Evaluation of SE Jonah Prospect
T27N R107W
Sublette County, Wyoming

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Executive Summary

This report by Schlumberger Data and Consulting Services (DCS) summarizes the evaluation of the SE Jonah Prospect (Prospect), which covers 2,480 acres in T27N R107W, Sublette County, Wyoming (**Figure 1**). This report has been re-issued to Grid Petroleum (Grid). The Prospect is located 6 miles southeast of the prolific Jonah Field which has reserve estimates ranging from 8 to 15 TCF. Production in this field is from fluvial sandstones of the Late Cretaceous Lance and Mesaverde formations and Early Tertiary Fort Union Formation (**Figure 2**). The western part of the Prospect is included in the 19,290 acre Teakettle Federal Unit which was proposed by EnCana USA (EnCana) in 2005. At the present time it is uncertain if EnCana will move ahead with forming this unit. It is possible that they may be willing to entertain offers on their acreage position.

The objectives of this evaluation were to:

- Review existing seismic over the Prospect and make recommendations on possible purchase,
- Review the available maps, wells and seismic data to evaluate the feasibility of the Prospect,
- Undertake a data audit of available public data,
- Provide an evaluation of industry activity in and around the Prospect
- Review production from surrounding fields in the Lance Formation to determine potential production rates, original gas – in – place (OGIP) and estimated ultimate recoveries (EUR),
- Assess possible drilling locations based on available geological, geophysical and engineering data.
- Provide recommendations for additional data purchase and acquisition including seismic.

Based on the available geological and engineering data the SE Jonah Prospect has a good probability of encountering producible hydrocarbons. Many of the geological features and conditions are similar to those found at Jonah Field. The major difference between the Prospect and Jonah Field is the pressure gradient. In the area surrounding the Prospect the pressure gradient averages 0.65 psi/ft. At Jonah the pressure gradient averages 1.15 psi/ft after the base of the Fort Union and is responsible for the high production rates.

A SW-NE aligned anticlinal nose, which plunges toward the NE, and trends almost directly through the middle of the Teakettle unit at top of the Fort Union Coal Zone and Lance Formations. This feature is most prominent in the Sublette Flat #1 well (sec 7, T27N, R107W) and Sagebrush Federal #3-8 well (sec 8, T27N, R107W); both located within the northeastern part of the unit and on the acreage. Gross sand in the Lance Formation, which is the primary reservoir interval, exceeds 1000 feet in the Prospect. This area of higher gross sand thickness trends to the northwest through Jonah Field. A similar fluvial environment of channel sandstones with interbedded floodplain shales, which occurs at Jonah Field, is expected in the Prospect.

The OGIP and EUR on a ‘per well basis' were calculated for the Prospect by integrating the available geological, petrophysical and reservoir engineering data, and the results are presented in the following table.

Case	Gross Sand ft	Drainage acres	OGIP MMscf	Recovery Factor	EUR MMscf
Low - 10 acre	560	10	474	54%	256
Base – 10 acre	1000	10	1786	66%	1179
High – 10 acre	1720	10	6456	80%	5165
Low - 20 acre	560	20	949	42%	399
Base – 20 acre	1000	20	3572	57%	2036
High – 20 acre	1720	20	12912	70%	9038

The low, base and high cases (P10, P50 and P90) were calculated by varying the gross sand thickness and recovery factor. Gas reservoirs with no or low liquid production can commonly have recovery factors in excess of 80%. The values used for recovery factor in this evaluation are conservative. OGIP volumes for the acreage positions are provided in the following table for the current acreage of 2,480 acres and the entire Teakettle Unit which consists of 19,290 acres:

	SE Jonah Prospect			Teakettle Unit		
Case	**OGIP Bscf**	**Recovery Factor**	**EUR Bscf**	**OGIP Bscf**	**Recovery Factor**	**EUR Bscf**
Low	118	54%	63.7	915	54%	494.1
Base	443	66%	292.4	3445	66%	2273.7
High	1601	80%	1280.8	12,454	80%	9963.2

An analysis of the production and completion results in the Prospect and the surrounding area indicate that under-stimulation occurs in some of the wells. Optimized completions may result in higher initial productive rates and EURs.

Moving forward, the following recommendations and observations are being made for the Prospect:

- There is a good possibility of productive hydrocarbons being encountered in the Prospect and the surrounding area. The geological, petrophysical, and engineering conditions are similar to the giant Jonah Field. The one difference is the lower pressure gradient in the Prospect area, which will result in lower production rates.
- At the present time it is possible that Grid may be able to assist EnCana in promoting activity in the Teakettle Unit. This may allow Grid to secure a substantially larger position in the area.
- Additional seismic should be acquired over the Prospect either by purchase or shooting. This will allow for more subsurface control and better positioning of drilling locations
- At the present time it is difficult to make a firm drilling recommendation. While the Prospect is on a structural high it would be better to acquire and review the available seismic data before selecting a drilling location. Construction of a three dimensional property model that incorporates a more rigorous petrophysical evaluation would provide a more accurate assessment of OGIP and production.

A more detailed review of the geological, petrophysical and engineering data is presented in the following sections.

Geology

Introduction

The interval of interest for this study is the fluvial Cretaceous Lance Formation, which lies below the fluvial Tertiary Fort Union and inter-fingers at its base with the Cretaceous Mesaverde Formation. Maps and representative well-log cross sections are included with this study as PDF files in large format and are referred to in the following discussions.

A brief discussion of data, methods, and results of the geologic study is presented in the following sections.

Data and Methods

A model encompassing most of six (6) townships (T26 – 28N, R107 -108W) and excluding Jonah Field in the northeast part of the area was prepared in Petra® with data extracted from IHS and other vendors for well locations, tops, and Township/Range/Section data (Map 1). The outline of the acreage, the proposed Teakettle Unit and South Pass Shear Fault were added to the maps based on an EnCana map provided during the original evaluation.

Rasters (tiff images) of thirty-four (34) wells were available from MJ Systems and were input into mapping/correlation software from Petra (IHS). These wells formed the basis for this interpretation, maps, and net sand and are highlighted with a purple circle on all of the maps. A variety of logs were available, some penetrated only part of the formations mapped in this study, and some were not suitable for tabulating net sand (e.g., lithologic logs, and some gamma ray logs that appeared top be incorrectly calibrated). Stratigraphic cross sections A-A', B-B', and C-C' are located on the Base Map (**Map 1**) and are included as large size PDF files and one set of paper copies. Cross sections were datumed on the top of the Lance Formation to more explicitly show variation in thickness of the Lance Formation and variation of net sand content.

Tops for the Fort Union Coal Zone, the Lance and the Mesaverde formations were picked based on correlations with a well in southeast Jonah Field; 4-18

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Jonah Federal (NWNW sec 18, T28N, R108W). Not all wells were logged through the top of the Fort Union Coal Zone, and several wells did not penetrate the Mesaverde Formation, which meant that a Lance isopach could not be generated in these wells. All formation tops are best picks based on log character but tops are an interpretation by DCS and are subject to change. The variations of the tops data compiled by IHS are an indication of the difficulty of making picks from the logs in this area, but are consistent based the position of the Fort Union Coals, and the interval at the base of the Lance where Mesaverde shales become more prominent. There may be upside potential in Tertiary sands in the Fort Union, and within the Mesaverde, but these were not examined in this study.

Gross sand, defined as sand cleaner than a gamma ray cutoff of 75° API in most wells and 60° API in several wells where the calibration appeared to give too much clean sand, was counted in the Lance Formation. Gross sand was not counted in wells that did not penetrate the entire Lance Formation in order to eliminate the minimum thickness bias that would be imparted to the isopach maps.

Data posted around the well symbol are well name and top for all wells above the well symbol, and subsea structural elevation, isopach thickness, or gross sand thickness on the respective maps. Maps included are listed in **Table 1**.

Table 1: List of maps

Map	Description
Map 1	Basemap
Map 2	Structure at top Fort Union Coal Zone
Map 3	Structure at top Lance Formation
Map 4	Structure at top Mesaverde
Map 5	Fort Union Thickness Isopach
Map 6	Lance Formation Isopach
Map 7	Gross Sand Isopach, Lance Formation

Structure Maps

Subsea structure maps for the top of Fort Union Coals, Lance Formation, and Mesaverde Formation within the study area (**Maps 1**, **2** and **3**) show a basinward deepening from southwest toward the northeast. In general there is about 2200 feet of structural difference at the tops of both the Fort Union Coal Zone and Lance Formations (**Maps 1** and **2**), and 3500 feet of difference in the Mesaverde Formation (**Map 3**). The latter increase in structural difference reflects thickening of the Lance Formation toward the northeast (see also **Map 6**).

A SW-NE trending, NE plunging, anticlinal nose is an especially noticeable feature that breaks regional basinward dip is present on all of the maps, but more prominent at the top Fort Union and Lance formations. This anticlinal nose trends almost directly through the middle of the Teakettle unit on both maps, and is most prominent in the Sublette Flat #1 well (sec 7, T27N, R107W) and Sagebrush Federal #3-8 well (sec 8, T27N, R107W) within the northeastern part of the unit and on the acreage. The exact location of the South Pass Shear Fault may actually be a few miles northwest of where it is shown on the maps. Seismic data could be used to better define its location. In any case, the anticlinal nose can be defined from well control in the area. This nose is also present on the Mesaverde Formation structural map (**Map 3**), but is less prominent in the unit area It does, however, represent an area of change of dip direction into the basin.. A seismic line through this area confirms the presence of this nose.

Isopach maps

Isopach maps of the Fort Union Coal Zone (**top Fort Union Coal Zone to top Lance Formation-Map 5**), and Lance Formation (**top Lance Formation to top Mesaverde Formation-Map 6**) were prepared from the available data. The interval thicknesses are given in **Table 2**.

The Fort Union Coal Zone varies from about 930' to 1100' thick in wells with data. Thickness decreases from southwest to northeast on the map, probably reflecting decreasing thickness of continental environments toward the basin during deposition. In the same vicinity of the anticlinal nose on the Fort Union and Lance structure maps, there is a thinning of the Fort Union Coal Zone. This could be a reflection of deposition over a growing anticlinal structure during the Laramide Orogeny, or could be a result of mis-picks in these wells.

The Lance Formation thickness isopach (**Map 6**) shows thickening of roughly 100+ feet per mile toward the north-northeast. This reflects both interfingering of the continental fluvial Lance Formation with the marine Mesaverde Formation, and greater basin subsidence toward the northeast during Lance deposition. Additionally, the Lance is thinner toward the southeast, possibly reflecting movement along the fault shown on the maps.

Gross Sand

Total gross sand for the Lance Formation varies from 585 feet to 1737 feet in wells (**Table 2**). The lowest gross sand values occur south and west of the Teakettle unit, and the greatest is just northeast of the unit and the acreage position. Most wells within the Teakettle Unit did not penetrate the full thickness of the Lance and for this reason were not tabulated. However, Sagebrush Federal 3-8 located on the acreage has over 1000 feet of net sand and based on the contours much of the Teakettle Unit has over 800 feet of sand that meet the gross sand cutoff criteria of 60° or 75° API units. Just northeast of the unit, gross sand reaches its greatest thickness of over 1700 feet. Note that some of these wells with the greatest gross sand thickness were counted with more stringent 60°API because of questionable calibrations based on log character and could actually be higher.

The trend of thick sand fairways and thin sand in Jonah Field are northwest to southeast based on much denser data (see AAPG Studies 52/RMAG 2004 Guidebook)[1]. Fluvial channels flowed generally from northwest to southeast and preferential deposition in channel belts created the NW-SE trending fairways. This trend is not apparent on the data in the acreage, but may be an artifact of contouring widely spaced well data.

Production and Reservoir Engineering

The objectives of this production and reservoir engineering review were to:

- Audit the available public data,
- Provide an evaluation of industry activity in and around the Prospect
- Review production from surrounding fields in the Lance Formation to determine potential production rates, gas-in-place (GIP) and estimated ultimate recoveries (EUR),
- Provide recommendations for additional data requirements.

Figure 1 shows the prospect area with surrounding wells. **Tables 3** and **4** are summaries of the original gas-in-place (OGIP) and estimate ultimate recovery (EUR) for the Prospect and also the Teakettle Unit based on the engineering review and technical literature. **Figures 3** and **4** show the detailed properties used to compute these values. Note that net (potential pay) sand thickness varies from 35-50% of gross sand (**Tables 3** and **4**). The use of net sand in the calculation will directly result in lower EUR values.

Table 3: Summary GIP and EUR values:

Case	Gross Sand ft	Drainage acres	OGIP MMscf	Recovery Factor	EUR MMscf
Low - 10 acre	560	10	474	54%	256
Base – 10 acre	1000	10	1786	66%	1179
High – 10 acre	1720	10	6456	80%	5165
Low - 20 acre	560	20	949	42%	399
Base – 20 acre	1000	20	3572	57%	2036
High – 20 acre	1720	20	12912	70%	9038

Table 4: Summaries of OGIP and EUR for the Prospect (current acreage) and Teakettle Unit

	Current Acreage			**Teakettle Unit**		
Case	OGIP Bscf	Recovery Factor	EUR Bscf	OGIP Bscf	Recovery Factor	EUR Bscf
Low	118	54%	63.7	915	54%	494.1
Base	443	66%	292.4	3445	66%	2273.7
High	1601	80%	1280.8	12,454	80%	9963.2

Data Audit

Public data used in this review were obtained from the Wyoming Oil and Gas Commission and a subscription database for production and well data. Public data from the state of Wyoming was available from http://wogcc.state.wy.us/. The production and well data subscriptions are available from PI/Dwights Plus (IHS Energy).

Subscription production and well data from PI/Dwights was the origin of the production database in *Oilfield Manager** (OFM). The OFM database contains well locations of producing, exploratory, abandoned and permitted wells in the area. The production data was reviewed and subsequently used for decline curve analysis (DCA).

The Wyoming Oil and Gas (WOG) site provided additional well reports, several core data reports and pressure data from drill stem tests (DST). Data and forms downloaded from the WOG site are available electronically.

Four (4) DSTs exist in the WOG public records for the study area; however, none are in the actual Prospect area. Furthermore, many pressure tests were not utilizing tight-gas sand testing concepts, so the results were not useful (i.e. testing times never left wellbore storage). However, two drill stem tests in the general study area did provide suitable pressure data to provide ranges for the analysis. The pressures from these two wells (Jonah Gulch 1and Golden Rod 1) are shown in **Figure 5** and indicate the area is slightly over-pressured in the

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Lance Formation. The pressure model for the Jonah area is plotted for reference purposes.

Five (5) wells with core data were found in the general study area; however, none in the actual prospect area. These files were in pdf format and were initially only visually reviewed. Three (3) core report files were converted to obtain depth versus porosity and porosity versus permeability charts and to investigate potential relationships. The depth versus porosity graph for the Jonah Federal 2-5 well is shown in **Figure 6**. The porosity-permeability plot is shown in **Figure 7**. Both figures show different values at different net overburden (NOB) or net confining pressures. **Figure 8** for the Hacienda 6-19 well shows depth versus porosity for the Lance sands. **Figure 9** shows depth versus porosity for the Lance and deeper Mesaverde sands for the Cabrito 30-30 well. These values fit with the petrophysical analysis performed by DCS for this well.

Original Gas-In-Place Estimates

The original gas-in-place (OGIP) estimation was performed by integrating the available geological, petrophysical and reservoir engineering data. Where property distribution data were available, the P10 value was used for the low case, the P50 value was used for the average case and the P90 values was used for the high case of OGIP (**Figures 3** and **4**). When property distributions were not available, ranges of the properties from literature were used to be able provide low and high estimates of OGIP.

During the geological review, gross sand values were determined from analysis in Petra software. The gross sand values for wells in the prospect area were utilized in conjunction with the petrophysical analysis to determine OGIP. **Figure 10** shows the gross sand in the Lance as a cumulative probability plot.

Petrophysical analysis was performed on the Hacienda 6-19 well which is northwest of the acreage. This well was chosen because it provided the most comprehensive data set. The ranges of pay for porosity and water saturation were used as ranges in the OGIP calculations. **Figure 11** is a cumulative probability plot of the porosity distribution calculated from the petrophysical analysis. **Figure 12** is a cumulative probability plot of the water saturation distribution calculated from the petrophysical analysis. Cutoffs for pay were 4.5% porosity and 65% water saturation. The OGIP for the low, average and high cases (P10, P50 and P90) using gross sand thicknesses are shown in **Table 3**.

Once a better property distribution is known, a three dimensional property model would provide a more accurate assessment of OGIP. Additionally, a Monte Carlo or statistical analysis would provide enhanced understanding of the range of OGIP results.

Production/Completion Engineering Review

Once the production database was complete, a decline curve analysis (DCA) was performed to determine EUR of the producing wells in the general area. **Figure 13** shows the ranges of EUR as a cumulative probability chart. Because of the inherent limitations of DCA for low permeability gas sands and the relatively few number of long term producing wells, these EUR were not considered adequate and should be considered a low side.

Figure 14 shows the EUR as function of date of first gas production. As shown in the figure, the highest EUR was from a well completed in 2001. From the public records, most of the wells were stimulated with crosslinked gel fluids.

The completion review was performed to quickly evaluate the effectiveness of the current completion practices in the area. Because of the lack of adequate data, no detailed recommendations can be provided. No correlations could be found between proppant volumes and production indicators such as EUR or Initial Potential (IP). **Figure 15** shows the relationship of proppant volume (lbs of proppant) versus EUR and IP. In **Figure 16** the correlation coefficients were plotted. The R-squared values are too low (below 0.15) and do not suggest any relation between these properties. From previous studies performed by DCS in this area, a combination of completion and reservoir parameters will determine the actual productivity of a particular well.

A more detailed single well review was conducted on the Hacienda 6-19 well. The production history of the well is shown in **Figure 17**. The petrophysical results for the each of three frac stages are shown in **Figures 18**, **19** and **20**.

Two different techniques were performed to determine the reservoir and fracture parameters of the well. The first method was to build a single well model in the

ProCADE[*] software. The second technique was to use a Bayesian Production Analysis tool developed by DCS. Both techniques utilize the available petrophysical, production and reservoir data.

Because limited fracture treatment and pressure data existed, a history match in the *ProCADE* model was not useful; instead only a multilayer forecast was performed. The objective was to vary reservoir properties and fracture parameters until a reasonable match with production occurs. This approach provides a non-unique solution. **Figure 21** shows the match obtained between the actual production data and the model. The fracture properties were assumed to be 150 ft and the permeability was varied to obtain the final match. Final permeabilities were form 0.0012 to 0.0018 mD. This model was the basis for determining recovery factors for the EUR analysis.

The Bayesian Production Analysis tool gives the most probable reservoir and fracture parameters given some known data, such as porosity and pressures. Based on general knowledge of the area, various assumptions were made about the pressure history. Initially, production logging (PL) results were assumed using stage transmissibility ratios as the percentage contributions from each stage. By varying the percentage contribution from the PL results, an improved history match could be performed with more reasonable results. **Figure 22** shows the history match of the model versus actual production. **Figure 23** shows the match of the model PL results versus assumed PL contribution. **Figure 24** shows the production history from each frac stage. **Figure 25** is a summary table of the results from the Bayesian tool.

Interestingly, both approaches showed frac lengths to be approximately 150 ft with micro-darcy permeability. Based on DCS's experience in this area expected frac length should be on the order of 250-500 ft. From the Bayesian approach, the conductivities for stages 2 and 3 were also low. Most likely, all stages were under-stimulated in this well.

As previously stated, limited data was available, so various assumptions were made to be able to complete the analysis. To provide a more rigorous analysis for either approach, a production log and fracture treatment records are required. In addition, pressure data and flowing pressure history should be acquired.

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Estimated Ultimate Recovery

Since there was limited production data in the prospect area, the evaluation of the estimate ultimate recovery (EUR) was heavily influenced by the results from an analog well modeled in analytical single well software. Available technical literature and previous engineering experiences in the tight gas market were used to provide upper limits of the EUR. During the evaluation, production data from wells in the general area was also utilized; however, the wells were not in the prospect area itself, and the completions did not appear optimized. The Completion Review section addressed some of the issues.

Recovery factors and optimum spacing depend on various reservoir parameters, so an integrated reservoir model would provide the best estimate for the prospect area. Recovery factors are dependent on the drainage area, depletion and pressure interference and the effect of the completion through effective hydraulic fracturing.

As a first step, production was updated through September 2009 from the IHS-Enerdeq public database. There are a total of thirty-six (36) wells that are currently producing or have produced in the area (**Figure 26**).

Decline curve analysis (DCA) was next performed for each well individually to determine EUR of the producing wells in the general area. The P/Z method of DCA was not used because of the lack of pressure history; only initial pressures were available. Instead two other DCA methods were employed:

- Log of gas production rate versus time (EUR 1)
- Gas production rate versus cumulative gas production (EUR 2)

For each well in study area, production was forecasted for 120 months (10 years) with an economic limit of 50 MSCF/day. Decline curve analysis results show that most wells have a hyperbolic decline. This type of decline is indicative of:

- Rate data existing only in the transient period
- Low matrix permeability with natural or hydraulic fractures
- Highly heterogeneous reservoirs

Figure 13A and **13B** show EUR probability plot for EUR 1 and 2 respectively. The P10, P50 and P90 EUR from each method are summarized in **Table 5**. The EURs for both methods are nearly identical.

Heterogeneity of production indicator is calculated using Dykstra-Parsons coefficient (**Equation 1**). In study area, production indicator heterogeneity index is about 0.48, which means medium heterogeneity.

Equation 1:

$$V_{EUR} = \frac{EUR_{50} - EUR_{84.1}}{EUR_{50}} \qquad \text{-- Eq. 1}$$

Where:

- EUR_{50} = EUR value with 50% probability.
- $EUR_{84.1}$ = EUR at 84.1% of the cumulative sample.
- V_{EUR} = Production Indicator Heterogeneity Index.

Table 6: Comparison of EURs calculated by two different PCA analysis

	EUR 1 (log gas rate versus time) (MMscf)	**EUR 2 (linear gas rate versus gas cumulative) (MMscf)**
P10	13.74	13.76
P50	262.93	274.55
P90	513.47	601.02

Figure 13 shows the ranges of EUR as a cumulative probability chart. As a result of the inherent limitations of DCA and the relatively few number of long term producing wells, these EUR were not considered adequate and should be considered a low side. Literature review and engineering experience from previous studies were then used to enhance the guidelines for the recovery factors.

Literature reviewed suggests gas recovery factor can be improved to 80% depending on well spacing[2]. Previous proprietary reservoir simulation studies performed by DCS for various clients in tight gas sands such as the Lance and Mesaverde formations show recoveries of up to 90% for 10 acre spacing and 60 year recovery times. The analytical model used for this analysis was limited by time of production and the available data. However, the high case numbers from the literature will be considered in this evaluation.

The analytical well model for a single well was developed during this evaluation using *ProCADE*. *ProCADE* is proprietary software that can model multilayer reservoirs. This single well model provides a baseline for the expected recovery from a single well without effects of interference. Finally, analytical single well models were used to provide ranges of recovery factors for production over 10,000 days. **Table 5** provides a summary of the cases run in *ProCADE*. The results for the 10 and 20 acre enhanced completion cases are similar to the base 10 and 20 acre calculations using petrophysical properties (**Table 3**).

Table 5: Recovery Factors from ProCADE

Case	**GIP MMscf**	**EUR MMscf**	**Recovery Factor**
10 acres	1689	908	54%
15 acres	2533	1215	48%
20 acres	3377	1419	42%
10 acres - enhanced completion	2533	1112	66%
15 acres - enhanced completion	2533	1439	57%
20 acres - enhanced completion	3377	1929	57%

In summary, EURs were calculated using average petrophysical properties, a *ProCADE* and two PCA techniques. The petrophysical properties and *ProCADE* model calculated similar results. The PCA techniques yielded lower EURs, because the wells in this area were not completed optimally and have a short production history.

Production Data Analysis

Scatter plots, bubble and grid maps were used constructed and used to assist in the production data analysis. The left plot in **Figure 27** is the top of Lance versus peak gas rate and indicates that wells completed in the Top Lance have a higher peak gas rate, based on limited statistics. The right plot in **Figure 27** is net thickness versus peak gas rate. It shows higher peak gas rate with lower net thickness, which is the inverse of the norm; higher net pay, better production. Because there are only 4 points in this plot, a more complete petrophysical analysis coupled with completion information is needed to improve understanding of the reservoir. **Figure 28** is the map of EUR, which shows that northwest study area has superior EUR performance. **Figures 29, 30,** and **31** are maps of cumulative gas, oil and water. Water production is observed in a downdip direction or to the southwest. It should be noted that these maps are probably pessimistic in Tea Kettle Unit and on acreage position because of the lack of established prolonged production in these areas.

Summary and Conclusions

- Additional study is needed to understand the relationship between petrophysical properties and production heterogeneity.
- Marginal P50 EUR performance shows reservoir and completion optimization is required – Focus on high side well performance.
- All wells produce water. This needs to be incorporated into well flow performance.
- Structural position is important to well performance. The northwest part of the study area has better EUR performance, and is highest structurally.
- Petrophysical analysis on all wells could improve the range of uncertainties for OGIP.

References

1 *Jonah Field: Case Study of a Giant Tight-Gas Fluvial Reservoir*, J. W. Robinson and K. W. Shanley, eds.: AAPG Studies in Geology 52 and Rocky Mountain Association of Geologists 2004 Guidebook

2 Tight *Gas Sand Development – How to Dramatically Improve Recovery Efficiency*, Kuuskraa, V.A., GasTIPS, Winter 2004, pp. 15 – 20.

3 *Reserves in Western Basins*, Caldwell, R.H., Scotia Group, US DOE Report, Contract DE-AC21-91MC28130.

4 *Economically Recoverable Natural Gas Resources Beneath Inventories Roadless Areas of Forest Service Lands, Analysis and Results*, Advanced Resources International, Inc., November 2000.

