry holes, is quite different and can be successfully differentiated.

Background electrical resistivity tomography (ERT) readings were taken over two areas of the leasehold. Two initial, 2-D resistivity lines were shot in lines running North-South and

adjacent to the original corehole #1 (Figure 1). Data obtained indicated that the depth of the ERT survey did not extend through the Warner Sand. This work indicated that the electrode spacing for future surveys would need to be altered. The electrode spacing was modified to achieve a greater depth of investigation. Three, 2-D lines were then shot E-W, between coreholes #4 and #5, since geochemical results indicated slightly stronger response in this area.

ERT probes for the ERT wells were also constructed. Three strings of plastic tubing were equipped with electrodes and wired for connections to surface. The initial plan provided for two ERT monitoring wells. After discussing the imaging methods, it was determined that three wells should be equipped with ERT probes to create a 3-D image with ERT. Three ERT probes were constructed, shipped to location and placed in storage.

Five wells were to be drilled in the project. Well logs, core data and results from the geochemical survey were reviewed to determine the optimum location, and general well configuration, for the five wells. ERT background work indicated wells equipped with ERT probes would need to be no more than 70' apart and could not be cased (initially). It was determined that the ERTs wells would be configured in an equilateral triangle, and the two wells to be fractured would be located 200-300 ft outside this triangle. The fractured wells would be cased and cemented.

Five wells were drilled through the Warner Sand to depths of approximately 220 ft. All wells were air drilled with 6-1/4" hole to total depth. The wells were logged openhole with resistivity, porosity and density tools. Well log data is included in this report. Well logs indicated that the Bluejacket and Warner sands in these wells were similar to the historical coreholes (Figure 1).

Three ERT wells (2,3,4) were arranged in an equilateral triangle, spaced 70 feet apart and these wells were completed open hole. ERT arrays constructed during phase I were installed and background surveys were taken.

Two wells (1,5) were drilled, one to the north of the ERT wells and the other to the south of the ERT wells (Figure 2). These wells were cased with 4-1/2" casing, cemented and perforated in the top of the Warner Sand.

Continuous cores from wells (coreholes) drilled prior to this project were selectively sampled to develop a geomechanical dataset for designing the hydraulic fracturing treatment. The process of developing a geomechanical dataset includes the development of a profile with

depth versus Young's Modulus, in-situ stress and fracture fluid leak-off. Fifteen samples were taken from the Cushard #1 core, ranging from the shale immediately above the Bluejacket Sandstone, through the Bluejacket and Warner Sandstones, and into the Graydon Shale immediately below the Warner Sandstone. These samples were sent to NSI and analyzed in their laboratory. Results of this analysis indicated that the Warner sand was much more competent than the published geological reports indicated.

Based on the geomechanical study, a hydraulic fracture treatment was designed for wells #1 and #5 (Figure 2). The intent was to tip screen out (TSO) and perform high permeability fracturing. Each well was to be stimulated with a linear, 30 lb/gal guar based gel and 20/40 mesh Brady sand with an end of job concentration of 10 lb/gal. Total volumes per well were 23,000 gallons of fluid and 94,000 lbs of sand. Well #1 was stimulated according to plan but TSO was not possible. Blender problems were encountered while pumping on well #5. Sand concentrations of up to 17 lb/gal were pumped near the end of this treatment, but no TSO could be effected. It was concluded that the leakoff rate in the Warner was too low to accommodate a tip screen out.

Fifteen latest generation, self-leveling tiltmeters were placed in prepared surface holes, located around the #1 well in a circular array. Results of the tiltmeter readings are given in this report. The tiltmeters confirmed that a horizontal fracture was generated and verified the extent of the fracture. However, tiltmeter data could not confirm the exact depth of the fracture. At this point it is not clear if the induced fracture remained in the Warner Sand, or whether it propagated into another formation.

Although it was planned to begin MEOR treatments during the first year, delays due to an extremely cold winter and very wet spring meant that drilling and fracturing could not take place as planned. MEOR treatments commenced in October, 2003, after surface equipment was set.

All other technical work performed during the first annual period was successful. The geochemical analysis of soil samples was completed and provided useful results. Adjustments to the ERT array were made and those adjustments subsequently proved the ability to image through the Warner Sand. Three ERT arrays were constructed and successfully installed in the three ERT wells. Available Cushard cores were sampled selectively for supporting the final hydraulic fracture design. Two wells were successfully stimulated and fracture morphology was verified.

2.0 First Year Objectives and Results

The following sections of this report provide additional detail for proposed tasks that were completed from September 2002 through September, 2003. This discussion is arranged according to the original tasks proposed in each phase of the first year's work.

Phase I, Task 1 – Develop Surface Geochemical Sampling Plan and Grid

In November 2002, Direct Geochemical met with the faculty at UMR and Mr. Jim Long to devise a soil-sampling scheme. The initial concept for the field-sampling plan involved two aspects, modeling and grid sampling.

Modeling

It was proposed to take sufficient sample to develop both local and regional models. Each model was expected to consist of one or more wells with known characteristics, i.e. a good well and a very bad well. The following sampling was proposed (referencing corehole locations shown in Figure 1):

- * Well (corehole) 1 and Well (corehole) 4: 10 samples near each well
- * Well (corehole) 12: 15 samples near the well
- * Offsite Good well: 15 samples near the well
- * Offsite Bad well: 15 samples near the well

"Near the well" samples were to be taken all the way around the location, in a rough circle. All of the samples were to be obtained close enough to be representative of the subsurface geologic characteristics but far enough away to be in natural or at least non-oil disturbed ground.

Grid

Three connected grids were initially proposed. Grid number 1 was to cover the main target area, in the E1/2 of the NE 1/4 of Section 32. The proposed grid for the target comprised 66 samples, approximately 265 feet on center. The grid proposed 11 rows of 6 samples.

Grid number 2 consisted of 160 acres in the SW1/4 of the SE1/4 and the SE1/4 of the SW1/4 of Section 29 plus the NW1/4 of the NE1/4 and NE1/4 of the NW1/4 of Section 32. Sampling was proposed to be on 530' spacing, and consist of 33 samples arranged generally as 6 rows of 5 samples, plus 3 on the east line. This grid connected the main grid across to Well 4 (Corehole #4 in Figure 1).

Grid number 3 was proposed to connect Well 1 and the main grid across to Well 7, which was the medium quality well. It consisted of 3 rows of 5 samples in the S1/2 of the NW1/4 of Section 33.

The grids included 114 soils samples and the models proposed a further 65 soil samples.

The non-productive wells (offsite bad, offsite good) selected were the Ellis #1 dry hole located approximately one mile SE of the leasehold and the Harpel well, located several miles to the north-northeast of the leasehold area. These wells were selected because they were recent wells (2001), and the operator had leasehold rights for access to the wells.

Phase I, Task 2 – Collect Soil Samples for Surface Geochemistry

Direct Geochemical provided soil sample instructions, sample field note sheets and sample jars for collecting the soil samples. GPS units were provided by the University, for noting the location of soil samples taken.

During January, 2003, model soil samples were collected, but weather conditions limited the number of samples taken and prevented grid samples from being collected. Extremely cold winter conditions hampered soil sampling efforts considerably.

During February, 2003, UMR students and faculty returned to the leasehold and collected approximately 100 soil samples over the three proposed grid areas. Figure 3 is a photograph from the soil collection effort.

The samples collected consisted of three sections, and approximated the proposed grids. The center section incorporated 53 samples, acquired on approximately 200-foot centers. The western section used 31 samples on 400-500 foot centers. The eastern section used 15 samples on 300-400 foot centers. These sample locations are shown as a base map in Figure 4.

Soil samples and GPS data were transmitted to Direct Geochemical for analysis. Figures 5-11 show sample hydrocarbon analysis and other results for the soil samples collected. A copy of the complete report from Direct Geochemical is provided in the Appendix.

Preliminary findings indicated that the area around corehole #4 might be slightly better than corehole #1. Based on these findings (and ERT results), it was decided to drill to the five wells for the project east of corehole #4, rather than near corehole #1 as originally planned.

The geochemical analysis revealed a difference between areas known to be productive and dry holes. The Ellis dry hole and Cushard (corehole) 12 both appeared quite dry.

The Harpel well, which did have oil present, appeared different than the Cushard coreholes. It exhibited a lower overall concentration of hydrocarbons almost always. It predicted as a weaker version of the Cushard coreholes #1 and #4.

On a limited data set, it also appeared that the oil wells as a group show higher arsenic, calcium, and magnesium than the dry holes. The application of metals is difficult to understand at this point.

A simple analysis of the geochemical data strongly supports the notion that the surface geochemistry can be used to differentiate where oil occurs in the Warner Sand.

Phase I, Task 3. Construct Plastic Tubing with Electrodes for ERT Work

Three ERT arrays were constructed for deployment in the wells. Array design was based on a modification of instrumentation used by Dr. Lee Slater in previous DOE funded projects and is summarized in Figure 12.

Lead electrodes were used as previous field experience has indicated that they are electrically quieter than electrodes constructed from Type 304 stainless steel mesh. We intend to obtain reliable cross-borehole induced polarization data in addition to electrical resistivity data during ERT data acquisition. For each array twenty-four electrodes were placed on 3-inch diameter PVC pipe at 1.5 m intervals. This provides a vertical dimension of 38 m for the image zone (Figure 12). The ERT image aspect ratio is 1.52 (35 m/22.9 m), which is appropriate for cross-borehole ERT imaging. Note that the zone of interest is designed to occupy about 33 % of the image plane (Figure 12).

Each electrode is connected to two 18 gauge copper wires that provide electrical contact with the electrical imaging system placed on the surface and at the center of the boreholes.

The arrays were constructed in 3.1 m sections for transportation and final construction during well installation. They were designed for removal and re-installation on an as-required

basis by two-three persons. A heavy-grade rope is attached for lowering and retrieving the array to/from the approximately 50 m installation depth.

All three arrays were stored on-site until drilling was completed in August, 2003. The ERT arrays were then installed in the three openholes, #2, #3, #4 (Figure 2). Two arrays (#2,#3) were inadvertently set on bottom in the well and became stuck in borehole mud and other sediments. These arrays cannot be removed without a major workover. The array placed in well #4 was suspended with ropes and has been successfully retrieved once, and re-run one time. Despite the fact that the array can be pulled and re-run, it was deemed impractical to perform this on a monthly basis, as the connections to the array electrodes may become damaged. Hence, it was decided to leave the array in place until ERT measurements are concluded. As a result, none of the ERT wells can be produced between MEOR treatments.

Phase I, Task 4. Record A Baseline ERT Survey

Geophysical students acquired 2 dimensional background resistivity data around corehole #1 in the late fall 2002 using a dipole-dipole array (DD). The results indicated that electrode spacing of 8 m (for a total spread length of 820 m) did not provide enough depth to image the entire reservoir (Warner). As a result new array geometry was recommended.

Weather conditions delayed the acquisition of the background resistivity data. Frozen ground during the winter and heavy rains in the spring hampered field data acquisition. Students returned to the field in early May, but could not complete the survey until June, because the fields were excessively muddy. Data acquired in May and June using new array geometry (pole-dipole array) allowed for greater depth penetration. We were able to image to depths exceeding the depth of the reservoir.

Resistivity profiles were acquired for three lines running E-W, between coreholes #4 and #5. Results of these 2-D profile surveys are shown in Figure 13.

The resistivity profile in Figure 13 shows that the shallow subsurface is very conductive with resistivities less than 12 Ohm.m. We interpret this to be due to shallow clays. Below this is a more resistive layer approximately 50 m thick, with resistivity values ranging from 32 to 50 Ohm.m. We correlate this with a shale unit. The reservoir layer is imaged beneath this more resistive layer at a depth of approximately 55-60 m with apparent resistivity values between 26-

30 Ohm.m (dark tan color image). This layer appears to thicken towards the east (towards corehole #5).

Phase I, Task 5. Preliminary Fracturing Review and Design

During February, 2003 samples were selected from the Cushard #1 core, for geo-mechanical analysis. A summary of core samples selected for analysis is presented in Table 1. These samples were taken to NSI Laboratories in Tulsa, Oklahoma for analysis.

Table 1 presents results of the tri-axial compression tests on the core samples. Evaluation of these tests indicates that the Bluejacket and Warner Sandstones have an average Young's modulus of 3.1 and 1.3×10^6 psi, respectively. These values are relatively high, indicating that the formation is hard or consolidated. This was surprising since a geological study had previously reported the Warner sand a friable and somewhat unconsolidated.

Figure 14 depicts the geomechanical data set developed for the fracture design. In Figure 14, the first track of the geomechanical profile is the true vertical depth and perforation indicator track. Track two of the profile represents the closure pressure while tracks three and four represent the Young's Modulus and toughness, respectively. Tracks five and six show the fluid loss coefficient and spurt and track seven shows the gamma ray log.

Based on geomechanical results and known formation permeability of 350 mD (historical core analyses) it was believed that high permeability fracturing methods should be applied to the Warner sand.

The hydraulic fracturing treatment designed is summarized in Table 2. As shown, the preliminary design consists of pumping 94.5 Mlbs of 20/40 Brady sand in 23 Mgals of 30 lb/gal linear gel fracturing fluid. The treatment is designed for a proppant addition schedule from 0.5 ppg to 10 ppg. The purpose of the 0.5 lb/gal proppant stage is to mitigate the detrimental effects of near wellbore pressure loss due to the anticipated complex fracture geometry. Predicted net treating pressure and other details of the design can be found in the Appendix .

Phase I, Task 6. Technology Transfer/Publicity

A preliminary website has been developed for this project. The website URL is www.umn.edu/~doe.

Publicity for the project was generated through press releases and through KY3 in Springfield Missouri. KY3 ran a television spot in February, 2003 on the research project. The local Nevada, MO newspaper covered the hydraulic fracturing treatment. Copies of press releases will be provided in the final report.

Phase II, Task 1 – Drill Five Wells

Five wells were drilled through the Warner Sand to depths of approximately 220 ft. All wells were air drilled with 6-1/4" hole to total depth. Each well was drilled to total depth in approximately 2-3 hours.

Drilling cuttings samples were collected every 5 feet, washed and placed into sample bags. Direct Geochemical provided a UV light box, and microscope for onsite analysis. Mr. John Fontana of Direct Geochemical was onsite during drilling and provided mud logging support for two wells drilled. This geological analysis is not included in this annual summary, but will be included in the project final report.

All wells were logged openhole with resistivity, porosity and density tools. Tool failure meant that the resistivity logs for wells #1 and #5 had to be computed from the density porosity log. Figures 15-18 are resistivity and porosity logs for wells #1 and #5. Complete well log data is included in the Appendix of this report.

Well logs indicated that the Bluejacket and Warner sands in all wells drilled in this project were similar to the historical coreholes. Figure 19 depicts the log for corehole #1, and highlights the Bluejacket and Warner Sands.

Three ERT wells (2,3,4) were arranged in an equilateral triangle, spaced 70 feet apart and these wells were completed open hole. ERT arrays constructed during phase I were installed and background surveys were taken.

Two wells (1,5) were drilled, one to the north of the ERT wells and the other to the south of the ERT wells (Figure 2). These wells were cased with 4-1/2" casing, cemented with Portland A cement, and perforated in the top of the Warner Sand. Cement returns were noted at surface or the annulus was filled from surface. Well #1 was perforated from 164-179 ft feet, 4 shots per foot (spf) using 60° phasing. Well #5 was perforated from 162-177 ft. using the same density and phasing. Perforations were 0.25 inches in diameter.

Pictures taken from during the drilling and cementing operation are shown in Figure 20 and Figure 21.

Phase II, Task 2 – Fracture Stimulate Two Wells

Halliburton Energy Services (HES) provided fracture stimulation services and fracture analysis in September, 2003. Each well was stimulated with a linear, 30 lb/gal guar based gel and 20/40 mesh Brady sand as planned. Two frac tanks were supplied by Garland Oil and Gas and frac water was trucked from Ft. Scott Kansas. Total fluid volumes per well were 23,000 gallons of fluid and 94,000 lbs of sand. The fluid injection rate was 15 bbl/min.

Although it was considered, microbes were not placed in the fracturing fluid. Microbes were not included due to the ERT work. ERT arrays were placed in the openhole wells after the hydraulic fracturing. It was believed that hydraulic fracturing with microbes might place the microbes near the ERT wells and disturb background reading when the arrays were installed.

Well #1 was stimulated according to plan. Figure 22 depicts the fracture data collection summary. An initial breakdown and step rate test was performed first. Following the step rate test, formation pressure was allowed to bleed off until closure pressure was observed. A mini-frac was then pumped to determine fluid efficiency. The main fracture stimulation follows the mini-frac.

A similar procedure (breakdown, step rate, minifrac and main treatment) was followed on well #5. However, blender problems were encountered while pumping on well #5. The treatment was shutdown after the slurry pumping schedule had begun. When the treatment was re-started, the slurry schedule was also re-started. Hence, there was insufficient fluid to pump the entire treatment as planned. Approximately 25% of the proppant was not placed in formation. In addition, control problems with the blender resulted in erratic concentrations, with values as high as 17 lb/gal pumped near the end of this treatment.

Hydraulic Fracturing Analysis

Figure 22 provides a summary of the initial break down, step-rate test and main treatment performed on well #1. Figure 23 is a detailed view of the step rate test. The step rate test was

conducted with the 30 lb/gal linear gel and pump rates in increments from 2 bbl/min to 15 bbl/min (treatment design rate), with a step down to 4 bbl/min.

Formation breakdown pressure for well #1 was 770 psi. Analysis of the step-rate test revealed that the entire test was conducted above fracturing pressure, but the step down portion of the test was used to estimate a fracture extension pressure of approximately 140 psi. The 1.75 slope of the pressure-rate curve during step down also indicated there was considerable perforation friction.

Figure 24 provides a summary of the pressure fall-off following the mini frac treatment on well #1. Closure pressure was found to be 107 psi, which agrees well with the closure pressure found from fall-off data following the step-rate test. Pipe friction is evident in the early portion of the data and this friction may be explained by the complex fracture geometry due to the horizontal fracture orientation. Fluid efficiency was found to be 85%, which is very high in the context of conventional hydraulic fracturing. The high fluid efficiency is a result of low leakoff rate, which is expected in a heavy oil reservoir. This indicates that the pad volume (2000 bbls) is being 'spent' very slowly as the fracture propagates.

A mini frac net pressure history match was prepared, comparing the predicted net pressure to the actual net pressure of the treatment (Figure 25). As shown, early time data are not in agreement, but late time data do agree with the predicted net pressure. Early time data are affected by friction effects, which occur through the perforations due to tortuosity. Again, this is attributed to the creating of a horizontal fracture.

The actual treatment performed on well #1 is given in Figure 26. This treatment is exactly according to the treatment schedule prescribed in Table 1. A 2000 bbl pad was pumped. Following the pad, a sand slurry schedule of 0.5, 1.0, 2.0, 4.0, 6.0, 8.0, and 10.0 lb/gal was pumped. A constant injection rate of 15 bbl/min was used. Although it is not shown in Figure 26, treating pressure increased slightly every time sand concentration was increased. This indicated that the perforations or formation was reacting adversely to the increased concentration. During the treatment, bottomhole treating pressure declined continuously, indicating a radial fracture. The treatment never indicated a tip screen out.

Knowing the fluid efficiency was 85% in the first fracture treatment, and that tip screen out was not achieved, it was decided to reduce the pad volume by 50% (to 1000 gal) in well #5. It was hoped that with such a small pad volume, a tip screen out would occur.

However, due to problems with the blender, it was not possible to pump the treatment as planned on well #5. As shown in Figure 27, the pumps were stopped at 2 lb/gal slurry rate, and then re-started. Difficulty with the computer card in the blender meant that the proppant addition could not be controlled, and the addition of proppant was erratic. Concentrations of up to 17 lb/gal were reached, which is extraordinary for sand transport in a linear gel. Because the treatment was stopped and re-started, there was not sufficient fluid to continue pumping and inject all the sand volume. Approximately 25% of the 94,000 lbs of sand were not placed in the formation.

Despite the high sand concentrations applied to well #5, the continuous decline in pressure also indicated that a tip screen out did not occur. It was simply not possible to tip screen out. It is concluded that high permeability fracturing would not be possible in these subsurface conditions.

Figure 28 is a photograph of the hydraulic fracturing treatment applied in the project. Approximately 20 students and two faculty were on-site for the treatment (Figure 29). The local newspaper also ran a feature article.

Tiltmeters and Tilt Analysis

Pinnacle Technologies, Inc. provided the use of surface tiltmeters in support of the hydraulic fracturing treatment. The purpose of using tiltmeters was to confirm fracture morphology. Fifteen, self-leveling tiltmeters were placed in prepared surface holes (Figure 30), located around the #1 well in a circular array.

Results of the tiltmeter data were analyzed by Pinnacle Technologies and by a graduate student at UMR. Figure 31 depicts the tiltmeter data and final fracture morphology.

Tilt signals were extremely clear because of the shallow depth of the formation. A video movie of the fracturing treatment was prepared from the raw data. The movie clip is included on the disc containing this report, as a separate file.

Analysis of the tiltmeter information showed that the deformation was located approximately 80 ft. East and 20 ft. North of the well (#1). The primary feature induced is near horizontal, and elliptical, with dimensions of 200 ft by 300 ft. There appeared to be a vertical fracture that accompanied the horizontal fracture, with an azimuth of about N 73° E. The vertical

fracture is a questionable feature. If it exists, it is no larger than 25% of the injected fluid volume and it is not present above 150 ft. The tiltmeters used in the fracturing treatments confirmed fracture morphology and extent. However, tiltmeter data could not confirm the exact depth of the fracture. At this point it is not clear if the induced fracture remained in the Warner Sand, or whether it propagated into another formation. Methods of trying to determine the fracture depth are being investigated.

Phase II, Task 3 – MEOR Treatments and ERT Monitoring

The initial project proposed treating all wells monthly with MEOR treatments beginning in Phase II of the first year. MEOR treatments commenced in October, 2003 due to project delays. Results of the MEOR treatments will be provided in the semi-annual, second year report.

3.0 Phase III Future Plans

Phase III includes a 10 month period of repeated microbial treatment, ERT measurement and pumping. Due to first year delays, MEOR treatments commenced six months behind schedule, in October 2003. Due to technical difficulties in placing the ERT arrays in the openhole monitoring wells, it is not possible to produce the ERT wells. Two ERT arrays are permanently lodged in the wells. Only one array can still be removed. After removing the array one time, it was deemed impractical and risky to do so on a monthly basis. Hence, all ERT arrays will remain in the wells and the ERT wells cannot be produced.

At the present time, it is expected that at least 6 months of treating and ERT measurement will be performed in phase III. At that point, a decision will be made with respect to pumping at least one of the ERT wells.

Oil samples were taken from ERT well #4 and the sample is currently being analyzed to compare its composition with published literature and to verify whether the samples are Bluejacket oil, Warner oil, or a mixture of the two. This is necessary because the ERT wells are currently completed openhole. Brine samples have also been taken and will be analyzed. Water samples may prove insightful in determining the depth of the fractures created, and in monitoring microbial activity. This work was not specified in the original proposal but is necessary.

4.0 Results and Discussion

Results of the geochemical analysis are an interesting aspect of the work completed in phase I of the first project year. Examining the results for the Ellis #1 and Cushard #12 (insets to Figures 4,5,6,7 and 9) it is clear that the dry holes exhibit responses quite different than the productive wells found in the main leasehold. This strongly suggests that surface geochemistry might be used as an inexpensive way of identifying the existence of hydrocarbons in western Missouri. The finding is important, since no regional geochemical study has been undertaken to date.

Another significant result of the work performed to date is confirmation of ERT capabilities. Through adjustment of probe spacing and background surveys, it was demonstrated that the Warner sand can be successfully imaged. ERT arrays were successfully deployed in the ERT wells drilled, and background measurements provide a baseline for future, post MEOR ERT readings.

The hydraulic fracturing work clearly demonstrates a fracture at this depth (200 ft) is near horizontal and this work provided the first fully characterized fracture treatment in the Warner sand. Much was learned by pumping this treatment, including formation breakdown, strength and fracture response characteristics. Fluid leakoff was very low, which translates to an extremely high fluid efficiency. Based on these findings, it is unlikely that one could ever pump a high permeability fracture design in the Warner sand. Further, it is concluded that the Warner sand can sustain very high proppant concentrations during pumping, even with a linear gel.

Although tiltmeter data confirmed the existence of a horizontal fracture, the exact depth of the fracture could not be determined from tiltmeter data alone. Hence, it is not known if the fracture remained in the Warner formation or propagated to another zone.

Beyond the technical success of the work performed, it should be mentioned that the project publicity has also been highly effective, and that the University and project PI have had numerous calls regarding the work. At least four, major land and mineral owners in Western Missouri are now hoping to gain from the results of this work.

6.0 Conclusions

The first year of the project “Development Practices for Optimized MEOR in Shallow Heavy Oil Reservoirs” has been successfully completed. Soil samples were collected as planned and geochemical analysis of the surface samples providing insights into how surface geochemistry may be used as an exploration tool in Western Missouri. Background ERT surveys were conducted and the surveys provided insights into the proper electrode spacing to image through the Warner sand. Three ERT arrays were constructed and installed. Core samples were taken from the Cushard #1 corehole and used to prepare the geomechanical dataset for designing the hydraulic fracturing treatment. Five wells were drilled and two wells were hydraulically fractured. MEOR treatments began just after the end of this project period.

This DOE funded project has already been highly effective in promoting interest for other work in the area. The principal investigator has been contacted by many individual interested in the work, and landowners hoping to benefit from the results of this research.

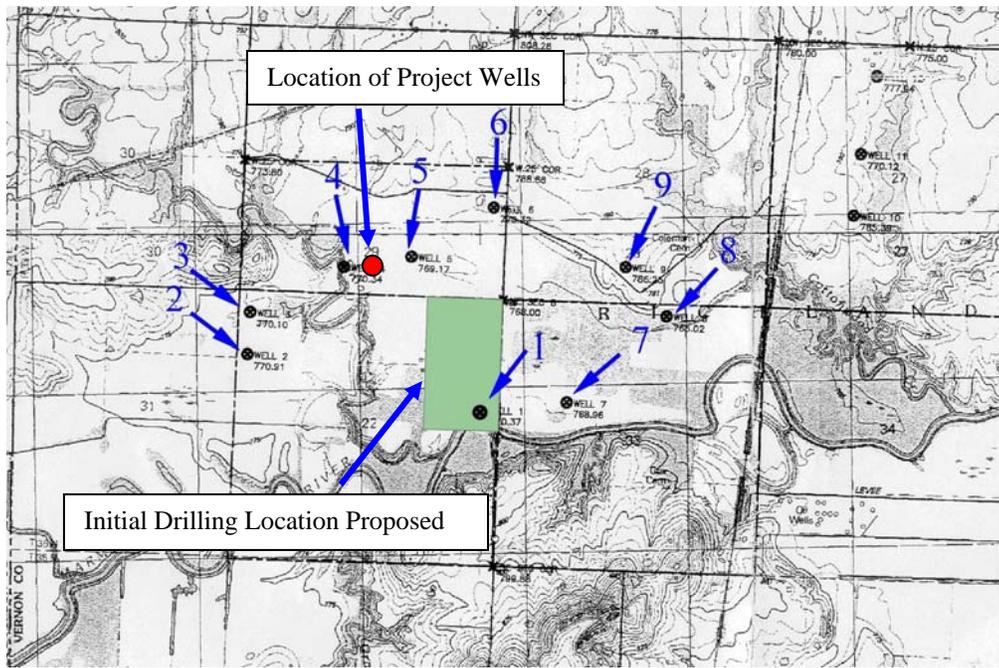


Figure 1. Leasehold in Vernon County.

Figure depicts the location of coreholes previously drilled and abandoned. Initially it was believed that area shaded in green would be proposed drilling area. Surface geochemistry and ERT surveys led to the project wells being drilled between coreholes #4 and #5.

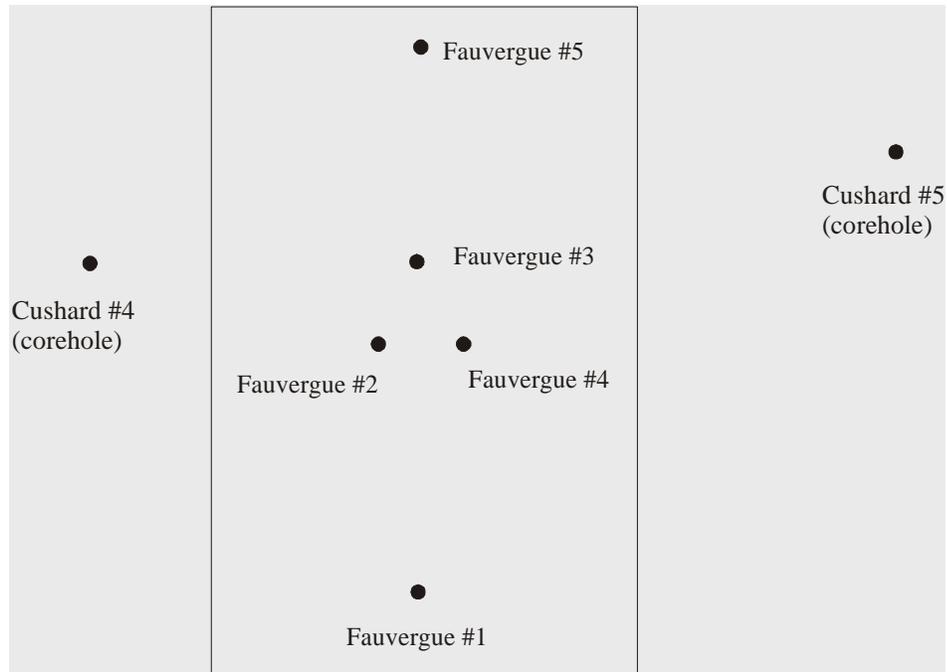


Figure 2. Arrangement of Wells Drilled (Fauvergue #1-5)



Figure 3. Student collecting soil samples over leasehold, February 2003.

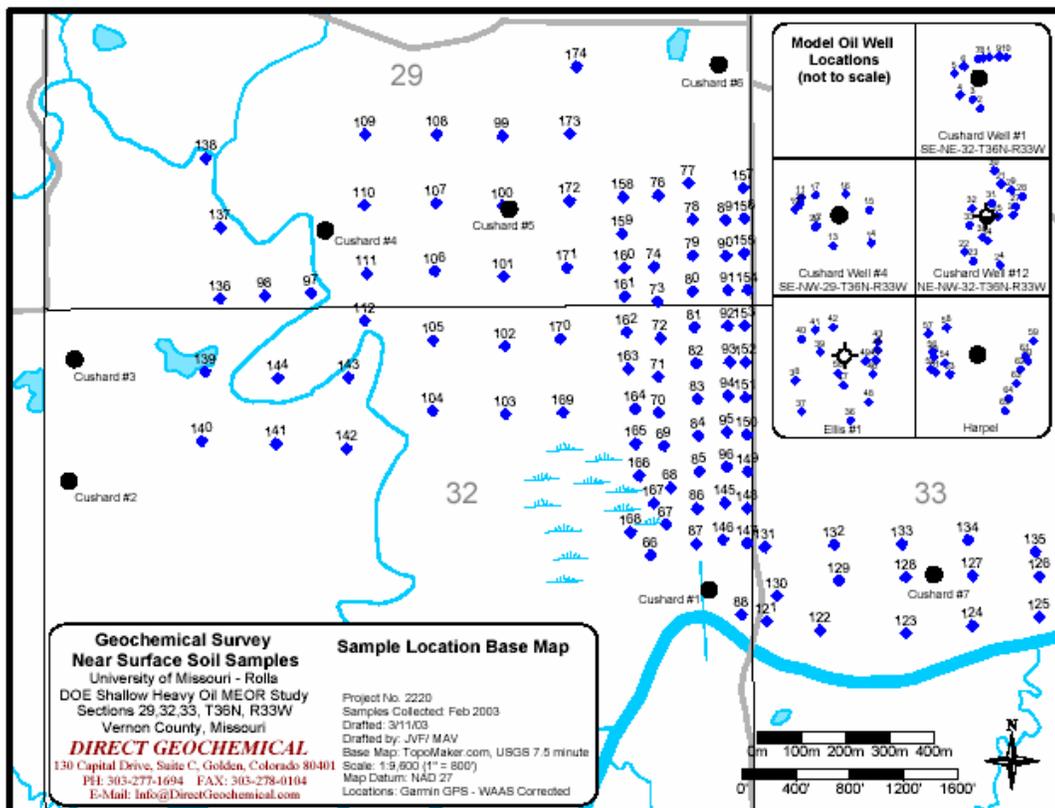


Figure 4. Leasehold Base Map showing location of soil samples.

