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PLEASE REPLY TO SANTA FE

NOV - 9

File

November 5, 1998

Mr. Rand Carroll, Counsel
New Mexico Oil Conservation Division
2040 S. Pacheco
Santa Fe, N.M. 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Rand:

Consistent with our earlier commitment to keep you advised of developments in the related district court litigation, I am enclosing a copy of a Memorandum Decision issued by Judge Encinias on October 30, 1998 granting the Defendants' Motion to Stay Discovery. As you will see in the Memorandum Decision, the Court agrees to stay the litigation discovery pending the resolution of the central issues by the NMOCD. The Court also holds open the possibility of extending the stay in the event of an appeal to the Commission.

Should you require further information regarding this matter, please do not hesitate to contact me.

Very Truly Yours,

J. Scott Hall

J. Scott Hall

JSH:cw
Enclosures:
cc: J.E. Gallegos (w/o enclos.)

FIRST JUDICIAL DISTRICT COURT
STATE OF NEW MEXICO
COUNTY OF SANTA FE

NO. **D-0101-CV-98-1295**

WHITING PETROLEUM CORPORATION, et al.
Plaintiffs

vs

PENDRAGON ENERGY PARTNERS, et al.
Defendants

and

PENDRAGON ENERGY PARTNERS, et al.
Counterclaimants

vs

WHITING PETROLEUM CORPORATION, et al.
Counterclaim-Defendants

MEMORANDUM DECISION

THIS MATTER came before the court upon the Defendants Pendragon for a Stay of Discovery. The Plaintiffs timely filed a Response in Opposition thereto and, thereafter, the Defendants filed a Reply. Because the Motion, Response and Reply are clear and comprehensive, the court finds no necessity for hearing in order to resolve the matter.

Mindful that the central issues in this case are before the New Mexico Oil Conservation Division [NMOCD] for determination in a presently pending administrative proceeding and that there is provision for discovery by the parties in this context, the court finds that a Stay of discovery in the present civil litigation would reduce costs to the parties, avoid duplication of effort in decision-making and promote judicial economy.

The Defendants' Motion, insofar as it seeks to stay discovery in this case untili the merits of the administrative dispute are resolved by the NMOCD, should be granted. While no provision is made at this time for stay of discovery beyond resolution by NMOCD, there is no bar to the Defendants' request to extend the stay in the event of appeal of that resolution to the New Mexico Oil Conservation Commission, provided that good cause is shown therefor.

UEG
MJC

Directions to Counsel

Mr. Hall, please prepare a form of Order of Stay of Discovery in accord with the court's Decision, circulate the form of Order to opposing counsel for approval as to form and submit the approved form to the court for signature and entry no later than November 13, 1998 at 9:00 a.m.

In the event, there are objections to the form of the Order, please present your proposed form to the Court on November 13, 1998 at 9:00 a.m. Objections, if any, shall be in writing and filed with the Clerk of the Court -- with courtesy copies to the Judge -- no later than three (3) working days before the date set for presentment.

ORIGINAL SIGNED BY
ART ENCINIAS

ART ENCINIAS, District Judge

Michael J. Condon, Esq.
Gallegos Law Firm
460 St. Michael's Drive, Bldg 300
Santa Fe, NM 87505

J. Scott Hall
Miller, Stratvert, Torgerson & Schlenker
150 Washington Avenue
Santa Fe, NM 87501

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PLEASE REPLY TO SANTA FE

October 29, 1998

HAND-DELIVERED
Michael J. Condon, Esq.
Gallegos Law Firm, P.C.
460 St. Michaels Dr., #300
Santa Fe, New Mexico 87505

Re: Whiting Petroleum Corp. and Maralex Resources, Inc. vs. Pendragon Energy Partners Inc., and J.K. Edwards Associates, Inc. No D-0101-CV-98-0129

Dear Counsel:

Enclosed are the responses of Pendragon Energy Partners, Inc., Pendragon Resources, L.P. and J.K. Edwards Associates, Inc. to the Plaintiffs' First Set of Request for Production of Documents propounded to each of the Defendants/Counterclaimants. Also enclosed is the Defendants' Response and Objections to the Notice of Deposition Duces Tecum served on Paul Thompson/Walsh Engineering & Production Corp.

As you know, there has been no ruling on the September 8, 1998 Motion to Stay Discovery pending the NMOCD's action on our application in Case No. 11996. Consequently, because of the imminent deadlines, we are providing these responses and will engage in further discovery with the plaintiffs without waiving the right to interpose further objections or seek protective orders. The further conduct of discovery under these circumstances is also without prejudice to any arguments we have asserted with respect to the primary jurisdiction of the NMOCD/NMOCC.

Should these circumstances change by virtue of a ruling of the Court or the NMOCD, we will revisit the matter with you at that time.

Very Truly Yours,

J. Scott Hall

JSH:cw
cc: Rand Carroll – NMOCD (w/o enclosure)

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PLEASE REPLY TO SANTA FE

October 6, 1998

Mr. Rand Carroll, Counsel
New Mexico Oil Conservation Division
2040 S. Pacheco
Santa Fe, N.M. 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Mr. Carroll:

The purpose of this letter is to report on the status of the District Court litigation related to the above-referenced application, as requested by your June 25, 1998 letter to counsel.

As you know, on July 7, 1998, pursuant to an application filed by Whiting and Maralex, the District Court issued a preliminary injunction shutting-in four of the Pictured Cliffs wells operated by Pendragon for ninety days. As the ninety day period was scheduled to expire on October 5, 1998, Whiting and Maralex filed a motion to extend the preliminary injunction pending action by both the Division and the Commission. Alternatively, Pendragon and Edwards proposed that the 90 day preliminary injunction be extended until the Division issues its order in Case No. 11996 and until the Court has an opportunity to consider the same. In the end, Judge Encinias rejected both forms of orders proposed by the parties and simply extended the preliminary injunction "until further order of the Court." Copies of both the July 7, 1989 Order of Preliminary Injunction and the September 30, 1998 Order Extending Preliminary Injunction are enclosed for your review.

Additionally, although some discovery has been conducted, we have filed a motion on behalf of Pendragon and Edwards to stay discovery in the District Court proceeding. There has been no ruling on that motion to date.

If I may provide you with any additional information, please do not hesitate to contact me.

Very Truly Yours,

J. Scott Hall

J. Scott Hall

JSH:cw

cc: J.E. Gallegos, Esq.
Al Nicol, Pendragon Energy
Keith Edwards, Edwards Energy

ENDORSED

JUL 07 1998

FIRST JUDICIAL DISTRICT COURT
SANTA FE, RIO ARRIBA & LOS ALAMOS COUNTIES
P. O. Box 2268
Santa Fe, New Mexico 87504-2268
JoAnn Vigil Quintana
Court Administrator/District Court Clerk

FIRST JUDICIAL DISTRICT COURT
COUNTY OF SANTA FE
STATE OF NEW MEXICO

WHITING PETROLEUM CORPORATION, a corporation, and MARALEX RESOURCES, INC., a corporation,

Plaintiffs,

vs. **No. SF-CV-98-01295**

PENDRAGON ENERGY PARTNERS, INC., a corporation, and J.K. EDWARDS ASSOCIATES, INC., a corporation

Defendants.

PRELIMINARY INJUNCTION

THIS MATTER came before the Court on June 29, 1998 on Plaintiffs' Verified Application for Preliminary Injunction with the parties appearing by their corporate representatives and counsel. The Court having received evidence and arguments of counsel for all parties, FINDS that good grounds have been established in behalf of the plaintiffs' Application and it should be granted.

Upon the evidence presented and application of the law concerning issuance of preliminary injunctions the Court CONCLUDES AS FOLLOWS:

1. The Court has jurisdiction of the parties and of the subject matter.

2. Plaintiffs have established a substantial likelihood that they will prevail on the merits of their claim that defendants have trespassed into plaintiffs' Fruitland formation and that defendants are converting the plaintiffs' gas.

3. Issuance of an injunction may cause harm to defendants but the continuing harm to plaintiffs should the injunction not issue greatly outweighs the harm

to the defendants.

4. Issuance of an injunction against defendants' continued taking of plaintiffs' gas will not be adverse to the public interest.

5. The Court has weighed the factors to be considered under New Mexico law in determining whether to issue a preliminary injunction and having done so concludes that the Application for Preliminary Injunction in behalf of plaintiffs is well taken and should be granted.

IT IS THEREFORE ORDERED AS FOLLOWS:

1. The defendants upon entry of this Preliminary Injunction shall immediately shut-in Chaco wells 1, 2R, 4 and 5 and cease and desist all gas production therefrom.

2. This Preliminary Injunction is to remain in force for a period of ninety (90) days from entry, or until further order of the Court, to permit review by the Court and consideration by the New Mexico Oil Conservation Division or New Mexico Oil Conservation Commission on certain issues within their administrative jurisdiction.

3. The Court will review this matter prior to the expiration of ninety (90) days from entry to consider the disposition of an administrative proceeding, if any, and to make any further orders as may be deemed appropriate or necessary.

4. No bond shall be required of plaintiffs, however, defendants are encouraged to track production loss in the event they become entitled to claim they have been wronged by the issuance of this Preliminary Injunction.

____

The Honorable Art Encinias
District Judge

ORIGINAL SIGNED BY
ART ENCINIAS

Submitted on Notice of Presentment:

GALLEGOS LAW FIRM, P.C.

By [signature]
J.E. Gallegos
Michael J. Condon
460 St. Michael's Drive, Bldg. 300
Santa Fe, New Mexico 87505

Attorneys for Plaintiffs

ENDORSED

SEP [illegible] 1998

FIRST JUDICIAL DISTRICT COURT
SANTA FE, RIO ARRIBA & LOS ALAMOS COUNTIES
P.O. Box 2268
Santa Fe, New Mexico 87504-2268
JoAnn Vigil Quintana
Court Administrator/District Court Clerk

FIRST JUDICIAL DISTRICT COURT
COUNTY OF SANTA FE
STATE OF NEW MEXICO

RECEIVED
SEP 30 1998
MILLER, STRATVERT, TORGERSON & SCHLENKER, P.A.
SANTA FE, NEW MEXICO

WHITING PETROLEUM CORPORATION, a corporation, MARALEX RESOURCES, INC., a corporation, and T.H. McELVAIN OIL & GAS, Limited Partnership,

Plaintiffs,

vs. **No. SF-CV-98-01295**

PENDRAGON ENERGY PARTNERS, INC., a corporation, PENDRAGON RESOURCES, L.P., and J.K. EDWARDS ASSOCIATES, INC., a corporation,

Defendants.

ORDER EXTENDING PRELIMINARY INJUNCTION

THIS MATTER having come before the Court on September 25, 1998 upon Plaintiffs' Motion to Extend Preliminary Injunction, the parties having appeared by their attorneys and the Court having reviewed the Preliminary Injunction previously entered, and having considered the Motion and being advised in the premises, FINDS that the Motion is well taken and should be granted.

IT IS THEREFORE ORDERED that the Preliminary Injunction entered by this Court on July 7, 1998, will remain in full force and effect until further order of the Court.

ORIGINAL SIGNED BY
ART ENCINIAS

The Honorable Art Encinias
District Judge

Submitted:
GALLEGOS LAW FIRM, P.C.

By ______________________
J.E. Gallegos
Michael J. Condon
460 St. Michael's Drive, Bldg. 300
Santa Fe, New Mexico 87505

Attorneys for Plaintiffs

Approved as to form:

MILLER, STRATVERT, TORGERSON
& SCHLENKER, P.A.

By______________________________
J. Scott Hall
150 Washington Avenue
Santa Fe, New Mexico 87501

Attorneys for Defendants

GALLEGOS LAW FIRM

A Professional Corporation

460 St. Michael's Drive
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Telephone No. 505-983-6686
Telefax No. 505-986-1367
Telefax No. 505-986-0741

CONFIRMATION COPY
OF FACSIMILE

August 31, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA TELECOPY
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

SEP - 1

Re: Pendragon Application; NMOCD Cause No. 11996

Dear Mr. Catanach:

I just received a copy of Mr. Hall's August 28, 1998 letter to Frank Chavez. Apparently, Mr. Chavez asked for a "written summary of the rebuttal testimony presented by Jack McCartney at the recent Examiner hearing in the above matter." I am not sure why Mr. Chavez requested this information. More importantly, I am not sure why Mr. Hall felt obligated to provide you with a copy of the written summary. In light of Mr. Hall's recent correspondence complaining that the record in this case has been closed, see Mr. Hall's letter to you dated August 28, 1998, it is unclear why Pendragon seeks to provide you with a written summary of the rebuttal testimony. We believe such a summary to be inappropriate. Obviously, if you wish to review the transcript of the hearing, where Mr. McCartney testified under oath and was subject to cross-examination, that is entirely appropriate. However, it is not appropriate to submit written summaries after the close of the evidence.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: John Hazlett
Mickey O'Hare
Rand Carroll
cc: Scott Hall
ioc: J.E. Gallegos

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CLIENT: WHITING
CLIENT NO.: 98-266.00

DATE: **August 31, 1998**

TO: **David Catanach**

COMPANY: **New Mexico Oil Conservation Division**

TELEFAX NO.: **(505) 827-8177**

FROM: **Michael J. Condon**

MESSAGE:

NUMBER OF PAGES INCLUDING COVER SHEET: 2

GALLEGOS LAW FIRM
A Professional Corporation

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Telephone No. 505-983-6686
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August 31, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

<u>VIA TELECOPY</u>
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

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Very truly yours,

GALLEGOS LAW FIRM, P.C.

By Michael J. Condon
MICHAEL J. CONDON

MJC:sa
fxc: John Hazlett
Mickey O'Hare
Rand Carroll
cc: Scott Hall
ioc: J.E. Gallegos

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PLEASE REPLY TO SANTA FE

August 28, 1998

Mr. Frank Chavez
District Supervisor
New Mexico Oil Conservation Division
1000 Rio Brazos Road
Aztec, New Mexico 87410

Re: NMOCD Case 11996; Application of Pendragon Energy Partners, Inc. And J.K. Edwards Associates, Inc. To Confirm Production From The Appropriate Common Source Of Supply, San Juan County, New Mexico

Dear Mr. Chavez:

In accordance with your recent request, enclosed is a copy of the written summary of the rebuttal testimony presented by Jack McCartney at the recent Examiner hearing in the above matter.

If we may provide you with any additional information, please do not hesitate to contact us.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

JSH/eam
enclosure
cc: David Catanach, NMOCD w/enclos.
✓ Rand Carroll, NMOCD w/enclos.
J.E. Gallegos w/enclos.
Al Nicol no/enclos.
Keith Edwards no/enclos.

McCartney Engineering, LLC
Consulting Petroleum Engineers
1888 Sherman Street, Suite 760 Denver, CO 80203 (303)830-7208 Fax (303)830-7004

August 21, 1998

VIA FACSIMLE, Original sent by U.S. mail

J. Scott Hall, Esquire
Miller, Stratvert & Torgerson, P.A.
150 Washington Avenue, Suite 300
Santa Fe, New Mexico 87504-1986

Re: NMOCD Case No. 11996 Rebuttal Testimony

Dear Mr. Hall:

Pursuant to your request, please find attached data regarding the rebuttal testimony I gave at the subject hearing on July 30, 1998. The rebuttal testimony consisted of two primary subjects and some secondary issues. The primary subjects were as follows:

1. Analysis of the "skin damage" for the Chaco #5 well, as well as an estimate of the post stimulation flow rate and current flow rate using the Darcy radial flow equation.

2. Comparison of the cumulative production from both the Fruitland Coal wells and the Chaco wells with the original gas-in-place in the Fruitland Coal formation for the 1320-acre area consisting of the E/2 Sections 1 and 12-26N-13W and the W/2 Sections 6 and 7-26N-12W. This area includes four Chaco Pictured Cliffs wells and four Whiting Fruitland Coal wells.

Secondary issues included modification of the Isotherm Exhibit No. M-6 to account for an undersaturated coal reservoir. The modification to account for an undersaturated coal reservoir would slightly decrease the ultimate recovery of gas from the coal at a given abandonment pressure. I also noted on a copy of Exhibit M-6 the point at which the potential shape of an isotherm that would be necessary to achieve the recovery factor testified to by Mr. O'Hare, which, as I recall, was about 80% OGIP, or a gas content at 25 psig of about 22 SCF/ton. (See attached graph)

Other points were raised regarding the potential for the Whiting/Maralex fracs in the Coal to breach the PC sands, and the fact that the Whiting/Maralex wells in the area of concern are much better than other Whiting/Maralex wells in the area as well as the typical Fruitland Coal well in an expanded area around the area of interest.

Attached are summary explanations of the data and testimony presented in rebuttal. Hopefully, this data will help in understanding the dynamics at work in this area with respect to the PC and Fruitland Coal production.

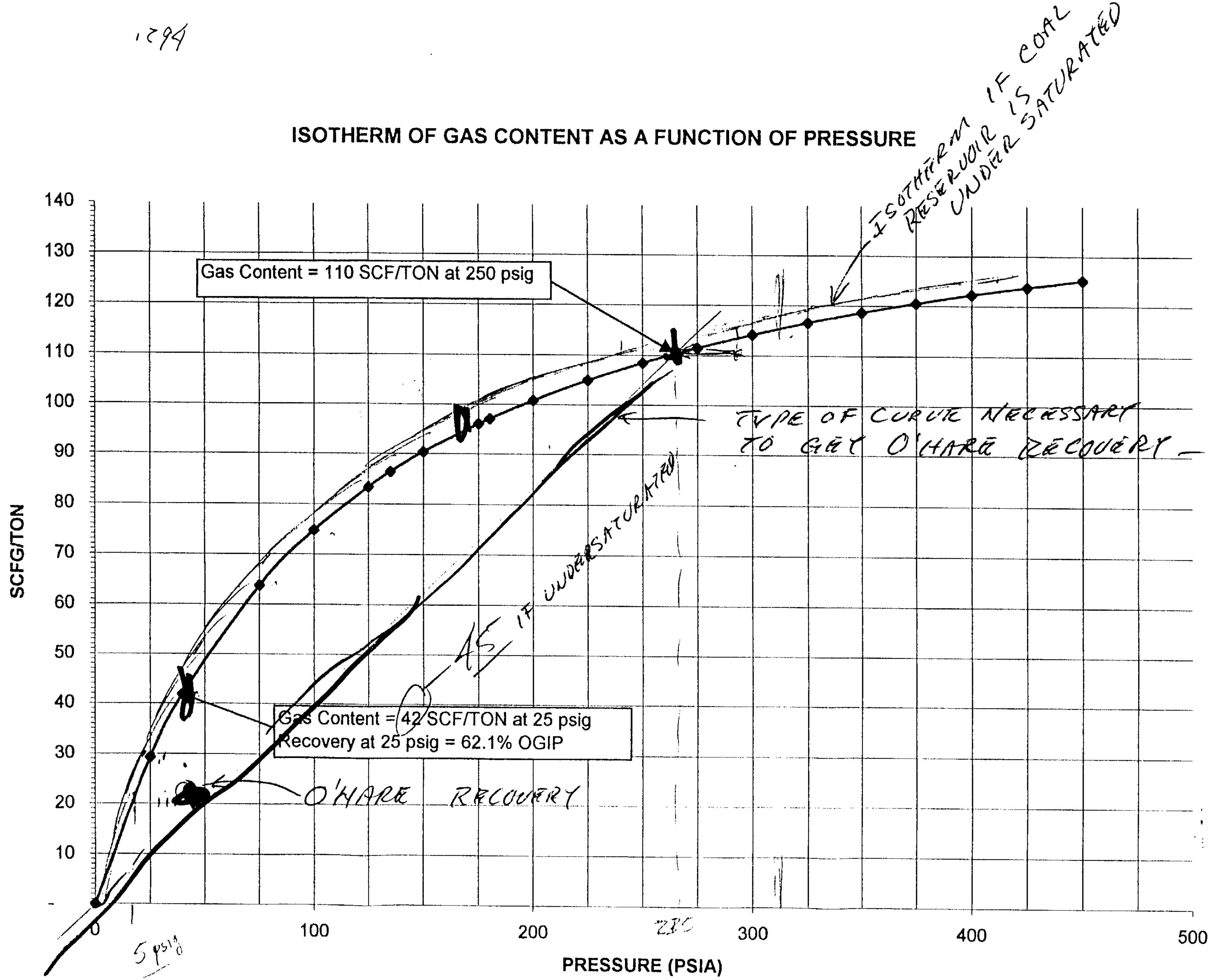
If additional information is needed, please advise.

Yours truly,
McCartney Engineering, LLC

Jack A. McCartney
Manager

1294

ISOTHERM OF GAS CONTENT AS A FUNCTION OF PRESSURE



Pictured Cliffs Flow Rate Analysis
Chaco #5 Well

Darcy Radial Flow Calculations

An analysis was made to determine the estimated flow rate for the Pictured Cliffs formation in the Chaco #5 well at various points in time using actual shut-in pressure data and estimated flowing pressures. The objective was to determine the effective permeability at initial reservoir conditions that resulted in the observed initial flow rate. The apparent "skin damage", or reduction in flow capacity, could then be calculated at a later date with a known shut-in pressure, flow rate, and estimated flowing pressure (line pressure).

With the reservoir effective permeability determined, the flow capacity of the well upon fracture stimulation can be estimate by assuming a larger wellbore diameter.

The following table gives the data used in the analysis of the reservoir parameters and flow capacity of the Chaco #5 well using the Darcy radial flow equation as shown below:

Q = 703 k h (Pe^2 - Pw^2) / (u T Z ln(re/rw))

Date	*Area (Acres)*	*Re (ft)*	*Rw (ft)*	*Pe (psia)*	*Pw (psia)*	*Viscosity (cp)*	*Temp (deg R)*	*Z factor*	*Perm (md)*	*Thickness (ft)*	*Flow Rate MCFD*	*Flow Rate MCF/Mo.*	*Estimated Skin Factor*
Nov-77	160	1,489	0.2396	242	40	0.015	560	0.97	25	25	**352**	**10,550**	-
Jun-80	160	1,489	0.2396	136	40	0.015	560	0.97	9	25	**38**	**1,127**	**2.78**
May-95	320	2,106	70.00	165	60	0.015	560	0.97	25	25	**374**	**11,227**	**-2.67**
May-98	320	2,106	70.00	110	75	0.015	560	0.97	25	25	**103**	**3,077**	**-2.67**

The November 1977 date represents the initial pressure in this well. The peak flow rate for the Chaco #5 was 10,477 MCF in its first full producing month (May 1978). With an estimated line pressure of 40 psia, the reservoir permeability calculates to be 25 md., which appears reasonable for the PC sand. Using the shut-in pressure in June 1980 of 136 psia, a line pressure of 40 psia, and an actual flow rate of 1,142 MCF/mo. (August 1980), the permeability calculates to be only 9 md, indicating a reduction in flow capacity, or "skin damage" of 2.78.

Using the reservoir permeability of 25 md and the shut-in and flowing pressures in May 1995 after stimulation, the actual flow performance is closely matched using an effective wellbore radius of 70 ft. The actual rate was approximately 12,104 MCF/mo. (June 1995) as compared to the calculated rate of 11,227 MCF/mo. By calculating the flow rate associated with an unstimulated well condition (wellbore radius = .2396 ft), the skin factor can again be estimated In this well, the skin factor calculates to be -2.67. Again, this seems reasonable given a successful stimulation treatment.

Finally, the flow rate was calculated based on the pressure data of May, 1998. Using the same reservoir and fracture characteristics, the flow rate calculates to be 3,077 MCF/mo. compared to the actual May 1998 production of 3,521 MCF/mo.

The drainage area used in the calculations shown below are based on 160 acres pre stimulation and 320 acres post stimulation. If a 160 acre drainage area is assumed post stimulation, then an effective wellbore radius of 50 ft would yield similar results.

In summary, the flow rate calculations show that damage did exist in the Chaco #5 well prior to stimulation, and that the post stimulation flow rates are similar to what would be expected with a negative skin of 2.67, both immediately after the frac, and again in May 1998.

Comparison of Production and Fruitland Coal Volumetrics

The allegation from Whiting/Maralex is that certain Pendragon Pictured Cliffs wells are completed such that most of the gas produced from these wells is from the Fruitland formation. Analysis of the volumetrics of the Fruitland Coal and the cumulative production from both the Pictured Cliffs and the Fruitland Coal wells show that this is not the case.

Mr. O'Hare stated that the gas-in-place in the Fruitland Coal formation was, as I recall, in the range of 1.2 to 1.4 BCF per 320 acres. Mr. Robinson indicated that his estimate of the gas-in-place for the Fruitland Coal was about 1.1 BCF per 320 acres. I provided estimates of the gas-in-place of about 1.26 BCF per 320 acres in the Basal Fruitland Coal. On average we seem to agree that the gas-in-place is about 1.2 BCF per 320 acres.

However, if we total the cumulative production to date from the wells completed in four 320 acre tracts, we see that the production already exceeds the expected ultimate recovery from the Fruitland Coal, and nearly exceeds the original gas-in-place for this formation. Cumulative production through June 1998 are as follows:

Tract	Well Name	Cumulative Production
E/2 Sec. 1-26N-13W	Gallegos Fed 26-13-1 #1	435 MMCF
	Chaco #5	500 MMCF
	Chaco #2J	41 MMCF
E/2 Sec. 12-26N-13W	Gallegos Fed 26-13-12 #1	611 MMCF
W/2 Sec. 6-26N-12W	Gallegos Fed 26-12-6 #2	675 MMCF
W/2 Sec. 7-26N-12W	Gallegos Fed 26-12-7 #1	822 MMCF
	Chaco #4	597 MMCF
	Chaco #2R	118 MMCF
Total – Four 320 Acre Tracts		3,799 MMCF

It was pointed out that about 500 MMCF of the cumulative production came from the Pictured Cliffs wells prior to their stimulation treatments in 1995. Therefore the cumulative production from the four Fruitland wells and the four Pictured Cliffs wells (post frac) would be about 3,299 MMCF, or approximately 69% of the original gas-in-place in the Fruitland Coal formation, which exceeds the probable ultimate recovery from this formation. These figures include only the cumulative production to date, which is only about half of the anticipated ultimate recovery from both formations.

Based on this, the conclusion is simply that there is not enough gas in the Fruitland Coal formation to justify the production from both the Fruitland completions and the Pictured Cliffs completions. The Pictured Cliffs wells must be producing primarily from their own common source of supply, the Pictured Cliffs formation.

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PLEASE REPLY TO SANTA FE

August 28, 1998

David Catanach
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87504

HAND DELIVERED

Re: NMOCD Case 11996; Application of Pendragon Energy Partners, Inc. And J.K. Edwards Associates, Inc. To Confirm Production From The Appropriate Common Source Of Supply, San Juan County, New Mexico

Dear Mr. Catanach:

I recently received opposing counsel's August 25, 1998 letter to you and feel more than just a little inconvenienced that I am compelled to respond to the rather preposterous arguments it contains.

In my view, the letter misrepresents the purpose of litigational notice pleading under the New Mexico Rules of Civil Procedure and falsely seeks to create the impression before the Division that we have taken inconsistent positions in the administrative and judicial proceedings. Counsel is absolutely wrong. We are content to let our respective filings speak for themselves and should you wish to confer with the Division's counsel about the operation of the court's rules in this regard, I am confident you will conclude that opposing counsel seeks to sow confusion and create a conflict where none exists.

On July 30, 1998, evidence was closed in the case and the matter was taken under advisement. Since that time, counsel for Whiting and Maralex have attempted to re-argue their case more than once. In view of all the post-hearing activity, Whiting and Maralex should be reminded that the

Division issues its orders with findings and conclusions based on competent geological and engineering evidence, not the arguments of counsel. Were this otherwise, we would be obliged to point out the "judicial admission" of Whiting and Maralex contained in Paragraph 45 of their District Court Complaint. There, it is asserted:

> "If during the completion of their Fruitland formation wells, plaintiffs created conditions allowing or contributing to the migration of coalbed gas into defendants' Pictured Cliffs formation, plaintiffs have thus conferred upon defendants' use and enjoyment of value which constitutes an economic benefit that defendants have retained to plaintiffs' detriment and loss."

Of course, this assertion is one of several that, on its face, is directly contrary to the position Whiting and Maralex have taken before the Division and, according to counsel's August 25th letter, should constitute the basis for a finding by the Division that Whiting and Maralex admit to having frac'd out of zone. It is doubtful Whiting and Maralex actually believe their own district court pleadings should operate against them in this fashion.

On June 23, 1998, the Division denied the Whiting/Maralex Motion To Dismiss. More recently, the District Court rejected the Whiting/Maralex motion to enjoin this administrative proceeding and in so doing, gave broad deference to the Division's exercise of its primary jurisdiction over this subject matter. Accordingly, the Division should resist the obvious efforts to confuse the judicial and administrative proceedings. The specious arguments of Whiting and Maralex mock the integrity of the Division and should be rejected outright.

Very truly yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall

JSH/eam
Cc: Rand Carroll, Esq. NMOCD
Michael Condon, Esq.
Al Nicol
Keith Edwards

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OIL CONSERVATION DIV.

98 AUG 25 PM 3:54

August 25, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA HAND-DELIVERY
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

Dear Examiner Catanach:

I want to bring an important development to your attention for consideration in connection with this case.

On August 21, 1998, Pendragon filed an Answer and Counterclaim in the Santa Fe County District Court proceeding. A copy of that pleading is enclosed for your review. Pendragon has asserted affirmative claims for relief in that case based upon the allegation that there is communication between the Fruitland coal formation and Pictured Cliffs formation. See Counterclaim, ¶¶ 10-11, 43-45, 49-50. While we agree that there is communication, we obviously deny any claim by Pendragon that the Whiting / Maralex coal seam gas wells are producing Pictured Cliffs gas. Pendragon certainly presented no evidence to support such an allegation at the hearing in this case.

We call Pendragon's recent pleading to your attention since the allegations in that pleading are completely contrary to the proposed findings which Pendragon has submitted in its proposed form of Division order. Specifically, the allegations in the Counterclaim are contrary to Pendragon's proposed Finding 44 ("This evidence establishes that the subject Pictured Cliffs wells do not appear to be in communication with the same reservoir in which the Subject Coal wells are completed"); Finding 59 ("The evidence available on the date of the hearing was insufficient to allow for a determination whether the significantly higher fracture treatments on the Whiting / Maralex coal wells actually penetrated into the Pictured Cliffs formation"); and Finding 79 ("The Subject Pictured Cliffs wells and Subject Coal Gas wells are completed in separate common sources of supply, the production from and the operations in one pool do not result in the impairment of correlative rights in the other"). Pendragon's Counterclaim also contradicts its proposed Finding No. 56, "That coal is an effective barrier to fracture growth. . . ". If that were true, then the Whiting / Maralex fracture treatments, all of which were performed in the upper, massive coal seam in the area, would not have penetrated the Basal coal seam which is reflected as consistent throughout this area on Whiting / Maralex Exhibit 16.

The administrative record should show that Pendragon participated in a three day hearing before the Division on its own application, and failed to present a shred of evidence that the Whiting / Maralex coal seam gas wells were producing Pictured Cliffs gas, submitted proposed findings to the Division which deny communication between the Fruitland formation and the Pictured Cliffs formation in its Chaco wells, and then filed a counterclaim in the district court proceeding which takes a completely contradictory position. The position taken by Pendragon in the litigation refutes the Application it filed with the Division seeking an order that both the Pendragon Chaco wells and the Whiting coal seam gas wells are producing from the appropriate common share of supply.

Pendragon has judicially admitted communication between the formations. The only remaining question for the Division, based upon Pendragon's own application and the evidence presented at hearing, is to decide to what extent does this communication between formations results in the Pendragon Chaco wells producing coal seam gas. In light of this development, we would request that the Division incorporate the following findings in its Order:

> (   ) While Pendragon denied at the hearing in this case that there was any communication between the Fruitland formation and the Pictured Cliffs formation in Pendragon's Chaco wells, Pendragon has filed an Answer and Counterclaim in the pending district court lawsuit in which Pendragon has admitted communication between the two formations.
>
> (   ) Pendragon introduced no evidence at the hearing in this matter that Whiting was producing any Pictured Cliffs gas through its coal seam wells. In fact, given the depleted state of the Pictured Cliffs formation, and the pressure differential between the coal seam gas formations and the Pictured Cliffs sandstone formation, it is improbable that the Whiting Coal Seam wells produce Pictured Cliffs sandstone gas.
>
> (   ) The only evidence of gas production as a result of communication between the Fruitland formation and the

Pictured Cliffs formation which was introduced at the hearing in this case, and the only conclusion that is consistent with sound geologic, hydraulic and engineering principles, is that the Pendragon Chaco wells are producing coal seam gas.

Thank you for your attention to these matters. If you need any additional information, or have any questions, please feel free to contact me.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: John Hazlett
Mickey O'Hare
cc: Scott Hall
Rand Carroll
ioc: J.E. Gallegos

FIRST JUDICIAL DISTRICT COURT
COUNTY OF SANTA FE
STATE OF NEW MEXICO

WHITING PETROLEUM CORPORATION, a corporation, and MARALEX RESOURCES, INC., a corporation and T. H. McELVAIN OIL AND GAS, a Limited Partnership,

Plaintiffs,

vs.

PENDRAGON ENERGY PARTNERS, INC., a corporation, PENDRAGON RESOURCES, L.P. and J.K. EDWARDS ASSOCIATES, INC., a corporation

Defendants,

and

No. CV-98-01295

PENDRAGON ENERGY PARTNERS, INC., a corporation, PENDRAGON RESOURCES, L.P. and J.K. EDWARDS ASSOCIATES, INC., a corporation

Counterclaimants,

vs.

WHITING PETROLEUM CORPORATION, a corporation, and MARALEX RESOURCES, INC., a corporation and T. H. McELVAIN OIL AND GAS, a limited Partnership,

Counterclaim-Defendants.

ANSWER OF PENDRAGON ENERGY PARTNERS, INC., PENDRAGON RESOURCES, L.P. AND J.K. EDWARDS ASSOCIATES, INC. TO COMPLAINT FOR TORTIOUS CONDUCT, AND FOR DAMAGES AND EQUITABLE RELIEF AND COUNTERCLAIM FOR QUIET TITLE, SLANDER OF TITLE, DAMAGES, AND FOR DECLARATORY AND OTHER EQUITABLE RELIEF

Defendants, Pendragon Energy Partners, Inc. ("Pendragon Energy") Pendragon Resources, L.P. ("Pendragon Resources") and J.K. Edwards Associates, Inc. ("Edwards"), for their Answer to the Plaintiffs' First Amended Complaint for Tortious Conduct, and For Damages and Equitable Relief ("Complaint") state:

IDENTIFICATION OF PARTIES

1. The allegations of Paragraph 1, 2 and 3 are admitted.

2. In response to the allegations of Paragraph 4 of the Complaint, Defendants admit that Pendragon Energy operates certain wells identified in Paragraph 16 of the Complaint, but denies Pendragon Energy owns the oil and gas leasehold working interest dedicated to such wells. By way of further response, Defendants state that approximately seventy-five percent of the working interest is owned by Pendragon Resources, L.P. The remaining allegations of Paragraph 4 are admitted.

3. The allegations of Paragraph 5 and 6 are admitted.

JURISDICTION AND VENUE

4. Defendants admit that this Court has jurisdiction over the parties. Defendants deny that venue is proper in Santa Fe County, and deny the remaining allegations in Paragraph 7 of the Complaint.

FACTS COMMON TO ALL CLAIMS FOR RELIEF

5. The first sentence of Paragraph 8 of the Complaint does not contain allegations for which an answer is required. To the extent that an answer is required, Defendants admit the allegations of the first sentence of paragraph 8 of the Complaint. In response to the second sentence of Paragraph 8 of the Complaint, Defendants admit that in certain

areas, stratigraphic ownership is held by different parties under the same surface acreage. Defendants deny the remaining allegations of Paragraph 8 of the Complaint.

6. Defendants admit the allegations contained in the first sentence of Paragraph 9, with the exception of the erroneous legal description for the Gallegos Federal 26-12-6 No. 2 Well which is in fact located in the west half of Section 6, T26N, R12W, NMPM, San Juan, County New Mexico. In further response, Defendants state that the terms of New Mexico Oil Conservation Division (NMOCD) Order No. R-8768, as amended, more completely and accurately speak for themselves. To the extent that the allegations of Paragraph 9 are inconsistent therewith, they are denied. With respect to the remaining allegations of Paragraph 9, Defendants state that they are without information sufficient to form a belief as to the truth thereof and therefore deny the same and demand strict proof thereof.

7. In response to the allegations in Paragraphs 10 and 11, Defendants state that the terms of the instruments by which the parties acquired their ownership interests in the subject leases more completely and accurately speak for themselves. To the extent that the allegations of Paragraphs 10 and 11 differ from the terms of those instruments, they are denied.

8. With respect to the allegations set forth in Paragraph 12, 13, 14, and 15 of the Complaint, Defendants are without information sufficient to form a belief as to the truth thereof and therefore deny the same and demand proof thereof.

9. To the extent that Paragraph 16 of the Complaint alleges that Pendragon Energy Partners, Inc. owns the oil and gas leasehold working interest dedicated to the referenced wells, it is denied. By way of further response, the referenced working interests are

owned by Pendragon Resources, L.P. Otherwise, all other allegations of Paragraph 16 are admitted.

10. In response to the allegations in Paragraph 17 of the Complaint, Defendants state that the subject wells are completed in the Pictured Cliffs formation. By way of further response, Defendants state that the terms of the NMOCD well spacing and acreage dedication requirement regulations more completely and accurately speak for themselves and that the size of a spacing unit is not necessarily reflective of the actual drainage area of any particular well. To the extent that the allegations of Paragraph 17 are inconsistent with those regulations, they are denied.

11. In response to the allegations in paragraph 18 of the Complaint, Defendants state that the terms of the instruments by which they acquired their ownership interests in the subject leases more completely and accurately speak for themselves. To the extent the allegations of Paragraph 18 are inconsistent therewith, they are denied. By way of further response, the referenced wells are properly completed in and produce from the Pictured Cliffs formation.

12. Defendants deny the allegations contained in the first two sentences of Paragraph 19 of the Complaint. Defendants are without knowledge or information sufficient to form a belief as to the allegations in the third and fourth sentences of Paragraph 19 of the Complaint and therefore deny the same and demand proof thereof.

13. Defendants are without knowledge or information sufficient to form a belief as to the truth of the allegations in Paragraphs 20 and 21 and therefore deny the same and demand strict proof thereof.

14. In response to the allegations of Paragraph 22, Defendants state that they performed stimulation treatments on certain of the Subject Pictured Cliffs wells.

15. In response to the allegations of Paragraph 23, Defendants state that they "acidized" certain of the Subject Pictured Cliffs wells and fracture stimulated ("frac'd") certain other wells. Two of the Subject Pictured Cliffs wells were reperforated in the same intervals as the original perforations. To the extent that Paragraph 23 alleges that any of these operations were "recompletions", they are specifically denied. The remainder of Paragraph 23 does not contain allegations for which a response is required.

16. Defendants deny the allegations of Paragraphs 24, 25, 26, and 27 of the Complaint.

FIRST CLAIM FOR RELIEF

(TRESPASS)

17. Defendants reallege and incorporate by reference their answers to Paragraphs 1 through 27 of the Complaint as their answer to Paragraph 28 of the First Amended Complaint.

18. The allegations of Paragraph 29 of the Complaint are more in the nature of conclusory legal statements for which no response is required. Otherwise, the allegations of Paragraph 29 are denied.

19. Defendants deny the allegations in Paragraphs 30, 31, 32 and 33 of the First Amended Complaint.

SECOND CLAIM FOR RELIEF

(CONVERSION)

20. Defendants reallege and incorporate by reference their answers to Paragraphs 1 through 27 of the Complaint, and Paragraphs 28 through 33 of the Complaint as their answer to Paragraph 34 of the Complaint.

21. Defendants deny the allegations in Paragraphs 35, 36, 37, 38 and 39 of the Complaint.

THIRD CLAIM FOR RELIEF

(NEGLIGENCE)

22. Defendants reallege and incorporate by reference their answers to Paragraphs 1 through 27 of the Complaint, Paragraphs 28 through 34 of the Complaint, and Paragraphs 35 through 39 of the Complaint as their answer to Paragraph 40 of the Complaint.

23. The allegations of Paragraph of 41 of the Complaint are more in the nature of conclusory legal statements for which no response if required. Otherwise, the allegations of Paragraph 41 are denied.

24. Defendants deny the allegations in Paragraphs 42, 43 and 44 of the Complaint.

FOURTH CLAIM FOR RELIEF

(IMPLIED QUASI-CONTRACT; UNJUST ENRICHMENT; ACCOUNTING)

25. Defendants reallege and incorporate by reference their answers to Paragraphs 1 through 27, Paragraphs 28 through 34, Paragraphs 35 through 39, and Paragraphs 40 through 44 as their answer to Paragraph 45 of the Complaint.

26. The allegations of Paragraph 46 are so vague and ambiguous that Defendants cannot reasonably be required to frame a response thereto.

27. Defendants are without sufficient knowledge or information to form a belief as to the truth of the allegations of Paragraph 47 in the Complaint and therefore deny the same and demand proof thereof.

28. The allegations of Paragraph 48 of the Complaint are denied.

FIFTH CLAIM FOR RELIEF

(ACCOUNTING)

29. Defendants reallege and incorporate by reference their answers to Paragraphs 1 through 27 of the Complaint, Paragraphs 28 through 34, Paragraphs 35 through 39, Paragraphs 40 through 44, and Paragraphs 45 through 48 of the Complaint as their answer to Paragraph 49 of the Complaint.

30. Defendants deny the allegations of Paragraph 50 of the Complaint.

31. In response to the allegations of Paragraph 51 of the Complaint, Defendants specifically deny that they had any duty to account to Plaintiffs or to acknowledge Plaintiffs interest in future revenues. All other allegations contained in Paragraph 51 are denied.

32. Defendants deny the allegations in Paragraph 52 of the Complaint.

33. Defendants deny all claims for relief as stated in the Complaint and all allegations in the Complaint not expressly responded to above are hereby denied.

AFFIRMATIVE AND/OR ADDITIONAL DEFENSES

FIRST DEFENSE

The Complaint fails to state a claim, in whole or in part, upon which relief may be granted.

SECOND DEFENSE

If damages were sustained, by Plaintiffs, which is specifically denied, such damages were a direct and proximate cause of acts, occurrences, omissions, negligence, or other wrongful conduct of individuals or entities other than Defendants, or due to causes within the control and dominion of individuals or entities other than Defendants, thereby barring any relief, in whole or in part against Defendants.

THIRD DEFENSE

There is insufficient factual or legal predicate for an award of punitive damages.

FOURTH DEFENSE

Plaintiffs' claims for punitive damages are barred by the United States Constitution and the New Mexico Constitution.

FIFTH DEFENSE

Plaintiffs were contributarily or comparatively negligent and/or engaged in other wrongful conduct, thereby barring, in whole or in part, any recovery against Defendants.

SIXTH DEFENSE

The damages complained of, which are specifically denied, resulted from independent intervening causes, thereby barring any recovery against Defendants.

SEVENTH DEFENSE

Plaintiffs have unclean hands thereby barring any recovery against Defendants.

EIGHTH DEFENSE

If Plaintiffs have suffered any damages, which is specifically denied, Plaintiffs have failed to mitigate their damages.

NINTH DEFENSE

This Court lacks jurisdiction, to proceed with any and all claims concerning any remedies because governmental entities other than this Court have primary jurisdiction.

TENTH DEFENSE

Plaintiffs have an adequate remedy at law and have not been irreparably harmed and, therefore, are barred from equitable or injunctive relief.

ELEVENTH DEFENSE

Plaintiffs caused or allowed in whole or in part the damages, if any, complained of in the Complaint.

TWELFTH DEFENSE

Plaintiffs' claims are barred in this judicial district because venue is improper.

THIRTEENTH DEFENSE

Plaintiffs' have failed to join necessary or indispensable parties which is required under NMRA 1-019 of the New Mexico Rules of Civil Procedure.