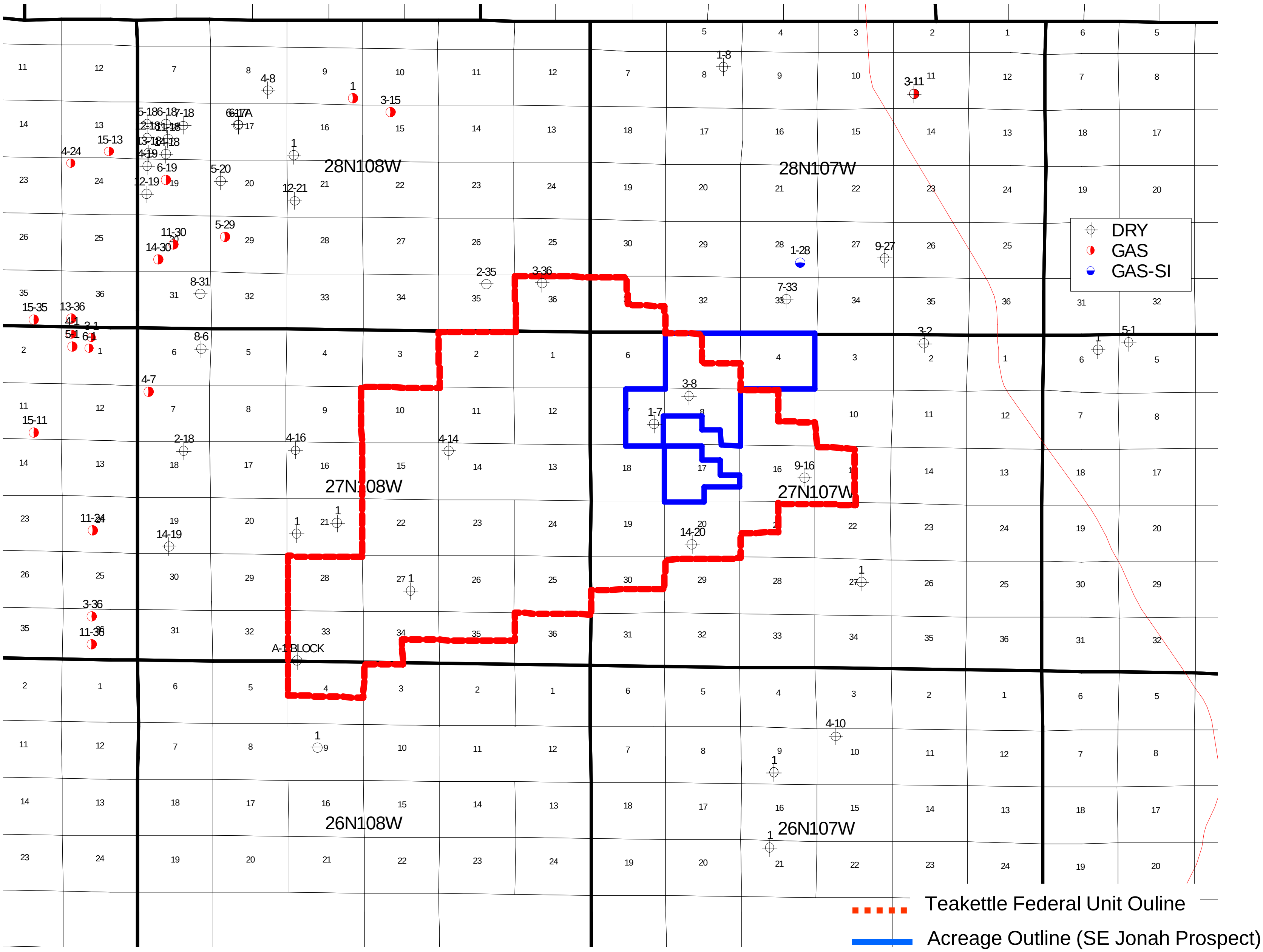

Figure 1: Location map of SE Jonah Prospect

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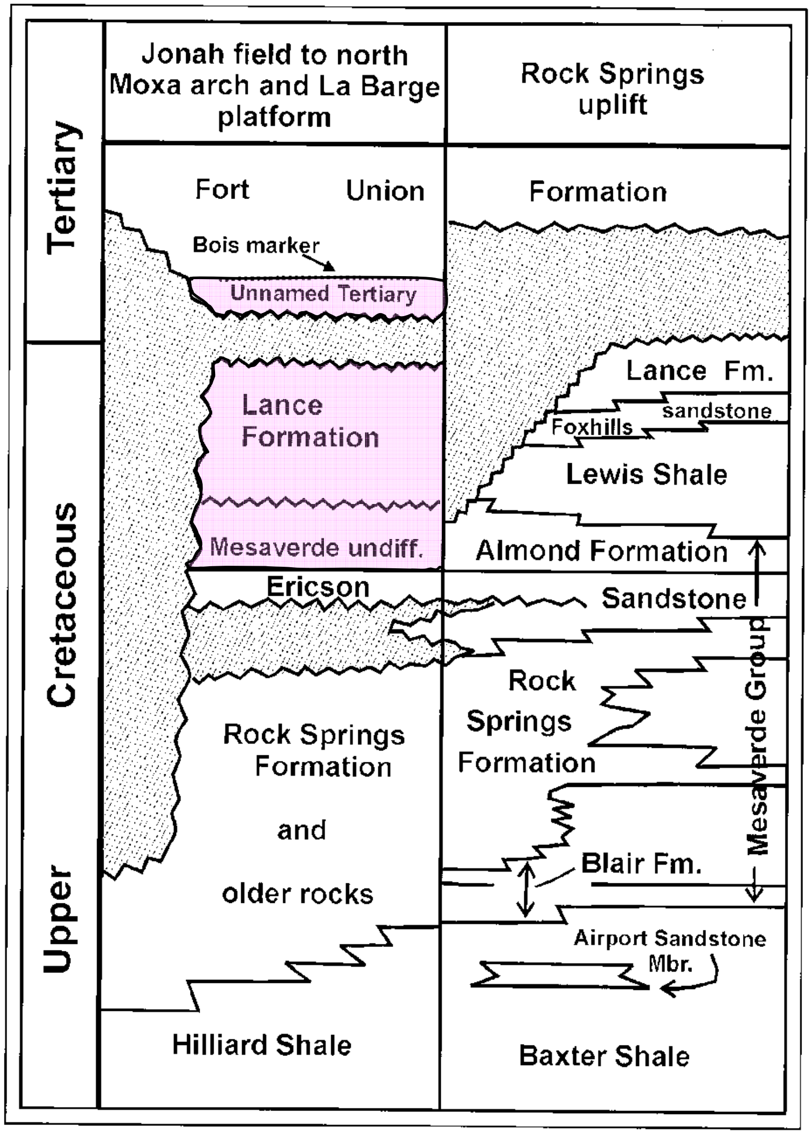

Modified from Harrison et. al, (2004)[1]
After Law (1984)[2] and
Law and Johnson, 1989)[3]

Figure 2: Stratigraphic column of Upper Cretaceous and Lower Tertiary in western Wyoming. The Cretaceous Lance and Mesaverde along with part of the Tertiary Fort Union (highlighted in pink) are the productive intervals at Jonah Field located 6 miles northwest of the SE Jonah prospect acreage position

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Reservoir Engineering – OGIP (10 acre spacing)

Example Well	Main Objective	Gross Sand (ft)	Net Interval Thickness (ft)	Avg. ϕ	Sw %	Pressure Gradient (psi/ft)	Reservoir Pressure (psi)	Reservoir Temp. (degF)	Gas In Place mmscf	Recovery %	Estimated Ultimate Recovery mmscf
Low Case	Lance	560	**196**	**6.5%**	**62.7 %**	0.433	3551	185	474	54%	332
Average	Lance	1000	**400**	**8.5%**	**50.2 %**	0.450	3780	190	1786	66%	1339
High Case	Lance/ Mesaverde	1720	**860**	**10.2 %**	**38.9 %**	0.500	4350	195	6456	80%	5165

Figure 3: Original gas-in-place (OGIP) cases for 10 acre spacing

Reservoir Engineering – OGIP (20 acre spacing)

Example Well	Main Objective	Gross Sand (ft)	Net Interval Thickness (ft)	Avg. ϕ	Sw %	Pressure Gradient (psi/ft)	Reservoir Pressure (psi)	Reservoir Temp. (degF)	Gas In Place mmscf	Recovery %	Estimated Ultimate Recovery mmscf
Low Case	Lance	560	**196**	**6.5%**	**62.7 %**	0.433	3551	185	949	42%	399
Average	Lance	1000	**400**	**8.5%**	**50.2 %**	0.450	3780	190	3572	57%	2036
High Case	Lance/ Mesaverde	1720	**860**	**10.2 %**	**38.9 %**	0.500	4350	195	12912	70%	9038

Figure 4: Original gas-in-place (OGIP) cases for 20 acre spacing

Schlumberger

Reservoir Engineering – DST Data

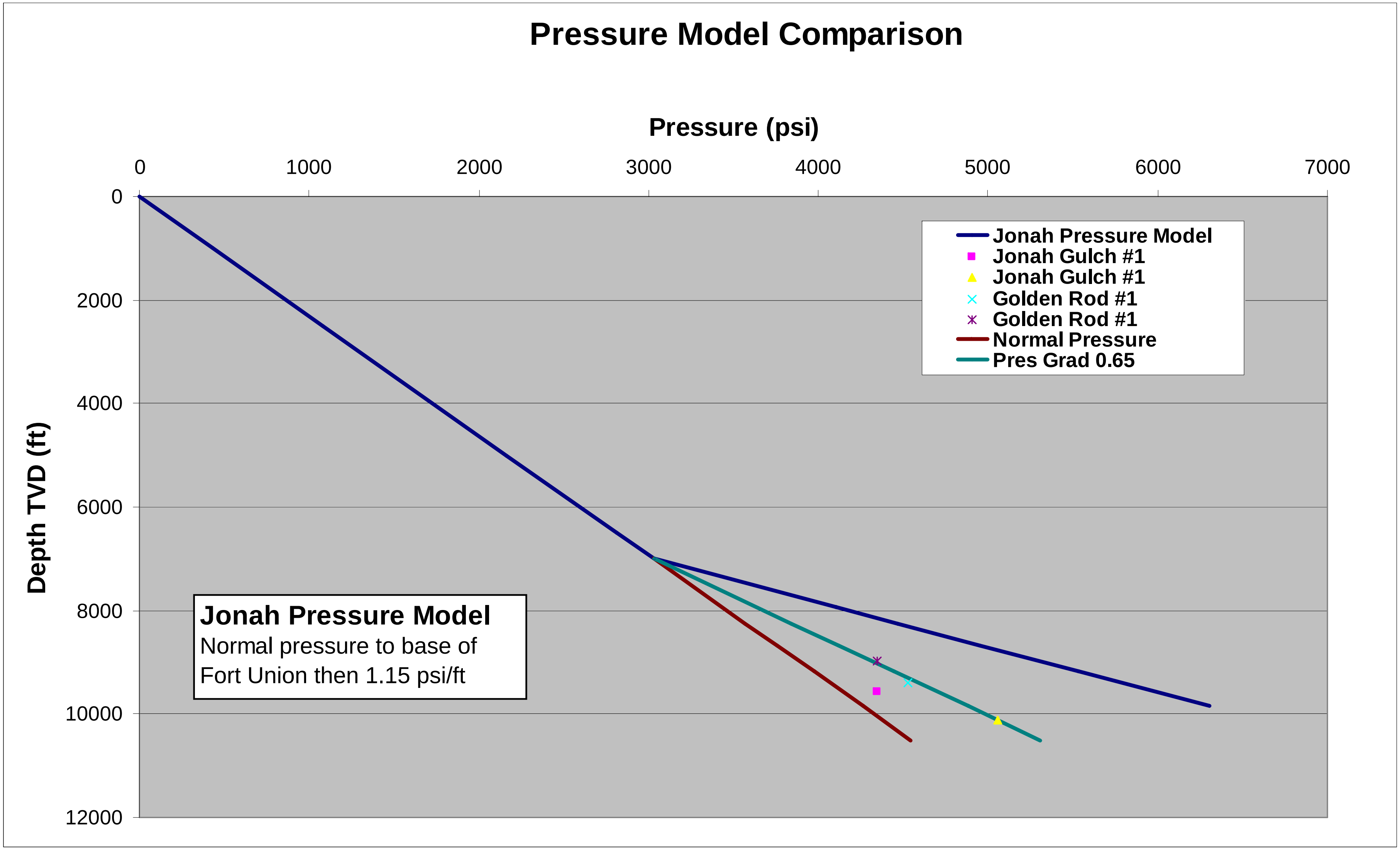

Figure 5: Pressure versus depth plots for drill stem tests (DST) in study area

Schlumberger

Reservoir Engineering – Core Data

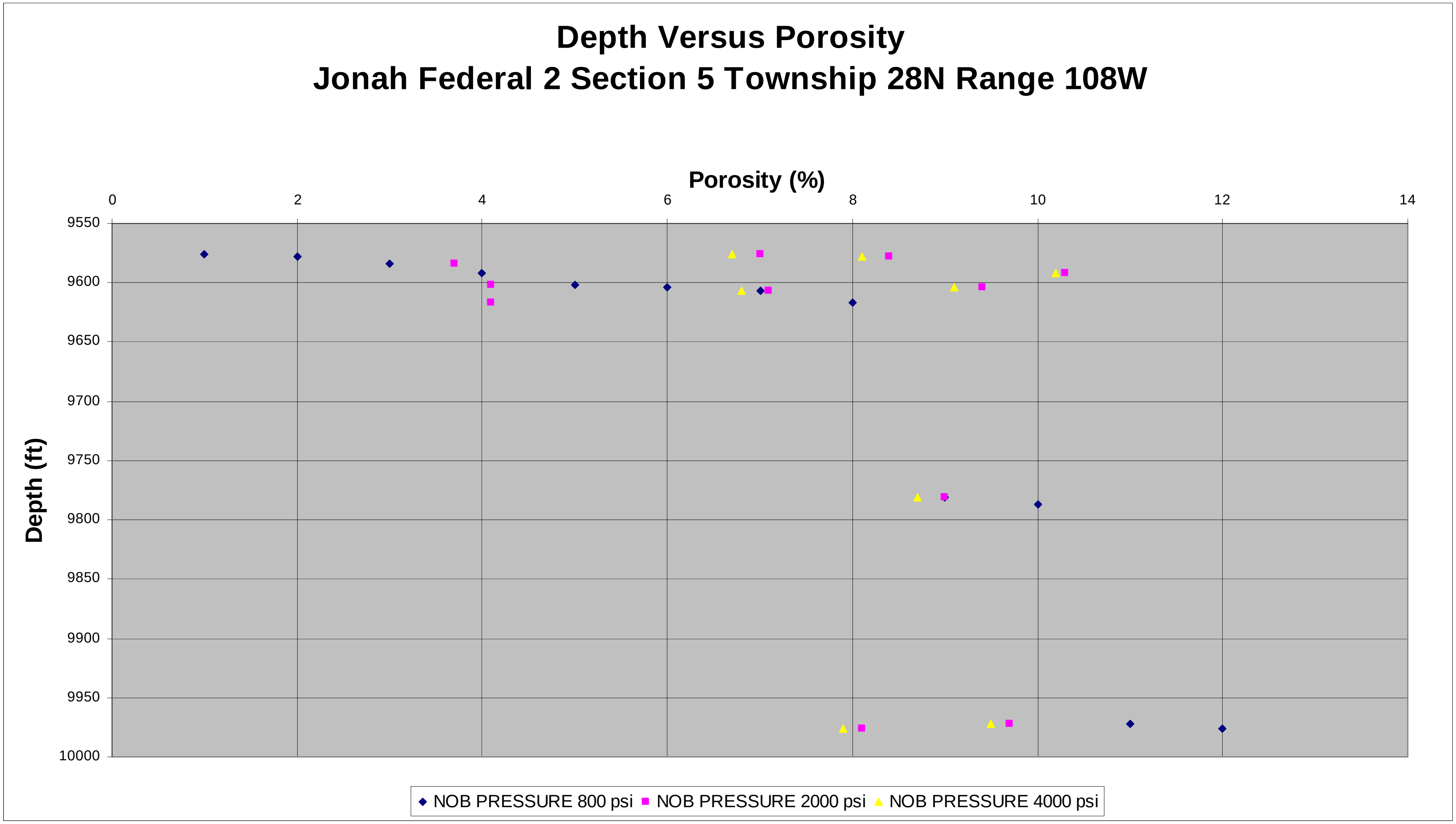

Figure 6: Porosity versus depth plots for the Jonah Federal 2 well (Sec 5 T28N R108W) at varying net overburden pressures (NOB).

Schlumberger

Reservoir Engineering – Core Data

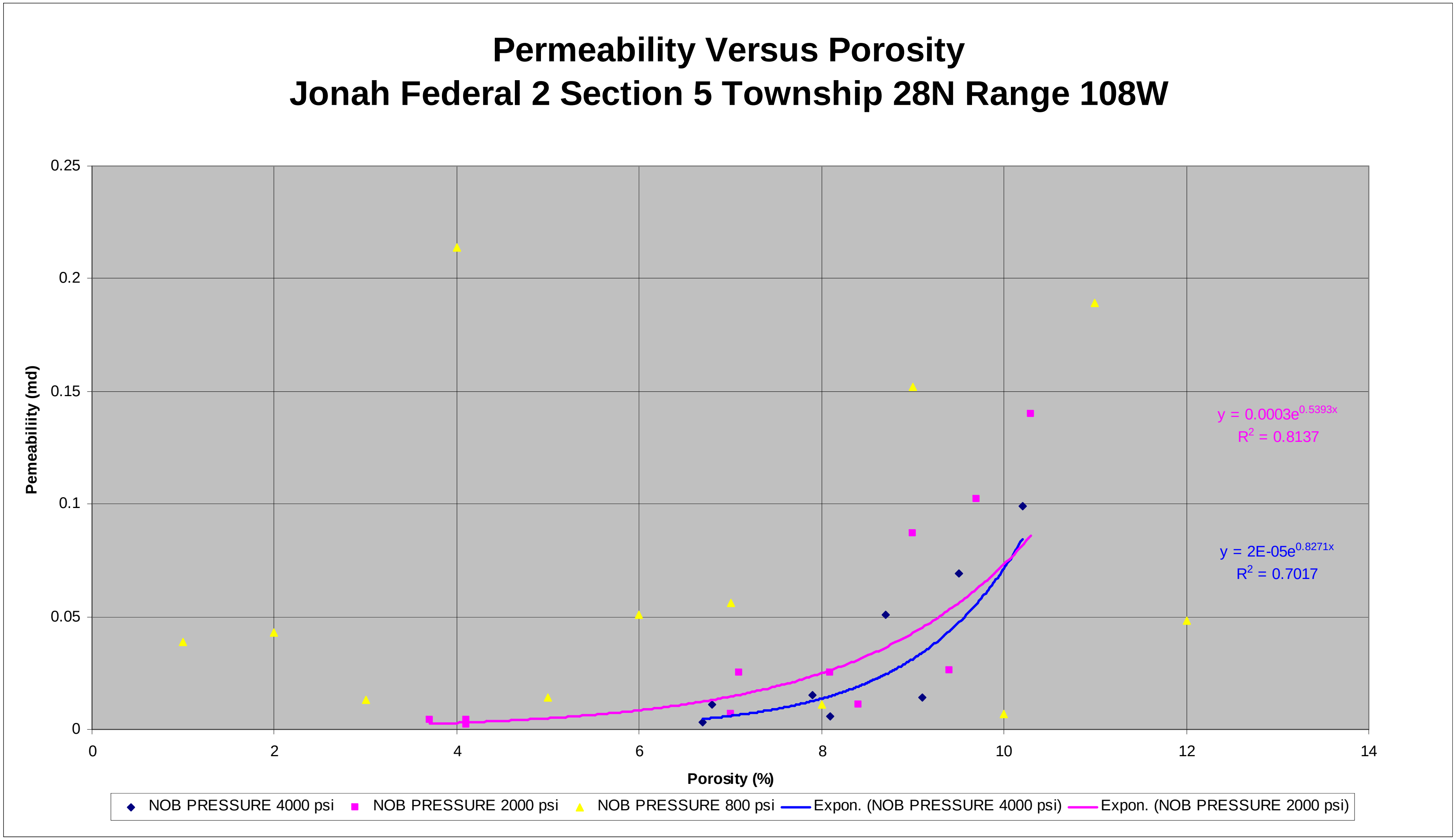

Figure 7: Permeability versus porosity plot for the Jonah Federal 2 well (Sec 5 T28N R108W) at varying net overburden pressures (NOB).

Schlumberger

Reservoir Engineering – Core Data

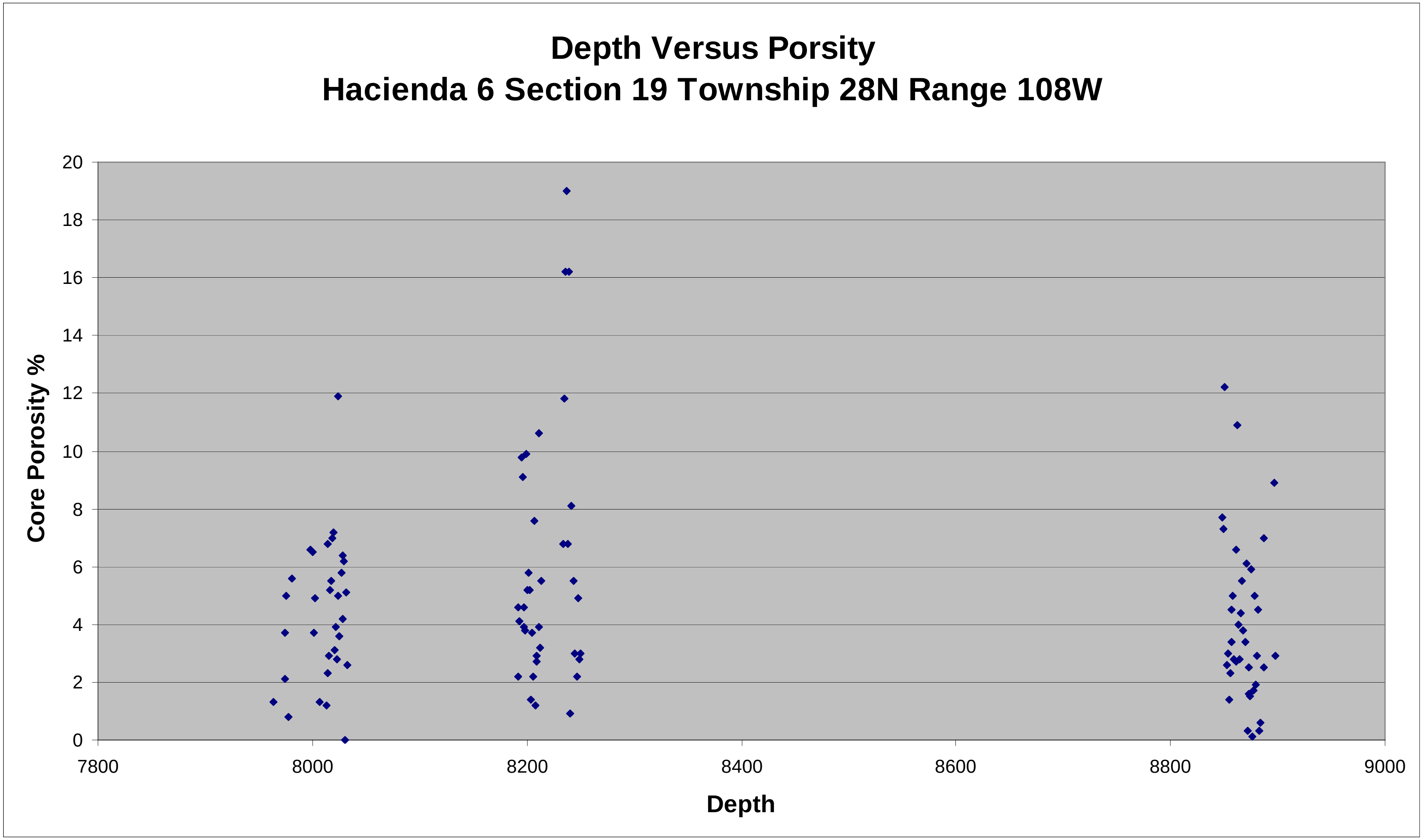

Figure 8: Core porosity versus depth plots for the Hacienda 6-19 well (Sec 19 T28N R108W)

Reservoir Engineering – Core Data

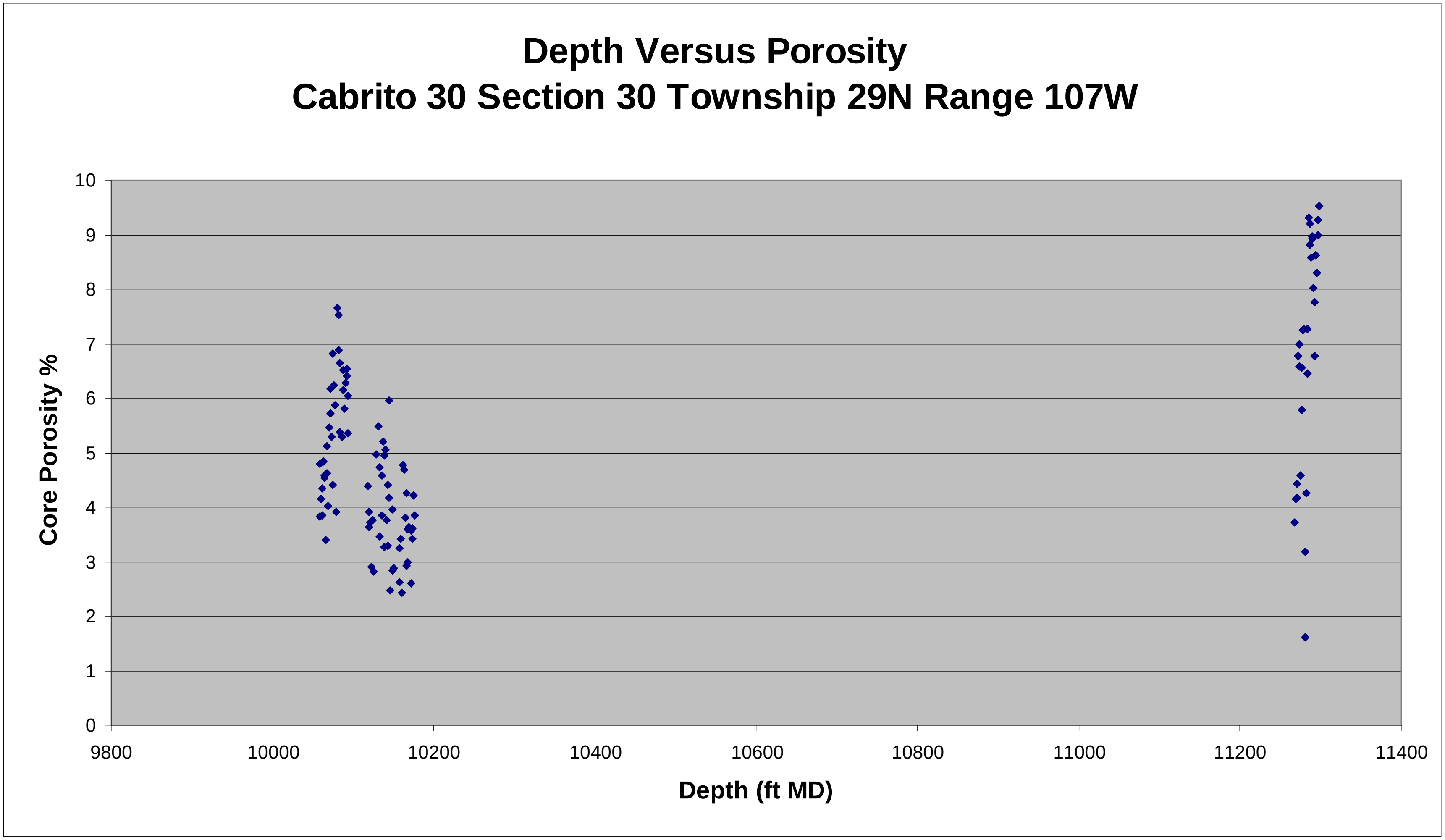

Figure 9: Core porosity versus depth plots for the Cabrito 30-30 well (Sec 30 T29N R107W)