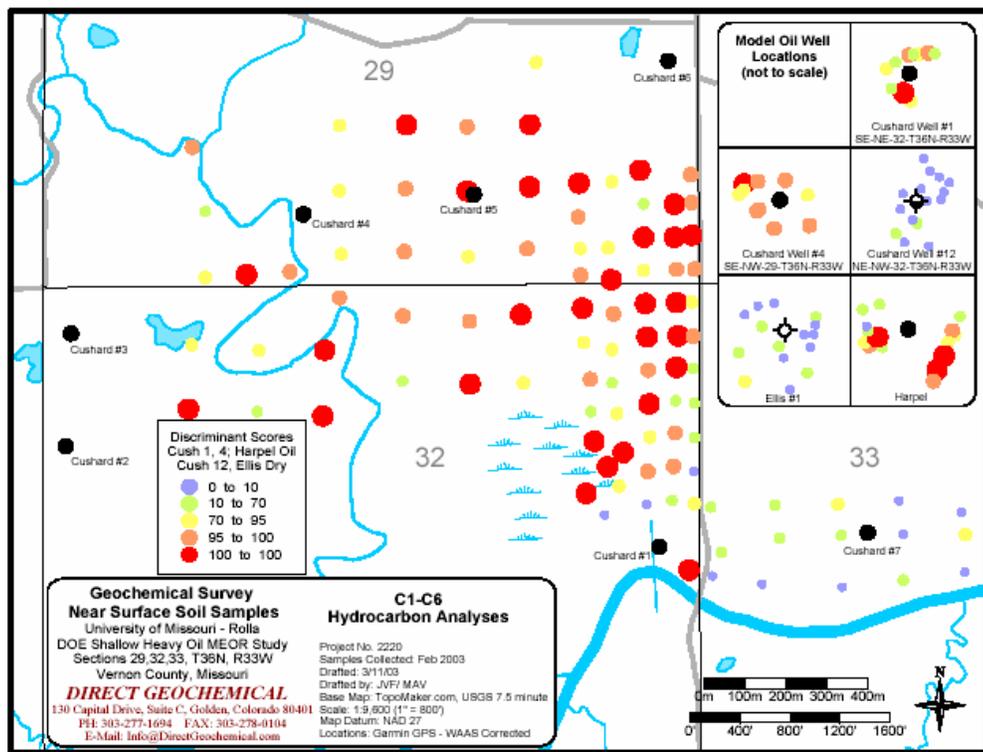
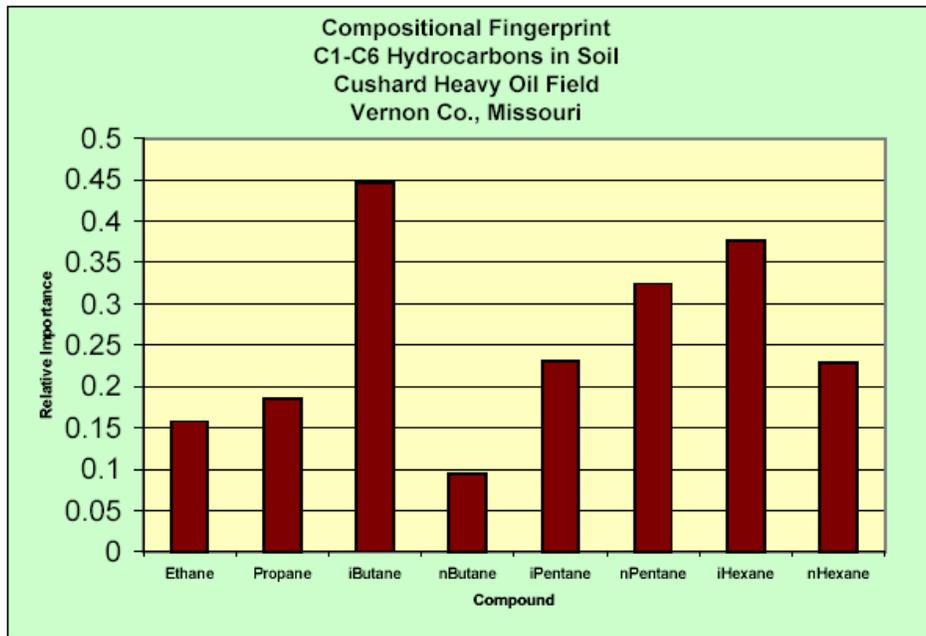


Figure 5. C₁-C₆ Composition



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info@directgeochemical.com

Figure 6. C₁-C₆ Discrimination

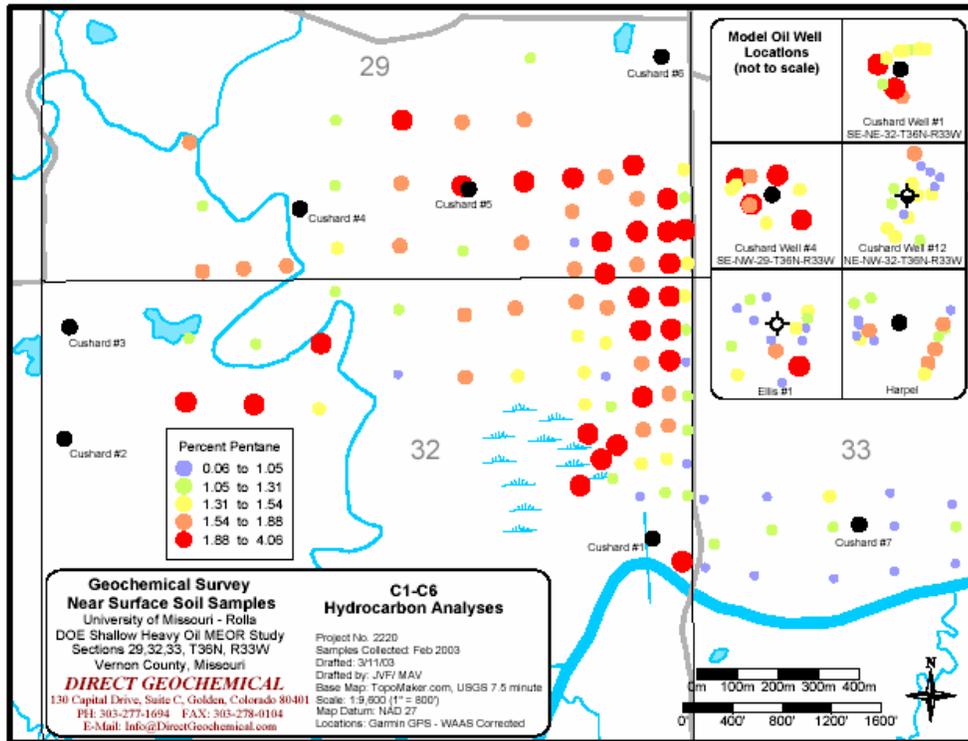


Figure 7. Percent Pentane

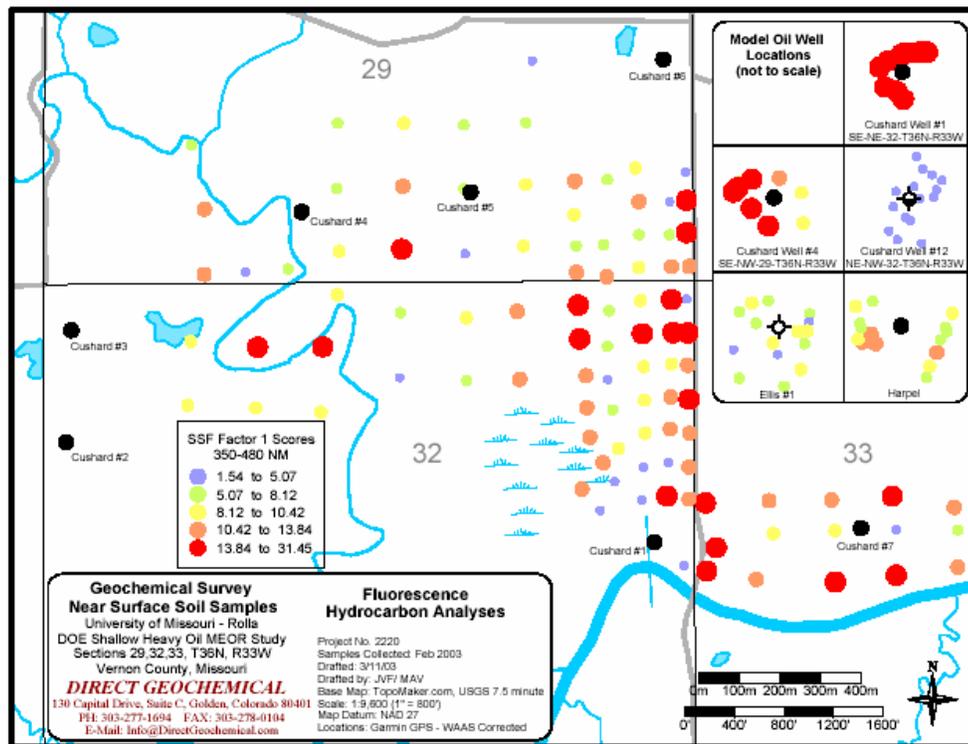


Figure 8. Fluorescence Hydrocarbon Analysis SSF 1

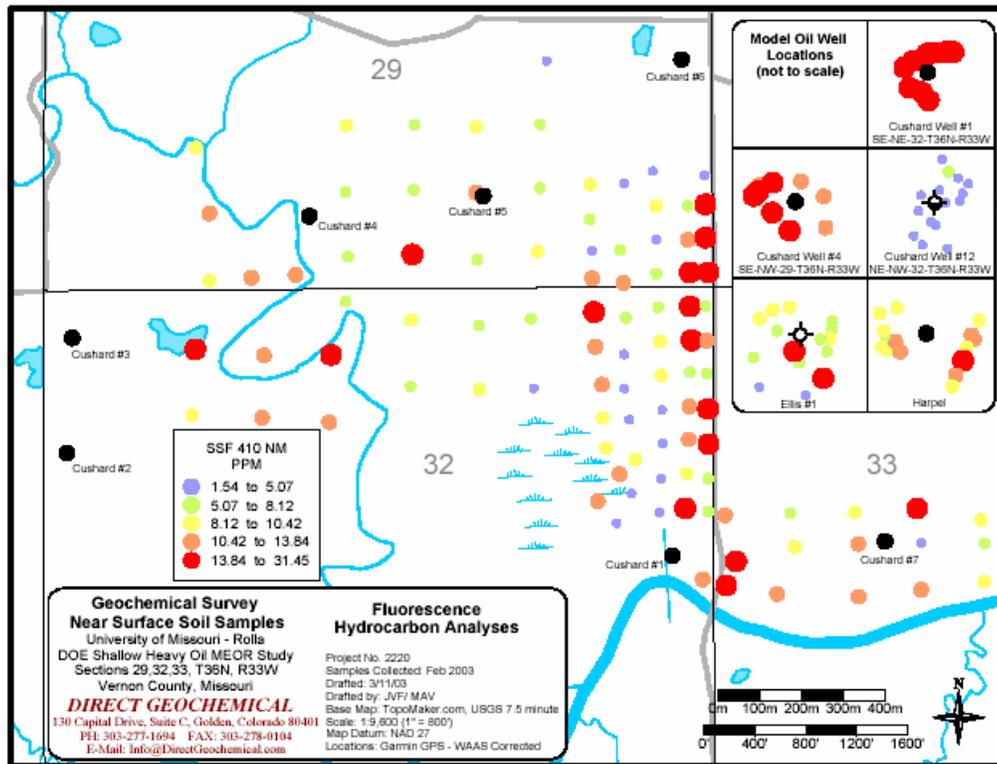


Figure 9. Fluorescence Hydrocarbon Analysis SSF 410

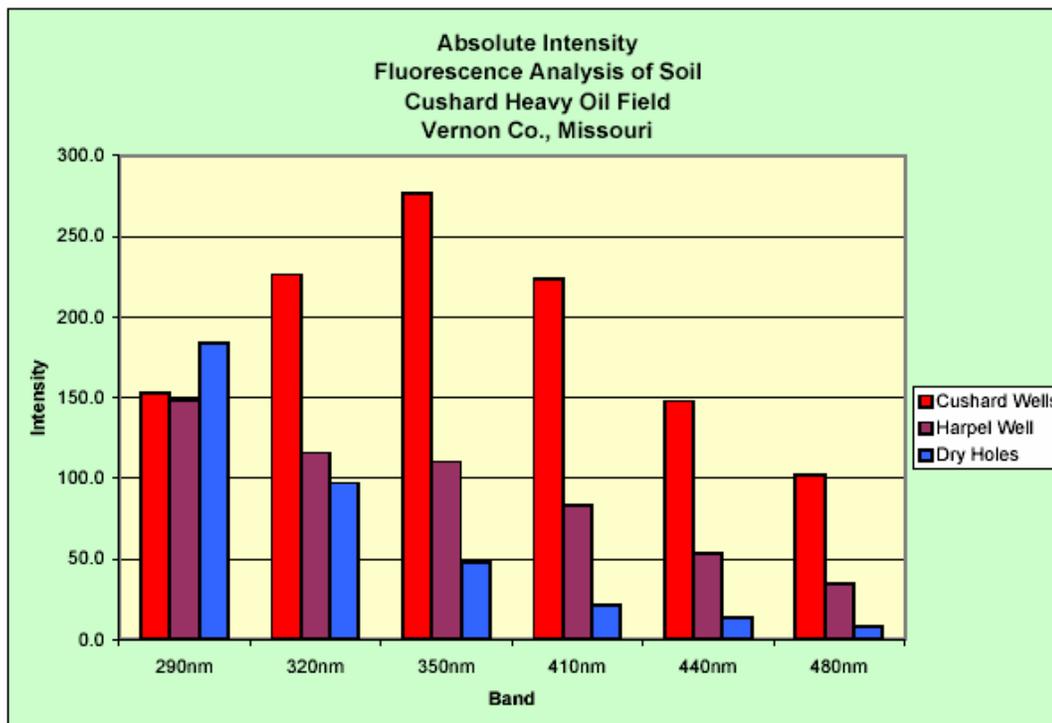


Figure 10. SSF Intensity by Well

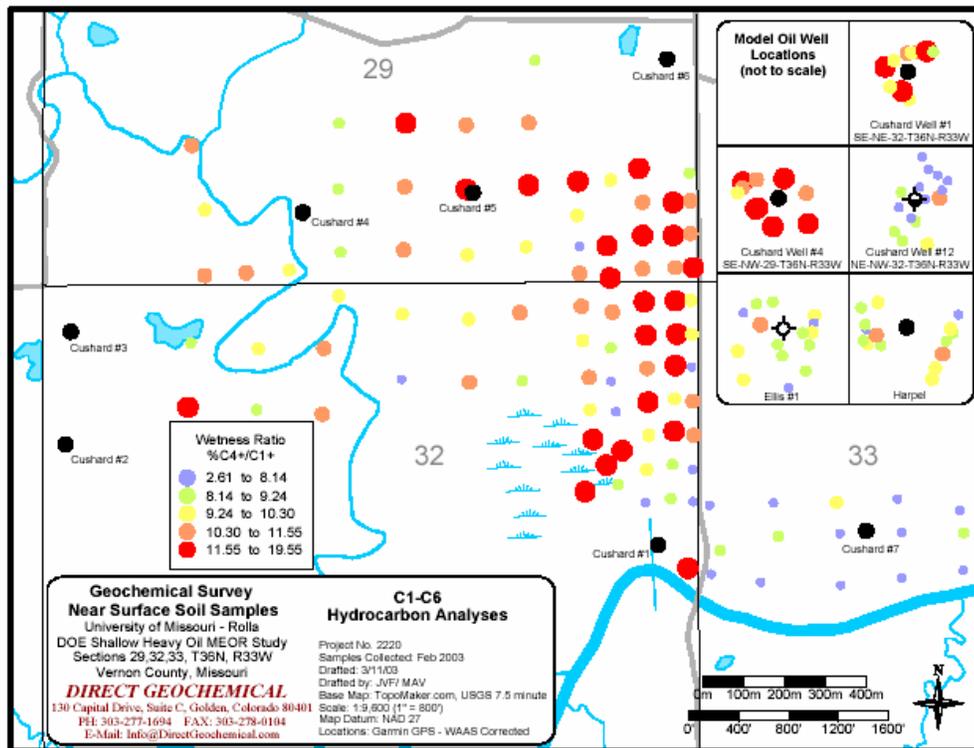


Figure 11. Wetness Ratio

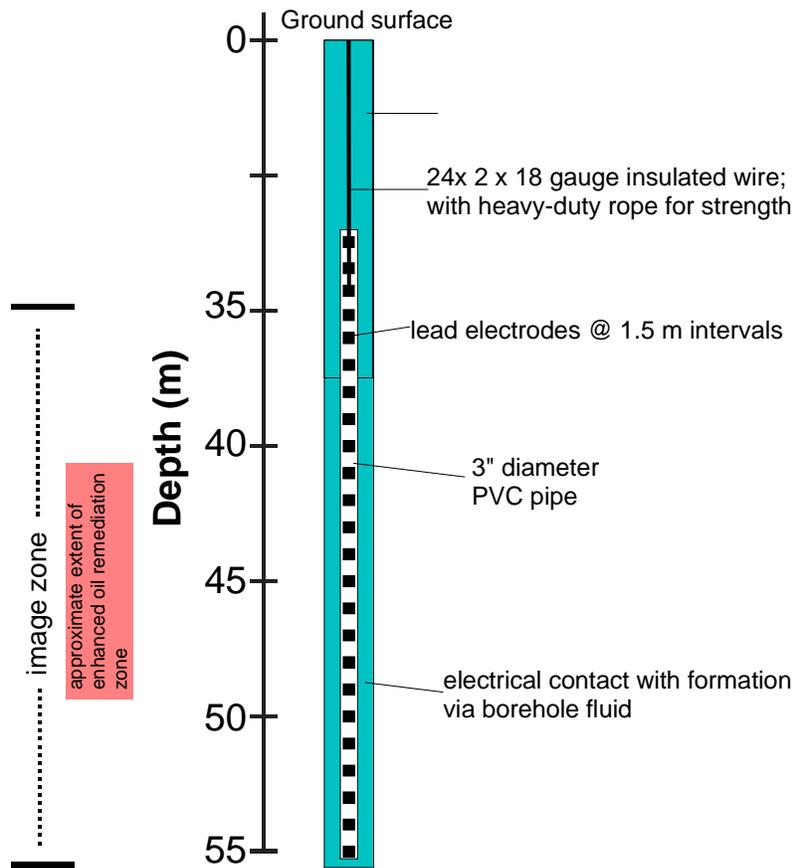
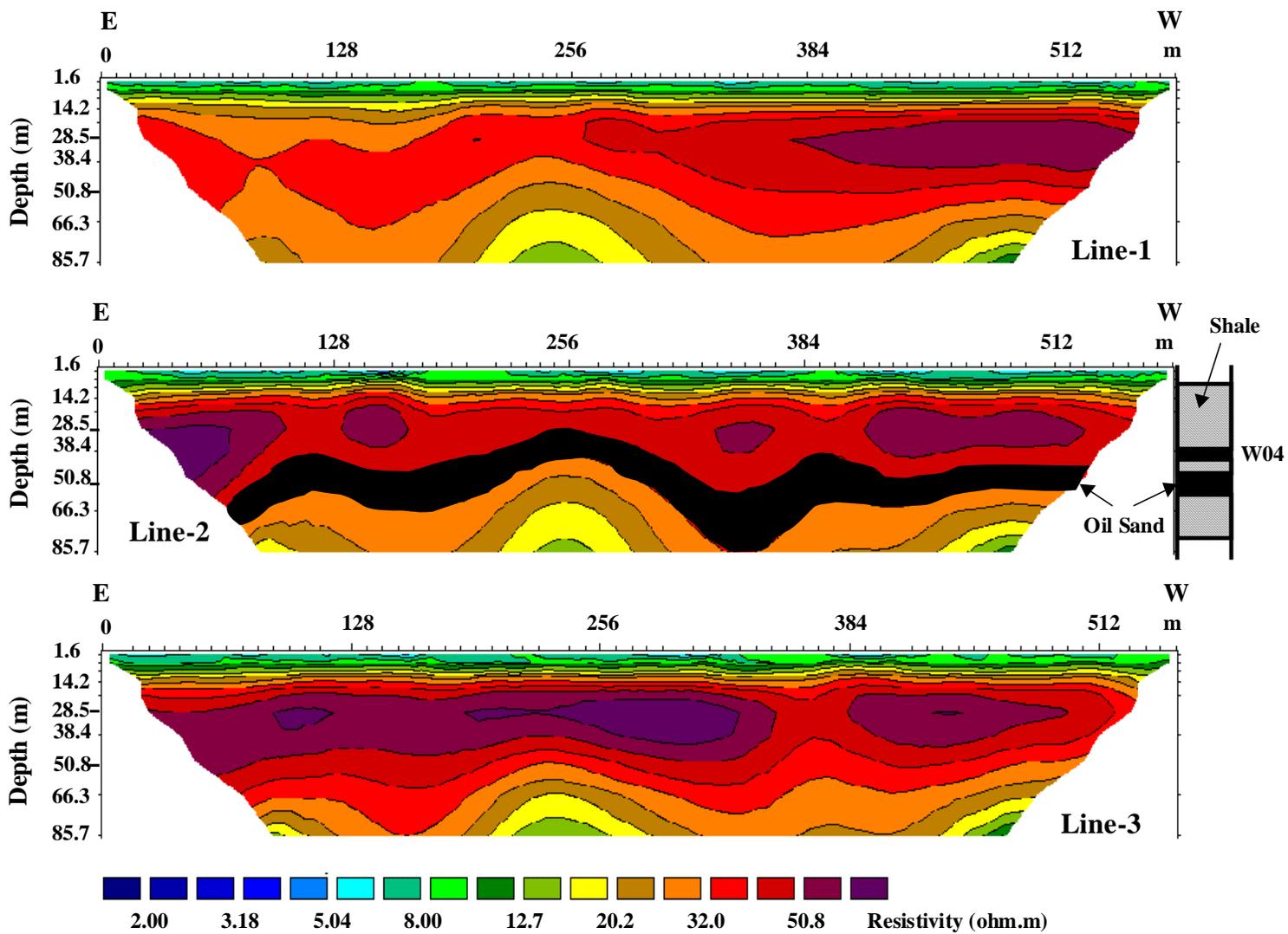


Figure 12. Schematic of electrode arrays constructed for ERT imaging and relationship to depth in formation and location of zone of interest for MEOR



East

West

Figure 13. Electrical Resistivity Tomography Lines Between Corehole #5 to Corehole #4. Vertical scale is depth in meters.

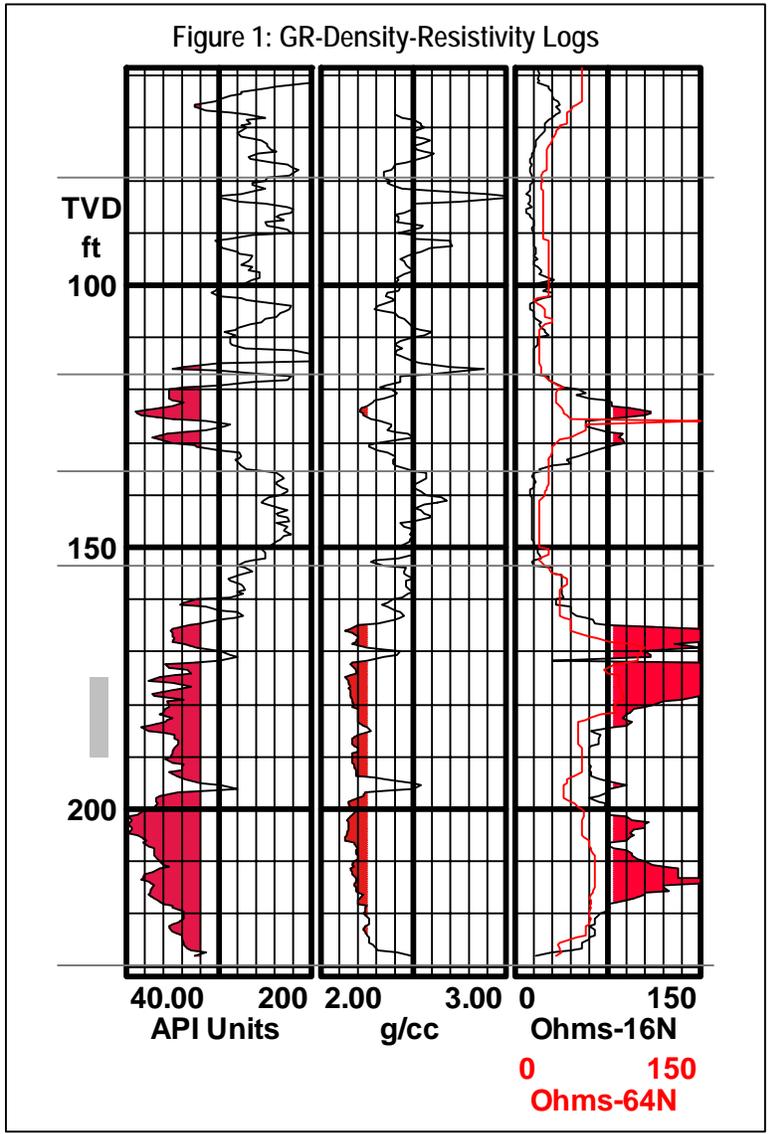


Figure 14. Composite Well Log, Corehole #1
 This log was part of historical corehole data acquired prior to current project.