FOURTEENTH DEFENSE

Plaintiffs' claims are barred under the doctrines of waiver, estoppel, and acquiescence.

FIFTEENTH DEFENSE

Plaintiffs lack standing.

SIXTEENTH DEFENSE

Plaintiffs' claims are barred under the doctrine of laches.

SEVENTEENTH DEFENSE

This Court lacks jurisdiction over the subject matter of this action.

EIGHTEENTH DEFENSE

Plaintiffs' claims are barred and otherwise precluded by virtue of the doctrine of force majeure and the occurrence of force majeure events.

NINETEENTH DEFENSE

Defendants reserves the right to plead additional affirmative defenses and counterclaims which may become known during the course of discovery.

WHEREFORE, Defendants pray that the Complaint and each of its individual counts against them be dismissed with prejudice, that the Court enter an award in their favor, for their costs and attorneys fees for defending this action, and for such other and further relief as the Court deems just and proper.

**COUNTERCLAIM FOR QUIET TITLE,
SLANDER OF TITLE, DAMAGES, AND FOR
FOR DECLARATORY AND OTHER EQUITABLE RELIEF**

Counterclaimants Pendragon Energy Partners Inc., Pendragon Resources, L.P. and J.K. Edwards Associates Inc., for their Counterclaim against Whiting Petroleum Corporation, Maralex Resources, Inc., and T.H. McElvain Oil and Gas, L.P. state:

THE PARTIES

1. Counterclaimant Pendragon Energy Partners, Inc. ("Pendragon Energy") is a Colorado Corporation authorized to do business in New Mexico with its principal place of business in Denver, Colorado. Counterclaimant Pendragon Resources, L.P. ("Pendragon Resources") is a Delaware Limited Partnership authorized to do business in New Mexico with its principal place of business in Denver, Colorado. Counterclaimant J.K. Edwards Associates, Inc. ("Edwards") is a Colorado Corporation authorized to do business in New Mexico with its principal place of business in Denver, Colorado.

2. Counterclaim-Defendant Whiting Petroleum Corporation ("Whiting") is a Delaware Corporation authorized to do business in New Mexico with its principal place of business in Denver, Colorado. Counterclaim-Defendant Maralex Resources, Inc. ("Maralex") is a Colorado Corporation authorized to do business in New Mexico with its principal place of business in Ignacio, Colorado. Counterclaim-Defendant T.H. McElvain Oil and Gas, L.P. ("McElvain") is a New Mexico limited partnership with its principal place of business in Santa Fe, New Mexico.

JURISDICTION AND VENUE

3. This Court has jurisdiction over the parties, but venue is contested in this County.

FACTUAL BACKGROUND

4. Pendragon Resources and J.K. Edwards, together, are the owners of oil and gas leasehold working interests from the base of the Fruitland Coal formation to the base of the Pictured Cliffs formation in and to certain acreage located in San Juan County, New Mexico more particularly described in Paragraph 14, below (referred to herein as the "Subject Lands"), subject only to valid and subsisting easements, rights-of-way, contracts, leases, and other instruments of record in the chain of title to the Subject Lands which are not material to the subject of this action. The ownership of these Counterclaimants arises pursuant to various mesne assignments of interests and transfers of operating rights in Federal Oil and Gas Leases covering the Subject Lands and limited, generally, by depth or formation. Copies of said conveyances, assignments and transfers are not attached hereto for the reason that said instruments are of public record and are lengthy.

5. Whiting, Maralex and McElvain acquired ownership of oil and gas leasehold working interests in the lands described in Paragraph 6, below, and in other lands, from the surface to the base of the Fruitland "Coal-Gas" formation, subject only to valid and subsisting easements, rights of way, contracts, leases, and other instruments of record in the chain of title to the subject lands which are not material to the subject of this action. The ownership of Whiting, Maralex and McElvain arises pursuant to various mesne assignments of interests, farm-outs and transfers of operating rights under Federal Oil and Gas Leases covering the Subject Lands and limited, generally, by depth or formation. Copies of said conveyances and transfers are not attached hereto for the reason that said instruments are of a public record and are lengthy.

6. On or about July 1992, Maralex acquired its interests in the Subject Lands and, as operator, began drilling a number of wells completed in the Basin-Fruitland Coal Gas Pool prior to the expiration of certain federal tax credits at the end of that calendar year. These wells ("the Subject Coal Gas Wells") are identified as follows:

Well Name	Location
Gallegos Federal 26-12-6 No. 2	W ½, Section 6, T12N, R12W, N.M.P.M.
Gallegos Federal 26-12-7 No. 1	W ½, Section 7, T26N, R12W, N.M.P.M.
Gallegos Federal 26-13-1 No. 1	E ½, Section 1, T26N, R13W, N.M.P.M.
Gallegos Federal 26-13-1 No. 2	W ½, Section 1, T26N, R13W, N.M.P.M.
Gallegos Federal 26-13-12 No.1	N ½, Section 12, T26N, R13W, N.M.P.M.

7. Pursuant to the Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool established by the New Mexico Oil Conservation Division (NMOCD) in Order No. R-8768 and R-8768-A, each of the Subject Coal Gas Wells was required to have a

standard spacing unit containing 320 acres dedicated to it. The Subject Coal Gas Wells were to be drilled and completed within the horizontal limits of the Basin-Fruitland Coal Gas Pool as defined by Order No. R-8768, as amended. The Order also established the vertical limits of the pool.

8. In 1993, subsequent to the drilling of the Subject Coal Gas Wells, Maralex attempted to "complete" its wells by performing heavy, aggressive fracture stimulation treatments (or "Frac" treatments) in the Fruitland Coal formation by the injection of extraordinarily large volumes of fracturing fluids into the coal at extremely high rates. To "frac" a well is a term used to refer to the methods used by the oil and gas industry to increase the deliverability of a producing well by pumping a liquid or other substance into a well under pressure to crack (fracture) and prop open the hydrocarbon bearing formation. Fracture treatments are a commonly used method to stimulate oil and gas production that has been applied to well over half of the wells drilled in the United States.

9. The fracture completions performed by Maralex on the Subject Coal wells consisted of fracture fluid volumes on the average of 41,030 gallons at proppant weights averaging 72,656 pounds, injected at treating rates ranging between 45 to 60 barrels per minute ("BPM"). The specific fracture completions for the Gallegos Federal 26-12-6 No. 2 well consisted of a fracture fluid volume of 81,025 gallons with a 121,700 pound proppant weight injected at treating rates between 45 to 60 BPM. The fracture completion for the Gallegos Federal 26-12-7 No. 1 consisted of a fracture fluid volume of 85,223 gallons with a proppant weight of 119,200 pounds injected at treating rates of 45 to 60 BPM.

10. The design, supervision and implementation of the fracture treatments of the Subject Coal Wells by the officers, employees and/or agents of the Counterclaim-Defendants were knowingly undertaken in such a manner that the fractures escaped out of the coal formation and grew vertically downward thereby causing the escape of the fracture and fracturing fluids out of zone and, on information and belief, into the Pictured Cliffs formation.

11. As a result of the conduct of the Counterclaim-Defendants, the fractures induced by them have escaped out of zone and, on information and belief, into the Pictured Cliffs formation now owned by the Counterclaimants, allowing Pictured Cliffs formation hydrocarbon reserves to become communicated with certain Fruitland formation intervals and to be produced through the Counterclaim-Defendants' coal wells.

12. In addition to draining Pictured Cliffs formation reserves owned by the Counterclaimants, on information and belief, Whiting and Maralex have adversely affected pressures in the Pictured Cliffs reservoir and have further damaged the Pictured Cliffs formation by the introduction of foreign fracturing fluids and waters desorbed from the Fruitland Coal formation. By allowing fracturing fluids and desorbed waters to penetrate to the Pictured Cliffs formation, Whiting and Maralex have caused damage to the formation, resulting in the loss or "waste" of hydrocarbon resources.

13. Subsequent to the drilling and fracturing of the Subject Coal Gas Wells by Maralex, Whiting acquired approximately 75 percent of the oil and gas leasehold working interests in the acreage dedicated to the subject coal gas wells. Whiting became "Designated Operator" of the Subject Coal Gas Wells. Pursuant to a contract, Maralex is the field operator of the wells.

14. On or about December 14, 1994, Edwards acquired from its predecessor in interest title to the oil and gas leasehold working interests in the Subject Lands from the base of the Fruitland Coal Formation to the base of the Pictured Cliffs Formation. In addition to the leasehold working interest, Edwards also acquired the following wells ("The Subject Pictured Cliffs Wells"):

Well Name	Location
Chaco No. 1	NW ¼, Section 18, T26N, R12W, N.M.P.M.
Chaco No.2R	SW ¼, Section 7, T26N, R12W, N.M.P.M.
Chaco No 4	NW ¼, Section 7, T26N, R12W, N.M.P.M.
Chaco No 5	SE ¼, Section 1, T26N, R13W, N.M.P.M.
Chaco Ltd. No. 1J	SW ¼, Section 1, T26N, R13W, N.M.P.M.
Chaco Ltd. No. 2J	NE ¼, Section 1, T26N, R13W, N.M.P.M.

15. Each of the foregoing Subject Pictured Cliffs Wells was drilled and completed in the Pictured Cliffs formation between 1977 and 1982 by Edwards's predecessor in interest, Merrion and Bayless Oil and Gas. The Subject Pictured Cliffs wells were originally completed and perforated in and have been producing from the Pictured Cliffs formation sandstone within the vertical limits of the WAW Fruitland-Pictured Cliffs Pool.

16. On acquiring ownership, Edwards became the "Designated Operator" of the Subject wells. On or about December 1994, Edwards conveyed approximately 75 percent of its working interest in the Subject Lands and wells to Pendragon Resources, L.P. Pendragon Energy Partners, Inc. became the designated operator of the Subject Pictured Cliffs Wells in February, 1996.

17. Beginning in about January, 1995 and continuing through June of 1995, Edwards, as successor operator, began certain workover operations on the Subject Pictured Cliffs Wells to stimulate the production of additional Pictured Cliffs formation gas reserves.

18. On or about January 1995, Edwards "acidized" the Pictured Cliffs formation in the Chaco 4, Chaco 1-J and Chaco 2-J wells.

19. Beginning in January 1995 and continuing through May of 1995, Edwards instituted fracture stimulation treatments on the Chaco 1, Chaco 2-R, Chaco 4 and Chaco 5 wells. The foam fracs used on the Subject Pictured Cliffs wells consisted of fluid volumes averaging 31,248 gallons at proppant weights averaging 38,421 pounds injected at treating rates ranging from between 22 to 34 barrels per minute ("BPM").

20. Unlike the earlier frac jobs performed on the Whiting/Maralex wells, the fracture treatment jobs on the Counterclaimants' wells were specifically designed and implemented to remain contained within specific lithologic intervals of the Pictured Cliffs formation. Compared to the aggressive and heavy frac jobs performed by Maralex on the Fruitland Coal formation, the injection volumes and rates of the Counterclaimants' frac jobs were relatively light. As a result, the fractures induced by the Counterclaimants in their wells grew primarily in a horizontal manner and remained contained within the Pictured Cliffs formation.

21. Such fracture stimulation treatments were reasonable, prudent and necessary to produce additional Pictured Cliffs gas reserves that would have otherwise remained unrecovered and Counterclaimants had the right to perform the operations.

22. Whiting and Maralex first invoked the jurisdiction of the New Mexico Oil Conservation Division ("NMOCD" or "Division") well over two years ago when it

sought the agency's expertise in resolving a perceived problem of communication between the Pictured Cliffs formation in the WAW Fruitland-Pictured Cliffs Pool and the Basin-Fruitland Coal formation.

23. At the request of Whiting and Maralex, the NMOCD Aztec District Office convened a number of public meetings between January and April of 1998. These meetings were attended by, among others, representatives from Whiting, Maralex, Pendragon, J.K. Edwards and the BIA/BLM.

24. Contemporaneous with the first meeting before the Division, Whiting and Maralex filed their Application in NMOCD Case No. 11921. In their initial Application, Whiting and Maralex generally alleged that the drilling and fracture restimulation operations in the Pictured Cliffs formation had caused that formation to become communicated with the Basin-Fruitland Coal formation. Whiting and Maralex also claimed that Pendragon's Pictured Cliffs wells were draining reserves owned by Whiting and the other interest owners in its wells and that their correlative rights were being impaired. Whiting and Maralex specifically invoked the Division's jurisdiction under N.M. Stat. Ann. § 70-2-12. B. (2), (7) and (10), NMOCD Rule 104.D (3), and Order No. R-8768, Special Pool Rules 2 and 3, seeking regulatory relief.

25. On February 10, 1998, Whiting and Maralex filed their Amended Application seeking additional administrative relief, including down-hole commingling in accordance with Rule 12 of the Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool as promulgated by the Division in Order No. R-8768-A.

26. In the interim, the parties continued to participate in the public meetings before the Division and Whiting and Maralex persisted in seeking regulatory redress for their

claims. Pendragon and Edwards expended significant time, effort and cost in preparing for the Division hearing on the Whiting/Maralex Application and the matter was set to proceed to hearing on June 11, 1998.

27. At a meeting with NMOCD officials on March 27, 1998, a petroleum engineer employed by Whiting acknowledged that, despite considerable testing and fact gathering by the parties, others, and the NMOCD, Whiting could not show any harm to its wells. Subsequently, on May 26, 1998, Whiting and Maralex attempted to withdraw from the administrative proceeding which they, themselves, initiated and that same day, Whiting and Maralex filed their District Court lawsuit in circumvention of NMOCD jurisdiction.

28. On May 26, 1998, Pendragon Energy and J.K. Edwards filed their own Application before the NMOCD in Case No. 11996 asking that administrative agency to determine many of the issues precipitated by Whiting and Maralex (Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc. To Confirm Production From The Appropriate Common Source Of Supply, San Juan County, New Mexico.) Whiting and Maralex unsuccessfully attempted to have Case No. 11996 dismissed and the matter proceeded to hearing before the Division's petroleum engineer hearing examiner on July 28, 29 and 30, 1998.

29. The Counterclaimants expended significant time, effort and cost in preparing for and attending the NMOCD hearing in Case No. 11996 and in subsequent related activities.

CAUSES OF ACTION

COUNT I

QUIET TITLE

30. Counterclaimants adopt and incorporate herein by reference the allegations

contained in Paragraphs 1 through 29 of these Counterclaims.

31. Counterclaimants are credibly informed and believe and, upon such information and belief, allege that Whiting, McElvain and Maralex claim some right, title, interest or lien adverse to the estate of Counterclaimants in and to the Subject Lands, or some portion thereof.

32. The casings of the Subject Pictured Cliffs wells were perforated at various levels within the Pictured Cliffs formation in order to provide a means for gas to enter the wellbore. In a number of public statements, both verbal and written, agents of the Counterclaim-Defendants have stated that the upper-most sets of perforations in each of the wells are located above the Pictured Cliffs formation and that the Counterclaimants do not own the oil and gas leasehold rights at those depths.

33. In addition to the public statements of their agents that the Counterclaimants do not own the oil and gas leasehold rights at the levels of the upper-most set of perforations in the Pictured Cliffs formation, The Counterclaim-Defendants have asserted ownership to the oil and gas leasehold rights at those depths for themselves, adverse to the ownership interests of the Counterclaimants.

34. Based on the allegations set forth in Paragraphs 1 through 33 above, the Counterclaimants' estate in and to the Subject Lands should be established against the adverse claims of Whiting, McElvain and Maralex, and each of them, and Whiting, McElvain and Maralex should be barred and estopped from having or claiming any right, title, interest or lien upon the right or title to the estate of the Counterclaimants in and to said lands, or any portion thereof, adverse to Counterclaimants; and that Counterclaimants' titles therein and thereto be forever quieted and set at rest.

COUNT IV
CONVERSION

41. Counterclaimants adopt and incorporate by reference the allegations contained in Paragraphs 1 through 40 of these Counterclaims.

42. Whiting, McElvain and Maralex have no right, interest, title or permission to invade, enter upon, or produce Pictured Cliffs Formation gas through the Subject Coal wells.

43. Whiting, McElvain and Maralex have wrongfully and physically entered and invaded Counterclaimants' real property interests in and to the Pictured Cliffs formation, thereby depriving Counterclaimants' of the use, right and enjoyment of their real and personal property, and directly infringing on Counterclaimants rights of possession.

44. As a result of the wrongful conduct of the Counterclaim-Defendants, Counterclaimants' Pictured Cliffs formation gas reserves have been drained and produced through the Subject Coal Wells. As a further result, the reservoir energy of the Pictured Cliffs formation has been adversely affected and the Counterclaimants' opportunity and ability to produce their gas reserves has been impaired.

45. Whiting, McElvain and Maralex have wrongfully exercised dominion and control and taken possession of Counterclaimants' Pictured Cliffs gas reserves, reservoir energy, and the opportunity to produce without accounting to Counterclaimants.

46. The volumes of gas converted by the Counterclaim-Defendants are known exclusively by them and Counterclaimants are without means of knowing or determining their exact damages.

47. As a direct and proximate result of Counterclaim-Defendants' conduct, Counterclaimants have been and continue to be irreparably and irretrievably injured.

COUNT II
SLANDER OF TITLE

35. Counterclaimants adopt and incorporate herein by reference the allegations contained in Paragraphs 1 through 34 of these Counterclaims.

36. The public statements of the agents of The Counterclaim-Defendants referenced in Paragraph 31 through 33, above were knowingly and maliciously made without any basis in fact and as a consequence, a cloud against title has been cast adverse to the interests of the Counterclaimants in the Subject Lands.

37. Counterclaim-Defendants' conduct has harmed Counterclaimants and Counterclaimants have suffered special damages. These damages include, but are not limited to, Counterclaimants' attorneys' fees in bringing this action and in related administrative proceedings.

COUNT III
DECLARATORY JUDGMENT

38. Counterclaimants adopt and incorporate by reference the allegations contained in Paragraphs 1 through 37 of these Counterclaims.

39. Counterclaimants state that there exists an actual controversy in that they have rights and remedies pursuant to their legal title to produce gas through the Subject Pictured Cliffs wells.

40. Alternatively, if it is proved that gas from the Fruitland Coal formation is being produced from the Subject Pictured Cliffs Wells as a result of the operations and fracture treatments performed by Whiting, McElvain and Maralex, then the Counterclaimants are entitled to claim exclusive ownership of such gas and produce the same by virtue of the rule of capture and other legal and equitable doctrine.

COUNT V
TRESPASS AND PRIVATE NUISANCE

48. Counterclaimants incorporate Paragraphs 1 through 47 by reference herein.

49. Counterclaim-Defendants are without any right, title, interest or permission to invade, enter upon or produce gas reserves from the Picture Cliffs formation owned by Counterclaimants.

50. Through their improperly performed fracture stimulation jobs on the Subject Coal Gas Wells, Counterclaim-Defendants have wrongfully physically entered and invaded Counterclaimants' real property interests in and to the Picture Cliffs formation, thereby depriving Counterclaimants of the use, profits and enjoyment of their real and personal property, and directly infringing on Counterclaimants' rights of possession.

51. As a direct and proximate result of wrongful conduct of the Counterclaim-Defendants, Counterclaimants have been and continue to be irreparably and irretrievably injured.

52. The Counterclaim-Defendants' conduct was taken intentionally, wantonly, willfully, and in conscious disregard of Counterclaimants' rights.

COUNT VI
NEGLIGENCE

53. Counterclaimants incorporate by reference Paragraphs 1 through 52.

54. In the alternative, if Whiting, McElvain and Maralex did not intentionally invade Counterclaimants property, then in developing and operating their wells, Whiting, McElvain and Maralex owed to Counterclaimants a duty of care to prevent injury or damage or entry into the Pictured Cliffs formation.

55. By their failure to maintain the segregation of production and by allowing the escape of water and other fluids from the Fruitland formation, the Counterclaim-Defendants

violated and continue to be in violation of the rules, order, regulations and statutes of the New Mexico Oil Conservation Division, including 19 NMAC 15.E.303.A and N.M. Stat. Ann. §70-2-12 (B) (2), N. M. Stat. Ann. §70-2-12 (B) (4) and N. M. Stat. Ann. §70-2-12 (B) (7) of the New Mexico Oil and Gas Act. The Counterclaim-Defendants' conduct therefore constitutes negligence per se.

56. As alleged herein, Whiting and/or Maralex, their employees and agents, have negligently or recklessly breached the duty owed to Counterclaimants

57. As a direct and proximate cause of the Whiting's and/or Maralex's negligence, Counterclaimants have been and continue to be irreparably and irretrievably injured.

COUNT VII
UNJUST ENRICHMENT

58. Counterclaimants incorporate by reference Paragraphs 1 through 57.

59. In the alternative, it is inequitable and unjust for Whiting, McElvain and Maralex to retain and enjoy the benefit of Counterclaimants' valuable mineral rights without compensating Counterclaimants and Whiting, McElvain and Maralex should be required to compensate Counterclaimants by virtue of a contract implied in equity.

COUNT VIII
ACCOUNTING

60. Counterclaimants incorporate by reference Paragraphs 1 through 59.

61. In the alternative, the wrongful conduct of Whiting, McElvain and Maralex has deprived Counterclaimants of gas sales revenues rightfully belonging to Counterclaimants.

62. Whiting, McElvain and Maralex are in control of records reflecting gas sales, volumes and revenues from their wells.

63. Whiting, McElvain and Maralex have failed and refused to account to Counterclaimants for revenues from Subject Coal Wells and have refused to acknowledge Counterclaimants' interest in future revenues from such sales.

COUNT IX
VIOLATION OF THE NEW MEXICO OIL AND GAS PROCEEDS PAYMENT ACT

64. Counterclaimants incorporate by reference Paragraphs 1 through 63.

65. The actions of Counterclaim-Defendants in failing to account for and pay to Counterclaimants for their share of proceeds derived from the production of Pictured Cliffs gas through the Subject Coal Gas wells violates the New Mexico Oil and Gas Proceeds Payment Act, N.M. Stat. Ann. § 70-10-1, et seq..

66. Counterclaimants are entitled to recover actual and consequential damages in amounts to be proved at trial, plus pre- and post-judgment interest and penalties thereon as provided by N.M. Stat. Ann. § 70-10-4 and N.M. Stat. Ann. § 70-10-5, along with their costs and attorneys fees pursuant to N.M. Stat. Ann. § 70-10-6.

WHEREFORE, Pendragon Energy Partners, Inc., Pendragon Resources, L.P. and J.K. Edwards Associates, Inc. pray for judgment in their favor (1) quieting their title to the Subject Lands; (2) awarding them actual, compensatory and special damages; (3) permanently enjoining the Counterclaim-Defendants from further operating and/or producing their wells that are in communication with the Pictured Cliffs formation and requiring that those wells be shut-in permanently and enjoining the Counterclaim-Defendants' trespass, conversion and nuisance; (4) declaring the rights of the parties, including, specifically, the rights of the Counterclaimants to the ownership of Fruitland Coal gas produced through the Subject Pictured Cliffs wells as a result of the

Counterclaim-Defendants' conduct; (5) for an accounting by the Counterclaim-Defendants for revenues attributable to past sales of Counterclaimants' Pictured Cliffs formation gas; (6) for an equitable allocation of future production and revenues from the Subject Coal Wells; (7) for pre-and post-judgment interest and penalties as permitted by law, together with costs and attorneys' fees in this action and in related administrative proceedings; and (8) such other relief as the Court deems proper. To the extent that any of the foregoing issues or prayers for relief are within the proper jurisdictional authority of any administrative agency, the Counterclaimants do not seek their determination by the Court.

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I CERTIFY that a true and correct copy of the foregoing has been mailed to the following counsel of record this 21 day of Aug, 1998.

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PLEASE REPLY TO SANTA FE

August 20, 1998

David Catanach
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87504

Re: NMOCD Case 11996; Application of Pendragon Energy Partners, Inc. And J.K. Edwards Associates, Inc. To Confirm Production From The Appropriate Common Source Of Supply, San Juan County, New Mexico

Dear Examiner Catanach:

By cover letter dated August 13, 1998, counsel for Whiting/Maralex submitted a rather large volume of documents claimed to be in response to requests made at the hearing by me or the Division. Under tab 6 of the binder are a compilation of advertisements, articles and abstract excerpts largely relating to proprietary simulator programs being promoted by S.A. Holditch & Associates.

We compiled comprehensive notes from the hearing. Our review of those notes does not reveal that the materials under tab 6 are responsive to any requests for additional information made by you, Mr. Chavez or me during the course of the hearing. Moreover, the materials are submitted without any foundation whatsoever and their tender following the close of evidence is inappropriate. Accordingly, on behalf of the Applicants, we object to the unsolicited materials submitted by Whiting and Maralex and request that they be given no consideration.

GALLEGOS LAW FIRM

A Professional Corporation

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CONFIRMATION COPY OF FACSIMILE

MICHAEL J. CONDON

August 25, 1998
(Our File No. 98-266.00)

VIA TELECOPY
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

Dear Examiner Catanach:

I just received in the mail two letters to you from Scott Hall dated August 20, 1998. In one letter, Mr. Hall objects to Tab 6 of the binder we provided which included numerous materials related to the simulator program utilized by our expert witness at the hearing in this case, Bradley Robinson, in support of his testimony that the Pendragon fracs went out of zone and communicated with the Fruitland coal seam gas formations. Mr. Hall objects to your considering these materials. We understood that you requested these materials based upon Pendragon's unsubstantiated charges at hearing that the simulation program is unreliable.

The materials at Tab 6 confirm that the simulation program utilized by Mr. Robinson is accepted and commonly used by the industry. You would be entitled to take administrative notice of these materials, even if the subject had not come up during the course of the hearing. However, since Mr. Hall's clients did raise an issue as to the propriety of the program, it is entirely appropriate for you to review these materials so that you could judge for yourself whether the program is generally accepted in the industry. If you have any concerns about the authenticity of the documents, we can certainly provide you with an affidavit. We believe that Pendragon's objections on this matter are baseless.

Mr. Hall's second letter involves page 558 of Exhibit 47 which we introduced at the hearing. I understand from Mr. Hall's letter that the copy of the exhibit which we presented to Mr. Brenner has the correct last page for the Dugan No. 1 WAW well in Section 32, T-27-N, R-13-W. Our file copy also has the correct page. I am not sure how Mr. Hall's copy, which I assume he is referring to, got the incorrect third page for

To eliminate any confusion regarding the contents of the actual record in this proceeding, I would suggest that the tab 6 materials be removed from the binder and returned to Mr. Condon.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall

JSH/eam
cc: Michael Condon, Esq.
✓Rand Carroll, Esq.

the No. 1-G Navajo well. If there is any confusion regarding the Division's copy, please let me know and I will be happy to provide you with another complete copy of Exhibit 47.

Thank you for your attention to these matters.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: John Hazlett
Mickey O'Hare
cc: Scott Hall
ioc: J.E. Gallegos

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PLEASE REPLY TO SANTA FE

August 20, 1998

David Catanach
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87504

Re: NMOCD Case 11996; Application of Pendragon Energy Partners, Inc. And J.K. Edwards Associates, Inc. To Confirm Production From The Appropriate Common Source Of Supply, San Juan County, New Mexico

Dear Examiner Catanach:

In reviewing the exhibits submitted on behalf of Whiting and Maralex in the above case, I discovered that my set contains an error which, if repeated in the other sets, should be corrected.

Whiting/Maralex Exhibit 47 is a compilation of certain articles excerpted from the Four Corners Geological Society publication **Oil and Gas Fields Of The Four Corners Area**. Page 558 of Exhibit 47 is an article by K. Fagrelius on the Dugan Production Corporation No. 1 WAW well in Section 32, T-27-N, R-13-W. However, the attachment for the article is a type log for the Skelly No. 1-G Navajo well located in Section 12, T-26-N, R-12-W.

Enclosed is a copy of the correct type log that should accompany the Fagrelius article in the event your set of exhibits has the erroneous attachment. I have confirmed with Steve Brenner that his set is correct.

Very Truly Yours,
MILLER, STRATVERT & TORGERSON

J. Scott Hall J. Scott Hall

JSH/eam
enclosure
cc: Michael Condon, Esq.

WAW FRUITLAND-PICTURED CLIFFS

(Gas)

T. 26-27 N., R. 13 W., NMPM
San Juan County, New Mexico

By: **K. Fagrelius**
Dugan Production Corporation

GEOLOGY

Regional Setting: Southwest flank, San Juan Basin

Surface Formations: Tertiary, Ojo Alamo Sandstone and Nacimiento Formation

Exploration Method Leading to Discovery: Subsurface study

Type of Trap: Stratigraphic

Producing Formation: Cretaceous, Fruitland Formation and Pictured Cliffs Sandstone

Gross Thickness and Lithology of Reservoir Rocks: 15 feet, sandstone

Geometry of Reservoir Rock: Lenticular sandstone bodies

Other Significant Shows: None

Oldest Stratigraphic Horizon Penetrated: Cretaceous, Pictured Cliffs Sandstone

DISCOVERY WELL

Name: Dugan Production Corporation No. 1 WAW

Location: NW SW (1500′ FSL and 950′ FWL) sec. 32, T. 27 N., R. 13 W.

Elevation (KB): 6,175 feet

Date of Completion: June 30, 1970

Total Depth: 1,411 feet

Production Casing: 2 7/8″ set at 1,400 feet with 50 sacks of cement

Perforations: 1,325 to 1,329 feet

Stimulation: Sand-water fracture, 10,000 lbs sand and 360 barrels water

Initial Potential: 603 MCFGD (absolute open flow)

Bottom Hole Pressure: 200 psia

DRILLING AND COMPLETION PRACTICES

The discovery well was sand-water fractured but it has subsequently been learned that fracturing does not greatly enhance producibility from these wells. Dugan Production now spuds a 7 7/8″ hole and sets one joint of 5½″ casing cemented to surface. A 4¾″ hole is then drilled with water or minimum mud to a total depth of approximately 125 feet into the Pictured Cliffs Sandstone. An Induction Electrical log is then run to total depth, and 2 7/8″ tubing is run for production casing and cemented with a lightweight cement slurry with lost circulation material to avoid formation damage. The drilling rig is then released and after waiting at least 48 hours, a swabbing unit is moved in. A gamma-ray correlation and collar log is run, and the 2 7/8″ casing is swabbed down to within 300 to 400 feet of the interval to be perforated. After perforating with 2 1/8″ glass jet charges of selected intervals, the casing is swabbed down. If commercial production is indicated at this point 1¼″ tubing is run and the well completed ready for production. If natural production is not indicated or of very slight amount, a small job of 250 gallons of 15 percent regular HCl acid followed by enough water to displace the acid into the formation is performed. The well is then swabbed in and tubing run. This field is located in an area of relatively flat terrain making it possible to use truck-mounted shot-hole rigs and requires a minimum of road and location building.

RESERVOIR DATA

Productive Area:
- Proved (as determined geologically): 8,960 acres (August 1, 1978)
- Unproved: 1,920 acres
- Approved Spacing: None
- No. of Producing Wells: 30 (plus 7 wells drilling)
- No. of Abandoned Wells: 10
- No. of Dry Holes: 7

Average Net Pay: 10 feet

Porosity: 18 percent

Permeability: 1 to 100 millidarcies (estimate)

Water Saturation: 50 percent

Initial Field Pressure: 250 psia

Type of Drive: Gas expansion

Gas Characteristics and Analysis: Btu 1,050, 90 percent methane

Associated Water Characteristics and Analysis: Not available

Original Gas, Oil, and Water Contact Datums: Unknown

Estimated Primary Recovery: 4,000,000 MCFG

Type of Secondary Recovery: Not available

Estimated Recovery: Unknown

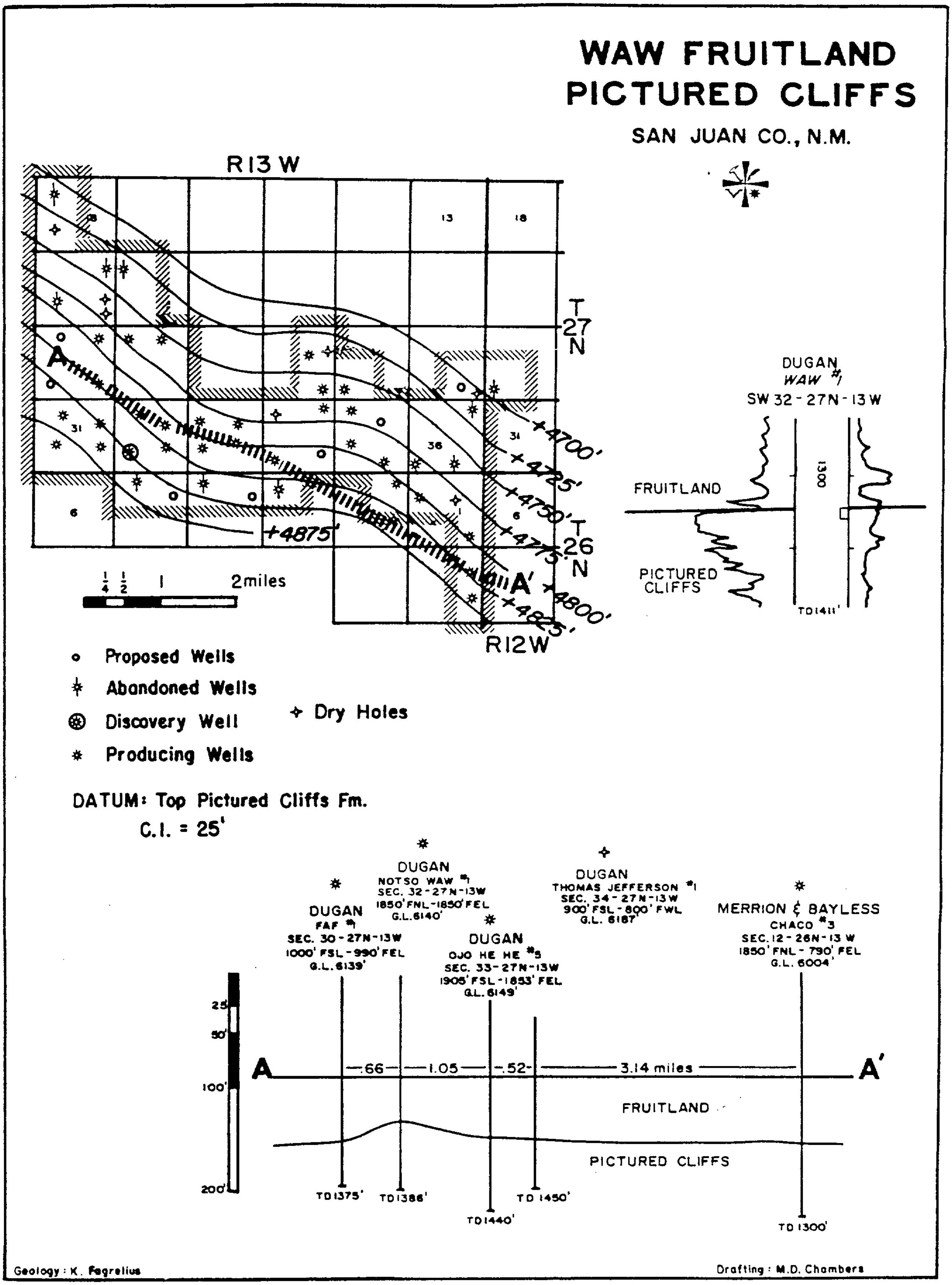
Present Daily Average Production: 750 MCFGD (January 1, 1978)

Market Outlets: El Paso Natural Gas Co.

FIELD COMMENTARY

The WAW Pictured Cliffs Pool was discovered by the drilling of the Dugan Production Corp. WAW No. 1 well. This well was spudded May 19, 1970, on a farmout from Aztec Oil and Gas Company, hence the well name "WAW" (Wild Aztec Well). A 7 7/8″ hole was drilled to 14 feet and 5½″ casing run and cemented to surface with 5 sacks of cement; a 4¾″ hole was then drilled to a total depth of 1,411 feet with water and minimum mud; an electric log was run; and 2 7/8″ tubing run and cemented for casing. The well was perforated from 1,325 to 1,329 feet. This well was sand-water fractured with 10,000 pounds of sand and 260 barrels of water; 1¼″ tubing was set at 1,303 feet. The well tested on a one point back pressure test for an absolute open flow of 603 MCFGD on June 30, 1970 with a seven-day shut-in pressure of 193 psig.

Because of the remote location of the discovery well from existing gas gathering facilities, a contract could not be


WAW FRUITLAND
PICTURED CLIFFS
SAN JUAN CO., N.M.
R13 W
R12W
T 27 N
T 26 N
+4700'
+4725'
+4750'
+4775'
+4800'
+4825'
+4875'
A
A'
2miles
DUGAN WAW #1
SW 32-27N-13W
FRUITLAND
PICTURED CLIFFS
1300
TD1411'
Proposed Wells
Abandoned Wells
Discovery Well
Producing Wells
Dry Holes
DATUM: Top Pictured Cliffs Fm.
C.I. = 25'
DUGAN
FAF #1
SEC. 30-27N-13W
1000' FSL-990' FEL
G.L. 6139'
DUGAN
NOTSO WAW #1
SEC. 32-27N-13W
1850' FNL-1850' FEL
G.L. 6140'
DUGAN
OJO HE HE #5
SEC. 33-27N-13W
1905' FSL-1853' FEL
G.L. 6149'
DUGAN
THOMAS JEFFERSON #1
SEC. 34-27N-13W
900' FSL-800' FWL
G.L. 6187'
MERRION & BAYLESS
CHACO #3
SEC. 12-26N-13 W
1850' FNL-790' FEL
G.L. 6004'
.66
1.05
.52
3.14 miles
FRUITLAND
PICTURED CLIFFS
25
50'
100'
200'
TD1375'
TD1386'
TD1440'
TD 1450'
TD 1300'
Geology: K. Fagrelius
Drafting: M.D. Chambers

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AUG 24 1998
OIL CONSERVATION DIV.

August 20, 1998

David Catanach
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87504

Re: NMOCD Case 11996; Application of Pendragon Energy Partners, Inc. And J.K. Edwards Associates, Inc. To Confirm Production From The Appropriate Common Source Of Supply, San Juan County, New Mexico

Dear Examiner Catanach:

By cover letter dated August 13, 1998, counsel for Whiting/Maralex submitted a rather large volume of documents claimed to be in response to requests made at the hearing by me or the Division. Under tab 6 of the binder are a compilation of advertisements, articles and abstract excerpts largely relating to proprietary simulator programs being promoted by S.A. Holditch & Associates.

We compiled comprehensive notes from the hearing. Our review of those notes does not reveal that the materials under tab 6 are responsive to any requests for additional information made by you, Mr. Chavez or me during the course of the hearing. Moreover, the materials are submitted without any foundation whatsoever and their tender following the close of evidence is inappropriate. Accordingly, on behalf of the Applicants, we object to the unsolicited materials submitted by Whiting and Maralex and request that they be given no consideration.

To eliminate any confusion regarding the contents of the actual record in this proceeding, I would suggest that the tab 6 materials be removed from the binder and returned to Mr. Condon.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall

JSH/eam
cc: Michael Condon, Esq.
Rand Carroll, Esq.

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Telefax No. 505-986-1367
Telefax No. 505-986-0741

August 18, 1998
(Our File No. 98-266.00)

<u>VIA HAND-DELIVERY</u>
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

Dear Mr. Catanach:

Enclosed please find a disk containing Whiting's draft Orders which were provided to you on August 13, 1998 in Word format.

If you should have any questions concerning this matter, please do not hesitate to contact our office.

Sincerely,

GALLEGOS LAW FIRM, P.C.

Sandra Arrison

SANDRA ARRISON

/sa
Enclosure

GALLEGOS LAW FIRM
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Telefax No. 505-986-1367
Telefax No. 505-986-0741

August 14, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA TELECOPY
Rand Carroll, Esq.
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

VIA TELECOPY
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

Gentlemen:

I wanted to write to confirm that we had filed a Memorandum in Lieu of Closing Statement yesterday. That pleading is not designated on any of my transmittal letters. If you would like, I can provide you each with an additional copy. Please let me know.

Very truly yours,

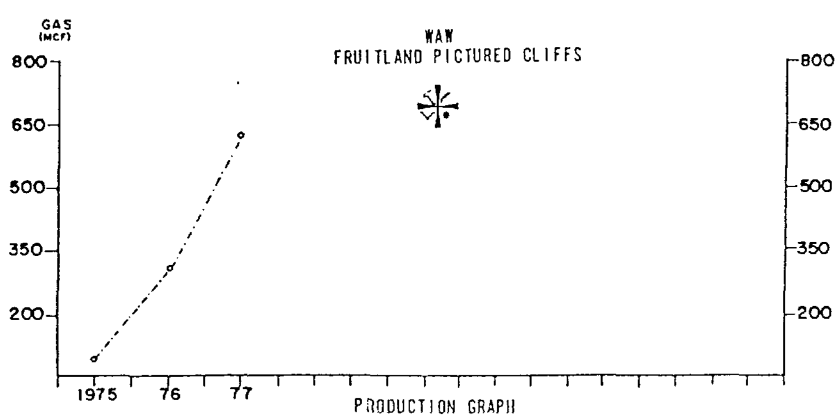
GALLEGOS LAW FIRM, P.C.

By MICHAEL J. CONDON

MJC:sa
fxc: J. Scott Hall
John Hazlett
Mickey O'Hare
ioc: J.E. Gallegos

secured for the sale of gas from the discovery well. In December, 1974, Dugan Production Corp. made an application to the Bureau of Land Managemet to secure a pipeline right-of-way to lay approximately 4 miles of pipeline to tie into the El Paso Natural Gas Company low pressure gathering facility located in the NE¼ sec. 35, T. 27 N., R. 13 W. This application was granted April 15, 1975, and a 3" fiberglass line was laid to connect the WAW No. 1 and the Notsowaw No. 1 well, which was completed April 12, 1975. During the remainder of 1975 and 1976, Dugan Production completed 13 additional wells for which more right-of-way was secured and there are now 15 wells operated by Dugan producing into the pipeline system. Two additional wells have been completed in the field by Kirby Exploration, neither of which has gas sales outlets at this writing, and one well has been completed by Dietrich Exploration Company for which approximately one mile of pipeline was laid.

NUMBER OF WELLS AT YEARS END				– PRODUCTION – OIL IN BARRELS GAS IN MCF	
YEAR	TYPE	PROD	S I / ABN	ANNUAL	CUMULATIVE
1975	Gas	2	0	58,657	58,657
1976	Gas	16	1	250,799	309,456
1977	Gas	16	1	316,894	626,412



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Telefax No. (505) 986-0741 or (505) 986-1367

CLIENT: WHITING
CLIENT NO.: 98-266.00

DATE: **August 14, 1998**

TO: **David Catanach**

COMPANY: **New Mexico Oil Conservation Division**

TELEFAX NO.: **(505) 827-8177**

FROM: **Michael J. Condon**

MESSAGE:

NUMBER OF PAGES INCLUDING COVER SHEET: 2

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August 13, 1998

HAND DELIVERED

David Catanach
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87504

Re: NMOCD Case 11996; Application of Pendragon Energy Partners, Inc. And J.K. Edwards Associates, Inc. To Confirm Production From The Appropriate Common Source Of Supply, San Juan County, New Mexico

Dear Mr. Catanach:

In connection with the above-referenced case, we enclose the Applicants' draft Order in hard copy form and on disk in Word format. We are also able to provide the draft Order in WordPerfect format, if needed.

Should you require any additional information or materials, please do not hesitate to contact me.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

J Scott Hall by Elizabeth Ann McGee

J. Scott Hall

JSH/eam
enclosures
cc: J.E. Gallegos
Rand Carroll, NMOCD

STATE OF NEW MEXICO
ENERGY, MINERALS, AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

IN THE MATTER OF THE HEARING CALLED BY THE OIL CONSERVATION DIVISION FOR THE PURPOSE OF CONSIDERING:

CASE NO. 11996

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC., AND J. K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO.

ORDER OF THE DIVISION

BY THE DIVISION:

This cause came on for hearing at 8:15 a.m. on July 28, 1998 at Santa Fe, New Mexico, before Examiner David R. Catanach.