Schlumberger

Reservoir Engineering – Gross Sand

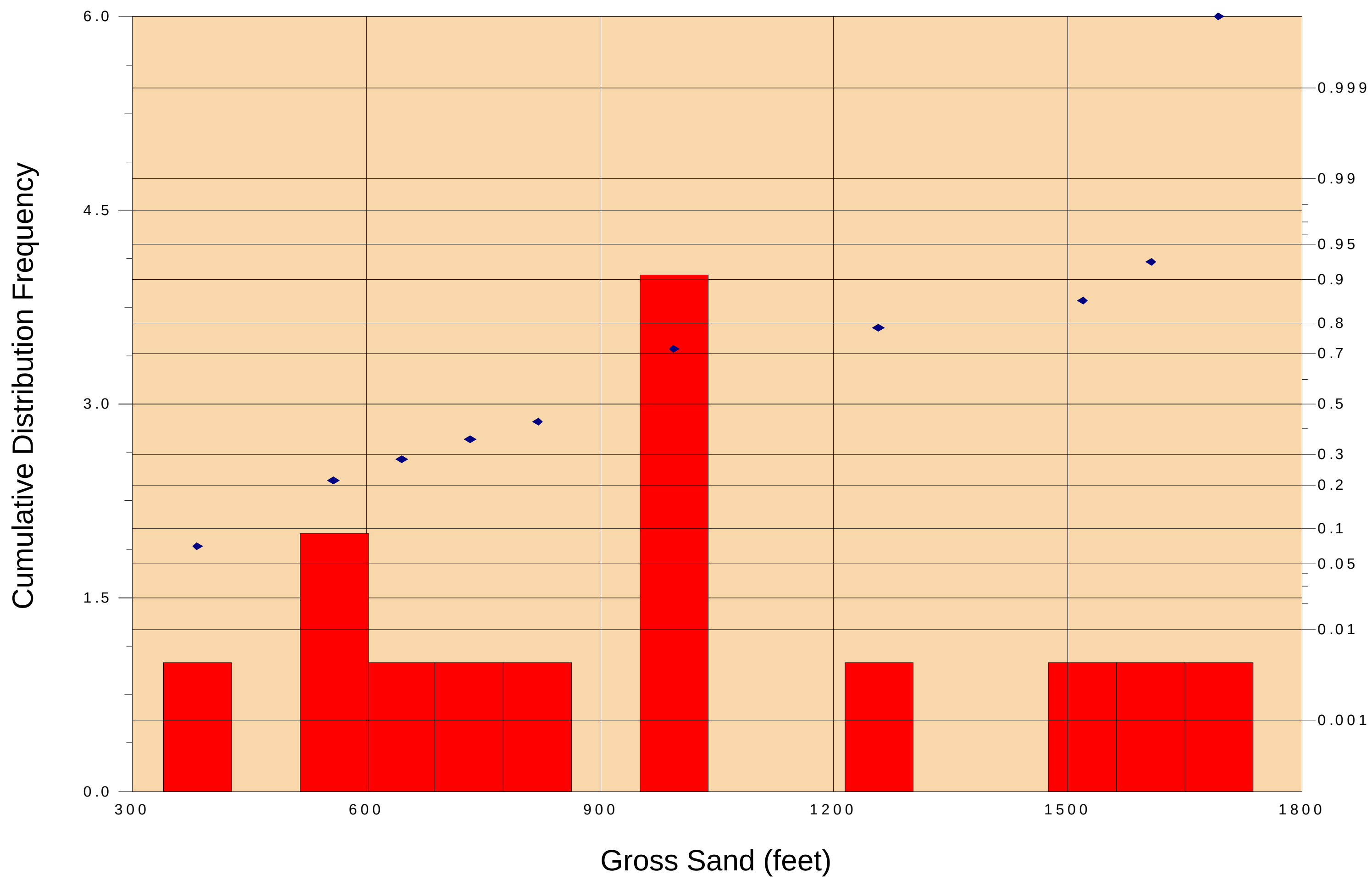

Figure 10: Gross sand probability plot for the Lance Formation.

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Reservoir Properties for OGIP from Hacienda 6-19

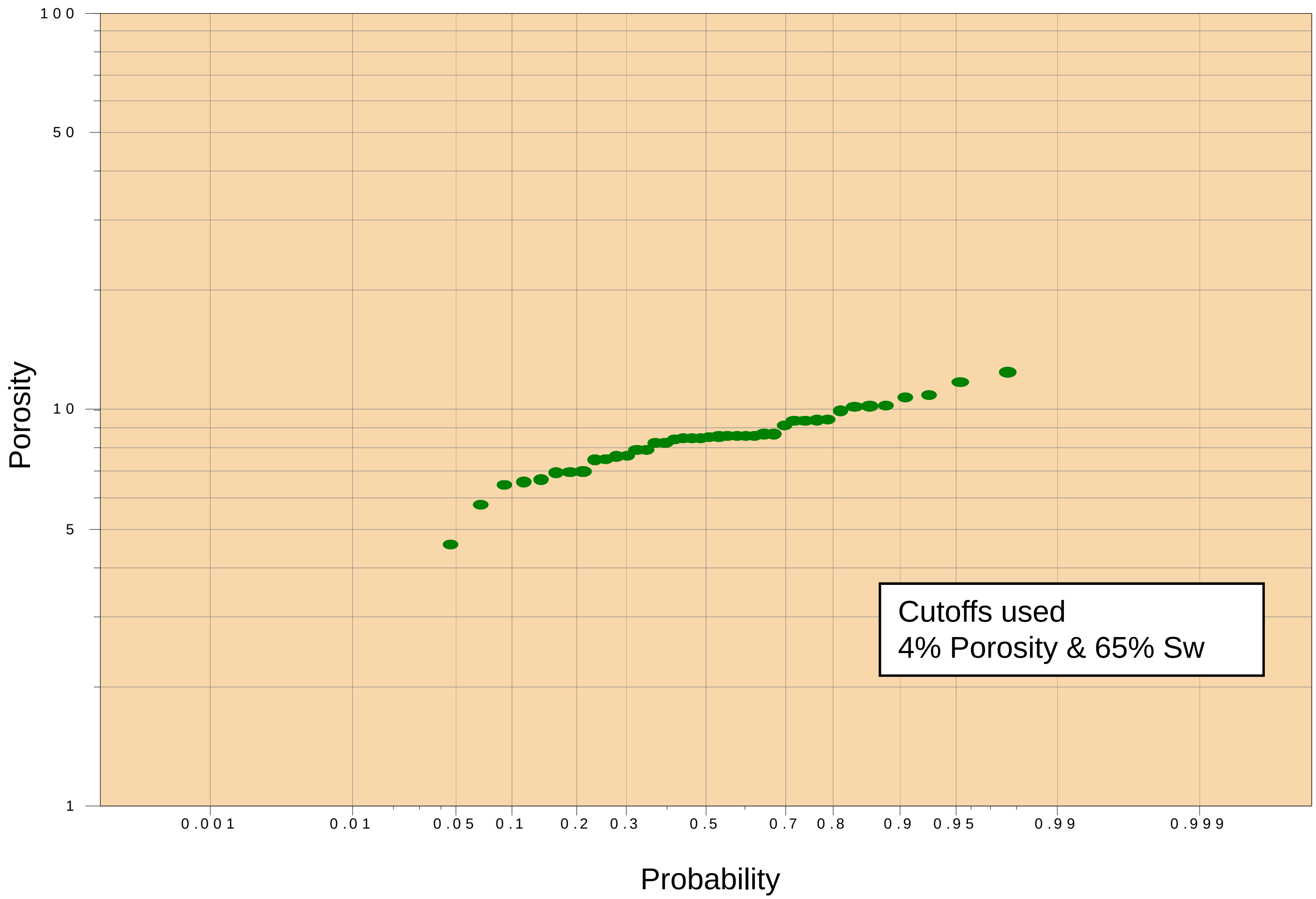

Figure 11: Porosity distribution plot for the Hacienda 6-19 well (Sec 19 T28N R108W).

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Reservoir Properties for OGIP from Hacienda 6-19

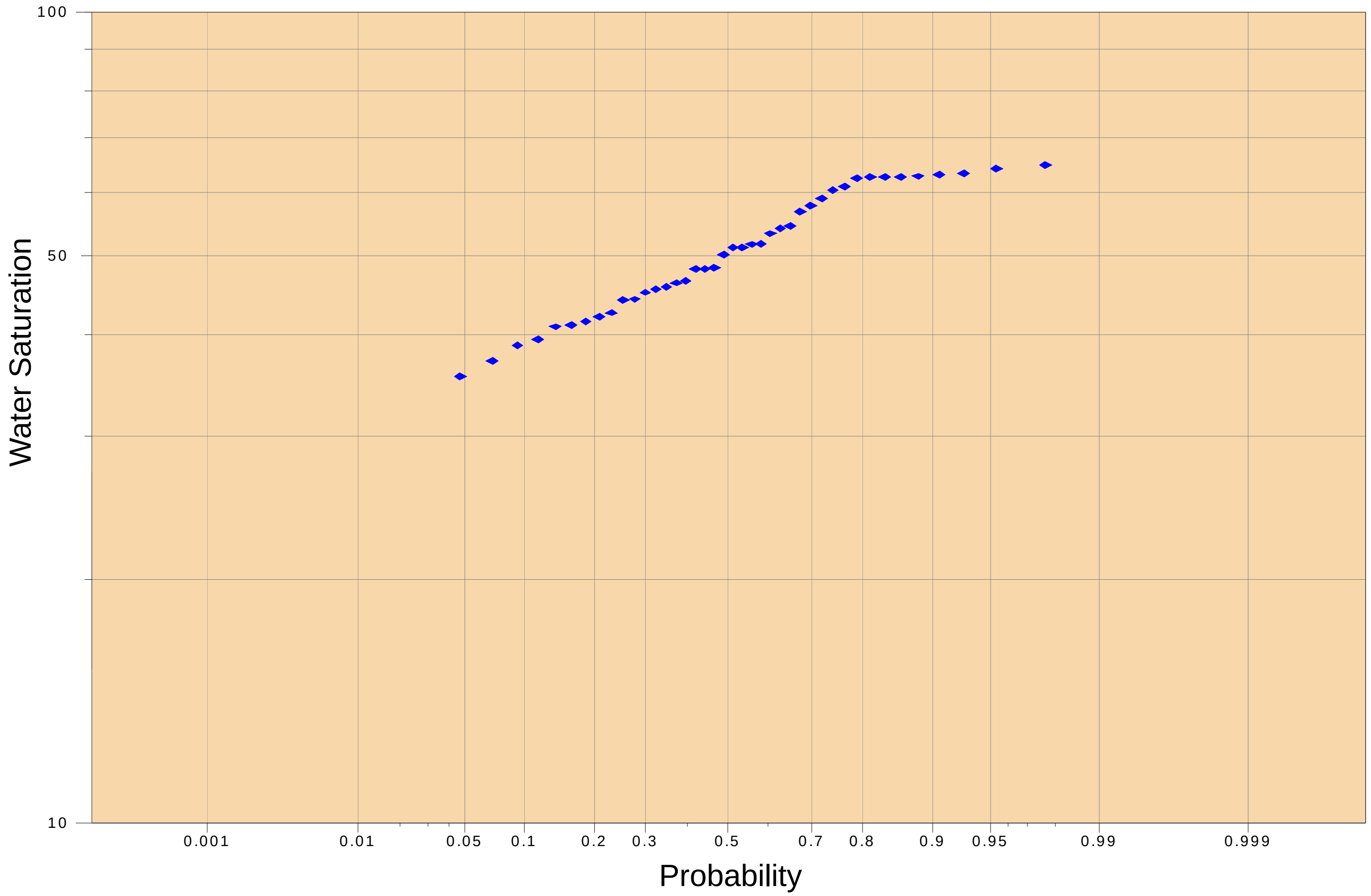

Figure 12: Water saturation distribution plot for the Hacienda 6-19 well (Sec 19 T28N R108W) .

Production Engineering – DCA Results

Date:6/1/2009

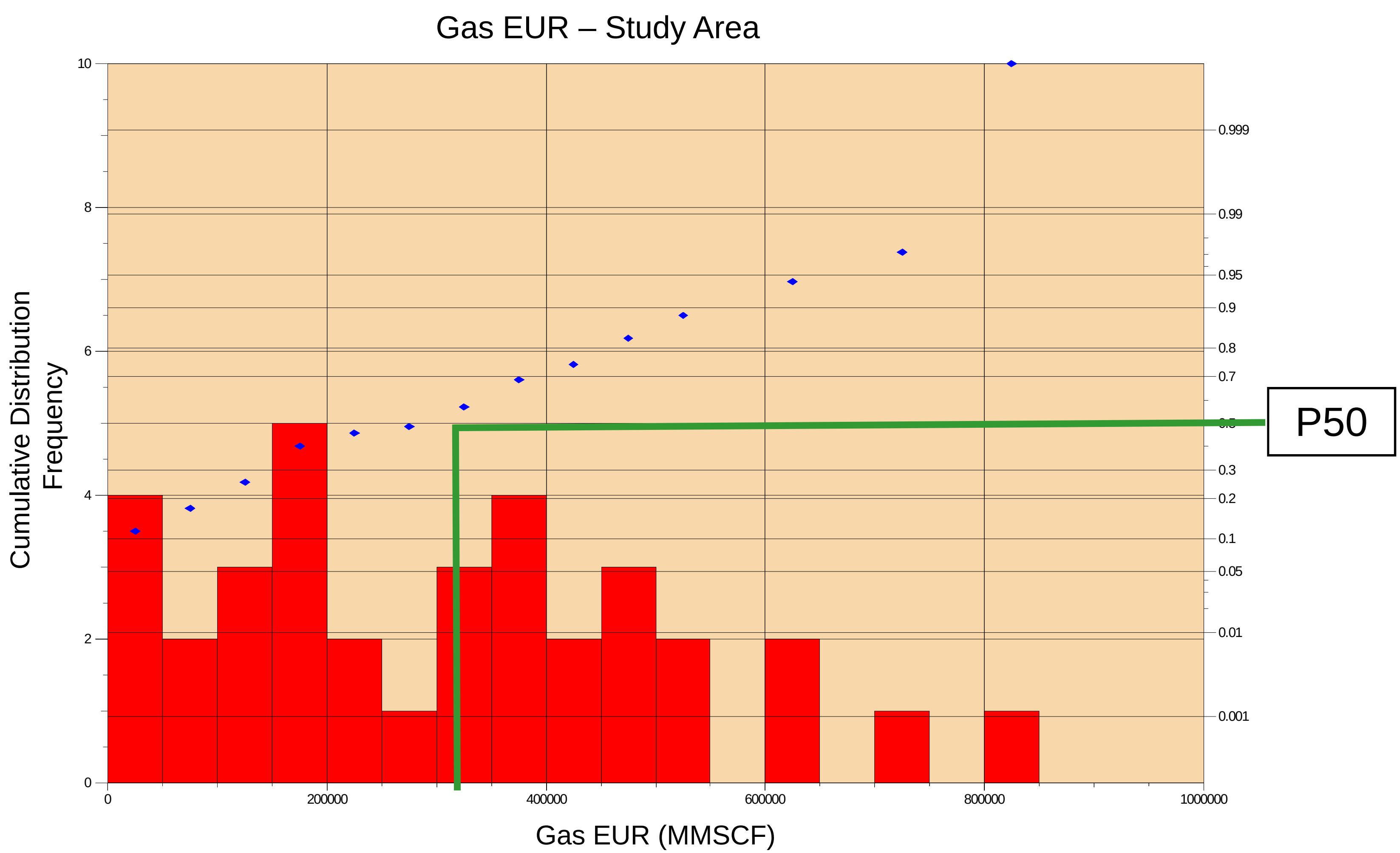

Figure 13A: Estimated ultimate recovery (EUR) distribution plot.

Schlumberger

Production Engineering – DCA Results

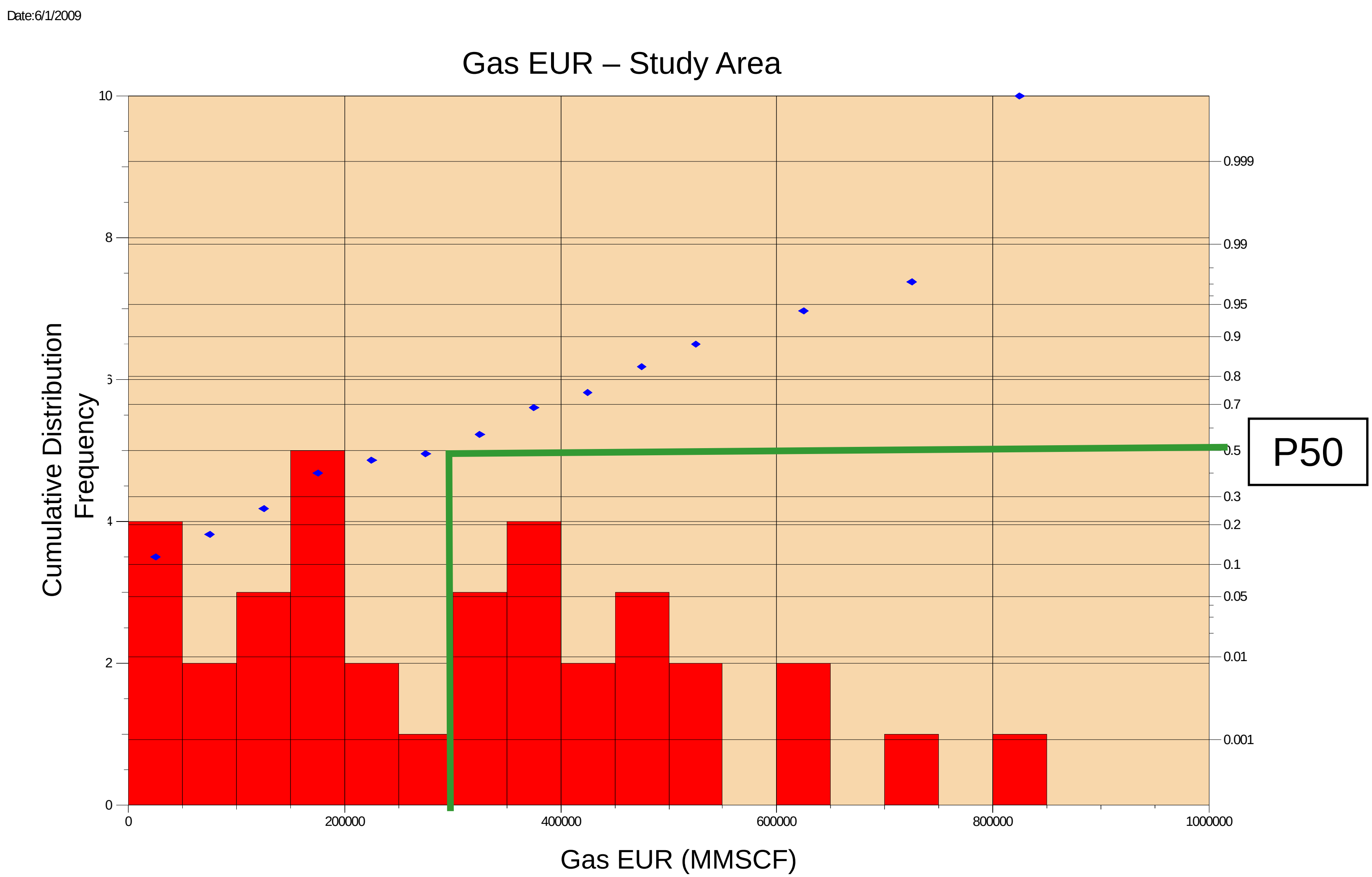

Figure 13B: Estimated ultimate recovery (EUR) distribution plot.

Schlumberger

Production Engineering

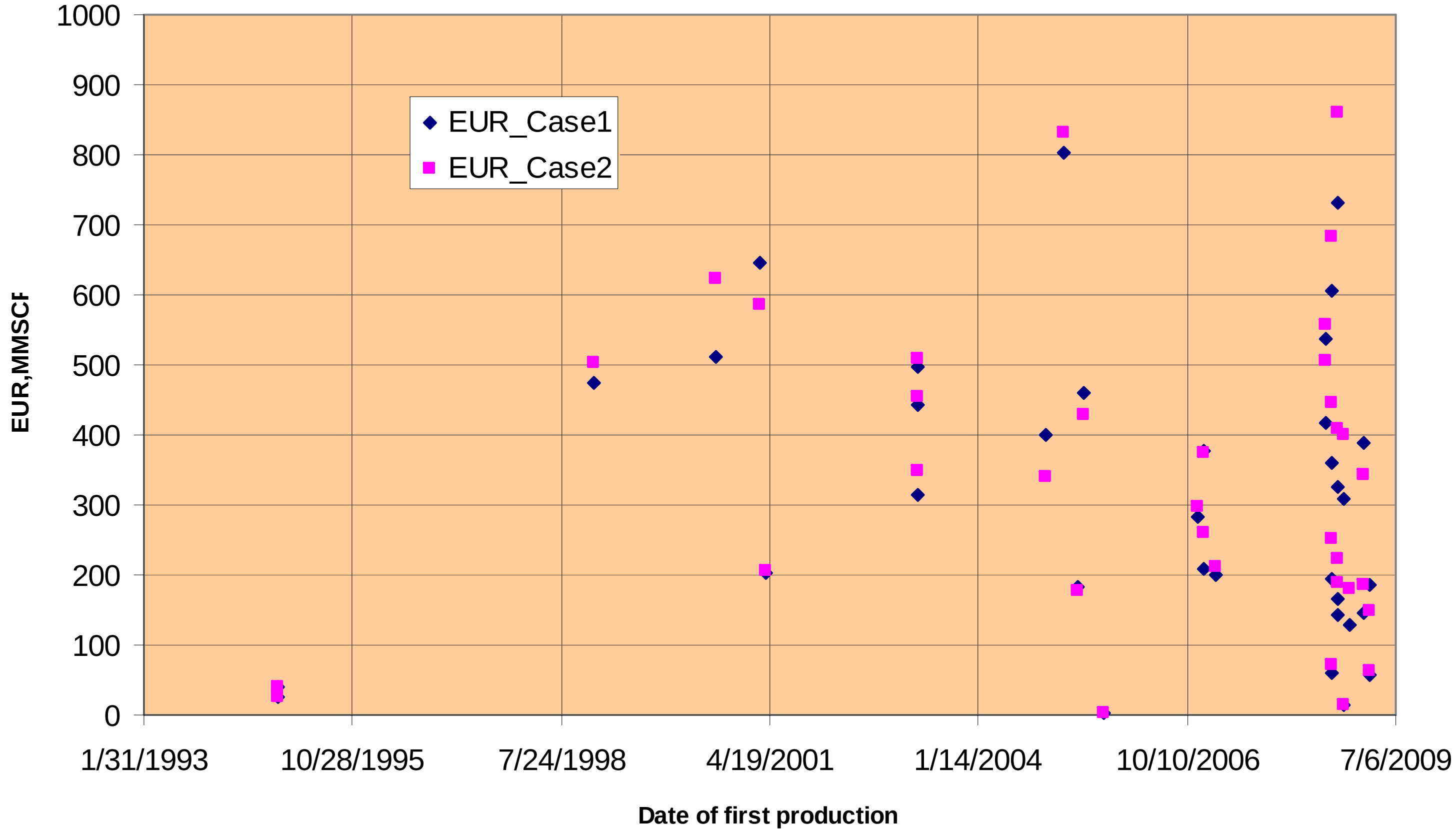

Figure 14: Date of first production versus EUR.

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Completion Engineering

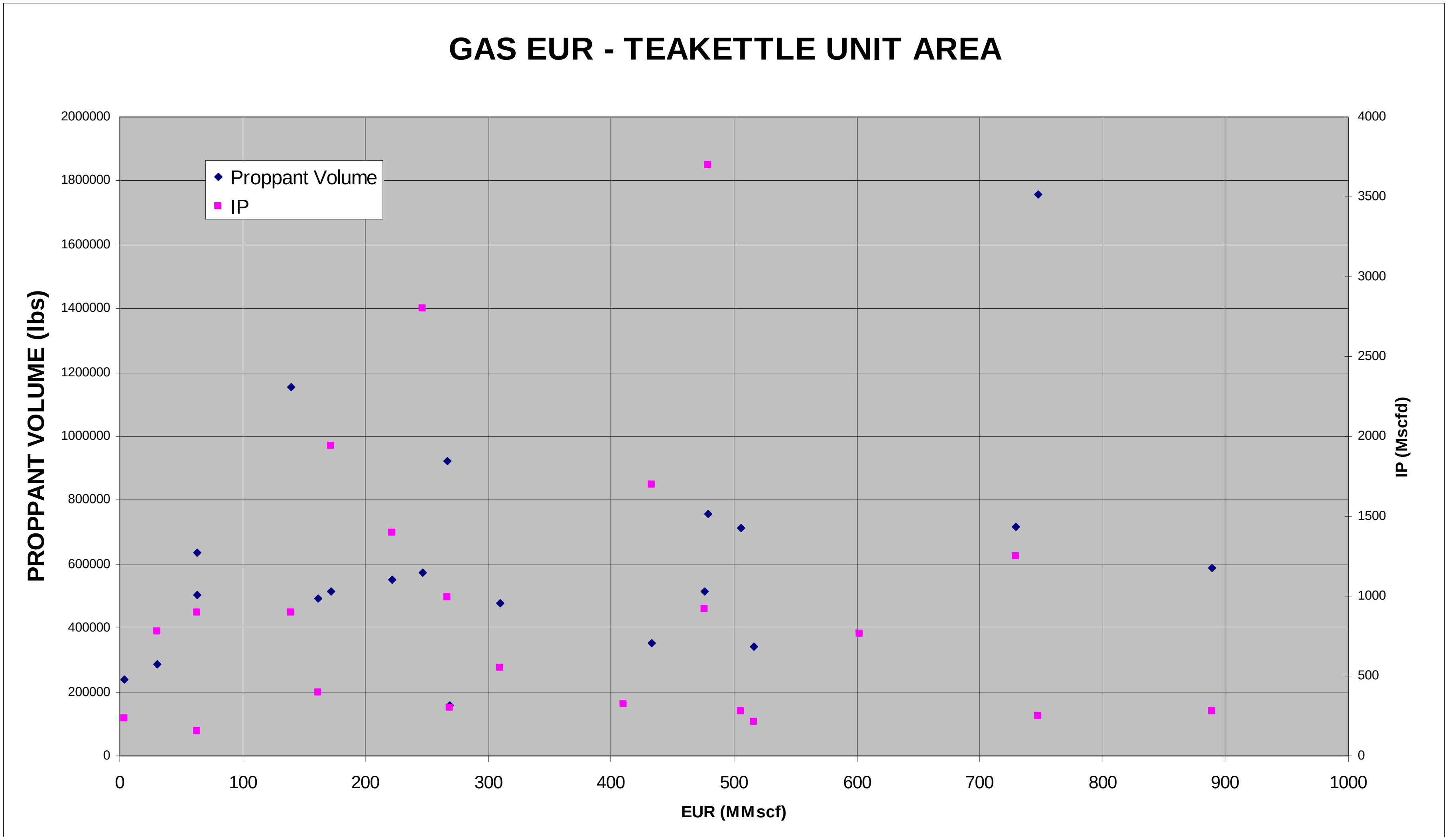


Figure 15: Proppant volume versus EUR.