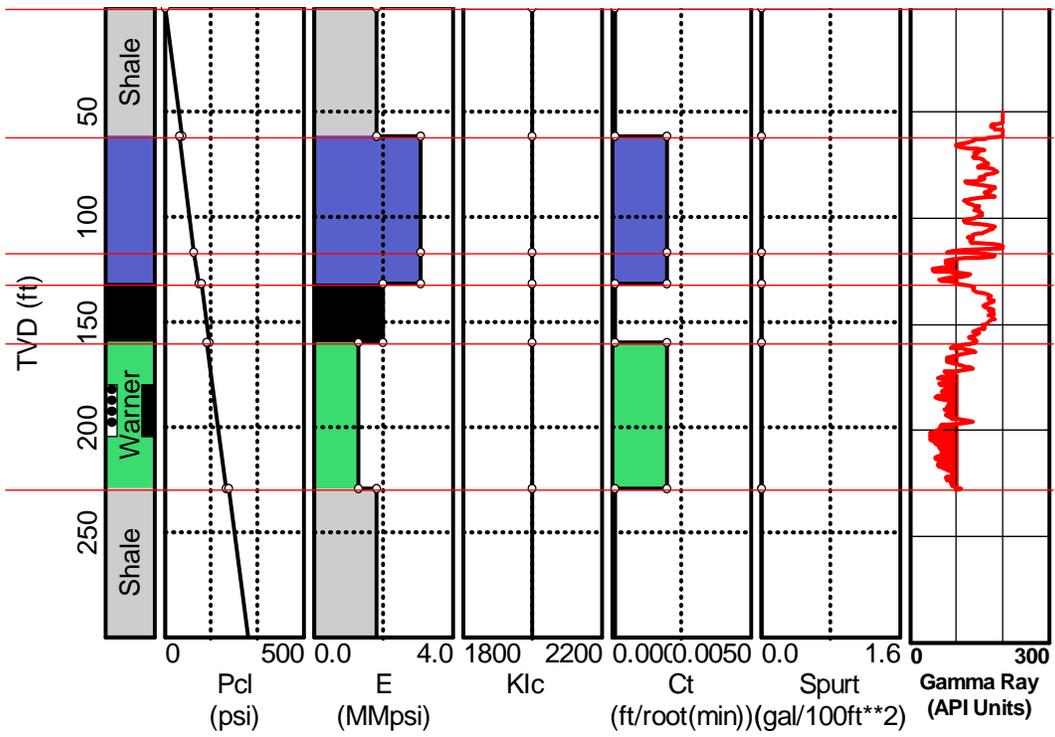


Figure 15. Geomechanical Dataset used for Hydraulic Fracturing Design

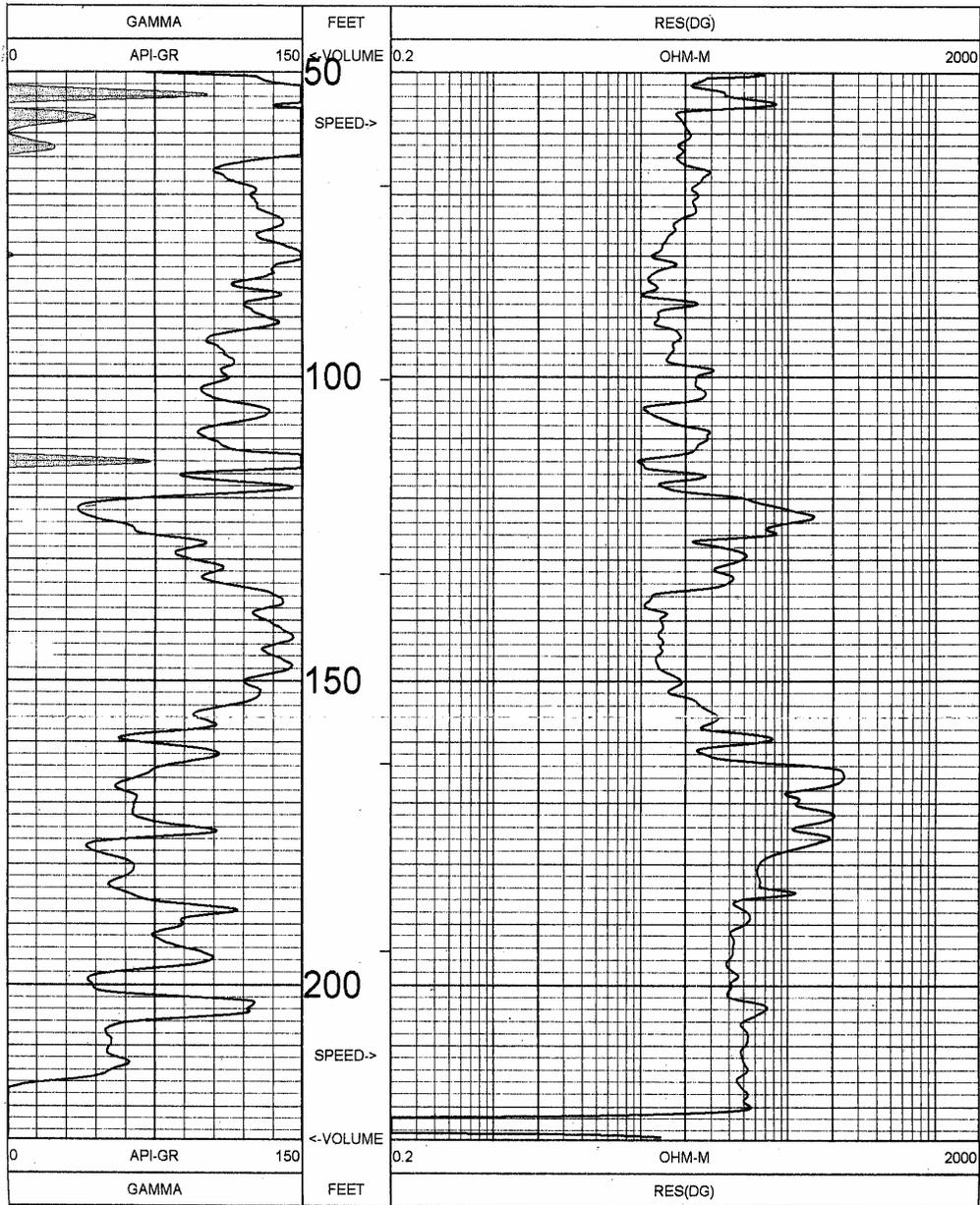


Figure 16. Well #1 Resistivity Log

5 INCH LOG, POROSITIES NO.1 08/12/03

LOG PARAMETERS

MATRIX DENSITY : 2.65	NEUTRON MATRIX : SANDSTONE	MATRIX DELTA T : 54
MAGNETIC DECL :	ELECT. CUTOFF : 2500	BIT SIZE : 6.5

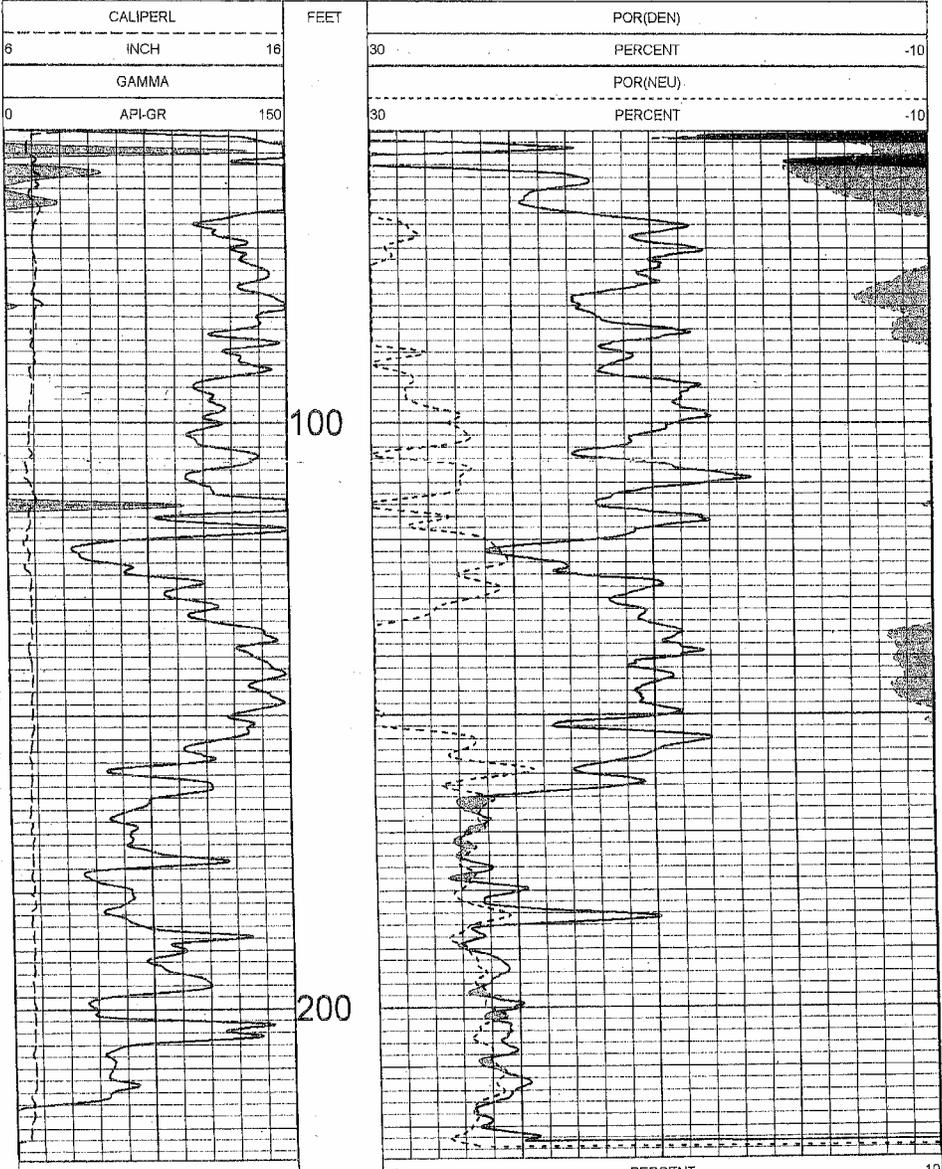


Figure 17. Well #1 Density Neutron Porosity Log

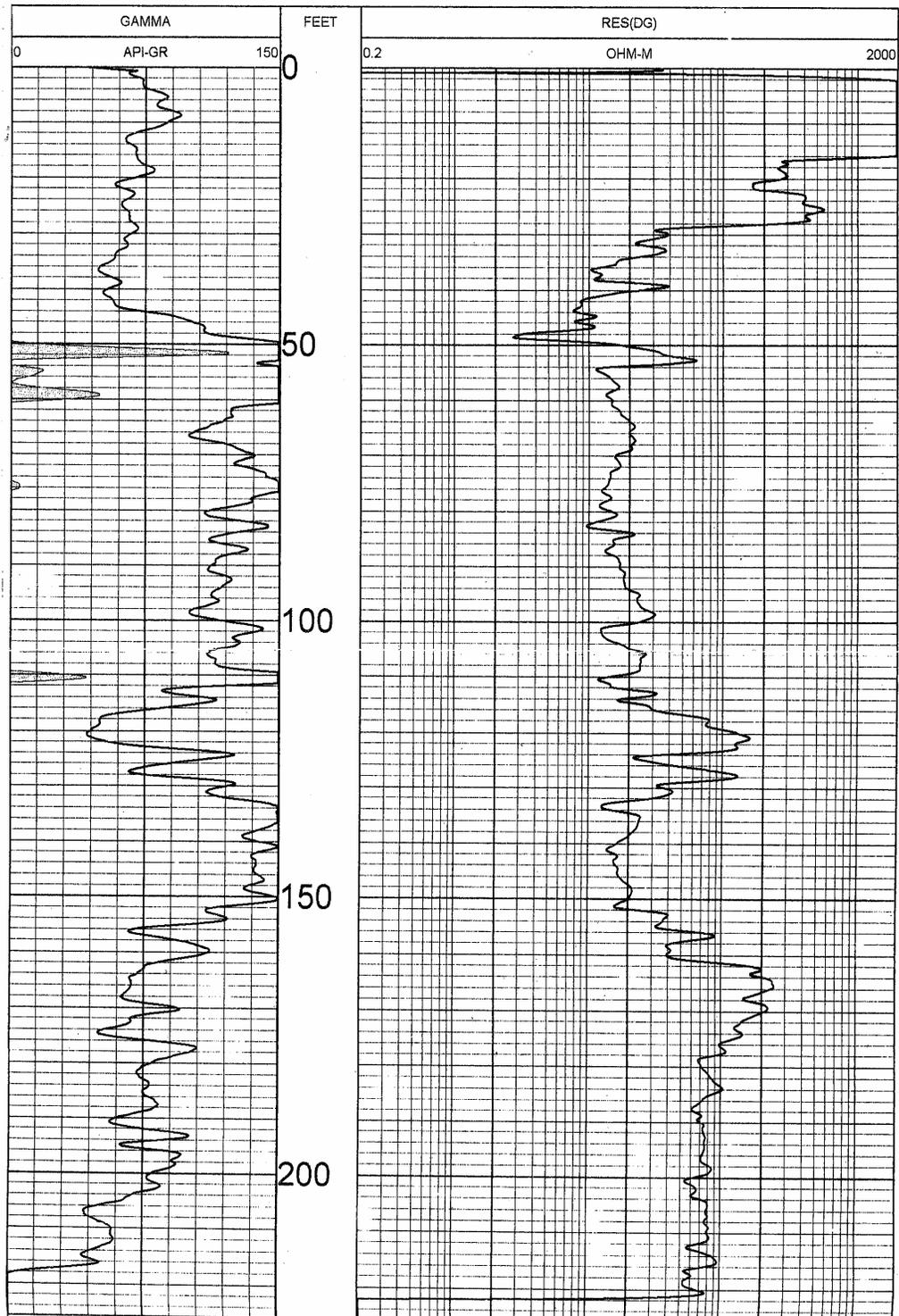


Figure 18. Well #5 Resistivity Log

5 INCH LOG, POROSITIES NO.5 08/12/03

<p>MATRIX DENSITY : 2.65 MAGNETIC DECL :</p>	<p style="text-align: center;">LOG PARAMETERS</p> <p>NEUTRON MATRIX : SANDSTONE ELECT. CUTOFF : 2500</p>	<p>MATRIX DELTA T : 54 BIT SIZE : 6.5</p>
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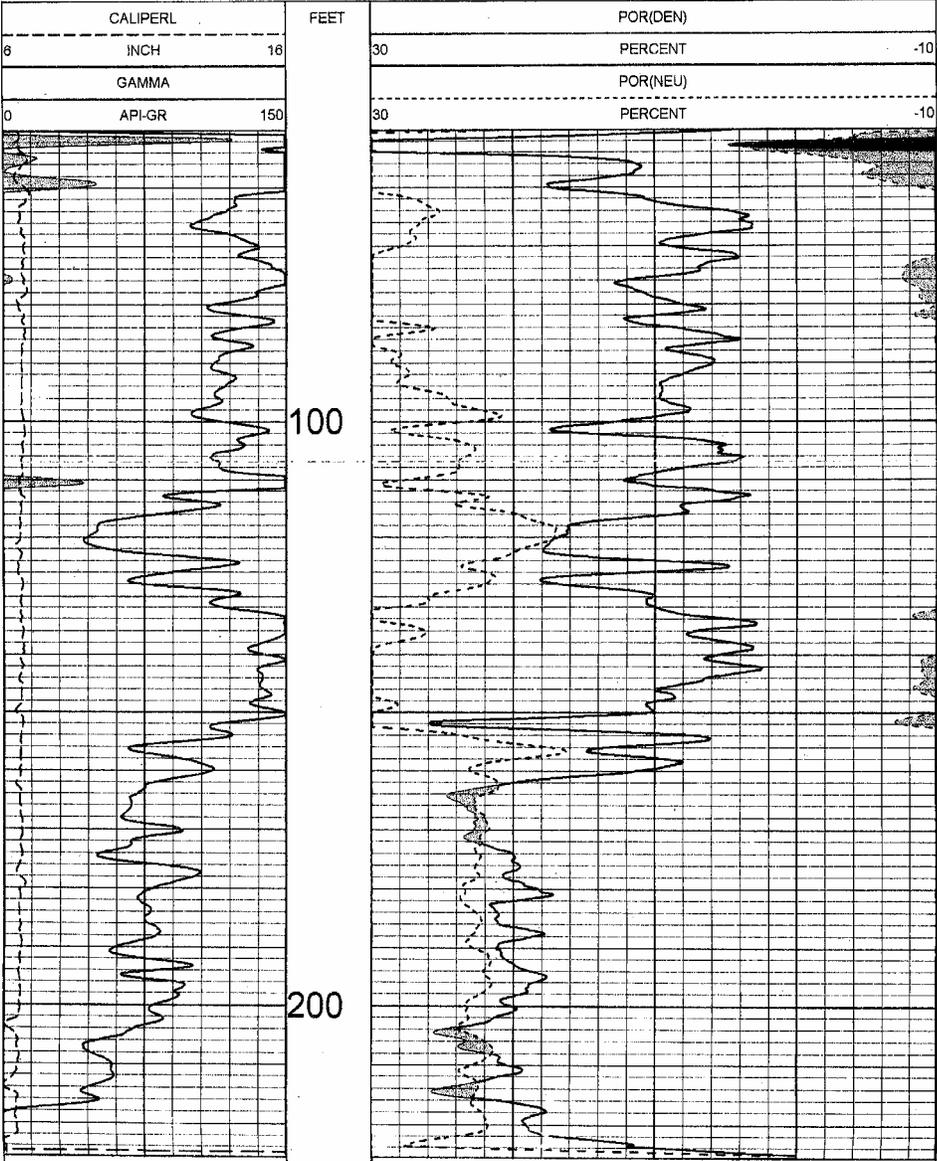


Figure 19. Well #5 Density Neutron Porosity Log



Figure 20. Photograph of Drilling Operation



Figure 21. Photograph of Cementing

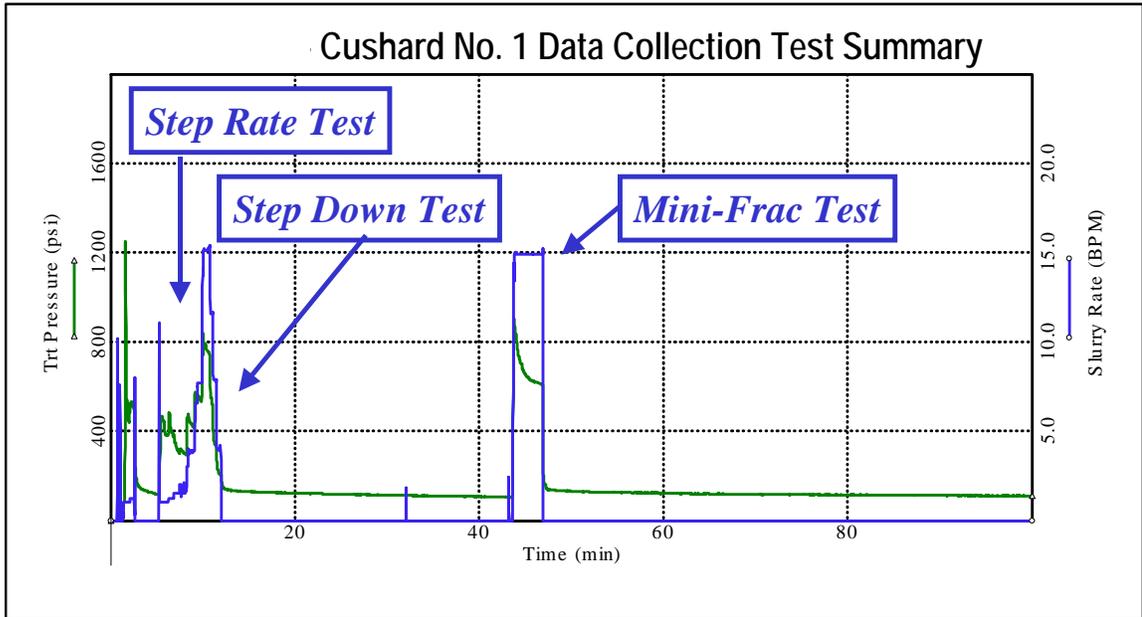


Figure 22. Well #1 Frac Treatment Data Collection Summary

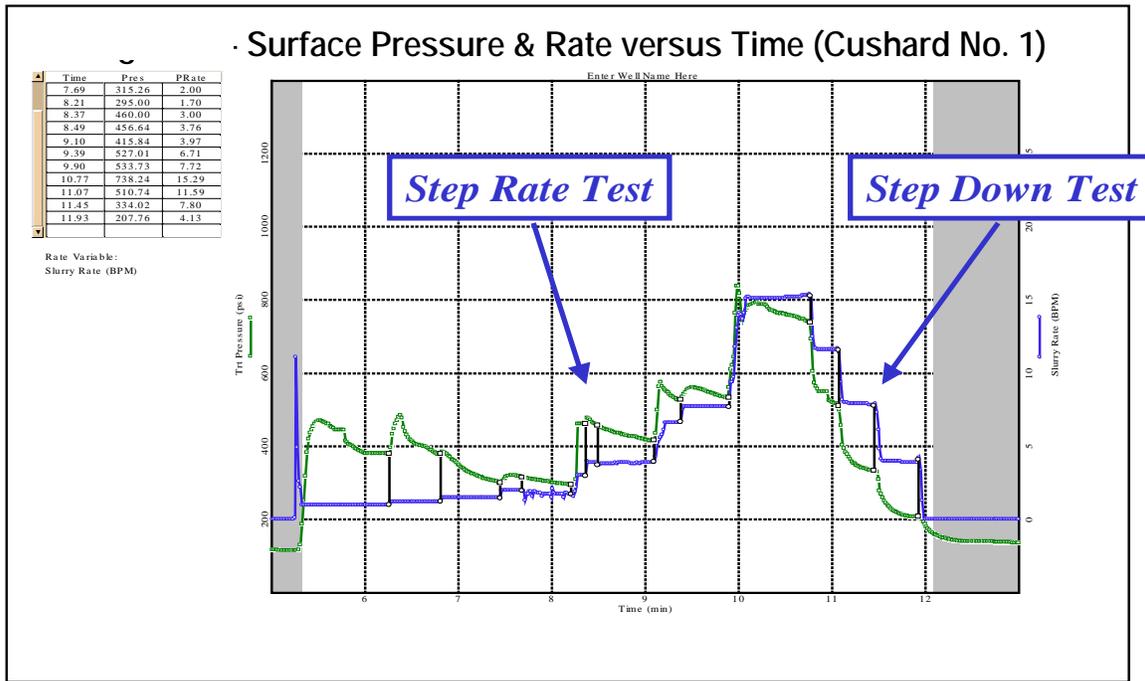


Figure 23. Well #1 Surface Pressure and Rate vs. Time

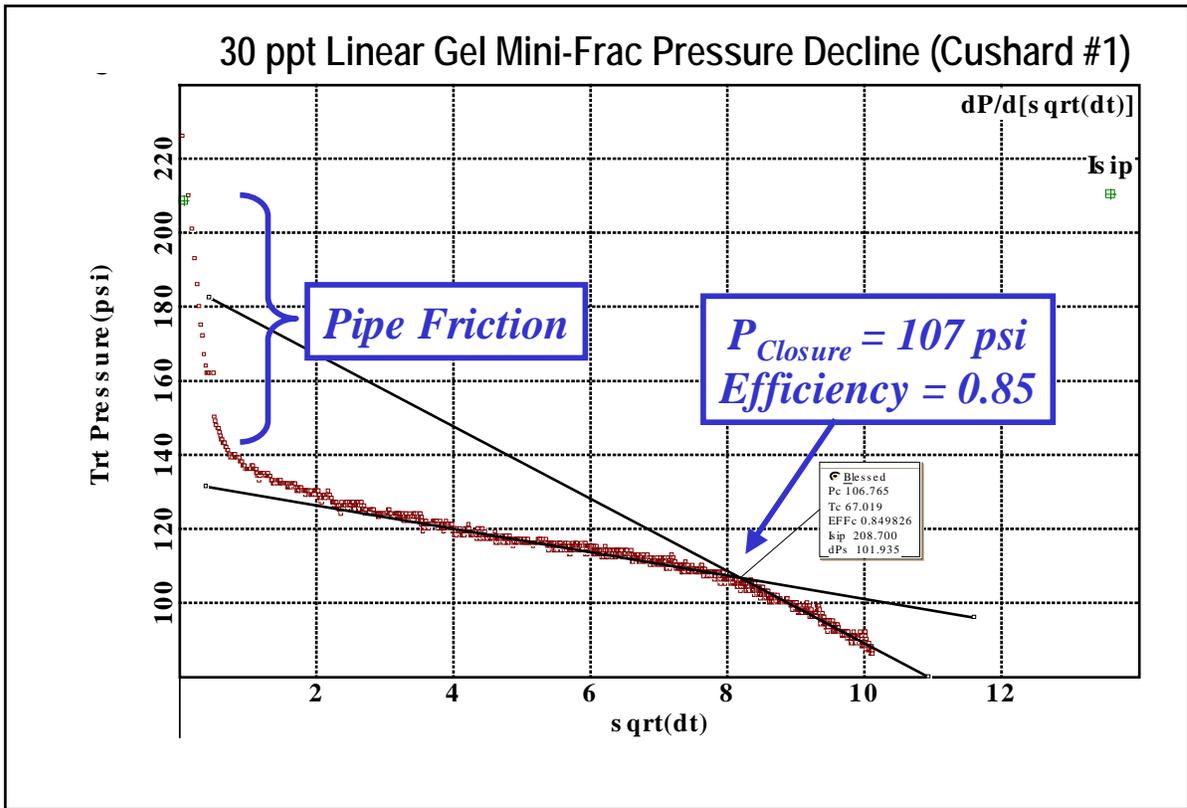


Figure 24. Well #1 Mini Frac Pressure Decline

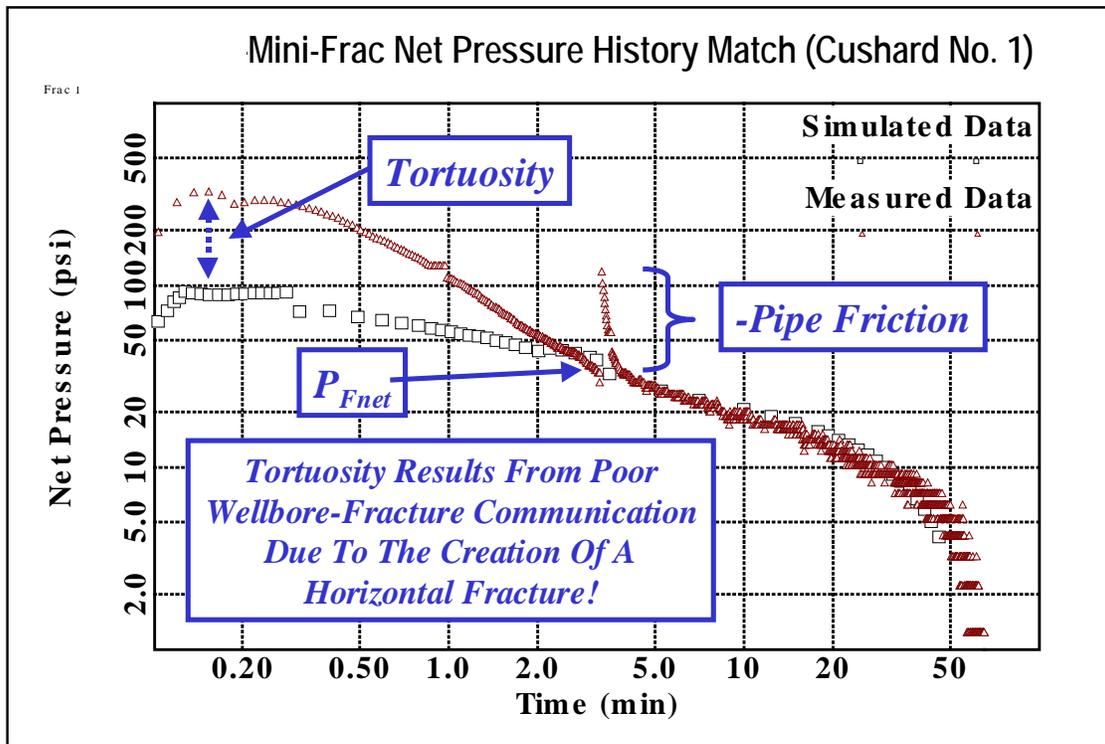


Figure 25. Well #1 Mini Frac Net Pressure History Match

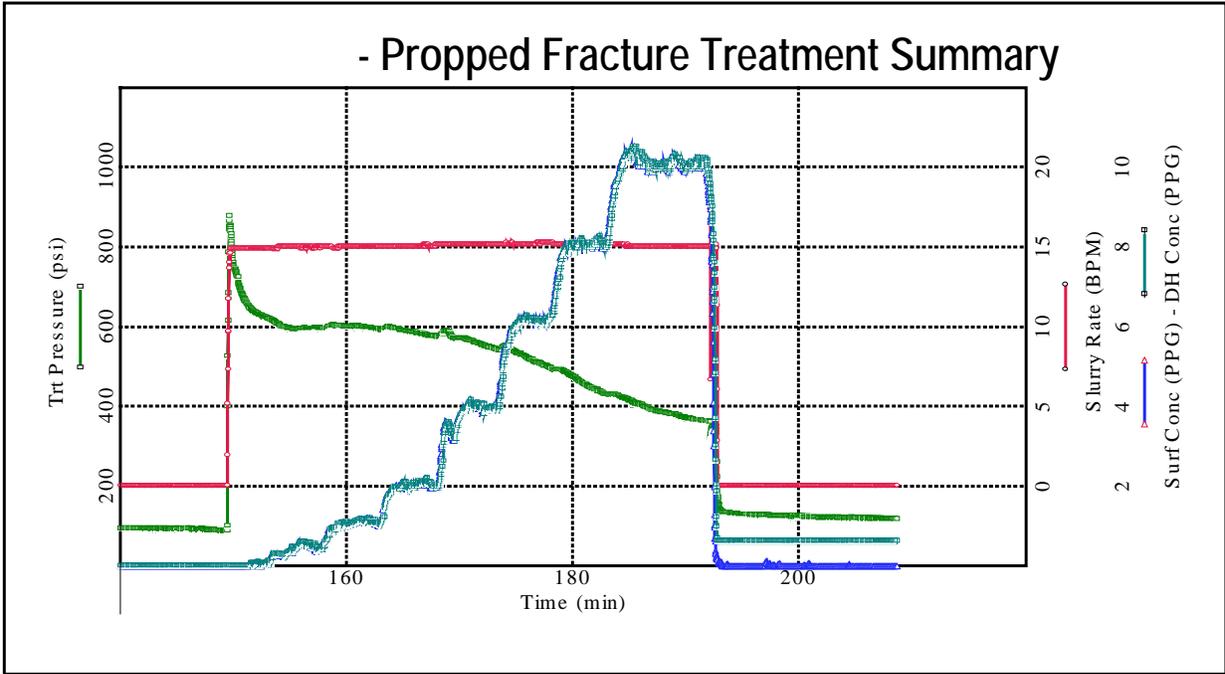


Figure 26. Well #1 Propped Fracture Treatment Summary

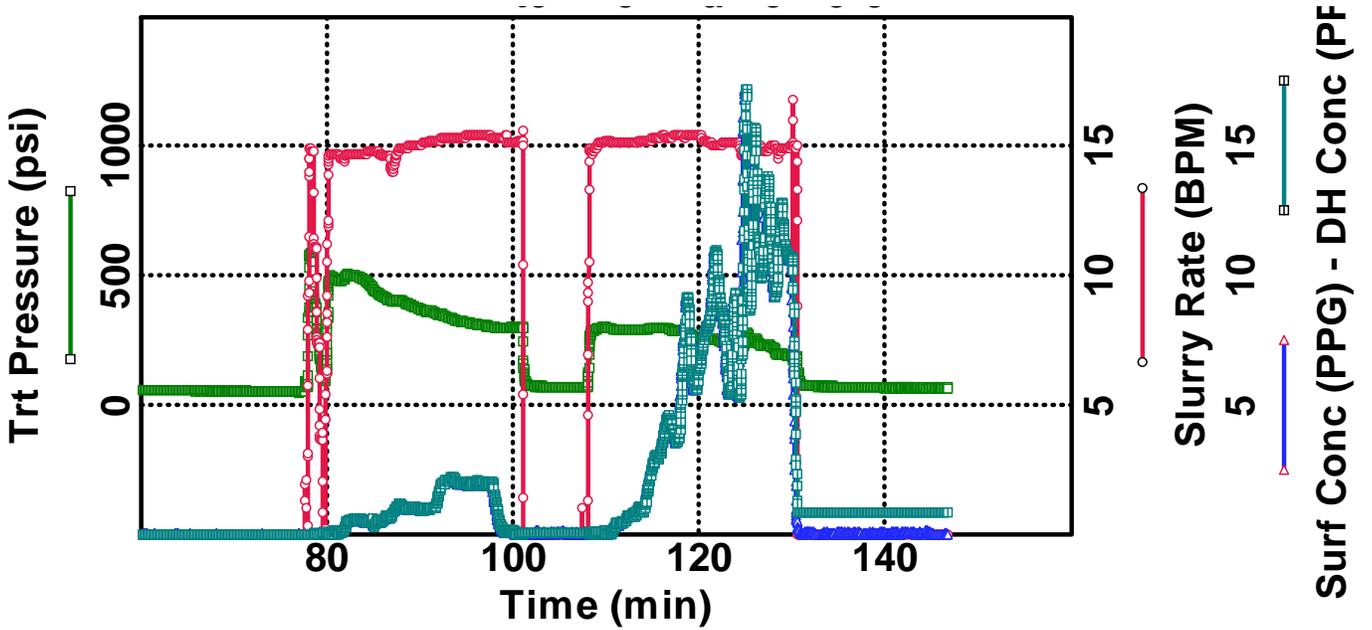


Figure 27. Well #5 Propped Fracture Treatment Summary



Figure 28. Photograph of Hydraulic Fracturing Treatment



Figure 29. Faculty and Students On-Site During Frac Treatment



Figure 30. Surface Hole Equipped with Tiltmeter

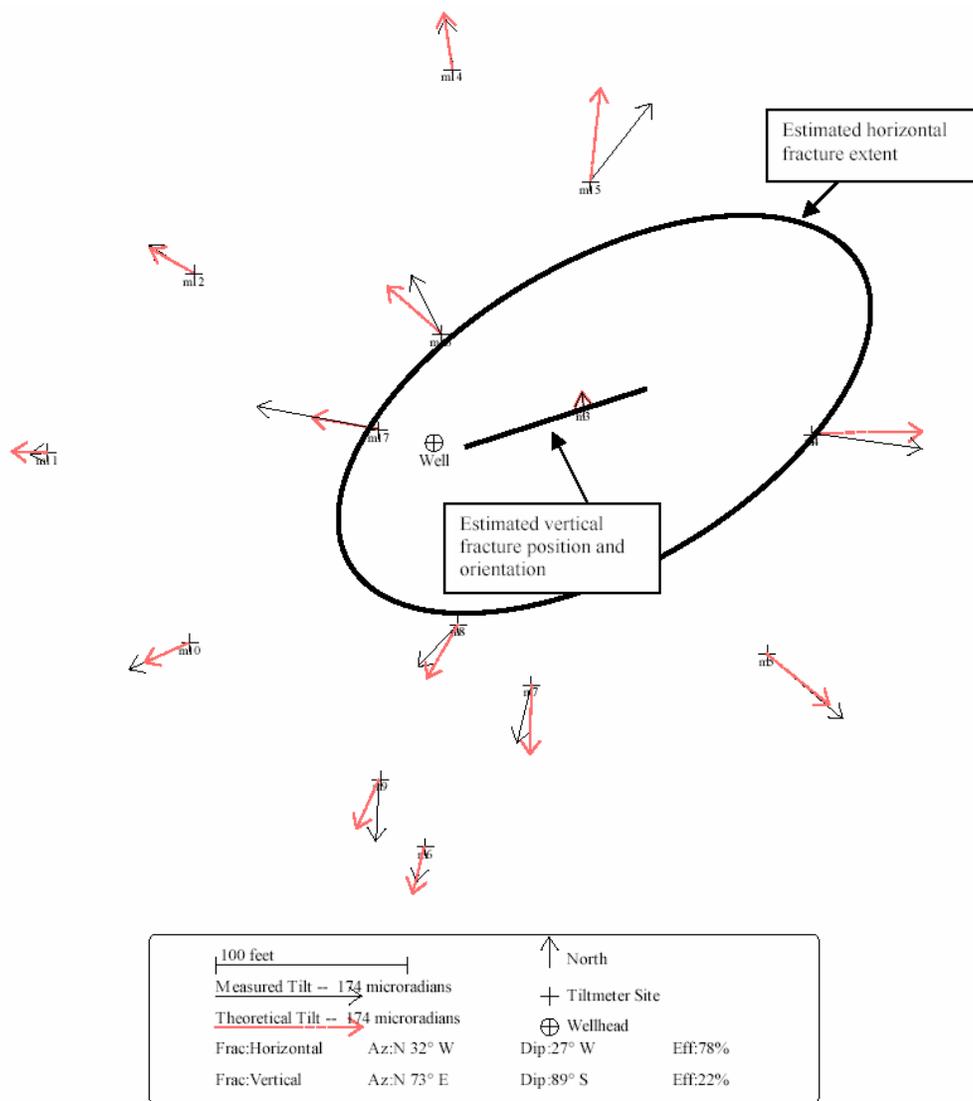


Figure 31. Tiltmeter Array and Results

Sample ID	Depth, feet	Formation	Rock Type	Young's Modulus, Mpsi	R ²
03030401-A	110.50	Shale	Shale	1.03	0.9996
03030501-A	119.00	Shale	Shale	1.44	0.9996
03030502-A	121.50	Bluejacket	SS	3.94	0.9998
03031101	128.50	Bluejacket	SS	3.12	0.9995
03032401-B	130.00	Bluejacket	SS	2.33	0.9988
03032601	136.50	Rowe	Coal	1.48	0.9989
03032502-B	138.50	Rowe	SS	2.44	0.9996
03030701	144.00	Warner	SS	0.92	0.9994
03031102-A	167.00	Warner	SS	1.30	0.9985
03032402	170.00	Warner	SS	1.72	0.9984
03031001-A	176.00	Warner	SS	0.96	0.9988
03032501-B	178.00	Warner	SS	1.56	0.9991
03031002-B	191.00	Warner	SS	1.52	0.9957
03030601	200.30	Graydon	Shale	3.27	0.9987
00000211-B	211.00	Graydon	Shale	1.43	

Table 1. Triaxial Stress Analysis of Core Samples

Stage	Slurry Volume (M-Gal)	Fluid Volume (M-Gal)	Proppant Conc Strt (PPG)	Proppant Conc End (PPG)	Rate (BPM)	Fines Conc. (Vol Fraction)
1	2.00	2.00	0.00	0.00	15.0	0.00
2	3.07	3.00	0.50	0.50	15.00	0.00
3	3.14	3.00	1.00	1.00	15.0	0.00
4	3.27	3.00	2.00	2.00	15.0	0.00
5	3.54	3.00	4.00	4.00	15.0	0.00
6	3.82	3.00	6.00	6.00	15.0	0.00
7	4.09	3.00	8.00	8.00	15.0	0.00
8	4.36	3.00	10.00	10.00	15.0	0.00

Table 2. Hydraulic Fracture Treatment Design

Appendix

This appendix contains a copy of the preliminary report from Direct Geochemical, scanned copies of all well logs, the hydraulic fracture design provided by NSI and the frac treatment data collected from the two fractured wells (1,5).