NOW, on this ______day of August 1998, the Division Director, having considered the testimony, the record, and the recommendations of the Examiner, and being fully advised in the premises,

FINDS THAT:

(1) Due public notice having been given as required by law, the Division has jurisdiction of this cause and the subject matter thereof.

(2) The Applicants, Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc. seek the issuance of an order determining that six of the Pictured Cliffs Formation Wells owned and operated by them are completed in and producing from the appropriate common source of supply pursuant to Rule 3 of the Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool, Order No. R-8768, as amended, and 19 NMAC 15.E.303.A of the Division's Rules and Regulations requiring the segregation of production from separate sources of supply.

(3) The Applicant, Pendragon Energy Partners, Inc. ("Pendragon") is the operator of the following wells (The "Subject Pictured Cliffs wells" or the "Chaco

wells") previously drilled to and completed in the Pictured Cliffs formation at the locations described below (the "Subject Lands") on the following respective dates:

Well Name	Location	Date
Chaco No. 1	NW¼, Section 18, T26N, R12W	March, 1977
Chaco No. 2R	SW¼, Section 7, T26N, R12W	January, 1980
Chaco No. 4	NW¼, Section 7, T26N, R12W	May, 1977
Chaco No. 5	SE¼, Section 1, T26N, R13W	May, 1977
Chaco Ltd. No. 1J	SW¼, Section 1, T26N, R13W	April, 1982
Chaco Ltd. No. 2J	NE¼, Section 1, T26N, R13W	May, 1979

(4) By Order No. R-8768 and No. R-8768-A, the Division created a new pool in all or parts of San Juan, Rio Arriba, McKinley and Sandoval Counties New Mexico classified as a gas pool for the production from the Fruitland Coal seams and designated the pool as the Basin-Fruitland Coal Gas Pool. The wells and the lands that are the subject of this proceeding are located within the horizontal limits of the Basin-Fruitland Coal Gas Pool as defined by Order R-8768 in R-8768-A. The Order also established the vertical limits of the pool by reference to the Amoco Schnieder Gas Com "B" well No. 1 located in Section 28, T-32-N, R-10-W.

(5) By Order No. R-8769 entered by the New Mexico Oil Conservation Division on October 17, 1988 in Case No. 9421 and subsequently amended by Order No. R-8768-A, nunc pro tunc, the Division defined the vertical limits of the WAW Fruitland-Pictured Cliffs Pool as follows:

> The vertical limits of the WAW Fruitland-Pictured Cliffs Pool in San Juan County, New Mexico are hereby contracted to include only the Pictured Cliffs formation and the sandstone interval of the Fruitland formation and said pool is hereby redesignated as the WAW Fruitland Sand-Pictured Cliffs Pool.

(6) At the hearing in this matter, Pendragon Resources, L.P. entered its appearance in support of the Application. Whiting Petroleum Corporation and Maralex Resources, Inc. also entered their appearance and presented evidence in opposition to the application.

(7) Whiting Petroleum Corporation and Maralex Resources Inc. both own working interests dedicated to the following Fruitland Coal Wells (the "Subject Coal Wells") operated by Maralex and drilled in 1992 and which were frac'd by Maralex in 1993:

Well Name	Location
Gallegos Federal 26-12-6 No. 2	W½, Section 6, T26N, R12W
Gallegos Federal 26-12-7 No. 1	W½, Section 7, T26N, R12W
Gallegos Federal 26-13-1 No. 1	E½, Section 1, T26N, R13W
Gallegos Federal 26-13-1 No. 2	W½, Section 1, T26N, R13W

Gallegos Federal 26-13-12 No. 1 N½, Section 12,T26N, R13W

(8) Whiting and Maralex were applicants in an earlier proceeding before the Division in Case No. 11921 wherein they alleged generally, that as a result of drilling or the fracture stimulation, the Pendragon operated Pictured Cliffs Wells had become communicated with and are producing from the Basin-Fruitland Coal Gas Pool. Whiting and Maralex further contended that the Pendragon Pictured Cliffs wells were draining reserves owned by Whiting and the other interest owners in its wells and that their correlative rights were being impaired as a result. In their application, Whiting and Maralex sought to have Pendragon's Pictured Cliffs Wells shut in. On May 26, 1998, Whiting and Maralex sought to withdraw their application in Case No. 11921. Whiting and Maralex have subsequently asserted that Pendragon reperforated its Chaco No. 1, Chaco No. 2-R, Chaco No. 4 and Chaco No. 5 wells directly into the Fruitland formation coal bed.

(9) The parties presented evidence establishing that J.K. Edwards and Associates, Inc. and Pendragon Energy Partners, Inc. and Pendragon Resources L.P. acquired rights from the base of the Fruitland Coal Formation to the base of the Pictured Cliffs Formation and that Maralex Resources Inc. and Whiting Petroleum Corporation obtained rights from the surface to the base of the Fruitland (Coal Gas) Formation.

(10) Evidence presented by Pendragon established that the Subject Chaco Wells were perforated at the following intervals and received acid or fracture stimulation treatments on the following dates:

Well Name	Perforation Interval	Date	Stimulation	Date
Chaco, Ltd 1-J	1200-1209'	08/82	Acidized	01/95
Chaco 4	1163-66' 1173-89'	05/77	Frac'd & Acidized	05/95 01/95
Chaco 2 R	1132-1142'	01/80	Frac'd	01/95
Chaco, Ltd 2-J	1186-88.5' 1200-1202.5'	12/79	Frac'd Acidized	12/79 02/95
Chaco 5	1165-69' 1174-92'	05/77	Frac'd Frac'd	05/79 05/95
Chaco 1	1113-19' 1126-28' 1134-39'	03/77	Frac'd	01/95

(11) The referenced perforations were made by Pendragon's predecessor in interest, Merrion and Bayless Oil and Gas Company, and were reported to the Division on C-102 forms and to the Bureau of Land Management on BLM Sundry Notice forms.

(12) Whiting and Maralex have asserted and continue to assert that the upper set of perforations for each of the Subject Pictured Cliffs wells are at depths equivalent to the Fruitland Sandstone member of the Fruitland formation. It is the position of the Applicants that the upper set of perforations are located in what has been identified the as the Upper Pictured Cliffs sand and what has been recognized by geologists, operators and the Division as Pictured Cliffs.

Pendragon and Edwards presented geologic evidence which established the following:

(13) Casing collar survey logs performed in May and June of 1998 conclusively established that none of the subject Pictured Cliffs wells were perforated or reperforated in the Fruitland Coal Formation.

(14) The discovery well for the WAW Pictured Cliffs field, was the WAW No. 1 drilled in the NW/4 of Section 32, T-27-N, R-13-W, NMPM and completed on June 30, 1970 by Dugan Production Corporation. The pick for the top of the Pictured Cliffs formation sandstone by Dugan geologists for the WAW No. 1 was at a depth of 1317 feet, which is above the Upper Pictured Cliffs sand.

(15) The Chaco Plant No. 1 well, the discovery well for the NIIP Pictured Cliffs field, was drilled in the SE/4 of Section 17, T-26-N, R-12-W, NMPM by Dugan Production Company on April 1, 1975. The pick for the top of the Pictured Cliffs sandstone is at approximately 1,132 which is also above the top of the Upper Pictured Cliffs sand.

(16) In its numerous cross section exhibits, Pendragon located its upper sets of perforations in the Subject Chaco Wells in that member of the Pictured Cliffs sandstone which it has identified in its cross sections and geologic literature exhibits as the Upper Pictured Cliffs sand.

(17) In its cross section C-C' Pendragon identified the "stratigraphic equivalent" as that term is used in Order No. R-8768 and reflected on the well log for the Amoco Schneider Gas Com "B" Well No. 1 as the first sandstone below the Fruitland Coal formation. Evidence also presented by Pendragon established that the term "stratigraphic equivalent" means "the same kind of rock material".

(18) The primary distinguishing characteristic of the Pictured Cliffs sandstone is its creation in a marine depositional environment. Conversely, the Fruitland Coal and the Fruitland Sandstone were deposited in a non-marine depositional environment.

(19) Pendragon's isopach of the Upper Pictured Cliffs sand shows the occurrence of that sandstone along the shoreline trending from a northwest to a southeast direction in a barrier bar marine littoral environment. Pendragon's exhibit also established that the Upper Pictured Cliffs sand occurs in a continuous sheet sand that coalesces into the main body or bench of the Pictured Cliffs formation as the sand trends from the shoreline environment on the southwest toward the center of the San Juan basin to the northeast.

(20) The core analysis for the Lansdale Federal No. 1 located in the SE/4 Sec. 7, T-26-N,R-12-W established the average permeability and porosity for the Upper Pictured Cliffs sand and that grain size and sorting throughout the Upper Pictured Cliffs sand are uniform, consistent with a marine depositional environment.

(21) The geologic evidence presented by Pendragon also established that the Fruitland sands are deposited along a trend from the Southwest to the Northeast on a channelized basis and that those sands thin towards the Northeast to the edge of the Pictured Cliffs sandstone body.

(22) Pendragon also established that its picks for the top of the Pictured Cliffs formation are consistent with those of other operators in the area and with a wide body of geologic literature accepted and relied on for decades by geologic experts, administrative agencies and industry.

(23) The evidence presented by Pendragon established that approximately 34 wells in the area were perforated in the Upper Pictured Cliffs sand in conjunction with other Pictured Cliffs intervals and reported as Pictured Cliffs completions, consistent with the picks for the top of the Pictured Cliffs for the Chaco Plant No. 1 and the Subject Chaco Wells. The evidence also established that those reported completions were accepted by the Division and the Bureau of Land Management and that industry and geologists have placed substantial reliance on those reported completions as Pictured Cliffs completions.

(24) Well logs from wells in the subject area indicate the existence of other coal stringers below the base of the Fruitland formation but they are not the "stratigraphic equivalent" to the coal stringers reflected on the well log for the Amoco Schneider Gas Com "B" Well No. 1.

(25) Whiting and Maralex contended that the log picks for the Pictured Cliffs-Fruitland contact is usually placed at the top of the massive of sandstone below the lower-most coal of the Fruitland formation . However, the Whiting expert geologist agreed that the term "massive" is somewhat arbitrary and its use for differentiating between the Fruitland formation and the Pictured Cliffs formation is not always practicable. In addition, the geologic literature for the area indicates that it is more common to place the contact between the Fruitland and Pictured Cliffs formations at the top of the highest ophiomorpha-major bearing sandstone. Consequently, the more widely accepted technical definition of a Pictured Cliffs sandstone is whether the formation is of

marine deposition, such as shoreline, wave-dominated, delta-front chenier, barrier bar and tidal channel-type environments.

(26) The geologic testimony and literature further established that Fruitland sands are consistently recognized as non-marine (continental) deposits such as fluvial channels, deltaic-distributary channels and other landward deposits. Additionally, the geologic literature indicates that the pick for the top of the Pictured Cliffs formation is often at the base of the basal Fruitland coal. The Fruitland formation is the non-marine facies tract consisting of inter bedded sandstone, mudstone, and coal beds deposited landward of the marine facies tract of the Pictured Cliffs sandstone.

(27) In the area of the Subject Lands, the Upper Pictured Cliffs sand appears as a classic shoreline or chenier-type sand grading from 0 to approximately 13 feet toward the northeast where it coalesces into the main body of the Pictured Cliffs where the thin underlying shale stringers are not present. The Upper Pictured Cliffs sands cannot otherwise be differentiated from the main body of the Pictured Cliffs formation.

(28) In the area of the Subject Lands, the core analysis from the Lansdale Federal No. 1 well, the physical descriptions of the sand appearing in the Upper Pictured Cliffs bench and the two lower benches are gray, fine grained with little variation in clay content, consistent with a marine sand that has been laterally transported to the point where the energy available sorts the sand into uniform size. Sand sorting characteristics of this sort are not consistant with a fluvial deposit with graded bedding and coarsening downward.

(29) The Upper Pictured Cliffs sand coalesces into thicker and undifferentiated Pictured Cliffs sands to the east, northeast and north, indicating they are part of the same depositional environment. The Upper Pictured Cliffs sand also correlates and is continuous in character over a large area covering portions of four townships.

(30) The Upper Pictured Cliffs sand is elongated along a northwest to southeast strike that on-laps and thickens to the northeast.

(31) There is no evidence establishing that the Pictured Cliffs sandstone in the area of the subject wells is associated with any stream channels or down-cutting as would be the case in a fluvial environment. Rather, the deposition of a sand with the consistency in geometry of the Pictured Cliffs sand requires a marine setting with a flat, stable base and a source of sand with consistant grain size spread by tidal or wave energy. Such conditions do not occur onshore and behind the shoreline.

(32) In Order No. R-8768, the Division defined the vertical limits of Basin Fruitland Coal Gas Pool as all coal seams within the equivalent of the stratigraphic interval from a depth of approximately 2450 feet to 2880 feet as shown on the well log from the Amoco Schneider Gas Com "B" well No. 1. The pick for the base of the pool is the top of the Pictured Cliffs. The pick is also the break between marine and non-marine sediments. It is undisputed that those coals or shale layers occurring below the

stratigraphic pick set forth in Order No. R-8768 would not be included in the Fruitland coal pool or in the Fruitland formation.

(33) By referring to the stratigraphic equivalent, as that term is used by geologists and the Division, it was the intent of Order No. R-8768 to define the vertical limits of the Basin-Fruitland Coal pool by the identification of rock and rock material of the same type rather than by time equivalence or lateral equivalence. For this reason, in addition to the reasons cited above, it is appropriate to conclude that the Subject Chaco wells are completed in and are producing from the Pictured Cliffs formation.

(34) A number of wells in the area of the Subject Lands produce from the top portion of the third Pictured Cliffs sandstone bench. Well logs indicate the existence of some tight streaks between the third bench and the main bench of the Pictured Cliffs sandstone but it is not clear that those intervals act as a barrier between the third and the main bench. The evidence, including the geologic literature, establishes that operators in the area have refrained from fracture completions in the lower bench of the Pictured Cliffs sandstones due to concerns of fracing into water. However, the existence of a natural water drive mechanism along with gas reservoir pressures in this zone establish that the lower bench of the Pictured Cliffs is a recharge source for both reservoir pressures and gas reserves in the main body of the Pictured Cliffs sandstone.

(35) Additional wellhead shut-in pressures taken subsequent to the June 28, 1998 court-ordered shut in of the Chaco No. 1, Chaco No. 4, Chaco No. 5 and Chaco No. 2-R reflect modest but normal shut-in pressure build up. Slight variations in the shut-in pressures may be attributable to competition from other Pictured Cliffs wells in the reservoir, or from periods of higher pressures throughout the reservoir due to El Paso Field Services shut-in periods, slight water build up in the well bores or measurement inaccuracies.

(36) The production and pressure data from the Whiting and Maralex Fruitland Coal wells for the same period of time, many of which have been placed on compressor, indicate no correlation with the shut-in pressures for the Subject Pictured Cliffs wells.

(37) The production history of the Subject Pictured Cliffs wells compared to the pressure data accumulated prior to the acid jobs and frac jobs on those wells establishes that the reservoir in the immediate vicinity of the well bores had experienced skin damage or other forms of reservoir damage. As a result, production from the Pictured Cliffs had significantly declined prior to the frac jobs and acidization jobs in 1995.

(38) Pendragon presented production history data for the Subject Coal wells as well as production data from six additional Fruitland Coal wells operated by Whiting and Maralex outside the area of the Subject Lands. The Maralex production data for the Subject Coal wells showed that after their initial completion, the wells were unable to produce sufficient volumes of gas to power pumps to unload water produced from the coal de-sorption process. However, by mid 1994, the Subject Coal wells had reached a

state of gas production incline as well as a stabilized rate of decline for water production, indicating that the wells were benefiting from the dewatering process. The production data also established the Subject Wells were behaving much like typical Fruitland Coal wells. The gas and water production decline curves for the coal wells show no inflections indicating any interference from the Subject pictured Cliffs wells.

(39) Production plots for the Whiting/Maralex Fruitland Coal wells outside of the area of the application showed similar production behavior of both gas and water production as the Subject Fruitland Coal wells. However, the same data established that the Maralex Coal wells within the area of the application produced significantly higher volumes of gas than did those wells outside the area of review. The production data establishes that the Subject Fruitland Coal wells are not experiencing interference from the Subject Pictured Cliffs wells.

(40) The production curves montage of the Whiting/Maralex coal gas wells demonstrated that the Subject Coal Gas Wells have been and are presently performing better than the Non-Subject Coal Gas Wells.

(41) The drops in production for the Subject and Non-Subject Coal Gas Wells in August, 1995 correspond to the frequent shut-ins of the El Paso Chaco plant and were preceded and followed by long periods of unusually high line pressure. The production drops during this time do not appear to be the result of any interference from other wells. The shut-ins during this period occurred while the coal wells were in the early stages of de-watering. After the coal gas wells were placed back on production following the shut-in, the wells required addition time to further de-water and the wells did not reestablish their earlier production levels for some time. During this same period, the Pictured Cliffs wells experienced no difficulties in reestablishing pre-shut-in production rates, a further indication that the Subject Chaco Wells were not producing from the coal.

(42) In 1977, initial reservoir pressures in the Pictured Cliffs were between 230 to 250 PSI. Pressure draw-down in the Pictured Cliffs was first indicated in late 1978 and became more apparent by 1983. All of the Subject Pictured Cliffs wells experienced generally the same rate of pressure decline regardless of the volumes of gas produced, suggesting reservoir pressure communication over a very large area. As the rate of decline continued, most of the Pictured Cliffs wells were in the 90 to 130 PSI range. In 1995 pressure readings taken in the Chaco 1J and 2J wells and before the Chaco 4 well was frac'd indicate that pressures had substantially increased from the initial pressure readings taken in 1983 and 1984 and range from between 140 PSI to 190 PSI, indicating the reservoir was only drawn down by 40 percent from the initial reservoir pressures in 1977. Additionally the pressure information indicates the Pictured Cliffs reservoir pressure was increasing prior to Pendragon's fracture stimulations. Moreover, by 1995, there were significantly fewer wells competing for reservoir pressure in the Pictured Cliffs formation, and providing a larger drainage area for a re-stimulated well.

(43) Although the Chaco 1J well was not frac'd, its recent bottom hole pressure of 159 PSI is unchanged from 1995. It is located 600 feet from one of the Subject coal

wells operated by Whiting and Maralex but there is no evidence of interference between the two wells. The Chaco 2J well is currently producing at a 178 PSI pressure, lower than the 198 PSI reported in 1995. Although the Chaco 2J was not frac'd it is located some 200 feet from the Whiting/Maralex Gallegos Federal 26-13-1 No. 1 which was treated with a 112,000 pound frac job.

(44) Casinghead pressures and production readings were taken from the Subject Coal Gas wells during the 1998 shut-in period for the Chaco wells. These readings give the instantaneous pressure and the cumulative production for the past 24 hours. Some of the following readings were taken on the morning after the day El Paso Field Services had declared less-than 24-hour shut-in period for the Chaco Plant. Whiting/Maralex wells were not manually shut-in during this period, but were allowed to produce as they could against the high line pressure resulting from the plant shut-in. The Gallegos Federal No. 1-2 showed a capability of producing between 126 and 154 MCFPD at flowing casing pressures within 6 PSI of the Chaco No. 4 15-day shut-in pressure of 91 PSI. The Gallegos Federal No. 1-1 had produced 240 MCFD with a flowing casing pressure 3 PSI higher than the shut-in pressure of the Chaco No. 4. The Gallegos Federal No. 6-2 produced 432 MCFD with an 82 PSI FCP. The Gallegos Federal No. 12-1 produced 298 MCFD at 91 PSI FCP which was identical to the shut-in pressure of the Chaco No. 4. The Gallegos Federal No. 7-1 produced 308 MCFD with a FCP of 74 PSI. The closest Pictured Cliffs well, the Chaco 2R, 800 feet away had a two-week shut-in pressure of 69 PSI. This evidence establishes that the Subject Pictured Cliffs wells do not appear to be in communication with the same reservoir in which the Subject Coal wells are completed.

(45) Well log and production data from three wells completed in the Pictured Cliffs sandstone in Section 11 reflect increasing porosity and decreasing conductivity in the third bench of the PC which indicates increasing gas saturation and decreasing water saturation. Significantly, the well in the SW/4 SW/4 of Section 11 produced exclusively from the third bench, making more than 93 MMCF. The High-Roll No. 4 produced from all three Pictured Cliffs sands and has made over .5 BCF. Following the recent installation of a compressor, the High-Roll No. 4 experienced more than a twelve-fold increase in production. The well log and production data from these wells support the conclusion that a considerable volume of movable gas exists below the perforations in the Subject Pictured Cliffs wells in tighter rock with lower gas saturations but which will produce commercial quantities with acceptable volumes of water due to the relative permeability's among the zones.

(46) Pressure data for the Chaco 4 and 5 wells reflects that in 1995 those wells were producing at less than 1 percent of their producing rates in 1979 and pressures were equivalent to reservoir pressures in 1979. Such evidence indicates the existence of reservoir damage or skin damage.

(47) Whiting and Maralex presented BTU content gas analysis data to support their position that the decrease in BTU content from the Chaco wells over time is evidence of communication with the Fruitland Coal formation. The gas analysis data

presented by Pendragon established no correlation between the BTU content in gas production and the acidization and fracture stimulation treatments on the Subject Pictured Cliffs wells. The variations in BTU content could be attributable to a number of factors, including variations in reservoir pressure draw-down rates and production over time affecting the production of various gas liquids.

(48) The Applicant presented Phase change graphs demonstrating the phased transition from gas to liquids in a low permeability reservoir showing significant variations for methane, ethane, propane, butane, and pentane. The production of these liquids and the resultant effect on gas BTU content was shown to be affected by a number of factors, including reservoir pressure and rates of production. As a result of these variable, dynamic forces, the various components move through the reservoir at different velocities, affecting the BTU content of the produced gas. As reservoir conditions are historically variable rather than static, the BTU content of the gas is continually affected. Consequently BTU data over time are not meaningful and do not provide a reliable means for determining the source of gas production.

The Applicant presented expert petroleum engineering testimony in the area of fracture technology which established that:

(49) Pressure and injection rate data derived from formation fracture treatments can be used to determine the vertical height growth and horizontal extension of fractures within the formation.

(50) Lithologic analysis from logs may be used to design fracture stimulation treatments that remain contained within the target zone or formation. Moreover, changes in lithology and facies changes will predictably act as a barrier to fracture growth out of zone. In the Subject Pictured Cliffs wells, the well logs reflect a strong lithology change at the top of the Pictured Cliffs formation, assuring that the fractures remain contained.

(51) The evidence presented by the parties established that the foam fracs used on the Subject Pictured Cliffs wells consisted of fluid volumes averaging 31,248 gallons at proppant weights averaging 38,421 pounds injected at treating rates ranging from between 22 to 34 BPM.

(52) The evidence further established that the fracture completions performed by Maralex on the Subject Coal wells consisted of fracture fluid volumes on the average of 41,030 gallons at proppant weights averaging 72,656 pounds, injected at treating rates ranging between 45 to 60 BPM. In addition, the specific fracture completions for the Gallegos Federal 26-12-6 No. 2 well consisted of a fracture fluid volume of 81,025 gallons with a 121,700 proppant weight injected at treating rates between 45 to 60 BPM. The fracture completion for the Gallegos Federal 26-12-7 No. 1 consisted of a fracture fluid volume of 85,223 gallons with a proppant weight of 119,200 pounds injected at treating rates of 45 to 60 BPM. Consequently, the Maralex fracture completions were accomplished at significantly higher rates and higher volumes with fracture fluids of

greater viscosity. By comparison, the Pendragon fracture treatments were accomplished at relatively low rates and low volumes.

(53) The evidence established that data derived from Nolte Plots are an effective and reliable means for determining vertical height growth and extension of formation fractures.

(54) The Nolte Plots for the Subject Pictured Cliffs wells showed a slight incline in pressure over the time of the treatment, indicating restricted height growth and lateral extensions of the fractures.

(55) The data derived from Nolte Plots for the Maralex fracture completions on the Subject Coal wells show negative slopes, indicating unrestricted, vertical growth and in one case, "run-away" vertical fractures.

(56) The evidence further established that coal is an effective barrier to fracture growth because it is more elastic than the surrounding sandstones. The cleat systems within the coal body also allow for the pressure at the fracture tip to become diffuse, negating the ability of the tip and fluids to fracture into the coal itself.

(57) The evidence established that the fracture treatments for the Subject Pictured Cliffs wells were designed specifically to utilize the thin coal and shale stringers as effective barriers to maintain containment of the fracture. The effective use of shale and coal sequences as fracture containment barriers was adequately demonstrated by the fracture profiles made available from the Eureka 33-32 well and the Don 44-7 well in the Raton Basin. The use of shale barriers as a reliable means to contain fracture growth was also demonstrated by the fracture profile on the Dome Federal 17 well completed in the WAW Pictured Cliffs formation in Section 17, T-27-N, R-13-W. Moreover, the fracture containment in the Pictured Cliffs sandstone in the Dome Federal 17 well was verified by a tracer survey.

(58) While Nolte Plots are regarded in the industry as a reliable means of determining fracture containment, the testimony and professional engineering literature evidence established that the use of fracture simulators such as "Frac-Pro" regularly exaggerate the height of actual fracture growth, thus making them a less reliable means for determining whether fractures remained contained within zone.

(59) The evidence and data presented were sufficient to support the conclusion that the fracture treatment jobs on the Pendragon Pictured Cliffs wells did not escape out of zone and remained contained within the Pictured Cliffs formation. The evidence available on the date of the hearing was insufficient to allow for a determination whether the significantly heavier fracture treatments on the Whiting/Maralex coal wells actually penetrated into the Pictured Cliffs formation. However, the evidence supports the conclusion that it is more likely than not that the Maralex frac jobs escaped out of the basal coal.

(60) The Applicants presented testimony through their contract pumper/operator that the locations of the perforations in the Subject Pictured Cliffs wells were accurately reported in the Upper Pictured Cliffs sand and that there are no perforations in the coal.

(61) The pumper/operator also testified that the Chaco wells were not producing significant volumes of water following the fracture treatments and what water was being produced is typical of the hundreds of other Pictured Cliffs wells with which the witness has had experience operating. The pumper/operator witness further testified that Fruitland Coal wells that have completed the de-watering process typically produce from between 20 to 30 barrels of water per day on pump while the Subject Pictured Cliffs wells have produced without pumps. The witness further testified that the installation of the equipment necessary to measure the small volumes of water being produced from the Subject Pictured Cliffs wells could not be economically justified. The witness further established that it was not possible to compare produced water rates before and after the fracture treatments on the Subject Pictured Cliffs wells for the reason that they had previously been equipped with one inch tubing, making it difficult to produce any liquids at all.

The Applicants presented reservoir engineering testimony establishing that:

(62) Pressure versus time data for the Subject Pictured Cliffs wells and Fruitland Coal wells established that the pressures in the Chaco wells have been historically stable and that there is no evidence of any equalization with pressures in the Fruitland Coal wells. In addition, pressures measured on the Chaco 2J which had not been frac'd showed no evidence of any pressure changes attributable to fracture completions on the nearby Fruitland Coal wells.

(63) The pressure data for both formations established that the Pictured Cliffs wells had lower pressure than the Fruitland Coal formation in early 1995, both prior to and after the stimulation treatments.

(64) The pressure data also established that the Pictured Cliffs formation has experienced some recharge and that the probable source of the recharge is the lower Pictured Cliffs sandstone, possibly supported in-part by a natural water drive mechanism.

(65) Log analyses on the Subject Pictured Cliffs wells established porosities in the perforated zones, generally, at 24.30 percent, with a 40.53 percent water saturation and a 11.31 percent clay content. In the lower zone of the Pictured Cliffs, porosities were determined to be, 20.15 percent, with water saturation approximately 78.37 percent with 18.80 percent clay content. These analyses indicate good porosity development with relatively low water saturation and clay content in the perforated zones, while the lower zones have good porosity but higher water saturation and clay content. However, the lower zones also have mobil gas saturations, acting as the possible re-charge source for the higher zone.

(66) Volumetric reserve estimates based on the log analyses establish that there are sufficient gas resources available in the Pictured Cliffs formation to correspond with the production experienced in the Subject Chaco wells.

(67) The Applicants presented historic gas production data and decline curve analyses for the Subject Pictured Cliffs wells that further substantiate the existence of sufficient in-place gas reserves to correspond with the performance of the Chaco wells. The Pictured Cliffs wells' cumulative production and estimated ultimate gas recoveries are supported by the volumetric analysis and establish the larger drainage area for the wells.

(68) The Applicants also presented material balance analyses establishing that Pictured Cliffs reserves reasonably equate to those reserves determined from the volumetric analysis.

(69) The gas content and pressure data derived from information provided by Whiting and Maralex established a basis for determining Fruitland Coal gas reserves from the Subject Coal wells. Pendragon's reserve estimates for the Fruitland Coal reservoir, based on volumetric calculations, yields reserves consistent with the cumulative production data provided by Whiting and Maralex. The evidence also established that the Subject Coal wells have produced substantially more gas than the other coal gas wells, indicating no loss of reserves from the Subject Coal Gas wells.

(70) The material balance analyses indicate that the Subject Fruitland Coal wells are draining a very large area and do not indicate any loss of reserves to the Subject Pictured Cliffs wells.

(71) The Applicants presented evidence comparing the production performance of the Subject Fruitland Coal wells with six other Whiting/Maralex Fruitland Coal wells in the general area but outside the lands described in the application. Such evidence established that the Subject Coal wells are producing at rates far exceeding the performance of the six non-Subject Fruitland Coal wells operated by Maralex, as well as the normalized production from all other Fruitland Coal wells in the area.

(72) Evidence of comparative water production from the Fruitland Coal wells and the Subject Pictured Cliffs wells presented by the Applicants established that the water production rates for the Fruitland Coal wells is typical. Moreover, the production of only minimal volumes of water by the Subject Pictured Cliffs wells indicated the absence of any communication between the Fruitland Coal formation and the Subject pictured Cliffs wells.

(73) The reservoir engineering evidence presented by Applicants establishes there is no physical evidence that the Subject Pictured Cliffs wells communicated with the Fruitland Coal formation following the fracture and acid stimulation treatments on the Chaco wells in 1995. It is established that the Subject Fruitland Coal wells have

experienced no interference from the production or operation of the Subject Pictured Cliffs wells.

(74) The reservoir engineering evidence presented by the Applicants establishes that the Pendragon Pictured Cliffs wells are producing from their own common source of supply and, further, that Fruitland Coal Bed methane reserves are not being produced from the Subject Pictured Cliffs wells.

(75) The Applicants' reservoir engineering testimony established that there is a substantial likelihood that the Chaco No. 1, Chaco No. 4, Chaco No. 5 and Chaco No.2-R wells, which were ordered shut-in at the request of Whiting and Maralex, will incur damage from water imbibing back into the surrounding reservoir as a result of the shut-in.

The Division, after consideration of the geologic and engineering evidence in testimony presented by all parties in this case, FINDS;

(76) The Basin-Fruitland Coal Gas Pool and the WAW Fruitland-Pictured Cliffs Pool have previously been declared to be separate common sources of supply by orders No. R-8768, as amended, and R-8769, as amended, respectively and are a separate common source of supply within the meaning of Section 70-2-33 of the Oil and Gas Act.

(77) The Subject Chaco wells are completed and perforated in and are producing from the Pictured Cliffs formation sandstone within the vertical limits of the WAW Fruitland-Pictured Cliffs Pool.

(78) The Subject Coal Gas wells operated by Maralex Resources, Inc. were drilled to and completed in the basal coal body of the Fruitland formation contained within the vertical limits of the Basin-Fruitland Coal Gas Pool.

(79) Consistent with the finding in paragraph 76, above, that the Subject Pictured Cliffs wells and Subject Coal Gas wells are completed in separate common sources of supply, the production from and the operations in one pool do not result in the impairment of correlative rights in the other. The upper sets of perforations found in each of the Subject Pictured Cliffs wells are located in and are producing gas from the Upper Pictured Cliffs bench of the Pictured Cliffs formation rather than from a Fruitland sandstone.

(80) That sandstone interval identified by the geologic exhibits and geologic literature as the Upper Pictured Cliffs sandstone is recognized to be a part of the marine Pictured Cliffs sandstone formation.

(81) The acidization and fracture stimulation treatments performed on the Applicants Subject Pictured Cliffs wells did not cause the Pictured Cliffs formation to become communicated or result in any interference with production from the Fruitland Coal formation.

(82) Applicants have the right to apply such stimulation treatments and operating procedures on the Subject Pictured Cliffs wells as they may determine are reasonable, prudent and necessary.

(83) The fracture stimulation treatments performed in 1995 on the Subject Chaco No. 1, Chaco No. 4, Chaco No. 5 and Chaco No. 2R as well as the acidization jobs Chaco No. 4, Chaco No. 1J and Chaco No. 2J resulted in the increased production of gas from the Pictured Cliffs formation. The fracture treatment and acidization jobs were reasonable, prudent and necessary to recover additional Pictured Cliffs gas reserves that otherwise would have remained unrecovered.

(84) Whiting and Maralex failed to demonstrate that the fracture treatments performed on the Subject Coal wells in 1993 remained contained within the basal coal of the Fruitland formation. Rather, the evidence established that it is more likely than not that the Maralex frac jobs escaped out of the basal coal. However, evidence available on the date of the hearing was insufficient to allow for a determination whether the heavier fracture treatments on the Whiting/Maralex Coal wells penetrated into the Pictured Cliffs formation.

(85) None of the perforations in the Subject Chaco wells were located in the Fruitland formation or any coal interval therein.

IT IS THEREFORE ORDERED THAT:

1. The Division determines that each of the Applicants' six Subject Chaco wells are completed in and producing from the appropriate common source of supply, the Pictured Cliffs formation.

2. The Applicants shall be allowed to continue to produce through all of the perforated intervals in the Subject Pictured Cliffs wells.

3. Whiting Petroleum Corporation as operator of the Subject Fruitland Coal Gas wells should be required to submit additional data and otherwise show proof to the satisfaction of the Division that the Subject Coal Gas wells will be and are currently producing from the appropriate common source of supply pursuant to Rule 3 of the Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool.

4. Whiting Petroleum Corporation should also be required to submit data and take such additional measures as required by the Division to assure the segregation of production from separate sources of supply in conformance with Rule 19 NMAC 15.E. 303.A of the Division's Rules.

5. Whiting Petroleum Corporation as operator of the Subject Fruitland Coal Gas wells, should also be required to submit such data to demonstrate to the satisfaction of the Division that the continued operation of and production from its wells do not result in the interference with production from the Subject Pictured Cliffs wells.

6. Jurisdiction of this cause is retained for the entry of such further Orders as the Division may deem necessary.

DONE at Santa Fe, New Mexico, on the day and year hereinafter designated.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION

____
Lori Wrotenbery, Director

STATE OF NEW MEXICO
ENERGY MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC., PENDRAGON RESOURCES, L.P., AND J.K EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

CASE NO. 11996

WHITING'S MEMORANDUM IN LIEU OF CLOSING STATEMENT

Whiting Petroleum Corporation and Maralex Resources, Inc. (collectively "Whiting"), submit this Memorandum in lieu of a closing statement. This pleading will discuss the evidence that was presented at the hearing in this matter on July 28-30, 1998, and summarize the numerous evidentiary bases upon which the Division should deny and dismiss the application filed by Pendragon Energy Partners, Inc., and J.R. Edwards & Associates, Inc. (collectively "Pendragon"). This Memorandum is submitted simultaneously with Whiting's proposed Order of the Division.

I.

INTRODUCTION

This case arises out of a rework program initiated in 1994-1995 by Pendragon with respect to several old wells in T-26-N, R12 and 13W, San Juan County. The specific wells at issue in this Application are the Chaco wells Nos. 1,1J, 2J, 2R, 4 & 5 ("Chaco wells"). It is undisputed that Pendragon owns interests in the lease at issue "Limited from the base of the Fruitland formation to the base of the Pictured Cliffs formation" ("PC") (emphasis added). Whiting owns interests in the leases from the surface of the earth to the base of the Fruitland formation. The conveyances to Pendragon expressly do not mention a sandstone formation in the coal formations.

Shortly after Pendragon initiated its 1995 restimulation program, Whiting noticed that the Chaco wells were producing volumes of gas extraordinarily greater than one could expect from a restimulated well in the depleted Pictured Cliffs sandstone reservoir. In addition, pressure readings indicated that the pressures on the Chaco wells were higher than one could expect given the production history of the PC, and were approximating pressure levels and slopes which Whiting had documented in its coal seam wells. Whiting observed significant water production from the Chaco wells into unlined pits. This raised suspicion of coal seam gas production. Whiting approached Pendragon to see if the parties could resolve their differences informally. Informal attempts at resolution did not work.

Whiting initially filed an Application with the Division in January, 1998, (since dismissed) seeking a determination that the Pendragon Chaco wells were producing from the Basin-Fruitland Coal Gas Pool, ordering the wells to be shut-in, and seeking an allocation for past production from the Chaco wells. District personnel in Aztec urged informal settlement meetings instead of proceeding to formal hearing, but months slipped by while the Chaco wells continued production. Whiting realized their losses were growing and that trespass and conversion of gas were ongoing and would not be remedied in an administrative proceeding. Whiting filed suit on May 26, 1998 against Pendragon in Santa Fe County District Court, Cause No. SF-CV-98-01295 seeking damages and injunctive relief. A preliminary injunction hearing was held on June 29, 1998, and the district court ordered Chaco wells Nos. 1, 2R, 4 and 5 shut-in. Prior to the preliminary injunction hearing, Pendragon sought sanctuary with the Division by filing this application. The district court, while granting the preliminary injunction, nevertheless decided to defer to the Division on matters presented by Pendragon's Application which were peculiarly within the Division's expertise. (Whiting Exhibit 5).

Pendragon applies for an Order that its Chaco wells are producing from the appropriate common source of supply, i.e., the PC formation. Fundamental legal principles provide that Pendragon, as the party alleging the affirmative, has the burden of proof. Bank of Santa Fe v. Petty, 116 N.M. 261, 264, 867 P.2d 431 (Ct. App. 1993); Carter v. Burn Construction Co., 85 N.M. 27, 32, 508 P.2d 1324 (Ct. App. 1973); Imperial American Resources Fund v. Railroad Commission of Texas, (Tex. 1997) 557 S.W.2d 280, 286 ("the applicants [must] discharge their burden of proof that the exceptions are necessary to prevent waste or confiscation of property.") Pendragon has to prove that all the Chaco wells' production is from the Pictured Cliffs. There is no burden on Whiting to prove otherwise, though it has absolutely done so.

The evidence presented to the Division at the hearing overwhelmingly established that: (a) Pendragon's 1995 rework program targeted the Fruitland coal formation and coincided with the dewatering of the Whiting wells, which had by then reached economic levels of gas production; (b) Pendragon acidized and fracture stimulated its Chaco wells Nos. 1, 1J, 2R, 4 and 5 in 1995 in such a manner as to cause communication with Whiting's coal seam gas reserves in the Fruitland formation; (c) Pendragon produces from perforations in its Chaco wells Nos. 1, 2J, 4 and 5 in a Fruitland sandstone formation within the Fruitland formation owned by Whiting; (d) Pendragon has been a rogue operator filing false reports with the Division and generally operating its wells, including the Chaco wells, in violation of the Division's Rules and Regulation.

The Division can deny Pendragon's Application and dismiss it in its entirety leaving the parties to resolve their dispute in the pending litigation in Santa Fe County District Court. If the Division rules on the merits, it should find that Pendragon has, from 1995 until June 29, 1998, produced Fruitland Sandstone and Fruitland coal seam gas belonging to Whiting from its Chaco wells Nos. 1, 2R, 4 and 5. The Chaco wells must be plugged and abandoned to prevent further trespass and conversion by Pendragon.

II.

DIVISION HISTORY AND STANDARDS FOR ANALYSIS

The issues here do not come before the Division in a vacuum. When the Division entered Order R-8768 in 1988 in Case No. 9420, it had the benefit of testimony from industry experts and advice of the special Coalbed Methane Committee on several issues which impact this Application. That Order established the Basin- Fruitland Coal Gas Pool in the Fruitland formation. Testimony was presented by Frank Chavez, the current director Division's Aztec office, that "it is not uncommon for a hydraulic fracture initiated in the Fruitland Sand or Pictured Cliff Sandstone, to break through the shale into a coal." TR. 105.[1] Kevin McCord, who testified on behalf of several independent operators who were seeking 160-acre spacing for coal wells in some areas of the Basin, testified that when operators drill and complete and stimulate Pictured Cliff formations, "for the most part they are fraccing up into the coals." TR. 161. Similar testimony was received from Rob Willis of Hixon Development Company. TR. 182. Thus, the issue of

[1] The transcript references "Tr. ___" are to the transcript of the hearing held on July 8, 1988 before Examiner David Catanach, Whiting Exhibit No. 7 in this proceeding.

Fruitland Sand or PC stimulations growing into and communicating with coal seams in the Basin was recognized and a matter of general industry knowledge in 1988.[2]

In order to address this situation, the Division adopted Special Rule 3 in Order No. R-8768. That rule authorizes the Director to place the burden on an operator of a proposed or existing Pictured Cliffs Sandstone well, here Pendragon, to submit certain data in order to demonstrate to the satisfaction of the Division that the well will be or is currently producing from the appropriate common source of supply. Rule 3 imposes upon the operator, here Pendragon, the burden of proof to demonstrate that its wells are producing only from the appropriate common source of supply. The Division also adopted Rule 2 which specifies the types of data to be used in the analysis, viz:

a. Electric Log Data
b. Drilling Time
c. Drill Cuttings or Log Cores
d. Mud Logs
e. Completion Data
f. Gas Analysis
g. Water Analysis
h. Reservoir Performance
i. Other evidence which may be utilized in making such determination

III.

ANALYSIS OF EVIDENCE AND DATA PRESENTED AT THE HEARING WHICH CONFIRMS THAT PENDRAGON IS PRODUCING COAL SEAM GAS FROM ITS CHACO WELLS

Pendragon's showing in support of its Application at the hearing in this matter was woefully inadequate, and utterly failed to support the relief requested. Pendragon's "evidence" was more notable for what it did not reveal. Production volumes, shut-in pressures, reservoir performance and gas analysis data on the Chaco wells did not emerge until Whiting's evidence was presented. Moreover, Pendragon failed to perform

[2] Paul Thompson, Pendragon's contract operator who designed and supervised the hydraulic fractures in

tracer surveys or temperature surveys which could have been run at the time the wells were being reworked. Knowing the likelihood of fracture growth into the coal, an operator who genuinely wanted to avoid such trespass would do so.[3] Pendragon failed to submit any studies or analyses which support its contention that the Pictured Cliffs formation in 1995 contained substantial volumes of reserves which had been untapped during primary development. While Pendragon raised the spectre of skin damage as an explanation for the poor performance of the Chaco wells prior to restimulation in 1995, it failed to present any evidence that would support a finding of skin damage. The Division cannot make a finding except where supported by substantial evidence. Continental Oil Co. v. Oil Conservation Commission, 70 N.M. 310, 320, 373 P.2d 809 (1962).

Having the burden of proof in addressing any type of data specified in Rule 2 of the Special Rules for the Basin-Fruitland Coal Gas Pool, Pendragon took the position that the evidence was "inconclusive." Its field representative, Paul Thompson, knew full well the likelihood that stimulation of the PC would penetrate the coal formations. Pendragon, having failed to perform recognized tests to confirm whether its fracs stayed in zone or not, cannot meet its burden under Rule 3 by arguing that evidence about the data specified by the Rule is only inconclusive. It was Pendragon's affirmative burden to show that its wells are producing from the appropriate common source of supply. Nevertheless, Whiting did demonstrate that the evidence is not inconclusive, but rather points inexorably to the conclusion that the Chaco wells have since 1995 produced coal

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issue here, was involved in those 1988 proceedings as a member of the Coalbed Methane Committee.

[3] In fact, the applicants fracture specialist (and part owner) recommended such tests but was out-voted by the other owners because "they were poor-boying it." A temperature survey costs about $1,000, and a radioactive tracer survey about $2,500.

seam gas in violation of Whiting's property rights, and the Division's rules and regulations.