Completion Engineering

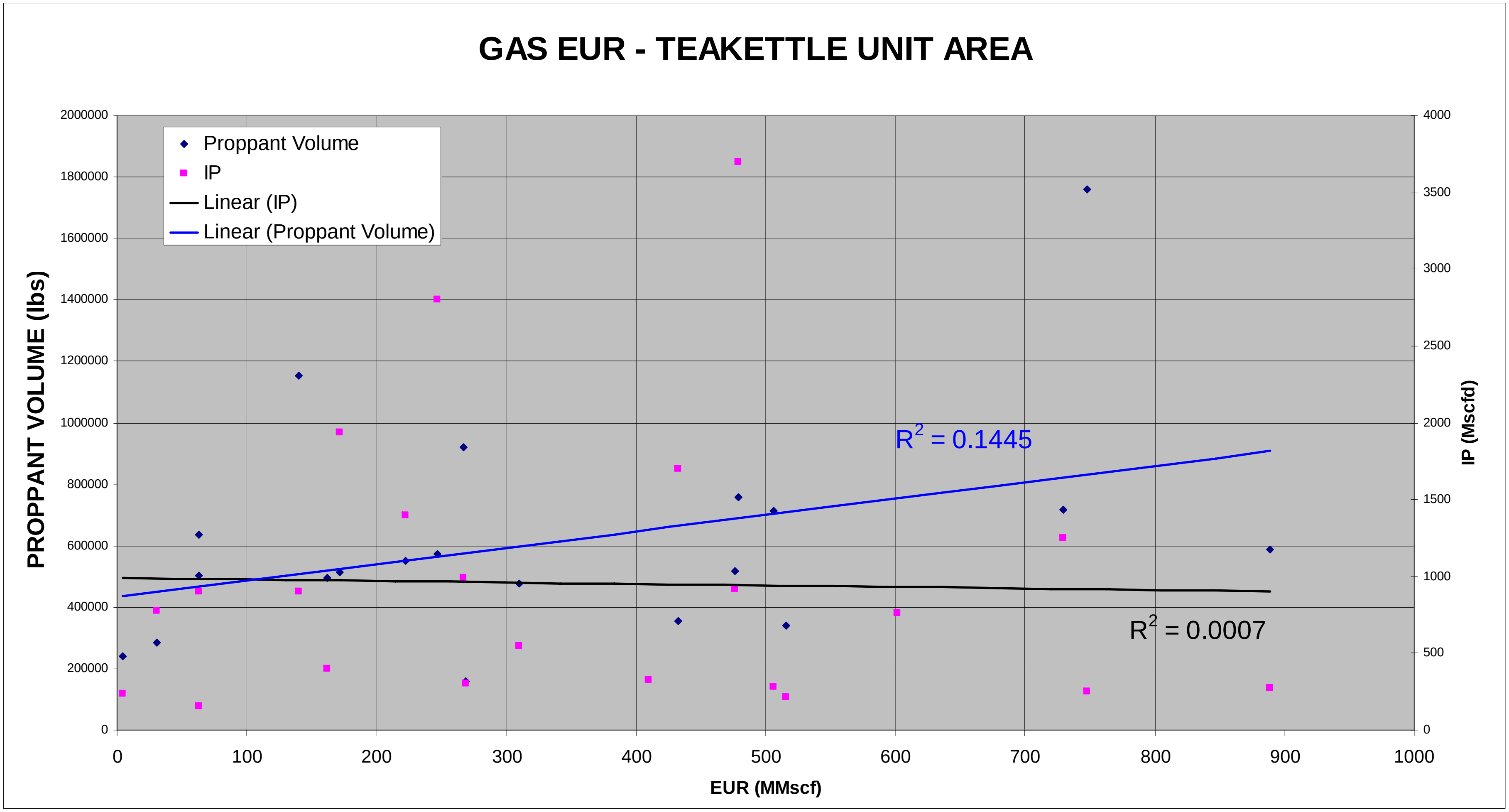


Figure 16: Proppant volume versus EUR with correlation coefficients. There is no correlation between proppant volume and EUR.

Schlumberger

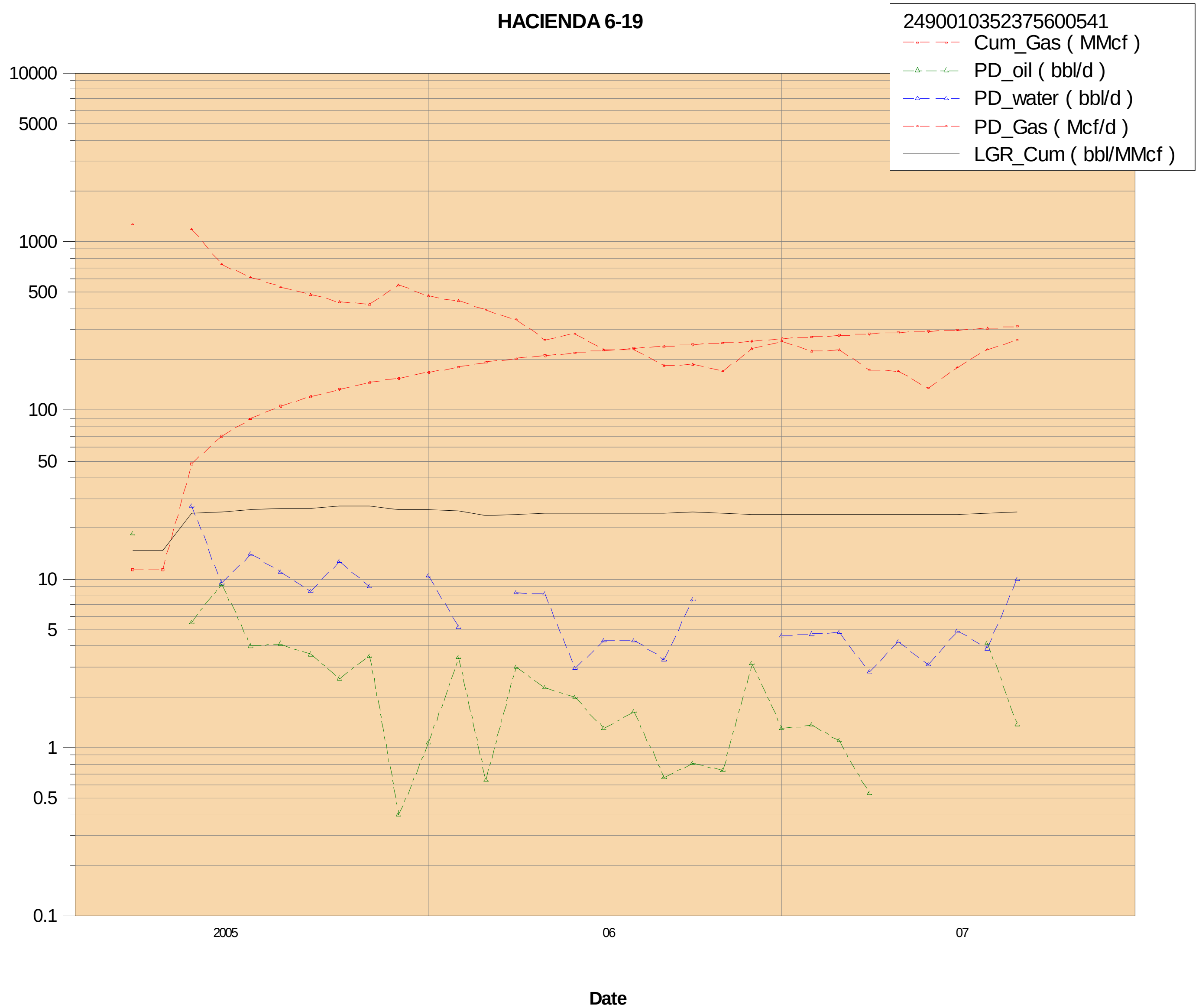
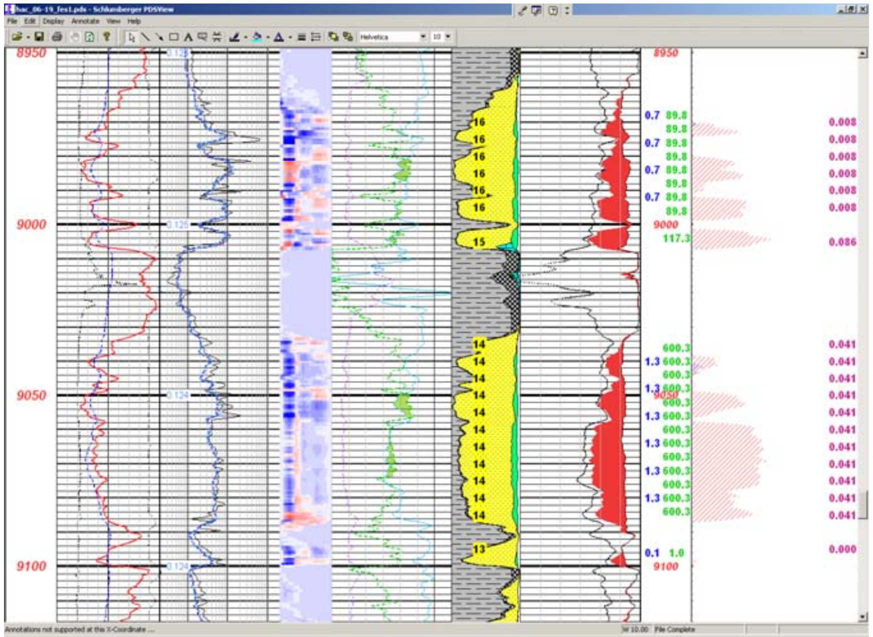
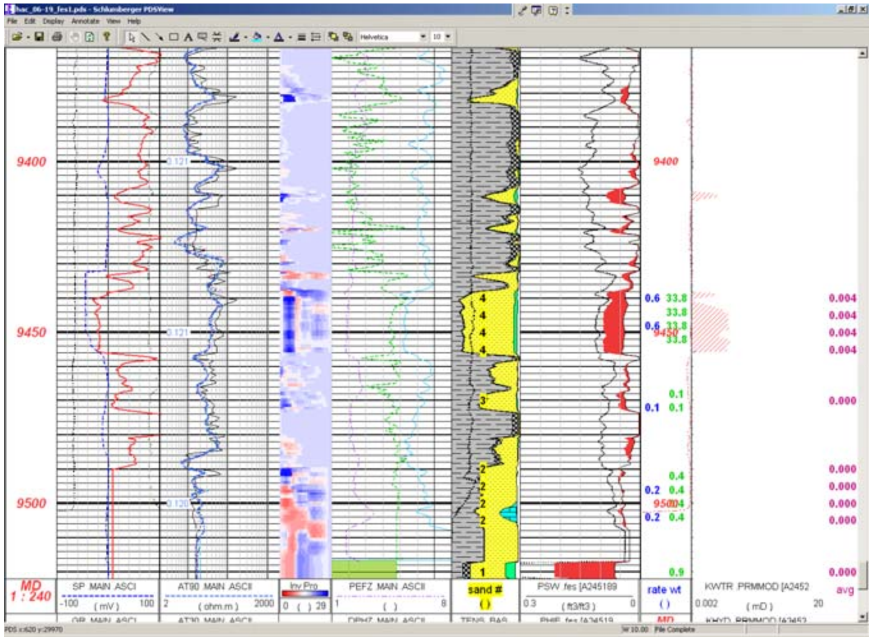


Figure 17: Production history of the Hacienda 6-19 well (Sec 19 T28N R108W).





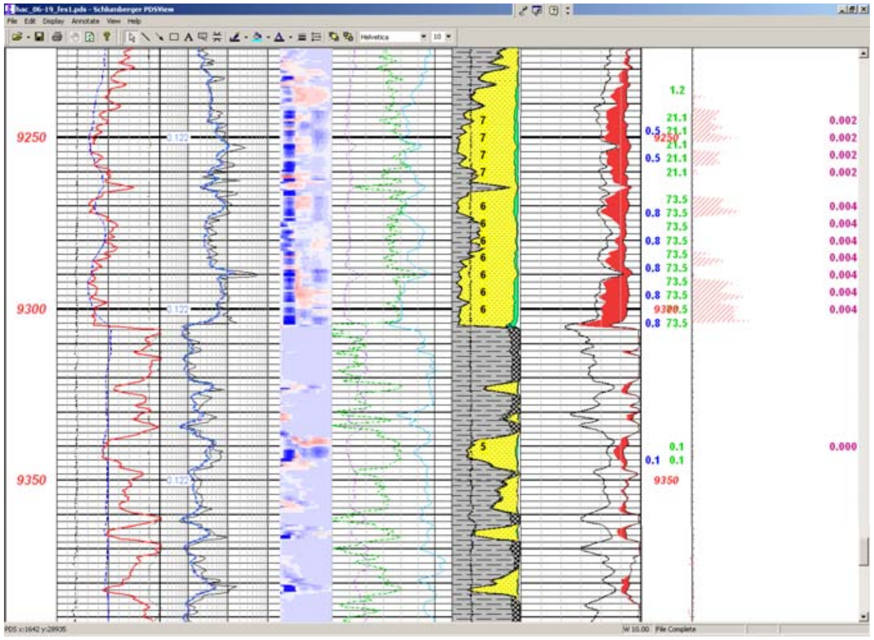
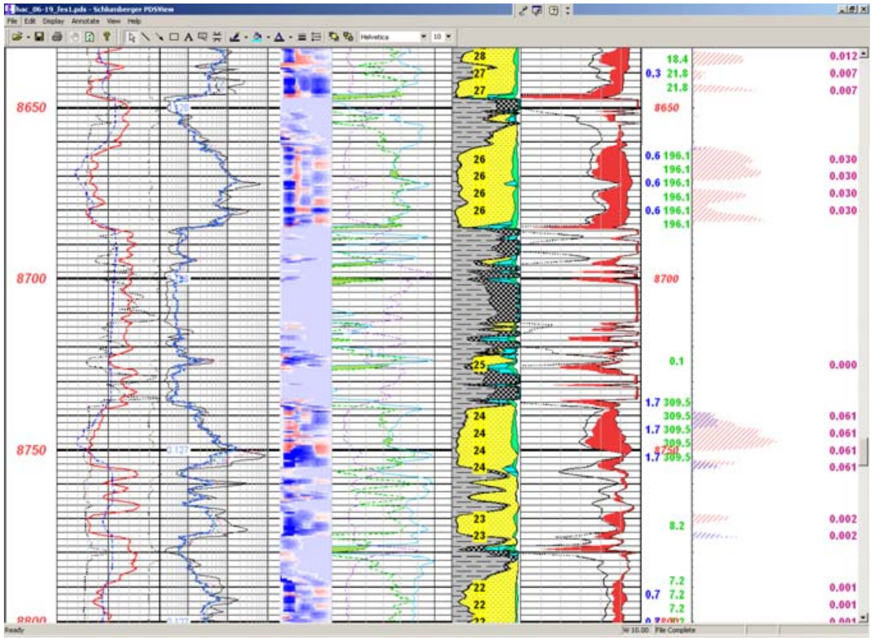
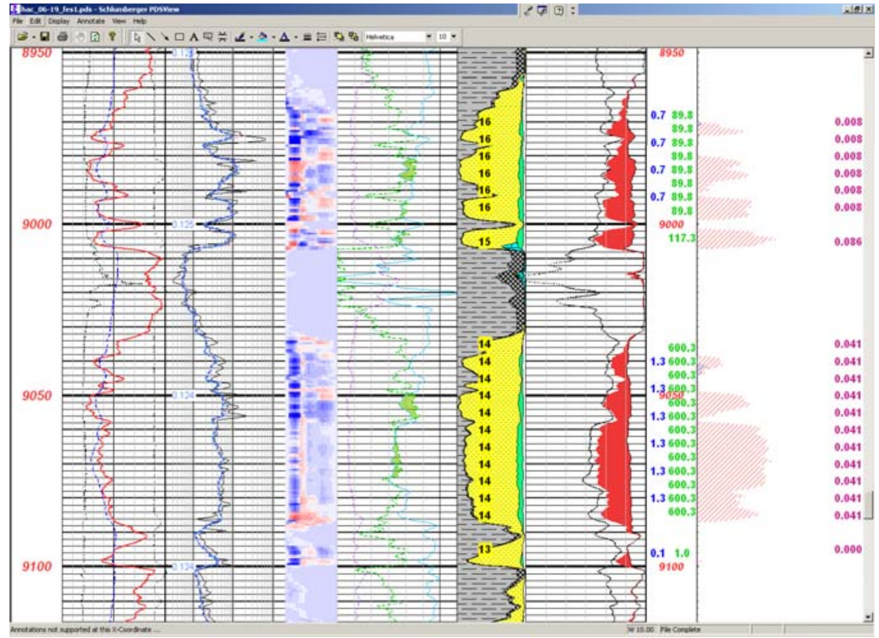


Figure 18: Petrophysical evaluation of the Hacienda 6-19 well (Sec 19 T28N R108W) over the interval hydraulically fractured in stage 1.

Schlumberger





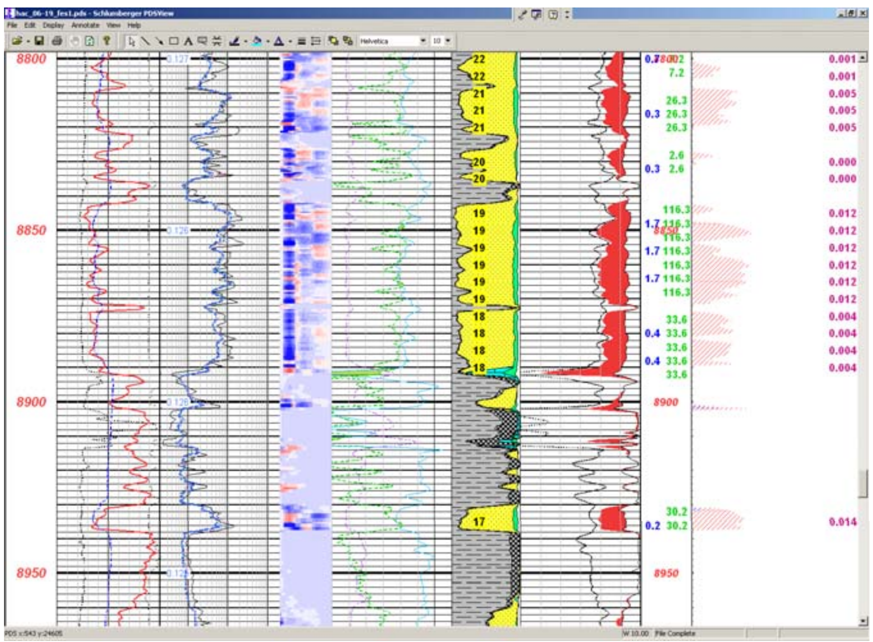
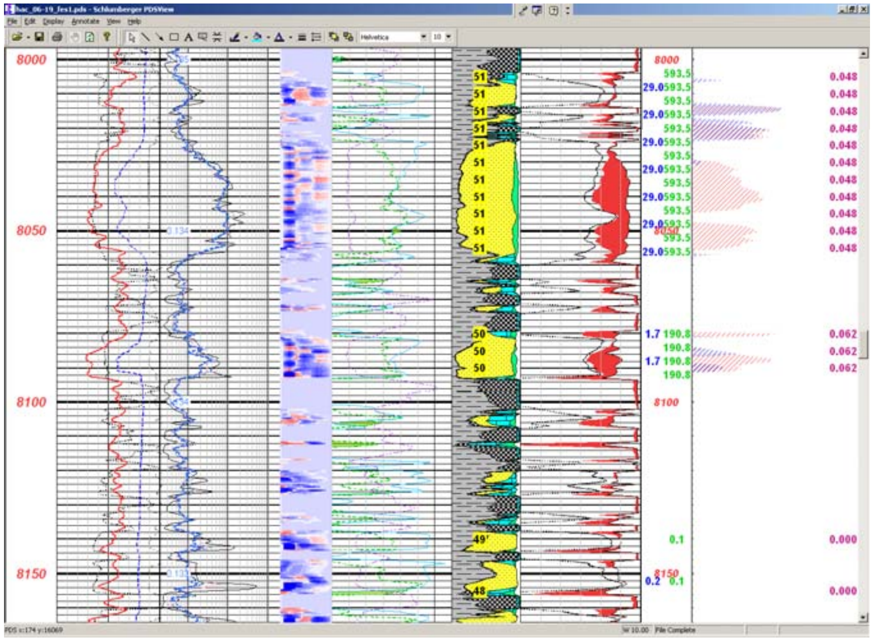
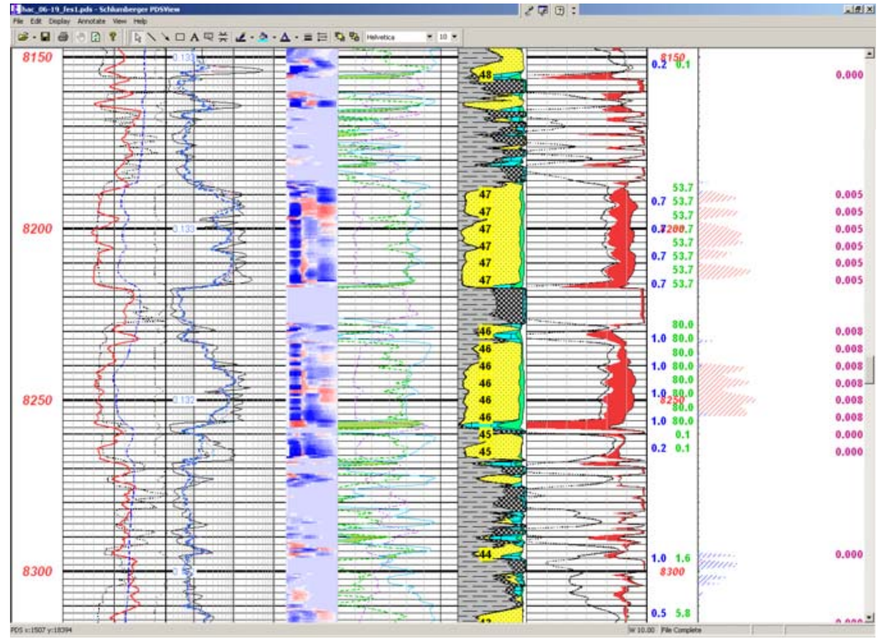


Figure 19: Petrophysical evaluation of the Hacienda 6-19 well (Sec 19 T28N R108W) over the interval hydraulically fractured in stage 2.





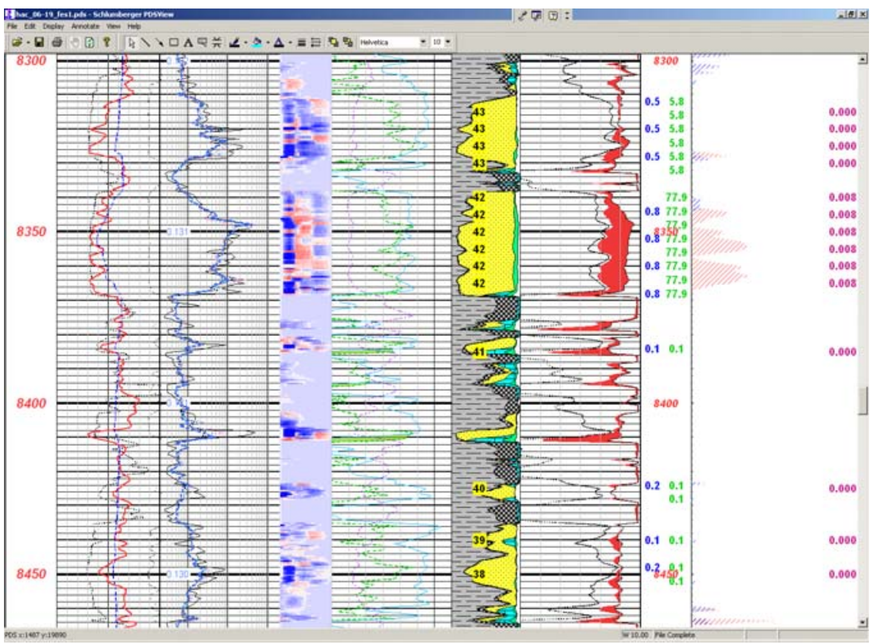


Figure 20: Petrophysical evaluation of the Hacienda 6-19 well (Sec 19 T28N R108W) over the interval hydraulically fractured in stage 3.