DIRECT GEOCHEMICAL

May 2, 2003

Dr. Shari Dunn-Norman
University of Missouri Rolla
149 McNutt Hall
1870 Miner Circle
Rolla, MO 65409-0420

Re: Initial Findings: Cushard Heavy Oil Field

Dear Shari:

The attached is a preliminary report on the findings of the surface geochemical survey undertaken by Direct Geochemical at the Cushard Heavy Oil Field, being part of a Department of Energy project entitled: "Development Practices for Optimized MEOR in Shallow Heavy Oil Reservoirs."

Under the original scope of work proposed, Direct Geochemical was to have received a set of soil samples and analyzed them for a variety of components, including light and heavy hydrocarbons using several methods. During the ensuing period of time, Direct Geochemical has developed additional experience with other methods and is in the process of applying such methods to the samples received from the field. This report deals with the first three methods applied:

- C1-C6 Light Hydrocarbons
- Synchronous Scan Fluorescence Heavy Hydrocarbons
- Trace metals by aqua regia extraction and ICP-ES finish

As additional data come available, they will be forwarded to you.

Thank you for the opportunity to participate in this project.

Sincerely,

Jim Viellenave
President

**Preliminary Findings
Surface Geochemical Survey
Cushard Heavy Oil Field
Vernon County, Missouri**

Introduction

Under terms of a US Department of Energy Project, entitled “Development Practices for Optimized MEOR in Shallow Heavy Oil Reservoirs,” DE=PS26-02NT15378-1, Direct Geochemical performed a surface geochemical survey across portions of the Cushard Oil Field in Vernon County, Missouri. The primary objective of the survey was to determine what geochemical characteristics most closely could be used to identify and map “sweet spots” in the Warner Sandstone. This process would optimize the location of both production wells and enhanced recovery system wells, as contemplated elsewhere in the project. In addition, the geochemical data would be evaluated to determine if other patterns or correlations were observed.

Procedures and Methods

Surface geochemical surveys rely on the movement of hydrocarbons from subsurface accumulations to the surface where they can be captured, analyzed, and evaluated as to meaning. In addition, they can rely on byproducts of chemical and biological processes at and near the surface, which alter such conditions as pH, redox, conductivity, and other characteristics. Finally, there is increasing evidence of the migration of very small concentrations of trace metals in response to geologic processes, including those that are responsible for the accumulation of hydrocarbons.

The above are manifestations of a series of physical and chemical processes, which have been described by various authors, but rarely documented thoroughly. Among the processes are pressure and temperature gradients from subsurface to surface, hydrodynamic influences, gas migration (methane, helium, etc.) and others. In the present case, virtually none of these exist in any significant way: the Warner SS is located a few hundred feet below grade; there is no gas pressure and no water drive. Were these processes operating, the oil would be producible. Thus, conventional reasons to expect surface geochemistry to operate are not obviously in play at this site.

The literature contained no significant reports of previous surface geochemical studies designed to find such sweet spots in heavy oil fields. As a result, Direct Geochemical proposed to evaluate a series of methods, ranging from conventional C1-C6 hydrocarbon concentrations in soil samples, to heavy hydrocarbon residues, trace metals, physical characteristics, etc.

The survey was divided into two components:

- The analog or model samples
- The grid of unknown or prospect samples

The model samples were obtained from the vicinity of 5 wells of known character. Three were located within the Cushard Field: Cushard 1 and Cushard 4, which have been identified as good wells for treatment by MEOR methods to enhance production; and Cushard 12, which was identified as being unsuitable for such treatment. Evaluation of the wells logs and permeability/porosity tests confirmed the characterization. In addition, soil from near two wells from outside the Cushard Field was also sampled. The Ellis 1 is a dry hole, located a mile or so SE of the field, in a separate producing area. The Harpel well is located several miles to the north-northeast of the Cushard field in a very different environment. No well logs were available to

Direct Geochemical from the Ellis or Harpel wells, so it is not possible to comment on their similarity to the Cushard field.

The grid consisted of three sections. The center section incorporated 53 samples, acquired on approximately 200-foot centers. The western section used 31 samples on 400-500 foot centers. The eastern section used 15 samples on 300-400 foot centers. The sampling locations are shown in Figure 1, Base Map. Students using protocols developed by Direct Geochemical acquired all of the samples.

Analysis

Several analytical methods were planned for the project.

- 1) Thermal Desorption C1-C6 Light Hydrocarbons by GC-FID
- 2) Heavy Hydrocarbons (C6-C30) by Synchronous Scan Fluorescence
- 3) Gasoline Range Hydrocarbons (C6-C13) by GC-PID/FID
- 4) Trace metals by various extractions
 - i. Aqua regia
 - ii. Partial extraction
- 5) Physical characteristics: pH, conductivity, ferrous iron ratios

Data Presentation

Methods 1, 2 and 4i have been completed and the results are included in this report. The data are presented in this report in two ways. Full, raw data are given from all three methods in a spreadsheet. In addition, we have used a variety of interpretive tools to characterize the geochemistry of productive and non-productive areas and then predict areas of high potential for productivity in the grid. These data are given in map form.

Interpretive Methods

The methods described here are applied to light hydrocarbon (C1-C6) data, Synchronous Scanning Fluorescence data, Gasoline Range Hydrocarbon (C6-C13) data, trace element data, including iodine, and oxidation/reduction conditions (O₂/CO₂, ferric/ferrous, etc.). The data can be used as somewhat independent data sets or can be fully integrated into a single data set.

Two independent methods are used to interpret geochemical data:

- Compositional
- Quantitative

Quantitative Interpretation

The absolute concentration of individual or groups of geochemical components is sometimes directly related to the subsurface accumulation of hydrocarbons, especially in simply stratified environments involving conventional trapping mechanisms. (It is less frequently observed in relation to coal bed methane deposits or accumulations such as the Heavy Oil Field.) Ratios of hydrocarbons provide additional information on source types. These include wetness and dryness ratios, plus hydrocarbon ratios that indicate whether the samples are in the oil, gas, or background window. Ratios, as well as raw data, can be mapped directly. Most regions exhibit “apical”

anomalies, but “halos” are not unknown. Multiple productive horizons, presence of intense fracturing or faulting, and other factors can make interpretation difficult and are the cause of both false positive and negative anomalies.

Compositional Interpretation

The composition of geochemical data can reflect the character of subsurface accumulations. It is important to identify and correlate the numerous near-surface compounds with their sources—particularly petroleum accumulations. Many compounds, including methane and ethane (plus such obvious ones as ethene and propene), have vegetative or biogenic origins. It is vital to separate the petroleum related compounds from the others. In addition, different accumulations yield different near-surface compositional signatures, which can be used to determine if the accumulation is in the oil or gas range. In the case of indirect indicators, metals, pH, conductivity, redox character, both genetic relationships and geographic patterns are important to evaluate.

Statistical Methods

Two primary statistical methods are generally applied to compositionally evaluate geochemical data:

- Principal Component (Factor) Analysis.
- Discriminant Analysis.

Both Factor and Discriminant Analysis are multivariate statistical tools that allow the evaluation of large numbers of data variables simultaneously. The use of these multivariate tools permits the user to appreciate the existence of complex factors, comprised of multiple individual variables in the data set. In oil and gas exploration, this is important because the presence of oil or gas in the subsurface is rarely imaged by one or two variables.

The basic statistical method summarizes the data set in a series of mathematical “vectors” or “factors,” which are combinations of co-varying hydrocarbon species. The Factors (when combined together) account for all of the variation in the dataset, but in fewer variables than are in the data set. For example, there may be 15 variables measured in a dataset, but there may be only 5 Factors of significance.

Factor Analysis identifies and ranks these factors in descending order of the amount of variance in the dataset that is accounted for. Factor 1 accounts for the most variance, Factor 2 the second greatest, and so on. For each Factor, it is possible to identify the mixture of variables (components) and their relative importance. An examination of the chemistry of each Factor may allow for the identification of the **source** (or cause or origin) of the mixture in the Factor.

It is very common for Factor Analysis of hydrocarbons to result in at least one Factor reflecting a mixture of light hydrocarbons (that can be related to “gas,”) and at least one reflecting a mixture of heavy hydrocarbons (that can be related to “oil,”) depending on the basin and environment. The other factors can be related to environmental characteristics, soil changes, or contamination, or sampling and laboratory procedural noise. Each Factor represents a group of correlated hydrocarbon components.

Correlated components are important because they describe compounds that vary together, meaning they relate to one another genetically, and belong together. As a result, they are probably **sourced** together. Thus, a Factor can allow the user to describe the spatial and chemical relationship of surface chemistry with subsurface chemistry or subsurface geologic processes. The degree to which any given sample exhibits the presence of a given factor can be mathematically calculated, and the result (Score) can be mapped and contoured.

Discriminant Analysis is a form of pattern recognition and matching, in which statistically significant groups of samples are used as “models” of known geologic conditions, and then compared against grid or unknown samples. The method calculates the probability of an unknown sample being like the model composition for a given geologic condition. The Discriminant probability values or scores are mapped and contoured. This method is usable under two circumstances:

- There is a sufficient number of model samples to generate a representative or statistically significant population
- The model area is representative of the production conditions desired

The objective of modeling is to identify two key phenomena for each known geologic condition (e.g., an oil or gas field). The first is to identify the chemical signature, which is most diagnostic of the geochemistry over oil (or gas) production while differentiating it from background. The second is to identify the **range** of chemical signature that is representative of that oil or gas production. To do so requires a potentially large number of samples, with experience showing that at least 20-25 samples per class of geologic condition being the minimum. If, however, reservoir, soil, or other conditions are variable, then a larger number of samples may be needed.

Once the statistical analysis is performed, whether using Factor Analysis or Discriminant Analysis, it is essential to evaluate the results in terms of both geology and chemistry. Both the Factor and Discriminant analyses of petroleum related geochemistry surveys reveal a compositional relationship among a number of co-varying hydrocarbon components. It is this group of components and their relative abundances that must make chemical sense when used to map a geologic phenomenon to be considered valid.

Results

Table 1 gives the raw data from the light and heavy hydrocarbon and trace metal (aqua regia extraction) analyses. These data were used for all of the interpretive work to follow. Table 2 provides average values for different classes: oil and dry for all of the analytes generated. First, some general observations:

- 1) The Harpel well is different from the Cushard productive wells. It exhibits lower overall concentrations of hydrocarbons almost always. It predicts as a “weaker” version of the Cushard 1 and 4 wells. It is a heavier oil, according to Jim Long. Its fingerprint is not heavier, using these measures, than the Cushard 1 and 4, but actually relatively similar to them. But, it generates a weaker signal, probably owing to its overall heavier nature.
- 2) The data suggest that the Cushard 4 well may be slightly better than the Cushard 1, but in the absence of testing a large number of wells, this could be minor variation on a theme.

- 3) The Ellis dry hole and Cushard 12 both look quite dry. The Ellis exhibits much high very light hydrocarbon responses, but these are not indicative of producible oil, so are not important in the analysis.
- 4) On a limited data set, it appears that the oil wells as a group show higher arsenic, calcium, and magnesium, than the dry holes, but are almost uniformly lower than dry holes in the transition elements. Because of limited data, we do not know to what extent this is a function of soil type and local conditions or whether it responds to redox conditions.
- 5) A simple observation of these data strongly supports the notion that the surface geochemistry is quite different and can be successfully differentiated. The differences in concentration among the light hydrocarbons is subtle, and well within naturally occurring variation. This means that the light hydrocarbons should be used to identify drilling locations only with the use of more sophisticated statistical tools. The fluorescence data exhibit more obvious variations between the producing wells and dry holes. This makes a great deal of sense, as we are looking for differences among liquid hydrocarbons, and the heavy hydrocarbon measure does an excellent job of seeing it. The C1-C6 data are probably just beginning to see the differences. The application of C6-C13 should enhance the effects.
- 6) The application of metals is difficult to understand at this point. If future field work is possible during reasonable weather, there are some measures that will be interesting. Further, it might be possible to get some subsurface correlations by acquiring produced water or in well water samples from the producing horizons across the field.

Light Hydrocarbon Data

Figure 3 provides a graphic illustration of the results of the compositional evaluation of the light hydrocarbons. The height of the bar indicates the relative importance of the compound for identifying producible oil. In other words, it is primarily the heavier of the hydrocarbons that differentiate the producing from dry areas. Note that methane is not a discriminant at all. Too much of the methane is not associated with oil and therefore is part of background.

Using this compositional model, we used Discriminant Analysis to calculate the probability of each unknown or grid sample being like the producing oil areas. A map of these is shown in Figure 4. Each map shows the three grid areas, and as insets, the model samples. The values are reported as bubbles of different colors and sizes. There is a clear zone of high scores extending from the NE part of the main grid to the southwest part of the grid, and extending in somewhat spotty fashion, across the western grid toward Cushard 4. Cushard 1 appears a bit isolated, although the grid did not expand around the well. Of note, Cushard 7 and the area around it, appears not to be particularly prospective using this measure.

Two other measures were mapped as well, to illustrate what the Discriminant function was accomplishing. Figure 5 maps percent Pentane, which approximates the findings of the Discriminant. Figure 6 shows the Wetness Ratio, which is the percent C4+ hydrocarbons. The Harpel well is not particularly strong using this analysis. It is easy to see, among the 3 maps and the compositional fingerprint, that the higher carbon number hydrocarbons are clearly differentiating producible from dry.

Fluorescence Data

As seen in the tables, the fluorescence data quite strongly differentiate producible from dry well areas in the model. This is shown graphically in Figure 7. Using only the lightest hydrocarbons, the 290 NM band (single ring aromatics), all of the wells look alike. As hydrocarbons increase into the 2-5 ring range, the intensity at oil wells rises dramatically, while the intensity at the dry holes drops dramatically. This suggests that the evaluation may use both compositional and quantitative measures to assess producibility. Figures 8

and 9 illustrate the results. Figure 8 is the result of compositional analysis, with the key parameters being the 350, 410, and 480 NM bands (heaviest hydrocarbons). Figure 9 shows the intensity readings from the 410 NM band. The distributions are very nearly the same, and are generally similar to those from the light hydrocarbons.

In particular, the areas in the NE corner and along the eastern edge of the main grid appear to be most anomalous. Unlike the light hydrocarbons, the heavy hydrocarbons find the area around Cushard 7 to be anomalous and prospective.

Preliminary Conclusions

Both of the hydrocarbon tests exhibit the ability to discriminate between productive and background models, and predict similar regions of the main grid as most prospective. This area should be considered the most appropriate for future drilling. The area around Cushard 7 needs further investigation. The density of sampling is low, but the differences between the light and heavy hydrocarbons suggest a need for some validation. Perhaps the additional tools we bring to the project will help us.



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NO.1

COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES: CDL CNL
WELL	: NO.1	
FIELD	: FAUVERGUE	
COUNTY	: VERNON	
STATE	: MISSOURI	

LOCATION	: 525' FSL & 2855 'FEL
SECTION	: 29
TOWNSHIP	: 36N
RANGE	: 33W
API NO.	:
UNIQUE WELL ID.	:

PERMANENT DATUM	: 770.9	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 770.9

DATE	: 08/12/03
RUN NO.	: 1
DEPTH DRILLER	: 220'
BIT SIZE	: 6.5
LOG TOP	: 1.60
LOG BOTTOM	: 225.30
CASING OD	: 7.0"
CASING BOTTOM	: 50'
CASING TYPE	: STEEL
BOREHOLE FLUID	: WATER
RM TEMPERATURE	:
MUD RES	:
WITNESSED BY	: MR.LONG
RECORDED BY	: RUNNELS
REMARKS 1	:
REMARKS 2	:

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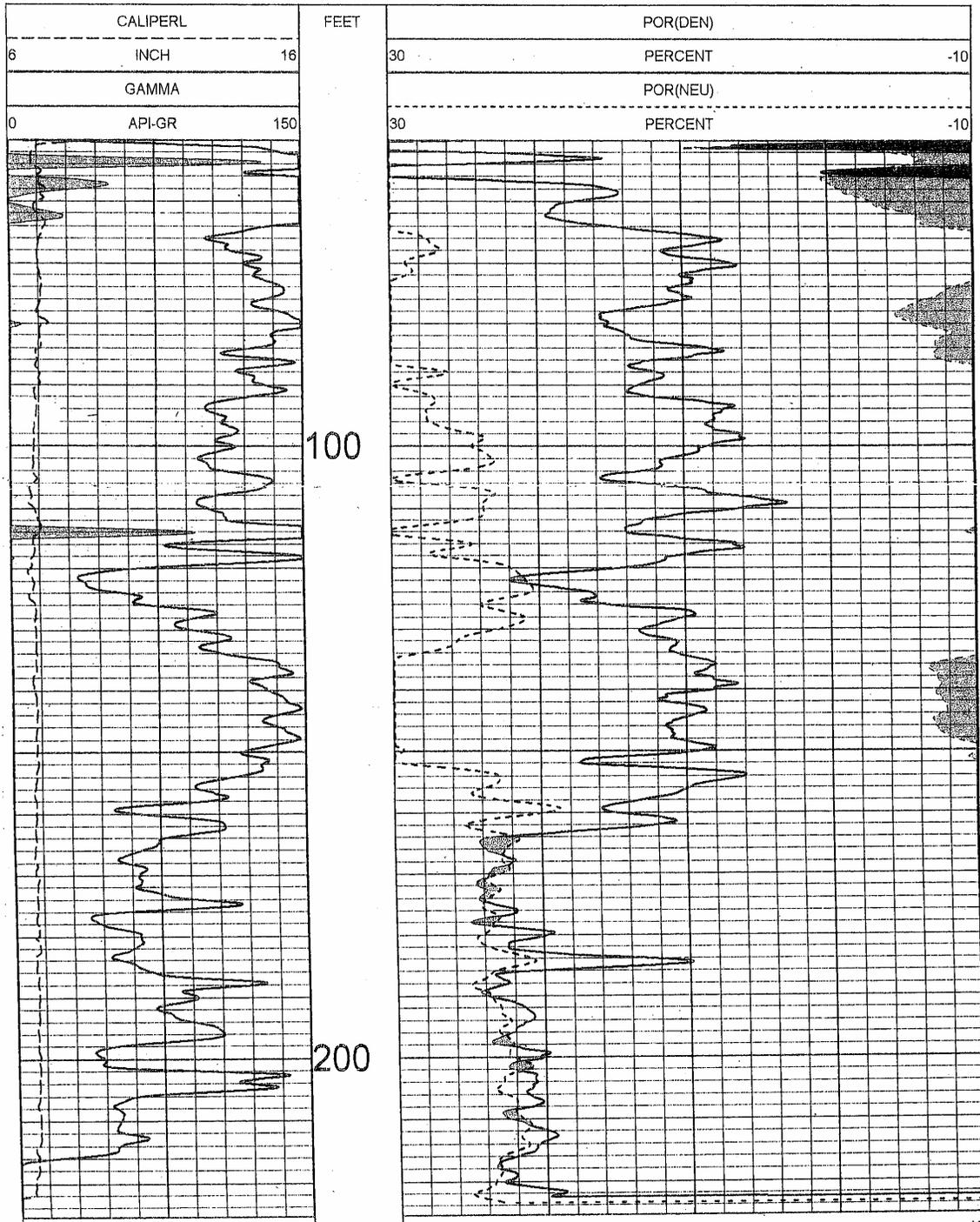
5 INCH LOG, POROSITIES NO.1 08/12/03

LOG PARAMETERS

MATRIX DENSITY : 2.65
 MAGNETIC DECL :

NEUTRON MATRIX : SANDSTONE
 ELECT. CUTOFF : 2500

MATRIX DELTA T : 54
 BIT SIZE : 6.5





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GAMMA RAY-RES

NO.1

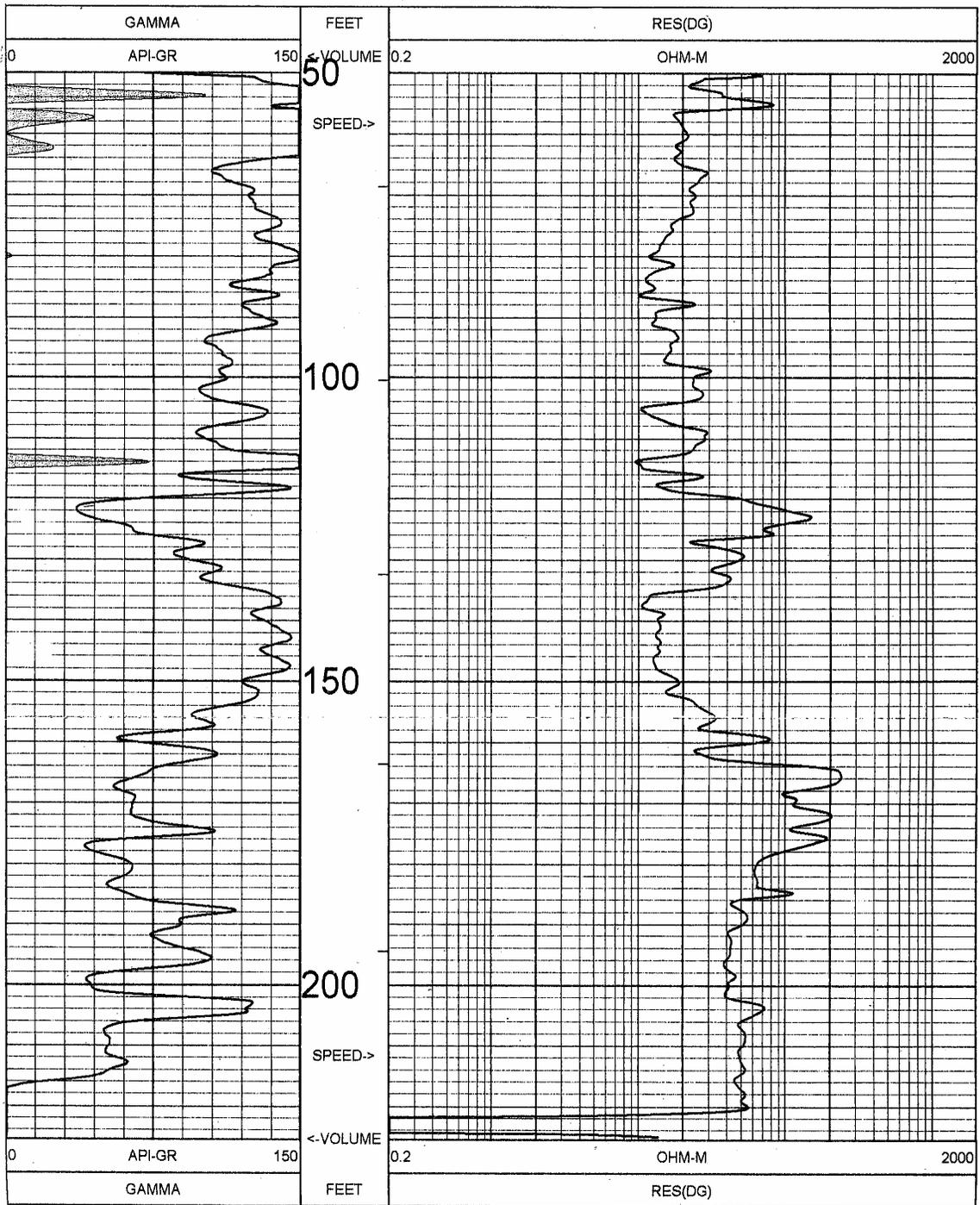
COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES: CDL CNL
WELL	: NO.1	
FIELD	: FAUVERGUE	
COUNTY	: VERNON	
STATE	: MISSOURI	

LOCATION	: 525' FSL & 2855' FEL
SECTION	: 29
TOWNSHIP	: 36N
RANGE	: 33W
API NO.	:
UNIQUE WELL ID.	:

PERMANENT DATUM	: 770.9	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 770.9

DATE	: 08/12/03
RUN NO.	: 1
DEPTH DRILLER	: 220'
BIT SIZE	: 6.5
LOG TOP	: 1.60
LOG BOTTOM	: 225.30
CASING OD	: 7.0"
CASING BOTTOM	: 50'
CASING TYPE	: STEEL
BOREHOLE FLUID	: WATER
RM TEMPERATURE	:
MUD RES	:
WITNESSED BY	: MR.LONG
RECORDED BY	: RUNNELS
REMARKS 1	:
REMARKS 2	:

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COMPENSATED DENSITY
COMPENSATED NEUTRON
NO.2

COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES:
WELL	: NO.2	9057
FIELD	: FAUVERGUE	CNL
COUNTY	: VERNON	CDL
STATE	: MISSOURI	

LOCATION	: 790' FSL & 2905' FEL
SECTION	: 29
TOWNSHIP	: 36N
RANGE	: 33W
API NO.	:
UNIQUE WELL ID.	:

PERMANENT DATUM	: 771'	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 771'

DATE	: 08/14/03
RUN NO.	: 1
DEPTH DRILLER	: 230'
BIT SIZE	: 6.5
LOG TOP	: 1.20
LOG BOTTOM	: 227.70
CASING OD	: 7.0
CASING BOTTOM	:
CASING TYPE	: STEEL
BOREHOLE FLUID	: WATER
RM TEMPERATURE	:
MUD RES	:
WITNESSED BY	: MR.LONG
RECORDED BY	: RUNNELS
REMARKS 1	:
REMARKS 2	:

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS

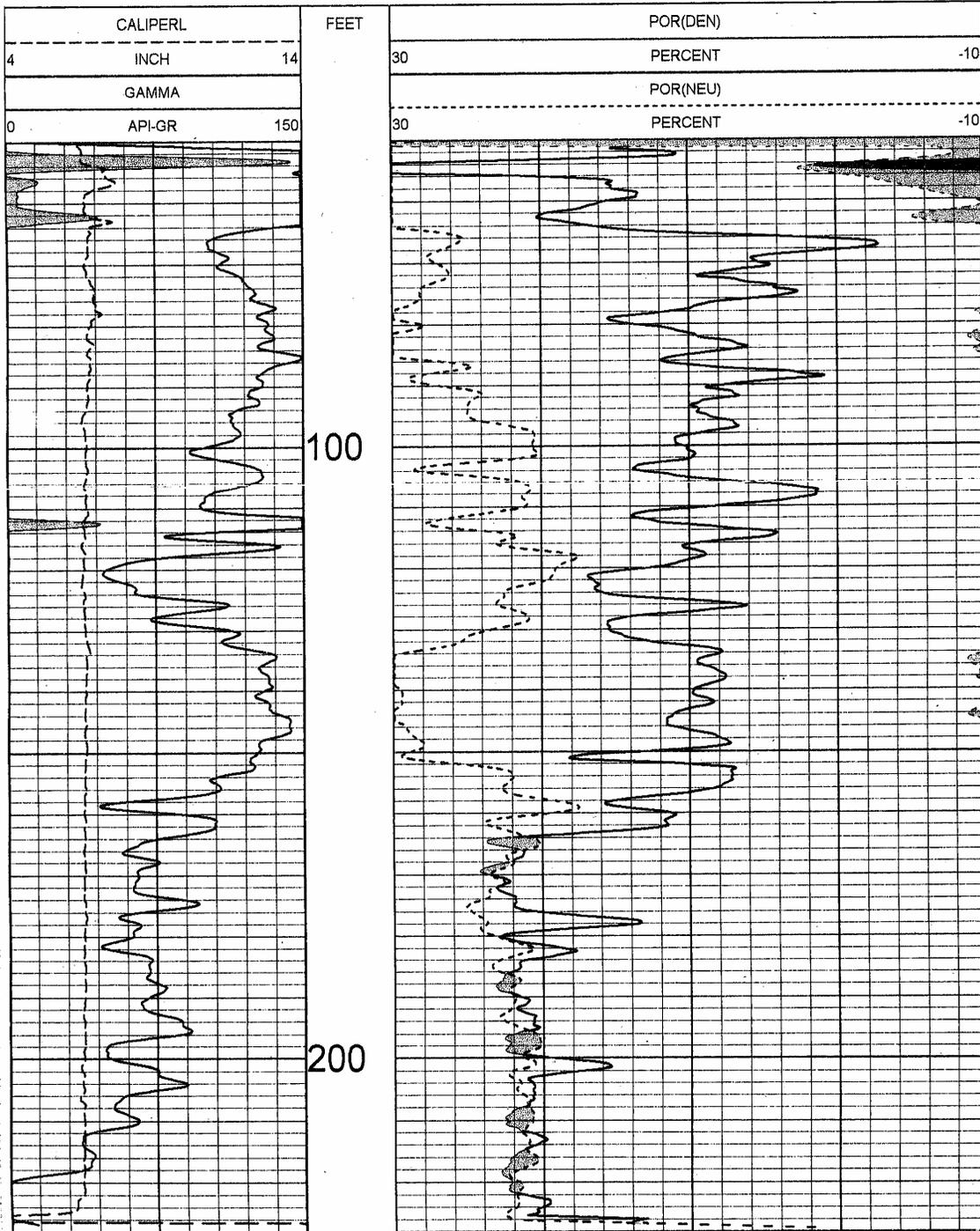
5 INCH LOG, POROSITIES NO.2 08/14/03

LOG PARAMETERS

MATRIX DENSITY : 2.65
MAGNETIC DECL : 0

NEUTRON MATRIX : SANDSTONE
ELECT. CUTOFF : 2500

MATRIX DELTA T : 54
BIT SIZE : 6.5





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GAMMA RAY-RESISTIVITY LOG

NO.2

COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES: 9057 CNL CDL
WELL	: NO.2	
FIELD	: FAUVERGUE	
COUNTY	: VERNON	
STATE	: MISSOURI	