A. Pre-stimulation Reservoir Performance Demonstrated that the Pictured Cliffs Formation was a Relatively Depleted Reservoir

The Chaco wells had produced for some fifteen years before being acquired by Edwards. They were shallow, inexpensive slim hole completions. The wells performed as one would expect of the Pictured Cliffs sandstone formation. Each of the Chaco wells had moderate initial production rates, with the Chaco 4 and 5 wells exhibiting the highest initial rates around 200 MCF per day. They then exhibited a classic pressure and volume decline. Whiting Exhibits 17-22. By the mid-1980s, all of the Chaco wells were producing nothing or a maximum of 5 to 10 MCF of gas per day. Pressures in the wells, which were originally in the range of 200 to 250 psi, had declined by the mid-1980s to between 90 and 150 psi. Deliverability tests were discontinued in about 1984.

Merrion, et al., had offered Maralex the Pictured Cliffs rights in the Chaco wells and interests in various other Pictured Cliffs wells back in 1992. Maralex analyzed the properties and determined that the Pictured Cliffs formation was depleted, and that the wells were not economic. A copy of the summary of that analysis is being presented to the Division along with this Memorandum. In short, prior to the stimulation work performed by Pendragon in 1995, there was no evidence that the Pictured Cliffs formation in these wells contained economic, untapped reserves, or that there was any significant repressurization in the reservoir.

Pendragon would have the Division believe that the lower, water sautéed PC zones contain untapped reserves, even though no operator in the area, including Pendragon, perforates its PC wells in those lower zones. Obviously, the location by an operator of perfs in a well is the best indicator of where the operator believes economically recoverable reserves exist. Moreover, the "larger-drainage-area theory" advanced by Pendragon completely misses the mark. Spacing in this particular area is still on 160 acres with many wells still productive. The drainage theory totally ignores Darcy's radial flow equation. As the source of the gas is farther from the wellbore, it is physically impossible to get the flow rates seen by the Chaco wells from PC production alone.

Pendragon offered no pre-stimulation studies or projections which any engineer had performed to support the pursuit of allegedly untapped reserves in the PC formation. In other words, only after the prolific coal gas production was flowing and Whiting discovered the trespass has Pendragon developed theories that the gas somehow comes from the PC.

The most reasonable inference from the evidence is that the Lansdale Federal No. 1 was the Pendragon guinea pig. Pendragon justified investment in the Chaco well restimulations on the work that it had performed in December, 1994 when it intentionally completed the Fruitland coal formation in its Lansdale Federal No. 1 well, failed to report the well as a coal well in notices filed with the Division, failed to document water production from the well, but began producing coal seam gas from what it falsely reported as a "Pictured Cliffs well."

B. <u>Production Volumes and Pressure Readings from the Chaco Wells Since Restimulation Confirmed the Production of Coal Seam Gas</u>

Following the Pendragon fracture stimulations and acidizations which began in January, 1995, the Chaco wells show gas production levels which exceeded production levels experienced when the wells were first drilled under virgin reservoir conditions. Whiting Exhibits 17-22.

Pressures rose in the Chaco wells following either acidization or fracture stimulation to levels resembling pressures in the Fruitland coal formation. The Chaco 4 well reflected a 97 psi WHSIP on a C-122A in July 1983; the rig report when acidization was to be done in January 1995 read 119 psi. In twelve years the reservoir had "repressured" 22 psi. Two weeks following Pendragon's acidization of the Chaco 4 the rig reported pressure of 170 psi – a 51 psi increase in two weeks! The only scientific conclusion to be drawn from the data is that the acidization caused communication between the Pictured Cliffs formation and the higher pressured and relatively untapped Fruitland coal formation. The Chaco 5 well, relied upon by Pendragon as having pressure increases prior to stimulation, had a casing leak that was discovered in February, 1995, prior to the stimulation. Communication with the coal was already established.

Pendragon offered several pitiful explanations that the post-stimulation production volumes and pressure readings could be explained by the Pictured Cliffs formation itself. First, Pendragon claimed that all of the Chaco wells suffered from skin damage which was remedied by the acidizations and fracture stimulations. No evidence of skin damage was presented. Wells with such damage reflect relatively high shut-in pressures with very low gas production. To the contrary, the Chaco wells experienced normal declines in both pressure and gas output. The well files do not reference skin damage. No tests were run on the Chaco wells prior to the restimulations to confirm any alleged skin damage. In short, Pendragon asks the Division to just accept, without any concrete evidence, its notion that all of the Chaco wells suffered from undocumented skin damage.

Moreover, even if the wells had suffered skin damage, resolving skin damage would not explain the monumental production and pressure increases experienced after the restimulations. No evidence was presented by Pendragon, because none exists, which would support the theory that resolving a skin damage problem in a well would result in production increases 300 to 400 fold and which exceed original production levels under virgin reservoir conditions.

The clinching evidence was gathered since the Chaco wells were shut-in in June 30th of this year demonstrating the communication between the PC and the coal seam formations in this area. Whiting Exhibit 31 proves the Chaco wells pressure readings have fluctuated markedly since the wells were shut-in. That cannot occur if the Chaco wells were not in communication with the coal. The Chaco wells should have exhibited basically a flat line of pressure after reaching their static pressure following shut-in, with perhaps a very slight rise as pressure builds. However, the fluctuations in the Chaco well pressure readings have coincided with up-turns in production in the Whiting coal seam wells, as well as periods when the coal seam wells have been shut-in due to pipeline and plant constraints. The fact that the Chaco well pressure readings would so fluctuate since shut-in is conclusive evidence of communication.

C. Evidence Regarding Pendragon's Restimulations Program Confirms the Coal Seam Gas as Target

Evidence presented by Whiting at the hearing demonstrated that Pendragon knew exactly what it was doing in its redevelopment program on the Chaco wells, and that Pendragon had intentionally targeted the coal seam gas formations in the area. In December, 1994, as demonstrated by Walsh Engineering Production and Workover and Completion Report for the Lansdale Federal No. 1 well, Whiting Exhibit 41, Pendragon expressly planned to and did perforate that well in the Fruitland coal formation and treat the well with acid on December 20, 1994. Pendragon then lied in notices filed with the Division, mischaracterizing the well as a Pictured Cliffs well, notwithstanding the perfs in the Fruitland coal formation. While Paul Thompson attempted to mischaracterize the work on the Lansdale Federal No. 1 well as an "oops" and a "mistake," the documents demonstrate that Pendragon planned to and did complete in the coal. Pendragon then produced from the coal some 3 ½ years, failing to report water production and failing to disclose to the NMOCD that the well was perfed in the Fruitland coal formation. The reason is obvious: Pendragon could not legally operate the well as a coal seam well, since it only had 160 acres to dedicate to the well. Pendragon supposedly squeezed off the perfs in the Lansdale Federal No. 1 well in the coal formation, but only in the week prior to this hearing. Whether that was actually done has yet to be confirmed by any official filing.

Even if Pendragon had ownership rights in the sandstone formation within the coal, which is obviously disputed, there is no justification to fracture treat in that area when it could have been isolated by a bridge plug. The only logical explanation for fracture stimulating through those perfs in the Fruitland sandstone formation is because those fracture stimulations were sure to migrate vertically a couple of feet in order to reach the main coal formation in the area. Indeed, if there were any credence to Pendragon's theory about the untapped reserves in the lower PC formation, then Pendragon would have shot new perforations below existing perfs in the Pictured Cliffs formation and fractured that portion of the formation, not in the sandstone layer between the coals.

D. **Water and Gas Analysis from the Chaco Wells Since Stimulation Confirms the Production of Coal Seam Gas**

Ironically, Pendragon relies on its own malfeasance as evidence in its favor. Some of the spin Pendragon put on the evidence in this case has been to cite the supposed lack of water production from its Chaco wells as evidence that the wells were not in communication with the coal formations. Prior to July 27, 1998, one day before the hearing, Whiting had no documentary evidence from Pendragon's files regarding water production. On July 27, by order of the Division counsel, Pendragon finally coughed up documents demonstrating water production from the Chaco wells in sufficient volumes to require transport.

The Pendragon documents showed substantial water production from the Chaco wells. Indeed, for a period in March, 1998, records demonstrated that Pendragon was hauling 80 barrels of water away from its Chaco 1 well site every two or three days. Given that the water was being dumped into unlined earthen pits, substantially larger volumes of water must have been produced by the Chaco wells during that period. Contrary to the requirements of Rule 3, Pendragon purposely did not keep the water data. Pendragon has not produced all water-related documents.

More importantly, the evidence demonstrates that the Pendragon Chaco wells had been producing significant volumes of water since the restimulations in 1995. Mickey O'Hare, the president of Maralex, testified that he observed substantial water production from the Chaco wells into the unlined earthen pits as early as 1995. Pictures submitted by Whiting at the hearing, Whiting Exhibit 46, demonstrate that the unlined pits have, in various times in their existence, been completely full. Pendragon magically began reporting water production from the Chaco wells in March, 1998 following a site visit by Ernie Busch of the Division's Aztec office in connection with the informal talks being held by the parties.[4] Pendragon offered no explanation, because there is no valid scientific or engineering explanation, to account for the Chaco wells producing no water for three years, then mysteriously producing large volumes of water in 1998.

Pendragon officials admitted at the hearing that they had not reported volumes of water beginning in 1995 following the Chaco well restimulations.[5] They claimed at the hearing the reason for the failure to report was (1) low volumes and (2) problems with accurately measuring water given the unlined pits into which water was disposed. The fact of the matter is Pendragon has destroyed evidence both by depositing produced water into an unlined pit, where much of that water was absorbed into the soil and evaporated, and by failing to report water production from the Chaco wells until it realized that the Aztec office staff had visual confirmation of water production.

Under the theory of spoliation of evidence, all inferences regarding water production from the Chaco wells must be decided against Pendragon and in favor of Whiting in this proceeding. Coleman v. Eddy Potash, Inc., 120 N.M. 645, 905 P.2d 185 (1995) (recognizing tort of intentional spoliation or destruction of evidence); Aranburu v. The Boeing Co., 112 F.3d 1398, 1407 (10th Cir. 1997) (bad faith destruction of document relevant to proof of issue generally gives rise to inference that evidence would be unfavorable to party responsible for destruction); Miller v. Montgomery County, 494 A.2d 761, 768 (Md. Ct. Spec. App. 1985) (the appropriate remedy for spoliation of evidence by party is evidentiary presumption that evidence is unfavorable).

[4] There is no evidence in any of the Division's files that the Division's Aztec office has taken any corrective action against Pendragon with respect to either the use of unlined pits for water disposal or the failure of Pendragon to report water production from the Chaco wells.

[5] For instance, Pendragon's C-115 reports for March, 1998 show that the Chaco 1 produced no water. See copy attached. However, records produced the day before the hearing show that 640 barrels of water were hauled from the Chaco 1 from March 12 through March 31. Whiting Exhibit 57, copy attached.

Gas analyses from gas produced by the Chaco wells also confirm that those wells are producing coal seam gas. As Whiting Exhibits 28 and 29 demonstrate, prior to the development of coal seam reserves in this area in 1992-94, gas from the Chaco wells had typically exhibited BTU readings consistent with Pictured Cliffs gas, around 1050 to 1100 BTU. However, following the coal seam development and Pendragon's restimulations in 1995, gas analyses showed that the gas from the Chaco wells was beginning to approach gas from the Whiting coal wells in BTU content. Pendragon offered no explanation for this anomaly except to argue that the gas analysis was "inconclusive."

E. <u>The Fracture Stimulation Treatments of the Chaco Wells Caused Communication with the Coals</u>

Whiting introduced evidence through Brad Robinson, an independent consultant petroleum engineer with S.A. Holditch and Associates, which demonstrated that Pendragon's fracture simulations of the Chaco wells 1, 2R, 4 and 5 clearly migrated vertically out of the PC formation through the upper Fruitland coal formation. Unlike Pendragon's fracture "expert," Mr. Robinson has no financial interest in this matter. He used a FracPro Simulator to illustrate fractures out of zone on the Chaco wells. The FracPro Simulator is widely used and accepted in the industry as modeler of fracture behavior. Use of a simulator was necessary in this case because Pendragon did not perform temperature surveys or tracer surveys when the wells were fracced, even though such tests would have provided evidence as to whether the fracture stimulations were or were not within the Pictured Cliffs zone. Supposedly, the failure to perform such tests was contrary to the recommendation of Pendragon's engineer Roland Blauer. As in the case of water data, Pendragon has intentionally avoided collection of evidence that could bear strongly on resolving the Fruitland coal vs. Pictured Cliffs sandstone issue. Pendragon was fully aware of the split-ownership problem when it restimulated the Chaco wells.

Mr. Robinson gave conclusive evidence that the Chaco wells 1, 4 and 5 communicated with the coal formation because there was no natural stress barrier that would have prevented vertical migration of the fractures in those wells. In response, Pendragon again offered theories on this issue from its part owner, Roland Blauer. First, Pendragon claimed that Nolte plots on the Chaco wells demonstrated that the fractures had stayed in zone and had migrated only horizontally. The obvious problem with this testimony is that fractures simply do not behave this way in the real world. Moreover, as Mr. Robinson testified, the Nolte plots were wrong and miscalculated as demonstrated by the precipitous pressure drop at the end of pumping. These pressure drops indicate an error in the test formula. Corrected Notle plots are being provided by Whiting.

Next, Mr. Blauer testified that the coal formation itself would act as a natural barrier to any vertical fracture migration (the windshield analogy). This is pure baloney. It is has been accepted and known by the industry as of 1988 that fracture stimulations in the PC formation communicate with the coal formations. The coal formations have a natural fracture pattern ("cleating") that readily receives and opens to high pressure hydraulic injection.

IV.

LOG DATA AND GEOLOGIC EVIDENCE CONFIRMS THE BOUNDARY BETWEEN THE FRUITLAND FORMATION AND THE PICTURED CLIFFS FORMATION AT THE TOP OF THE MASSIVE SANDSTONE

In 1988 when the Division created the Basin-Fruitland Coal Gas Pool, it recognized the Amoco Production Company Schneider Gas Com "B" Well No. 1 as the marker well for the pool. Order R-8768 found that the coal gas pool was comprised of "all coal seams" (emphasis added) within the vertical limits of the stratagraphic interval in the Schneider well from a depth of approximately 2450 feet to 2880 feet as shown on the well's Grama Ray/Bulk Density log. That log demonstrates two coal gas seams, one thick seam separated by a small sandstone interval, and a low coal stringer resting on top of a massive sandstone formation. Since 1988, the boundary between the Fruitland formation and the Pictured Cliffs formation in the Schneider well has been identified at the top of the massive sandstone underlying the smaller continuous coal stringer.

Whiting introduced evidence at the hearing based upon log data from the Chaco wells and Whiting's coal seam wells in the area in question that demonstrated a remarkable similarity with the lithology of the Schneider well. Whiting's Exhibit 16 shows a thick coal which is continuous in the area, designated on the Exhibit as the B Coal. Whiting's Exhibit 16 also demonstrates a continuous coal stringer, designated by Whiting as the basal coal, which underlies the B Coal and sits above the massive Pictured Cliffs sandstone Unit 1. Between the Basal and B Coal stingers is a small sandstone layer, similar to the sandstone layer which lies between the two coal stringers in the Schneider B location.

Since 1971, authorities who have no financial interest in this dispute have picked the boundary between the Fruitland formation and the Pictured Cliffs sandstone formation "at the top of the massive sandstone below the lower most coal of the Fruitland except in those areas where the Fruitland and the Pictured Cliffs intertongue." Pendragon Exhibit N-5. An identical pick was made in the 1988 hearing. Tr. 39. In reopened Case No. 9420 before Examiner Catanach in February, 1991, experts uniformly recognized the existence of a lower basal coal stringer above the massive Pictured Cliffs sandstone. Whiting Exhibit 6. Whiting's witness, Walter Ayers, is the dean of San Juan Basin geologists. Dr. Ayers testified the use of the massive sandstone as the boundary marker for the two formations is geologically correct, and also offers a means to avoid the need to redefine the boundary in every well in the area, since there is a consistent, marine deposition Pictured Cliffs massive sandstone. See Whiting Exhibit 16. Dr. Ayers is an independent consultant with no financial interest in the dispute who has studied coal and sandstone deposition in the San Juan Basin for many years, and has published two dozen articles on the subject prior to this dispute.

It is undisputed that Pendragon stimulated and produces from perforations in the Chaco wells Nos. 1, 2J, 4 and 5 in the sandstone formation which lies between the two coal seams. These perfs are in a sandstone formation which is above the top of the massive sandstone formation. No witness characterized the Fruitland sandstone interval at issue here as massive. Dr. Ayers established that this sandstone interval is not marine in deposition, but rather is a coastal plain, non-marine deposition. Pendragon's geologist is its president. He conceded that if the sandstone interval was not a marine deposition, it could not be a Pictured Cliffs sandstone.

When the formation ownership was common in the 1980s there was no problem. But Pendragon acquired only ownership "Limited from the base of the Fruitland coal formation. . ." Since it is undisputed that Pendragon's Chaco wells had produced from the upper perfs in the sandstone interval at issue, and given that that sandstone interval lies above the base of the Fruitland formation, it is undisputed that Pendragon has produced gas from the Fruitland formation since 1995 from its Chaco wells.

Pendragon's president-geologist contends, without offering any supporting core data or sand analysis, that the sandstone interval between the B Coal and the Basal Coal was a marine deposition. This contention is unsupported by evidence from any other source or literature. Mr. Nicol also admitted that he coined the phrase "Upper Pictured Cliffs Sand," which he used to designate this Fruitland sandstone formation, in anticipation of this hearing, and that that designation found no support in the literature.

Whiting recognizes that many operators in the Basin have mischaracterized the Fruitland sandstone as a PC sandstone in notice filings which have been accepted by the Division without correction. Whiting also recognizes that there is considerable justification in this area for developing the coal on 160-acre spacing, which has lead to a de facto combining of the coal and the Pictured Cliffs in wells on that size drill block. This practice is based not on formal geologic study,[6] but rather on historical practice. When the wells in this region were initially drilled and perfed, there was typically common ownership from the surface to the base of the PC formation, and there were no pool rules specifying 320-acre drill blocks for the coal.

Today, however, where divided ownership occurs between the Fruitland formation and the PC formation in this area, it is essential to delineate the different producing formations based on sound geology. If there is a widespread problem that has been caused by administrative designations, that problem should be dealt with administratively in an above-board manner. Subterfuge and junk science is not the way to address a serious problem of correlative rights.

[6] A Dugan engineer, K. Fagrelius, in writing about the marker well for the subject area, the Dugan WAW No. 1 well, accurately picked the boundary between the Fruitland and the PC at the top of the massive sandstone below the lowermost continuous coal. Whiting Exhibit 47.

VII.

CONCLUSION

The only conclusion available based upon the technical and substantive evidence presented at the hearing in this matter is that the Chaco wells have been producing coal seam gas since the 1995 restimulations and until shut-in by order of the Santa Fe County District Court. As of the shut-in date, June 30, 1998, Pendragon had already produced through its Chaco wells volumes of gas which greatly exceeded not only recoverable reserves, but total gas in place for the wells in the PC formation. The only evidence presented regarding an allocation from these wells was presented by Whiting. It established that a conservative but fair allocation was 90% coal seam gas and 10% PC gas since the time of the 1995 reworks.

Since Pendragon has already produced more than its fair share of available reserves from the PC through the Chaco wells following restimulation, it would be unfair and violative of Whiting's correlative rights to allow Pendragon to continue to operate these wells. Every Mcf of coal gas that is produced through the Chaco wells deprives Whiting of not only its reserves and sales revenues, but valuable I.R.C. Section 29 tax credits as well. Allowing Pendragon to continue operating these wells would only serve as official sanction for trespass and conversion, in violation of the Division's mandate to protect correlative rights and prevent waste. Shutting in the Chaco wells will not cause waste, since the Pictured Cliffs gas has been produced and the coal seam gas reserves will ultimately be produced by Whiting through its coal seam gas wells.

Merely requiring Pendragon to plug and abandon the Chaco wells does not, however, address the evidence presented at the hearing that Pendragon has acted as a rogue operator in the San Juan Basin. Pendragon has been engaged for some years now in an ongoing and consistent practice of violating Division rules and regulations by (1) operating the Lansdale Federal No. 1 well as a PC well, fully knowing that the well was producing coal seam gas, (2) operating that well on a 160-acre proration unit in violation of Orders R-8768 and R-8768-A, and (3) failing to document, report and adequately dispose of volumes of water produced from the Chaco wells since the restimulations in 1995. The Division should issue an Order to Show Cause and require Pendragon to appear and show cause why the Division should not prohibit Pendragon from further serving as record operator of wells in New Mexico as a result of this ongoing pattern and practice of misconduct.

Respectfully submitted,

GALLEGOS LAW FIRM, P.C.

By ____________________
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CERTIFICATE OF SERVICE

I hereby certify that I have caused a true and correct copy of the foregoing to be mailed on this 13th day of August, 1998 to the following:

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____
MICHAEL J. CONDON

JUNCO TRUCKING COMPANY

TER & OILFIELD HEAVY HAULING

INVOICE

REMIT TO:
P.O. BOX 676779
DALLAS, TEXAS 75267-6779
(505) 327-0416

INVOICE NO. 27177

PENDRAGON PARTNERS
SUITE 750
621 17TH STREET
DENVER, CO 80293

ACCOUNT NO.	INVOICE DATE	PAGE
01422	03/31/98	1

RECEIVED
APR 14 1998
PENDRAGON ENERGY PARTNERS, INC.

JOB NO: 27177

CHACO 1

TO: ~~CHACO~~ Frontier A-1 1

DESCRIPTION	BBLS	DATE	FREIGHT BILL NO.	AMOUNT
NSFER PRODUCED WATER	80	3/12/98	80404	68.2
NSFER PRODUCED WATER	80	3/14/98	80407	68.2
NSFER PRODUCED WATER	80	3/15/98	80415	68.2
NSFER PRODUCED WATER	80	3/17/98	80426	68.2
NSFER PRODUCED WATER	80	3/21/98	80442	68.2
NSFER PRODUCED WATER	80	3/25/98	80470	68.2
NSFER PRODUCED WATER	80	3/28/98	80484	91.0
NSFER PRODUCED WATER	80	3/30/98	80494	68.2
5.625 % SALES TAX				32.0

MMARY: BBLS

UCKING W/TAX: 640 600.75 = .94 PER BBL
SPOSAL W/TAX: .00 = .00 PER BBL

TAL : 640 600.75 = .94 PER BBL.

OK NM 4/24/98

SW612
400203

st Charged at the Rate of 1½% **PER MONTH OR 18% PER ANNUM** on Accounts Not Paid Within 30 Days. osts and Reasonable Attorney Fees for Collection Will be Paid by Purchaser. The terms and conditions as d on the reverse side apply.

TOTAL AMOUNT DUE 600.7

ORIGINAL

C-115 - Operator's Monthly Report (Continuation Page - Instructions are on the back of form C - 115)

2 Operator: **Pendragon Energy Partners, Inc.**	3 OGRID: **145295**	4 Month/Year 03 98	6 Page 5 OF 7

7 POOL NO. AND NAME Property No. and Name Well No. & U-L-S-T-R API No.	8 CODE 1	INJECTION 9 Volume	10 Pressure	11 CODE 2	PRODUCTION 12 Barrels of oil/condensate produced	13 Barrels of water produced	14 MCF Gas produced	15 Days Produced	DISPOSITION OF OIL, GAS, AND WATER 16 CODE 3	17 Point of Disposition	18 Gas BTU or Oil API Gravity	19 Oil on hand at beginning of month	20 Volume (Bbls/mcf)	21 Transporter OGRID	22 CODE 4	23 Oil on hand at end of month
87190 WAW Fruitland Sand PC (Gas):																
021495 Lansdale Federal																
001 P-07-26N-12 W						465			W				465	36401		
30-045-22787	F				-0-	-0-	5,528	31	G	2816033	1069		5,528	007057		
71629 Basin Fruitland Coal (Gas):																
21062 Dome Federal 07-27-13																
003 G 07-27N-13W																
30-045-24047	F				-0-	-0-			G	2515130	1176			007057		
87190 WAW Fruitland Sand PC (Gas):																
017164 Chaco 5 Plant																
005 E-21-26N-12 W																
30-045-21884	F				-0-	-0-	1,494	31	G	919430	1188		1,494	007057		
018288 Chaco 2J																
002 B-01-26N-13 W																
30-045-23593	F				-0-	-0-	159		G	1915830	1029		159	007057		
018288 Chaco 1J																
001 K-01-26N-13 W																
30-045-25134	F				-0-	-0-	160	31	G	1915730	1078		160	007057		
018287 Chaco 1																
001 F-18-26N-12 W																
30-045-22309	F				-0-	-0-	4,442	30	G	1913230	1095		4,442	007057		

C-115 - Operator's Monthly Report (Continuation Page - Instructions are on the back of form C - 115)

2 Operator: **Pendragon Energy Partners, Inc.**	3 OGRID: **145295**	4 Month/Year **03 98**	6 Page **6 OF 7**

		INJECTION			PRODUCTION				DISPOSITION OF OIL, GAS, AND WATER							
7 POOL NO. AND NAME Property No. and Name Well No. & U-L-S-T-R API No.	8 CODE 1	9 Volume	10 Pressure	11 CODE 2	12 Barrels of oil/conden-sate produced	13 Barrels of water produced	14 MCF Gas produced	15 Days Prod-uced	16 CODE 3	17 Point of Disposition	18 Gas BTU or Oil API Gravity	19 Oil on hand at beginning of month	20 Volume (Bbls/mcf)	21 Transporter OGRID	22 CODE 4	23 Oil on hand at end of month
87190 WAW Fruitland Sand PC (Gas):																
018287 Chaco 4																
004 D-07-26N-12 W						27			W				27	36401		
30-045-22410	F				-0-		3,704	27	G	1915430	1153		3,704	007057		
018287 Chaco 5																
005 P-01-26N-13 W						-										
30-045-22411	F				-0-	-0-	7,152	31	G	1915530	1149		7,152	007057		
018287 Chaco 2R																
002 K-07-26N-12 W						-										
30-045-23691	F				-0-	-0-	3,835	30	G	1913330	1095		3,835	007057		
21062 Dome Federal 07-27-13																
001 E-07-N27-13W																
30-045-23397	F				-0-	-0-	91	18	G	1912330	1147		91	007057		
21062 Dome Federal 07-27-13																
002 O-07-N27-13W																
30-045-23581	F				-0-	-0-			G	2501130	1158			007057		
77310 Gallegos Fruitland Sand PC, S (Gas):																
21485 Bengal A																
004R C-01-26N-12W						-										
30-045-24524	F				-0-	-0-	5,876	31	G	2812936	1034		5,876	007057		

GALLEGOS LAW FIRM
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August 13, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA HAND DELIVERY
Rand Carroll, Esq.
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

VIA HAND DELIVERY
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

Gentlemen:

Enclosed please find two (2) proposed forms of Order presented on behalf of Whiting Petroleum Corporation and Maralex Resources, Inc. in the above-captioned matter.

If you have any questions or need any additional information, please feel free to contact me.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By MICHAEL J. CONDON

MJC:sa
Enclosures
cc: J. Scott Hall
fxc: John Hazlett
Mickey O'Hare
ioc: J.E. Gallegos

STATE OF NEW MEXICO
ENERGY MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC., PENDRAGON RESOURCES, L.P., AND J.K EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

CASE NO. 11996

ORDER OF THE DIVISION

(Proposed by Whiting Petroleum Corporation and Maralex Resources, Inc.)

BY THE DIVISION:

This cause came on for hearing at 8:15 a.m. on July 28, 1998 at Santa Fe, New Mexico, before Examiner David R. Catanach, and continued through July 30, 1998.

NOW, on this ____ day of August, 1998, the Division Director, having considered the testimony, the record, and the recommendations of the Examiner, and being fully advised in the premises,

FINDS THAT:

(1) Due public notice having been given as required by law, the Division has jurisdiction of this cause and the subject matter thereof.

(2) The applicants, Pendragon Energy Partners, Inc., J.K. Edwards Associates, Inc., and Pendragon Resources LP (collectively "Pendragon"), seek an order finding that Pendragon is producing from the appropriate common source of supply, i.e., the Pictured Cliffs Formation, from the following wells in San Juan County, New Mexico:

Well Name	Location
Chaco No. 1	NW ¼, Section 18, T26N, R12W, N.M.P.M.
Chaco No. 2R	SW ¼, Section 7, T26N, R12W, N.M.P.M.
Chaco No. 4	NW ¼, Section 7, T26N, R12W, N.M.P.M.
Chaco No. 5	SE ¼, Section 1, T26N, R13W, N.M.P.M.

Chaco Ltd. No. 1J	SW ¼, Section 1, T26N, R13W, N.M.P.M.
Chaco Ltd. No. 2J	NE ¼, Section 1, T26N, R13W, N.M.P.M.

(3) Pendragon, as the Applicant, has the burden to establish that its Chaco wells are producing from the appropriate common source of supply which would be the Pictured Cliffs formation below the base of the Fruitland formation.

(4) Pendragon has failed to meet its burden in this proceeding.

IT IS THEREFORE ORDERED THAT:

(1) Pendragon's Application is denied in its entirety.

(2) The rights and remedies and defenses between and among the parties that may exist under common law remain to be decided by the district court in which litigation between the parties is pending and are not within the jurisdiction of the Division.

DONE at Santa Fe, New Mexico, on the day and year hereinabove designated.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION

Lori Wrotenbery
Director

STATE OF NEW MEXICO
ENERGY MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC., PENDRAGON RESOURCES, L.P., AND J.K EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

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FINDS THAT:

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PARTIES AND NATURE OF DISPUTE

(2) The applicants, Pendragon Energy Partners, Inc., J.K. Edwards Associates, Inc., and Pendragon Resources LP (collectively "Pendragon"), seek an order finding that Pendragon is producing from the appropriate common source of supply, i.e., the Pictured Cliffs Formation, from the following wells in San Juan County, New Mexico:

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Chaco No. 2R	SW ¼, Section 7, T26N, R12W, N.M.P.M.
Chaco No. 4	NW ¼, Section 7, T26N, R12W, N.M.P.M.

Chaco No. 5	SE ¼, Section 1, T26N, R13W, N.M.P.M.
Chaco Ltd. No. 1J	SW ¼, Section 1, T26N, R13W, N.M.P.M.
Chaco Ltd. No. 2J	NE ¼, Section 1, T26N, R13W, N.M.P.M.

These wells are referred to as the "Chaco wells."

(3) Pendragon Resources LP and J.K. Edwards Associates, Inc. are interest owners in the referenced Chaco wells. Pendragon Energy Partners, Inc. operates the wells.

(4) Whiting Petroleum Corporation and Maralex Resources, Inc. (collectively "Whiting") own working interests in the following wells completed within the Basin-Fruitland Coal Gas Pool in San Juan County, New Mexico:

Well Name	Location
Gallegos Federal 26-12-6 No. 2	W ½, Section 6, T12N, R12W, N.M.P.M.
Gallegos Federal 26-12-7 No. 1	W ½, Section 7, T26N, R12W, N.M.P.M.
Gallegos Federal 26-13-1 No. 1	E ½, Section 1, T26N, R13W, N.M.P.M.
Gallegos Federal 26-13-1 No. 2	W ½, Section 1, T26N, R13W, N.M.P.M.
Gallegos Federal 26-13-12 No. 1	N ½, Section 12, T26N, R13W, N.M.P.M.

These wells are referred to herein as the "Whiting Coal wells."

(5) Pendragon and Whiting received assignments of oil and gas leases in the acreage identified in paragraphs (2) and (4) above, San Juan County, from common grantors, Robert Bayless, Merrion Oil and Gas, et al. ("Merrion"), during the period 1992-94. The assignments of rights to Whiting are as follows:

> Operating rights **from the surface of the earth to the base of the Fruitland (Coal-Gas) Formation,** subject to the terms and provisions of that certain Farmout Agreement, dated December 7, 1992 by and between Merrion Oil & Gas et al., Robert L. Bayless, Pitco Production Company, and Maralex Resources, Inc.

(6) The assignments of rights to Pendragon are as follows:

> **Limited from the base of the Fruitland Coal Formation to the base of the Pictured Cliffs Formation.**

(7) Whiting contends that Pendragon produces its Pictured Cliffs wells from casing perforations in formations that are within the vertical limits owned solely by Whiting. Whiting also contends that in 1995 acidization and fracture stimulations performed by Pendragon on its Chaco wells Nos. 1, 1J, 2J, 2R, 4 and 5 have caused communication into the Fruitland formation, and that those wells are producing gas from the Fruitland formation.

REGULATORY HISTORY

(8) On October 17, 1988, the Division entered Order No. R-8768 in Case No. 9420. That proceeding was initiated to consider the creation of a new pool for the production of gas from coal seams within the Fruitland formation underlying various Northwest New Mexico counties, the geographic area of which encompassed the properties at issue in this application. In companion Case No. 9421, the Division sought to contract the vertical limits of twenty-six existing Fruitland and/or Fruitland-Pictured Cliffs Gas Pools to include only the Pictured Cliffs Sandstone and/or Fruitland Sandstone intervals and to exclude the coal formations.

(9) Geologic evidence was presented at the hearing in Case No. 9420 by the Fruitland Coalbed Methane Committee, including evidence that the Fruitland formation is composed of alternating layers of shales, sandstones, and coal seams. Evidence was also presented at the hearing that the intent of the Committee was to include all of the coals beds as part of the Basin Fruitland Coal Gas Pool.

(10) Evidence was presented to the Division by the Committee in Case No. 9420 that there may be intertonguing between the sandstones and the Fruitland coal formation in some parts of the San Juan Basin. This could make picking the boundary between the two formations difficult unless a specific marker is located. The Committee relied on the accepted definition of formation boundaries and the work of established experts, such as James E. Fassett and Jim S. Hinds, in a study titled "Geology and Fuel Resources of the Fruitland Formation and the Kirtland Shale of the San Juan Basin, New Mexico and Colorado, Geological Survey Professional Paper 676 (1971)." In that work, Fassett and Hinds placed the contact between the Pictured Cliffs formation and the overlying Fruitland formation "at the top of the massive sandstone below the lowermost coal of the Fruitland except in those areas where the Fruitland and the Pictured Cliffs intertongue." The Committee relied on industry-recognized boundaries in making their recommendations to the Division in Case No. 9420.

(11) The vertical boundary between the Fruitland formation and the Pictured Cliffs formation in the area in question is and has historically been the top of the massive marine sandstone below the lowermost coal of the Fruitland.

(12) Evidence was also presented to the Division in those proceedings that due to their close proximity, fracture stimulations of the Pictured Cliffs sandstone in the Basin frequently caused communication with the coal formations.

(13) In Order R-8768, the Division created the Basin-Fruitland Coal Gas Pool, with vertical limits comprising all coal seams within the equivalent of the stratigraphic interval from a the depth of approximately 2,450 feet to 2,880 feet as shown on the Gama Ray/Bulk Density Log from the Amoco Production Company's Schneider Gas Com "B" Well No. 1. Spacing for coal gas wells was established on 320-acre proration units.

(14) In Order No. R-8768, the Division adopted Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool. Rule 3 authorizes the Director to require an operator of a proposed or existing Pictured Cliffs Sandstone well to submit certain data in order to demonstrate to the satisfaction of the Division that the well will be or is currently producing from the appropriate common source of supply. Rule 2 of the Special Rules identifies the following data to be used in such a determination:

a. Electric Log Data
b. Drilling Time
c. Drill Cuttings or Log Cores
d. Mud Logs
e. Completion Data
f. Gas Analysis
g. Water Analysis
h. Reservoir Performance
i. Other evidence which may be utilized in making such determination

(15) On July 16, 1991, the Division entered Order No. R-8768-A in reopened Case No. 9420. The Division considered in the course of that proceeding whether the Special Rules and Regulations promulgated by Order No. R-8768 afforded owners of properties in the Basin-Fruitland Coal Gas Pool the opportunity to produce their just and equitable share of gas in that pool, and concluded that the Special Rules and Regulations of Order R-8768 did satisfactorily provide owners with that opportunity.

(16) Order No. R-8768-A confirmed 320-acre spacing for coal gas wells in the Basin-Fruitland Coal Gas Pool, and amended Rule No. 3 which provided that confirmation that a well is producing exclusively from the Basin-Fruitland Coal Gas Pool would consist of approval of Division Form C-104, but that that approval would be for Division purposes only, and should not preclude any other governmental jurisdictional agency from making its own determination of production origination utilizing its own criteria.

(17) In Case No. 9421, the Division entered Orders R-8769 and R-8769-A on October 17, 1988 and April 11, 1989 respectively. Those Orders established the vertical limits of the WAW Fruitland-Pictured Cliffs Pool in San Juan County, New Mexico as follows:

(z) The vertical limits of the WAW Fruitland-Pictured Cliffs Pool in San Juan County, New Mexico, are hereby contracted to include only the Pictured Cliffs formation and the sandstone interval of the Fruitland formation and said pool is hereby redesignated as the WAW Fruitland Sand-Pictured Cliffs Pool.

PRODUCTION AND PRESSURE HISTORY

(18) The Chaco wells were originally drilled by Merrion in the late 1970s. At that time, Merrion owned unified interests from the surface of the earth to the base of the Pictured Cliffs formation in the Chaco wells. The well casings were perforated at various sandstone layers, and were classified as Pictured Cliffs formation wells producing from the WAW Fruitland PC or NIIP PC Pool in notices filed with the Division. The Chaco wells were drilled and completed prior to the establishment of the Basin-Fruitland Coal Gas Pool.

(19) By the mid-1980s, the Chaco wells exhibited signs consistent with production from a depleting Pictured Cliffs sandstone reservoir. Pressures were steadily declining, and production levels had dropped to between 2 and 5 mcf per day. No evidence of skin damage or other mechanical problems with the wells that would account for the low production figures and low pressures is found in any of the Chaco well files which were made exhibits in this proceeding. The decline in both volume of gas and pressure is consistent with a depleted sandstone reservoir.

(20) Whiting drilled its Gallegos Canyon Coal wells in 1992. After completion the wells exhibited performance typical of coal seam wells. They produced high volumes of water initially and virtually no (or little) gas production in the initial months of production. Gas production inclined as the wells dewatered and by 1995 gas production was at economic levels except for the 26-13-1 No. 1 and No. 2 wells.

(21) Pendragon began its activities in this area in December 1994 by reworking the Lansdale Federal No. 1 well on 160-acres in the SE/4 of Section 7, T-26-N, R-12-W. Pendragon owns rights in the Lansdale from a depth of 536 feet to a depth of 1340 feet, including the Fruitland formation and Pictured Cliffs sandstone.

(22) When the Lansdale Federal No. 1 well was originally completed in March, 1980, the operator recovered black water and noted rising casing pressures. Water from the well showed a heavy coal content, and coal fines were recovered, indicating that the well was in communication with coal seams when it was originally completed.

(23) A Walsh Engineering Production Workover and Completion Report for the Lansdale Federal No. 1 well, dated December 19, 1994, shows that Pendragon expressly planned to perforate the Fruitland Coal and treat the well with acid. Pendragon in fact did perforate the Fruitland coal formation on December 20, 1994 in the Lansdale Federal No. 1 well from 1042' to 1056'.

(24) Pendragon failed to report the perforations in the Fruitland coal in sundry notices filed with the Division. Pendragon's regulatory filings misrepresented the well as a Pictured Cliffs well. The Lansdale Federal No. 1 well was on 160-acre spacing, at a nonstandard location. One Hundred Sixty-acre spacing is appropriate for a Pictured Cliffs well, but is illegal for a Fruitland coal seam gas well.

(25) Pendragon illegally produced the Lansdale Federal No. 1 well from December, 1994 until the week prior to the hearing in this case from the Fruitland coal. For 3 and 1/2 years, Pendragon operated the Lansdale Federal No. 1 well under false regulatory filings which failed to disclose that the well was producing from the Fruitland Coal. No water production was reported on the well until March, 1998. Pendragon represented that it squeezed off the perfs in the Fruitland formation less than one (1) week before the hearing in this case on July 28-30, 1998.

(26) Pendragon began its rework program on the Chaco wells in January, 1995. Pendragon acidized and/or fracture stimulated the Chaco 1, 1J, 2J 2R, 4 and 5 wells during the period January, 1995 through May, 1995. These wells are direct offsets to the Whiting Coal wells which, by early 1995, had shown declines in water production and were on an incline for coal seam gas production.

(27) In each case of reworking the Chaco wells Nos. 1, 2R, 4 and 5, Pendragon achieved significant pressure increases in the wells following the acidization or fracture stimulation. A chart demonstrating the pressure increases resulting from the rework of these wells is as follows:

Well Name	Pre-Treatment Wellhead Shut-in Pressure	Treatment Date and Type	Post-Treatment Wellhead Shut-in Pressure
Chaco 1	137 (07/05/83)	Frac (01/27/95)	170 (03/14/95)
Chaco 4	119(01/30/95)	Acid (01/30/95)	170 (02/14/95)
Chaco 5	121 (06/21/80)	Frac (05/10/95)	151 (05/19/95)

(28) Pendragon introduced evidence at the hearing that pressures in the Chaco No. 5 well had risen prior to any acidization or fracture stimulation on that well. However, the well file indicates that a casing leak occurred in that well prior to May, 1995. In February, 1995, black water was discovered flowing from the bradenhead. Given the evidence of the casing leak, and water behind the column, it is clear that communication in the Chaco No. 5 well had already been established between the PC sandstone and the coal prior to January, 1995.

(29) The significant pressure increase achieved in these wells was markedly higher than the natural pressure increase experienced in the wells prior to acidization and fracture treatment from the early 1980s, and demonstrates that the Chaco wells became in communication with the coal formations following the acidizations or fracture stimulations.

(30) Following the acidization and fracture treatment on the Chaco wells, Pendragon experienced very large increases in gas production from the Chaco wells which was not characteristic of Pictured Cliff restimulations. In each case, production levels exceeded production levels experienced when the wells were originally drilled under virgin reservoir conditions. The increases in production from about 3 to 5 MCFD to sustained rates of 400 MCFD are far above any results that could be expected had Pendragon simply been overcoming skin damage by the stimulations.

(31) From 1995 until the Chaco wells were shut-in by order of the Santa Fe County District Court on June 30, 1998, each of the Chaco wells produced volumes of gas which exceeded the total of original gas in place per well for the Pictured Cliffs reservoir in this area. The Chaco wells have produced significantly more gas from 1995 to the present than they produced in the entire first 15-17 years of production.

(32) The evidence of production volumes and pressure data on the Chaco wells since the acidization and fracture stimulations in 1995 is consistent with the conclusion that these wells have been producing significant volumes of coal seam gas.

(33) Since the Chaco wells were shut-in by Order of the Santa Fe County District Court, pressure readings in the Chaco wells have confirmed communication with the coal formations. As Whiting Exhibit 31 demonstrates, the shut-in pressure readings on the shut-in Chaco wells have fluctuated. The fluctuations in the Chaco wells wellhead shut in pressures have coincided with periods when the Whiting Coal wells were shut-in due to pipeline and plant restrictions and when the Whiting wells went back on. If there were no communication between the Pictured Cliffs and the Fruitland coal formations in the Chaco wells, the Chaco wells should exhibit a basically flat line of pressure once they achieved their static pressure following shut-in.

FRACTURE STIMULATIONS

(34) There is little or no stress barrier between the massive Pictured Cliffs sandstone and overlying coal seams. Perforations in the Chaco wells though which hydraulic fractures were administered lay in the Fruitland sandstone between coal seam layers.

(35) The acidizations performed on Chaco wells Nos. 1J, 2J, 2R, and 4 resulted in communication between the Fruitland formation coal seams and the Pictured Cliffs sandstone in these wells. The result of this communication is that since the acid stimulations were performed in 1995, these Chaco wells have been producing coal seam gas from the Fruitland formation which is owned by Whiting.