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ProCADE Results

Frac Stage	Perm (md)	Half Length (ft)	Porosity (%)	Sw (%)
1	0.0018	150	8.8 %	52 %
2	0.0014	150	8.7 %	46 %
3	0.0012	150	8.3 %	47 %

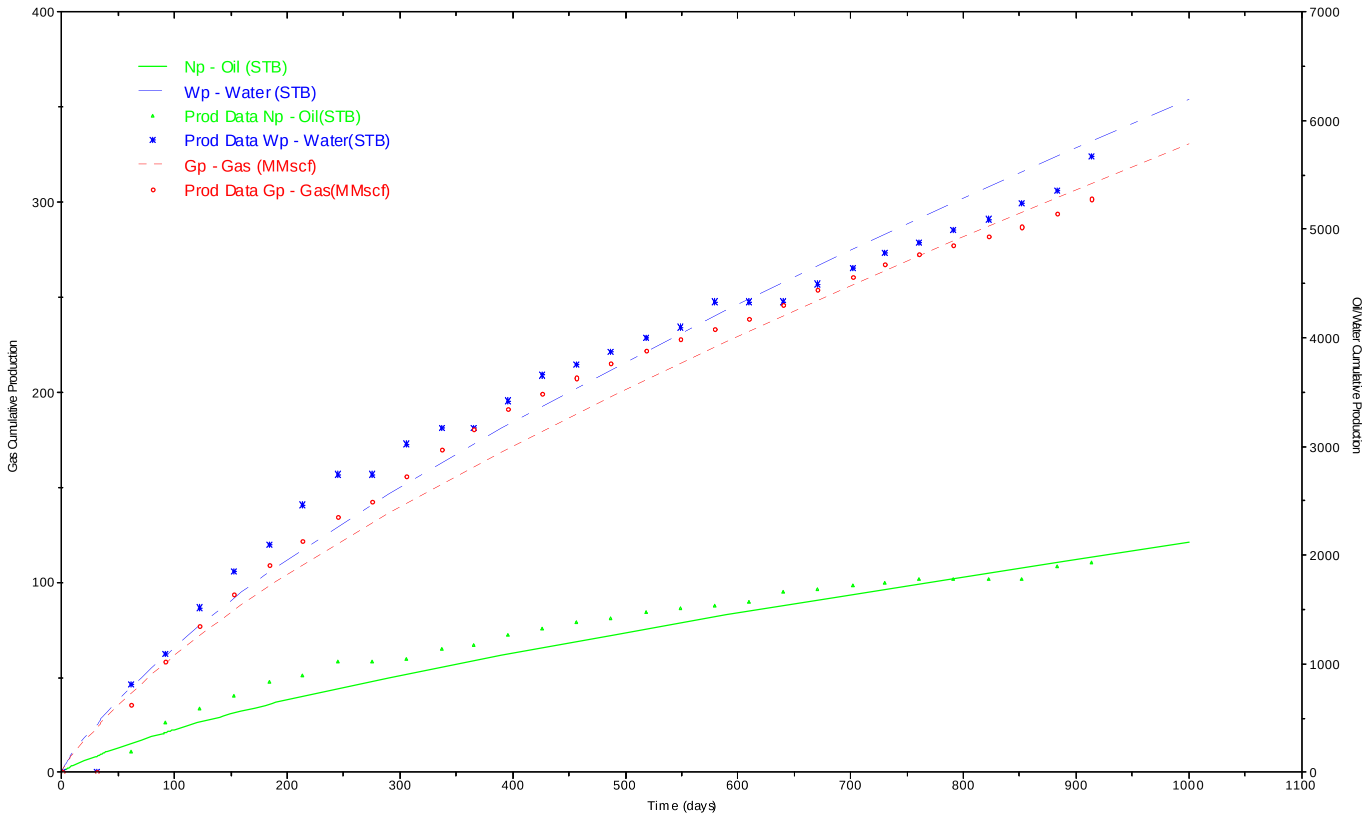

Figure 21: Production match of the Hacienda 6-19 well (Sec 19 T28N R108W) using *ProCADE*. Table shows results from the 3 hydraulic fracture stages

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Bayesian Production Analysis

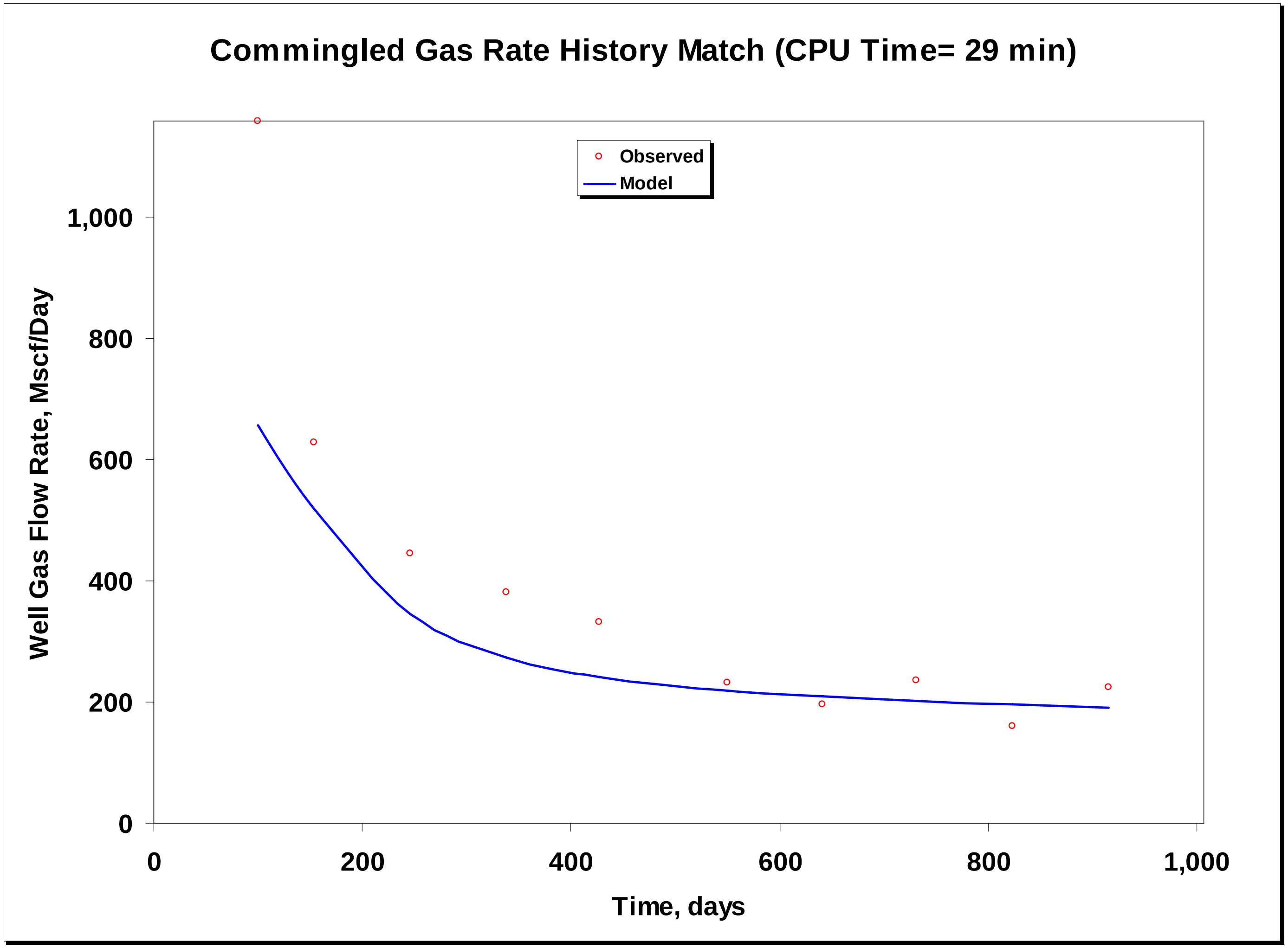

Figure 22: Commingled gas rate history match of the Hacienda 6-19 well (Sec 19 T28N R108W) using Bayesian Production Analysis

Schlumberger

Bayesian Production Analysis Production Log Match

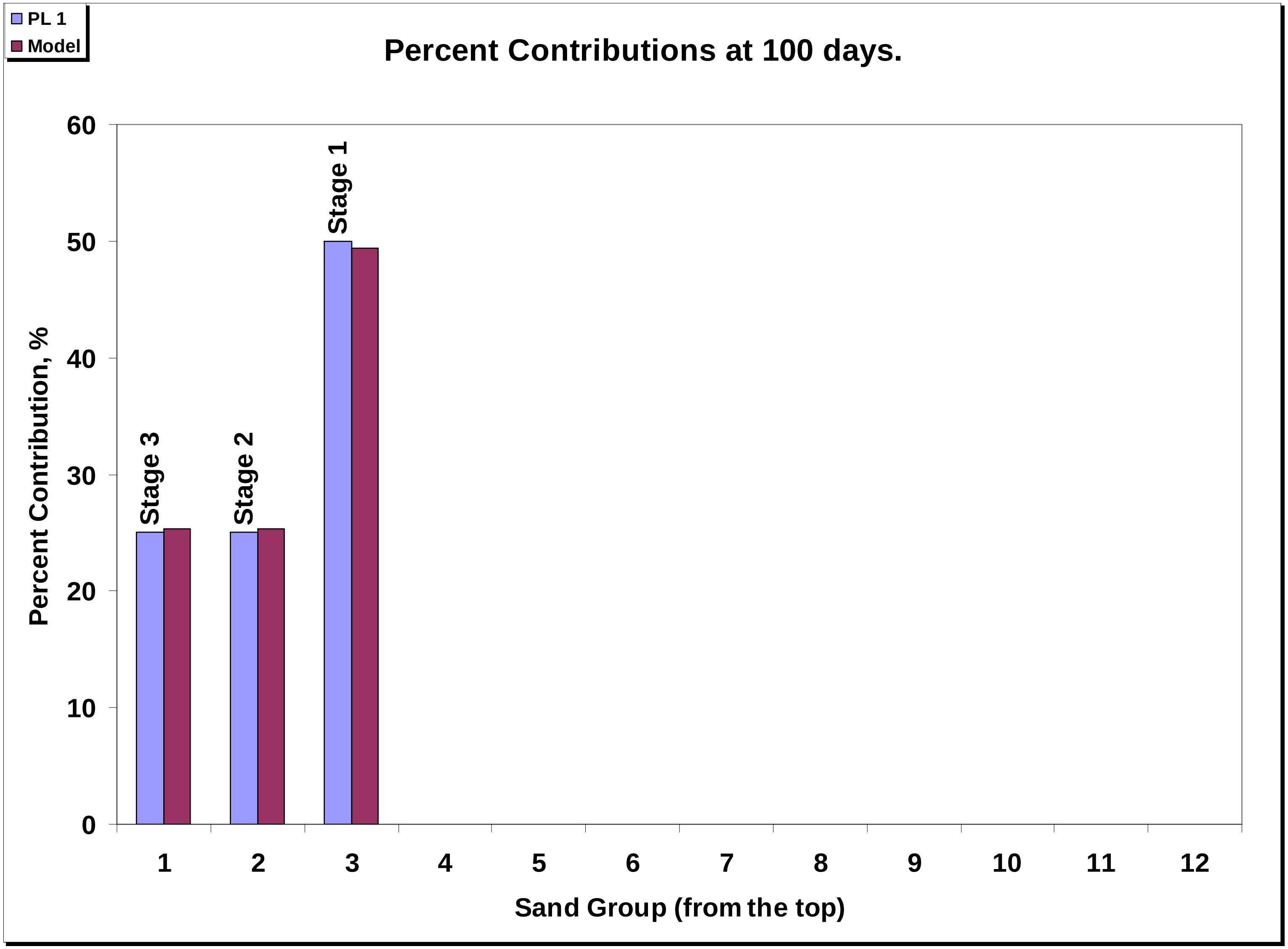

Figure 23: Production log match of the Hacienda 6-19 well (Sec 19 T28N R108W) using Bayesian Production Analysis

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Bayesian Production Analysis Production Per Stage

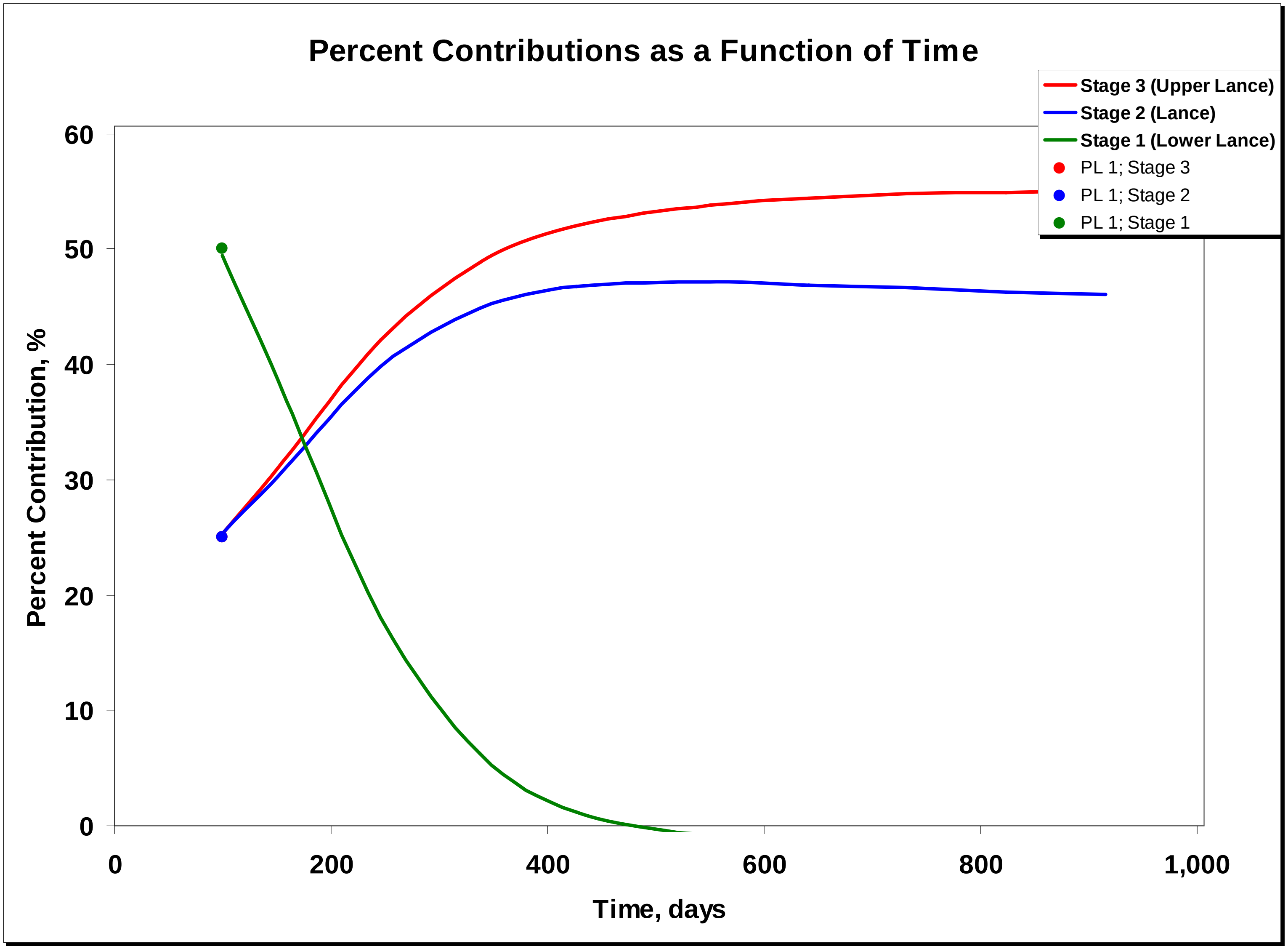

Figure 24: Production history of each hydraulic fracture stage in the Hacienda 6-19 well (Sec 19 T28N R108W) using Bayesian Production Analysis

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Bayesian Production Analysis Summary Results

Stage	PLT, %	Sand(s)	k, md	xf, ft	Net, ft	kfw, md-ft	kxf, md-ft	CfD
3	25.00	Upper Lance	2.40E-03	110	116.0	3.87	0.26	14.62
2	25.00	Lance	1.21E-03	154	129.0	1.81	0.19	9.68
1	50.00	Lower Lance	8.05E-02	2	129.5	0.12	0.13	0.90

Figure 25: Summary of results for each hydraulic fracture stage in the Hacienda 6-19 well (Sec 19 T28N R108W) using Bayesian Production Analysis

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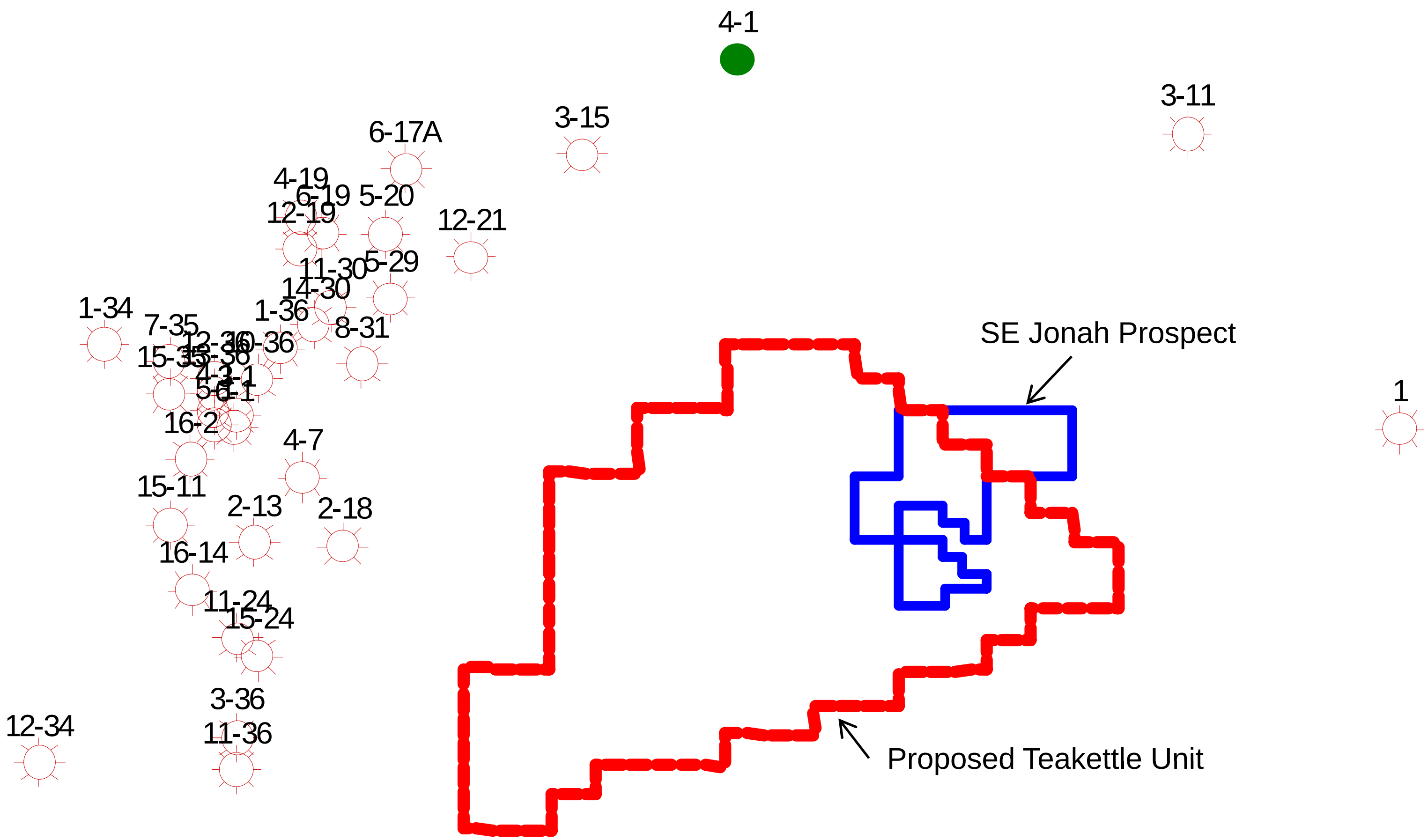

Figure 26: Map of wells with production data

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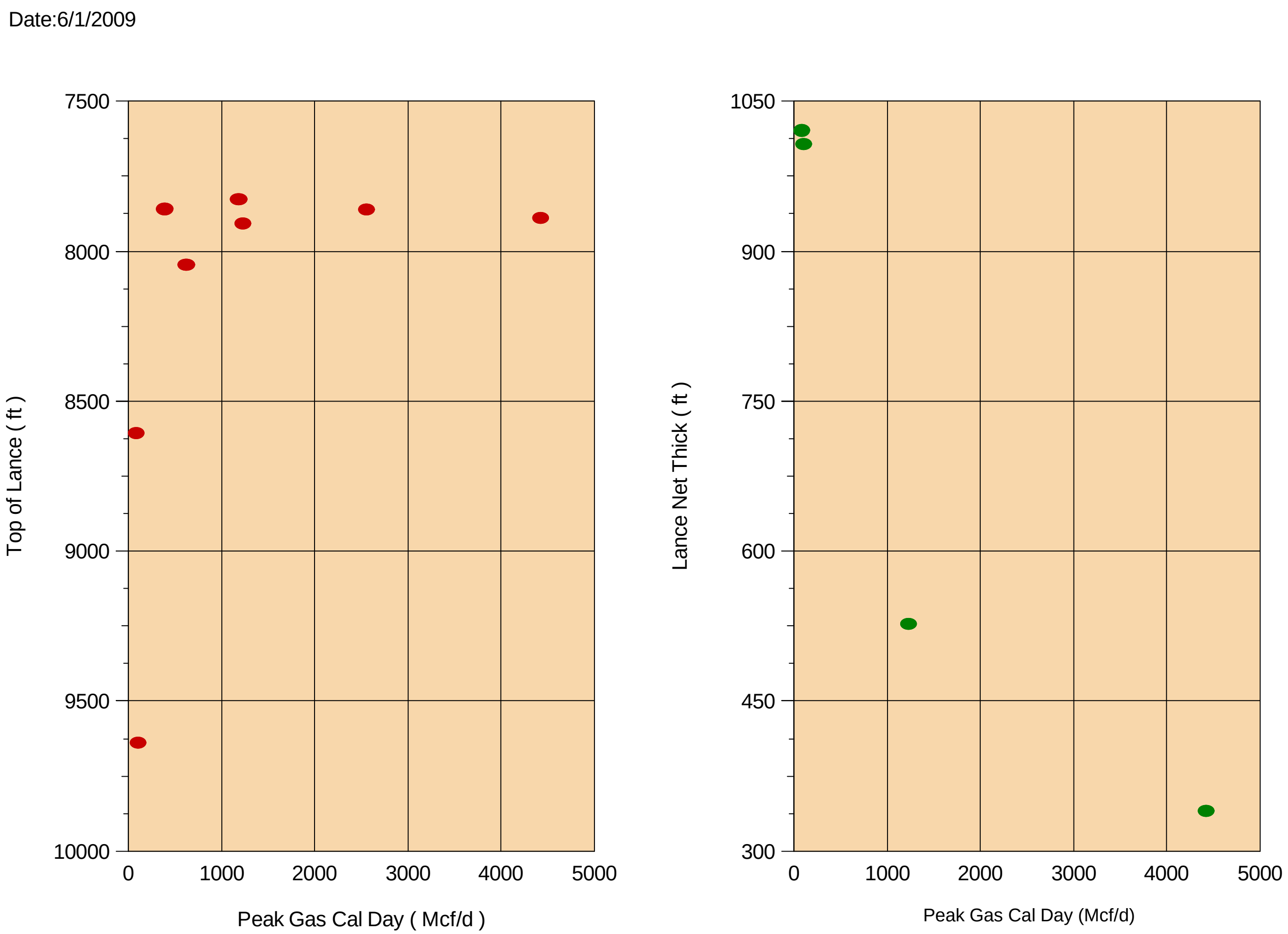


Figure 27: Scatter plot of structural top Lance and net thickness versus peak gas rate