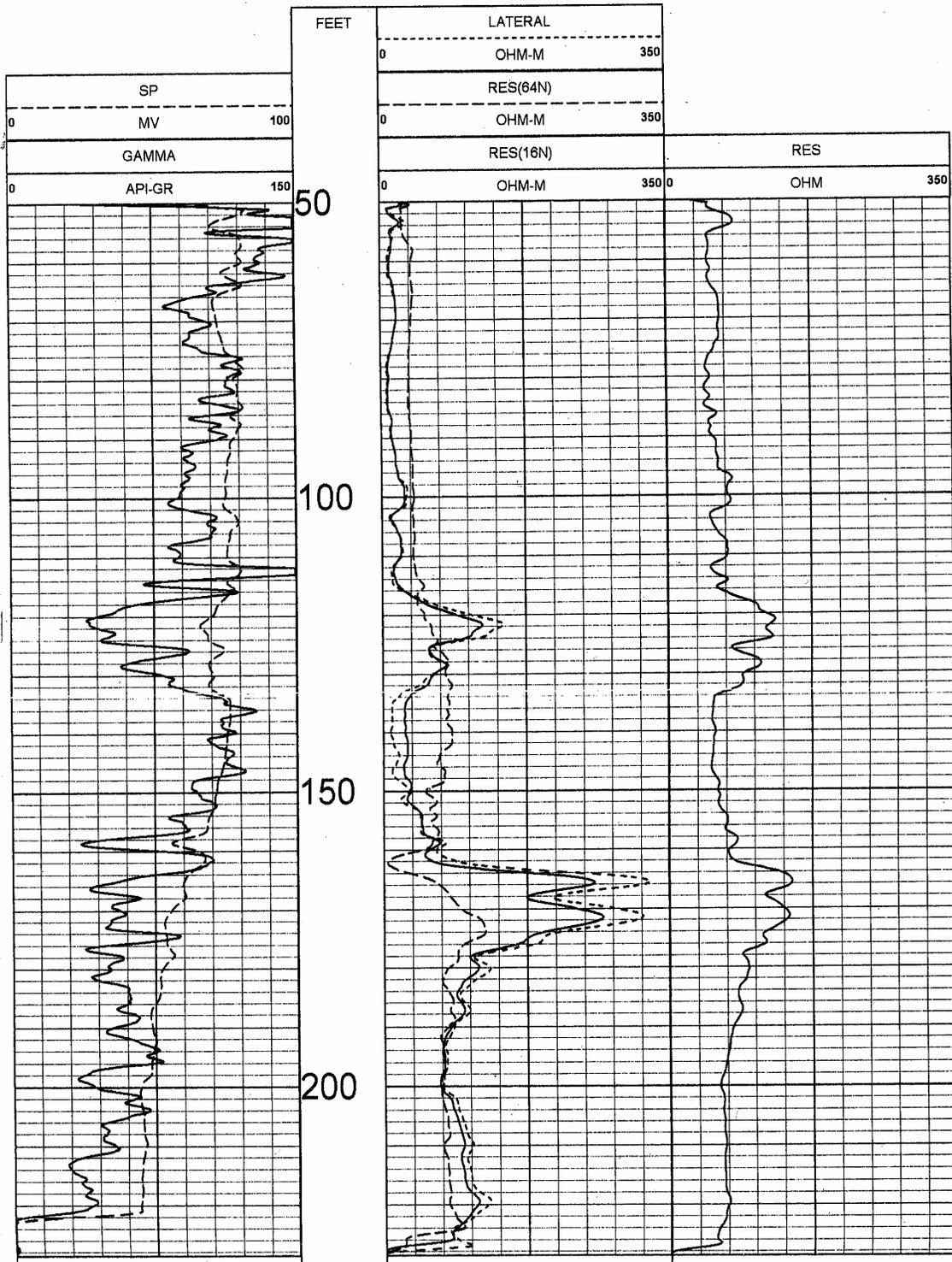
LOCATION	: 790' FSL & 2905' FEL
SECTION	: 29
TOWNSHIP	: 36N
RANGE	: 33W
API NO.	:
UNIQUE WELL ID.	:

PERMANENT DATUM	: 771'	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 771'

DATE	: 08/14/03
RUN NO.	: 1
DEPTH DRILLER	: 230'
BIT SIZE	: 6.5
LOG TOP	: 40.40
LOG BOTTOM	: 228.40
CASING OD	: 7.0
CASING BOTTOM	:
CASING TYPE	: STEEL
BOREHOLE FLUID	: WATER
RM TEMPERATURE	:
MUD RES	:
WITNESSED BY	: MR.LONG
RECORDED BY	: RUNNELS
REMARKS 1	:
REMARKS 2	:

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS

GAMMA RAY-RESISTIVITY LOG
NO 2





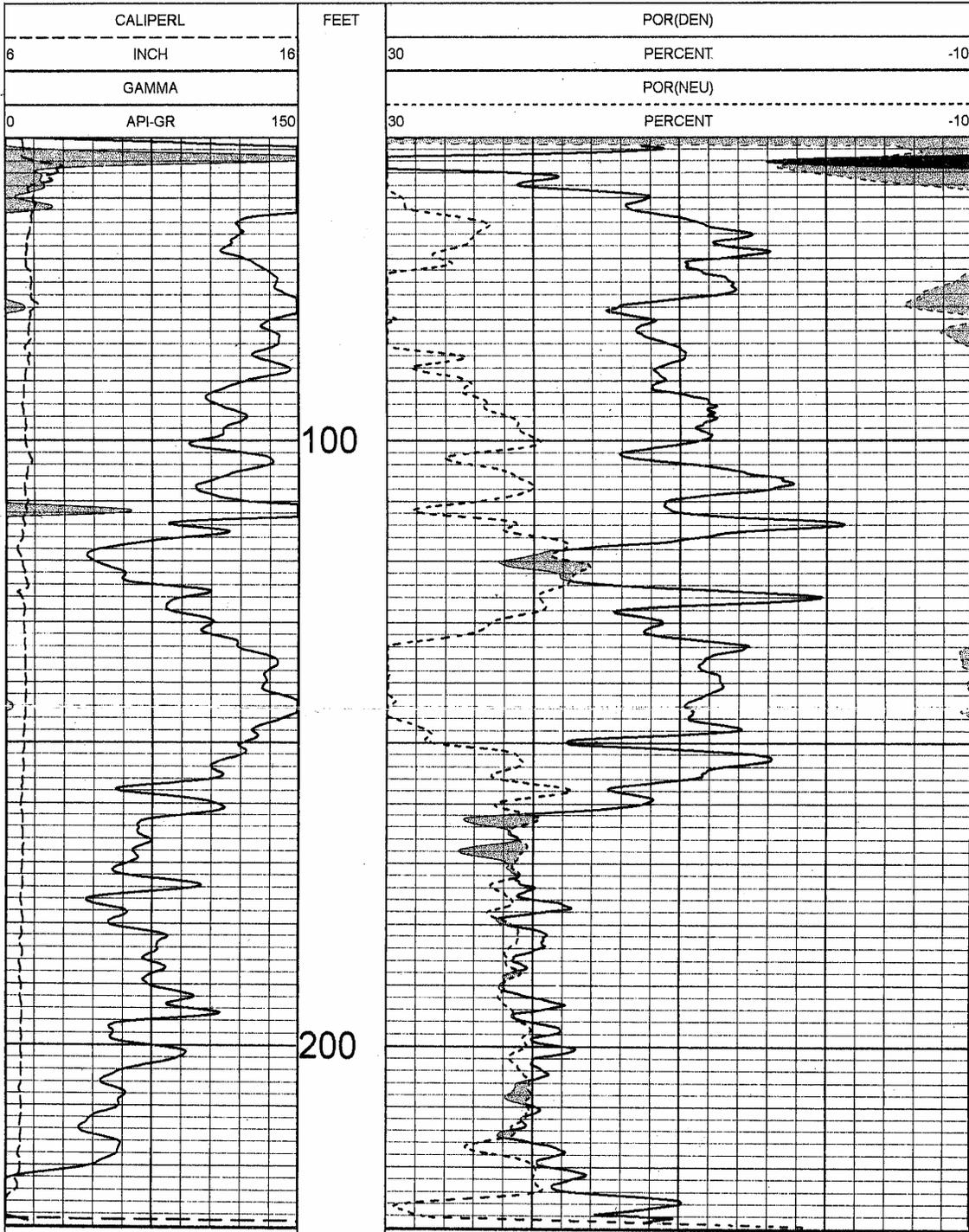
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COMPENSATED DENSITY
COMPENSATED NEUTRON
NO.3

COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES:
WELL	: NO.3	9057
FIELD	: FAUVERGUE	CNL
COUNTY	: VERNON	
STATE	: MISSOURI	
LOCATION	: 840' FSL & 2855' FEL	
SECTION	: 29	
TOWNSHIP	: 36N	
RANGE	: 33W	
API NO.	:	
UNIQUE WELL ID.	:	
PERMANENT DATUM	: 770.9	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 770.9
DATE	: 08/14/03	
RUN NO.	: 1	
DEPTH DRILLER	: 230'	
BIT SIZE	: 6.5	
LOG TOP	: 1.40	
LOG BOTTOM	: 230.00	
CASING OD	: 7.0	
CASING BOTTOM	:	
CASING TYPE	: STEEL	
BOREHOLE FLUID	: WATER	
RM TEMPERATURE	:	
MUD RES	:	
WITNESSED BY	: MR.LONG	
RECORDED BY	: RUNNELS	
REMARKS 1	:	
REMARKS 2	:	

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COMPENSATED DENSITY
 COMPENSATED NEUTRON
 NO 3





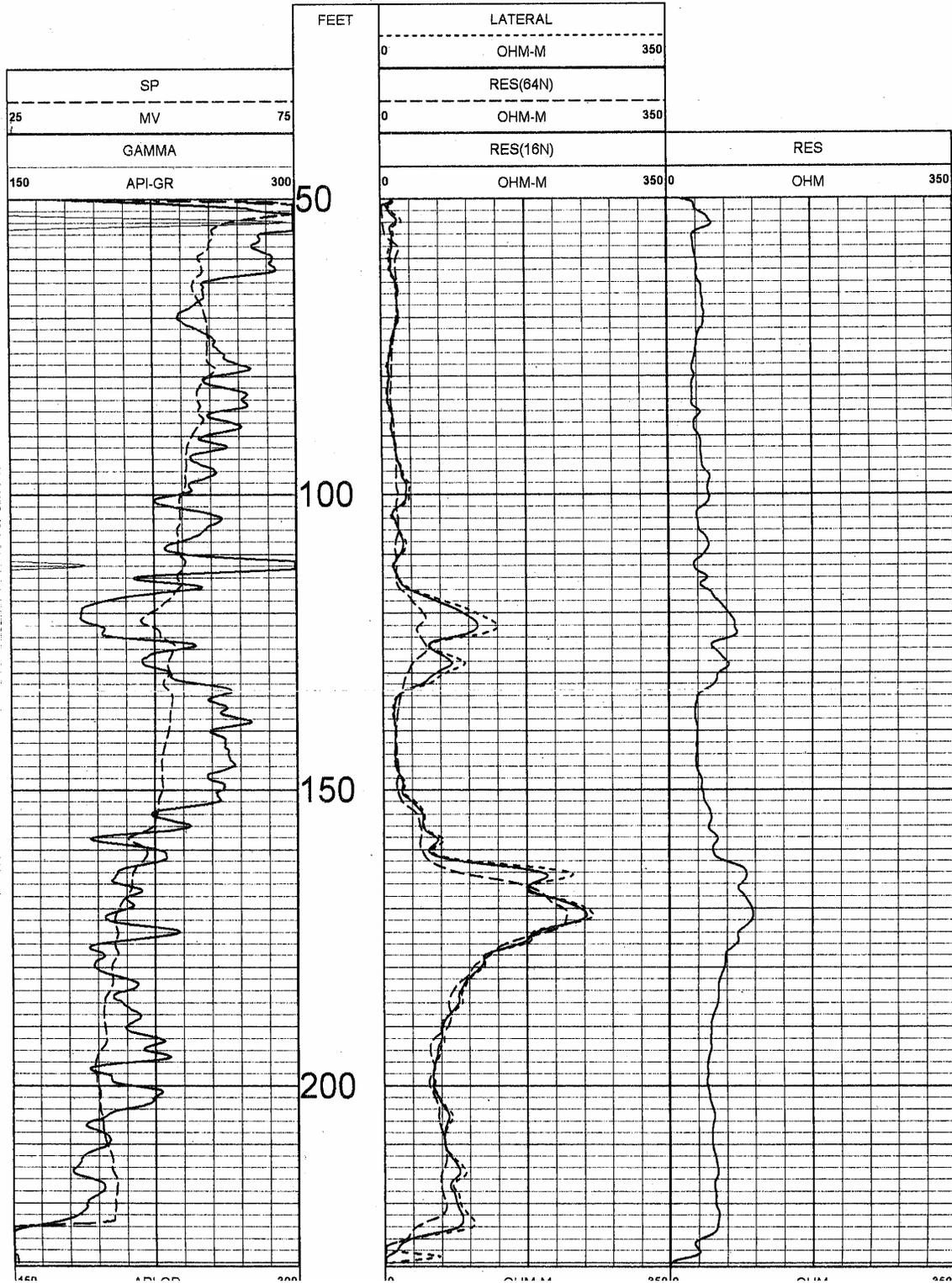
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GAMMA RAY-RESISTIVITY LOG

NO.3

COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES: CNL CDL
WELL	: NO.3	
FIELD	: FAUVERGUE	
COUNTY	: VERNON	
STATE	: MISSOURI	
LOCATION	: 840' FSL & 2855' FEL	
SECTION	: 29	
TOWNSHIP	: 36N	
RANGE	: 33W	
API NO.	:	
UNIQUE WELL ID.	:	
PERMANENT DATUM	: 770.9	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 770.9
DATE	: 08/14/03	
RUN NO.	: 1	
DEPTH DRILLER	: 230'	
BIT SIZE	: 6.5	
LOG TOP	: 1 60	
LOG BOTTOM	: 230.40	
CASING OD	: 7.0	
CASING BOTTOM	:	
CASING TYPE	: STEEL	
BOREHOLE FLUID	: WATER	
RM TEMPERATURE	:	
MUD RES	:	
WITNESSED BY	: MR.LONG	
RECORDED BY	: RUNNELS	
REMARKS 1	:	
REMARKS 2	:	
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GAMMA RAY-RESISTIVITY LOG
NO 3





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COMPENSATED DENSITY
COMPENSATED NEUTRON
NO.4

COMPANY : GARLAND OIL & GAS, INC.	OTHER SERVICES: RES CNL
WELL : NO.4	
FIELD : FAUVERGUE	
COUNTY : VERNON	
STATE : MISSOURI	

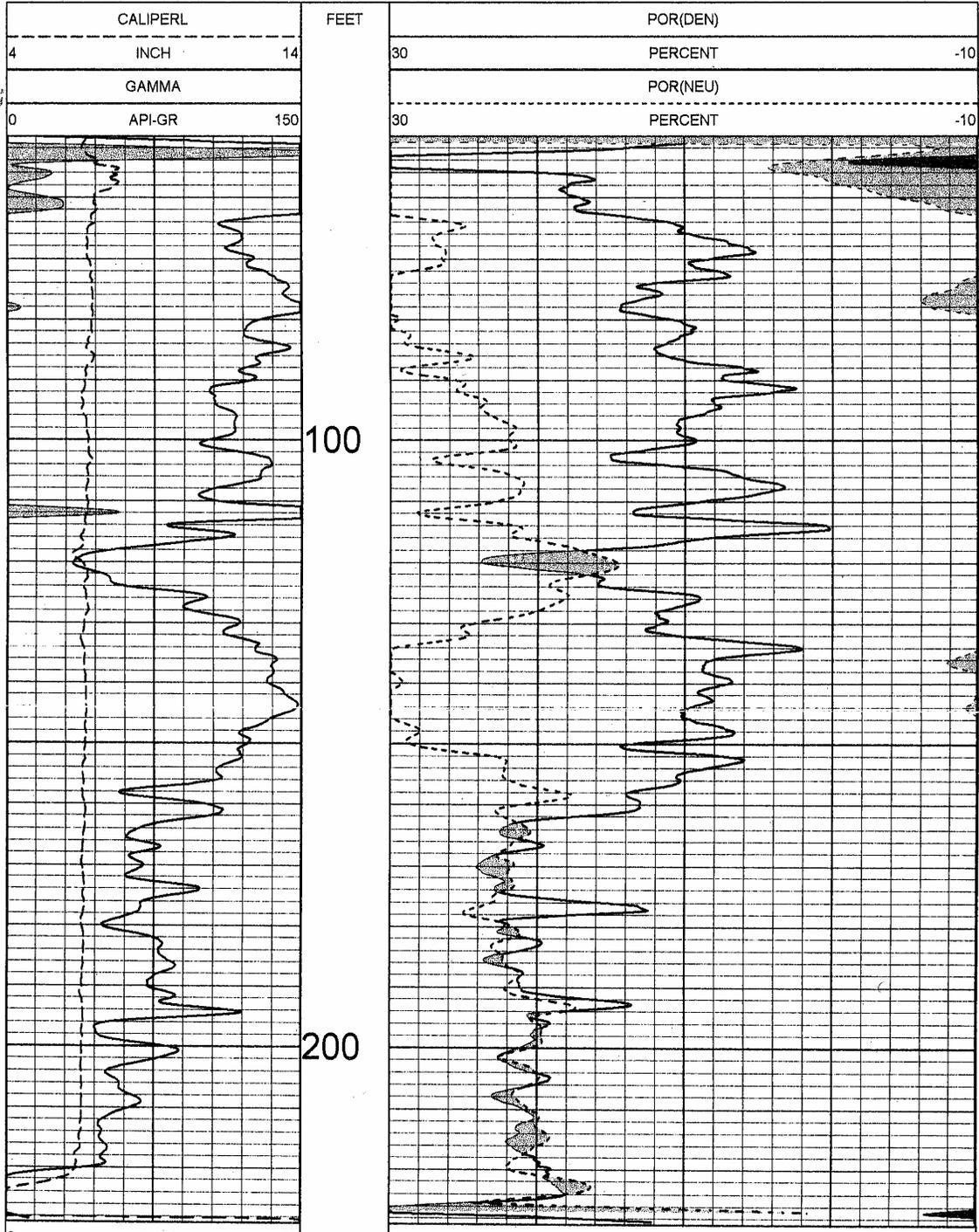
LOCATION : 790' FSL & 2805' FEL
SECTION : 29
TOWNSHIP : 36N
RANGE : 33W
API NO. :
UNIQUE WELL ID. :

PERMANENT DATUM : 770.8	ELEVATION KB:
LOG MEASURED FROM: G.L.	ELEVATION DF:
DRL MEASURED FROM: G.L.	ELEVATION GL: 770.8

DATE : 08/14/03
RUN NO. : 1
DEPTH DRILLER : 220'
BIT SIZE : 6.5
LOG TOP : 0.90
LOG BOTTOM : 228.70
CASING OD : 7.0
CASING BOTTOM :
CASING TYPE : STEEL
BOREHOLE FLUID : WATER
RM TEMPERATURE :
MUD RES :
WITNESSED BY : MR.LONG
RECORDED BY : RUNNELS
REMARKS 1 :
REMARKS 2 :

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COMPENSATED DENSITY
 COMPENSATED NEUTRON
 NO 4





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GAMMA RAY-RESISTIVITY LOG

NO.4

COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES: CDL CNL
WELL	: NO.4	
FIELD	: FAUVERGUE	
COUNTY	: VERNON	
STATE	: MISSOURI	

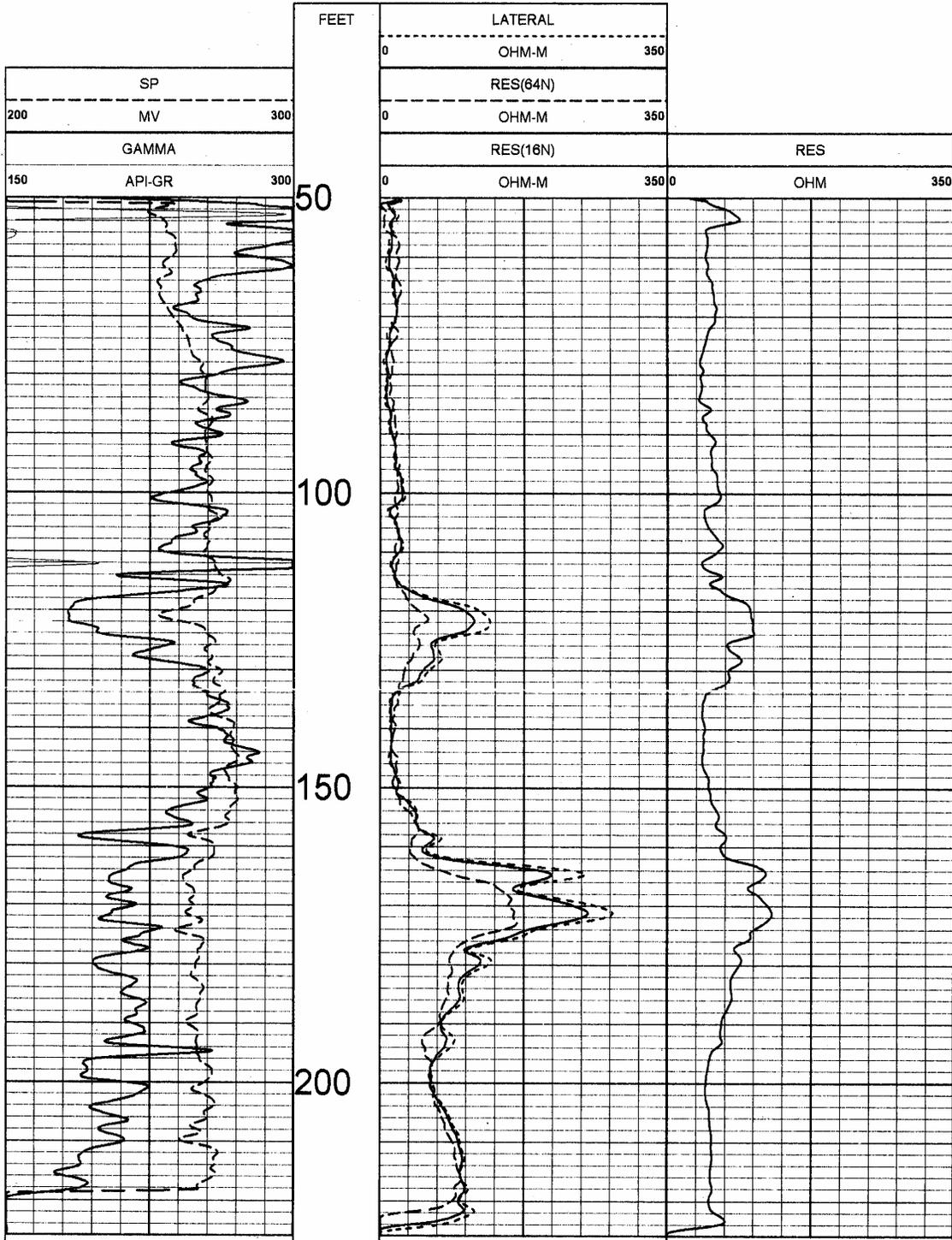
LOCATION	: 790' FSL & 2805' FEL
SECTION	: 29
TOWNSHIP	: 36N
RANGE	: 33W
API NO.	:
UNIQUE WELL ID.	:

PERMANENT DATUM	: 770.8	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 770.8

DATE	: 08/14/03
RUN NO.	: 1
DEPTH DRILLER	: 220'
BIT SIZE	: 6.5
LOG TOP	: 4.00
LOG BOTTOM	: 225.60
CASING OD	: 7.0
CASING BOTTOM	:
CASING TYPE	: STEEL
BOREHOLE FLUID	: WATER
RM TEMPERATURE	:
MUD RES	:
WITNESSED BY	: MR.LONG
RECORDED BY	: RUNNELS
REMARKS 1	:
REMARKS 2	:

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS

GAMMA RAY-RESISTIVITY LOG
NO 4





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COMPENSATED DENSITY
COMPENSATED NEUTRON
NO.5

COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES: CDL CNL
WELL	: NO.5	
FIELD	: FAUVERGUE	
COUNTY	: VERNON	
STATE	: MISSOURI	

LOCATION	: 1155' FSL & 2855' FEL
SECTION	: 29
TOWNSHIP	: 36N
RANGE	: 33W
API NO.	:
UNIQUE WELL ID.	:

PERMANENT DATUM	: 770.7	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 770.7

DATE	: 08/12/03
RUN NO.	: 1
DEPTH DRILLER	: 220'
BIT SIZE	: 6.5
LOG TOP	: -2.20
LOG BOTTOM	: 225.50
CASING OD	:
CASING BOTTOM	:
CASING TYPE	:
BOREHOLE FLUID	: WATER
RM TEMPERATURE	:
MUD RES	:
WITNESSED BY	: MR.LONG
RECORDED BY	: RUNNELS
REMARKS 1	:
REMARKS 2	:

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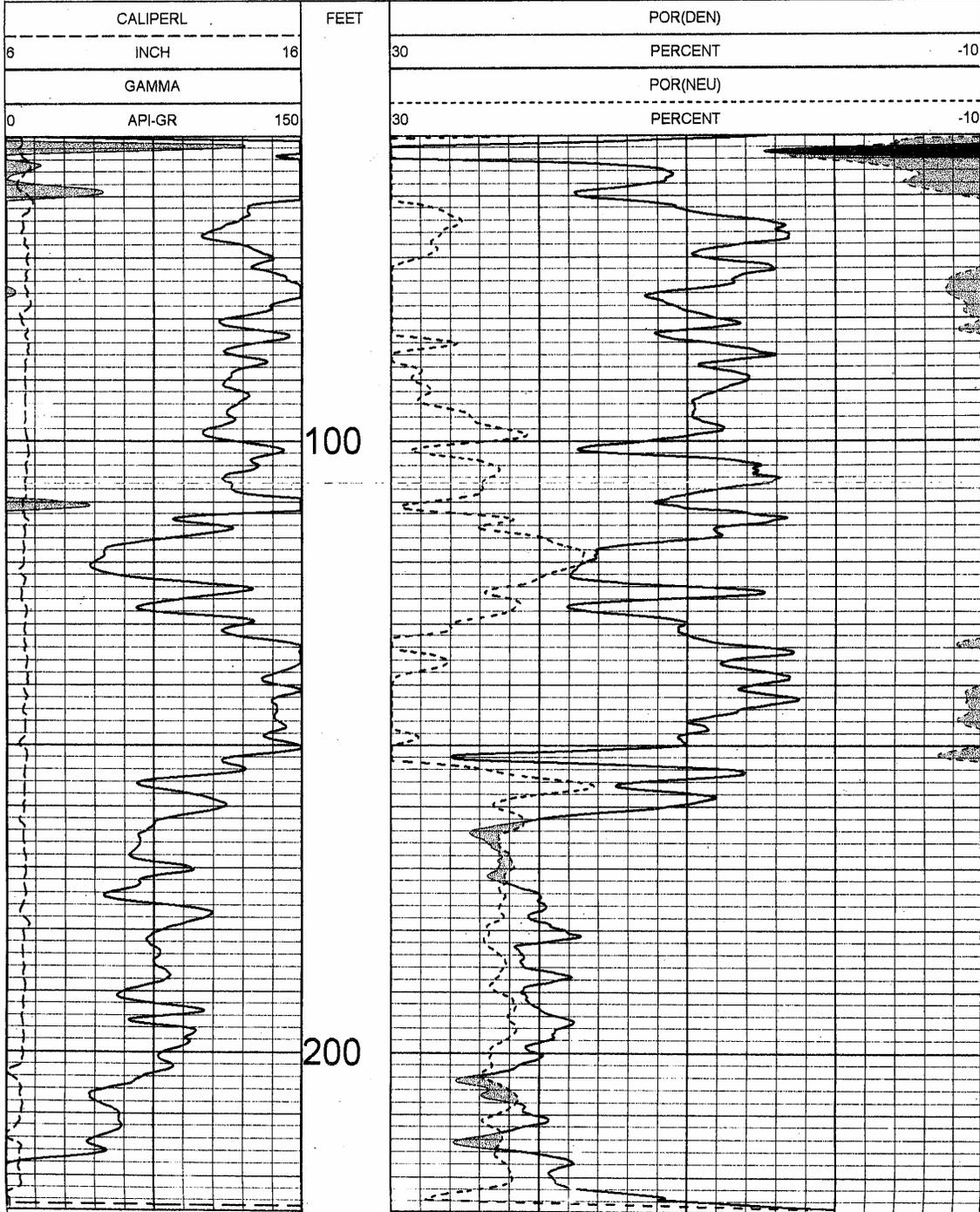
5 INCH LOG, POROSITIES NO.5 08/12/03

LOG PARAMETERS

MATRIX DENSITY : 2.65
MAGNETIC DECL :

NEUTRON MATRIX : SANDSTONE
ELECT. CUTOFF : 2500

MATRIX DELTA T : 54
BIT SIZE : 6.5





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GAMMA RAY-RES

NO.5

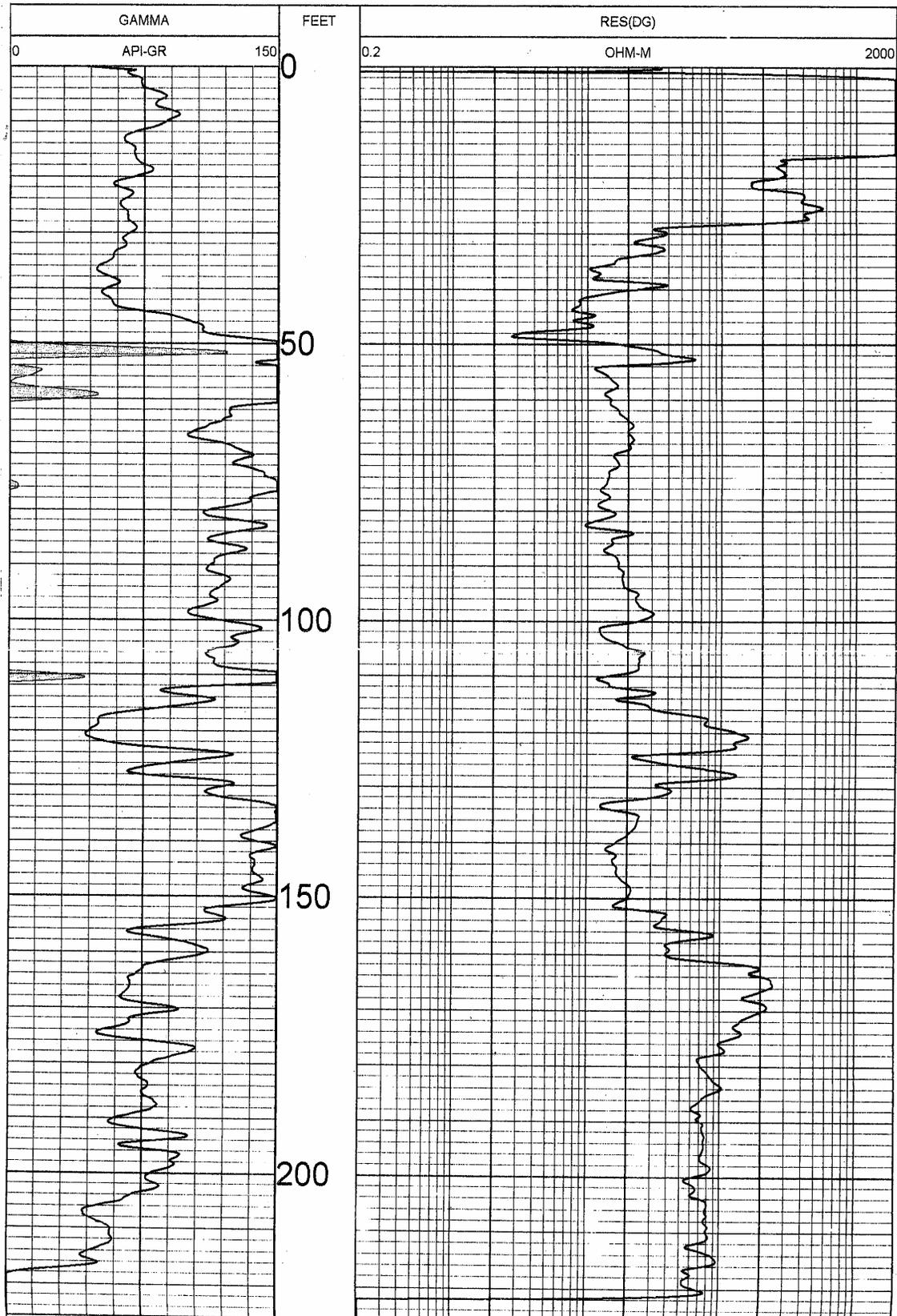
COMPANY	: GARLAND OIL & GAS, INC.	OTHER SERVICES: CDL CNL
WELL	: NO.5	
FIELD	: FAUVERGUE	
COUNTY	: VERNON	
STATE	: MISSOURI	

LOCATION	: 1155' FSL & 2855' FEL
SECTION	: 29
TOWNSHIP	: 36N
RANGE	: 33W
API NO.	:
UNIQUE WELL ID.	:

PERMANENT DATUM	: 770.7	ELEVATION KB:
LOG MEASURED FROM:	G.L.	ELEVATION DF:
DRL MEASURED FROM:	G.L.	ELEVATION GL: 770.7

DATE	: 08/12/03
RUN NO.	: 1
DEPTH DRILLER	: 220'
BIT SIZE	: 6.5
LOG TOP	: -2.20
LOG BOTTOM	: 225.50
CASING OD	:
CASING BOTTOM	:
CASING TYPE	:
BOREHOLE FLUID	: WATER
RM TEMPERATURE	:
MUD RES	:
WITNESSED BY	: MR.LONG
RECORDED BY	: RUNNELS
REMARKS 1	:
REMARKS 2	:

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS





UMR-DOE Fracture Stimulation Design for the Warner Sandstone in the Cushard No. 4

Background:

The Cushard No. 1 and 5 are planned Warner sandstone completions and fracture stimulations as part of the United States Department of Energy (DS-PS26-02NTI5378-1) project entitled: "Development Practices For Optimized MEOR in Shallow Heavy Oil Reservoirs." The objective of the fracture stimulations is to generate sufficient fracture dimensions (fracture length and conductivity) to facilitate the injection of an MEOR solution and production of the resulting hydrocarbons. To meet these objectives, the treatment will include the use of a 30 ppt linear gel and 20/40 Brady sand to create an effective fracture half length of 200 feet and fracture conductivity of approximately 5 pounds per square foot. The purpose of this memorandum is to document the fracture stimulation and data collection designs for the Cushard Nos. 1 and 5.