(36) The evidence presented to the Division established that Pendragon's fracture stimulations on Chaco wells No. 1, 2R, 4 and 5 extended into and through the lower and upper coal seams in the Fruitland formation (B Coal and Basal coal) which is owned by Whiting. These fracture stimulations caused communication between the

Fruitland coal seams and the Pictured Cliffs sandstone and thence to the Chaco well bores, and have, since performed in 1995, resulted in the production of coal seam gas from these Chaco wells by Pendragon.

WATER PRODUCTION

(37) Water production from wells is one indicator of whether a well is producing strictly Pictured Cliffs sandstone gas or coal seam gas. Wells producing coal seam gas would tend to show high volumes of water production in the early stages of production, with water production declining as gas production increases. No significant water production would be expected from a well producing only from the Pictured Cliffs sandstone.

(38) The Chaco wells have produced significant volumes of water since the acidizations and fracture stimulations performed in 1995 on the Chaco wells Nos. 1, 2R, 4 and 5. The produced water volumes in these wells since 1995 are inconsistent with production of solely Pictured Cliffs sandstone gas, and are consistent with the conclusion that these wells are producing coal seam gas from the Fruitland formation.

(39) The problem with accurately quantifying volumes of produced water from the Chaco wells since 1995 exists because Pendragon failed to report volumes of water production as required by NMOCD Form C-115. The evidence in this case established that Pendragon did not begin reporting water volumes from its Chaco wells until, and only for February, 1998, which coincided with a site visit to the Chaco wells by Ernie Busch of the Division's Aztec office.

(40) Pendragon disposed of the produced water from its Chaco wells in unlined earthen pits in an area of sandy soils. The result of such disposal is that significant amounts of produced water were disposed of through evaporation and absorption into the soil, thus making it impossible to precisely quantify the volumes of water produced from the Chaco wells because the water production was not recorded by the pumpers or contract operator.

(41) Pendragon has not, to date, produced all documents related to water production from the Chaco wells. Evidence presented by Whiting at the hearing, based on documents first produced by Pendragon the day before the start of the hearing, indicated that Pendragon continued to produce water from the Chaco wells into at least June, 1998. Pendragon's C-115 reports for that period of time do not reflect water production, even though their internal files demonstrated water production and water hauling from the Chaco wells.

(42) While water production evidence on the Chaco wells is sparse owing to Pendragon's non-preservation of the information and ongoing violations of Division rules and regulations and its failure to report water production from these wells, the water production records and generally evidence in this case are consistent with a finding that the Pendragon Chaco wells have, since their acidizations and fracture stimulations in

1995, been producing coal seam gas in significant quantities from these Chaco wells. The water/gas ratio on the Chaco wells generally shows a higher water/gas ratio than the Whiting coal wells for the same period.

(43) Presumptions on the issue of water from the Chaco wells will be made adverse to Pendragon in this proceeding in light of Pendragon's failure to report water production from its Chaco wells.

GAS ANALYSIS

(44) The Division has recognized that gas analysis is one method of differentiating coal seam gas from Pictured Cliffs sandstone gas. Pictured Cliffs sandstone gas typically has a BTU content in this area of between 1050 and 1100, whereas Fruitland coal seam gas in this area typically has a BTU content of approximately 1000.

(45) Historical data submitted in this case demonstrated that the Pendragon Chaco wells prior to the acidization and fracture stimulations in 1995 produced gas with a BTU content consistent with Pictured Cliffs sandstone gas.

(46) Following the acidizations and fracture stimulations in 1995, the Pendragon Chaco wells began producing gas with a BTU content consistent with Fruitland coal seam gas. The documentary evidence presented to the Division demonstrated that the BTU readings on Whiting's coal seam gas and Pendragon's gas produced from the Chaco wells has become increasingly similar and consistent overtime, thus indicating that the Chaco wells are producing significant volumes of coal seam gas.

GEOLOGIC EVIDENCE

(47) As demonstrated in Whiting Exhibit 16, a cross-section of logs for the Chaco wells at issue in this proceeding, there are two continuous lower Fruitland coal seams in the area. The upper coal seam, characterized on Whiting Exhibit 16 as the B Coal, is approximately 20 feet thick throughout the subject area. The lower continuous coal seam in the area, characterized by Whiting at the hearing as the Basal coal, varies from 2 feet to 4 feet in thickness and overlies the massive marine sandstone formation designated on the Whiting Exhibit 16 as the Pictured Cliffs Sandstone formation.

(48) There is in this area a small, 2 to 7 feet in thickness sandstone stringer which runs between the B Coal and the Basal coal. Whiting presented geologic evidence that demonstrated that this sandstone layer is a Fruitland sandstone. The sandstone stringer is not a marine sandstone, but rather is a coastal plain sandstone.

(49) The vertical boundary between the Fruitland formation and the Pictured Cliffs Sandstone formation in this area is set below what is characterized as the Basal Coal stringer on the Whiting Exhibit 16, at the top of the massive Picture Cliffs

sandstone. This boundary is consistent with industry-accepted standards, the work of the U.S. Geological Survey, and the Coalbed Methane Committee. The Division rejects the attempt by Pendragon to characterize this Fruitland sandstone stringer as an "Upper Pictured Cliffs Sand," a phrase coined by Pendragon's president for this hearing, and which finds no support in the literature or prior geologic testimony taken before the Division, or in prior Orders of the Division.

(50) Pendragon produces from perforations in the Fruitland Sandstone in its Chaco wells Nos. 1, 2J, 4 and 5. These perfs are located in the Fruitland formation owned by Whiting.

BASED ON THE FOREGOING, THE DIVISION FINDS THAT:

(1) Pendragon, as the Applicant, has the burden to establish that its Chaco wells are producing from the appropriate common source of supply which would be the Pictured Cliffs formation below the base of the Fruitland formation.

(2) Pendragon has failed to meet its burden in this proceeding.

(3) Pendragon's Chaco wells Nos. 1, 2J, 4 and 5 include perforations open in the Fruitland sandstone above the base of the Fruitland formation owned by Whiting. These wells have been producing gas to which Whiting is solely entitled since 1995.

(4) Pendragon's acidizations and/or fracture stimulations on its Chaco wells Nos. 1, 1J, 2J, 2R, 4 and 5 caused communication with the coal seams in the Fruitland formation. Whiting is solely entitled to produce coal seam gas from this formation. The Chaco wells 1, 2R, 4 and 5 since 1995 have been producing predominantly coal seam gas. Chaco wells 1J and 2J have also produced coal seam gas since 1995.

(5) A fair and equitable allocation based upon the engineering evidence presented at the hearing demonstrates that following the 1995 stimulations, 90% of gas production from the Chaco wells should be allocated to Whiting's Coal wells, and 10% should be allocated to Pendragon's Chaco wells.

(6) Given the volumes produced by the Chaco wells beginning in 1995 and on the basis of the 90% source in Fruitland formation gas and 10% source in Pictured Cliffs sandstone gas, well before June 30, 1998 the Pendragon wells had produced more than all of the gas which they were capable of producing from the Pictured Cliffs sandstone.

(7) Pendragon's Application seeking an order that Pendragon's Chaco wells are producing from the appropriate common source of supply is not supported by the evidence and should be denied.

(8) It would be violative of correlative rights, inequitable, and injurious to Whiting to allow the Pendragon Chaco wells to continue to produce coal seam gas.

(9) Pendragon has already produced in excess of its allocable Pictured Cliffs share of gas from the Chaco wells. Whiting will produce all coal seam gas, which might otherwise be produced from the Chaco wells, from Whiting's own wells if the Chaco wells are shut-in.

(10) Pendragon has engaged in an ongoing and consistent practice of violating Division rules and regulations by (a) operating the Lansdale Federal No. 1 well as a Pictured Cliffs well, fully knowing that the well was producing coal seam gas, (b) operating the Lansdale Federal No. 1 well on a 160-acre proration unit at a nonstandard location in violation of Order R-8768 and R-8768-A, and (c) failing to document and report volumes of water production from the Chaco wells since the stimulation treatments in 1995.

(11) Plugging and abandoning Pendragon's Chaco wells will prevent waste and protect the correlative rights of the parties.

IT IS THEREFORE ORDERED THAT:

(1) Pendragon is to plug and abandon Chaco wells Nos. 1, 1J, 2J, 2R, 4 and 5 within thirty (30) days and duly report such procedures by Sundry Notice, Form C-103, in accordance with the Rules and Regulations of the Division.

(2) Pendragon is ordered to appear before the Division and show cause why the Division should not prohibit Pendragon from further serving as the record operator of wells in New Mexico a result of the ongoing, knowing and persistent violations of the Division's rules and regulations which were established at the hearing in this matter.

(3) Pendragon's Application is denied in its entirety.

(4) The rights and remedies and defenses between and among the parties that may exist under common law remain to be decided by the district court in which litigation between the parties is pending and are not within the jurisdiction of the Division.

(5) Jurisdiction of this cause is retained for the entry of such further orders as the Division may deem necessary within the scope of its regulatory authority.

DONE at Santa Fe, New Mexico, on the day and year hereinabove designated.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION

Lori Wrotenbery
Director

MERRION

OIL & GAS

August 12, 1998

Mr. David Catanach
New Mexico Oil Conservation Division
2040 S. Pacheco
Santa Fe, New Mexico 87505

Fax (505) 827-1389

Re: **Case 11996**
Statement of Merrion Oil & Gas

Dear Mr. Catanach:

Enclosed is a statement from Merrion Oil & Gas Corp. regarding the subject case. Thank you for the opportunity to have input prior to your issuing a ruling.

Sincerely,

George Sharpe

George F. Sharpe
Manager – Oil & Gas Investments

Xc: Tommy Roberts
Mr. Scott Hall – Attorney for Pendragon et al
Mr. Gene Gallegos – Attorney for Whiting et al
Frank Chavez – Aztec OCD

610 Reilly Avenue • Farmington, New Mexico 87401 • 505-327-9801 / 505-326-5900 (Fax)

STATEMENT OF MERRION OIL & GAS CORP
CASE 11996

APPLICATION OF PENDRAGON ENERGY PARTNERS AND JK EDWARDS
TO CONFIRM PRODUCTION FROM COMMON SOURCE OF SUPPLY
SAN JUAN COUNTY, NEW MEXICO

BACKGROUND

Merrion Oil & Gas (Merrion) created the problem now before the OCD by (unwisely, it turns out) farming out the Fruitland Coal rights to Whiting etal and subsequently selling the Pictured Cliffs (PC) rights to Pendragon. Merrion has retained an economic interest in the wells in question in the form of an override in Whiting's Fruitland Coal wells and in the fact that we are still a working interest owner in the Fruitland Coal in the Chaco 1 spacing unit.

Merrion believes that in the area encompassed by the WAW Pictured Cliffs (PC) pool, fracture stimulation of Fruitland Coal wells and fracture stimulation of PC wells could possibly result in the communication of the two zones. Prior to the coal being segregated to allow for coal gas tax credits, the entire PC and Fruitland Formation formerly was combined in the WAW PC/Fruitland Pool because of the close vertical proximity of the two formations. Because of the difficulty in isolating the two zones, operators in the pool (Merrion, Dugan, Bayless, etc.) argued before the OCD that the Fruitland Coal in the WAW area should have the same 160 acre spacing as the PC and Fruitland Sands. In that hearing, the OCD ruled against the WAW area operators. Merrion submits this background information to provide a basis for our recommendation that any ruling be limited in scope to the WAW area.

PENDRAGON PERFORATIONS ARE IN PICTURED CLIFFS INTERVAL

Merrion believes that the "Upper PC" as outlined in Al Nichol's testimony is a marine sand historically recognized as PC by Merrion and other operators in the area. Merrion never intended to farmout to Whiting etal the rights to zones where our producing wells were perforated, nor would we purposefully sell wells to Pendragon etal that were perforated in zones that we didn't own. Therefore, Merrion believes that Pendragon's wells are appropriately perforated in the PC.

OPERATORS HAVE RIGHT TO STIMULATE AND PRODUCE LEGAL PERFS

Merrion believes operators should have a right to stimulate "legal" perforations in a defined pool and to subsequently produce their well. If communication is determined to exist between another zone or pool, Merrion believes that situation should be handled with some sort of downhole commingling provision as discussed next. Therefore, Merrion believes that, regardless of the ruling on whether there is communication or not between the PC and the Fruitland, Pendragon should be allowed to continue to produce the perforated interval in their respective wells.

COMMUNICATION SHOULD BE HANDLED WITH COMMINGLING ORDER

Concerning the existence of communication between the two zones, Merrion does not have a recommendation on how the OCD should rule, and are glad that it is you and not us making this decision. If the OCD is convinced that communication does exist, Merrion recommends that the following points be considered for inclusion in a ruling to that effect.

1.) Any rule should be a special pool rule, applicable to the WAW PC-Fruitland Pool only.

2.) Within the boundaries of the WAW Pool, the rule should allow for the retroactive downhole commingling of the PC and Fruitland in wells where only one zone is perforated, yet communication is demonstrated to exist.

3.) The allocation of commingled production should be retroactive to the point in time the commingling occurred, or back 3 years prior to the date of the application, whichever is less.

4.) Applications for commingling should only be accepted in cases where the economic ownership in the PC and Fruitland Coal are not identical.

5.) Any party (working interest owner, override owner, or royalty owner) with an economic interest in either formation within the spacing unit(s) of a well may make an application to the OCD for the commingling. The applicant must provide convincing evidence of communication and must propose and provide support for a method of allocation of production and costs.

6.) Notification of the application must be provided to all the interest owners of both zones. If both zones already have a designated operator and if the applicant is someone other than the operator, the operator must supply to the applicant the names and addresses of all interest owners in the well or zone. In the case where one zone does not have an operator, the applicant must determine through title examination who the interest owners are in that zone.

7.) The "old" working interest owners should have the ability to recoup all of their costs (i.e. net revenue exceeds operating costs plus capital expenditures) before the "new" working interest owners "back-in" for a share of the well. The "new" owners should be subject to any existing operating agreements covering the well.

8.) The operator should generate a gas balancing statement showing to what degree the "old" revenue interest owners are "overproduced" and to what degree the "new" revenue interest owners are "underproduced". The underproduced parties will receive their proportionate share of the production plus half of the overproduced parties' share of the production (but not to reduce the overproduced parties' revenue to the point where it's less than the overproduced parties' share of the operating expense) until their balance is made up (standard gas balancing terms). In no case should overproduced parties be required to give gas (or money) to the underproduced parties in excess of what the well is capable of producing in the future.

9.) The order should allow for the continued uninterrupted production of all existing wells through special spacing unit rules. It is plausible that one might have 2 PC wells and 1 coal well, all on the same 320 and all producing from both formations.

10.) The Fruitland Coal drilling density within the WAW Pool boundaries should be increased to 2 wells per 320 acres (as originally proposed by the operators in the pool) because of the possibility of offset drainage from two "PC" wells.

Obviously, the ramifications of an order allowing retroactive commingling are complicated and far reaching. Therefore, the above suggested provisions notwithstanding, we feel that additional Industry input should be solicited before finalizing any special pool rules for the WAW field.

Signature: George Sharpe Date: 5-12-95

By: George Sharpe
Manager – Oil & Gas Investments
Merrion Oil & Gas Corp

File: S\INVEST\GFS\WAW PC-COAL STATEMENT

MILLER, STRATVERT & TORGERSON, P. A.

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PLEASE REPLY TO SANTA FE

August 7, 1998

Mr. David Catanach
New Mexico Oil Conservation Division
2040 South Pacheco Street
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J. K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Mr. Catanach:

Last week, during the course of the hearing in the above matter, we indicated we would provide additional evidence of the shutdown of the El Paso Chaco Plant in August of 1995. Accordingly, I am enclosing three copies of Walsh Engineering and Production Well Reports for August 1995 for the following wells: Chaco 1 and Chaco 2-R CPD; Chaco 1; Chaco 5; Chaco 4; Chaco 2-R. These copies are marked Pendragon Exhibit T-3.

We request these materials be included in and made a part of the record in Case No. 11996.

Thank you for your cooperation.

Very Truly Yours,
MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall

JSH/eam
cc: Steve Brenner w/enclos
J.E. Gallegos w/enclos

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco 1 & Chaco 2R CPD

CO-EFF: 5.95
RANGE: 100
SPRING: 100
PLATE: 1.000
HRS ON ____ OFF ____

	PRESSURE			METER			
DATE	LINE	TUBING	CASING	DIFF.	STAT.	MCF	REMARKS
1				6.0	7.7	275	
2				6.0	7.7	275	
3				5.8	7.8	269	
4				5.2	8.4	260	
5				5.4	8.0	257	
6				5.2	8.3	257	
7				4.0	9.0	214	
8	64			0.0	8.7		EL PLANT SHUT IN
9				0.0	8.0		
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	7.1		
14				0.0	7.3		
15				0.0	7.7	145	well on 4:00 PM
16				7.3	6.9	300	
17				7.3	6.9	300	
18				5.0	8.2	244	
19				6.3	7.5	281	
20				6.5	7.3	282	
21				5.1	8.2	249	
22				5.1	8.2	249	
23	43			6.3	7.4	277	
24				4.5	9.0	241	
25				4.8	9.1	260	
26				5.5	8.4	275	
27				5.4	8.4	270	
28				5.5	8.4	275	
29				5.9	7.2	270	
30	49			5.9	7.8	273	
31				5.9	7.8	273	
						6271	

NMOCD CASE #11996
PENDRAGON ENERGY
EXHIBIT

T-3

Serial Number for Separator 30 K 2820

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco #1

CO-EFF: 7.18
RANGE: 100
SPRING: 250
PLATE: .875
HRS ON ____ OFF ____

DATE	PRESSURE LINE	PRESSURE TUBING	PRESSURE CASING	METER DIFF.	METER STAT.	METER MCF	REMARKS
1				7.6	4.8	261	
2				7.6	4.8	261	
3				7.2	4.9	253	
4				6.5	5.2	242	
5				5.5	5.8	229	
6				5.5	5.8	229	
7				5.0	6.0	215	
8			143	0.0	7.5		EL PLANT SHUT IN
9				0.0	8.0		
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	8.0		
14				0.0	8.0		
15		154	154	9.5	6.0	136	well on 4:45 PM-8hrs
16				8.4	4.6	362	
17				8.4	4.6	362	
18				7.0	5.8	292	
19				7.8	5.0	280	
20				8.0	4.6	264	
21				6.7	5.2	250	
22				6.5	5.3	247	
23	43			7.5	4.7	253	
24				6.0	6.0	258	
25				6.4	5.8	266	
26				6.4	5.4	248	
27				6.3	5.7	258	
28				6.5	5.3	247	
29				7.2	4.8	248	
30	58			7.1	4.8	245	
31				7.1	4.8	245	
						6151	

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCAITES

WELL NAME: Chaco #5

CO-EFF: 13.56
RANGE: 100
SPRING: 100
PLATE: 1.500
HRS ON ___ OFF ___

	PRESSURE			METER			
DATE	LINE	TUBING	CASING	DIFF.	STAT.	MCF	REMARKS
1				3.9	7.4	391	
2				3.8	7.8	402	
3				3.9	7.8	412	
4				3.6	8.4	410	
5				3.5	8.5	403	
6				3.4	8.4	387	
7				3.5	8.5	403	
8			107	3.2	8.5	369	
9				3.4	8.5	391	
10				3.5	8.4	399	
11				3.5	8.2	389	
12				3.4	8.1	373	
13				4.4	7.3	435	
14				4.4	7.3	435	
15	47	47	107	4.0	7.7	418	
16				4.2	7.3	415	
17				4.2	7.3	415	
18				3.3	8.0	358	
19				3.6	8.4	410	
20				3.8	7.3	376	
21				3.2	8.3	360	
22				3.0	8.6	350	
23	53		111	3.5	8.1	384	
24				3.1	8.2	345	
25				2.8	9.0	342	
26				3.1	7.4	311	
27				3.0	8.1	329	
28				2.8	8.1	346	
29				3.0	8.0	325	
30	54		106	3.2	8.1	351	
31				3.2	8.1	351	
						11735	

9004-1

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco #4

CO-EFF: 13.56
RANGE: 100
SPRING: 100
PLATE: 1.500
HRS ON ____ OFF ____

DATE	PRESSURE			METER			REMARKS
	LINE	TUBING	CASING	DIFF.	STAT.	MCF	
1				4.6	7.4	461	
2				4.3	7.7	449	
3				4.4	7.7	459	
4				3.6	9.4	459	
5				4.0	8.3	450	
6				4.0	8.4	456	
7				4.2	8.2	467	
8	64		114	4.3	8.7	507	
9				4.9	8.5	564	
10				5.0	8.4	569	
11				5.1	8.3	374	EL PASO SHUT IN 4:00 PM
12				0.0	4.0		
13				0.0	4.0		
14				0.0	4.0		
15		153	153	0.0	4.0		well on at 4:00 PM
16				6.5	7.2	634	
17				6.2	7.2	605	
18				4.6	8.0	499	
19				4.0	8.4	456	
20				4.8	7.5	488	
21				4.0	8.2	448	
22				4.0	8.2	448	
23	47			4.5	7.7	470	
24				4.0	8.3	450	
25				3.5	8.9	422	
26				3.8	8.4	432	
27				3.7	8.3	416	
28				3.8	9.0	463	
29				4.3	7.9	460	
30	50		109	4.0	7.9	428	
31				4.0	7.9	428	
						13033	

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J.K. EDWARDS ASSOCIATES

WELL NAME: Chaco #2R

CO-EFF: 1.32
RANGE: 100
SPRING: 250
PLATE: .375
HRS ON ____ OFF ____

DATE	PRESSURE LINE	PRESSURE TUBING	PRESSURE CASING	METER DIFF.	METER STAT.	METER MCF	REMARKS
1				1.0	4.8	6	
2				1.0	4.7	6	
3				1.0	4.9	6	chg battery in clock
4			107	1.0	5.2	7	blow well to atmospher
5				1.0	5.0	7	3 hrs. and put down li
6				1.0	5.4	7	
7				1.0	6.0	8	
8	140	109	109	0.8	7.5	8	high line pressure
9				0.0	8.0		EP shut in (plant) 8/8
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	8.0		
14				0.0	8.0		
15		110	110	0.0	8.0		well shut in
16				2.0	4.5	4	soaped well-10 gal
17				2.0	4.5	4	1 hr on- 2 off
18				2.0	5.5	4	
19				2.0	4.8	4	
20				2.0	4.6	4	
21				2.0	5.0	4	
22				2.0	5.3	4	
23	55			2.0	4.7	4	
24				2.0	5.9	4	
25				2.0	5.7	4	
26				2.0	5.3	4	
27				2.0	5.6	4	
28				2.0	5.3	4	
29				2.0	4.8	4	
30	58		110	2.0	4.8	4	
31				2.0	4.8	4	
						119	

8/4 blow well - well started making H20 after 5 minutes

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco 1 & Chaco 2R CPD

CO-EFF: 5.95
RANGE: 100
SPRING: 100
PLATE: 1.000
HRS ON ____ OFF ____

DATE	PRESSURE LINE	PRESSURE TUBING	PRESSURE CASING	METER DIFF.	METER STAT.	METER MCF	REMARKS
1				6.0	7.7	275	
2				6.0	7.7	275	
3				5.8	7.8	269	
4				5.2	8.4	260	
5				5.4	8.0	257	
6				5.2	8.3	257	
7				4.0	9.0	214	
8	64			0.0	8.7		EL PLANT SHUT IN
9				0.0	8.0		
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	7.1		
14				0.0	7.3		
15				0.0	7.7	145	well on 4:00 PM
16				7.3	6.9	300	
17				7.3	6.9	300	
18				5.0	8.2	244	
19				6.3	7.5	281	
20				6.5	7.3	282	
21				5.1	8.2	249	
22				5.1	8.2	249	
23	43			6.3	7.4	277	
24				4.5	9.0	241	
25				4.8	9.1	260	
26				5.5	8.4	275	
27				5.4	8.4	270	
28				5.5	8.4	275	
29				5.9	7.2	270	
30	49			5.9	7.8	273	
31				5.9	7.8	273	
						6271	

NMOCD CASE #11996
PENDRAGON ENERGY
EXHIBIT

T-3

Serial Number for Separator 30 K 2820

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco #1

CO-EFF: 7.18
RANGE: 100
SPRING: 250
PLATE: .875
HRS ON ____ OFF ____

	PRESSURE			METER			
DATE	LINE	TUBING	CASING	DIFF.	STAT.	MCF	REMARKS
1				7.6	4.8	261	
2				7.6	4.8	261	
3				7.2	4.9	253	
4				6.5	5.2	242	
5				5.5	5.8	229	
6				5.5	5.8	229	
7				5.0	6.0	215	
8			143	0.0	7.5		EL PLANT SHUT IN
9				0.0	8.0		
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	8.0		
14				0.0	8.0		
15		154	154	9.5	6.0	136	well on 4:45 PM-8hrs
16				8.4	4.6	362	
17				8.4	4.6	362	
18				7.0	5.8	292	
19				7.8	5.0	280	
20				8.0	4.6	264	
21				6.7	5.2	250	
22				6.5	5.3	247	
23	43			7.5	4.7	253	
24				6.0	6.0	258	
25				6.4	5.8	266	
26				6.4	5.4	248	
27				6.3	5.7	258	
28				6.5	5.3	247	
29				7.2	4.8	248	
30	58			7.1	4.8	245	
31				7.1	4.8	245	
						6151	

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCAITES

WELL NAME: Chaco #5

CO-EFF: 13.56
RANGE: 100
SPRING: 100
PLATE: 1.500
HRS ON ____ OFF ____

DATE	PRESSURE LINE	PRESSURE TUBING	PRESSURE CASING	METER DIFF.	METER STAT.	METER MCF	REMARKS
1				3.9	7.4	391	
2				3.8	7.8	402	
3				3.9	7.8	412	
4				3.6	8.4	410	
5				3.5	8.5	403	
6				3.4	8.4	387	
7				3.5	8.5	403	
8			107	3.2	8.5	369	
9				3.4	8.5	391	
10				3.5	8.4	399	
11				3.5	8.2	389	
12				3.4	8.1	373	
13				4.4	7.3	435	
14				4.4	7.3	435	
15	47	47	107	4.0	7.7	418	
16				4.2	7.3	415	
17				4.2	7.3	415	
18				3.3	8.0	358	
19				3.6	8.4	410	
20				3.8	7.3	376	
21				3.2	8.3	360	
22				3.0	8.6	350	
23	53		111	3.5	8.1	384	
24				3.1	8.2	345	
25				2.8	9.0	342	
26				3.1	7.4	311	
27				3.0	8.1	329	
28				2.8	8.1	346	
29				3.0	8.0	325	
30	54		106	3.2	8.1	351	
31				3.2	8.1	351	
						11735	

90041

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco #4

CO-EFF: 13.56
RANGE: 100
SPRING: 100
PLATE: 1.500
HRS ON ____ OFF ____

	PRESSURE			METER			
DATE	LINE	TUBING	CASING	DIFF.	STAT.	MCF	REMARKS
1				4.6	7.4	461	
2				4.3	7.7	449	
3				4.4	7.7	459	
4				3.6	9.4	459	
5				4.0	8.3	450	
6				4.0	8.4	456	
7				4.2	8.2	467	
8	64		114	4.3	8.7	507	
9				4.9	8.5	564	
10				5.0	8.4	569	
11				5.1	8.3	374	EL PASO SHUT IN 4:00 PM
12				0.0	4.0		
13				0.0	4.0		
14				0.0	4.0		
15		153	153	0.0	4.0		well on at 4:00 PM
16				6.5	7.2	634	
17				6.2	7.2	605	
18				4.6	8.0	499	
19				4.0	8.4	456	
20				4.8	7.5	488	
21				4.0	8.2	448	
22				4.0	8.2	448	
23	47			4.5	7.7	470	
24				4.0	8.3	450	
25				3.5	8.9	422	
26				3.8	8.4	432	
27				3.7	8.3	416	
28				3.8	9.0	463	
29				4.3	7.9	460	
30	50		109	4.0	7.9	428	
31				4.0	7.9	428	
						13033	

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J.K. EDWARDS ASSOCIATES

WELL NAME: Chaco #2R

CO-EFF: 1.32
RANGE: 100
SPRING: 250
PLATE: .375
HRS ON ____ OFF ____

DATE	PRESSURE LINE	PRESSURE TUBING	PRESSURE CASING	METER DIFF.	METER STAT.	METER MCF	REMARKS
1				1.0	4.8	6	
2				1.0	4.7	6	
3				1.0	4.9	6	chg battery in clock
4			107	1.0	5.2	7	blow well to atmospher
5				1.0	5.0	7	3 hrs. and put down li
6				1.0	5.4	7	
7				1.0	6.0	8	
8	140	109	109	0.8	7.5	8	high line pressure
9				0.0	8.0		EP shut in (plant) 8/8
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	8.0		
14				0.0	8.0		
15		110	110	0.0	8.0		well shut in
16				2.0	4.5	4	soaped well-10 gal
17				2.0	4.5	4	1 hr on- 2 off
18				2.0	5.5	4	
19				2.0	4.8	4	
20				2.0	4.6	4	
21				2.0	5.0	4	
22				2.0	5.3	4	
23	55			2.0	4.7	4	
24				2.0	5.9	4	
25				2.0	5.7	4	
26				2.0	5.3	4	
27				2.0	5.6	4	
28				2.0	5.3	4	
29				2.0	4.8	4	
30	58		110	2.0	4.8	4	
31				2.0	4.8	4	
						119	

8/4 blow well - well started making H20 after 5 minutes

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco 1 & Chaco 2R CPD

CO-EFF: 5.95
RANGE: 100
SPRING: 100
PLATE: 1.000
HRS ON ____ OFF ____

	PRESSURE			METER			
DATE	LINE	TUBING	CASING	DIFF.	STAT.	MCF	REMARKS
1				6.0	7.7	275	
2				6.0	7.7	275	
3				5.8	7.8	269	
4				5.2	8.4	260	
5				5.4	8.0	257	
6				5.2	8.3	257	
7				4.0	9.0	214	
8	64			0.0	8.7		EL PLANT SHUT IN
9				0.0	8.0		
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	7.1		
14				0.0	7.3		
15				0.0	7.7	145	well on 4:00 PM
16				7.3	6.9	300	
17				7.3	6.9	300	
18				5.0	8.2	244	
19				6.3	7.5	281	
20				6.5	7.3	282	
21				5.1	8.2	249	
22				5.1	8.2	249	
23	43			6.3	7.4	277	
24				4.5	9.0	241	
25				4.8	9.1	260	
26				5.5	8.4	275	
27				5.4	8.4	270	
28				5.5	8.4	275	
29				5.9	7.2	270	
30	49			5.9	7.8	273	
31				5.9	7.8	273	
						6271	

NMOCD CASE #11996
PENDRAGON ENERGY
EXHIBIT

T-3

Serial Number for Separator 30 K 2820

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco #1

CO-EFF: 7.18
RANGE: 100
SPRING: 250
PLATE: .875
HRS ON ____ OFF ____

	PRESSURE			METER			
DATE	LINE	TUBING	CASING	DIFF.	STAT.	MCF	REMARKS
1				7.6	4.8	261	
2				7.6	4.8	261	
3				7.2	4.9	253	
4				6.5	5.2	242	
5				5.5	5.8	229	
6				5.5	5.8	229	
7				5.0	6.0	215	
8			143	0.0	7.5		EL PLANT SHUT IN
9				0.0	8.0		
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	8.0		
14				0.0	8.0		
15		154	154	9.5	6.0	136	well on 4:45 PM-8hrs
16				8.4	4.6	362	
17				8.4	4.6	362	
18				7.0	5.8	292	
19				7.8	5.0	280	
20				8.0	4.6	264	
21				6.7	5.2	250	
22				6.5	5.3	247	
23	43			7.5	4.7	253	
24				6.0	6.0	258	
25				6.4	5.8	266	
26				6.4	5.4	248	
27				6.3	5.7	258	
28				6.5	5.3	247	
29				7.2	4.8	248	
30	58			7.1	4.8	245	
31				7.1	4.8	245	
						6151	

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCAITES

WELL NAME: Chaco #5

CO-EFF: 13.56
RANGE: 100
SPRING: 100
PLATE: 1.500
HRS ON ____ OFF ____

DATE	PRESSURE LINE	PRESSURE TUBING	PRESSURE CASING	METER DIFF.	METER STAT.	METER MCF	REMARKS
1				3.9	7.4	391	
2				3.8	7.8	402	
3				3.9	7.8	412	
4				3.6	8.4	410	
5				3.5	8.5	403	
6				3.4	8.4	387	
7				3.5	8.5	403	
8			107	3.2	8.5	369	
9				3.4	8.5	391	
10				3.5	8.4	399	
11				3.5	8.2	389	
12				3.4	8.1	373	
13				4.4	7.3	435	
14				4.4	7.3	435	
15	47	47	107	4.0	7.7	418	
16				4.2	7.3	415	
17				4.2	7.3	415	
18				3.3	8.0	358	
19				3.6	8.4	410	
20				3.8	7.3	376	
21				3.2	8.3	360	
22				3.0	8.6	350	
23	53		111	3.5	8.1	384	
24				3.1	8.2	345	
25				2.8	9.0	342	
26				3.1	7.4	311	
27				3.0	8.1	329	
28				2.8	8.1	346	
29				3.0	8.0	325	
30	54		106	3.2	8.1	351	
31				3.2	8.1	351	
						11735	

9004'1

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J. K. EDWARDS ASSOCIATES

WELL NAME: Chaco #4

CO-EFF: 13.56
RANGE: 100
SPRING: 100
PLATE: 1.500
HRS ON ____ OFF ____

DATE	PRESSURE LINE	PRESSURE TUBING	PRESSURE CASING	METER DIFF.	METER STAT.	METER MCF	REMARKS
1				4.6	7.4	461	
2				4.3	7.7	449	
3				4.4	7.7	459	
4				3.6	9.4	459	
5				4.0	8.3	450	
6				4.0	8.4	456	
7				4.2	8.2	467	
8	64		114	4.3	8.7	507	
9				4.9	8.5	564	
10				5.0	8.4	569	
11				5.1	8.3	374	EL PASO SHUT IN 4:00 PM
12				0.0	4.0		
13				0.0	4.0		
14				0.0	4.0		
15		153	153	0.0	4.0		well on at 4:00 PM
16				6.5	7.2	634	
17				6.2	7.2	605	
18				4.6	8.0	499	
19				4.0	8.4	456	
20				4.8	7.5	488	
21				4.0	8.2	448	
22				4.0	8.2	448	
23	47			4.5	7.7	470	
24				4.0	8.3	450	
25				3.5	8.9	422	
26				3.8	8.4	432	
27				3.7	8.3	416	
28				3.8	9.0	463	
29				4.3	7.9	460	
30	50		109	4.0	7.9	428	
31				4.0	7.9	428	
						13033	

WALSH ENGINEERING & PRODUCTION

WELL REPORT

DATE: AUGUST 1995

OPERATOR: J.K. EDWARDS ASSOCIATES

WELL NAME: Chaco #2R

CO-EFF: 1.32
RANGE: 100
SPRING: 250
PLATE: .375
HRS ON ____ OFF ____

	PRESSURE			METER			
DATE	LINE	TUBING	CASING	DIFF.	STAT.	MCF	REMARKS
1				1.0	4.8	6	
2				1.0	4.7	6	
3				1.0	4.9	6	chg battery in clock
4			107	1.0	5.2	7	blow well to atmospher
5				1.0	5.0	7	3 hrs. and put down li
6				1.0	5.4	7	
7				1.0	6.0	8	
8	140	109	109	0.8	7.5	8	high line pressure
9				0.0	8.0		EP shut in (plant) 8/8
10				0.0	8.0		
11				0.0	8.0		
12				0.0	8.0		
13				0.0	8.0		
14				0.0	8.0		
15		110	110	0.0	8.0		well shut in
16				2.0	4.5	4	soaped well-10 gal
17				2.0	4.5	4	1 hr on- 2 off
18				2.0	5.5	4	
19				2.0	4.8	4	
20				2.0	4.6	4	
21				2.0	5.0	4	
22				2.0	5.3	4	
23	55			2.0	4.7	4	
24				2.0	5.9	4	
25				2.0	5.7	4	
26				2.0	5.3	4	
27				2.0	5.6	4	
28				2.0	5.3	4	
29				2.0	4.8	4	
30	58		110	2.0	4.8	4	
31				2.0	4.8	4	
						119	

8/4 blow well - well started making H20 after 5 minutes

dugan production corp.

August 7, 1998

Mr. David Catanach
New Mexico Oil Conservation Division
P.O. Box 2088
Santa Fe, New Mexico 87504-2088

Re: NMOCD Case #11996

Dear Mr. Catanach:

As a representative for Dugan Production Corp. and being interested in Case #11996, I attended your examiner hearing for this case on July 28 and 29, 1998 and have looked at the exhibits that were presented by both parties. An article that I wrote was presented by Dr. Walter Ayers (Exhibit 47-M) has an error that I would like to clarify for submission into record .

My paper on the Waw Fruitland Pictured Cliffs gas pool in the Four Corners Geological Society guidebook Oil and Gas Fields of The Four Corners Area Volume II, 1978, page 560 shows an incorrect Pictured Cliffs top at 1324' on the Waw #1 type log (discovery well for the Waw Fruitland P.C. pool). The correct Pictured Cliffs top in this well is 1317' and was reported correctly on the original completion report for this well, which was submitted on July 13, 1970 to the NMOCD.

Please submit this letter of correction into record for Case #11996.

Very Sincerely,
Kurt H. Fagrelius
Kurt H. Fagrelius
Geologist

709 E. MURRAY DR. • P. O. BOX 420 • FARMINGTON, N.M. 87499-0420 • PHONE: (505) 325-1821 • FAX# (505) 327-4613

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PLEASE REPLY TO SANTA FE

August 5, 1998

Steven Brenner
Court Reporter
3 Camino Oriente
Santa Fe, New Mexico 87505

Re: Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc. to Confirm Production, Case No. 11996

Dear ~~Steven:~~ Steve

Pursuant to our telephone conversation today, enclosed is the document that I think was entered as an exhibit. Please let me know if it was in fact entered and the number.

Thank you.

Sincerely,

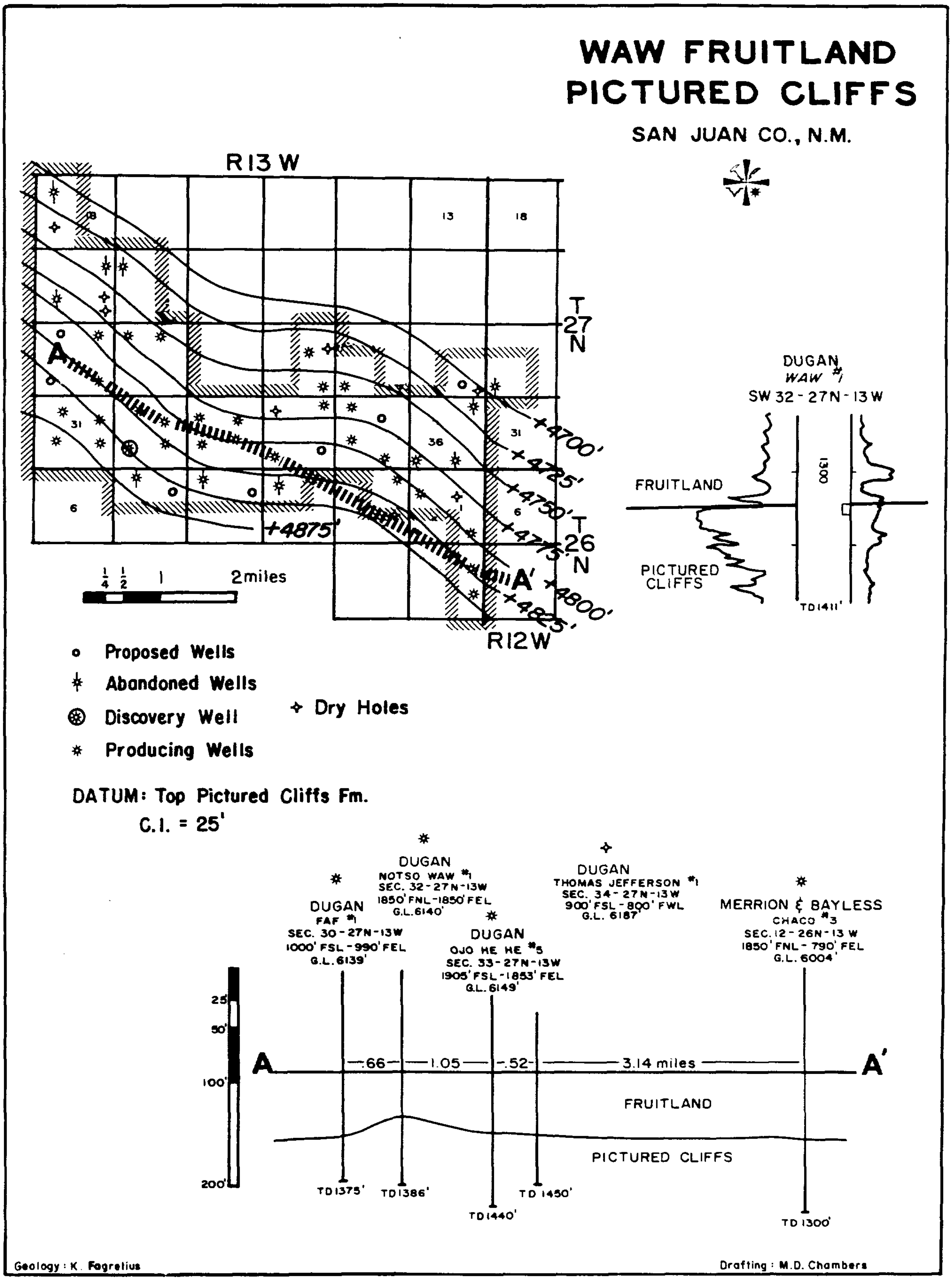
MILLER, STRATVERT & TORGERSON, P.A.