Date:6/1/2009

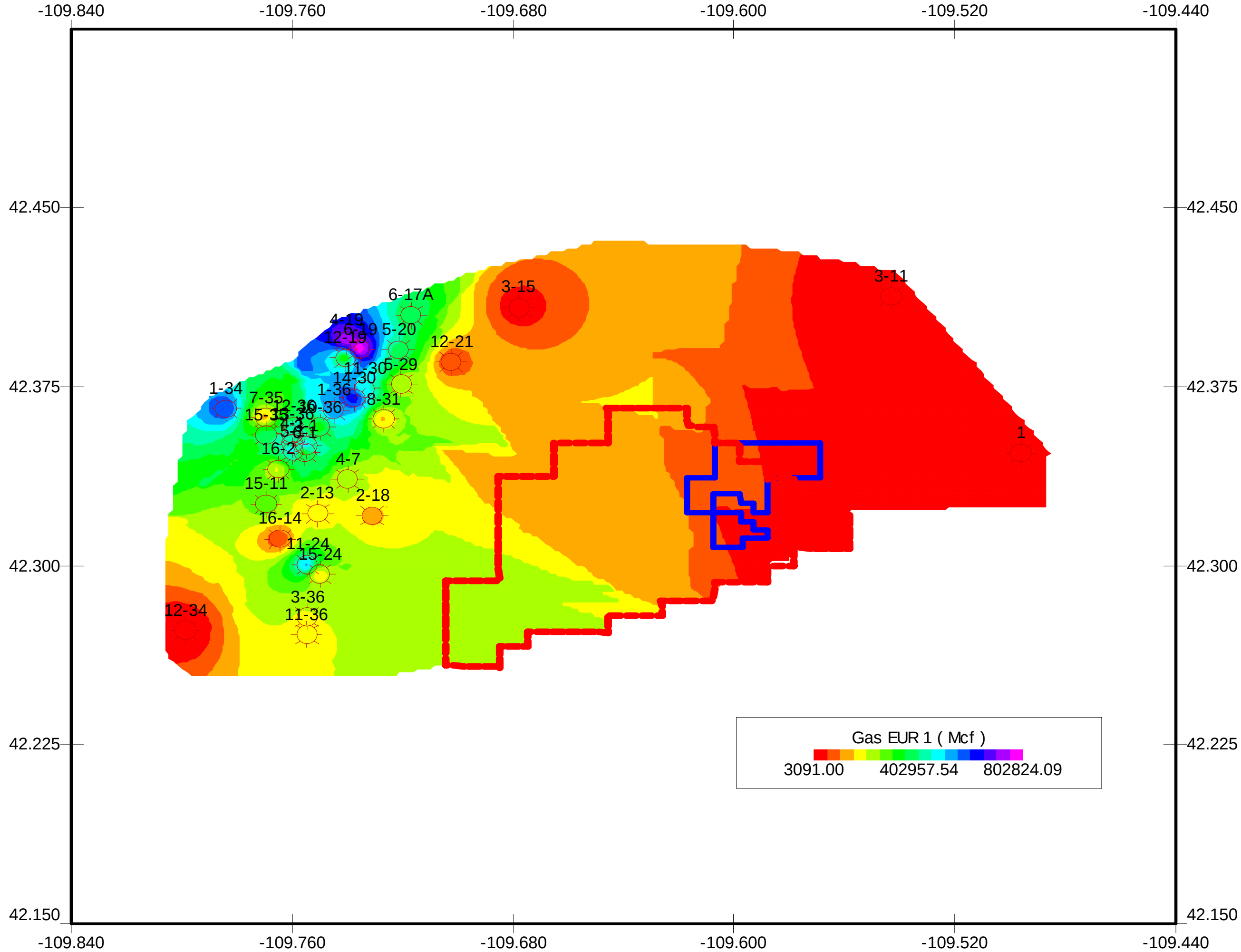


Figure 28: Map of EUR distribution

Schlumberger

Date:6/1/2009

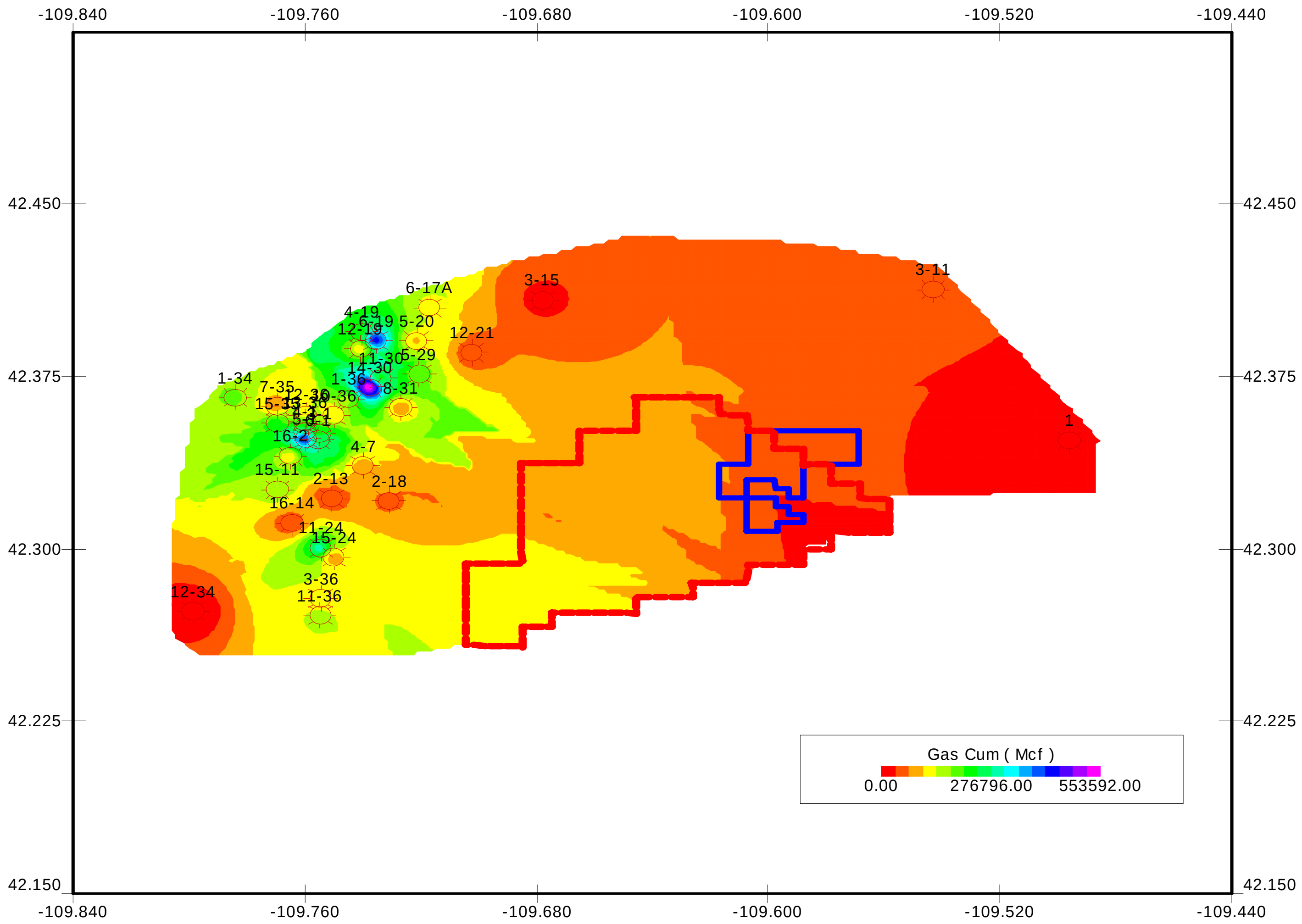


Figure 29: Map of cumulative gas production

Schlumberger

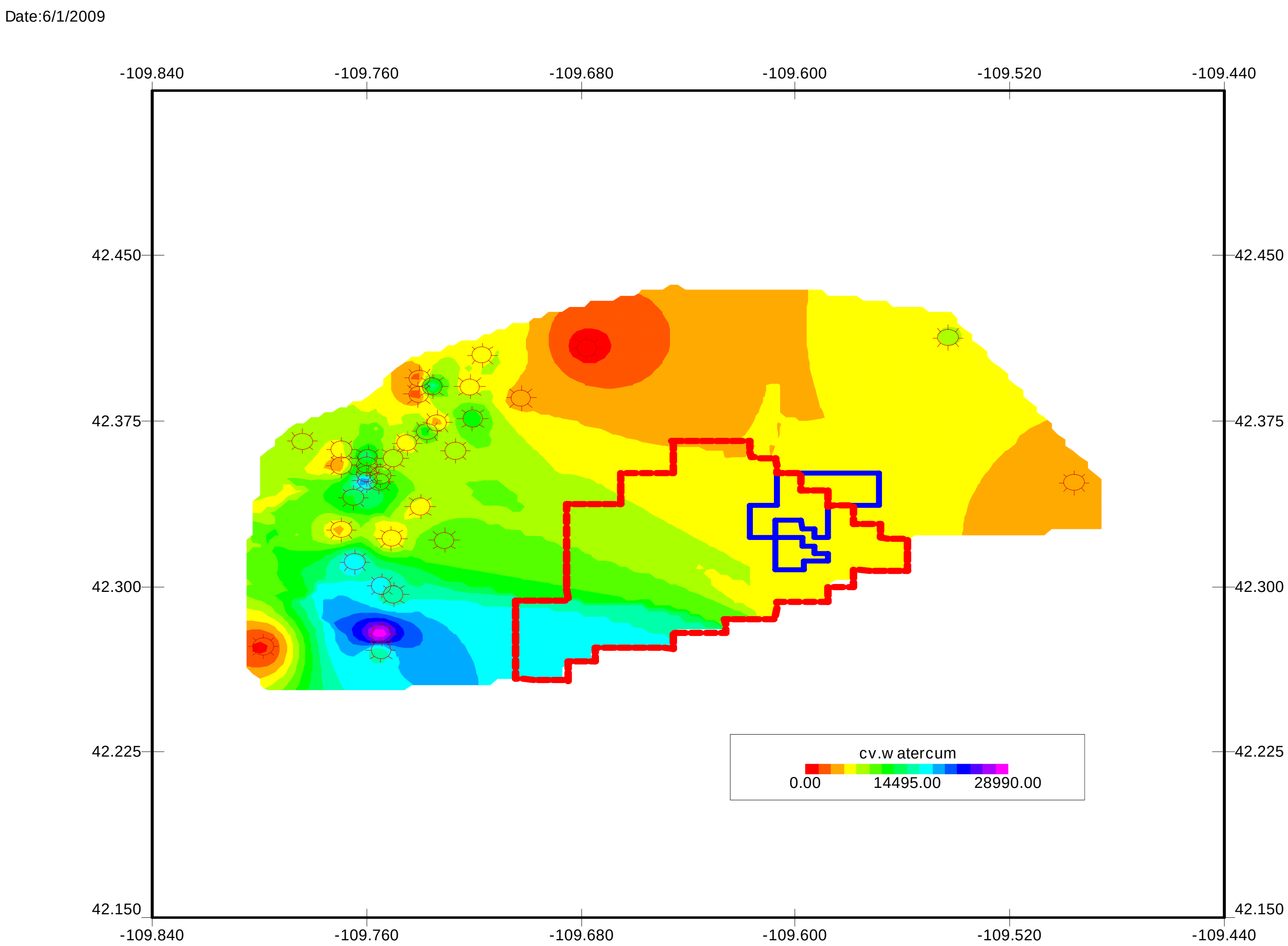


Figure 30: Map of cumulative water production

Schlumberger

Date:6/1/2009

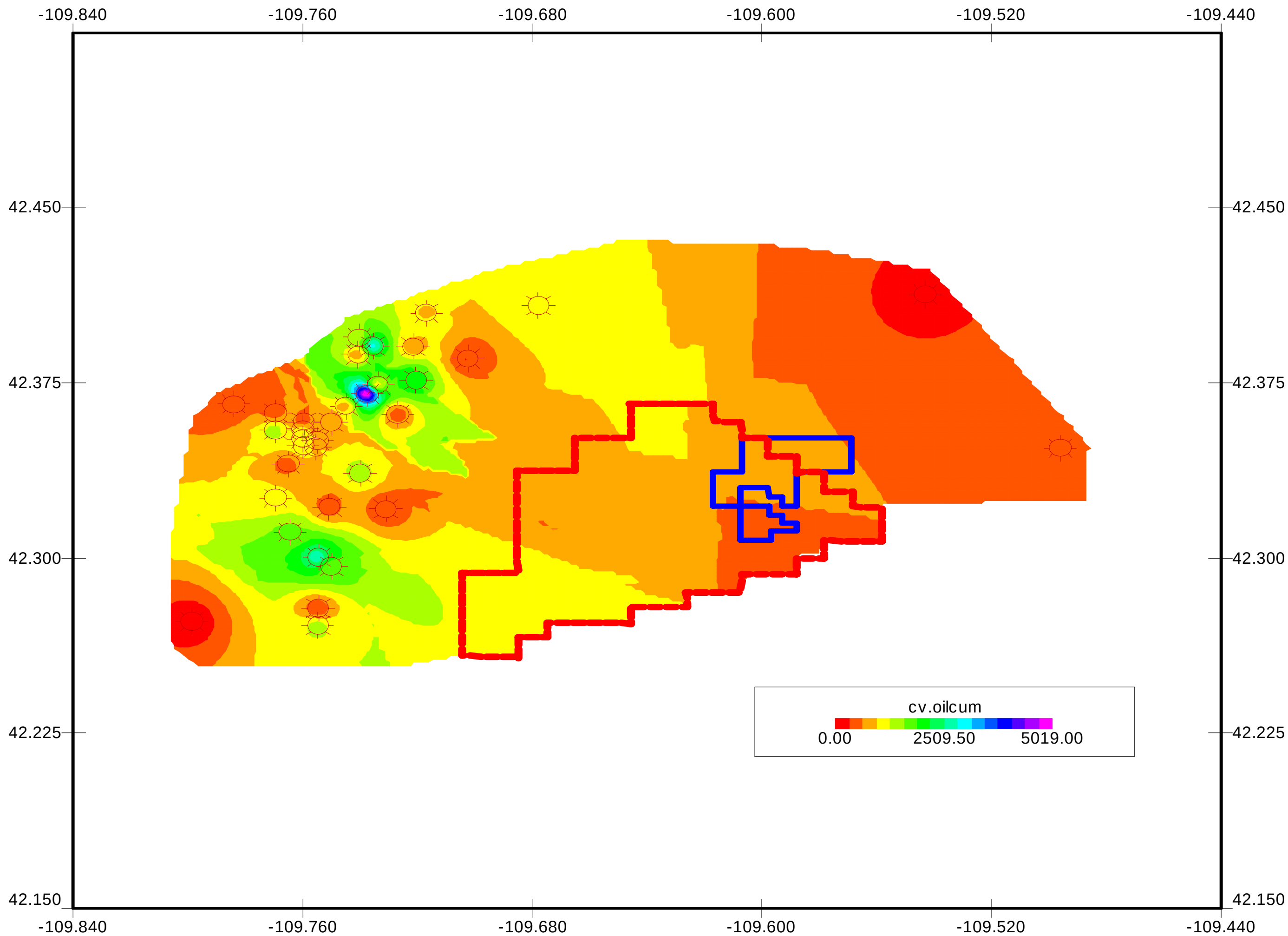
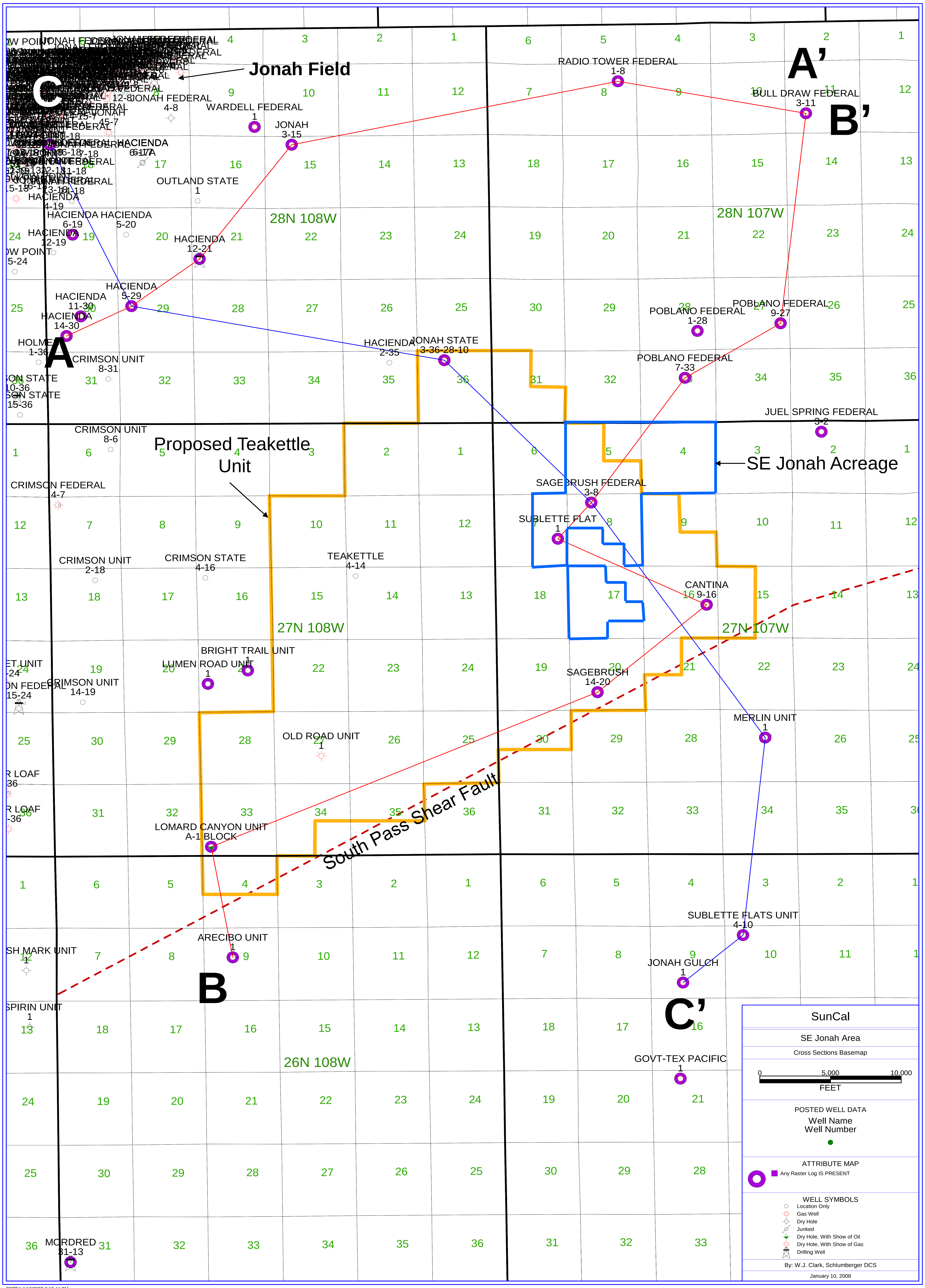


Figure 31: Map of cumulative oil production

Schlumberger

Base Map



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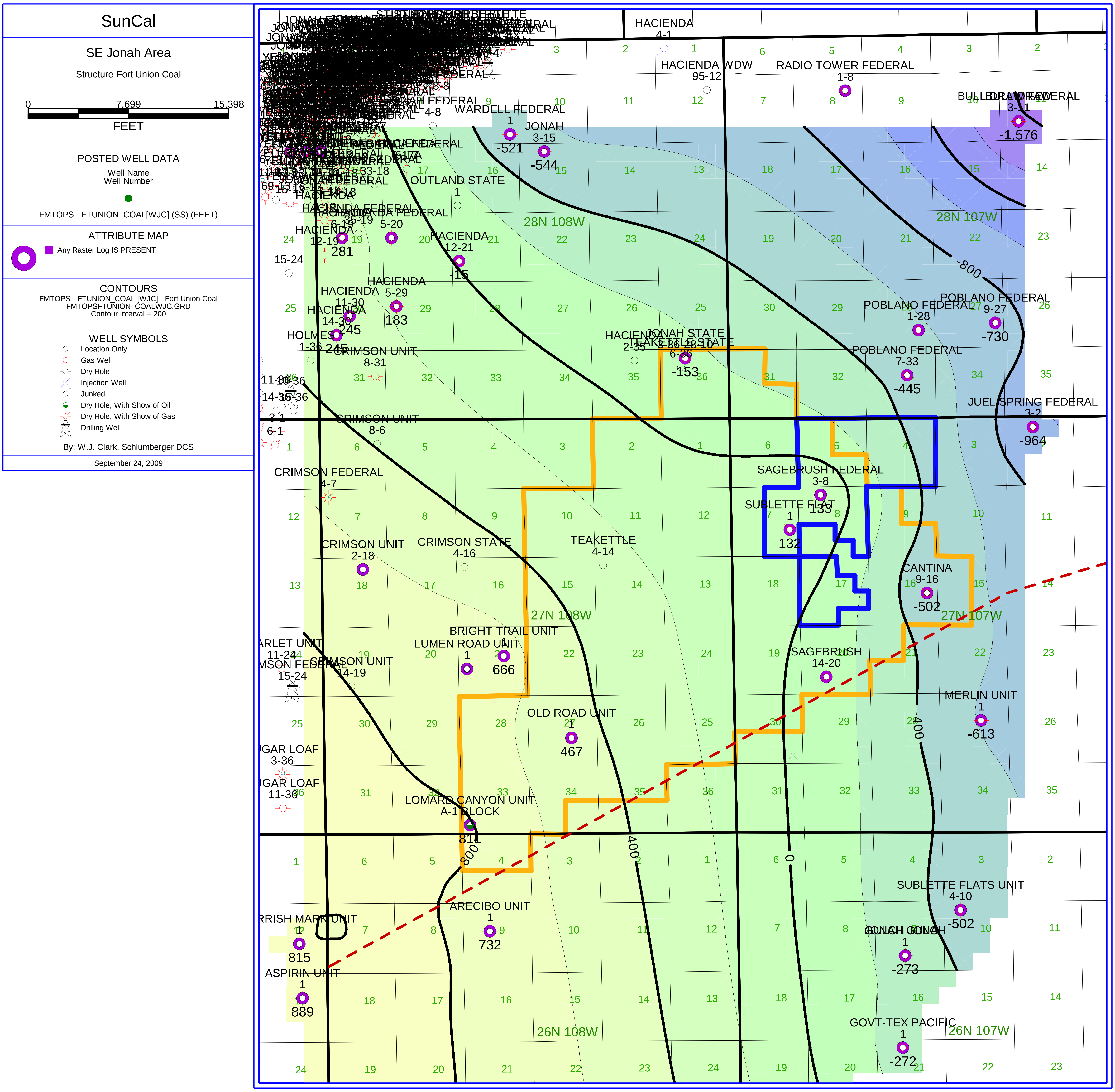
Map 1

Teakettle Unit

Acreage (SE Jonah Prospect)

Schlumberger

Structure at top Fort Union Coal Zone



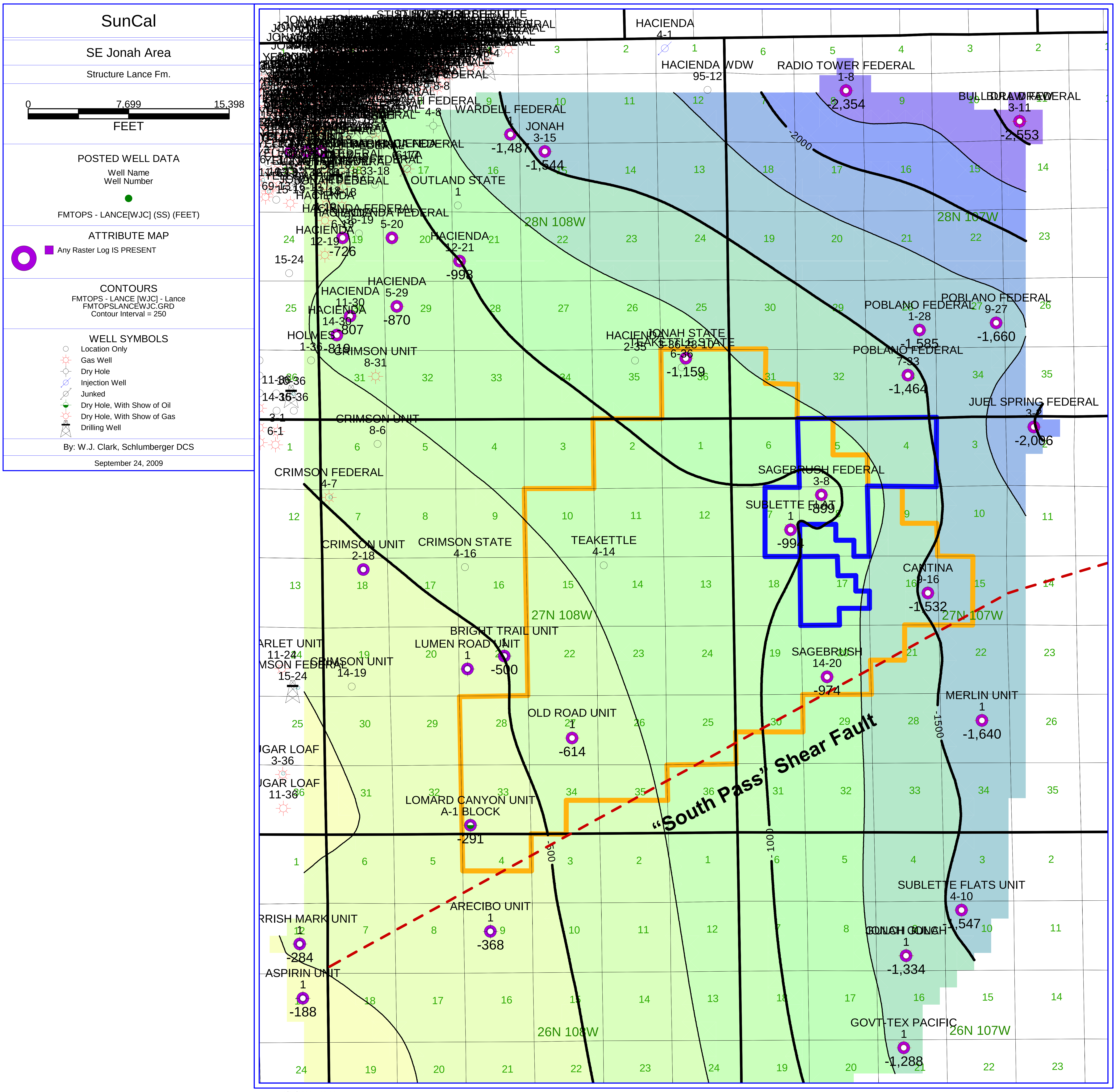
Teakettle Unit

Acreage (SE Jonah Prospect)

Map 2

Schlumberger

Structure at top Lance Formation



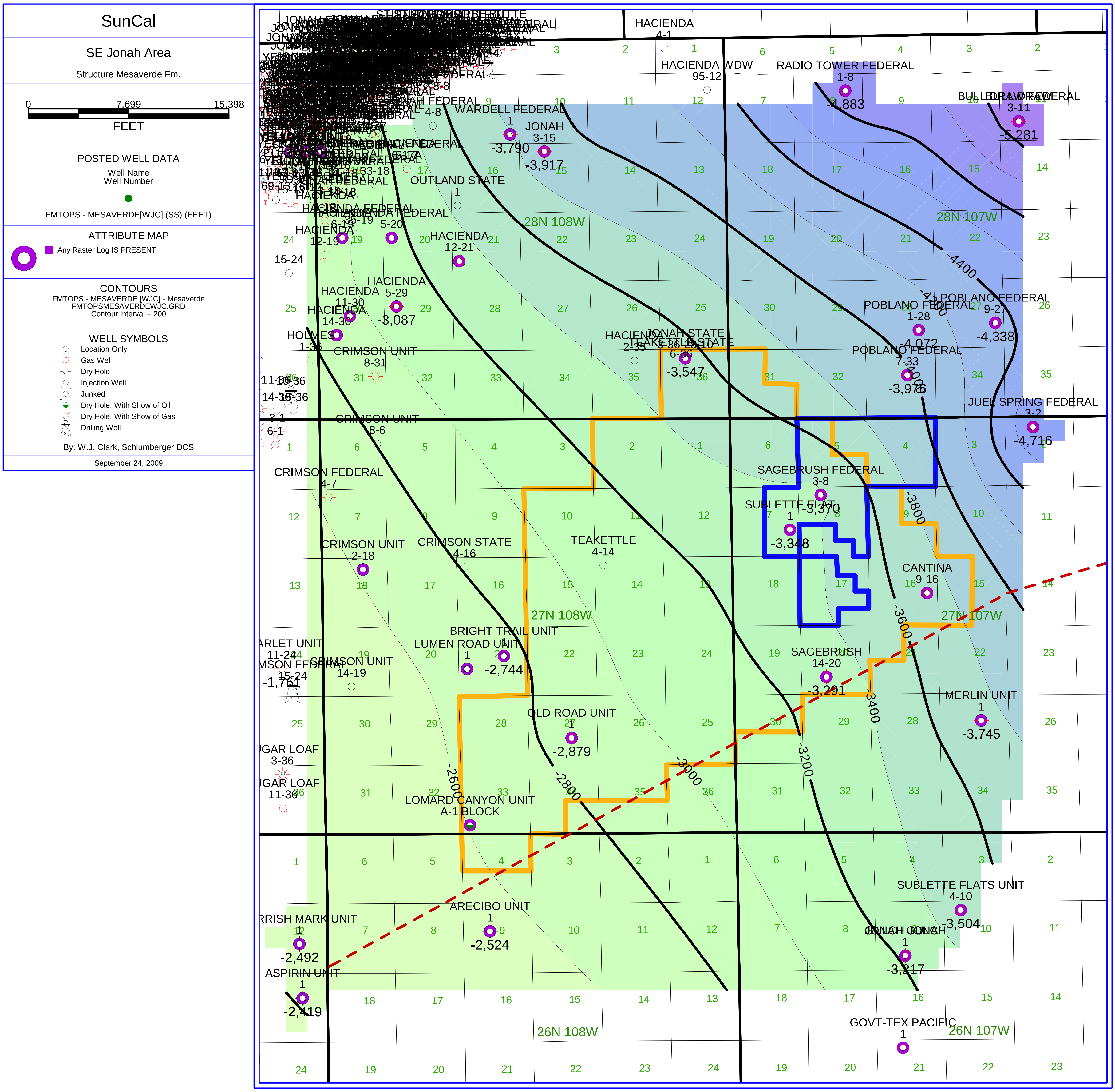
Teakettle Unit

Acreage (SE Jonah Prospect)