Conclusions:

- 1) The Warner Sandstone Formation should be perforated at 180 to 200 feet based on the Cushard No. 4 logs.
- 2) The static Young's Modulus for the Blue Jacket Sandstone Formation developed through tri-axial compression testing is 3.0×10^6 psi.
- 3) The static Young's Modulus for the Warner Sandstone Formation developed through tri-axial compression testing is 1.6×10^6 psi.
- 4) The static Young's Modulus for the bounding shale formations developed through tri-axial compression testing is 1.4×10^6 psi.
- 5) Executing a tip screen-out fracture stimulation may be difficult due to the limited leak-off resulting from the high oil viscosity in this reservoir.
- 6) The use of 20/40 Brady sand is warranted in the initial stimulation due to concerns over Near Wellbore Pressure Losses and mitigation strategies.
- 7) The use of a linear gel fracturing fluid is warranted in this shallow heavy oil reservoir.

Recommendations:

- 1) Perforate the Cushard No. 1 and 5 from 180 to 200 feet based on the Cushard No. 4 logs.
- 2) Utilize the Young's Modulus determined in the tri-axial compression testing to develop an initial geomechanical dataset and preliminary fracture design.
- 3) Conduct a small (approximately 500 gallon mini-frac) to determine leak-off coefficient and develop a tip screen-out fracture design while limiting extent of filter cake development.
- 4) Initially use 20/40 Brady sand but re-evaluate the use of larger more conductive materials following the first fracture stimulation.
- 5) Use a 30 ppt linear gel as the fracturing fluid.

Introduction:

The Cushard No. 1 and 5 are planned Warner sandstone completions and fracture stimulations as part of the United States Department of Energy (DS-PS26-02NTI5378-1) project entitled: "Development Practices For Optimized MEOR in Shallow Heavy Oil Reservoirs." The objective of the fracture stimulation is to generate sufficient fracture dimensions (fracture length and conductivity) to facilitate the injection of an MEOR solution and production of the resulting hydrocarbons. To meet these objectives, the treatment will include the use of a 30 ppt linear gel and 20/40 Brady sand to create an effective fracture half length of 200 feet and fracture conductivity of 5 pounds per square foot. The purpose of this memorandum is to document the fracture stimulation and data collection designs for the Cushard Nos. 1 and 5.

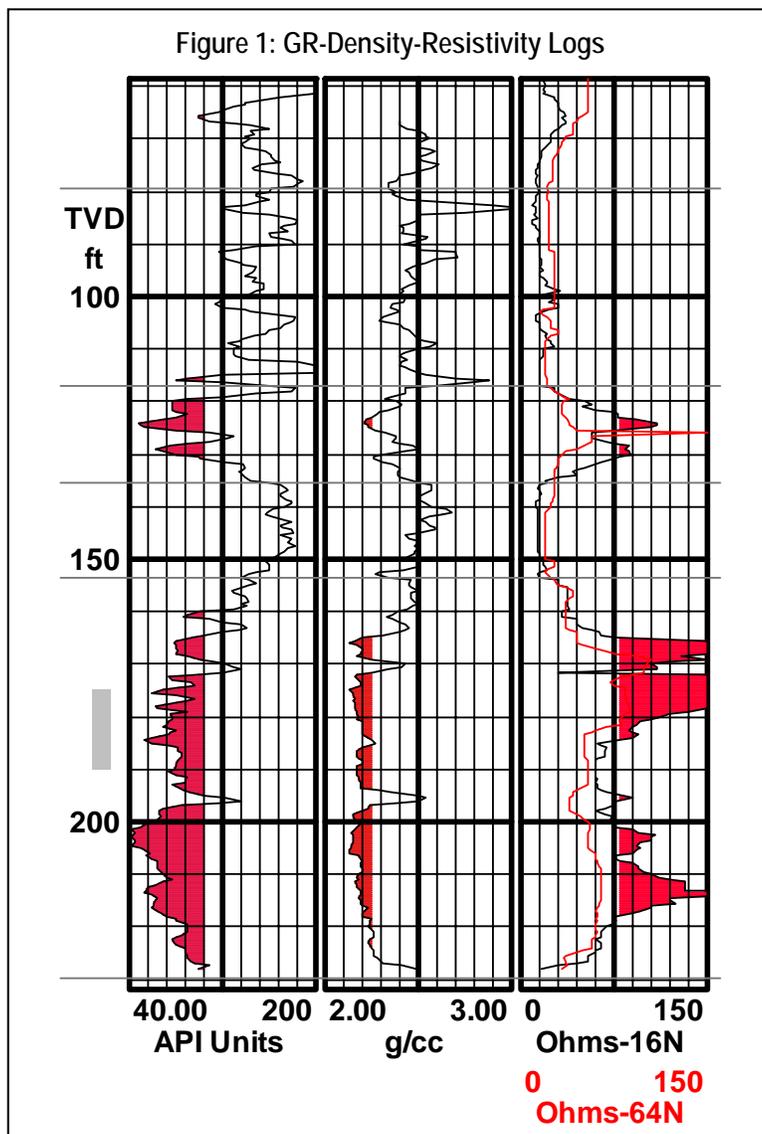
The purpose of this memorandum is to document the preliminary fracture stimulation design for the Cushard Nos. 1 and 5.

Geomechanical Dataset Development:

The purpose of this evaluation is to develop a geomechanical dataset that can be used to develop a preliminary design for the Warner Sandstone Formation in the Cushard Nos. 1 and 5. The process of developing a geomechanical dataset includes the development of a profile with depth of Young's Modulus, in-situ stress, and fracture fluid leak-off. Fortunately, core from the Blue Jacket and Warner Sandstone Formations and surrounding shales was available and tri-axial compression tests were conducted to determine Young's Modulus. In-situ stress and leak-off coefficient estimates were developed based on experience in similar shallow heavy oil reservoirs. The subsequent sections detail this evaluation and the development and calibration of a geomechanical dataset for use in optimizing the completion interval and fracture design. Note, since no logs are presently available from the Cushard Nos. 1 and 5, logs from the Cushard No. 4 were utilized in this analysis.

In-Situ Stress Contrast

The in-situ stress contrast in the Cushard No. 4 was assumed to be minimal given the shallow nature of the reservoir and limited production and subsequent lack of depletion from the Warner Sandstone Formation in the



area. As a result, a radial fracture geometry (either vertical or horizontal) was assumed. This assumption will be tested with the mini-frac test to be conducted prior to the fracture stimulation in each well.

Young’s Modulus

Evaluation of the tri-axial compression tests, shown in Table I, indicates that the Blue Jacket and Warner Sandstones have an average Young’s modulus of 3.1 and 1.3 x 10⁶ psi, respectively. The Rowe Coal and the bounding shales have an average Modulus of 2.0 and 1.8

Sample ID	Depth, feet	Lithology	Static E, 10 ⁶ psi
03030401-A	110.50	Shale	1.03
03030501-A	119.00	Shale	1.44
03030502-A	121.50	L. Bluejacket SS	3.94
03031101	128.50	L. Bluejacket SS	3.12
03032401-B	130.00	L. Bluejacket SS	2.33
03032601	136.50	Rowe Coal	1.48
03032502-B	138.50	Rowe SS	2.44
03030701	144.00	Warner SS	0.92
03031102-A	167.00	Warner SS	1.30
03032402	170.00	Warner SS	1.72
03031001-A	176.00	Warner SS	0.96
03032501-B	178.00	Warner SS	1.56
03031002-B	191.00	Warner SS	1.52
03030601	200.30	Graydon Shale	3.27
00000211-B	211.00	Graydon Shale	1.43

x 10⁶ psi, respectively.

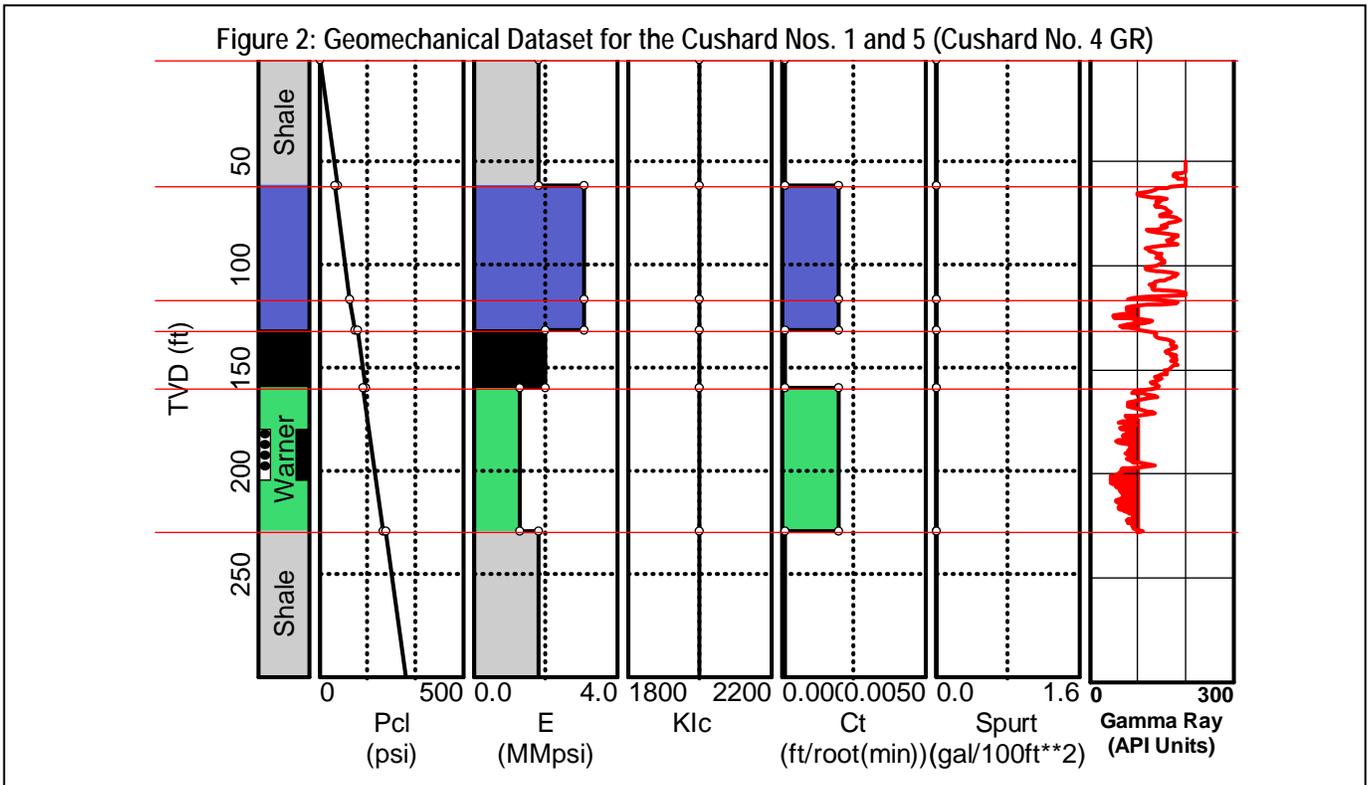
These static Young’s Moduli were utilized in this analysis to develop the preliminary fracture design for the Cushard Nos. 1 and 5.

Determination of Leak-off Coefficient

With the in-situ stress profile and Young’s Modulus determined in the preceding analysis, the next phase of developing a geomechanical dataset includes the determination of the leak-off coefficient. Due to the extremely high oil viscosity of the in-place hydrocarbons in this heavy oil project, a low value of fracture fluid leak-off given the 100 md reservoir permeability was assumed. For preliminary design purposes a leak-off coefficient of approximately 0.002 ft/min^{1/2} was assumed based on experience with other heavy oil projects. The actual leak-off coefficient to the fracturing fluid will be determined as part of the preliminary testing and data collection prior to the fracture stimulation of the Cushard Nos. 1 and 5.

Figure 2 shows the geomechanical dataset developed in this analysis and used to evaluate the data collection program and fracture stimulation of the Warner Sandstone Formation in the Cushard 1 and 5. As shown, the first track of the geomechanical profile is the true vertical

depth and perforation indicator track. Track two of the profile represents the closure pressure while tracks three and four represent the Young's Modulus and toughness, respectively. Tracks five and six show the fluid loss coefficient and spurt and Track seven shows the gamma ray log for this well. As shown in this profile, there are three Cadomin lobes separated by shaley/silty intervals. In order to best stimulate the entire Cadomin, while ensuring that the best porosity at the top of the Formation was adequately stimulated it is recommended that only the top two lobes of the Formation be perforated.



Fracture Stimulation Design:

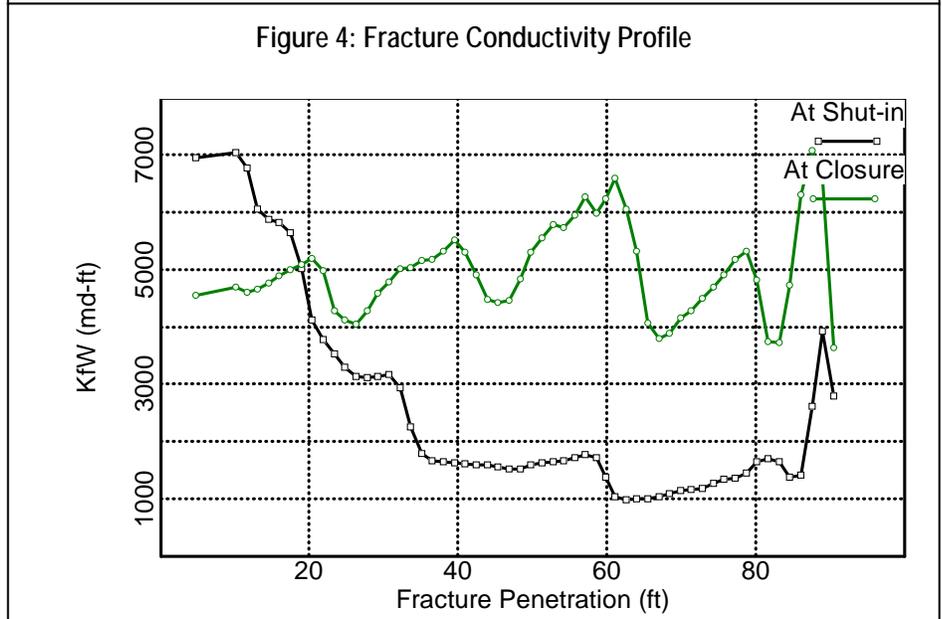
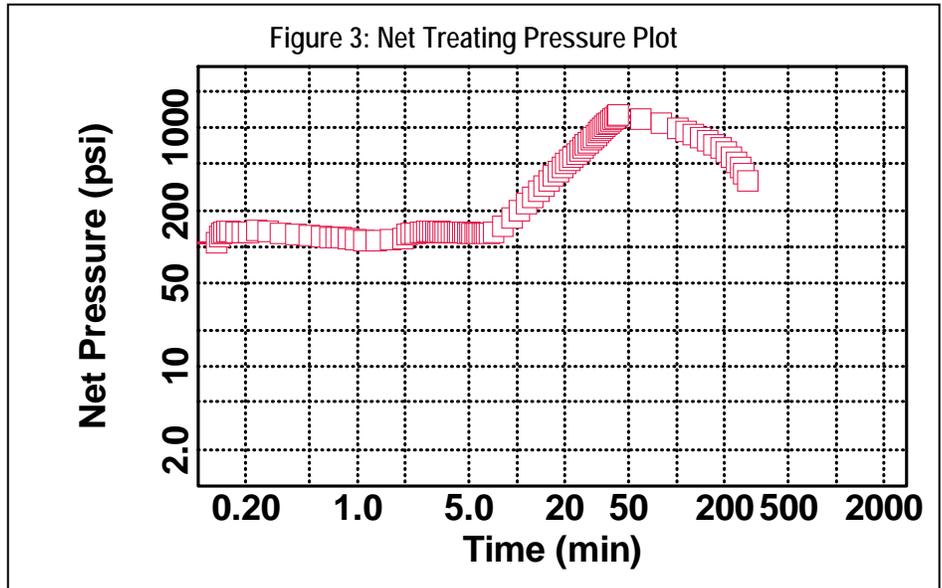
The geomechanical dataset developed in the preceding analysis was used to generate the fracture stimulation design for the Warner Sandstone Formation in the Cushard 1 and 5. Table II shows the preliminary fracture stimulation design developed in this analysis. As shown, the preliminary design consists of pumping 94.5 mlbs of 20/40 Brady sand in 23 mgals of 30 ppt linear gel fracturing fluid. The treatment is designed for a proppant addition schedule from 0.5 ppg to 10 ppg. Note, the purpose of the 0.5 ppg proppant

Table II: Preliminary Fracture Stimulation Design

Stage	Slurry Volume (M-Gal)	Fluid Volume (M-Gal)	Proppant Conc Strt (PPG)	Proppant Conc End (PPG)	Rate (BPM)	Fines Conc. (Vol Fraction)
1	2.00	2.00	0.00	0.00	15.0	0.00
2	3.07	3.00	0.50	0.50	15.00	0.00
3	3.14	3.00	1.00	1.00	15.0	0.00
4	3.27	3.00	2.00	2.00	15.0	0.00
5	3.54	3.00	4.00	4.00	15.0	0.00
6	3.82	3.00	6.00	6.00	15.0	0.00
7	4.09	3.00	8.00	8.00	15.0	0.00
8	4.36	3.00	10.00	10.00	15.0	0.00

stage is to mitigate the detrimental effects of Near Wellbore Pressure Loss due to the anticipated complex fracture geometry. In the event no NWPL is experienced, consideration should be given in the post mini-frac fracture redesign to eliminate this stage. Further, the use of 20/40 Brady sand is recommended for the first fracture stimulation in this reservoir, however, should no NWPL be experienced, larger more conductive 12/20 or 8/16 Brady sand should be considered for subsequent fracture stimulation treatments.

Figure 3 shows a fracturplot of net treating pressure versus pump time resulting from this preliminary fracture stimulation design based on STIMPLAN simulations. As shown, a net treating pressure build from approximately 100 to 1,000 psi was designed. Such a net pressure build, if achieved, would significantly increase the propped fracture width and fracture conductivity. Figure 4 highlights this effect. As shown in this plot of fracture conductivity versus fracture half length a fracture length of 100 feet and an average fracture conductivity of nearly 5,000 mdft result from this preliminary fracture design. By using these fracture dimensions and assuming a reservoir permeability of 250 md, a dimensionless fracture capacity, F_{CD} , of 2.0 would be achieved. Therefore, the preliminary fracture design should result in optimum fracture dimensions for placement of the microbial briat solution and hydrocarbon recovery.



Sincerely,

Larry K. Britt

Larry K. Britt

NSI Technologies, Inc.
918-496-2071

JOB LOG		TICKET #	TICKET DATE
FBM NA	NWA / COUNTRY CENTRAL AREA	BDA / STATE Missouri	COUNTY Vernon
MBU ID / EMPL # FS0501	H.E.S EMPLOYEE NAME FS0501 106288 EARL BARBER	PSL DEPARTMENT PE / STIMULATION	CUSTOMER REP / PHONE SHERI DUNN NORMAN
LOCATION Ft. Smith, Ar	COMPANY University Of Missouri-Rolla	WELL TYPE GAS	API/AVI #
TICKET AMOUNT \$0.00	DEPARTMENT FRAC	JOB PURPOSE CODE 275	
WELL LOCATION Nevada	SEC / TWP / RNG 0		
LEASE / WELL # Cushard #1			

H.E.S. EMP NAME / EMP # / (EXPOSURE HOURS)	HRS	H.E.S. EMP NAME / EMP # / (EXPOSURE HOURS)	HRS	H.E.S. EMP NAME / EMP # / (EXPOSURE HOURS)	HRS
EARL BARBER	6	GREG AYNES	6	DOLPH MATHIS	6
TOMMY CARR	6	DAVID HOLLAND	6	JEFF BATES	6
JOE SOUTHERN	6	DUSTIN DAWES	6	JOE ROAM	6
MARKAS JACKSON	6	NESTOR HINOJOS	6	FRAN HOFFMAN	6
				STELE JAMES	6
				VINCE CALVARUZO	6
				JAMES KING	6
				DAVID BLACK	6

Chart No.	Time	Rate (BPM)	Volume (BBL/GAL)	Pmps		Press.(PSI)		Job Description / Remarks
				T	C	Tbg	Csg	
	0530							ON LOCATION - JSA
	0540		STAGE					SAFETY MEETING
	0555		VOL					SPOT TRUCKS
	0630		BH					RIGGED UP
	0730		GALLONS					HSE MEETING PRIME AND TEST
	0750							TEST LINES
	0848							START JOB
	0849	4.5	1593			432		FLUID EFFICENCY TEST
	0931	14.5	2016			665		MINI FRAC
	1117	14.6	2302			673		30 # WATERFRAC G PAD
	1121	14.7	3074			597		30# WATERFRAC G W/ 1/2 PPG SAND
	1126	14.3	3152			598		30# WATERFRAC G W/ 1 PPG SAND
	1131	13.8	3199			585		30# WATERFRAC G W/ 2 PPG SAND
	1136	12.9	3437			562		30# WATERFRAC G W 4 PPG SAND
	1142	11.9	2989			520		30# WATERFRAC G W 6 PPG SAND
	1146	11.1	3131			460		30# WATERFRAC G W/ 8 PPG SAND
	1151	10.4	5803			387		30# WATERFRAC G W 10 PPG SAND
	1200	13.1	154			324		30# WATERFRAC G FLUSH
	1200							END JOB
								AVG PSI 528
								MAX PSI 1249
								AVG RATE 13.8
								MAX RATE 17.3
								ISIP 132
								5 MIN 123
								10 MIN 120
								15 MIN 116
								LOAD 633 BBLs
								TOTAL SAND PUMPED 950SKS
	1215							POST JOB MEETING
	1400							RIG DOWN MOVE OFF

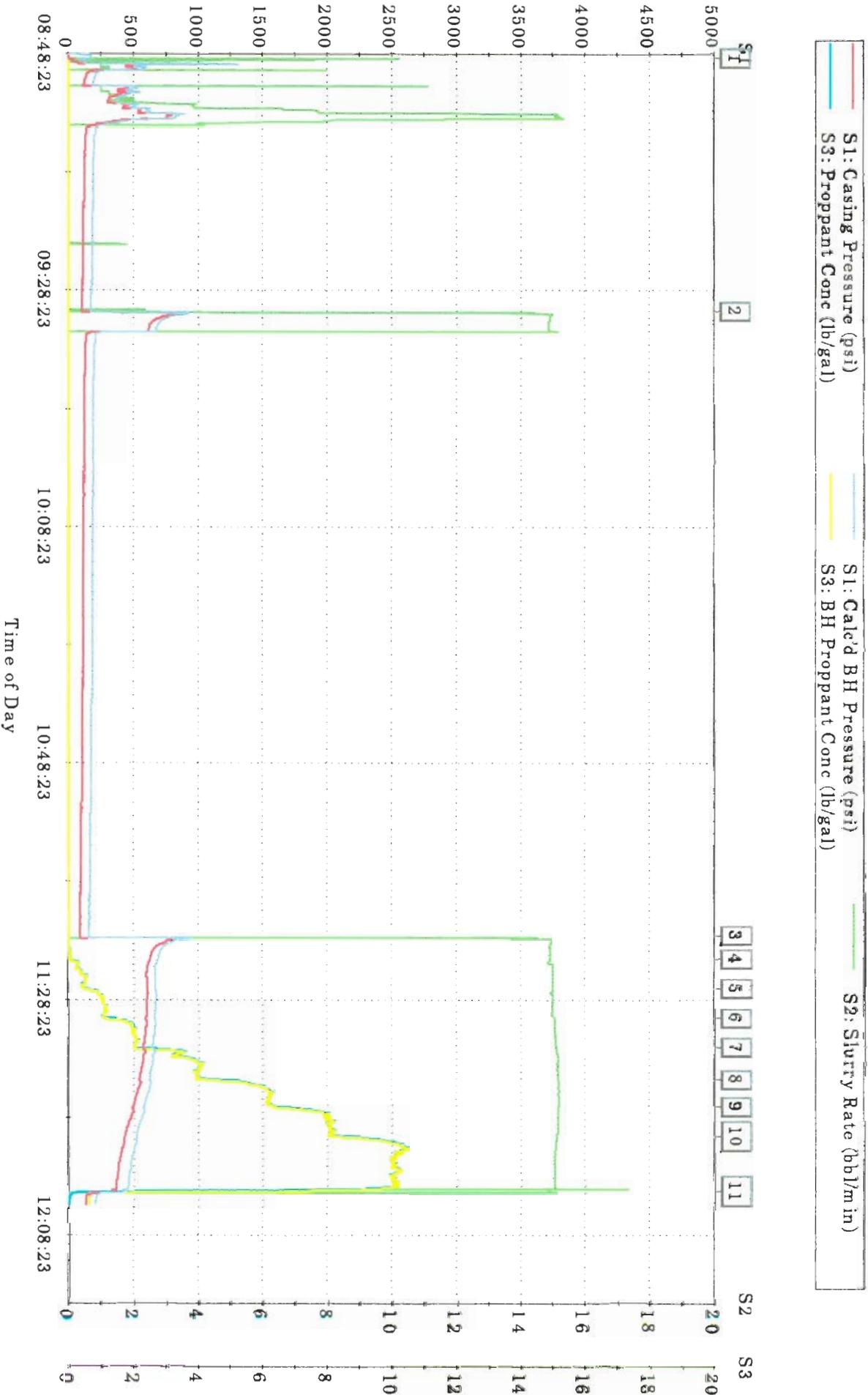
JOB LOG

JOB LOG		TICKET # 2660771	TICKET DATE 9/13/2003
FBM NA	MNA / COUNTRY CENTRAL AREA	BDA / STATE Missouri	COUNTY Vernon
MBU ID / EMPL # FS0501	H.E.S. EMPLOYEE NAME FS0501 106288 EARL BARBER	PSL DEPARTMENT PE / STIMULATION	
LOCATION Ft. Smith, Ar	COMPANY University Of Missouri-Rolla	CUSTOMER REP / PHONE SHERI DUNN NORMAN	
TICKET AMOUNT \$0.00	WELL TYPE GAS	API/UWI #	
WELL LOCATION Nevada	DEPARTMENT FRAC	JOB PURPOSE CODE 275	
LEASE / WELL # Cushard #1	SEC / TWP / RNG 0		

H.E.S. EMP NAME / EMP # / (EXPOSURE HOURS)	HRS	HRS	HRS	HRS			
EARL BARBER	6	GREG AYNES	6	DOLPH MATHIS	6	STELE JAMES	6
TOMMY CARR	6	DAVID HOLLAND	6	JEFF BATES	6	VINCE CALVARUZO	6
JOE SOUTHERN	6	DUSTIN DAWES	6	JOE ROAM	6	JAMES KING	6
MARKAS JACKSON	6	NESTOR HINOJOS	6	FRAN HOFFMAN	6	DAVID BLACK	6

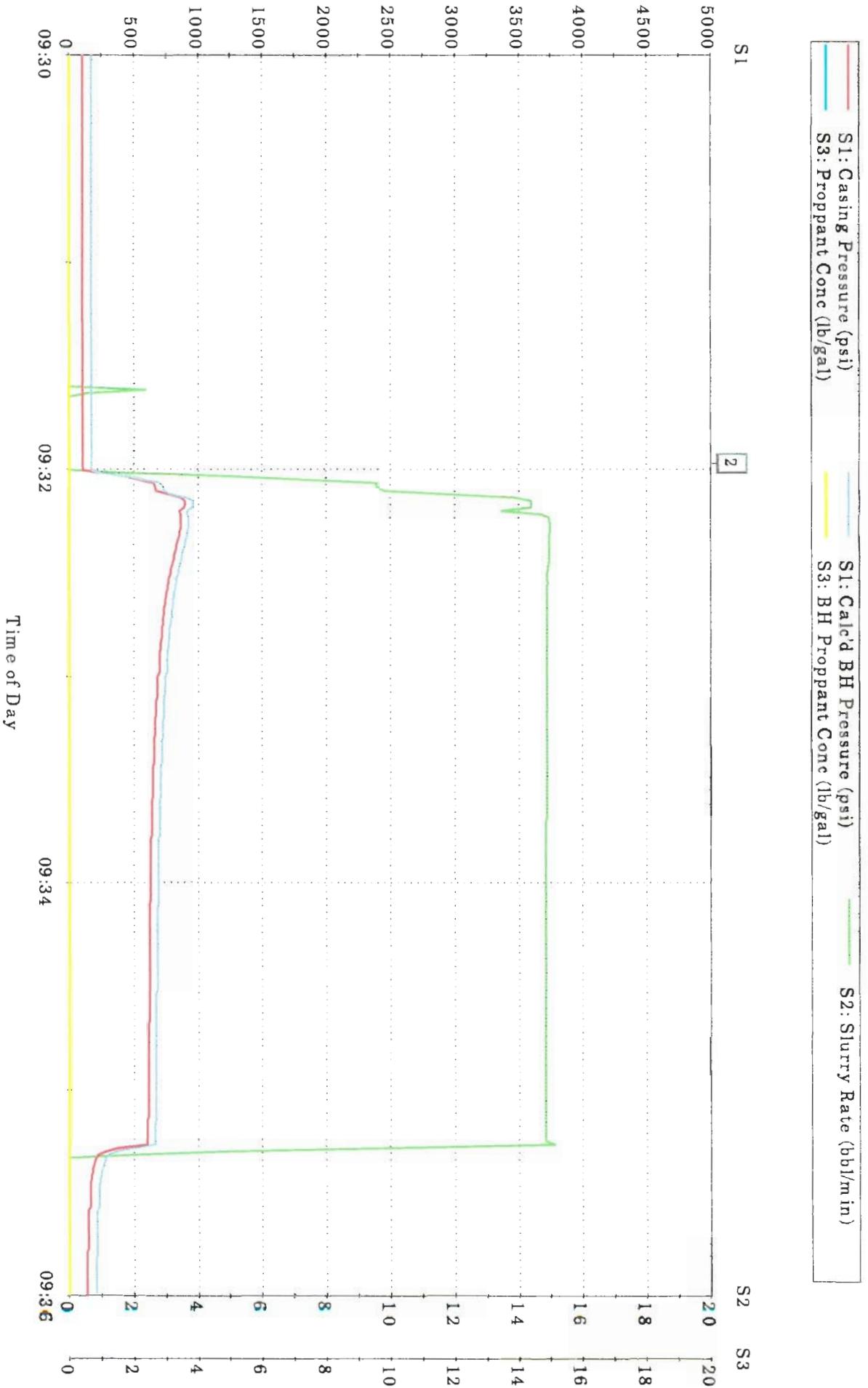
Chart No.	Time	Rate (BPM)	Volume (BBL)(GAL)	Prgps		Press.(PSI)		Job Description / Remarks
				T	C	Tbg	Csg	
	0530							ON LOCATION - JSA
	0540		STAGE					SAFETY MEETING
	0555		VOL					SPOT TRUCKS
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	0849	4.5	1593			432		FLUID EFFICENCY TEST
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								5 MIN 123
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								LOAD 633 BBLs
								TOTAL SAND PUMPED 950SKS
	1215							POST JOB MEETING
	1400							RIG DOWN MOVE OFF