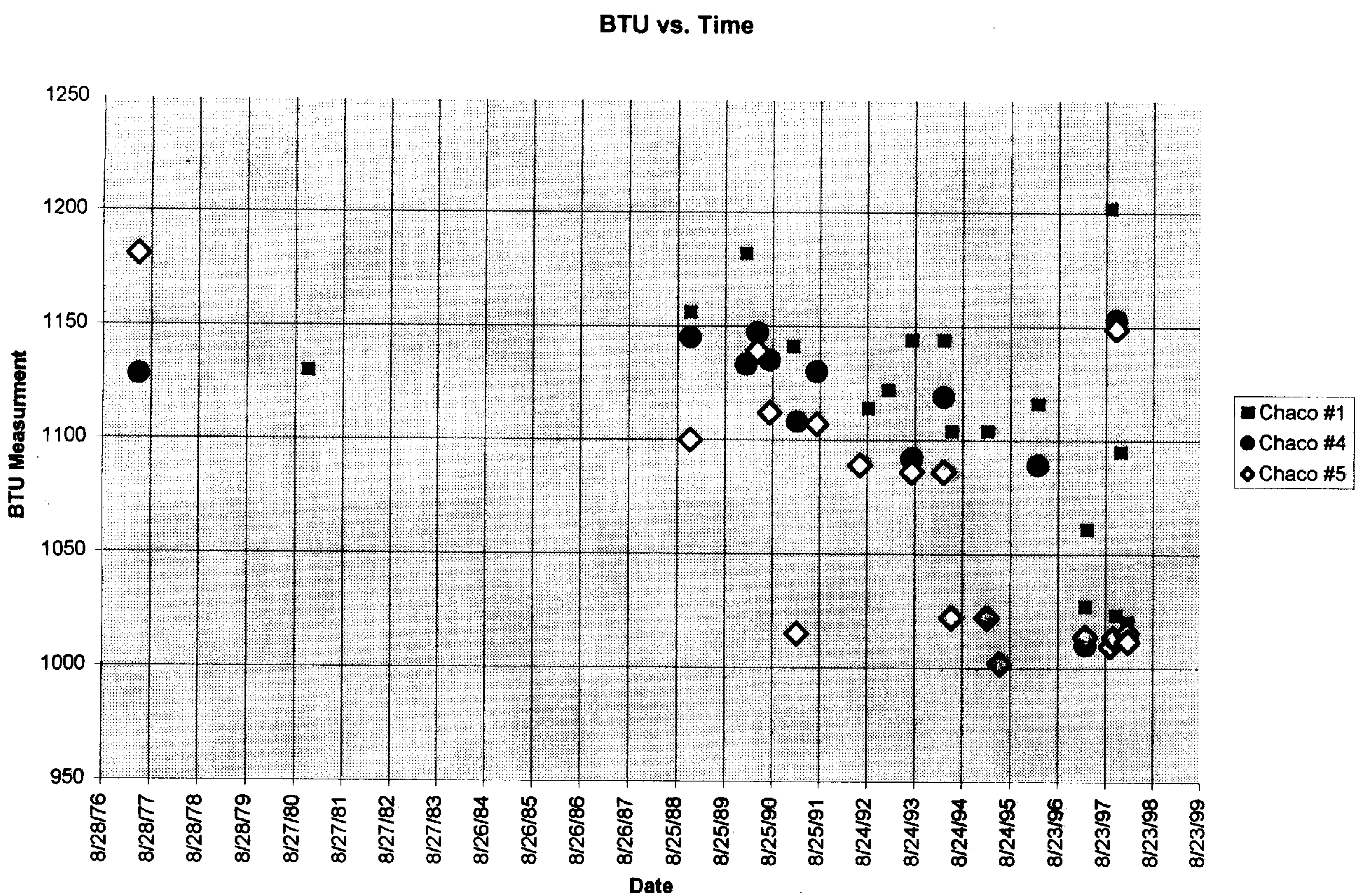
J. Scott Hall

J. Scott Hall

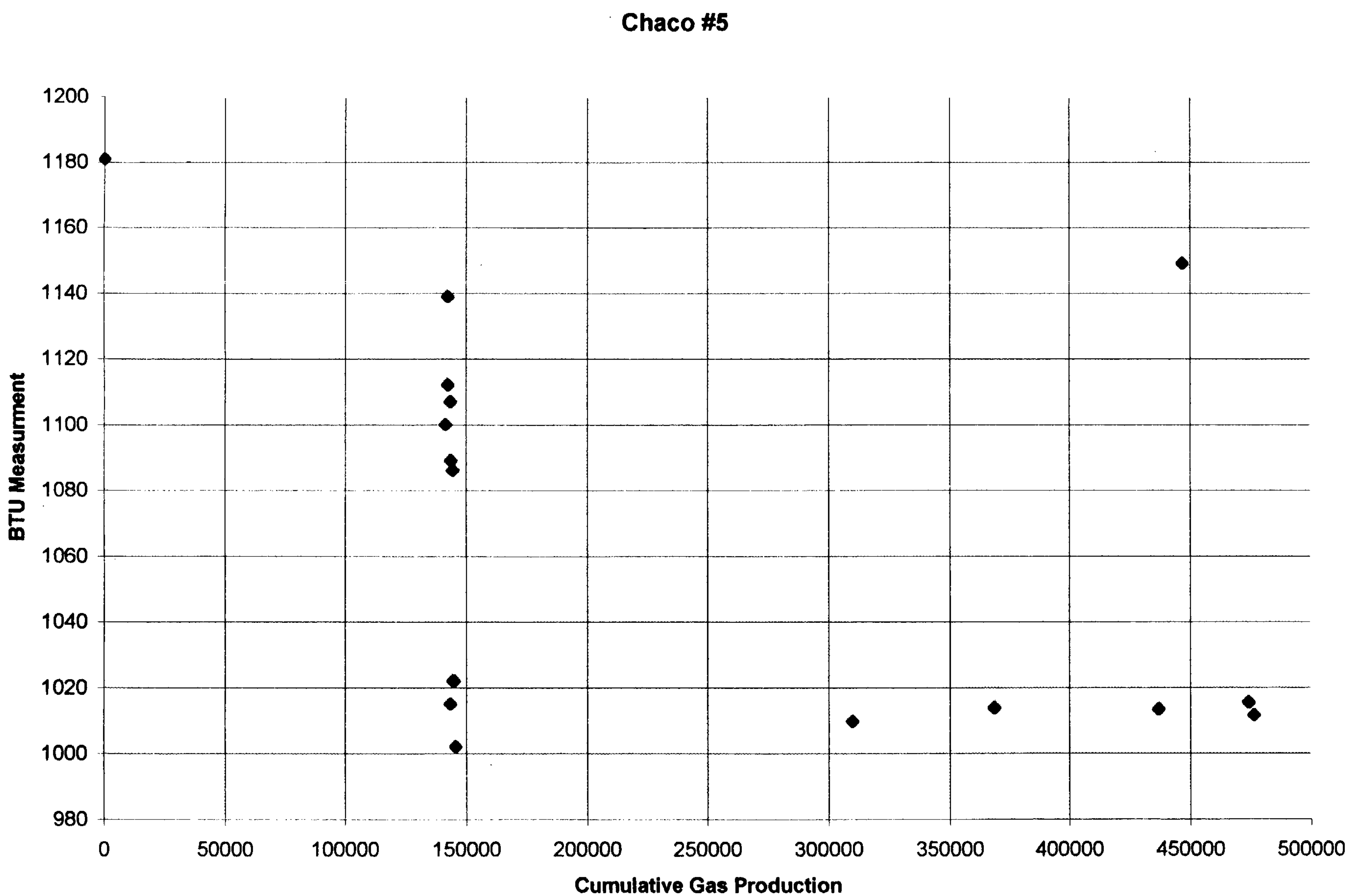
JSH/mg
Enclosure

Per phonecon w/ Scott Hall 8/19/98, this exhibit is part of Whiting/Maralex Ex. No. 47. It was not entered by Pendragon. — STB

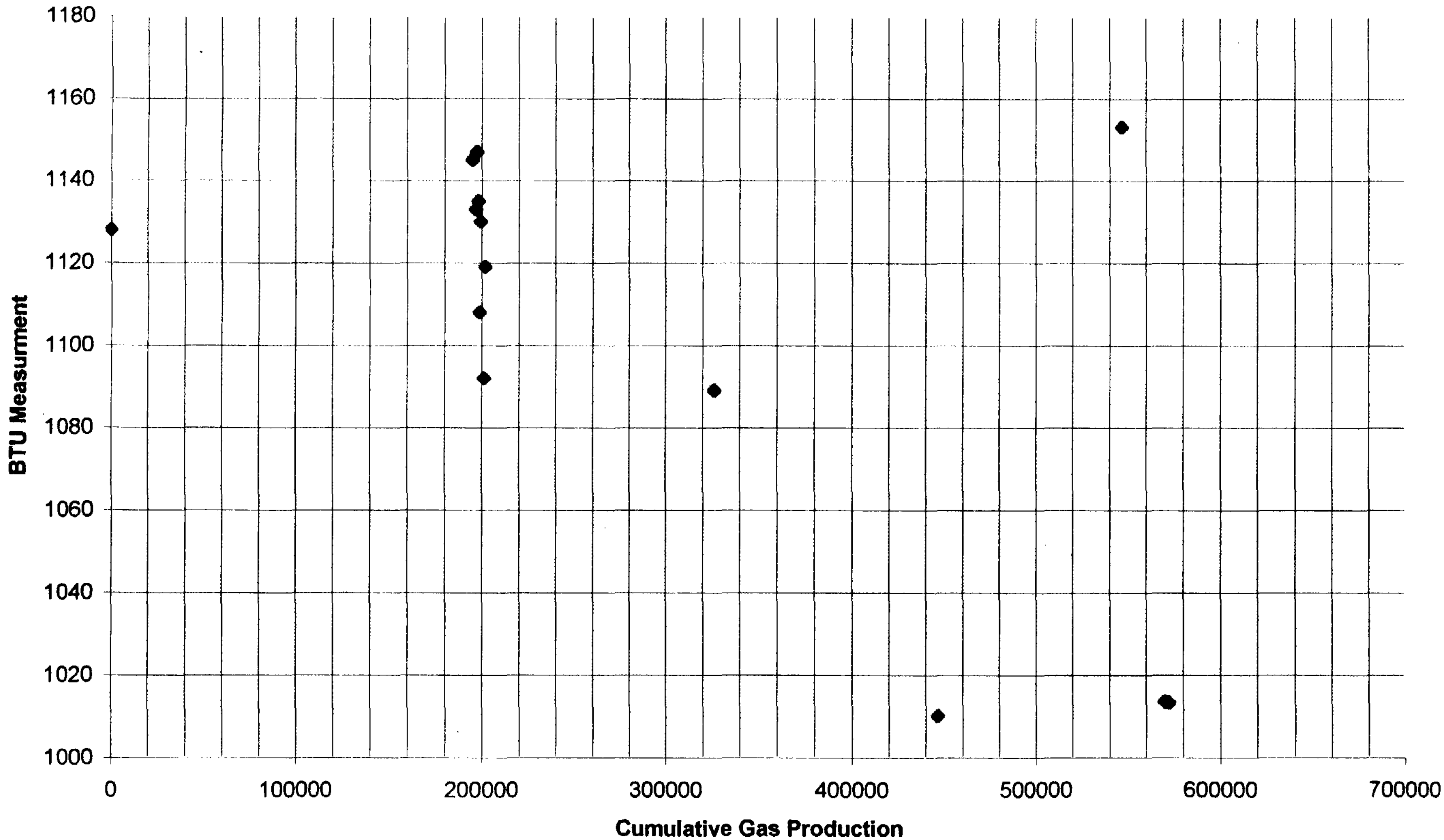

WAW FRUITLAND
PICTURED CLIFFS
SAN JUAN CO., N.M.
R13W
R12W
T 27 N
T 26 N
+4700'
+4725'
+4750'
+4775'
+4800'
+4825'
+4875'
A
A'
2 miles
DUGAN
WAW #1
SW 32-27N-13W
FRUITLAND
PICTURED CLIFFS
1300
TD 1411'
Proposed Wells
Abandoned Wells
Discovery Well
Producing Wells
Dry Holes
DATUM: Top Pictured Cliffs Fm.
C.I. = 25'
DUGAN
FAF #1
SEC. 30-27N-13W
1000' FSL-990' FEL
G.L. 6139'
DUGAN
NOTSO WAW #1
SEC. 32-27N-13W
1850' FNL-1850' FEL
G.L. 6140'
DUGAN
OJO HE HE #5
SEC. 33-27N-13W
1905' FSL-1853' FEL
G.L. 6149'
DUGAN
THOMAS JEFFERSON #1
SEC. 34-27N-13W
900' FSL-800' FWL
G.L. 6187'
MERRION & BAYLESS
CHACO #3
SEC. 12-26N-13W
1850' FNL-790' FEL
G.L. 6004'
.66
1.05
.52
3.14 miles
FRUITLAND
PICTURED CLIFFS
25'
50'
100'
200'
TD 1375'
TD 1386'
TD 1440'
TD 1450'
TD 1300'
Geology: K. Fagrelius
Drafting: M.D. Chambers


BTU vs. Time
BTU Measurment
1250
1200
1150
1100
1050
1000
950
8/28/76
8/28/77
8/28/78
8/28/79
8/27/80
8/27/81
8/27/82
8/27/83
8/26/84
8/26/85
8/26/86
8/26/87
8/25/88
8/25/89
8/25/90
8/25/91
8/24/92
8/24/93
8/24/94
8/24/95
8/23/96
8/23/97
8/23/98
8/23/99
Date
Chaco #1
Chaco #4
Chaco #5

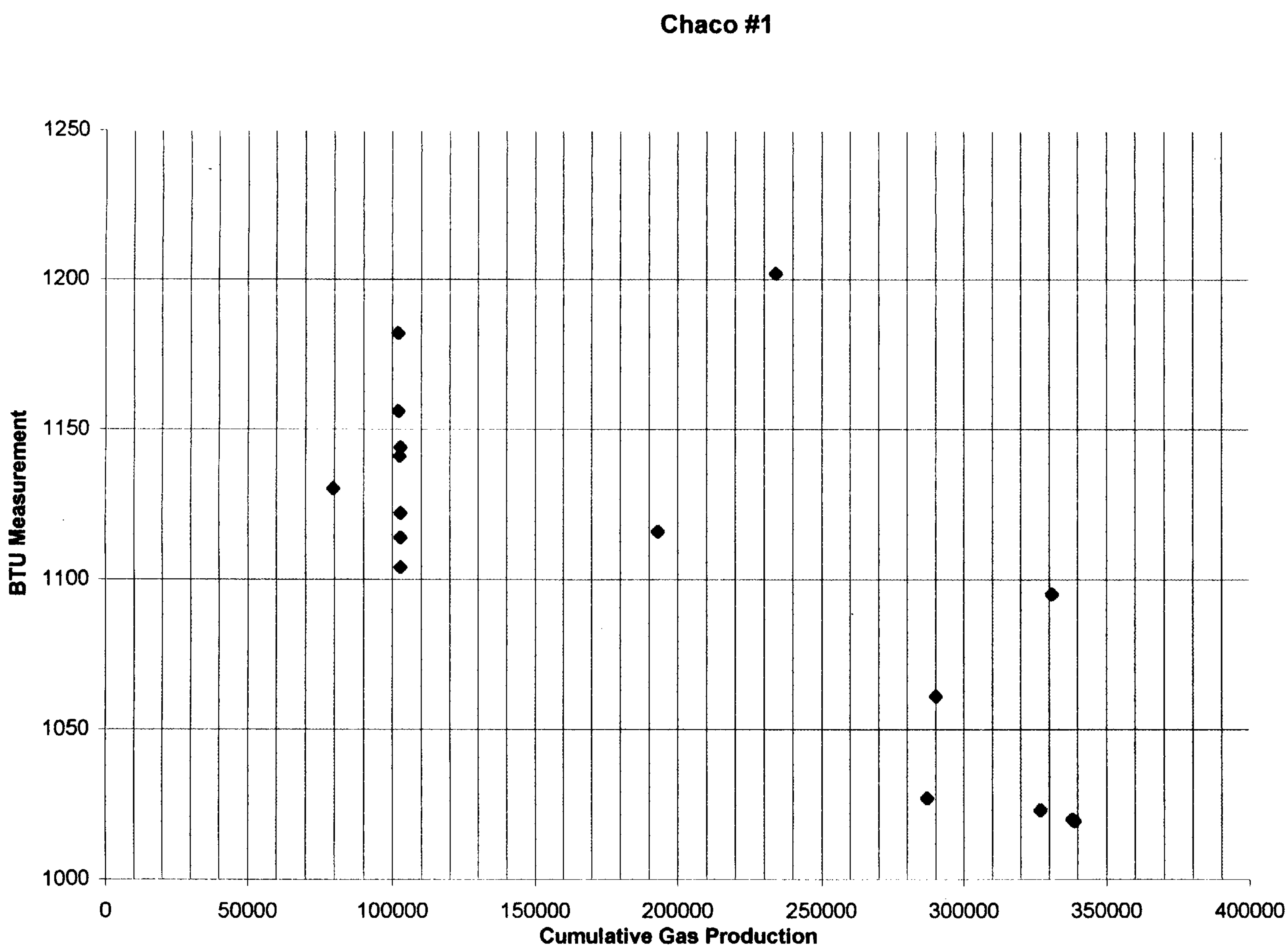
B.14


Chaco #5
BTU Measurment
1200
1180
1160
1140
1120
1100
1080
1060
1040
1020
1000
980
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000
Cumulative Gas Production

Chaco #4



BTU Measurment
1180
1160
1140
1120
1100
1080
1060
1040
1020
1000
0
100000
200000
300000
400000
500000
600000
700000
Cumulative Gas Production



Chaco #1
BTU Measurement
1250
1200
1150
1100
1050
1000
0
50000
100000
150000
200000
250000
300000
350000
400000
Cumulative Gas Production

Form 9-330
(Rev. 5-63)

5 USGS 2 Aztec O & G 1 File

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SUBMIT IN DUPLICATE* (See other instructions on reverse side)

Form approved. Budget Bureau

WELL COMPLETION OR RECOMPLETION REPORT AND LOG*

1a. TYPE OF WELL: OIL WELL ☐ GAS WELL ☒ (XX) DRY ☐ Other

b. TYPE OF COMPLETION: NEW WELL ☒ (XX) WORK OVER ☐ DEEP-EN ☐ PLUG BACK ☐ DIFF. RESVR. ☐ Other

2. NAME OF OPERATOR: **Dugan Production Corp.**

3. ADDRESS OF OPERATOR: **Box 234, Farmington, N. M.**

4. LOCATION OF WELL (*Report location clearly and in accordance with any State requirements*)*
At surface
At top prod. interval reported below **1500' fsl 950' fwl**
At total depth

5. LEASE DESIGNATION AND SERIAL NO.: **NM-[illegible]**

6. IF INDIAN, ALLOTTEE OR TRIBE NAME:

7. UNIT AGREEMENT NAME:

8. FARM OR LEASE NAME: **[illegible]**

9. WELL NO.: **1**

10. FIELD AND POOL, OR WILDCAT: **Wildcat**

11. SEC., T., R., M., OR BLOCK AND SURVEY OR AREA: **Sec. 32, T27N, R13W**

14. PERMIT NO.: | DATE ISSUED:

12. COUNTY OR PARISH: **San Juan** | 13. STATE: **N. M.**

RECEIVED JUL 14 1970 U.S. GEOLOGICAL SURVEY FARMINGTON, N. M.

JUL 20 '70

15. DATE SPUDDED	16. DATE T.D. REACHED	17. DATE COMPL. (*Ready to prod.*)	18. ELEVATIONS (DF, RKB, RT, GR, ETC.)*	19. ELEV. CASINGHEAD
5/19/70	5/25/70	6/20/70	6172' Gr.	---

20. TOTAL DEPTH, MD & TVD	21. PLUG, BACK T.D., MD & TVD	22. IF MULTIPLE COMPL., HOW MANY*	23. INTERVALS DRILLED BY	ROTARY TOOLS	CABLE TOOLS
1411'	1355'	Single	→	0-1411'	---

24. PRODUCING INTERVAL(S), OF THIS COMPLETION—TOP, BOTTOM, NAME (MD AND TVD)*: **Pictured Cliffs 1315' - 1400'**

25. WAS DIRECTIONAL SURVEY MADE: **Yes**

26. TYPE ELECTRIC AND OTHER LOGS RUN: **Schlumberger E.S.**

27. WAS WELL CORED: **No**

28. CASING RECORD (*Report all strings set in well*)

CASING SIZE	WEIGHT, LB./FT.	DEPTH SET (MD)	HOLE SIZE	CEMENTING RECORD	AMOUNT PULLED
5 1/2"	14#	14'	6 1/4"	5 sx.	
2 7/8"	6.5#	1401'	4 3/4"	50 sx.	---

RECEIVED JUL 15 1970 OIL CON. COM. DIST. 3

29. LINER RECORD

SIZE	TOP (MD)	BOTTOM (MD)	SACKS CEMENT*	SCREEN (MD)

30. TUBING RECORD

SIZE	DEPTH SET (MD)	PACKER SET (MD)
1 1/4"	1303'	

31. PERFORATION RECORD (*Interval, size and number*): **1325' - 1329'**

32. ACID, SHOT, FRACTURE, CEMENT SQUEEZE, ETC.

DEPTH INTERVAL (MD)	AMOUNT AND KIND OF MATERIAL USED
1325' - 29'	10,000# 20-40 sd. 360 bbls. water

33.* PRODUCTION

DATE FIRST PRODUCTION	PRODUCTION METHOD (*Flowing, gas lift, pumping—size and type of pump*)	WELL STATUS (*Producing or shut-in*)
---	Flowing	Shut In

DATE OF TEST	HOURS TESTED	CHOKE SIZE	PROD'N. FOR TEST PERIOD	OIL—BBL.	GAS—MCF.	WATER—BBL.	GAS-OIL RATIO
6/30/70	3 hrs.	5/8"	→	---	401	---	---

FLOW. TUBING PRESS.	CASING PRESSURE	CALCULATED 24-HOUR RATE	OIL—BBL.	GAS—MCF.	WATER—BBL.	OIL GRAVITY-API (CORR.)
35	197 SI	→	---	603 CAOF	---	---

34. DISPOSITION OF GAS (*Sold, used for fuel, vented, etc.*) | TEST WITNESSED BY

35. LIST OF ATTACHMENTS

36. I hereby certify that the foregoing and attached information is complete and correct as determined from all available records

SIGNED Original signed by T. A. Dugan TITLE **Engineer** DATE **7/13/70**

*(See Instructions and Spaces for Additional Data on Reverse Side)

A-1

General: This form is designed for submitting a complete and correct well completion report and log on all types of lands and leases to either a Federal agency or a State agenc or both, pursuant to applicable Federal and/or State laws and regulations. Any necessary special instructions concerning the use of this form and the number of copies to b submitted, particularly with regard to local, area, or regional procedures and practices, either are shown below or will be issued by, or may be obtained from, the local Federal and/or State office. See instructions on items 22 and 24, and 33, below regarding separate reports for separate completions.

If not filed prior to the time this summary record is submitted, copies of all currently available logs (drillers, geologists, sample and core analysis, all types electric, etc.), formation and pressure tests, and directional surveys, should be attached hereto, to the extent required by applicable Federal and/or State laws and regulations. All attachments should be listed on this form, see item 35.

Item 4: If there are no applicable State requirements, locations on Federal or Indian land should be described in accordance with Federal requirements. Consult local State or Federal office for specific instructions.

Item 18: Indicate which elevation is used as reference (where not otherwise shown) for depth measurements given in other spaces on this form and in any attachments.

Items 22 and 24: If this well is completed for separate production from more than one interval zone (multiple completion), so state in item 22, and in item 24 show the producing interval, or intervals, top(s), bottom(s) and name(s) (if any) for only the interval reported in item 33. Submit a separate report (page) on this form, adequately identified, for each additional interval to be separately produced, showing the additional data pertinent to such interval.

Item 29: *"Sacks Cement":* Attached supplemental records for this well should show the details of any multiple stage cementing and the location of the cementing tool.

Item 33: Submit a separate completion report on this form for each interval to be separately produced. (See instruction for items 22 and 24 above.)

37. SUMMARY OF POROUS ZONES:
SHOW ALL IMPORTANT ZONES OF POROSITY AND CONTENTS THEREOF; CORED INTERVALS; AND ALL DRILL-STEM TESTS, INCLUDING DEPTH INTERVAL TESTED, CUSHION USED, TIME TOOL OPEN, FLOWING AND SHUT-IN PRESSURES, AND RECOVERIES

FORMATION	TOP	BOTTOM	DESCRIPTION, CONTENTS, ETC.

38. GEOLOGIC MARKERS

NAME	TOP: MEAS. DEPTH	TOP: TRUE VERT. DEPTH
LOG TOPS		
Pictured Cliffs	1317'	
Total Depth	1411'	

MILLER, STRATVERT & TORGERSON, P. A.
LAW OFFICES

RANNE B. MILLER
ALAN C. TORGERSON
ALICE TOMLINSON LORENZ
GREGORY W. CHASE
ALAN KONRAD
LYMAN G. SANDY
STEPHEN M. WILLIAMS
STEPHAN M. VIDMAR
ROBERT C. GUTIERREZ
SETH V. BINGHAM
JAMES B. COLLINS
TIMOTHY R. BRIGGS
RUDOLPH LUCERO
DEBORAH A. SOLOVE
GARY L. GORDON
LAWRENCE R. WHITE
SHARON P. GROSS
VIRGINIA ANDERMAN
MARTE D. LIGHTSTONE
J. SCOTT HALL
THOMAS R. MACK
TERRI L. SAUER

JOEL T. NEWTON
JUDITH K. NAKAMURA
THOMAS M. DOMME
RUTH O. PREGENZER
JEFFREY E. JONES
MANUEL I. ARRIETA
ROBIN A. GOBLE
JAMES R. WOOD
DANA M. KYLE
KIRK R. ALLEN
RUTH M. FUESS
JAMES B. GREEN
KYLE M. FINCH
H. BROOK LASKEY
KATHERINE W. HALL
FRED SCHILLER
MICHAEL I. GARCIA
LARA L. WHITE
PAULA G. MAYNES
DEAN B. CROSS

WILLIAM K. STRATVERT, COUNSEL
PAUL W. ROBINSON, COUNSEL
RALPH WM. RICHARDS, COUNSEL
ROSS B. PERKAL, COUNSEL

ALBUQUERQUE
500 MARQUETTE N.W. SUITE 1100
POST OFFICE BOX 25687
ALBUQUERQUE, NM 87125-0687
TELEPHONE: (505) 842-1950
FACSIMILE: (505) 243-4408

LAS CRUCES
500 S. MAIN ST., SUITE 800
POST OFFICE BOX 1209
LAS CRUCES, NM 88004-1209
TELEPHONE: (505) 523-2481
FACSIMILE: (505) 526-2215

FARMINGTON
300 WEST ARRINGTON
POST OFFICE BOX 869
FARMINGTON, NM 87499-0869
TELEPHONE: (505) 326-4521
FACSIMILE: (505) 325-5474

SANTA FE
150 WASHINGTON AVE., SUITE 300
POST OFFICE BOX 1986
SANTA FE, NM 87504-1986
TELEPHONE: (505) 989-9614
FACSIMILE: (505) 989-9857

PLEASE REPLY TO SANTA FE

August 3, 1998

David Catanach
N.M.O. C.D
P.O. Box 6429
Santa Fe, New Mexico 87505

Re: NMOCD Case 11996; Application of Pendragon Energy Partners, Inc. In J.K. Edwards Associates, Inc., San Juan County New Mexico

Dear Mr. Catanach:

Enclosed is the original and two copies of the Affidavit of Notice which I have marked as Pendragon exhibit 1 (one). I neglected to offer this exhibit into evidence at the hearing on Thursday and would accordingly ask that the same be made part of the record in this matter.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON,P.A.

J. Scott Hall

JSH/eam
Enclosures
cc: Steve Brenner (w/enclos.)
Gene Gallegos (w/enclos.)
Rand Carroll (w/o enclos.)

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES
DEPARTMENT
OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC. and J.K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO.

CASE NO. 11996

AFFIDAVIT OF NOTICE

STATE OF NEW MEXICO)
) ss.
COUNTY OF SANTA FE)

J. SCOTT HALL, attorney for and authorized representative of Pendragon Energy Partners, Inc., the Applicant herein, being first duly sworn, upon oath, states that the Applicant has caused to be conducted a good faith diligent effort to find the correct addresses of all interested persons entitled to receive notice, as shown by Exhibit "A" attached hereto, and that pursuant to Rule 1207, notice has been given by certified mail at the correct address provided by such rule.

J. Scott Hall

J. SCOTT HALL

SUBSCRIBED AND SWORN to before me this 27th day of July, 1998 by J. Scott Hall.

Michelle M. [illegible]

NOTARY PUBLIC

My Commission Expires:

6-18-2001

NMOCD CASE #11996
PENDRAGON ENERGY
EXHIBIT

1

EXHIBIT A

Maralex Resources
Post Office Box 338
Ignacio, Colorado 81157

Whiting Petroleum Corporation
1700 Broadway, Suite 2300
Denver, Colorado 80290

Is your RETURN ADDRESS completed on the reverse side?

SENDER:
- Complete items 1 and/or 2 for additional services.
- Complete items 3, 4a, and 4b.
- Print your name and address on the reverse of this form so that we can return this card to you.
- Attach this form to the front of the mailpiece, or on the back if space does not permit.
- Write *"Return Receipt Requested"* on the mailpiece below the article number.
- The Return Receipt will show to whom the article was delivered and the date delivered.

I also wish to receive the following services (for an extra fee):

1. ☐ Addressee's Address
2. ☐ Restricted Delivery

Consult postmaster for fee.

3. Article Addressed to:
Mardley Resources
P.O.Box 338
Ignacio, Colo
81157

4a. Article Number
Z 432 550 168

4b. Service Type
☒ Registered ☒ Certified
☐ Express Mail ☐ Insured
☒ Return Receipt for Merchandise ☐ COD

7. Date of Delivery
6/8/98

5. Received By: *(Print Name)*
SUE C HERRERA

8. Addressee's Address *(Only if requested and fee is paid)*

6. Signature: *(Addressee or Agent)*
X [illegible]

PS Form **3811,** December 1994

Domestic Return Receipt

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Denver, CO 80290

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ENERGY, MINERALS AND NATURAL RESOURCES
DEPARTMENT
OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC. and J.K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO.

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NOTARY PUBLIC

My Commission Expires:
6-18-2001

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PENDRAGON ENERGY
EXHIBIT
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J. SCOTT HALL

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Michelle M. [illegible]
NOTARY PUBLIC

My Commission Expires:
6-18-2001

NMOCD CASE #11996
PENDRAGON ENERGY
EXHIBIT
1

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X Sue C Herrera

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X [illegible signature]

PS Form **3811**, December 1994 — Domestic Return Receipt

Thank you for using Return Receipt Service.

NEW MEXICO ENERGY, MINERALS
& NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION
2040 South Pacheco Street
Santa Fe, New Mexico 87505
(505) 827-7131

July 8, 1998

J. Scott Hall
Miller, Stratvert & Torgerson, P.A.
P. O. Box 1986
Santa Fe, NM 87504-1986

Attorneys for Pendragon Energy Partners, Inc. et. al

J.E. Gallegos
Michael J. Condon
Gallegos Law Firm
460 St. Michael's Drive
Santa Fe, NM 87505

Attorneys for Whiting Petroleum Corporation et. al

RE: OCD Case No. 11996--Application of Pendragon Energy Partners, Inc.

Gentlemen:

This will confirm that this case is set for a special hearing date of Tuesday, July 28 and, if needed, Wednesday, July 29. If the discovery issues between the parties have not yet been resolved, please notify the Division.

If you have any questions, please feel free to call me at 827-8156.

Sincerely,

Rand Carroll
Legal Counsel

c: David Catanach, OCD Hearing Examiner

GALLEGOS LAW FIRM

A Professional Corporation

460 St. Michael's Drive
Building 300
Santa Fe, New Mexico 87505
Telephone No. 505-983-6686
Telefax No. 505-986-1367
Telefax No. 505-986-0741

MICHAEL J. CONDON

August 13, 1998
(Our File No. 98-266.00)

VIA HAND DELIVERY
Rand Carroll, Esq.
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

VIA HAND DELIVERY
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

Gentlemen:

I am submitting concurrently with the submission of our proposed forms of Order in this matter numerous documents and data requested during the course of the hearing in this case on July 28-30, 1998. These items include the following:

1. Charts showing the Initial Gas Formation Volume Factors and Gas Recovery Facts used by Mr. Robinson in support of his analysis;

2. Three production decline curves from Maralex on various coal seam wells which exhibit smooth incline curves;

3. Exhibit titled Water/Gas Ratios, Pendragon v. Whiting Wells, which utilizes actual daily rates for water production from the Pendragon wells, rather than the average daily production figures utilized by Mr. O'Hare in his testimony at the hearing;

4. A copy of the production information from the Whiting coal wells used to calculate the water/gas ratios on those wells;

5. Mr. O'Hare's analysis on the Merrion wells performed in 1992 to confirm that the PC formation did not contain substantial reserves;

6. Materials on the PROMAT and FRACPRO software simulation programs;

7. Graphs depicting daily production data on the Whiting coal wells from January 1, 1998 through July, 1998;

8. The written analysis of Mr. Williams' volumetric calculations for the PC formation;

9. Corrected Nolte plots from Mr. Robinson and Holditch; and

10. Graphs demonstrating the most recent production data from the Whiting coal wells which continues to demonstrate communication.

11. Mr. Williams' explanation for the downturn in production on Whiting wells on June 3, 1998.

I believe this encompasses all documents and data requested either by the Division or Mr. Hall during the course of the hearing. If there is anything else you need, please feel free to contact me.

Very truly yours,

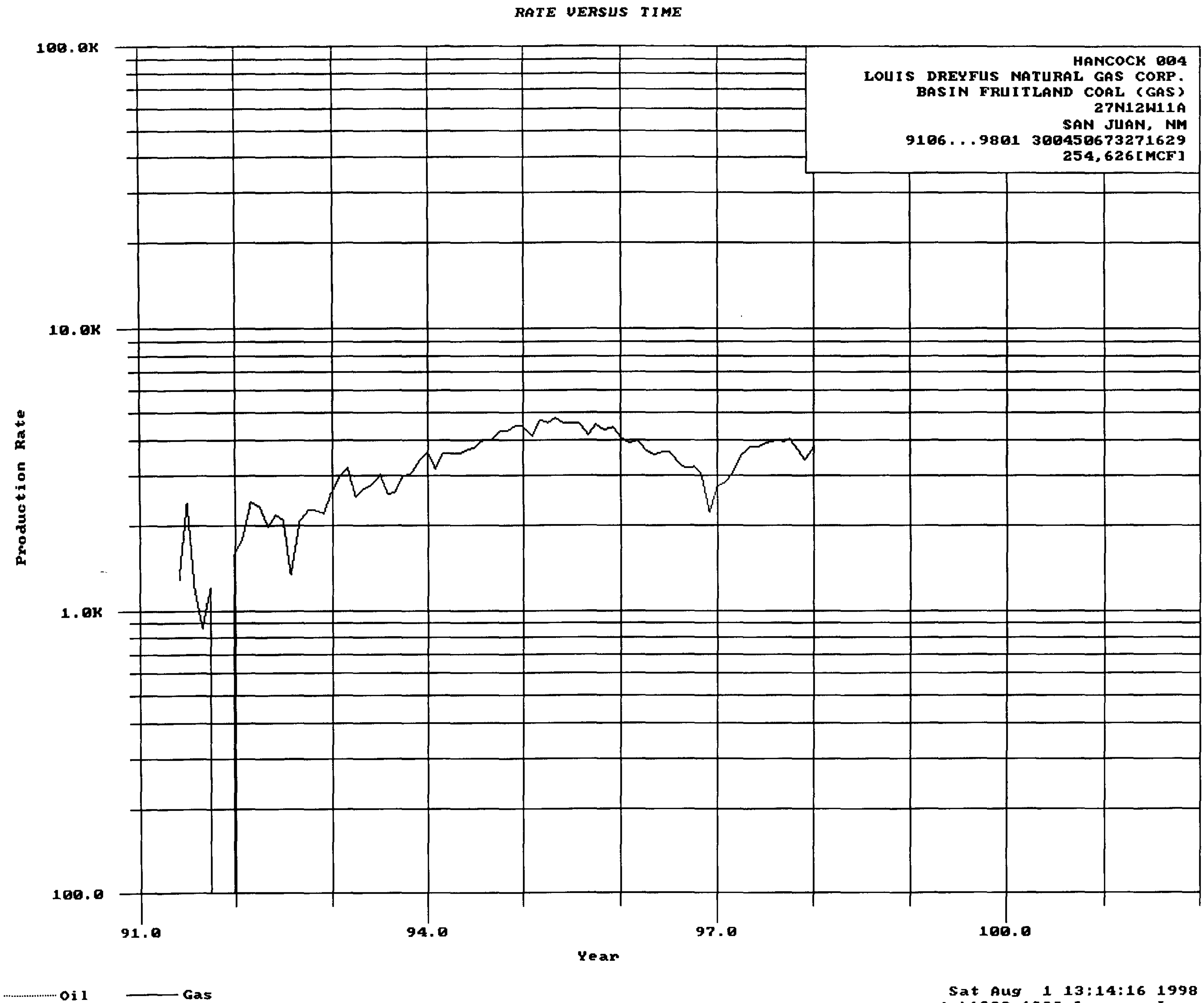
GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
Enclosures
fxc: John Hazlett
Mickey O'Hare
ioc: J.E. Gallegos

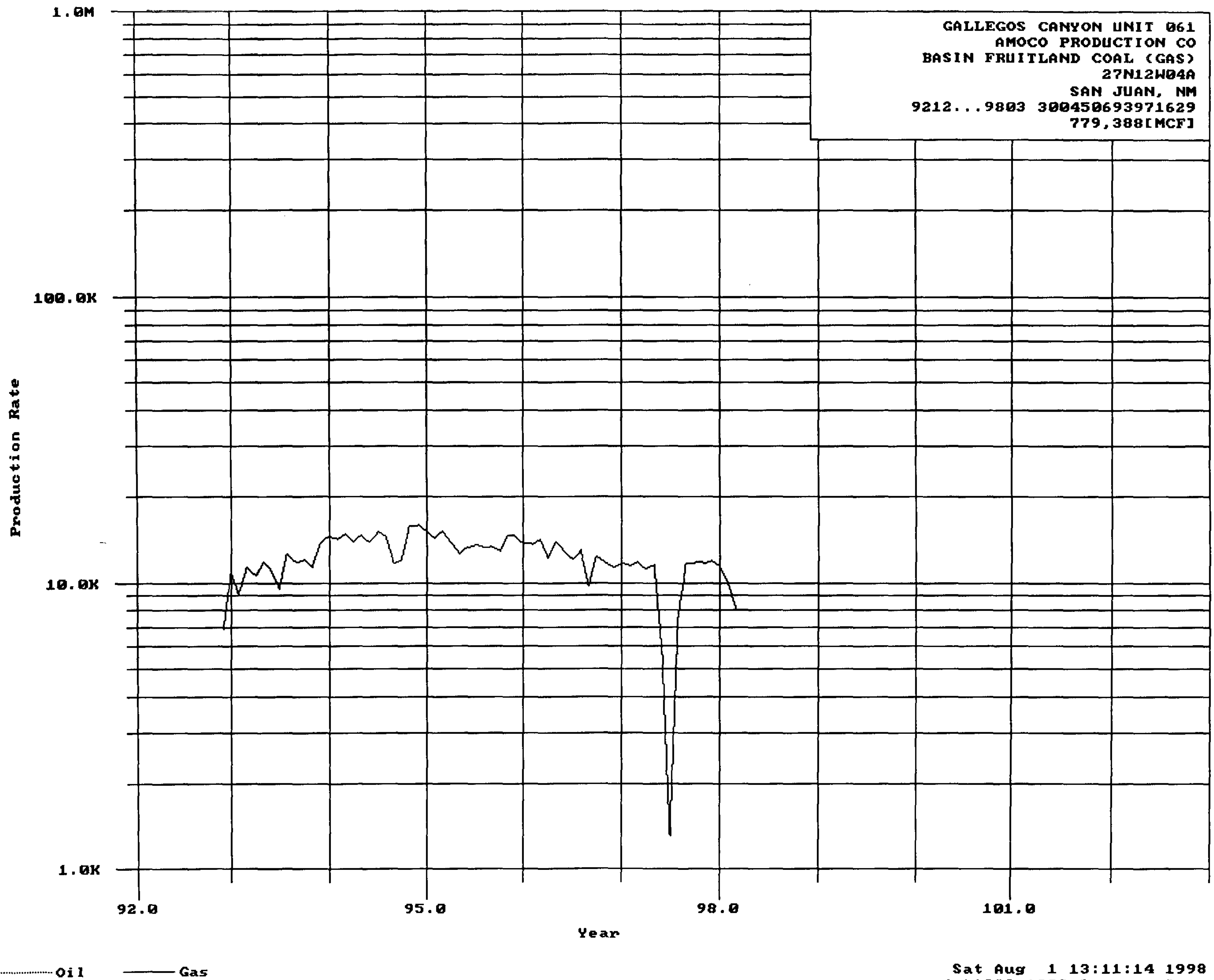
Well	Initial Gas Formation Volume Factor (Res. bbls/Mscf)
Chaco 1	10.41
Chaco 2R	10.86
Chaco 4	10.90
Chaco 5	10.88

Gas Recovery Factors		
Well	Pre-frac Recovery Efficiency (%)	Post-frac Recovery Efficiency (%)
Chaco 1	55	203
Chaco 2R	61	117
Chaco 4	75	220
Chaco 5	73	255

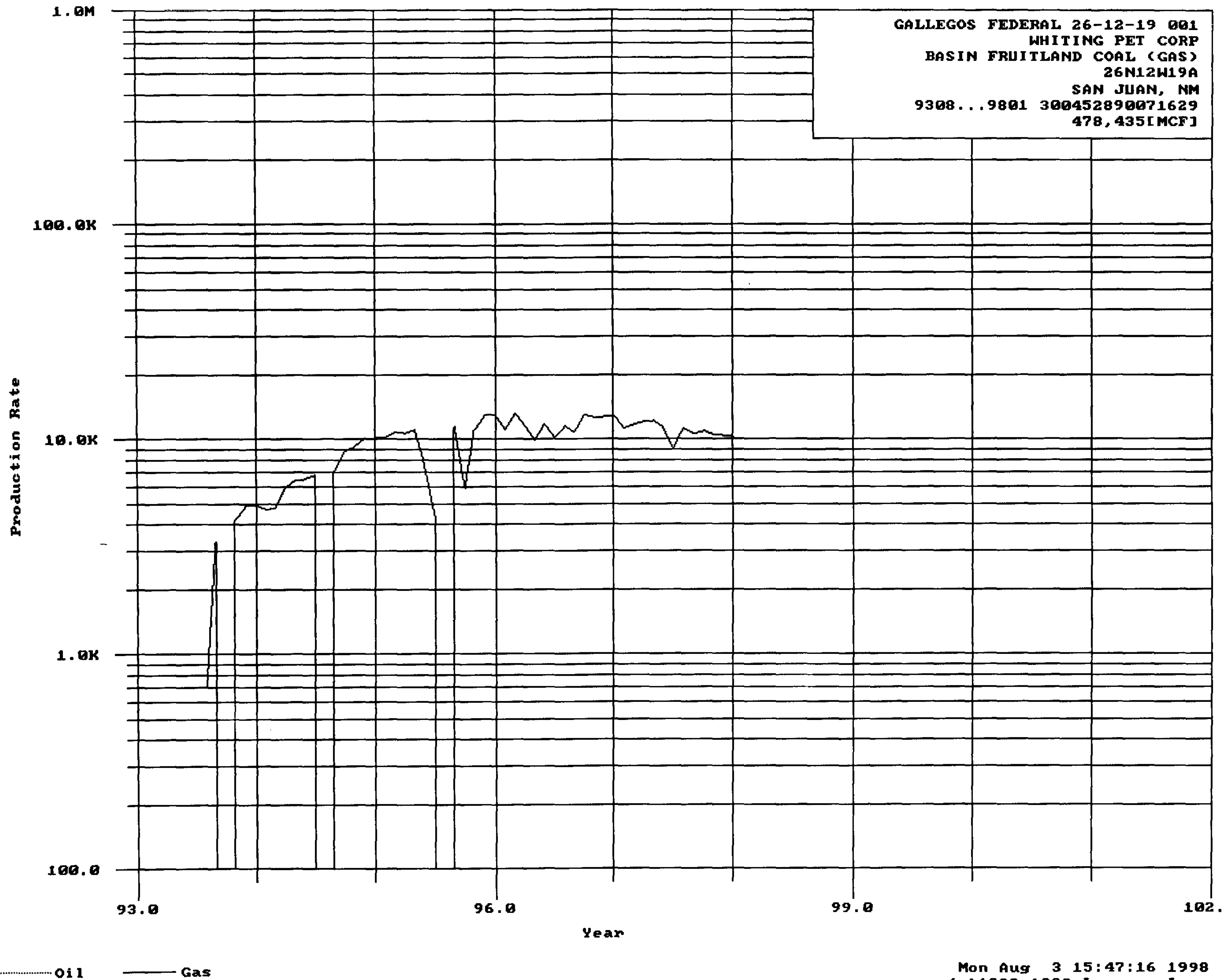


Sat Aug 1 13:14:16 1998

RATE VERSUS TIME



RATE VERSUS TIME



Mon Aug 3 15:47:16 1998

WATER/GAS RATIOS
PENDRAGON VS WHITING WELLS

DATE	PENDRAGON WELL	WATER/GAS RATIO*	WHITING OFFSET	WATER/GAS RATIO	NOTES
2/98	LANSDALE FED	0.03756	G.F. 26-12-7 #1	0.01542	160-acre offsets.
3/98**	LANSDALE FED	0.08502	G.F. 26-12-7 #1	0.01794	Lansdale well is
4/98	LANSDALE FED	0.06306	G.F. 26-12-7 #1	0.01451	completed illegally in
5/98	LANSDALE FED	0.09859	G.F. 26-12-7 #1	0.01341	coals.
4/98	CHACO #1	0.11594	G.F. 26-12-7 #1	0.01451	
5/98	CHACO #1	0.08610	G.F. 26-12-7 #1	0.01341	160-acre offset
7/96	CHACO #2R	1.00000	G.F. 26-12-7 #1	0.03317	This point is relatively
9/96	CHACO #2R	0.30822	G.F. 26-12-7 #1	0.03062	early in the dewatering
10/96	CHACO #2R	0.18235	G.F. 26-12-7 #1	0.03488	stage of the 2R well and
12/96	CHACO #2R	0.08824	G.F. 26-12-7 #1	0.02996	should be the most
2/98	CHACO #2R	0.09150	G.F. 26-12-7 #1	0.01542	representative comparison
3/98	CHACO #2R	0.10072	G.F. 26-12-7 #1	0.01794	of relative saturations.
4/98	CHACO #2R	0.10638	G.F. 26-12-7 #1	0.01451	Wells are within the
5/98	CHACO #2R	0.11309	G.F. 26-12-7 #1	0.01341	same 40-acre slot.
2/98	CHACO #4	0.02193	G.F. 26-12-6 #2	0.05816	Wells shown are 40-
			G.F. 26-13-12 #1	0.06240	acre offsets. Extensive
3/98	CHACO #4	0.01299	G.F. 26-12-6 #2	0.05397	dewatering has occurred
			G.F. 26-13-12 #1	0.06716	in this area prior to this
4/98	CHACO #4	0.04186	G.F. 26-12-6 #2	0.05084	time.
			G.F. 26-13-12 #1	0.04876	Chaco #4 is 160-acre
5/98	CHACO #4	0.04453	G.F. 26-12-6 #2	0.04183	offset to G.F. 26-12-7
			G.F. 26-13-12 #1	0.04576	#1 (see above).
3/98	CHACO #5	0.00424	G.F. 26-12-6 #2	see above	40-acre offsets. See
			G.F. 26-13-12 #1	see above	comments on Chaco #4

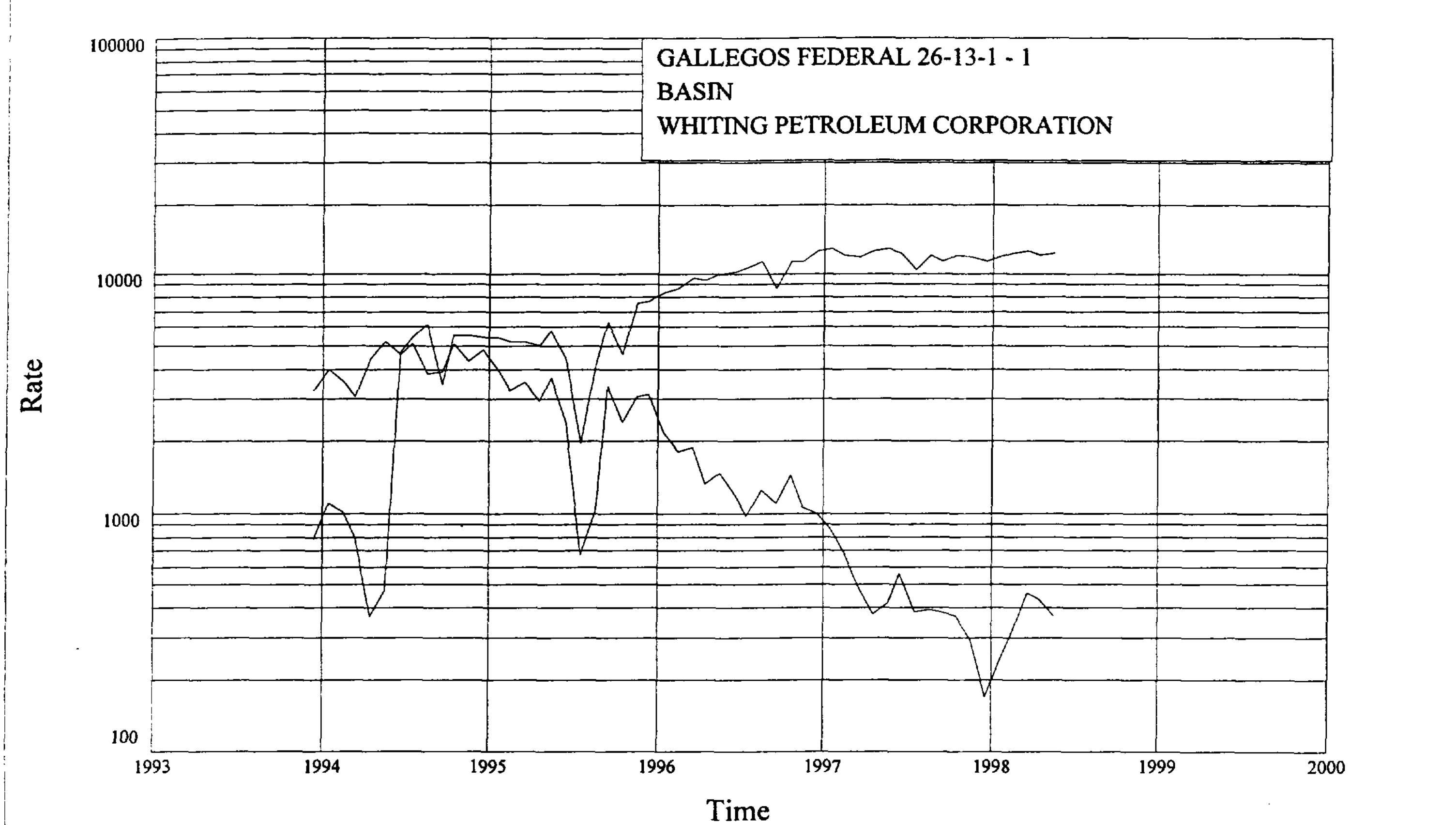
* This number is calculated from the water and gas volumes provided on Exhibit 57.
The Whiting numbers are calculated from production volumes reported to the proper regulatory agency for the particular month cited.