Map 3

Schlumberger

Structure at top Mesaverde

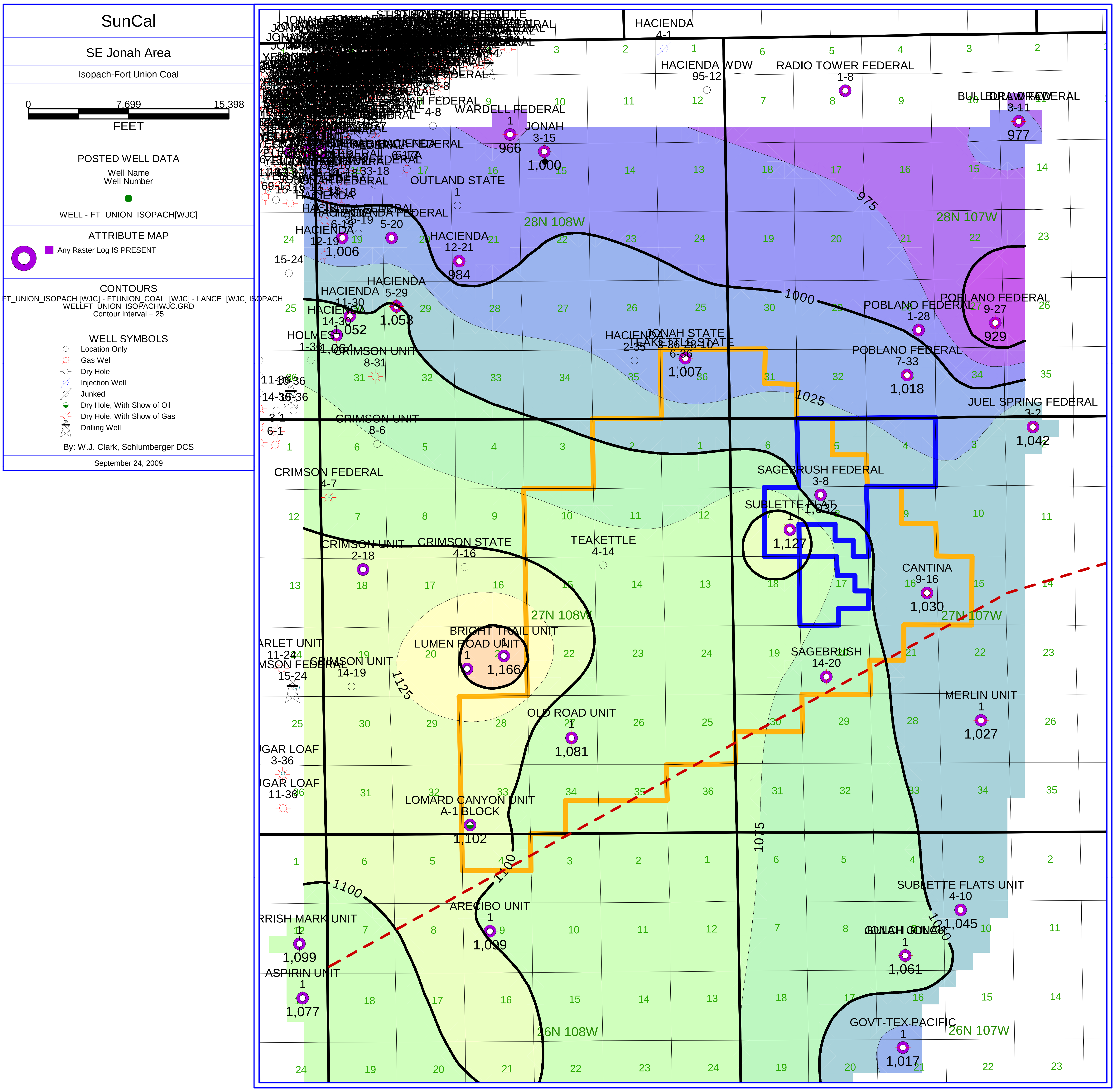


Teakettle Unit
Acreage (SE Jonah Prospect)

Map 4

Schlumberger

Fort Union Thickness Isopach



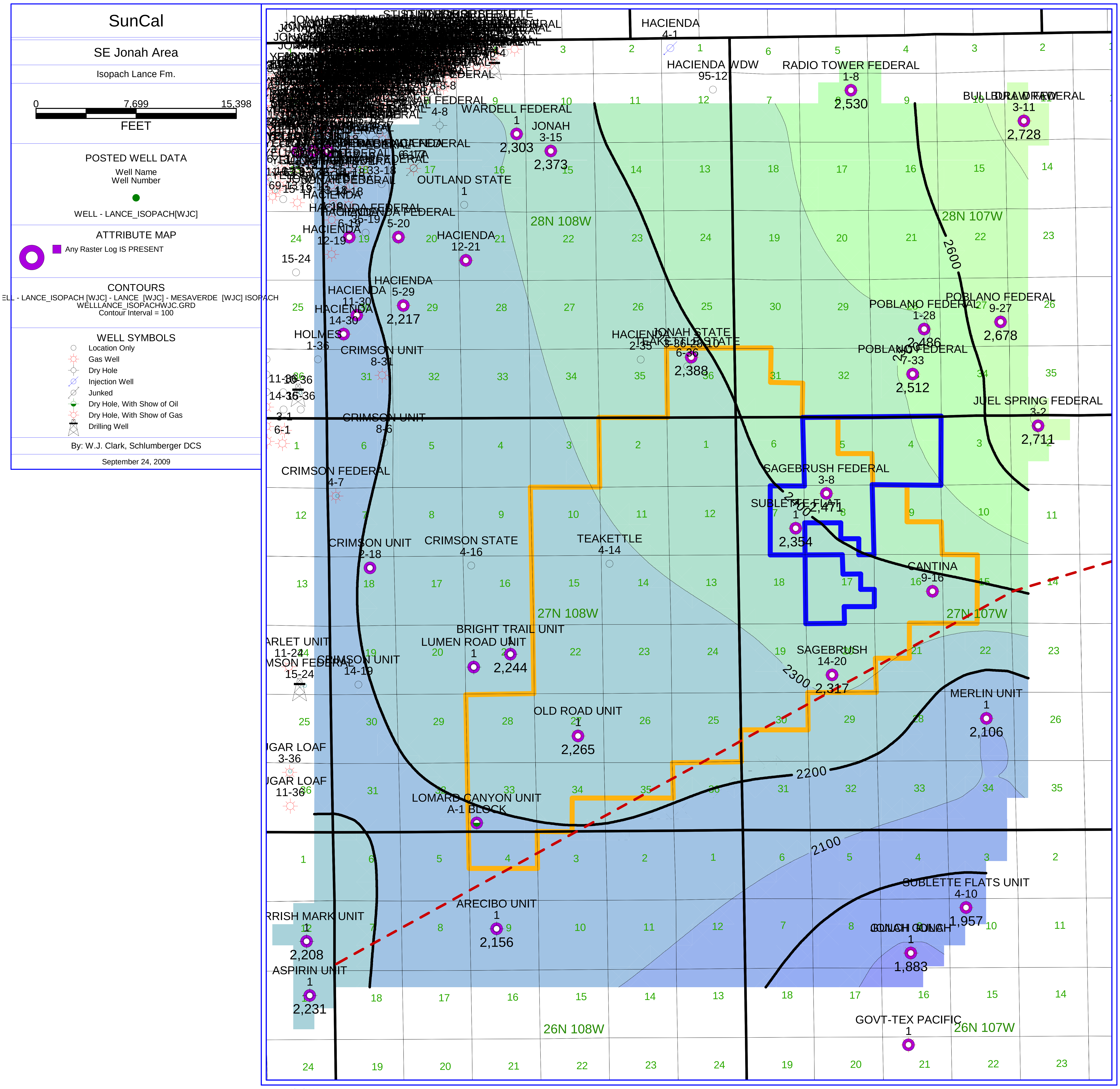
Teakettle Unit

Acreage (SE Jonah Prospect)

Map 5

Schlumberger

Lance Formation Thickness Isopach



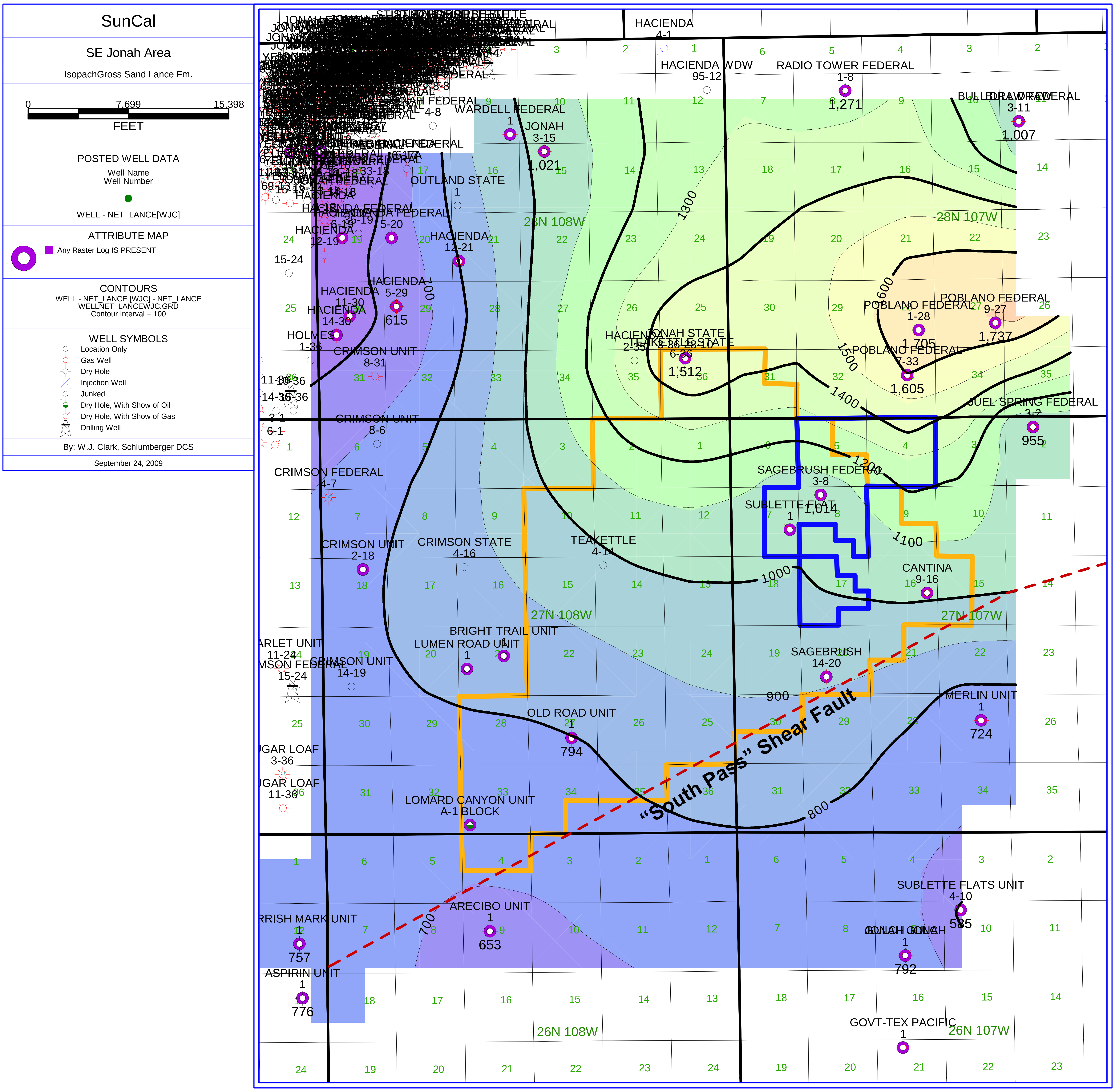
Teakettle Unit

Acreage (SE Jonah Prospect)

Map 6

Schlumberger

Gross Sand Isopach Lance Formation



Teakettle Unit

Acreage (SE Jonah Prospect)

Map 7

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UWI/API	WELLNAME	WELLNO	SURFLAT	SURFLON	TOWNSHIP	RANGE	FTUNION_COAL (MD)	LANCE (MD)	MESAVERDE (MD)	WELL FT_UNION_ISOPACH	WELL LANCE_ISOPACH	WELL SAND-GROSS_LANCE
49035237570000	HACIENDA	11-30	42.37429	-109.7338103	28N	108W	6808.09	7859.91		1051.82		
49035230250000	HACIENDA	14-30	42.37038	-109.7376203	28N	108W	6796.7	7860.84		1064.15		
49035215420000	CANTINA	9-16	42.31426	-109.5712502	27N	107W	7249.42	8279.17		1029.75		
49035213560000	JONAH	3-15	42.40825	-109.6778602	28N	108W	7606.56	8607.06	10980.24	1000.49	2373.18	1020.68
49035204110000	LUMEN ROAD UNIT	1	42.29987	-109.7020502	27N	108W	6742.43	7839.83		1097.41		
49035054330000	SUBLETTE FLAT	1	42.32803	-109.6098807	27N	107W	6816.05	7801.34	10155	985.29	2353.66	
49035225030000	HACIENDA	12-21	42.38551	-109.7024802	28N	108W	7061.5	8045.08		983.58		
49035237560000	HACIENDA	6-19	42.39078	-109.7356102	28N	108W	6821.42	7827.56		1006.14		
49035205240000	BRIGHT TRAIL UNIT	1	42.30245	-109.6915502	27N	108W	6720.17	7785.24	9799.42	1065.07	2014.17	
49037216150000	JONAH GULCH	1	42.23822	-109.5791209	26N	107W	6949.58	8010.98	9894.42	1061.4	1883.45	792.33
49037064480000	GOVT-TEX PACIFIC	1	42.21888	-109.5802302	26N	107W	6960.72	7977.34		1016.62		
49037261130000	ARECIBO UNIT	1	42.2447	-109.6966809	26N	108W	6089.38	7188.8	9106.36	1099.42	1917.56	653.19
49037269340000	MORDRED	31-13	42.18376	-109.7403103	26N	108W	6282.03	7390.92		1108.89		
49037234700000	SUBLETTE FLATS UNIT	4-10	42.24759	-109.5632601	26N	107W	7184.77	8229.91	10187.02	1045.13	1957.11	584.89
49035221480000	POBLANO FEDERAL	7-33	42.36005	-109.5758903	28N	107W	7341.31	8359.57	10871.7	1018.25	2512.14	1604.91
49035230920000	MERLIN UNIT	1	42.28731	-109.5565503	27N	107W	7317.01	8343.75	10449.43	1026.75	2105.68	723.95
49035230770000	SUGAR LOAF	11-36	42.2712	-109.7547804	27N	109W			8341			
49035218090000	JONAH STATE	3-36-28-10	42.36438	-109.6388004	28N	108W	7088.53	8095.36	10483.4	1006.82	2388.05	1512.48
49035221090000	JUEL SPRING FEDERAL	3-2	42.34875	-109.5404402	27N	107W	7859.16	8900.75	11611.38	1041.59	2710.63	954.93
49035221200000	POBLANO FEDERAL	1-28	42.36947	-109.5724003	28N	107W		8515.31	11001.64		2486.34	1704.68
49035221470000	POBLANO FEDERAL	9-27	42.37072	-109.5506003	28N	107W	7689.29	8618.77	11297.2	929.48	2678.43	1737.11
49035220170000	SCARLET UNIT	11-24	42.30053	-109.7545802	27N	109W			8728			
49035212830000	BULL DRAW FEDERAL	3-11	42.41295	-109.5430001	28N	107W	8660.77	9637.83	12365.86	977.06	2728.03	1006.97
49035213660000	SAGEBRUSH FEDERAL	3-8	42.33523	-109.6009908	27N	107W	6743.72	7686.71	10157.8	943	2471.08	1013.86
49035203420000	WARDELL FEDERAL	1	42.41195	-109.6875109	28N	108W	7570.5	8536.8	10670.39	966.3	2133.59	
49035201530000	LOMARD CANYON UNIT	A-1 BLOCK	42.26705	-109.7018703	27N	108W	5955.79	7075.46		1119.67		
49035226610000	SAGEBRUSH	14-20	42.29701	-109.6001902	27N	107W		7712	10033.24		2321.24	
49035216790000	RADIO TOWER FEDERAL	1-8	42.42002	-109.5921008	28N	107W		9357.72	11887.34		2529.62	1270.83
49035225410000	HACIENDA	5-29	42.37621	-109.7205103	28N	108W	6855.18	7908.18	9824.84	1053	1916.66	527.24
49035224160000	JONAH FEDERAL	4-18	42.40899	-109.7412302	28N	108W	6912.12	7889.51	9837.79	977.39	1948.28	340.28
49037269340000	MORDRED	31-13	42.18376	-109.7403100	26N	108W	6060.00	7132.00		1072.00		
49037213190000	PARRISH MARK UNIT	1	42.24265	-109.7507000	26N	109W	6066.00	7165.00	9373.00	1099.00	2208.00	757.30
49037218300000	ASPIRIN UNIT	1	42.23126	-109.7500000	26N	109W	6032.00	7109.00	9340.00	1077.00	2231.00	776.30
49035206220000	OLD ROAD UNIT	1	42.28502	-109.6727000	27N	108W	6368.00	7449.00	9714.00	1081.00	2265.00	793.68

Table 2: Well list showing wells with location, structure, and isopach data.

SE Jonah Prospect
Production Domain Update

Dr. Hui Gao and Andy Baker

Schlumberger Data and Consulting Services
Denver, CO

Work Summary

- Updated production history from public database (IHS/Enerdeq)
- Re-ran production decline curve analysis
- Updated production data analysis techiques
  - Scatter plots, grid maps, bubble maps

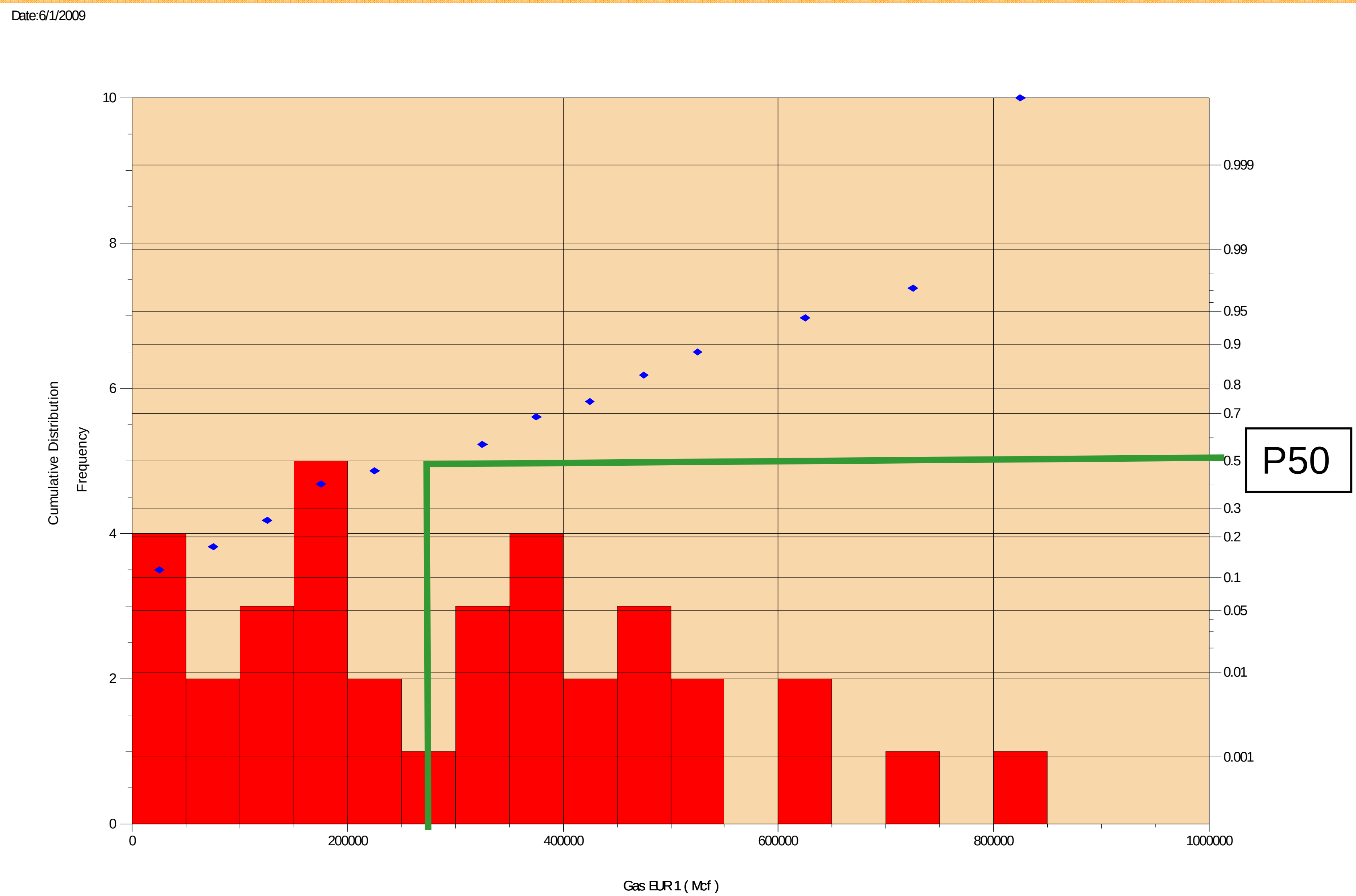
Results

- Water production occurs downdip
- Most wells show hyperbolic decline
  - Rate data existing only in the transient period
  - Low permeability with natural or hydraulic fractures
  - Highly heterogeneous reservoirs
- Wells completed on Top Lance have higher peak gas rate (limited statistics)
- Northwest study area has superior EUR performance
- Production Indicator shows medium heterogeneity. EUR Dykstra-Parsons equals to 0.48.