FRAC DATA

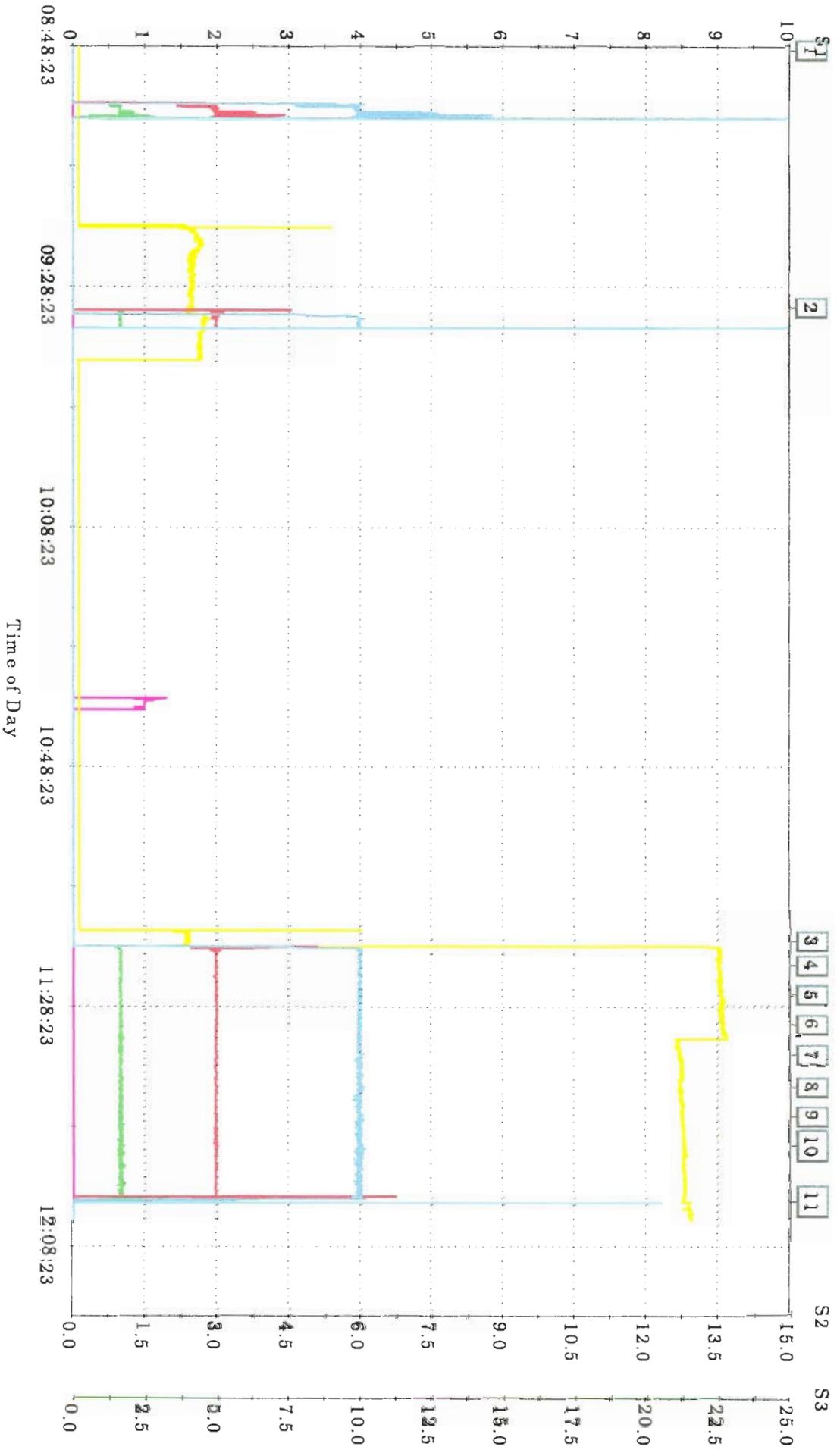


CUSTOMER: UNIV OF MISSOURI-ROLLA TICKET#: 2660771 DATE: Sat 13-Sep-03
 WELL DESC: CUSHARD 1 FORMATION: WARNER SANDSTONE

MINI FRAC



CUSTOMER: UNIV OF MISSOURI-ROLLA TICKET: 2660771 DATE: Sat 13-Sep-03
 WELL DESC: CUSHARD 1 FORMATION: WARNER SANDSTONE



S1: Bidr 1 CLAYFIX-2 (ga/l/1000) S1: Bidr 1 HPH (ga/l/1000)
 S2: Bidr 1 BC-140 (ga/l/1000) S2: Bidr 1 LOSURF (ga/l/1000)
 S3: Skid 2 Viscosity (cp)

CUSTOMER: UNIV OF MISSOURI-ROLLA TICKET: 2660771 DATE: Sat 13-Sep-03
 WELL DESC: CUSHARD 1 FORMATION: WARNER SANDSTONE

Customer: UNIV OF MISSOURI-ROLLA **Date:** 13-Sep-2003
Well Desc.: 1 **Ticket #:** 2660771
Formation: WARNER SANDSTONE **Job Type:** 30# WATERFRAC G

This report is based on sound engineering practices, but because of variable well conditions and other information which must be relied on, Halliburton makes no warranty, expressed or implied, as to the accuracy of the data or of any calculations or opinions expressed herein. You agree that Halliburton shall not be liable for any loss or damage, whether due to negligence or otherwise arising out of or in connection with such data, calculations or opinions.

**HALLIBURTON ENERGY SERVICES
SOLUTIONS IN ACTION!**

Time	Description
08:48:22	Start Job Saturday September 13, 2003
08:49:08	Stage Change Stage 1 - FET
09:31:58	Stage Change Stage 2 - PAD WATERFRAC G
09:52:26	SHUTDOWN MINIFRAC ANALYSIS 9.35 AM
11:17:34	Stage Change Stage 3 - PAD WATERFRAC G
11:21:42	Stage Change Stage 4 - PLF WATERFRAC G .5 PPG
11:26:35	Stage Change Stage 5 - PLF WATERFRAC G 1 PPG
11:31:37	Stage Change Stage 6 - PLF WATERFRAC G 2 PPG
11:36:40	Stage Change Stage 7 - PLF WATERFRAC G 4 PPG
11:42:05	Stage Change Stage 8 - PLF WATERFRAC G 6 PPG
11:46:48	Stage Change Stage 9 - PLF WATERFRAC G 8 PPG
11:51:44	Stage Change Stage 10 - PLF WATERFRAC G 10 PPG
12:00:56	Stage Change Stage 11 - WATERFRAC G FLUSH
12:17:03	End Job

Volumes

Stage	Job Slurry Vol gal	Stage Slurry Vol gal	Stage Clean Vol gal	Job Clean Vol gal
1	1593.2	1593.2	1593.2	1593.2
2	3609.6	2016.4	2016.4	3609.6
3	5901.2	2302.0	2299.2	5898.5
4	8964.8	3074.1	3017.9	8906.4
5	12127.4	3152.2	3010.2	11927.0
6	15326.3	3199.0	2936.2	14863.6
7	18763.2	3437.0	2932.7	17797.0
8	21752.2	2989.0	2345.4	20143.1
9	24883.7	3131.4	2298.1	22441.8
10	30686.7	5803.0	4004.8	26444.4
11	30851.9	154.8	151.7	26605.8
Totals:	(30851.9)	(30851.9)	(26605.7)	(26605.8)

Mass

Stage	Job Proppant Pumped sack	Stage Proppant Pumped sack	Proppant In Formation sack	Proppant In Wellbore sack
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0
3	0.6	0.6	0.5	0.1
4	12.8	12.3	12.1	0.7
5	43.9	31.1	42.7	1.3
6	101.5	57.6	99.3	2.2
7	211.9	110.6	207.6	4.3
8	352.9	141.1	347.1	5.8
9	535.5	182.7	528.4	7.1
10	930.4	394.3	925.9	4.4
11	931.2	0.7	930.9	0.3
Totals:	(931.2)	(931.2)	(930.9)	(0.3)

Pressure

Stage	Casing Pressure psi (avg/max)	Calc'd BH Pressure psi (avg/max)
1	432 / 1249	497 / 1316
2	665 / 901	725 / 962
3	673 / 877	733 / 938
4	597 / 616	660 / 678
5	598 / 603	663 / 668
6	585 / 599	655 / 667
7	562 / 589	638 / 664
8	520 / 551	603 / 632
9	460 / 492	548 / 579
10	387 / 428	480 / 520
11	324 / 351	396 / 425
Totals:	(528/1249)	(600/1316)

Rate

Stage	Clean Rate	Slurry Rate
	bbbl/min (avg/max)	bbbl/min (avg/max)
1	4.5 / 15.4	4.5 / 15.4
2	14.5 / 15.2	14.5 / 15.2
3	14.6 / 14.9	14.6 / 14.9
4	14.7 / 14.8	14.9 / 15.0
5	14.3 / 14.5	15.0 / 15.0
6	13.8 / 14.1	15.0 / 15.1
7	12.9 / 13.6	15.1 / 15.1
8	11.9 / 12.3	15.1 / 15.2
9	11.1 / 11.6	15.1 / 15.1
10	10.4 / 14.0	15.0 / 17.3
11	13.1 / 15.0	13.4 / 15.1
Totals:	(12.3/15.4)	(13.8/17.3)

STAGE 1	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	500.0	1593.2	Treating Pressure Avg/Max (psi)	432 / 1249	432 / 1249
Slurry Volume (gal)	500.0	1593.2	BHTP Avg/Max (psi)	497 / 1316	497 / 1316
Start Fluid Rate (bbl/min)	15.0	1.6	Total Avg. Rate (bbl/min)	4.5	4.5
End Fluid Rate (bbl/min)	15.0	0.0	Avg. HHP (hp)	59.0	
Friction Model	WG-19				
Description : FET					

STAGE 2	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	2000.0	2016.4	Treating Pressure Avg/Max (psi)	665 / 901	665 / 901
Slurry Volume (gal)	2000.0	2016.4	BHTP Avg/Max (psi)	725 / 962	725 / 962
Start Fluid Rate (bbl/min)	15.0	0.0	Total Avg. Rate (bbl/min)	14.5	14.5
End Fluid Rate (bbl/min)	15.0	0.0	Avg. HHP (hp)	238.1	
Friction Model	WG-19				
Description : PAD WATERFRAC G					

STAGE 3	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	2000.0	2299.2	Treating Pressure Avg/Max (psi)	673 / 877	673 / 877
Slurry Volume (gal)	2000.0	2302.0	BHTP Avg/Max (psi)	733 / 938	733 / 938
Start Fluid Rate (bbl/min)	15.0	0.0	Total Avg. Rate (bbl/min)	14.6	14.6
End Fluid Rate (bbl/min)	15.0	14.9	Avg. HHP (hp)	242.1	
Friction Model	WG-19				
Description : PAD WATERFRAC G					

STAGE 4	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	3017.9	Treating Pressure Avg/Max (psi)	597 / 616	597 / 616
Slurry Volume (gal)	3068.4	3074.1	BHTP Avg/Max (psi)	660 / 678	660 / 678
Start Fluid Rate (bbl/min)	15.0	14.9	Total Avg. Rate (bbl/min)	14.9	14.9
End Fluid Rate (bbl/min)	15.0	15.0	Avg. HHP (hp)	218.6	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	68.7	
Start Conc (lb/gal)	0.50	0.13	Avg. Prop Concentration (lb/gal)	0.41	0.39
End Conc (lb/gal)	0.50	0.69	Prop in Formation (lb)	1212.0	
Friction Model	WG-19				
Description : PLF WATERFRAC G .5 PPG					

STAGE 5	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	3010.2	Treating Pressure Avg/Max (psi)	598 / 603	598 / 603
Slurry Volume (gal)	3136.8	3152.2	BHTP Avg/Max (psi)	663 / 668	663 / 668
Start Fluid Rate (bbl/min)	15.0	15.0	Total Avg. Rate (bbl/min)	15.0	15.0
End Fluid Rate (bbl/min)	15.0	15.0	Avg. HHP (hp)	219.2	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	125.2	
Start Conc (lb/gal)	1.00	0.69	Avg. Prop Concentration (lb/gal)	1.03	1.02
End Conc (lb/gal)	1.00	1.23	Prop in Formation (lb)	4269.8	
Friction Model	WG-19				
Description : PLF WATERFRAC G 1 PPG					

STAGE 6	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	2936.2	Treating Pressure Avg/Max (psi)	585 / 599	585 / 599
Slurry Volume (gal)	3273.6	3199.0	BHTP Avg/Max (psi)	655 / 667	655 / 667
Start Fluid Rate (bbl/min)	15.0	15.0	Total Avg. Rate (bbl/min)	15.0	15.0
End Fluid Rate (bbl/min)	15.0	15.1	Avg. HHP (hp)	215.7	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	221.0	
Start Conc (lb/gal)	2.00	1.40	Avg. Prop Concentration (lb/gal)	1.96	1.93
End Conc (lb/gal)	2.00	2.32	Prop in Formation (lb)	9927.3	
Friction Model	WG-19				
Description : PLF WATERFRAC G 2 PPG					

STAGE 7	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	2932.7	Treating Pressure Avg/Max (psi)	562 / 589	562 / 589
Slurry Volume (gal)	3547.2	3437.0	BHTP Avg/Max (psi)	638 / 664	638 / 664
Start Fluid Rate (bbl/min)	15.0	15.1	Total Avg. Rate (bbl/min)	15.1	15.1
End Fluid Rate (bbl/min)	15.0	15.1	Avg. HHP (hp)	208.2	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	426.5	
Start Conc (lb/gal)	4.00	2.35	Avg. Prop Concentration (lb/gal)	3.77	3.69
End Conc (lb/gal)	4.00	4.62	Prop in Formation (lb)	20763.0	
Friction Model	WG-19				
Description : PLF WATERFRAC G 4 PPG					

STAGE 8	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	2345.4	Treating Pressure Avg/Max (psi)	521 / 551	521 / 551
Slurry Volume (gal)	3820.8	2989.0	BHTP Avg/Max (psi)	604 / 632	604 / 632
Start Fluid Rate (bbl/min)	15.0	15.1	Total Avg. Rate (bbl/min)	15.1	15.1
End Fluid Rate (bbl/min)	15.0	15.1	Avg. HHP (hp)	193.3	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	580.7	
Start Conc (lb/gal)	6.00	4.62	Avg. Prop Concentration (lb/gal)	6.01	5.94
End Conc (lb/gal)	6.00	6.67	Prop in Formation (lb)	34709.3	
Friction Model	WG-19				
Description : PLF WATERFRAC G 6 PPG					

STAGE 9	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	2298.1	Treating Pressure Avg/Max (psi)	460 / 492	460 / 492
Slurry Volume (gal)	4094.4	3131.4	BHTP Avg/Max (psi)	548 / 579	548 / 579
Start Fluid Rate (bbl/min)	15.0	15.1	Total Avg. Rate (bbl/min)	15.1	15.1
End Fluid Rate (bbl/min)	15.0	15.1	Avg. HHP (hp)	170.3	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	711.2	
Start Conc (lb/gal)	8.00	6.70	Avg. Prop Concentration (lb/gal)	7.95	7.87
End Conc (lb/gal)	8.00	8.73	Prop in Formation (lb)	52840.2	
Friction Model	WG-19				
Description : PLF WATERFRAC G 8 PPG					

STAGE 10	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	4004.8	Treating Pressure Avg/Max (psi)	388 / 428	388 / 428
Slurry Volume (gal)	4368.0	5803.0	BHTP Avg/Max (psi)	480 / 520	480 / 520
Start Fluid Rate (bbl/min)	15.0	15.1	Total Avg. Rate (bbl/min)	15.0	15.0
End Fluid Rate (bbl/min)	15.0	14.9	Avg. HHP (hp)	142.7	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	444.5	
Start Conc (lb/gal)	10.00	8.77	Avg. Prop Concentration (lb/gal)	9.89	9.96
End Conc (lb/gal)	10.00	1.98	Prop in Formation (lb)	92590.9	
Friction Model	WG-19				
Description : PLF WATERFRAC G 10 PPG					

STAGE II	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	108.0	151.7	Treating Pressure Avg/Max (psi)	326 / 351	326 / 351
Slurry Volume (gal)	108.0	154.8	BHTP Avg/Max (psi)	398 / 427	398 / 427
Start Fluid Rate (bbl/min)	15.0	14.9	Total Avg. Rate (bbl/min)	13.4	13.4
End Fluid Rate (bbl/min)	15.0	0.0	Avg. HHP (hp)	112.2	
None	None	0.00000 (gal/lb)	Prop in Wellbore (lb)	31.8	
Start Conc (lb/gal)	0.00	1.28	Avg. Prop Concentration (lb/gal)	0.46	3.21
End Conc (lb/gal)	0.00	0.00	Prop in Formation (lb)	93086.6	
Friction Model	WG-19				
Description : WATERFRAC G FLUSH					

Initial Conditions

<i>Treatment Parameters</i>	Job Type	30# WATERFRAC G
	Well Treated Down	Casing
	Static Column Used	NO
	Earth Temperature	70.0 f
	Slurry Temperature	69.0 f
	BHTT	60.0 f
	Reservoir Pressure	50 psi
	Expected BHTP	200 psi
<i>Initial Wellbore Data</i>	Wellbore fluid	Gel
	Density	8.33 lb/gal
	n-prime	0.4585
	K-prime	0.021500 lb*sec ⁿ /ft ²
<i>Perf Data</i>	Number of	61
	Diameter	0.500 in
	Disch. Coeff	0.600

Wellbore Data

Wellbore Segment Number	Actual Length (ft)	TVD (ft)	Casing ID (in)	Casing OD (in)	Tubing ID (in)	Tubing OD (in)
1	164	164	4.052	4.500	0.000	0.000

Time of Day	Casing Pressure psi	Slurry Rate bbl/min	Proppant Conc lb/gal	BH Proppant Conc lb/gal	Job Slurry Vol gal	Stage Slurry Vol gal	Job Clean Vol gal
08:48:23	0	0.0	0.00	0.00	0.0	0.0	0.0
08:49:23	32	7.6	0.00	0.00	40.2	40.2	40.2
08:50:23	439	1.0	0.00	0.00	79.4	79.4	79.4
08:51:23	156	0.0	0.00	0.00	125.3	125.3	125.3
08:52:23	130	0.0	0.00	0.00	125.3	125.3	125.3
08:53:23	117	0.0	0.00	0.00	125.3	125.3	125.3
08:54:23	381	1.0	0.00	0.00	168.4	168.4	168.4
08:55:23	350	1.5	0.00	0.00	219.8	219.8	219.8
08:56:23	302	1.5	0.00	0.00	290.8	290.8	290.8
08:57:23	418	3.9	0.00	0.00	427.8	427.8	427.8
08:58:23	837	13.9	0.00	0.00	728.6	728.6	728.6
08:59:23	521	11.6	0.00	0.00	1331.2	1331.2	1331.2
09:00:23	187	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:01:23	136	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:02:23	131	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:03:23	129	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:04:23	126	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:05:23	125	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:06:23	124	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:07:23	123	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:08:23	122	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:09:23	120	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:10:23	121	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:11:23	119	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:12:23	117	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:13:23	116	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:14:23	116	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:15:23	116	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:16:23	116	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:17:23	115	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:18:23	113	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:19:23	113	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:20:23	113	0.0	0.00	0.00	1589.7	1589.7	1589.7
09:21:23	112	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:22:23	111	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:23:23	110	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:24:23	108	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:25:23	109	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:26:23	108	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:27:23	108	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:28:23	108	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:29:23	106	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:30:23	106	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:31:23	106	0.0	0.00	0.00	1591.1	1591.1	1591.1
09:32:23	828	14.9	0.00	0.00	1790.7	197.6	1790.7
09:33:23	656	14.9	0.00	0.00	2416.3	823.1	2416.3
09:34:23	622	14.9	0.00	0.00	3040.7	1447.5	3040.7
09:35:23	186	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:36:23	136	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:37:23	133	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:38:23	130	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:39:23	130	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:40:23	127	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:41:23	126	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:42:23	127	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:43:23	125	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:44:23	124	0.0	0.00	0.00	3609.6	2016.4	3609.6

Time of Day	Casing Pressure psi	Slurry Rate bbl/min	Proppant Conc lb/gal	BH Proppant Conc lb/gal	Job Slurry Vol gal	Stage Slurry Vol gal	Job Clean Vol gal
09:45:23	124	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:46:23	123	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:47:23	123	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:48:23	122	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:49:23	122	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:50:23	121	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:51:23	120	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:52:23	118	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:53:23	119	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:54:23	120	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:55:23	118	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:56:23	117	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:57:23	117	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:58:23	117	0.0	0.00	0.00	3609.6	2016.4	3609.6
09:59:23	116	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:00:23	116	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:01:23	116	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:02:23	116	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:03:23	116	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:04:23	115	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:05:23	115	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:06:23	116	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:07:23	115	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:08:23	116	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:09:23	114	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:10:23	115	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:11:23	114	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:12:23	114	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:13:23	113	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:14:23	113	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:15:23	112	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:16:23	113	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:17:23	113	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:18:23	112	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:19:23	112	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:20:23	111	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:21:23	112	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:22:23	112	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:23:23	111	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:24:23	111	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:25:23	111	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:26:23	111	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:27:23	111	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:28:23	109	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:29:23	108	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:30:23	109	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:31:23	108	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:32:23	108	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:33:23	108	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:34:23	109	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:35:23	108	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:36:23	108	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:37:23	106	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:38:23	108	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:39:23	107	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:40:23	106	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:41:23	105	0.0	0.00	0.00	3609.6	2016.4	3609.6

Time of Day	Casing Pressure psi	Slurry Rate bbl/min	Proppant Conc lb/gal	BH Proppant Conc lb/gal	Job Slurry Vol gal	Stage Slurry Vol gal	Job Clean Vol gal
10:42:23	105	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:43:23	105	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:44:23	104	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:45:23	104	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:46:23	104	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:47:23	102	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:48:23	101	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:49:23	102	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:50:23	102	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:51:23	100	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:52:23	101	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:53:23	100	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:54:23	100	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:55:23	100	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:56:23	99	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:57:23	98	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:58:23	98	0.0	0.00	0.00	3609.6	2016.4	3609.6
10:59:23	98	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:00:23	97	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:01:23	97	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:02:23	97	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:03:23	96	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:04:23	94	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:05:23	95	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:06:23	95	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:07:23	92	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:08:23	92	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:09:23	92	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:10:23	92	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:11:23	90	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:12:23	91	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:13:23	90	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:14:23	91	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:15:23	88	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:16:23	88	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:17:23	87	0.0	0.00	0.00	3609.6	2016.4	3609.6
11:18:23	777	14.9	0.00	0.00	3849.0	239.4	3849.0
11:19:23	670	14.9	0.00	0.00	4474.6	865.0	4474.6
11:20:23	634	14.9	0.06	0.00	5099.1	1489.5	5098.4
11:21:23	621	14.9	0.11	0.06	5724.1	2114.5	5721.9
11:22:23	606	14.8	0.28	0.28	6347.8	436.2	6339.8
11:23:23	595	15.0	0.37	0.33	6975.9	1064.3	6959.8
11:24:23	592	15.0	0.55	0.55	7604.1	1692.4	7575.6
11:25:23	595	15.0	0.49	0.51	8232.1	2320.5	8189.0
11:26:23	593	15.0	0.58	0.46	8860.1	2948.5	8804.6
11:27:23	602	14.9	0.92	0.90	9487.9	502.1	9410.4
11:28:23	600	15.0	1.06	1.02	10115.9	1130.1	10010.3
11:29:23	601	15.0	1.09	1.06	10744.4	1758.7	10610.1
11:30:23	595	15.0	1.11	1.16	11373.0	2387.2	11207.8
11:31:23	591	15.0	1.06	1.02	12001.5	3015.8	11807.3
11:32:23	597	15.0	1.90	1.77	12632.0	494.1	12395.9
11:33:23	590	15.0	2.03	1.98	13262.7	1124.8	12974.7
11:34:23	584	15.0	2.01	2.06	13851.9	1714.0	13514.9
11:35:23	579	15.0	2.16	2.08	14525.6	2387.7	14130.8
11:36:23	574	15.1	2.06	1.98	15157.6	3019.7	14709.4
11:37:23	587	15.1	3.50	3.59	15791.1	454.3	15268.8
11:38:23	571	15.1	3.76	3.62	16425.4	1088.5	15818.2

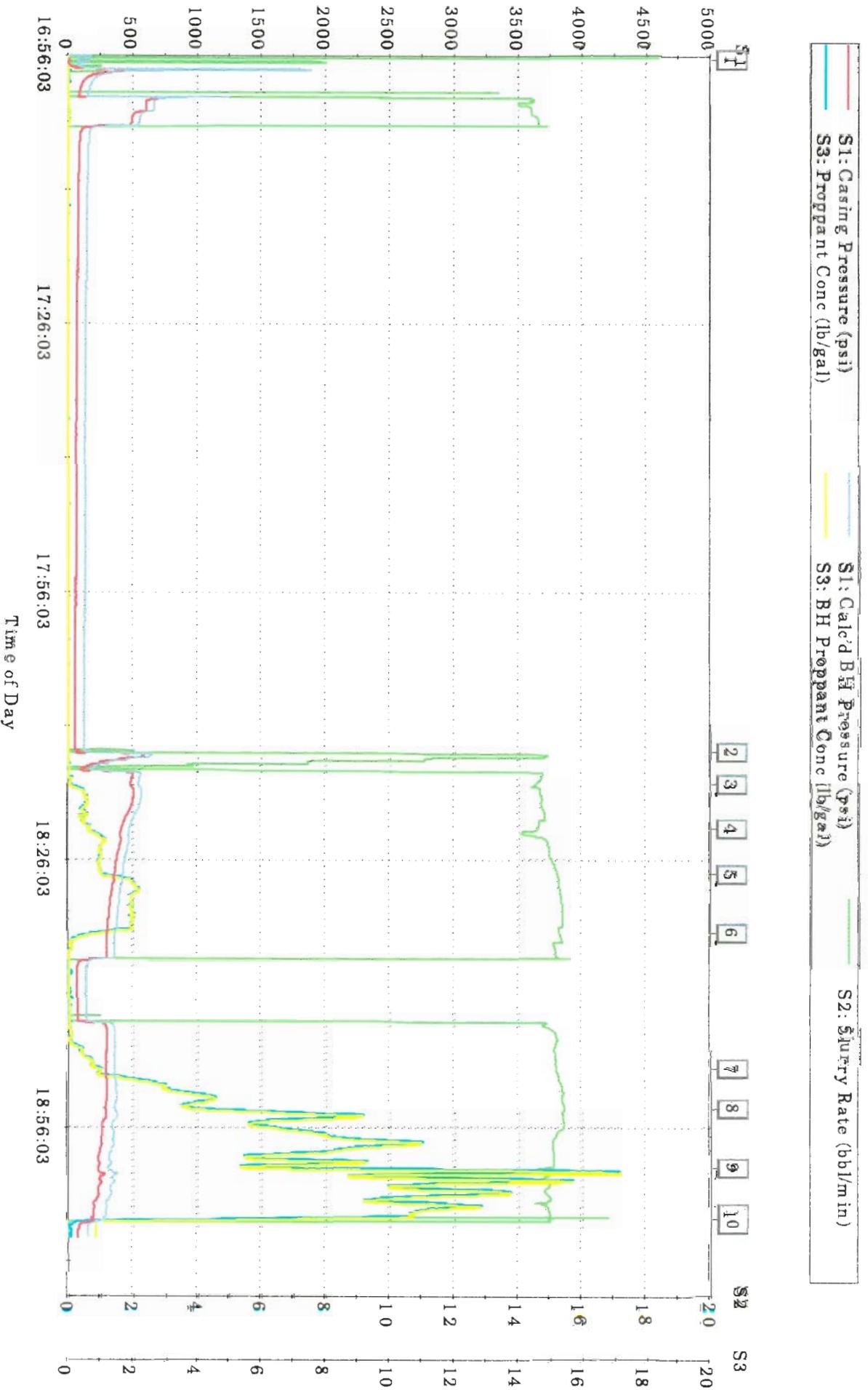
Time of Day	Casing Pressure psi	Slurry Rate bbl/min	Proppant Conc lb/gal	BH Proppant Conc lb/gal	Job Slurry Vol gal	Stage Slurry Vol gal	Job Clean Vol gal
11:39:23	563	15.1	3.99	4.11	17060.4	1723.5	16356.6
11:40:23	553	15.1	4.02	3.96	17694.8	2357.9	16893.2
11:41:23	544	15.1	3.90	3.93	18329.5	2992.6	17431.5
11:42:23	549	15.1	5.44	5.09	18964.5	190.5	17960.2
11:43:23	534	15.1	6.04	5.97	19600.3	826.4	18463.6
11:44:23	521	15.1	6.18	6.25	20236.1	1462.2	18960.3
11:45:23	508	15.2	6.18	6.08	20872.0	2098.1	19456.9
11:46:23	495	15.2	6.21	6.21	21508.3	2734.5	19954.0
11:47:23	492	15.1	7.70	7.47	22144.1	381.3	20437.4
11:48:23	475	15.1	8.02	8.02	22778.9	1016.0	20903.4
11:49:23	456	15.1	7.94	8.06	23413.5	1650.7	21368.0
11:50:23	441	15.1	8.14	8.02	24048.2	2285.4	21832.6
11:51:23	429	15.1	8.02	7.98	24682.8	2919.9	22296.1
11:52:23	426	15.1	9.75	9.61	25305.9	411.7	22737.6
11:53:23	414	15.0	10.27	10.31	25948.9	1054.7	23177.5
11:54:23	402	15.0	10.36	10.07	26580.5	1686.4	23607.2
11:55:23	389	15.0	9.93	10.07	27211.8	2317.6	24039.5
11:56:23	383	15.0	10.07	10.03	27842.8	2948.6	24472.6
11:57:23	379	15.0	10.22	10.12	28473.5	3579.3	24904.6
11:58:23	370	15.0	9.93	9.93	29104.7	4210.5	25337.2
11:59:23	364	15.0	10.12	10.07	29735.6	4841.4	25769.8
12:00:23	361	15.0	9.43	9.84	30366.5	5472.3	26202.7
12:01:23	146	0.0	0.04	0.62	30851.9	154.8	26605.8
12:02:23	131	0.0	0.00	0.62	30851.9	154.8	26605.8
12:03:23	129	0.0	0.00	0.62	30851.9	154.8	26605.8
12:04:23	125	0.0	0.00	0.62	30851.9	154.8	26605.8
12:05:23	125	0.0	0.00	0.62	30851.9	154.8	26605.8
12:06:23	123	0.0	0.00	0.62	30851.9	154.8	26605.8
12:07:23	123	0.0	0.00	0.62	30851.9	154.8	26605.8
12:08:23	123	0.0	0.00	0.62	30851.9	154.8	26605.8
12:09:23	120	0.0	0.00	0.62	30851.9	154.8	26605.8
12:10:23	119	0.0	0.00	0.62	30851.9	154.8	26605.8
12:11:23	120	0.0	0.00	0.62	30851.9	154.8	26605.8
12:12:23	117	0.0	0.00	0.62	30851.9	154.8	26605.8
12:13:23	119	0.0	0.00	0.62	30851.9	154.8	26605.8
12:14:23	118	0.0	0.00	0.62	30851.9	154.8	26605.8