** This Pendragon ratio was calculated from the amount of water hauled as shown on Sunco Trucking Co Invoice No. 27187. Had the number been calculated in the same manner as the rest of the water ratio numbers it would have been 0.03804, which indicates that the pumper reported water volumes are most likely very low compared to actual production.

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Lease Name:	GALLEGOS FEDERAL 26-13-1 (1)	Field Name:	BASIN
County, ST:	SAN JUAN, NM	Operator:	WHITING PETROLEUM CORPORATION
Location:	26N-13W-1		



Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
01/1993	0	0	0	0	0	0	0
02/1993	0	0	0	0	0	0	0
03/1993	0	0	0	0	0	0	0
04/1993	0	0	0	0	0	0	0
05/1993	0	0	0	0	0	0	0
06/1993	0	0	0	0	0	0	0
07/1993	0	0	0	0	0	0	0
08/1993	0	0	0	0	0	0	0
09/1993	0	0	0	0	0	0	0
10/1993	0	0	0	0	0	0	0
11/1993	0	0	0	0	0	0	0
12/1993	0	769	3,238	1	0	769	3,238
01/1994	0	1,111	3,988	1	0	1,880	7,226
02/1994	0	1,019	3,528	1	0	2,899	10,754
03/1994	0	793	3,057	1	0	3,692	13,811
04/1994	0	372	4,413	1	0	4,064	18,224
05/1994	0	476	5,278	1	0	4,540	23,502
06/1994	0	4,700	4,653	1	0	9,240	28,155
07/1994	0	5,393	5,098	1	0	14,633	33,253
08/1994	0	6,160	3,881	0	0	20,793	37,134
09/1994	0	3,452	3,955	1	0	24,245	41,089
10/1994	0	5,606	5,115	1	0	29,851	46,204
11/1994	0	5,559	4,358	1	0	35,410	50,562

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
12/1994	0	5,458	4,769	1	0	40,868	55,331
01/1995	0	5,390	4,028	1	0	46,258	59,359
02/1995	0	5,245	3,272	1	0	51,503	62,631
03/1995	0	5,175	3,539	1	0	56,678	66,170
04/1995	0	4,990	2,922	1	0	61,668	69,092
05/1995	0	5,766	3,666	1	0	67,434	72,758
06/1995	0	4,425	2,399	1	0	71,859	75,157
07/1995	0	1,959	671	1	0	73,818	75,828
08/1995	0	4,202	1,004	0	0	78,020	76,832
09/1995	0	6,251	3,425	1	0	84,271	80,257
10/1995	0	4,593	2,400	0	0	88,864	82,657
11/1995	0	7,584	3,076	0	0	96,448	85,733
12/1995	0	7,767	3,148	0	0	104,215	88,881
01/1996	0	8,421	2,155	1	0	112,636	91,036
02/1996	0	8,666	1,809	1	0	121,302	92,845
03/1996	0	9,706	1,888	1	0	131,008	94,733
04/1996	0	9,496	1,320	1	0	140,504	96,053
05/1996	0	10,065	1,472	1	0	150,569	97,525
06/1996	0	10,212	1,204	1	0	160,781	98,729
07/1996	0	10,752	965	1	0	171,533	99,694
08/1996	0	11,398	1,254	1	0	182,931	100,948
09/1996	0	8,746	1,097	1	0	191,677	102,045
10/1996	0	11,498	1,440	1	0	203,175	103,485
11/1996	0	11,409	1,064	1	0	214,584	104,549
12/1996	0	12,523	992	1	0	227,107	105,541
01/1997	0	12,968	838	1	0	240,075	106,379
02/1997	0	12,177	688	1	0	252,252	107,067
03/1997	0	11,938	490	1	0	264,190	107,557
04/1997	0	12,528	377	1	0	276,718	107,934
05/1997	0	12,883	417	1	0	289,601	108,351
06/1997	0	12,308	559	1	0	301,909	108,910
07/1997	0	10,392	384	1	0	312,301	109,294
08/1997	0	12,161	394	0	0	324,462	109,688
09/1997	0	11,383	387	0	0	335,845	110,075
10/1997	0	12,170	371	0	0	348,015	110,446
11/1997	0	11,940	298	0	0	359,955	110,744
12/1997	0	11,343	172	0	0	371,298	110,916
01/1998	0	11,907	232	0	0	383,205	111,148
02/1998	0	12,266	321	0	0	395,471	111,469
03/1998	0	12,712	465	0	0	408,183	111,934
04/1998	0	12,216	438	0	0	420,399	112,372
05/1998	0	12,333	370	0	0	432,732	112,742
06/1998	0	0	0	0	0	432,732	112,742
07/1998	0	0	0	0	0	432,732	112,742
08/1998	0	0	0	0	0	432,732	112,742
09/1998	0	0	0	0	0	432,732	112,742
10/1998	0	0	0	0	0	432,732	112,742
11/1998	0	0	0	0	0	432,732	112,742
12/1998	0	0	0	0	0	432,732	112,742
Total:	0	432,732	112,742				

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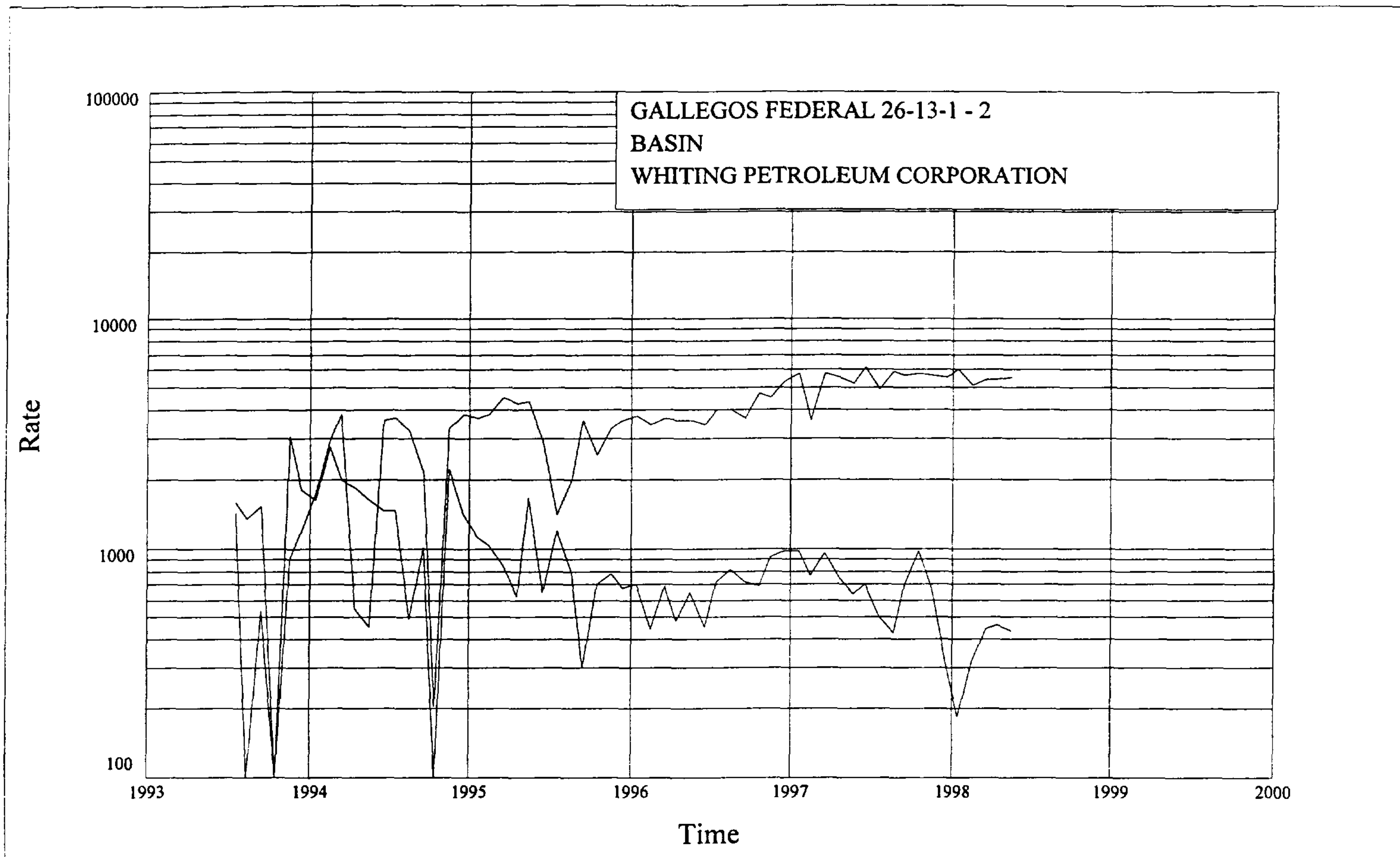
Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Lease Name:	GALLEGOS FEDERAL 26-13-1 (2)	Field Name:	BASIN
County, ST:	SAN JUAN, NM	Operator:	WHITING PETROLEUM CORPORATION
Location:	26N-13W-1		



Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
01/1993	0	0	0	0	0	0	0
02/1993	0	0	0	0	0	0	0
03/1993	0	0	0	0	0	0	0
04/1993	0	0	0	0	0	0	0
05/1993	0	0	0	0	0	0	0
06/1993	0	0	0	0	0	0	0
07/1993	0	1,595	1,441	1	0	1,595	1,441
08/1993	0	1,347	16	1	0	2,942	1,457
09/1993	0	1,517	532	1	0	4,459	1,989
10/1993	0	0	0	0	0	4,459	1,989
11/1993	0	890	3,041	1	0	5,349	5,030
12/1993	0	1,184	1,784	1	0	6,533	6,814
01/1994	0	1,740	1,623	1	0	8,273	8,437
02/1994	0	2,957	2,766	1	0	11,230	11,203
03/1994	0	3,810	1,996	1	0	15,040	13,199
04/1994	0	546	1,825	1	0	15,586	15,024
05/1994	0	459	1,637	1	0	16,045	16,661
06/1994	0	3,633	1,469	1	0	19,678	18,130
07/1994	0	3,666	1,471	1	0	23,344	19,601
08/1994	0	3,291	491	0	0	26,635	20,092
09/1994	0	2,104	1,024	1	0	28,739	21,116
10/1994	0	206	0	1	0	28,945	21,116
11/1994	0	3,316	2,229	1	0	32,261	23,345

Date: 6/19/1998 Time: [illegible]

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
12/1994	0	3,836	1,394	1	0	36,097	24,739
01/1995	0	3,698	1,125	1	0	39,795	25,864
02/1995	0	3,871	1,032	1	0	43,666	26,896
03/1995	0	4,528	847	1	0	48,194	27,743
04/1995	0	4,278	624	1	0	52,472	28,367
05/1995	0	4,338	1,647	1	0	56,810	30,014
06/1995	0	2,923	641	1	0	59,733	30,655
07/1995	0	1,421	1,197	1	0	61,154	31,852
08/1995	0	1,956	793	0	0	63,110	32,645
09/1995	0	3,630	303	1	0	66,740	32,948
10/1995	0	2,559	705	0	0	69,299	33,653
11/1995	0	3,343	780	0	0	72,642	34,433
12/1995	0	3,620	671	0	0	76,262	35,104
01/1996	0	3,739	702	1	0	80,001	35,806
02/1996	0	3,466	444	1	0	83,467	36,250
03/1996	0	3,665	689	1	0	87,132	36,939
04/1996	0	3,631	488	1	0	90,763	37,427
05/1996	0	3,619	644	1	0	94,382	38,071
06/1996	0	3,460	460	1	0	97,842	38,531
07/1996	0	4,013	714	1	0	101,855	39,245
08/1996	0	3,976	810	1	0	105,831	40,055
09/1996	0	3,657	721	1	0	109,488	40,776
10/1996	0	4,675	692	1	0	114,163	41,468
11/1996	0	4,562	906	1	0	118,725	42,374
12/1996	0	5,376	971	1	0	124,101	43,345
01/1997	0	5,819	976	1	0	129,920	44,321
02/1997	0	3,634	763	1	0	133,554	45,084
03/1997	0	5,772	944	1	0	139,326	46,028
04/1997	0	5,524	753	1	0	144,850	46,781
05/1997	0	5,203	636	1	0	150,053	47,417
06/1997	0	6,171	702	1	0	156,224	48,119
07/1997	0	4,951	510	1	0	161,175	48,629
08/1997	0	5,912	430	0	0	167,087	49,059
09/1997	0	5,701	701	0	0	172,788	49,760
10/1997	0	5,796	977	0	0	178,584	50,737
11/1997	0	5,698	652	0	0	184,282	51,389
12/1997	0	5,569	300	0	0	189,851	51,689
01/1998	0	5,975	185	0	0	195,826	51,874
02/1998	0	5,099	321	0	0	200,925	52,195
03/1998	0	5,482	443	0	0	206,407	52,638
04/1998	0	5,402	463	0	0	211,809	53,101
05/1998	0	5,524	440	0	0	217,333	53,541
06/1998	0	0	0	0	0	217,333	53,541
07/1998	0	0	0	0	0	217,333	53,541
08/1998	0	0	0	0	0	217,333	53,541
09/1998	0	0	0	0	0	217,333	53,541
10/1998	0	0	0	0	0	217,333	53,541
11/1998	0	0	0	0	0	217,333	53,541
12/1998	0	0	0	0	0	217,333	53,541
Total:	0	217,333	53,541				

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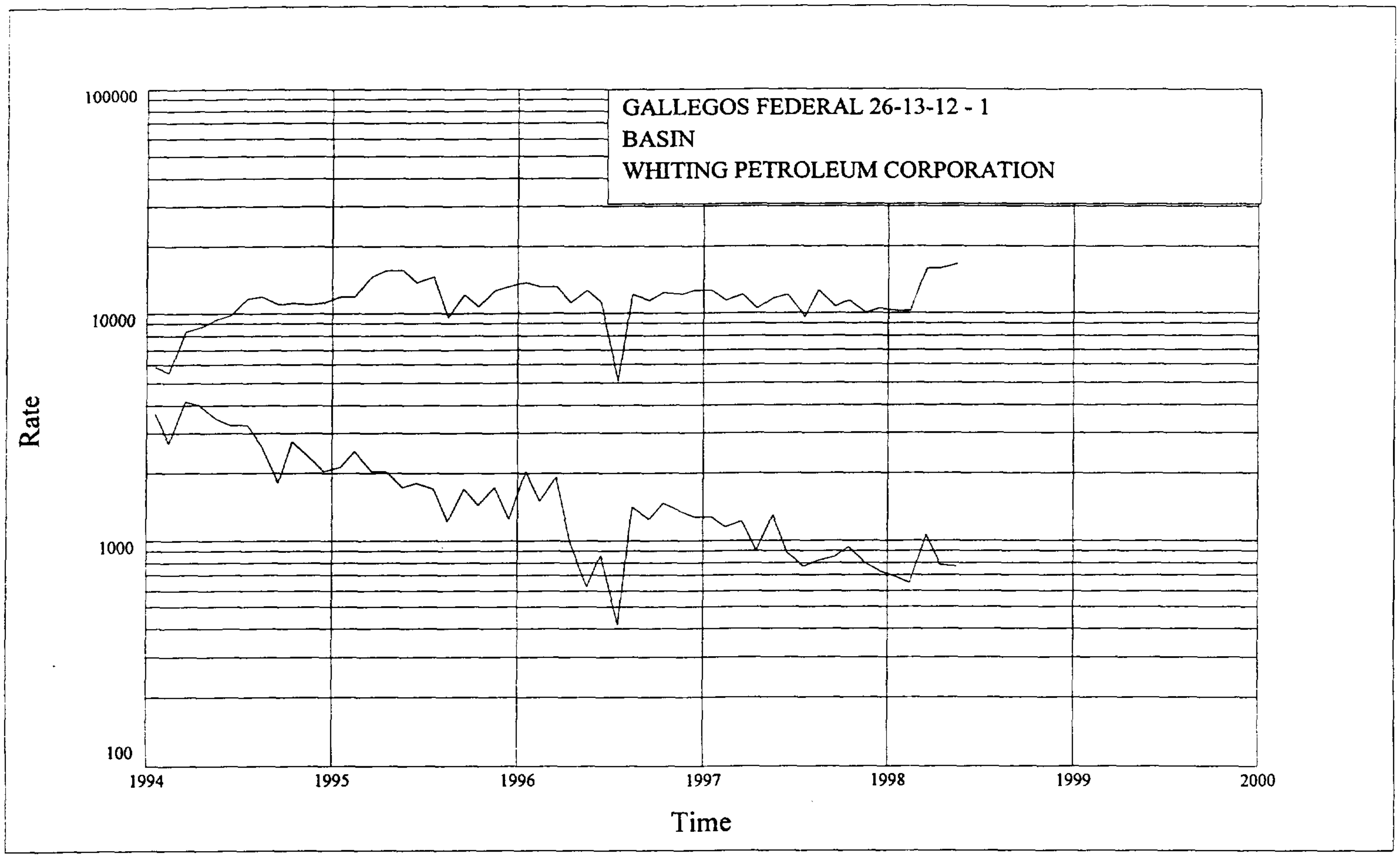
57
160

Date: 6/19/1998 Time: 11:32 AM

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Lease Name:	GALLEGOS FEDERAL 26-13-12 (1)	Field Name:	BASIN
County, ST:	SAN JUAN, NM	Operator:	WHITING PETROLEUM CORPORATION
Location:	26N-13W-12		



Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
01/1994	0	5,859	3,666	1	0	5,859	3,666
02/1994	0	5,573	2,694	1	0	11,432	6,360
03/1994	0	8,304	4,178	1	0	19,736	10,538
04/1994	0	8,797	4,002	1	0	28,533	14,540
05/1994	0	9,509	3,482	1	0	38,042	18,022
06/1994	0	9,808	3,293	1	0	47,850	21,315
07/1994	0	11,526	3,229	1	0	59,376	24,544
08/1994	0	11,898	2,684	0	0	71,274	27,228
09/1994	0	10,910	1,805	1	0	82,184	29,033
10/1994	0	11,199	2,766	1	0	93,383	31,799
11/1994	0	10,859	2,353	1	0	104,242	34,152
12/1994	0	11,069	2,015	1	0	115,311	36,167
01/1995	0	11,938	2,099	1	0	127,249	38,266
02/1995	0	11,938	2,518	1	0	139,187	40,784
03/1995	0	14,613	2,016	1	0	153,800	42,800
04/1995	0	15,460	2,032	1	0	169,260	44,832
05/1995	0	15,449	1,739	1	0	184,709	46,571
06/1995	0	13,648	1,812	1	0	198,357	48,383
07/1995	0	14,710	1,702	1	0	213,067	50,085
08/1995	0	9,624	1,207	0	0	222,691	51,292
09/1995	0	12,026	1,704	1	0	234,717	52,996
10/1995	0	10,634	1,428	1	0	245,351	54,424
11/1995	0	12,700	1,740	1	0	258,051	56,164

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
12/1995	0	13,254	1,238	1	0	271,305	57,402
01/1996	0	13,635	2,022	1	0	284,940	59,424
02/1996	0	13,080	1,482	1	0	298,020	60,906
03/1996	0	13,026	1,900	1	0	311,046	62,806
04/1996	0	11,143	982	1	0	322,189	63,788
05/1996	0	12,594	620	1	0	334,783	64,408
06/1996	0	11,220	862	1	0	346,003	65,270
07/1996	0	5,069	421	1	0	351,072	65,691
08/1996	0	12,151	1,410	1	0	363,223	67,101
09/1996	0	11,437	1,249	1	0	374,660	68,350
10/1996	0	12,454	1,471	1	0	387,114	69,821
11/1996	0	12,103	1,339	1	0	399,217	71,160
12/1996	0	12,629	1,261	1	0	411,846	72,421
01/1997	0	12,526	1,272	1	0	424,372	73,693
02/1997	0	11,364	1,146	1	0	435,736	74,839
03/1997	0	12,217	1,225	1	0	447,953	76,064
04/1997	0	10,505	896	1	0	458,458	76,960
05/1997	0	11,564	1,297	1	0	470,022	78,257
06/1997	0	11,987	872	1	0	482,009	79,129
07/1997	0	9,567	760	1	0	491,576	79,889
08/1997	0	12,619	815	0	0	504,195	80,704
09/1997	0	10,789	843	0	0	514,984	81,547
10/1997	0	11,312	940	0	0	526,296	82,487
11/1997	0	10,093	785	0	0	536,389	83,272
12/1997	0	10,554	729	0	0	546,943	84,001
01/1998	0	10,368	686	0	0	557,311	84,687
02/1998	0	10,273	641	0	0	567,584	85,328
03/1998	0	15,797	1,061	0	0	583,381	86,389
04/1998	0	15,957	778	0	0	599,338	87,167
05/1998	0	16,632	761	0	0	615,970	87,928
06/1998	0	0	0	0	0	615,970	87,928
07/1998	0	0	0	0	0	615,970	87,928
08/1998	0	0	0	0	0	615,970	87,928
09/1998	0	0	0	0	0	615,970	87,928
10/1998	0	0	0	0	0	615,970	87,928
11/1998	0	0	0	0	0	615,970	87,928
12/1998	0	0	0	0	0	615,970	87,928
Total:	0	615,970	87,928				

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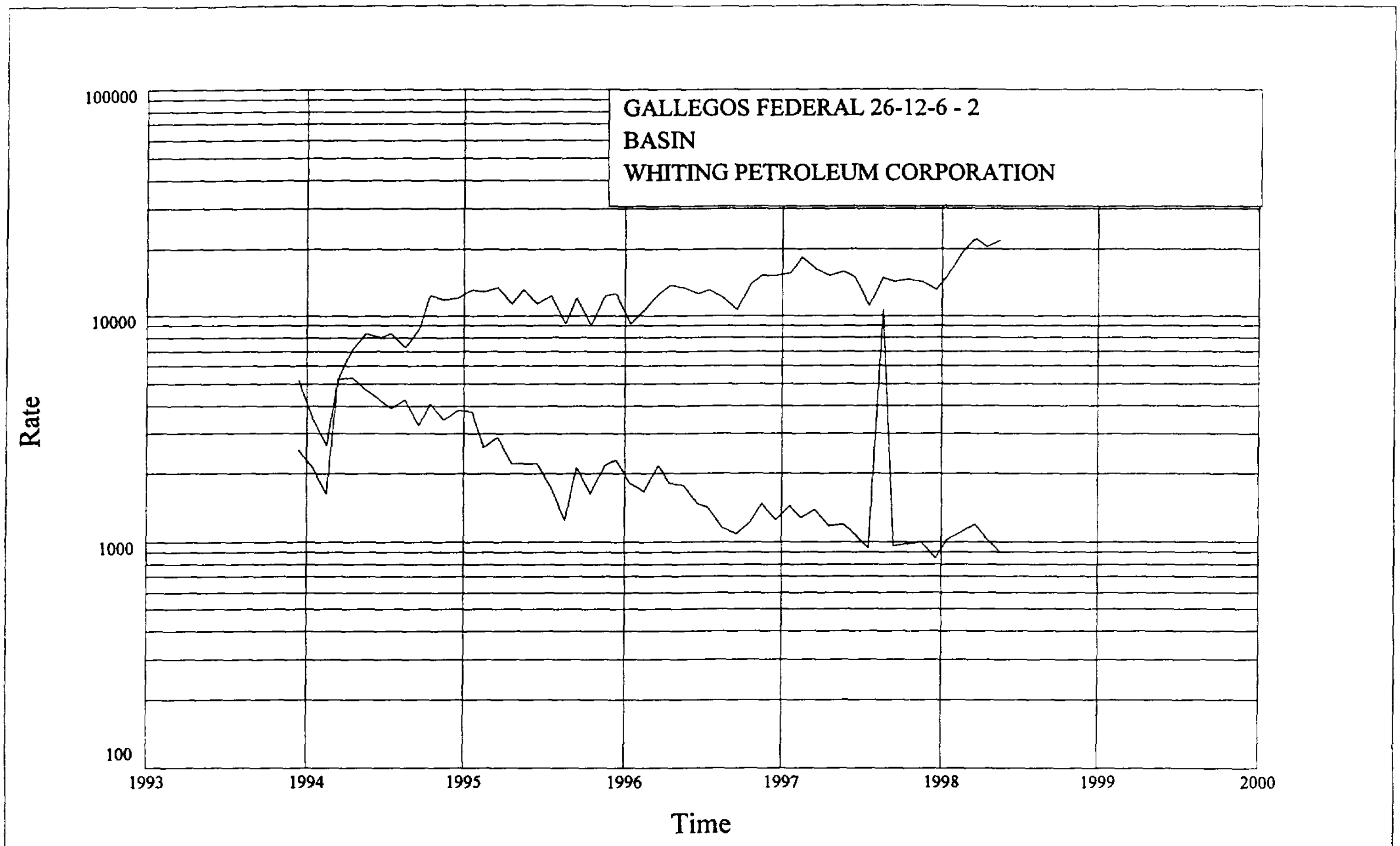
185
431

Date: 6/19/1998

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Lease Name:	GALLEGOS FEDERAL 26-12-6 (2)	Field Name:	BASIN
County, ST:	SAN JUAN, NM	Operator:	WHITING PETROLEUM CORPORATION
Location:	26N-12W-6		



Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
01/1993	0	0	0	0	0	0	0
02/1993	0	0	0	0	0	0	0
03/1993	0	0	0	0	0	0	0
04/1993	0	0	0	0	0	0	0
05/1993	0	0	0	0	0	0	0
06/1993	0	0	0	0	0	0	0
07/1993	0	0	0	0	0	0	0
08/1993	0	0	0	0	0	0	0
09/1993	0	0	0	0	0	0	0
10/1993	0	0	0	0	0	0	0
11/1993	0	0	0	0	0	0	0
12/1993	0	2,541	5,259	1	0	2,541	5,259
01/1994	0	2,140	3,552	1	0	4,681	8,811
02/1994	0	1,618	2,677	1	0	6,299	11,488
03/1994	0	5,249	5,270	1	0	11,548	16,758
04/1994	0	7,169	5,315	1	0	18,717	22,073
05/1994	0	8,414	4,692	1	0	27,131	26,765
06/1994	0	8,034	4,230	1	0	35,165	30,995
07/1994	0	8,321	3,945	1	0	43,486	34,940
08/1994	0	7,205	4,283	0	0	50,691	39,223
09/1994	0	8,654	3,274	1	0	59,345	42,497
10/1994	0	12,319	4,046	1	0	71,664	46,543
11/1994	0	11,855	3,495	1	0	83,519	50,038

Date: 6/19/1998 Time: [illegible]

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

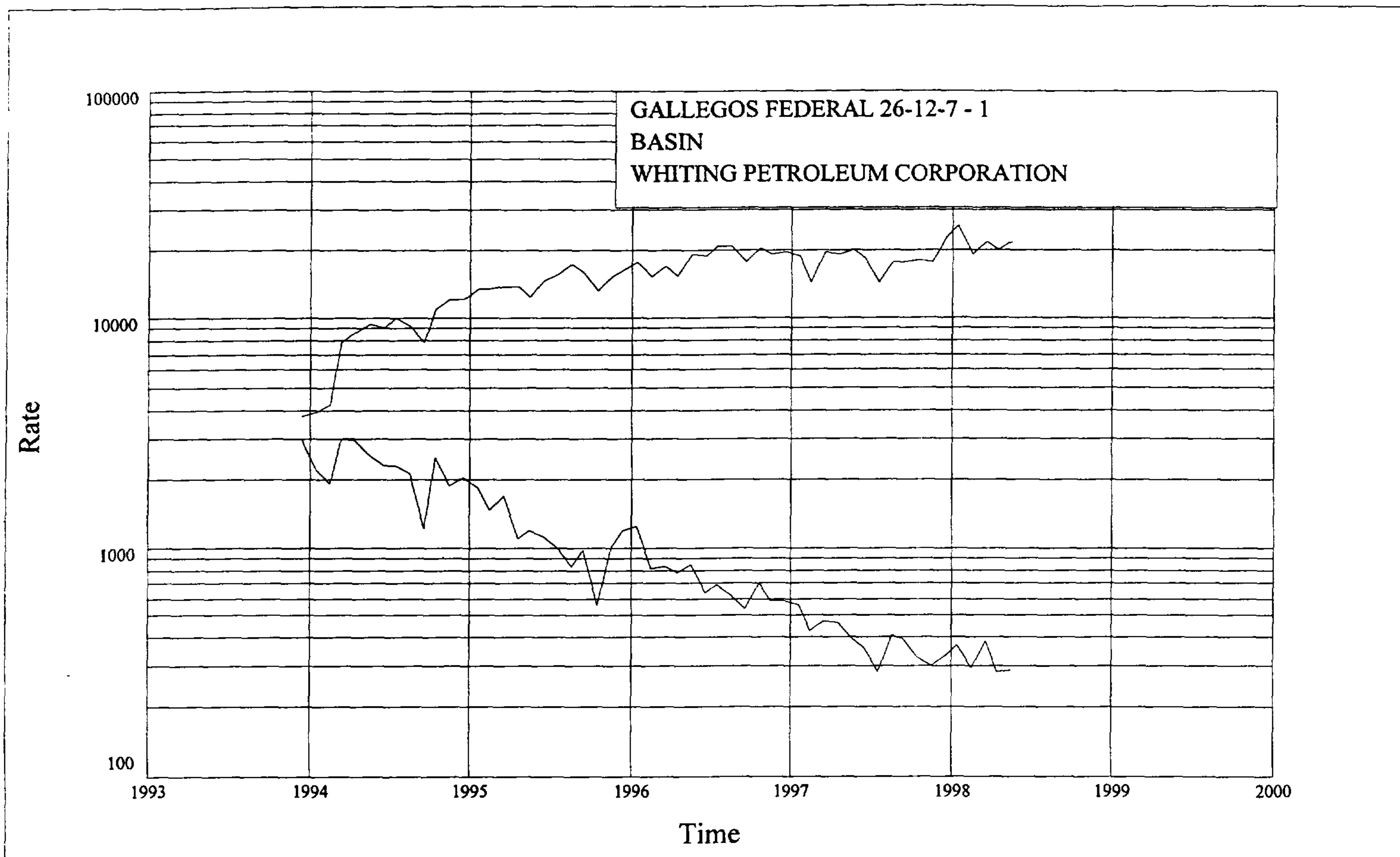
Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
12/1994	0	12,014	3,848	1	0	95,533	53,886
01/1995	0	13,078	3,726	1	0	108,611	57,612
02/1995	0	13,008	2,585	1	0	121,619	60,197
03/1995	0	13,442	2,864	1	0	135,061	63,061
04/1995	0	11,478	2,214	1	0	146,539	65,275
05/1995	0	13,160	2,204	1	0	159,699	67,479
06/1995	0	11,417	2,196	1	0	171,116	69,675
07/1995	0	12,286	1,741	1	0	183,402	71,416
08/1995	0	9,253	1,247	0	0	192,655	72,663
09/1995	0	12,139	2,142	1	0	204,794	74,805
10/1995	0	9,072	1,617	0	0	213,866	76,422
11/1995	0	12,440	2,159	0	0	226,306	78,581
12/1995	0	12,710	2,290	1	0	239,016	80,871
01/1996	0	9,310	1,800	1	0	248,326	82,671
02/1996	0	10,802	1,650	1	0	259,128	84,321
03/1996	0	12,677	2,144	1	0	271,805	86,465
04/1996	0	13,582	1,795	1	0	285,387	88,260
05/1996	0	13,497	1,754	1	0	298,884	90,014
06/1996	0	12,600	1,460	1	0	311,484	91,474
07/1996	0	13,212	1,411	1	0	324,696	92,885
08/1996	0	12,203	1,145	1	0	336,899	94,030
09/1996	0	10,780	1,072	1	0	347,679	95,102
10/1996	0	14,004	1,210	1	0	361,683	96,312
11/1996	0	15,096	1,462	1	0	376,779	97,774
12/1996	0	15,075	1,233	1	0	391,854	99,007
01/1997	0	15,540	1,427	1	0	407,394	100,434
02/1997	0	18,364	1,279	1	0	425,758	101,713
03/1997	0	15,971	1,383	1	0	441,729	103,096
04/1997	0	15,128	1,178	1	0	456,857	104,274
05/1997	0	15,701	1,205	1	0	472,558	105,479
06/1997	0	14,778	1,079	1	0	487,336	106,558
07/1997	0	11,140	934	1	0	498,476	107,492
08/1997	0	14,995	10,650	0	0	513,471	118,142
09/1997	0	14,280	950	0	0	527,751	119,092
10/1997	0	14,653	970	0	0	542,404	120,062
11/1997	0	14,273	1,000	0	0	556,677	121,062
12/1997	0	13,274	851	0	0	569,951	121,913
01/1998	0	15,281	1,023	0	0	585,232	122,936
02/1998	0	19,104	1,111	0	0	604,336	124,047
03/1998	0	21,977	1,186	0	0	626,313	125,233
04/1998	0	20,163	1,025	0	0	646,476	126,258
05/1998	0	21,609	904	0	0	668,085	127,162
06/1998	0	0	0	0	0	668,085	127,162
07/1998	0	0	0	0	0	668,085	127,162
08/1998	0	0	0	0	0	668,085	127,162
09/1998	0	0	0	0	0	668,085	127,162
10/1998	0	0	0	0	0	668,085	127,162
11/1998	0	0	0	0	0	668,085	127,162
12/1998	0	0	0	0	0	668,085	127,162
Total:	0	668,085	127,162				

668
160
508

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Lease Name:	GALLEGOS FEDERAL 26-12-7 (1)	Field Name:	BASIN
County, ST:	SAN JUAN, NM	Operator:	WHITING PETROLEUM CORPORATION
Location:	26N-12W-7		



Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
01/1993	0	0	0	0	0	0	0
02/1993	0	0	0	0	0	0	0
03/1993	0	0	0	0	0	0	0
04/1993	0	0	0	0	0	0	0
05/1993	0	0	0	0	0	0	0
06/1993	0	0	0	0	0	0	0
07/1993	0	0	0	0	0	0	0
08/1993	0	0	0	0	0	0	0
09/1993	0	0	0	0	0	0	0
10/1993	0	0	0	0	0	0	0
11/1993	0	0	0	0	0	0	0
12/1993	0	3,742	2,995	1	0	3,742	2,995
01/1994	0	3,953	2,208	1	0	7,695	5,203
02/1994	0	4,256	1,922	1	0	11,951	7,125
03/1994	0	7,946	2,993	1	0	19,897	10,118
04/1994	0	8,747	2,970	1	0	28,644	13,088
05/1994	0	9,481	2,533	1	0	38,125	15,621
06/1994	0	8,996	2,314	1	0	47,121	17,935
07/1994	0	10,034	2,304	1	0	57,155	20,239
08/1994	0	9,355	2,111	0	0	66,510	22,350
09/1994	0	7,850	1,228	1	0	74,360	23,578
10/1994	0	11,033	2,487	1	0	85,393	26,065
11/1994	0	12,218	1,873	1	0	97,611	27,938

Historic Production and Well Count Detail Report

Project: H:\PTOOLS25\GALLEGOS.MDB

Date	Oil (bbl)	Gas (mcf)	Water (bbl)	Well Count	OilCum (bbl)	GasCum (mcf)	WaterCum (bbl)
12/1994	0	12,119	2,032	1	0	109,730	29,970
01/1995	0	13,295	1,835	1	0	123,025	31,805
02/1995	0	13,346	1,454	1	0	136,371	33,259
03/1995	0	13,740	1,703	1	0	150,111	34,962
04/1995	0	13,617	1,104	1	0	163,728	36,066
05/1995	0	12,449	1,201	1	0	176,177	37,267
06/1995	0	14,529	1,133	1	0	190,706	38,400
07/1995	0	15,494	1,002	1	0	206,200	39,402
08/1995	0	16,993	828	0	0	223,193	40,230
09/1995	0	15,697	965	1	0	238,890	41,195
10/1995	0	13,084	554	0	0	251,974	41,749
11/1995	0	15,307	1,015	0	0	267,281	42,764
12/1995	0	16,258	1,194	1	0	283,539	43,958
01/1996	0	17,459	1,247	1	0	300,998	45,205
02/1996	0	15,157	816	1	0	316,155	46,021
03/1996	0	16,685	827	1	0	332,840	46,848
04/1996	0	15,163	770	1	0	348,003	47,618
05/1996	0	18,836	848	1	0	366,839	48,466
06/1996	0	18,636	637	1	0	385,475	49,103
07/1996	0	20,712	687	1	0	406,187	49,790
08/1996	0	20,533	615	1	0	426,720	50,405
09/1996	0	17,471	535	1	0	444,191	50,940
10/1996	0	20,009	698	1	0	464,200	51,638
11/1996	0	19,097	581	1	0	483,297	52,219
12/1996	0	19,596	587	1	0	502,893	52,806
01/1997	0	18,670	558	1	0	521,563	53,364
02/1997	0	14,124	426	1	0	535,687	53,790
03/1997	0	19,466	476	1	0	555,153	54,266
04/1997	0	18,836	463	1	0	573,989	54,729
05/1997	0	19,621	393	1	0	593,610	55,122
06/1997	0	18,174	363	1	0	611,784	55,485
07/1997	0	14,322	286	1	0	626,106	55,771
08/1997	0	17,469	408	1	0	643,575	56,179
09/1997	0	17,610	395	1	0	661,185	56,574
10/1997	0	17,883	326	1	0	679,068	56,900
11/1997	0	17,431	301	1	0	696,499	57,201
12/1997	0	22,236	335	1	0	718,735	57,536
01/1998	0	25,279	375	1	0	744,014	57,911
02/1998	0	19,196	296	1	0	763,210	58,207
03/1998	0	21,521	386	1	0	784,731	58,593
04/1998	0	19,785	287	1	0	804,516	58,880
05/1998	0	21,699	291	1	0	826,215	59,171
06/1998	0	0	0	0	0	826,215	59,171
07/1998	0	0	0	0	0	826,215	59,171
08/1998	0	0	0	0	0	826,215	59,171
09/1998	0	0	0	0	0	826,215	59,171
10/1998	0	0	0	0	0	826,215	59,171
11/1998	0	0	0	0	0	826,215	59,171
12/1998	0	0	0	0	0	826,215	59,171
Total:	0	826,215	59,171				

826
176
650

SUMMARY OF MERRION PROJECT PURCHASE ECONOMICS

MERRION PROJECT DISCOUNTED VALUE
OF EXISTING PRODUCTION

WELL NAME	DISCOUNT RATE 0	10	15	20	25	30
Chaco #1	0.00	0.00	0.00	0.00	0.00	0.00
Chaco #2R	3.06	2.54	2.28	2.04	1.82	1.63
Chaco #4	0.00	0.00	0.00	0.00	0.00	0.00
Chaco #5	0.00	0.00	0.00	0.00	0.00	0.00
Chaco #11	0.00	0.00	0.00	0.00	0.00	0.00
Chaco Ltd #1J	0.00	0.00	0.00	0.00	0.00	0.00
Chaco Ltd #2J	0.00	0.00	0.00	0.00	0.00	0.00
Chaco Ltd #3	23.85	15.99	13.38	11.33	9.70	8.39
Chaco Ltd #3J	12.79	8.60	7.20	6.10	5.22	4.51
Dome Fed 7-27-13 #1	9.25	6.14	5.11	4.31	3.68	3.17
Dome Fed 17-27-13 #2	30.73	18.32	14.71	12.04	10.03	8.48
Dome Fed 18-27-13 #2	0.00	0.00	0.00	0.00	0.00	0.00
Dome Fed 25-26-13 #1	0.00	0.00	0.00	0.00	0.00	0.00
Frew Fed #1	0.00	0.00	0.00	0.00	0.00	0.00
Frew Fed #2	2.38	1.78	1.56	1.37	1.22	1.09
Frew Fed #5	0.00	0.00	0.00	0.00	0.00	0.00
Frew Fed #8	0.00	0.00	0.00	0.00	0.00	0.00
Frew Fed #9	0.00	0.00	0.00	0.00	0.00	0.00
Frew Fed #12	0.00	0.00	0.00	0.00	0.00	0.00
Frew Fed #15	0.00	0.00	0.00	0.00	0.00	0.00
Hi Roll #1	0.00	0.00	0.00	0.00	0.00	0.00
Hi Roll #2	3.93	2.75	2.33	2.00	1.73	1.51
Hi Roll #4	17.58	12.27	10.44	8.97	7.77	6.79
Southland #1	7.95	5.25	4.37	3.68	3.14	2.70
Southland #2Y	0.00	0.00	0.00	0.00	0.00	0.00
Southland #3	0.70	0.58	0.53	0.49	0.45	0.42
Southland #6	12.16	8.48	7.21	6.19	5.36	4.68
Southland #7	0.30	0.23	0.21	0.19	0.17	0.15
Da On Pah #1	19.92	13.98	11.92	10.25	8.90	7.79
Frew Fed #3	0.00	0.00	0.00	0.00	0.00	0.00
Chaco #2	0.00	0.00	0.00	0.00	0.00	0.00
Chaco #3	0.00	0.00	0.00	0.00	0.00	0.00
Fusselman Fed #1	0.70	0.53	0.46	0.41	0.36	0.32
Hickman #7R	0.00	0.00	0.00	0.00	0.00	0.00
Pete #1R	0.00	0.00	0.00	0.00	0.00	0.00
Serendipity #1	0.00	0.00	0.00	0.00	0.00	0.00
Sullivan #9	0.00	0.00	0.00	0.00	0.00	0.00
Susco #3	0.00	0.00	0.00	0.00	0.00	0.00
TOTALS	145.30	107.44	96.71	89.37	84.55	81.63

[illegible]I/NRI				
[illegible]00%/82.5	Hi Roll #1R	27-13-35	SWSE	NM-33045
[illegible]00/82.5	" " #2	27-13-35	NESW	"
[illegible]0/82.5	" " #4	27-13-35	NWNW	"
[illegible]0%/41.75	Southland #1	26-13-3	NESW	NM-122[illegible]
[illegible]/41.75	" #24	26-13-3	SWSE	"
[illegible]/41.75	Southland #3	26-13-10	NENW	"
[illegible]/41.75	" #6	26-13-10	SENE	"
[illegible]/41.75	" #7	26-13-11	NWNW	"

all above are 160a sp.