EUR Tabular Results

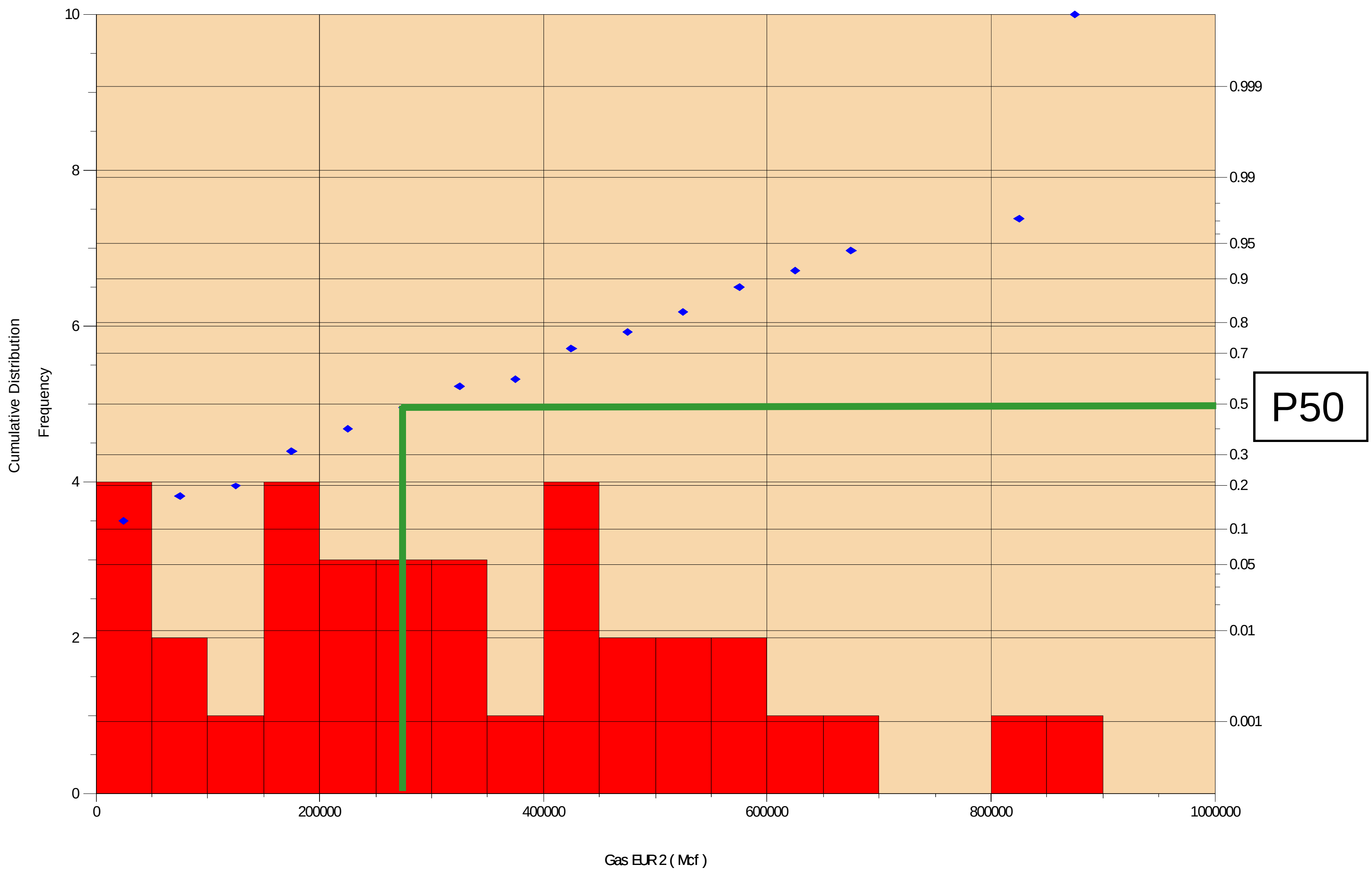
	EUR 1 (log gas rate versus time) (Mscf)	EUR 2 (linear gas rate versus gas cumulative) (Mcf)
p.50	262,931	274,553
p.90	513,469	601,023
p.10	13,739	13,761

EUR Probability Plot – Case1

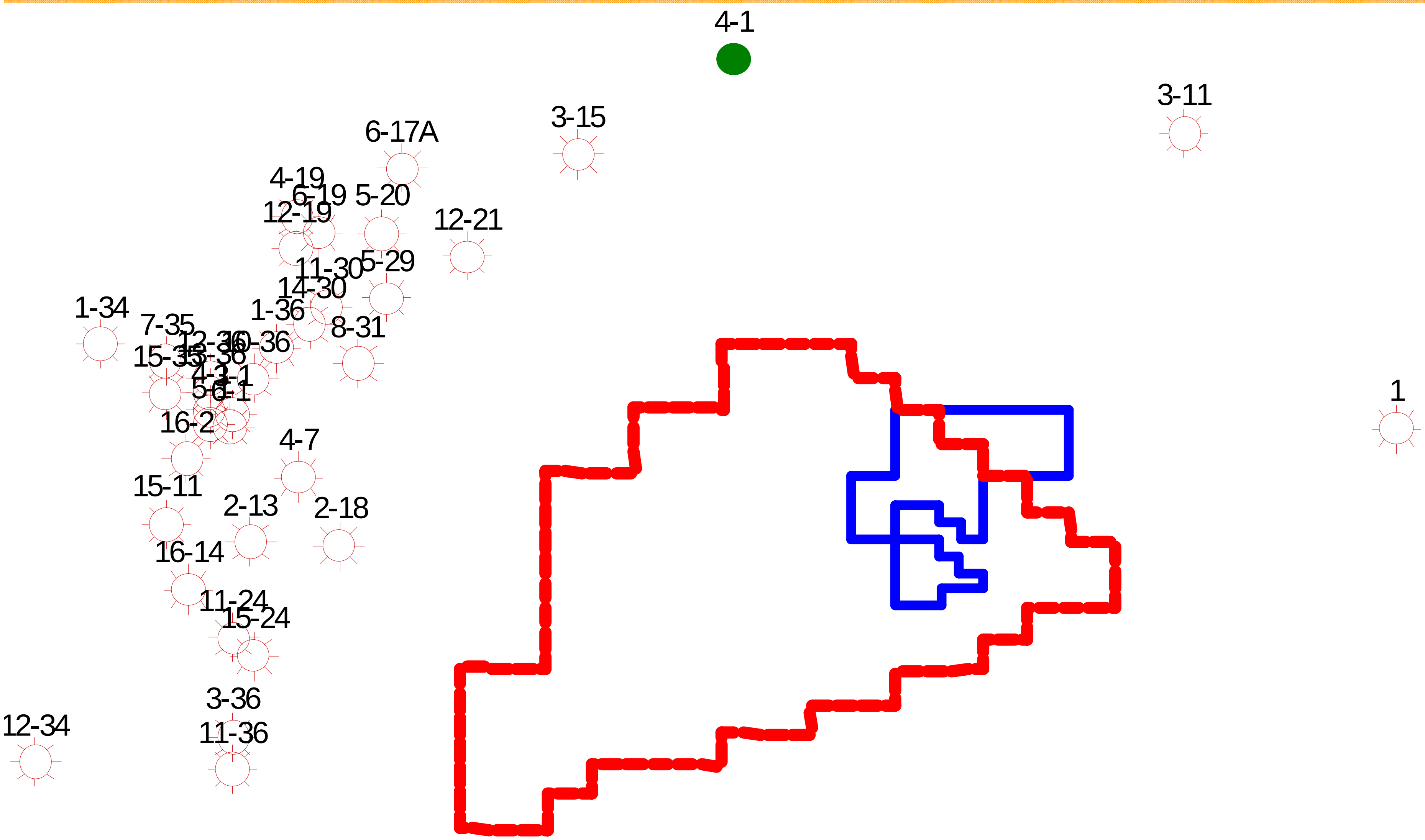


EUR Probability Plot – Case2

Date:6/1/2009

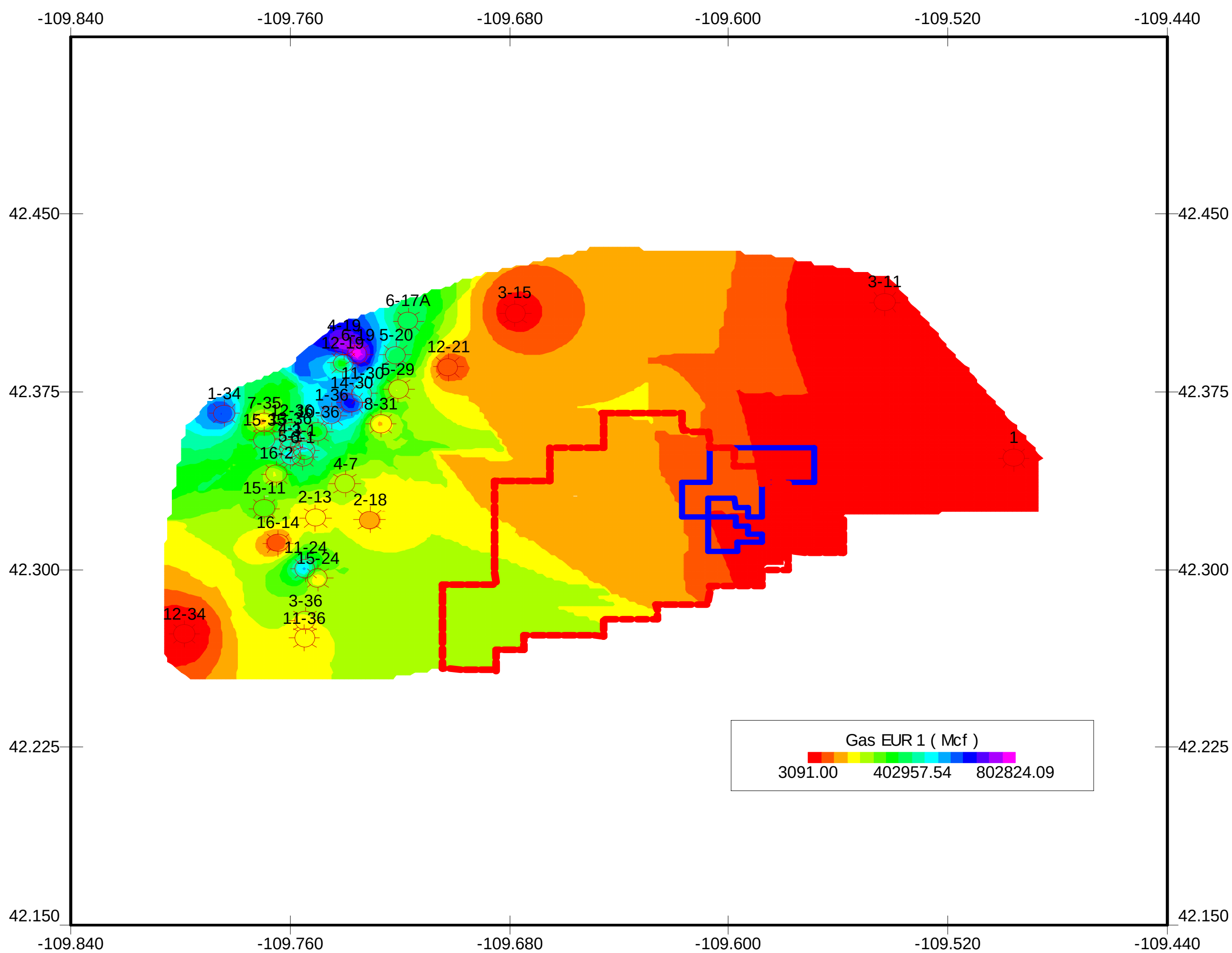


OFM Base Map

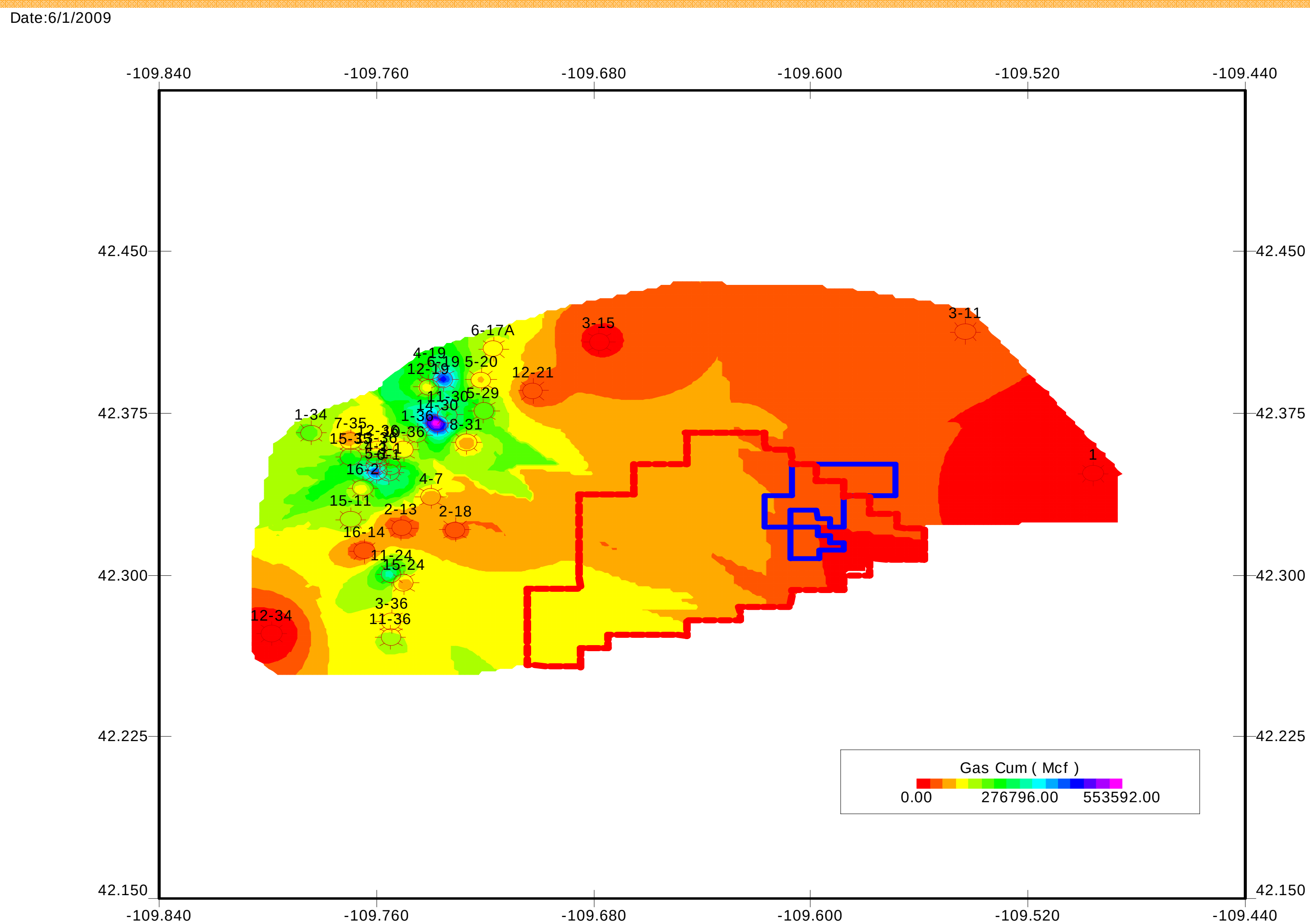

4-1
3-11
3-15
6-17A
4-19
6-19
5-20
12-19
12-21
11-30
5-29
14-30
1-36
1-34
7-35
8-31
15-35
16-2
4-7
15-11
2-13
2-18
16-14
11-24
15-24
3-36
11-36
12-34
1

EUR

Date:6/1/2009

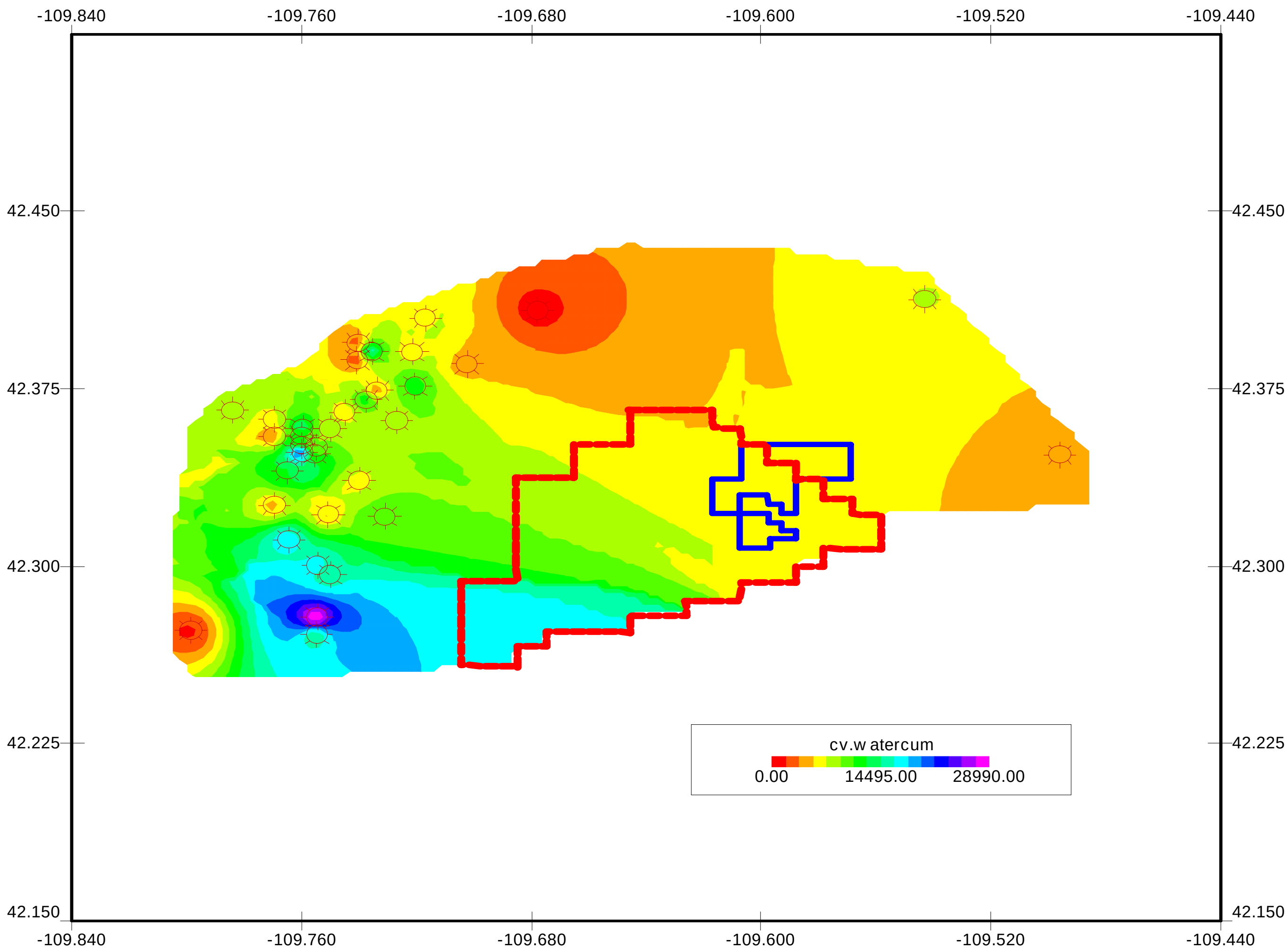


Cumulative Gas Production



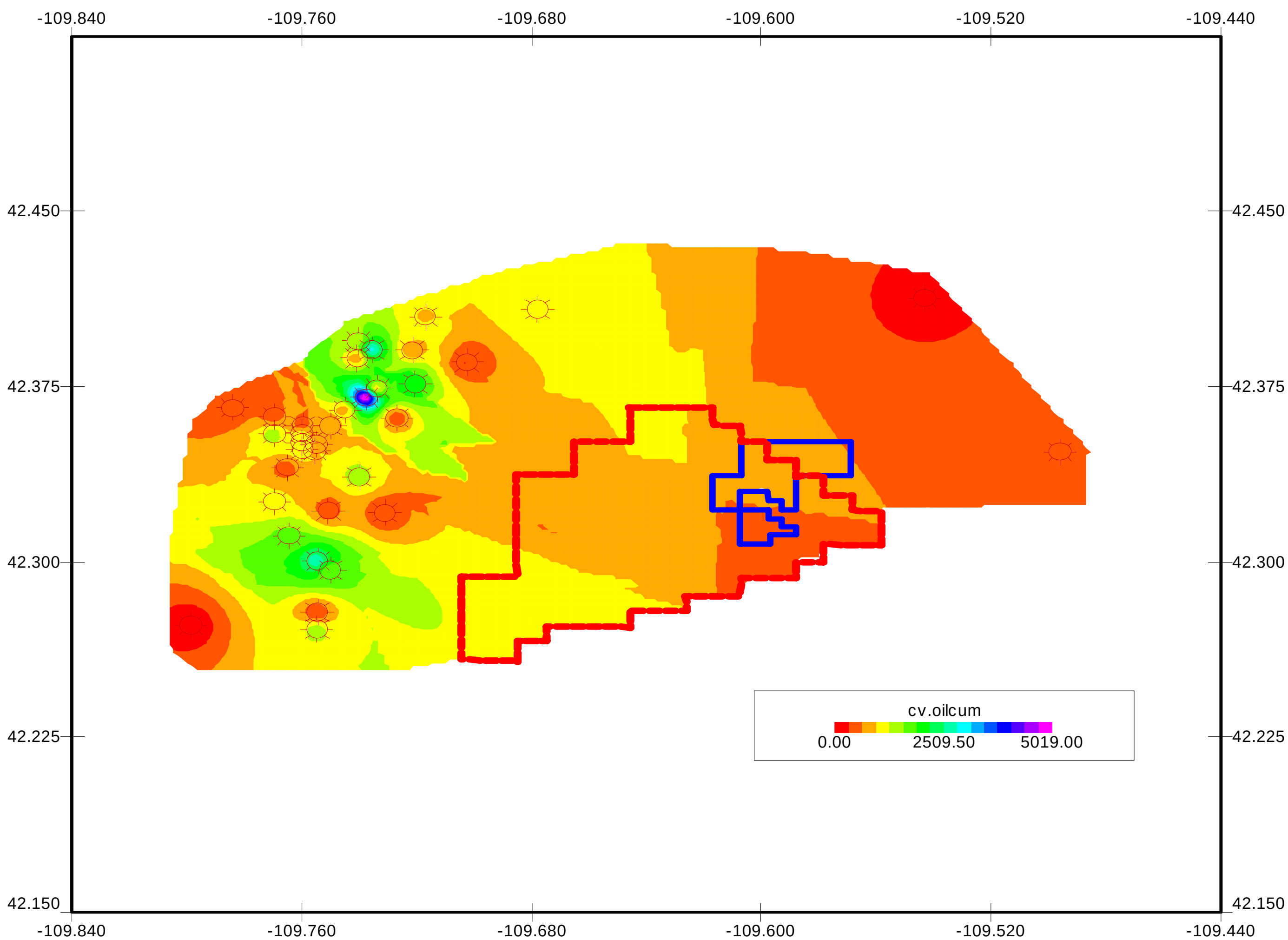
Cum Water Production

Date:6/1/2009



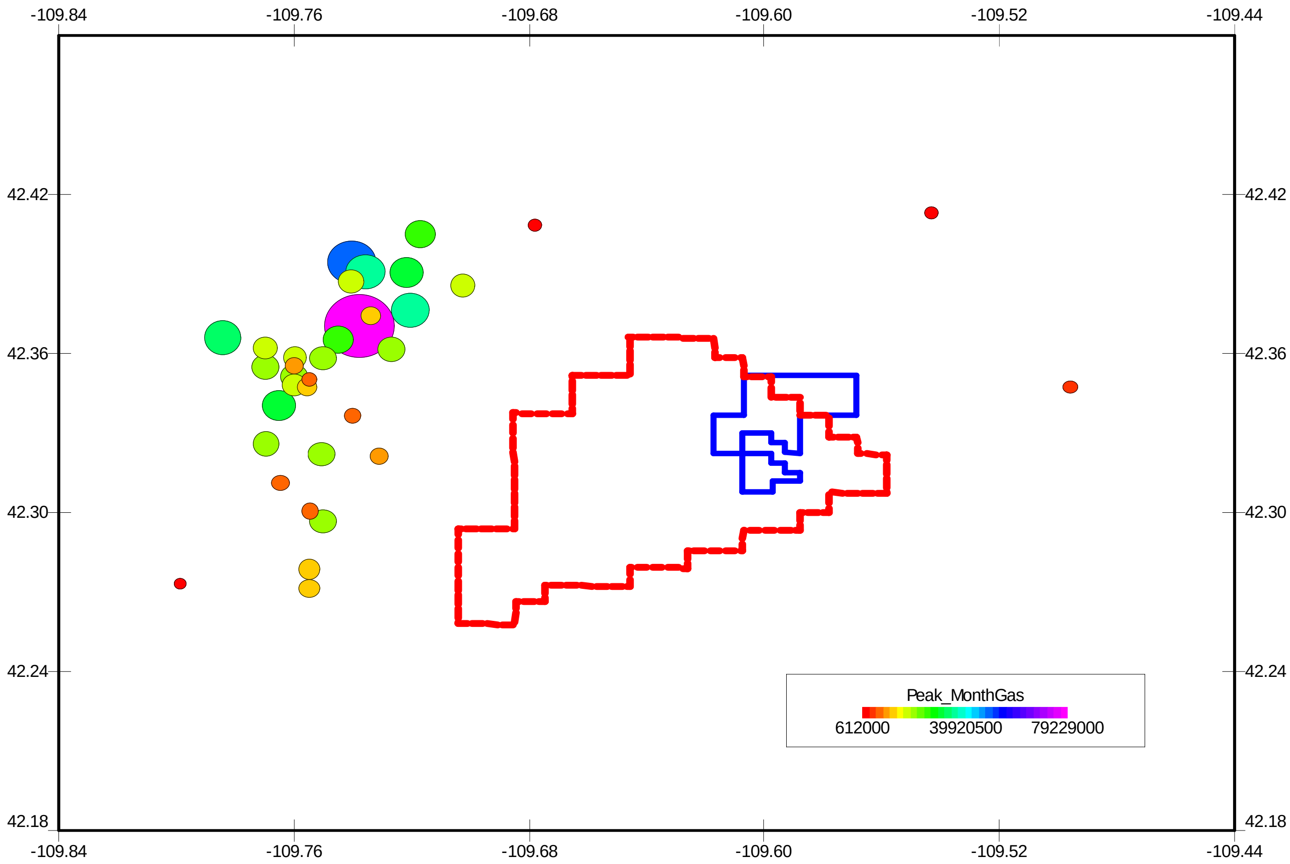
Cum Oil Production

Date:6/1/2009

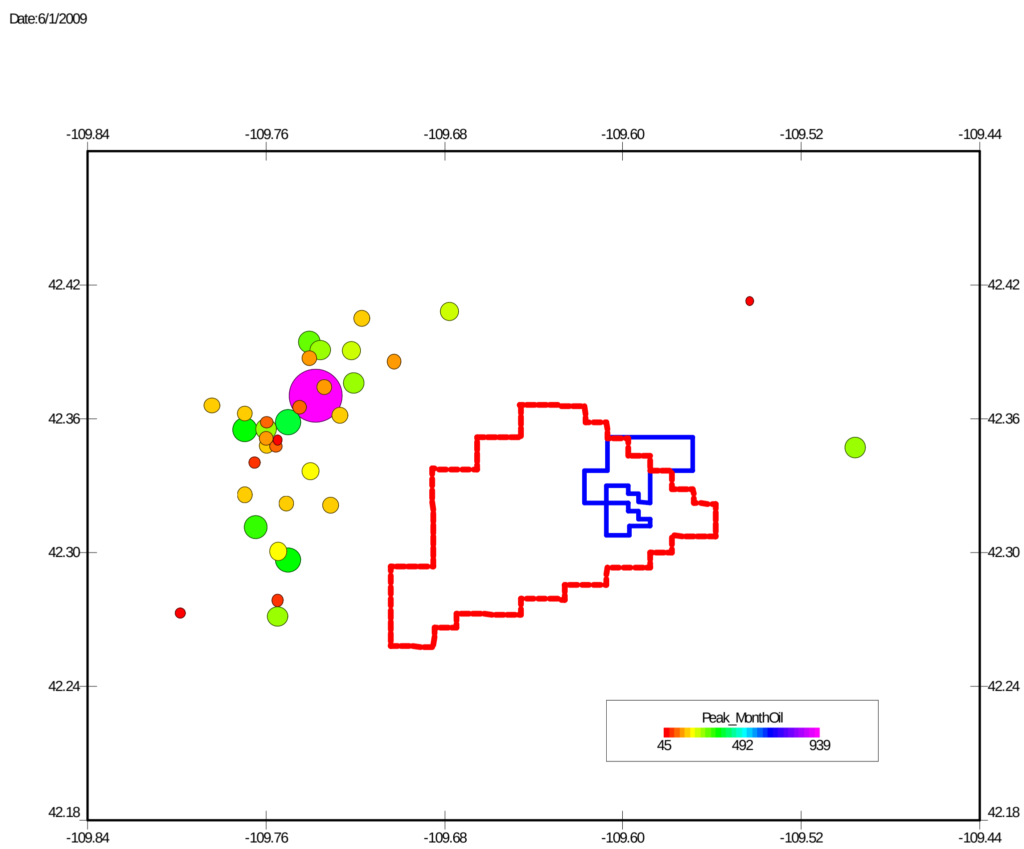


Peak Monthly Gas Rate

Date:6/1/2009



Peak Monthly Oil Rate



Summary and Conclusions

- Need to understand relationship between petrophysical properties and production heterogeneity
- Marginal P50 EUR performance shows reservoir and completion optimization is required
  - Focus on high side well performance
- All wells produce water. Need to incorporate into well flow performance
- Structural position is important to well performance
- Petrophysical analysis on all wells could improve the range of uncertainties of the study area reservoir OGIP