 HALLIBURTON		JOB LOG		TICKET # 2,660,781	TICKET DATE 9/13/2003
FBM NA	NWA / COUNTRY CENTRAL AREA	BDA / STATE Missouri	COUNTY Vernon		
MBU ID / EMPL # FS0501	H.E.S. EMPLOYEE NAME FS0501 106288 EARL BARBER	PSL DEPARTMENT PE / STIMULATION			
LOCATION Ft. Smith, Ar	COMPANY University Of Missouri-Rolla	CUSTOMER REP / PHONE Sheri Dunn Norman			
TICKET AMOUNT	WELL TYPE GAS	API/UWI #			
WELL LOCATION Nevada	DEPARTMENT FRAC	JOB PURPOSE CODE 275			
LEASE / WELL # Cushard	SEC / TWP / RNG #5				

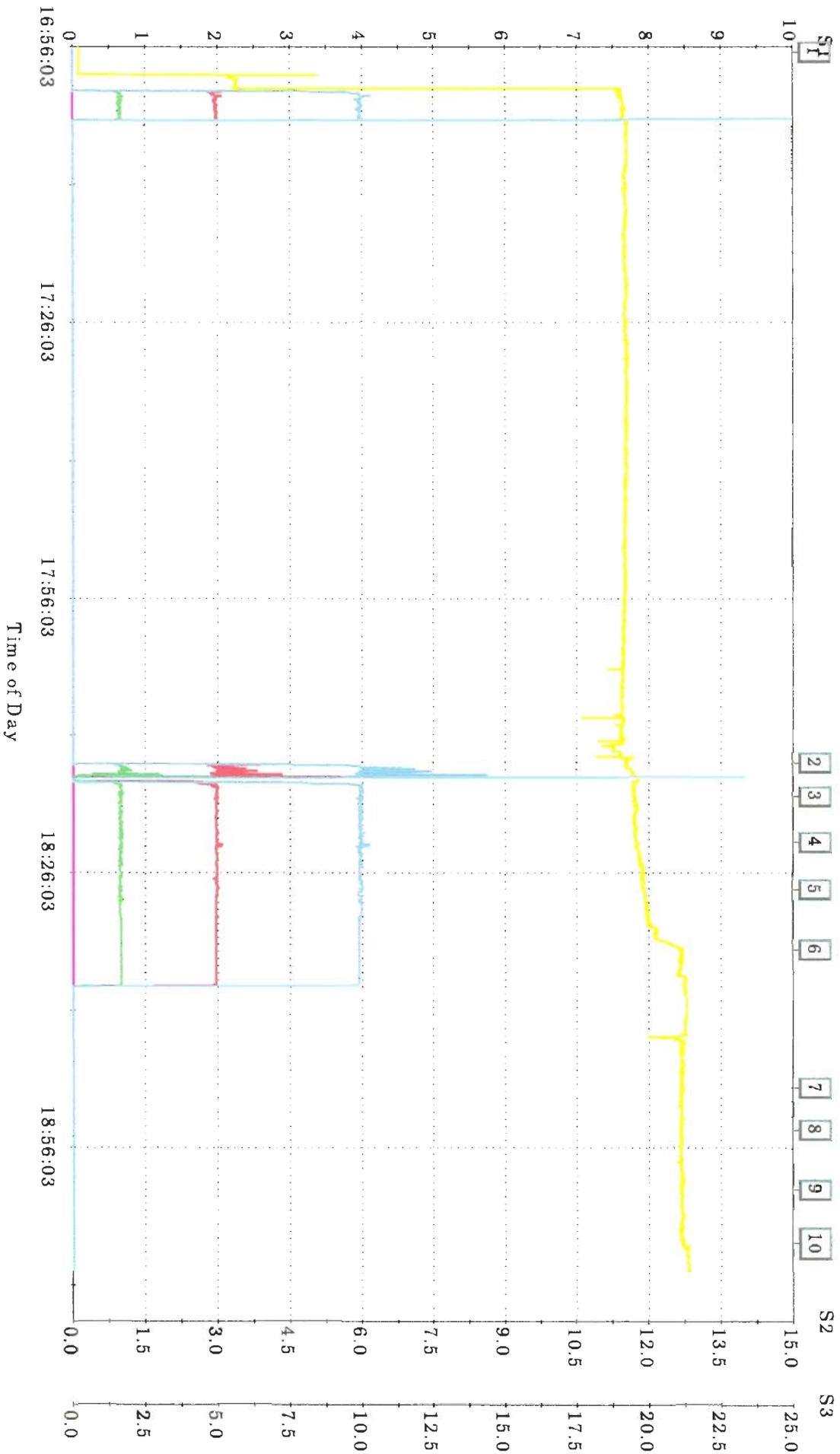
H.E.S. EMP NAME / EMP # / (EXPOSURE HOURS)	HRS	HRS	HRS	HRS			
EARL BARBER	6	GREG AYNES	6	DOLPH MATHIS	6	STELE JAMES	6
TOMMY CARR	6	DAVID HOLLAND	6	JEFF BATES	6	VINCE CALVARUZO	6
JOE SOUTHERN	6	DUSTIN DAWES	6	JOE ROAM	6	JAMES KING	6
MARKAS JACKSON	6	NESTOR HINOJOS	6	FRAN HOFFMAN	6	DAVID BLACK	6

Chart No.	Time	Rate (BPM)	Volume (BBL)(GAL)	Pmp		Press. (PSI)		Job Description / Remarks
				T	C	Tbg	Cog	
	1300							ON LOCATION - JSA
	1310		STAGE					SAFETY MEETING
	1330		VOL					SPOT TRUCKS
	1630		BH					RIGGED UP
	1640		GALLONS					HSE MEETING PRIME AND TEST
								TEST LINES
	1656							START JOB
	1656	11.2	2,065			509		FLUID EFFICENCY TEST
	1814	11.6	1,635			400		30 # WATERFRAC G PAD
	1817	14.7	3,065			466		30# WATERFRAC G W/ 1/2 PPG SAND
	1822	14.9	3,204			381		30# WATERFRAC G W/ 1 PPG SAND
	1827	15.3	4,245			320		30# WATERFRAC G W/ 2 PPG SAND
	1834	14.9	5,190			288		30# WATERFRAC G W 4 PPG SAND
	1849	15.3	2,906			291		30# WATERFRAC G W 6 PPG SAND
	1854	15.2	4,140			253		30# WATERFRAC G W/ 8 PPG SAND
	1900	14.9	3,659			219		30# WATERFRAC G W 10 PPG SAND
	1906	14.1	149			183		30# WATERFRAC G FLUSH
	1907							END JOB
								AVG PSI
								MAX PSI
								AVG RATE
								MAX RATE
								ISIP 82
								5 MIN 67
								10 MIN 65
								15 MIN 64
								LOAD 643 BBLs
								TOTAL SAND PUMPED 710 SKS
	1920							POST JOB MEETING
	2100							RIG DOWN MOVE OFF

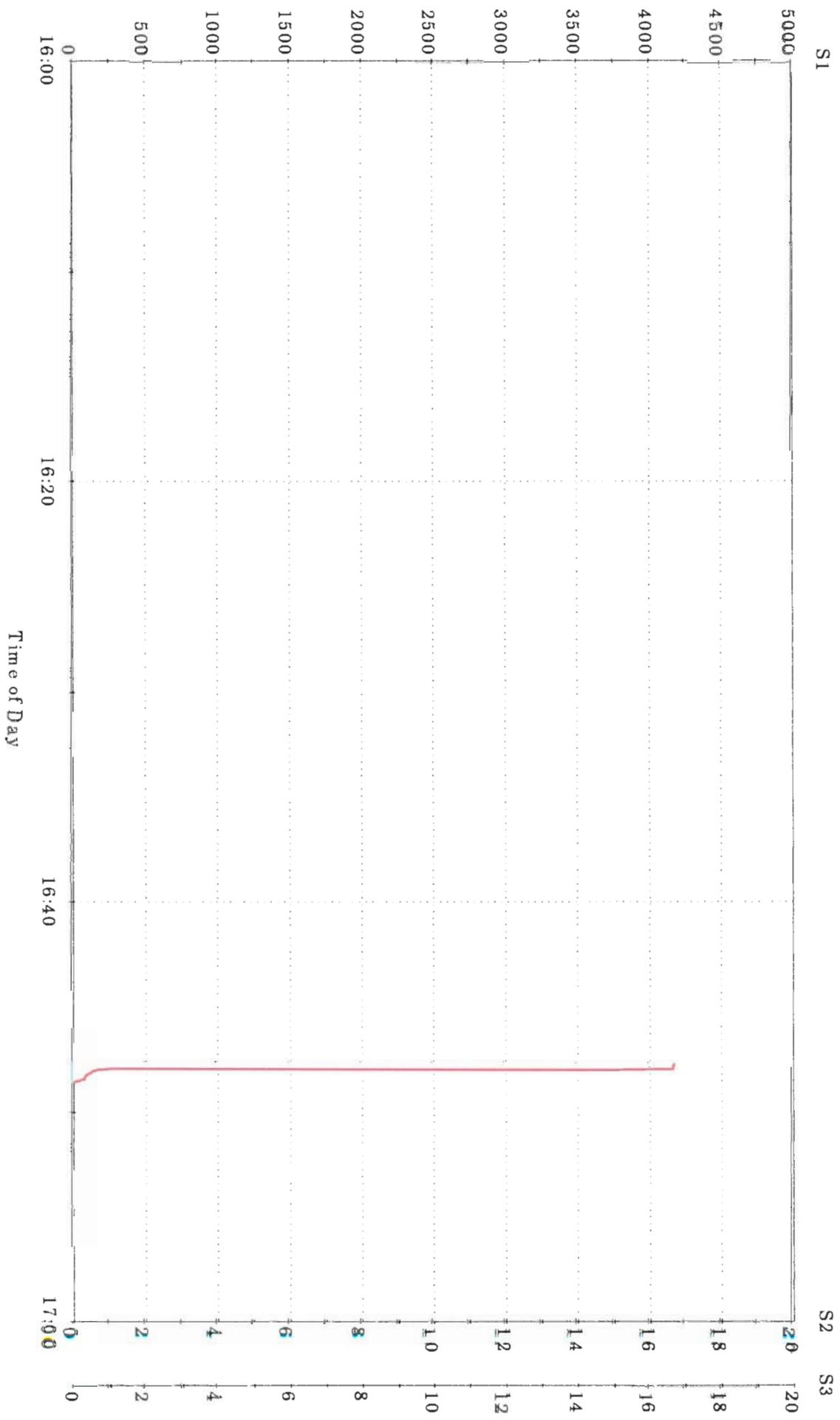
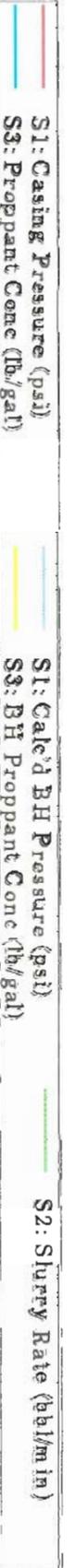
FRAC DATA



CUSTOMER: UNIVERSITY OF MISSOURI-ROLLA TICKET#: 2660781 DATE: Sat 13-Sep-03
 WELL DESC: CUSHARD #5 FORMATION: WARNER



CUSTOMER: UNIVERSITY OF MISSOURI-ROLLA TICKET: 2660781 DATE: Sat 13-Sep-03
 WELL DESC: CUSHARD #5 FORMATION: WARNER



CUSTOMER: UNIVERSITY OF MISSOURI-ROLLA TICKET: 2660781
 WELL DESC: CUSHARD #5 FORMATION: WARNER

Customer: UNIVERSITY OF MISSOURI-ROLLA **Date:** 13-Sep-2003
Well Desc.: #5 **Ticket #:** 2660781
Formation: WARNER **Job Type:** WATERFRAC G

This report is based on sound engineering practices, but because of variable well conditions and other information which must be relied on, Halliburton makes no warranty, expressed or implied, as to the accuracy of the data or of any calculations or opinions expressed herein. You agree that Halliburton shall not be liable for any loss or damage, whether due to negligence or otherwise arising out of or in connection with such data, calculations or opinions.

**HALLIBURTON ENERGY SERVICES
SOLUTIONS IN ACTION!**

Time	Description
16:56:03	Start Job Saturday September 13, 2003
16:56:36	Stage Change Stage 1 - FET WATERFRAC G
18:14:04	Stage Change Stage 2 - WATERFRAC G PAD
18:17:43	Stage Change Stage 3 - WATERFRAC G PLF .5 PPG
18:22:41	Stage Change Stage 4 - WATERFRAC G PLF 1 PPG
18:27:49	Stage Change Stage 5 - WATERFRAC G PLF 2 PPG
18:34:25	Stage Change Stage 6 - WATERFRAC G PLF 4 PPG
18:49:34	Stage Change Stage 7 - WATERFRAC G PLF 6 PPG
18:54:05	Stage Change Stage 8 - WATERFRAC G PLF 8 PPG
19:00:35	Stage Change Stage 9 - WATERFRAC G PLF 10 PPG
19:06:26	Stage Change Stage 10 - WATERFRAC G FLUSH
19:22:47	End Job

Volumes

Stage	Job Slurry Vol gal	Stage Slurry Vol gal	Stage Clean Vol gal	Job Clean Vol gal
1	2065.7	2065.7	2064.3	2064.3
2	3701.5	1635.8	1633.9	3698.2
3	6767.4	3065.8	2998.0	6696.1
4	9966.9	3204.8	3069.1	9760.3
5	14211.8	4245.0	3908.3	13668.3
6	19402.6	5190.8	5131.4	18799.8
7	22314.6	2906.6	2559.1	21364.0
8	26450.1	4140.7	3086.5	24446.6
9	30109.9	3654.6	2424.7	26875.2
10	30259.0	149.1	144.5	27019.8
Totals:	(30259.0)	(30259.0)	(27019.8)	(27019.8)

Mass

Stage	Job Proppant Pumped sack	Stage Proppant Pumped sack	Proppant In Formation sack	Proppant In Wellbore sack
1	0.3	0.3	0.3	0.0
2	0.7	0.4	0.6	0.1
3	15.6	14.9	14.9	0.7
4	45.3	29.8	44.1	1.2
5	119.2	73.8	118.3	0.9
6	132.2	13.0	131.1	1.1
7	208.5	76.2	203.9	4.6
8	439.3	231.2	433.9	5.5
9	709.3	269.7	705.4	3.9
10	710.4	1.0	709.8	0.6
Totals:	(710.4)	(710.4)	(709.8)	(0.6)

Pressure

Stage	Casing Pressure psi (avg/max)	Calc'd BH Pressure psi (avg/max)
1	509 / 1790	564 / 1891
2	400 / 587	463 / 647
3	466 / 503	529 / 566
4	381 / 405	446 / 470
5	320 / 352	388 / 419
6	288 / 299	349 / 359
7	291 / 296	362 / 373
8	253 / 288	338 / 377
9	219 / 280	313 / 377
10	183 / 188	251 / 262
Totals:	(331/1790)	(400/1891)

Rate

Stage	Clean Rate	Slurry Rate
	bbbl/min (avg/max)	bbbl/min (avg/max)
1	11.2 / 15.0	11.2 / 15.0
2	11.6 / 14.9	11.6 / 14.9
3	14.4 / 14.6	14.7 / 14.8
4	14.3 / 14.5	14.9 / 15.2
5	14.1 / 14.9	15.3 / 15.4
6	14.7 / 15.6	14.9 / 15.6
7	13.5 / 14.6	15.3 / 15.4
8	11.3 / 12.3	15.2 / 15.4
9	9.8 / 13.4	14.9 / 16.8
10	13.6 / 14.7	14.1 / 15.0
Totals:	(12.8/15.6)	(14.2/16.8)

STAGE 1	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	1500.0	2064.3	Treating Pressure Avg/Max (psi)	509 / 1790	509 / 1790
Slurry Volume (gal)	1500.0	2065.7	BHTP Avg/Max (psi)	564 / 1891	564 / 1891
Start Fluid Rate (bbl/min)	15.0	0.0	Total Avg. Rate (bbl/min)	11.2	11.2
End Fluid Rate (bbl/min)	15.0	3.1	Avg. HHP (hp)	150.3	
Friction Model	WG-19				
Description : FET WATERFRAC G					

STAGE 2	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	1000.0	1633.9	Treating Pressure Avg/Max (psi)	400 / 587	400 / 587
Slurry Volume (gal)	1000.0	1635.8	BHTP Avg/Max (psi)	463 / 647	463 / 647
Start Fluid Rate (bbl/min)	15.0	5.7	Total Avg. Rate (bbl/min)	11.6	11.6
End Fluid Rate (bbl/min)	15.0	14.5	Avg. HHP (hp)	127.4	
Friction Model	WG-19				
Description : WATERFRAC G PAD					

STAGE 3	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	2998.0	Treating Pressure Avg/Max (psi)	466 / 503	466 / 503
Slurry Volume (gal)	3068.4	3065.8	BHTP Avg/Max (psi)	528 / 566	528 / 566
Start Fluid Rate (bbl/min)	15.0	14.5	Total Avg. Rate (bbl/min)	14.7	14.7
End Fluid Rate (bbl/min)	15.0	14.6	Avg. HHP (hp)	167.8	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	69.9	
Start Conc (lb/gal)	0.50	0.15	Avg. Prop Concentration (lb/gal)	0.50	0.48
End Conc (lb/gal)	0.50	0.58	Prop in Formation (lb)	1492.6	
Friction Model	WG-19				
Description : WATERFRAC G PLF .5 PPG					

STAGE 4	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	3069.1	Treating Pressure Avg/Max (psi)	381 / 405	381 / 405
Slurry Volume (gal)	3136.8	3204.8	BHTP Avg/Max (psi)	446 / 470	446 / 470
Start Fluid Rate (bbl/min)	15.0	14.6	Total Avg. Rate (bbl/min)	14.9	14.9
End Fluid Rate (bbl/min)	15.0	15.2	Avg. HHP (hp)	139.0	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	124.6	
Start Conc (lb/gal)	1.00	0.60	Avg. Prop Concentration (lb/gal)	0.97	0.95
End Conc (lb/gal)	1.00	1.30	Prop in Formation (lb)	4407.6	
Friction Model	WG-19				
Description : WATERFRAC G PLF 1 PPG					

STAGE 5	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	3908.3	Treating Pressure Avg/Max (psi)	320 / 352	320 / 352
Slurry Volume (gal)	3273.6	4245.0	BHTP Avg/Max (psi)	388 / 419	388 / 419
Start Fluid Rate (bbl/min)	15.0	15.2	Total Avg. Rate (bbl/min)	15.3	15.3
End Fluid Rate (bbl/min)	15.0	15.3	Avg. HHP (hp)	120.2	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	88.1	
Start Conc (lb/gal)	2.00	1.30	Avg. Prop Concentration (lb/gal)	1.89	1.90
End Conc (lb/gal)	2.00	0.55	Prop in Formation (lb)	11831.7	
Friction Model	WG-19				
Description : WATERFRAC G PLF 2 PPG					

STAGE 6	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	5131.4	Treating Pressure Avg/Max (psi)	288 / 299	288 / 299
Slurry Volume (gal)	3547.2	5190.8	BHTP Avg/Max (psi)	349 / 359	349 / 359
Start Fluid Rate (bbl/min)	15.0	15.3	Total Avg. Rate (bbl/min)	14.9	14.9
End Fluid Rate (bbl/min)	15.0	15.2	Avg. HHP (hp)	106.2	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	112.7	
Start Conc (lb/gal)	4.00	0.53	Avg. Prop Concentration (lb/gal)	0.30	0.29
End Conc (lb/gal)	4.00	1.04	Prop in Formation (lb)	13107.2	
Friction Model	WG-19				
Description : WATERFRAC G PLF 4 PPG					

STAGE 7	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	2559.1	Treating Pressure Avg/Max (psi)	291 / 296	291 / 296
Slurry Volume (gal)	3820.8	2906.6	BHTP Avg/Max (psi)	362 / 373	362 / 373
Start Fluid Rate (bbl/min)	15.0	15.2	Total Avg. Rate (bbl/min)	15.3	15.3
End Fluid Rate (bbl/min)	15.0	15.4	Avg. HHP (hp)	108.9	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	456.9	
Start Conc (lb/gal)	6.00	1.02	Avg. Prop Concentration (lb/gal)	3.03	2.89
End Conc (lb/gal)	6.00	5.38	Prop in Formation (lb)	20388.4	
Friction Model	WG-19				
Description : WATERFRAC G PLF 6 PPG					

STAGE 8	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	3086.5	Treating Pressure Avg/Max (psi)	253 / 288	253 / 288
Slurry Volume (gal)	4094.4	4140.7	BHTP Avg/Max (psi)	338 / 377	338 / 377
Start Fluid Rate (bbl/min)	15.0	15.4	Total Avg. Rate (bbl/min)	15.2	15.2
End Fluid Rate (bbl/min)	15.0	14.9	Avg. HHP (hp)	94.2	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	548.4	
Start Conc (lb/gal)	8.00	5.44	Avg. Prop Concentration (lb/gal)	7.58	7.54
End Conc (lb/gal)	8.00	6.99	Prop in Formation (lb)	43386.6	
Friction Model	WG-19				
Description : WATERFRAC G PLF 8 PPG					

STAGE 9	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	3000.0	2424.7	Treating Pressure Avg/Max (psi)	219 / 280	219 / 280
Slurry Volume (gal)	4368.0	3654.6	BHTP Avg/Max (psi)	313 / 377	313 / 377
Start Fluid Rate (bbl/min)	15.0	14.8	Total Avg. Rate (bbl/min)	14.9	14.9
End Fluid Rate (bbl/min)	15.0	14.9	Avg. HHP (hp)	79.7	
Sand	20/40	0.04560 (gal/lb)	Prop in Wellbore (lb)	394.5	
Start Conc (lb/gal)	10.00	7.06	Avg. Prop Concentration (lb/gal)	11.32	11.38
End Conc (lb/gal)	10.00	2.01	Prop in Formation (lb)	70540.0	
Friction Model	WG-19				
Description : WATERFRAC G PLF 10 PPG					

STAGE 10	Planned	Actual	SUMMARY	@Surface	@Perfs
Clean Volume (gal)	108.0	144.5	Treating Pressure Avg/Max (psi)	183 / 188	183 / 188
Slurry Volume (gal)	108.0	149.1	BHTP Avg/Max (psi)	251 / 261	251 / 261
Start Fluid Rate (bbl/min)	15.0	14.9	Total Avg. Rate (bbl/min)	14.0	14.0
End Fluid Rate (bbl/min)	15.0	0.0	Avg. HHP (hp)	63.1	
None	None	0.00000 (gal/lb)	Prop in Wellbore (lb)	56.2	
Start Conc (lb/gal)	0.00	1.83	Avg. Prop Concentration (lb/gal)	0.67	3.08
End Conc (lb/gal)	0.00	0.00	Prop in Formation (lb)	70979.5	
Friction Model	WG-19				
Description : WATERFRAC G FLUSH					

Initial Conditions

<i>Treatment Parameters</i>	Job Type	WATERFRAC G
	Well Treated Down	Casing
	Static Column Used	NO
	Earth Temperature	70.0 f
	Slurry Temperature	69.0 f
	BHTT	70.0 f
	Reservoir Pressure	100 psi
	Expected BHTP	150 psi
<i>Initial Wellbore Data</i>	Wellbore fluid	WG-19
	Density	8.33 lb/gal
	n-prime	0.7951
	K-prime	0.000265 lb*sec^n/ft^2
<i>Perf Data</i>	Number of	61
	Diameter	0.500 in
	Disch. Coeff	0.600

Wellbore Data

Wellbore Segment Number	Actual Length (ft)	TVD (ft)	Casing ID (in)	Casing OD (in)	Tubing ID (in)	Tubing OD (in)
1	162	162	4.052	4.500	0.000	0.000

Time of Day	Casing Pressure	Slurry Rate	Proppant Conc	BH Proppant Conc	Job Slurry Vol	Stage Slurry Vol	Job Clean Vol
	psi	bbl/min	lb/gal	lb/gal	gal	gal	gal
16:56:03	-28	0.0	0.00	0.00	0.0	0.0	0.0
16:57:03	12	0.0	0.00	0.00	32.5	32.5	32.5
16:58:03	237	0.0	0.00	0.00	60.5	60.5	60.5
16:59:03	114	0.0	0.06	0.00	60.5	60.5	60.5
17:00:03	91	0.0	0.00	0.00	60.5	60.5	60.5
17:01:03	614	14.4	0.00	0.00	293.3	293.3	293.3
17:02:03	605	14.4	0.02	0.00	891.9	891.9	891.4
17:03:03	495	14.6	0.00	0.00	1500.2	1500.2	1499.2
17:04:03	148	0.0	0.02	0.00	2058.0	2058.0	2056.6
17:05:03	94	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:06:03	89	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:07:03	86	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:08:03	85	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:09:03	83	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:10:03	83	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:11:03	80	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:12:03	80	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:13:03	77	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:14:03	76	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:15:03	76	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:16:03	76	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:17:03	75	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:18:03	75	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:19:03	74	0.0	0.04	0.00	2058.0	2058.0	2056.6
17:20:03	73	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:21:03	73	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:22:03	72	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:23:03	73	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:24:03	71	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:25:03	70	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:26:03	69	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:27:03	70	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:28:03	68	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:29:03	68	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:30:03	68	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:31:03	68	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:32:03	67	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:33:03	66	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:34:03	66	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:35:03	64	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:36:03	66	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:37:03	65	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:38:03	64	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:39:03	64	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:40:03	63	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:41:03	63	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:42:03	62	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:43:03	62	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:44:03	61	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:45:03	62	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:46:03	60	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:47:03	61	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:48:03	60	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:49:03	60	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:50:03	60	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:51:03	58	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:52:03	58	0.0	0.00	0.00	2058.0	2058.0	2056.6

Time of Day	Casing Pressure psi	Slurry Rate bbl/min	Proppant Conc lb/gal	BH Proppant Conc lb/gal	Job Slurry Vol gal	Stage Slurry Vol gal	Job Clean Vol gal
17:53:03	58	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:54:03	59	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:55:03	56	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:56:03	56	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:57:03	56	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:58:03	55	0.0	0.00	0.00	2058.0	2058.0	2056.6
17:59:03	56	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:00:03	55	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:01:03	54	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:02:03	53	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:03:03	53	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:04:03	52	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:05:03	51	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:06:03	53	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:07:03	52	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:08:03	52	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:09:03	51	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:10:03	51	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:11:03	51	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:12:03	48	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:13:03	47	0.0	0.00	0.00	2058.0	2058.0	2056.6
18:14:03	113	3.1	0.00	0.00	2065.7	2065.7	2064.3
18:15:03	265	7.5	0.00	0.00	2575.8	510.1	2574.3
18:16:03	138	6.2	0.00	0.00	2723.7	657.9	2722.1
18:17:03	484	14.7	0.04	0.09	3302.5	1236.8	3300.2
18:18:03	495	14.6	0.46	0.26	3914.6	213.1	3908.6
18:19:03	499	14.7	0.58	0.60	4531.1	829.6	4511.1
18:20:03	483	14.7	0.44	0.53	5149.1	1447.6	5114.3
18:21:03	447	14.8	0.37	0.60	5769.2	2067.7	5721.4
18:22:03	419	14.6	0.55	0.51	6389.0	2687.5	6328.2
18:23:03	399	14.2	0.81	0.64	6999.2	231.8	6920.9
18:24:03	403	14.9	1.09	1.11	7610.0	842.7	7504.4
18:25:03	385	15.0	0.97	0.97	8237.1	1469.8	8104.4
18:26:03	370	15.0	0.92	0.99	8865.8	2098.4	8706.1
18:27:03	358	15.1	0.95	0.95	9499.4	2732.0	9313.6
18:28:03	348	15.2	1.67	1.43	10137.4	165.2	9920.0
18:29:03	335	15.3	2.08	2.03	10778.2	806.0	10507.9
18:30:03	325	15.3	1.90	2.01	11420.2	1448.0	11094.0
18:31:03	317	15.4	1.95	1.90	12064.0	2091.8	11685.4
18:32:03	312	15.4	1.98	1.98	12708.9	2736.6	12277.7
18:33:03	307	15.4	1.95	1.98	13354.2	3382.0	12869.7
18:34:03	300	15.3	1.28	1.83	13998.1	4025.9	13463.2
18:35:03	294	15.3	0.11	0.13	14640.2	423.0	14091.5
18:36:03	298	15.1	0.06	0.11	15278.4	1061.2	14726.6
18:37:03	296	15.2	0.02	0.04	15914.7	1697.5	15362.4
18:38:03	72	0.0	0.00	0.02	16017.3	1800.1	15464.9
18:39:03	70	0.0	0.02	0.02	16017.3	1800.1	15464.9
18:40:03	68	0.0	0.02	0.02	16017.3	1800.1	15464.9
18:41:03	67	0.0	0.02	0.02	16017.3	1800.1	15464.9
18:42:03	68	0.0	0.02	0.02	16017.3	1800.1	15464.9
18:43:03	66	0.0	0.00	0.02	16017.3	1800.1	15464.9
18:44:03	65	0.0	0.02	0.02	16018.0	1800.8	15465.6
18:45:03	292	15.0	0.06	0.00	16554.8	2337.6	16001.6
18:46:03	298	15.2	0.00	0.00	17188.6	2971.4	16633.4
18:47:03	292	15.1	0.40	0.24	17825.1	3607.9	17265.9
18:48:03	288	15.1	0.53	0.46	18459.6	4242.4	17888.4
18:49:03	287	15.1	0.64	0.78	19095.2	4878.0	18504.3

Time of Day	Casing Pressure psi	Slurry Rate bbl/min	Proppant Conc lb/gal	BH Proppant Conc lb/gal	Job Slurry Vol gal	Stage Slurry Vol gal	Job Clean Vol gal
18:50:03	288	15.2	0.92	0.92	19731.5	323.6	19115.2
18:51:03	295	15.3	2.72	2.53	20371.0	963.0	19703.4
18:52:03	294	15.4	3.62	3.20	21014.2	1606.2	20267.9
18:53:03	291	15.3	4.17	4.35	21658.4	2250.5	20807.1
18:54:03	281	15.4	5.35	3.93	22303.8	2895.8	21355.4
18:55:03	279	15.4	7.10	8.56	22948.9	634.3	21832.9
18:56:03	257	15.4	6.53	6.21	23594.8	1280.2	22340.3
18:57:03	256	15.1	8.18	8.02	24235.0	1920.4	22816.4
18:58:03	252	15.0	9.71	10.74	24868.0	2553.3	23253.8
18:59:03	234	15.1	5.61	6.70	25500.5	3185.9	23718.2
19:00:03	239	15.1	7.59	9.25	26133.7	3819.1	24197.4
19:01:03	243	14.7	17.10	16.15	26757.6	302.3	24638.7
19:02:03	252	14.8	15.24	15.12	27381.1	925.8	25042.5
19:03:03	225	14.8	13.10	10.74	28006.8	1551.6	25455.1
19:04:03	218	15.0	9.48	10.27	28631.6	2176.4	25859.2
19:05:03	196	14.9	11.75	12.71	29256.1	2800.8	26274.4
19:06:03	188	15.0	9.57	10.60	29883.4	3428.1	26694.9
19:07:03	79	0.0	0.02	0.83	30259.0	149.1	27019.8
19:08:03	71	0.0	0.02	0.83	30259.0	149.1	27019.8
19:09:03	71	0.0	0.00	0.83	30259.0	149.1	27019.8
19:10:03	68	0.0	0.00	0.83	30259.0	149.1	27019.8
19:11:03	68	0.0	0.06	0.83	30259.0	149.1	27019.8
19:12:03	68	0.0	0.00	0.83	30259.0	149.1	27019.8
19:13:03	67	0.0	0.00	0.83	30259.0	149.1	27019.8
19:14:03	67	0.0	0.04	0.83	30259.0	149.1	27019.8
19:15:03	67	0.0	0.02	0.83	30259.0	149.1	27019.8