[illegible]00%/82.5%	Dah on Rah #1 (E/2)	27-12-35:	SENE	# INDIAN 25-74[illegible]
[illegible]/44.69	Frew Fed #3 (E/2)	26-12-29:	NWNE	NM-0562[illegible]
[illegible]00/82.5	Chaco #2 (N/2)	26-12-7:	SESW	NM-220[illegible]
[illegible]00/82.5	Chaco #3 (N/2)	26-13-12:	SENE	SF-0802[illegible]
[illegible].83/58.43	Fusselman Fed N/2 #1	26-12-17:	NWSW	NM-0800[illegible]
%	Hickman #7R E/2 N/2	26-12-3	: NENE	SF-08035[illegible]
?%	Pete #1R	27-12-35:	? NESE	NOO-14-20-7[illegible]
[illegible]00%/82.5%	Serendipity #1 N/2	26-13-26:	NWSE	NM-330[illegible]
[illegible]%/82.5%	Sullivan #9 S/2	26-12-15:	NESW	SF-080384
[illegible]%/87.5%	SUSCO #3 S/2	26-12-9:	SESW	NM-63320

All above are 320a sp.

Gross W.I. includes: Merrion, Bayless, PITCO, et als

I assumed 82.5% NRI when I couldn't determine what it actually is -

Did you want to include Dome Fed.
26-13-14: SENE) 14-26-13 #2
PITCO WI is 32.5%

WAW Fruitland Sand PC
WI + NRI in well

WI/NRI		Well	Location		Lease
		Chaco #1	26N-12W-18:	SENW	NM-220
100%/85%		" #2R	26-12	7: NESW	NM220
100%/82.5%		" #4	26-12	7: NWNW	SF080238
100%/82.5		" #5	26-13	1: SESE	"
100%/82.5		" #11	26-13	1: SWNW	"
100%/82.5		" Ltd #1J	26-13	1: NESW	"
100%/82.5		" Ltd #2J	26-13	1: NWNE	"
100%/82.5%		" Ltd #3	26-13	12: SENW	"
100%/82.5%		" Ltd #3J	26-13	12: (NE/4)	"
60.625/50.00		Dome Fed. 7-27-13 #1	27-13-7	SWNW	NM-8
28.125/23.20	Texaco, et al	" 17-27-13 #2	27-13-17	NESW	NM-9
28.125/23.20	Texaco 39.375, Adobe 7.5, Apache 20	" 18-27-13 #2	27-13-18	SWNE	NM-8
70.83/58.43	Texaco 29.17%	" 25-26-13 #1	26-13-25:	SENE	NM-7785
70.83/58.43	Texaco 29.17	Frew Fed. #1	26-12-20	NWSE	NM-0560
37.50/30.9	Apache 33.33, Texaco 29.167	#2	26-12-20	SESW	"
70.83/58.43	Texaco 29.167	#5	26-12-19	NENE	"
70.83/58.43		#8	26-12-19	NWSE	"
70.83/58.43		#9	26-12-30	SENE	"
70.83/58.43		#12	26-12-30	SESE	"
70.83/58.43	Meridian 29.167	#15	26-12-29	SESE	"

Frew Fed 3, 7, 11, 16?

Gross Acres 12,921.58
Net Acres 9,077.14 x 10 = 90,770
89,370
+75,000
105,140

Post-it™ brand fax transmittal memo 7671 | # of pages ▸ 2
To Mickey | From Jenny
Co. | Co.
Dept. | Phone #
Fax # let me know if you can't read

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1989 PROD	ACCUM
KA DA PAH															
1M 325N12W	GAS	RECOMPLETED TO		BISTI FARMINGTON (GAS)											[illegible]
KA DAH PAH															
R 1N 325N12W	GAS		29		20	103								152	[illegible]
	WAT														6
2L 425N12W	GAS	885	650	910	447	417	575	23	574	1153	4696	7269	7894	25493	[illegible]
	WAT														3
LEASE TOTAL	GAS	885	679	910	467	520	575	23	574	1153	4696	7269	7894	25645	628259
	WAT														7
KA GEE TAH															
1F1025N12W	GAS	1152	2816	2459	3744	5558	4877	5545	5084	4563	5129	4780	5321	51028	417624
	WAT														3
MARIANA STATE COM															
1C 225N12W	GAS	5055	4197	5271	5256	1388	1417	2585	3181	3626	4496	4877	5304	46653	408073
2B 335N12W	GAS	5975	5619	6203	5689	7289	7623	8974	7191	7183	9467	9331	8624	89168	702610
LEASE TOTAL	GAS	11030	9816	11474	10945	8677	9040	11559	10372	10809	13963	14208	13928	135821	1110683
NIB STATE															
1C3226N12W	GAS	8634	8432	9296	8498	8869	8555	8644	9027	9106	10847	9647	9915	109470	1133548
PHILLIPS FEDERAL															
1E 925N12W	GAS	135	134	153	125	147	106	106	106	104	128	119	120	1483	30038
	WAT														3
CHRISTOPHER RAY COM															
1A 525N12W	GAS	876	1618	1374	3825	6678	6104	5636	4752	4395	4795	3807	2981	46441	108460
	WAT														2
SAM JACKSON															
1K3226N12W	GAS	6675	6684	7160	5235	7369	6733	6660	6284	6254	6450	6718	6724	78946	576586
VIRGINIA STATE															
3M 225N12W	GAS				2195									2195	7449
COMPANY TOTAL	GAS	57414	59149	64586	61524	65588	59268	63525	61250	60614	74177	73746	76192	777033	6313728
	WAT														5695
JEROME P. MCHUGH															
BENGAL C															
3A3627N13W	GAS	LAST PROD. DATE 06/88												S	62036
	WAT														1
5O3627N13W	GAS	405	378	352	375	304	280	232	360	357	337	352	297	4029	203954
	WAT														39
LEASE TOTAL	GAS	405	378	352	375	304	280	232	360	357	337	352	297	4029	265990
	WAT														42
CHACO PLANT															
3B2026N12W	GAS	PLUGGING APPROVED 1979													472
4H1626N12W	GAS	LAST PROD. DATE 05/81												0	14313
5E2126N12W	GAS	LAST PROD. DATE 08/88												0	63045
	WAT														13
6O 526N12W	GAS	PLUGGING APPROVED 1979													806
9H 526N12W	GAS	PLUGGING APPROVED 1979													120
12I2226N12W	GAS	LAST PROD. DATE 06/88												S	14511
19K2226N12W	GAS	PLUGGING APPROVED 1988													10919
	WAT														1
R 19N2226N12W	GAS	PLUGGING APPROVED 1988													67685
	WAT														25
20H2726N12W	GAS	LAST PROD. DATE 08/81												0	13744
35J2726N12W	GAS	PLUGGING APPROVED 1988													356146
36F3626N12W	GAS	LAST PROD. DATE 03/82												[illegible]	93134
LEASE TOTAL	GAS														675174
	WAT														49
COMPANY TOTAL	GAS	405	378	352	375	304	280	232	360	357	337	352	297	4029	941164
	WAT														91
MERIDIAN OIL INCORPORATED															
FAEM-FED															
6F1926N12W	GAS	LAST PROD. DATE 05/85												S	61483
	WAT														308
J K															
1F3027N12W	GAS	276										307	306	889	20318
COMPANY TOTAL	GAS	276										307	306	889	81801
	WAT														308
MERRION OIL AND GAS CORPORATION															
BARTLESVILLE															
1C 226N13W	GAS	56	46			25	21	27	77	65	45	75	58	495	62346
CHACO															
1F1826N12W	GAS									12				125	101882
2N 726N12W	GAS	LAST PROD. DATE 08/81												[illegible]	33815
R 2K 726N12W	GAS									13				135	41330
3H1226N13W	GAS		11				94	116	28	20	11	14	64	358	42674
4O 726N12W	GAS		5				63	232	188	176	167	132	371	1334	196234
5P 126N13W	GAS						52	60		106		1	67	286	141767
11E 126N13W	GAS						98	425	262	404	388	401	502	2480	299936
13I1026N13W	GAS	LAST PROD. DATE 05/86												S	23841
14K1026N13W	GAS	LAST PROD. DATE 05/86												S	2809
LEASE TOTAL	GAS		16				307	833	478	731	564	548	1004	4483	884288
CHACO LIMITED															
1M 126N13W	GAS		4											45	36686
	WAT														1590
J 1K 126N13W	GAS		21				12	169	112	213	225	216	208	1176	8491
2G 126N13W	GAS	LAST PROD. DATE 04/85												S	12015
	WAT														67
J 2B 126N13W	GAS		1				71	120	218	198	225	217	188	1238	33061
	WAT														101
3F1226N13W	GAS		3					268	613	612	665	636	620	3417	41376
	WAT														51
J 3E1226N13W	GAS							403	919	919	998	954	931	5124	57141
	WAT														19
LEASE TOTAL	GAS		29				83	960	1862	1942	2113	2023	1947	10959	190079
	WAT														1848
DOME FEDERAL 21-27-13															
1E2127N13W	GAS	LAST PROD. DATE 01/88												S	8453
	WAT														6511
HIGH HOLL															
R 1O3527N13W	GAS	14	20	23	33	30	19	41	28	36	38	35	16	333	59210
2K3527N13W	GAS	519	434	412	425	415	509	527	536	439	379	318	271	5184	[illegible]
3G3527N13W	GAS	73	111	291	141	63	58	65	32	107	148	16	221	1332	[illegible]
4D3527N13W	GAS	2094	2491	2400	1954	1054	913	1317	689	606	844	2368	977	17713	[illegible]
LEASE TOTAL	GAS	2700	3062	3126	2553	1562	1499	1950	1285	1188	1409	2737	1491	24562	869535
HIGH HOLL METER RUN															
1O3527N13W	GAS	PLUGGING APPROVED 1982													82583
HUGH LAKE															
1M3627N13W	GAS	LAST PROD. DATE 10/80												0	22515
	WAT														5
SOUTHLAND															
1K 326N13W	GAS		38											385	71563
	WAT														7
T 2O 326N13W	GAS	LAST PROD. DATE 05/86												S	41775
	OIL														1
	WAT														20
3C1026N13W	GAS		12											125	10911
	OIL														1
	WAT														19
4A 926N13W	GAS		12											125	[illegible]
	WAT														443
5G1126N13W	GAS	LAST PROD. DATE 01/86												S	50312
	OIL														1
	WAT														[illegible]
6H1026N13W	GAS		44											445	104173
	OIL														1
	WAT														[illegible]
7O1126N13W	GAS		19											195	16512
	OIL														1
	WAT														19
LEASE TOTAL	OIL														5
	GAS		125											125	[illegible]
	WAT														568
SUSCO FEDERAL															
1J 926N12W	GAS		5	1	1	106	129	177	62	61	92	74	67	775	[illegible]
COMPANY TOTAL	OIL														[illegible]
	GAS	2756	3283	3127	2554	1693	2039	3947	3764	3987	4225	5457	4567	41399	[illegible]
	WAT														6412
P-0-0 MANAGEMENT, INC.															
NAVAJO 4															
1E 425N12W	GAS	62	507	714	541	451	618		336	464	380		3839	7912	[illegible]
TEXACO INC.															
DOME FEDERAL 07-27-13															
1E 727N13W	GAS	457	429	482	421	708	480	413	599	500	437	418	473	5817	[illegible]
	WAT														[illegible]
2D 727N13W	GAS	449	276	729	109	396	185	340	241	367	599	729		4420	[illegible]
	WAT	24	28	31	11	20	14	26	23	27	31	30		265	[illegible]
3G 727N13W	GAS	3	16	70	144	98	103	100	119	170	146	48	75	1092	[illegible]
LEASE TOTAL	GAS	909	721	1281	674	1202	768	853	959	1037	1182	1195	548	11329	[illegible]
	WAT	24	28	31	11	20	14	26	23	27	31	30		265	[illegible]

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1990 PROD	MP	ACCUM
2P3526N12W	GAS	127	121	225	157	215	245	163	8		222	51	9	1543		193954
	WAT	81	78	93	90	18	90	72	6		93	90	75	846		12173
3D3526N12W	GAS	LAST PROD. DATE 06/89													S	593441
4A3526N12W	GAS	PLUGGING APPROVED 1986														361192
LEASE TOTAL	GAS	3384	3000	3203	2454	1449	1425	663	23		1134	51	525	17515		1820090
	WAT	97	92	109	105	91	105	85	6		109	90	89	978		13718
MARTHA WASHINGTON																
1A3426N12W	GAS	PLUGGING APPROVED 1990														386458
WAW																
1L3227N13W	GAS	131	153	135	113	136	157	99		38	124	30	118	1234		85539
	WAT															32
WAYOUT																
1L 527N13W	GAS	LAST PROD. DATE 04/87													S	59215
	WAT															36
COMPANY TOTAL	GAS	37448	29237	36050	29114	27432	31150	23494	3557	5427	25007	7358	22927	278101		13469277
	WAT	305	273	291	253	277	295	232	15	52	309	263	275	2846		52676
FLOYD OIL COMPANY																
NAVAJO 18																
1M3326N12W	GAS		4280	3011	784	788	2153	1912	19	83	2111	897	517	16555		596301
	WAT		616	114	20	17	28	21					6	882		882
GIANT EXPLORATION & PROD. CO.																
CARSON UNIT																
41A1425N12W	GAS	765	342	1157	1145	1090	483	294	38	523	1005	796	499	8137		133666
	WAT															2632
202A1025N12W	GAS	3532	3142	2955	1503	1772	452	569	27	381	513	509	415	16170		214519
206E1125N12W	GAS	3684	3281	3252	2780	2556	2627	2017	225	738	2176	992	1761	26091		236314
	WAT															3
207J1325N12W	GAS	594	458	473	518	632	488	466	103	359	938	280	1181	6490		64677
208A1025N12W	GAS	9390	8339	8431	7541	7755	6761	6341	805	1466	5805	1570	12103	76307		391469
LEASE TOTAL	GAS	17965	15562	16268	13887	13807	10811	9687	1198	3467	13437	4147	15959	133195		1100309
	WAT															2635
CARSON UNIT 11																
13L1125N12W	GAS	1019	916	1040	1013	566	241	989	213	744	1942	579	2446	11708		132177
	WAT															2030
34O1125N12W	GAS	1868	1693	1755	1701	1583	1402	1187	22	132	1245	497	830	13915		133309
	WAT															1034
LEASE TOTAL	GAS	2887	2609	2795	2714	2149	1643	2176	235	876	3187	1076	3276	25623		265486
	WAT															3034
CHACO WASH																
1O3226N12W	GAS	7678	6391	7368	7049	6696	7171	6989	5714	2132	7407	2198	4278	71471		728825
GEE NA NUP PAH																
1I 525N12W	GAS	881	809	867	867	862	872	784	688	350	1056	821	1186	10043		378807
	WAT															5
NIXON FEDERAL																
J 1B 425N12W	GAS	LAST PROD. DATE 01/89													S	2233
	WAT															6
SAM JACKSON																
1K3226N12W	GAS	6567	5228	5199	4784	3548	4731	4190	2063	285	2092	90		38777		635363
KA DAH PAH																
R 1N 325N12W	GAS	LAST PROD. DATE 05/85													S	76591
	WAT															4
2L 425N12W	GAS	7936	6927	7318	6613	5305	5399	4300	2296	777	3882	463	3094	54310		591578
	WAT															3
LEASE TOTAL	GAS	7936	6927	7318	6613	5305	5399	4300	2296	777	3882	463	3094	54310		682569
	WAT															7
KA GEE TAH																
1F1025N12W	GAS	5400	5251	5618	5117	4057	4174	4295	285	739	3195	747	2818	41896		459520
	WAT															3
MANUANA STATE COM																
1C 225N12W	GAS	5374	4765	5185	4639	4233	4863	4661	42	1083	5151	1526	5005	46531		455904
2B 225N12W	GAS	9040	7693	10496	7272	7431	7273	6667	205	960	7651	3326	9251	76765		777375
LEASE TOTAL	GAS	14414	12458	15685	11911	11664	12136	11328	247	2043	12802	5352	13256	123296		1233279
NIB STATE																
1C3226N12W	GAS	9479	8418	9002	8243	8187	8761	8672	5516	2447	8563	2525	7824	87637		1221185
PHILLIPS FEDERAL																
1E 925N12W	GAS	120	105	92	98	97	91	78	76	31	107	65	109	1069		31107
	WAT															3
CHRISTOPHER RAY COUN																
1A 525N12W	GAS	1982	1589	1534	1715		1468	1339	960	8	1721	197	1697	14210		122670
	WAT															2
COMPANY TOTAL	GAS	75309	65747	71746	62998	56372	57257	53838	19278	13355	54449	17681	53497	601527		6862581
	WAT															5693
NIXON DEVELOPMENT CO.																
CHACO WASH COM																
J 1I3226N12W	GAS	PLUGGING APPROVED 1983														
NIXON FEDERAL																
1G 425N12W	GAS	ZONE ABANDONED														2301
K 1G 425N12W	GAS	PLUGGING APPROVED 1984														5915
LEASE TOTAL	GAS															8219
IN NI DA PAH																
1I 425N12W	GAS	ZONE ABANDONED														15992
R 1I 425N12W	GAS	ZONE ABANDONED														3236
	WAT															2
LEASE TOTAL	GAS															19228
	WAT															2
KA DA PAH																
1M 325N12W	GAS	RECOMPLETED TO BISTI FARMINGTON (GAS)														17776
VIRGINIA STATE																
3M 225N12W	GAS	PLUGGING APPROVED 1990														7449
COMPANY TOTAL	GAS															52672
	WAT															2
JEROME P. MCHUGH																
BINGAL C																
3A3627N13W	GAS	LAST PROD. DATE 06/88													S	62036
	WAT															1
5O3627N13W	GAS	267	234		309	361	318	214	31	112	189	357		2392		206346
	WAT					1	1							2		41
LEASE TOTAL	GAS	267	234		309	361	318	214	31	112	189	357		2392		268382
	WAT					1	1							2		44
CHACO PLANT																
3B2326N12W	GAS	PLUGGING APPROVED 1975														472
4M1426N12W	GAS	LAST PROD. DATE 05/81													D	14313
5C2126N12W	GAS	LAST PROD. DATE 08/88													D	63095
	WAT															28
6O 526N12W	GAS	PLUGGING APPROVED 1975														606
9M 526N12W	GAS	PLUGGING APPROVED 1975														160
12I2226N12W	GAS	LAST PROD. DATE 04/88													S	14511
19K2226N12W	GAS	PLUGGING APPROVED 1988														10914
	WAT															1
R 19N2226N12W	GAS	PLUGGING APPROVED 1988														67065
	WAT															25
20M2726N12W	GAS	LAST PROD. DATE 08/81													D	13948
35J2726N12W	GAS	PLUGGING APPROVED 1988														396166
36F3626N12W	GAS	LAST PROD. DATE 03/82													T	93134
LEASE TOTAL	GAS															675174
	WAT															49
COMPANY TOTAL	GAS	267	234		309	361	318	214	31	112	189	357		2392		943556
	WAT					1	1							2		93
MERIDIAN OIL INCORPORATED																
FREW-FED																
6F1926N12W	GAS	LAST PROD. DATE 05/85													S	61483
	WAT															308
J K																
1F3027N12W	GAS	231	238	247	197	125	17							1055	S	21373
COMPANY TOTAL	GAS	231	238	247	197	125	17							1055		92856
	WAT															308
MERRION OIL AND GAS CORPORATION																
BARTLESVILLE																
1C 226N13W	GAS	68	44	48			4	49		27	59	17	58	374		62720
CHACO																
1F1826N12W	GAS	293	235	3										531	S	102413
2N 726N12W	GAS	RECOMPLETED TO BASIN FRUITLAND COAL (GAS)														33815
R 2K 726N12W	GAS	293	235	3										531	S	41861
3M1226N13W	GAS	4	27	4	21	43	64	32						195		42869
	WAT								6		1186			1192		1192
4O 726N12W	GAS	258	182	293	335	246	108	301	23	242	207	59	222	2476		148710
5P 126N13W	GAS	237	58	145	151	133	76	254		66	25		398	1583		143150
11E 126N13W	GAS	719	603	561	387	369	325	589	27	342	384	108		4414	S	304350
13I1026N13W	GAS	LAST PROD. DATE 05/86													S	23041
14K1026N13W	GAS	LAST PROD. DATE 05/86													S	2829
LEASE TOTAL	GAS	1804	1380	1009	854	791	573	1176	50	650	616	167	620	9730		894318
	WAT								6		1186			1192		1192
CHACO LIMITED																
1M 126N13W	GAS	LAST PROD. DATE 02/89													S	38086
	WAT															1540
J 1K 126N13W	GAS	205	190	263	448	374	122	46		218	79	146	176	2267		11158
2G 126N13W	GAS	LAST PROD. DATE 04/85													S	12015
	WAT															67

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1990 PROD	MP	ACCUM
J 2B 126N13W	GAS	165	144	141	118	87	172	143						9705		34031
	WAT															101
3F 1226N13W	GAS	602	398	557	644	540	331	49						31215		44197
	WAT															51
J 3E 1226N13W	GAS	904	598	836	566	811	497	73						46855		61[illegible]
	WAT															[illegible]
LEASE TOTAL	GAS	1876	1330	1797	2176	1812	1122	311		218	79	146	176	11043		291[illegible]
	WAT															1444
OCME FEDERAL 07-27-13 1E 727N13W	GAS		526	560	541	483	511	471	7	280	159	491	439	4468		45960
	WAT										6			6		348
P&A OCME FEDERAL 08-27-13 1M 827N13W	GAS	3	16	26					11					565		11473
	WAT										2			2		217
OCME FEDERAL 14-26-13 P&A 1P1426N13W	GAS	LAST PROD. DATE 01/87													S	19956
	WAT															1
SI 2H1426N13W	GAS		21	127	98	13	618	1		10	29			9175		256062
	WAT		784	31	30	31	840	29			4			1749		2465
P&A 3F1426N13W	GAS	25	4	3										325		59671
	WAT	31	28	23										82		937
LEASE TOTAL	GAS	25	25	130	98	13	618	1		10	29			949		335595
	WAT	31	812	54	30	31	840	29			4			1831		3663
OCME FEDERAL 17-27-13 2M1727N13W	GAS	2048	2251	2097	1878	1755	2063	1876	128	422	1964	474		16556		228477
	WAT	62	1568	62	60	62	60	62	16					1952		3650
OCME FEDERAL 18-27-13 2F1827N13W	GAS	421	1252	1861	1439	620	468	156	24	118	214	36		6609		350380
	WAT										7			7		7
P&A OCME FEDERAL 21-27-13 1E2127N13W	GAS	PLUGGING APPROVED 1990														8453
	WAT															6511
OCME FEDERAL 25-26-13 1H2526N13W	GAS	249	206	249	202	170	186	281	61	67	257	46		1904		18399
	WAT	31	28	31	30	31	30	30	8		4			223		1217
P&A FEDERAL 18 1I1827N13W	GAS	LAST PROD. DATE 08/82													S	679
P&A FEDERAL 24 1P2426N13W	GAS	137	44	49	52	92	170	137						681		22746
	WAT										4			4		4
FREW-FED 1J2026N12W	GAS	263	307	326	375	513	322	302	3		761	127		32995		137672
	WAT	31	784	31	30	31	30		3		3			943		1947
2N2026N12W	GAS	2148	1005	1590	1543	1039	934	1510	8039		740	131		196795		212219
	WAT										7			7		535
REC 3B2926N12W	GAS	808	831	766	370	337	297							34095		232347
P&A 4C2926N12W	GAS	LAST PROD. DATE 11/89													S	1030113
5A1926N12W	GAS	329	186	196	258	303	246	207	28		218	52		20235		72244
	WAT										8			8		162
8J1926N12W	GAS	442	331	260	240	194	72	236		6				1781		67642
	WAT										4			4		251
9H3026N12W	GAS	318	165	196	319	219	339	1024	12	82				2694		69534
	WAT										3			3		534
SI 12P3026N12W	GAS	198	25	642	528	473	761	108		134	217	42		3128		141433
	WAT										14			14		523
P&A 13N2926N12W	GAS			1										1	S	37718
	WAT															893
15P2926N12W	GAS	205	176	349	255	275	244	333	23	139	225	52	138	2414		31182
	WAT										2			2		1364
P&A 16K1926N12W	GAS	LAST PROD. DATE 04/84													S	5383
LEASE TOTAL	GAS	4711	3046	4326	3888	3353	3215	3720	8105	361	2161	404	138	37429		2010367
	WAT	31	784	31	30	31	30		3		41			981		5532
FUSSELMAN FEDERAL 1L1726N12W	GAS	19	41	128	96	68	13				66		887	1318		193415
	WAT				120						349		1179	1648		1549
R 2E1726N12W	GAS	LAST PROD. DATE 11/88													0	63237
	WAT															1389
LEASE TOTAL	GAS	19	41	128	96	68	13				66		887	1318		166652
	WAT				120						349		1179	1648		1516
HANLAD FEDERAL 2A3126N12W	GAS	LAST PROD. DATE 12/89													S	46035
	WAT				14									14		1213
HIGH ROLL R 1O3527N13W	GAS	34	39	1							78	10		162		59192
2K3527N13W	GAS	498	946	65							663	171		2343		256871
3G3527N13W	GAS	291	304	166										761	S	123879
4O3527N13W	GAS	1196	1048	33							630	135		3042		42[illegible]
	WAT										3			3		[illegible]
LEASE TOTAL	GAS	2019	2337	265							1371	316		6308		875[illegible]
	WAT										3			3		[illegible]
HIGH ROLL METER RUN 1O3527N13W	GAS	PLUGGING APPROVED 1982														[illegible]
HUGH LAKE 1M3627N13W	GAS	PLUGGING APPROVED 1585														22493
	WAT															
SOUTHLAND 1K 326N13W	GAS	1258	793	901	782	959	560	1006	10	293	193	267	875	7897		79467
	WAT															
Y 2O 326N13W	GAS	628	264	300	260	320	187	534		146	96	134	437	3276		45251
	OIL															
	WAT															23
3C1026N13W	GAS	LAST PROD. DATE 02/89													S	50811
	OIL															
	WAT															19
4A 926N13W	GAS	LAST PROD. DATE 02/89													S	23253
	WAT															
5G1126N13W	GAS	LAST PROD. DATE 01/86													S	[illegible]
	OIL															
	WAT															
6H1026N13W	GAS	1258	1188	1351	1172	1439	840	1343		390	258	356	1167	10762		194[illegible]
	OIL															
	WAT															
7D1126N13W	GAS	1048	396	450	351	480	280	504		146	96	133	437	4361		[illegible]
	OIL															
	WAT															
LEASE TOTAL	OIL															
	GAS	4192	2641	3002	2605	3198	1867	3357	10	975	643	890	2916	26294		[illegible]
	WAT															
SUSCO FEDERAL 1J 926N12W	GAS	67	48	34	52	48	32							291		11[illegible]
		PLUGGING APPROVED 1990														
COMPANY TOTAL	OIL															
	GAS	17639	15187	15561	13921	12403	13842	11465	8396	3128	7618	2987	5234	174431		[illegible]
	WAT	155	3192	178	224	155	960	121	33		1606		1179	7863		[illegible]

P-R-O MANAGEMENT, INC. **

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1990 PROD	MP	ACCUM
NAVAJO 4 1E 425N12W	GAS	1590	2797	3324	3386	3648	3106	1840	362		417	1769	3137	25376		97[illegible]

TEXACO INC. **

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1990 PROD	MP	ACCUM
OCME FEDERAL 07-27-13 2O 727N13W	GAS	401	798	480					2	174	556		330	2741		25[illegible]
	WAT		24	31				14	8	6	31	10	28	152		[illegible]
3G 727N13W	GAS	12	88	135	100	50				47				432		[illegible]
		RECOMPLETED TO BASIN FRUITLAND COAL (GAS)														
LEASE TOTAL	GAS	413	886	615	100	50			2	221	556		330	3173		[illegible]
	WAT		24	31				14	8	6	31	10	28	152		
OCME FEDERAL 17-27-13 3O1727N13W	GAS									91				91		14[illegible]
	WAT	31	28		30	31	30	31	31	30	31	30	31	334		
OCME FEDERAL 24-26-13 3H2426N13W	GAS	LAST PROD. DATE 10/83													S	[illegible]
	WAT															42
OCME NAVAJO 12-26-13 1M1226N13W	GAS	309	278	352	304	337	263	430	22	154	212	103	252	3016		82795
	WAT	31	28	31	30	31	30	30	1	6	25	30	31	304		1385
OCME NAVAJO 13-26-13 1I1326N13W	GAS	591	461	780	489	554	634	491	24	238	623	229	897	6211		95652
	WAT	45	42	47	45	47	45	44	2	15	38	45		415		1554
2G1326N13W	GAS	PLUGGING APPROVED 1988														45955
	WAT															691
3E1326N13W	GAS	2428	1582	2317	1906	1391	2493	2123		631	2012	576	2647	20506		370338
4M1326N13W	GAS	PLUGGING APPROVED 1988														36845
	WAT															145
LEASE TOTAL	GAS	3019	2043	3097	2395	1945	3127	2614	24	869	2635	805	3544	26717		548[illegible]
	WAT	45	42	47	45	47	45	44	2	15	38	45		415		2[illegible]
OCME NAVAJO 18-26-12 1M1826N12W	GAS	LAST PROD. DATE 01/88													S	57[illegible]
	WAT															
OCME NAVAJO 21-27-13 3M2127N13W	GAS	1239	1432	1934	745	785	993	1560	8	508	2034	471	2020	13729		215[illegible]
FREW-FED 7M1926N12W	GAS	LAST PROD. DATE 10/83													S	[illegible]

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1991	ACCUM
LEASE TOTAL	GAS		292	247		182	224	220	210	193	246			1814	270176
	WAT														44
CHACO PLANT															
3B2026N12W	GAS	PLUGGING APPROVED 1979													422
4M1426N12W	GAS	LAST PROD. DATE 05/81												D	14313
5E2126N12W	GAS	LAST PROD. DATE 08/88												C	63095
	WAT														23
60 526N12W	GAS	PLUGGING APPROVED 1979													406
9M 526N12W	GAS	PLUGGING APPROVED 1979													160
12I2226N12W	GAS	LAST PROD. DATE 06/88												S	14531
19K2226N12W	GAS	PLUGGING APPROVED 1988													10914
	WAT														1
R 19N2226N12W	GAS	PLUGGING APPROVED 1988													67335
	WAT														25
20M2726N12W	GAS	LAST PROD. DATE 08/81												C	13458
35J2726N12W	GAS	PLUGGING APPROVED 1988													396166
36F3626N12W	GAS	LAST PROD. DATE 03/82												T	93134
LEASE TOTAL	GAS														675174
	WAT														49
COMPANY TOTAL	GAS		292	247		182	224	220	210	193	246			1814	945370
	WAT														93
MERIDIAN OIL INCORPORATED															
FREW-FED															
6F1926N12W	GAS	LAST PROD. DATE 05/85												S	81483
	WAT														333
J K															
1F3027N12W	GAS	190	109	193	185	163	148	150	68	194	2		183	1585	22456
COMPANY TOTAL	GAS	190	109	193	185	163	148	150	68	194	2		183	1585	84541
	WAT														308
MERRION OIL AND GAS CORPORATION															
BARTLESVILLE															
1C 226N13W	GAS	35	5				7	49	10			8	43	157	62677
CHACO															
1F1826N12W	GAS	LAST PROD. DATE 03/90												S	102413
2M 726N12W	GAS	RECOMPLETED TO BASIN FRUITLAND COAL (GAS)													33015
R 2K 726N12W	GAS								155	383	393	228		1159S	41320
3M1226N13W	GAS											30		30	42879
	WAT														1192
4D 726N12W	GAS	53	89			77	135	129	52	117	176	134	36	998	197708
5P 1226N13W	GAS		20			17	8	75	23	71	23	30		267S	143517
11E 1226N13W	GAS	32	113			76	114	202	71	245	144	172		1169	305519
13I1026N13W	GAS	LAST PROD. DATE 05/86												S	23461
14K1026N13W	GAS	LAST PROD. DATE 05/86												S	2509
LEASE TOTAL	GAS	85	222			170	257	406	301	816	736	594	36	3623	897591
	WAT														1192
CHACO LIMITED															
1M 1226N13W	GAS	LAST PROD. DATE 02/89												S	38586
	WAT														1593
J 1K 1226N13W	GAS	133	176											309S	11457
2G 1226N13W	GAS	LAST PROD. DATE 04/85												S	12315
	WAT														67
J 2B 1226N13W	GAS	69				76	153	175	44	132	176	153		978	35339
	WAT														131
3F1226N13W	GAS					268	438	543	174	248	508	552	349	3080	47277
	WAT														51
J 3E1226N13W	GAS					403	658	815	261	373	762	828	524	4624	[illegible]
	WAT														14
LEASE TOTAL	GAS	202	176			747	1249	1533	479	753	1446	1533	873	8991	210705
	WAT														1698
DOME FEDERAL 07-27-13															
1E 727N13W	GAS	432	35									701	145	1313	47273
	WAT														398
DOME FEDERAL 09-27-13															
1M 527N13W	GAS	LAST PROD. DATE 08/90												S	11473
	WAT														217
DOME FEDERAL 14-26-13															
1P1426N13W	GAS	LAST PROD. DATE 01/87												S	19556
	WAT														1
2M1426N13W	GAS	1												1S	256363
	WAT														2665
3F1426N13W	GAS	LAST PROD. DATE 03/90												S	59671
	WAT														997
LEASE TOTAL	GAS	1												1	335590
	WAT														3663
DOME FEDERAL 17-27-13															
2M1727N13W	GAS	1044										1321		2365	230442
	WAT														3650
DOME FEDERAL 18-27-13															
2F1827N13W	GAS	167					241	85	49	23		33	35	633	351013
	WAT														7
DOME FEDERAL 21-27-13															
1E2127N13W	GAS	PLUGGING APPROVED 1990													8453
	WAT														6511
DOME FEDERAL 25-26-13															
1M2526N13W	GAS	31										189	196	416	18305
	WAT														1277
FEDERAL 19															
1I1927N13W	GAS	LAST PROD. DATE 08/82												S	529
FEDERAL 24															
1P2426N13W	GAS	LAST PROD. DATE 07/90												S	22746
	WAT														4
FREW-FED															
1J2026N12W	GAS	281										455	427	1163	160135
	WAT														1940
2N2026N12W	GAS	930	70	287	816	6					1130	398		3607S	215885
	WAT														535
3B2926N12W	GAS	LAST PROD. DATE 06/90												S	232062
4C2326N12W	GAS	LAST PROD. DATE 11/89												S	1030313
5A1926N12W	GAS	16										393		409	79553
	WAT														162
8J1926N12W	GAS	1										96		97	62739
	WAT														251
9M3026N12W	GAS											40	354	394	69928
	WAT														534
10F3026N12W	GAS	PLUGGING APPROVED 1991													2388
12P3026N12W	GAS	36												36S	141469
	WAT														323
13N2926N12W	GAS	LAST PROD. DATE 03/93												S	37716
	WAT														391
15P2926N12W	GAS	83				184						107	259	633	31315
	WAT														1364
16K1326N12W	GAS	LAST PROD. DATE 04/86												S	5989
LEASE TOTAL	GAS	1317	70	287	816	190					1130	1489	1040	6339	2018794
	WAT														5902
FUSSELMAN FEDERAL															
1L1726N12W	GAS		114	354										468	108083
	WAT			926										926	2574
		RECOMPLETED TO BASIN FRUITLAND COAL (GAS)													
R 2E1726N12W	GAS	LAST PROD. DATE 11/88												0	63237
	WAT														1389
LEASE TOTAL	GAS		114	354										468	167120
	WAT			926										926	4542
HANLAD FEDERAL															
2A3126N12W	GAS	LAST PROD. DATE 12/89												S	96035
	WAT														1210
HIGH ROLL															
R 1O3527N13W	GAS	37					7	44						885	59600
2K3527N13W	GAS	326										498		824	257715
3G3527N13W	GAS	LAST PROD. DATE 03/90												S	124973
4O3527N13W	GAS	832		964	272	73	193			302	304	841	304	4055	433745
	WAT														3
LEASE TOTAL	GAS	1165		964	272	73	200	44		302	304	1339	304	4967	880310
	WAT														3
HIGH ROLL METER RUN															
1O3527N13W	GAS	PLUGGING APPROVED 1982													82563
HUGH LAKE															
1M3627N13W	GAS	PLUGGING APPROVED 1985													22335
	WAT														5
SOUTHLAND															
1K 3226N13W	GAS	236	184	1		487	616	699	209	391	658	589		4070	83579
	WAT														7
Y 2O 3226N13W	GAS	118	92			243	308	350	104	195	330	294		2034	41233
	OIL														1
	WAT														23
3C1026N13W	GAS	LAST PROD. DATE 02/89												S	50411
	OIL														1
	WAT														47
4A 726N13W	GAS	LAST PROD. DATE 02/89												S	23130
	WAT														[illegible]
5G1126N13W	GAS	LAST PROD. DATE 01/86												S	50317
	OIL														1
	WAT														[illegible]

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1991 PROD	PP	ACCUM
6M1?26N13W	GAS	315	246			243	821	932	279	522	879	785		5022		193756
	OIL															1
	WAT															27
7??126N13W	GAS	118	92			649	308	349	104	195	330	294		2439		76732
	OIL															1
	WAT															13
LEASE TOTAL	OIL															5
	GAS	787	614	1		1622	2053	2330	696	1303	2197	1962		13565		533348
	WAT															569
SUSCO FEDERAL																
1J ??N12W	GAS	PLUGGING APPROVED 1990												-		11530
COMPANY TOTAL	OIL															5
	GAS	5266	1236	1606	1088	2802	4007	4447	1535	3197	5813	9169	2672	42838		5961631
	WAT			926										926		31317
R-B-O MANAGEMENT, INC.																
NAVAJO 6																
1F 6?5N12W	GAS	2167	1234	1872	2748	1722	1961	1384	1870	1721	1965	1177	1660	21481		998311
TEXACO EXPLORATION & PRODUCTION INC. N.M.																
DOME FEDERAL 07-27-13																
2O 727N13W	GAS	433	66	226	213	221	225	172	181	173	284	132	98	2424		28220
	WAT	22	2	25	30	31	30	31	31	30	31	25	31	319		933
DOME FEDERAL 17-27-13																
3O1727N13W	GAS	LAST PROD. DATE 09/90													S	14348
	WAT	6	3										31	40		537
DOME NAVAJO 12-26-13																
1M1226N13W	GAS	149	48	219	204	156	185	227	170	161	151	114	118	1902		84697
	WAT	31	3	31	30		30	25	30			26	31	237		1622
DOME NAVAJO 13-26-13																
1E1326N13W	GAS	275	123	584	517	379	397	307	295	203	369	309	109	3867		99519
	WAT	47	6	45	45		45	27	45	45	47	45	45	442		2396
3E1326N13W	GAS	903	262	2351	1885	1300	1697	1439	1068	1677	1492	1080		15154	S	385192
LEASE TOTAL	GAS	1178	385	2935	2402	1679	2094	1746	1363	1880	1861	1389	109	19021		484711
	WAT	47	6	45	45		45	27	45	45	47	45	45	442		2376
DOME NAVAJO 21-27-13																
3M2127N13W	GAS	978	71	1754	1275	751	435	1485	572	1277	1641	1302	118	11659		227302
COMPANY TOTAL	GAS	2738	570	5134	4094	2807	2939	3630	2286	3491	3937	2937	443	35006		838578
	WAT	106	14	101	105	31	105	83	106	75	78	96	138	1038		5648
TEXACO INC.																
DOME FEDERAL 07-27-13																
3G 727N13W	GAS	RECOMPLETED TO BASIN FRUITLAND COAL (GAS)														4907
DOME FEDERAL 24-26-13																
3M2426N13W	GAS	PLUGGING APPROVED 1987														8269
	WAT															42
DOME NAVAJO 13-26-13																
2G1326N13W	GAS	PLUGGING APPROVED 1988														45255
	WAT															691
4M1326N13W	GAS	PLUGGING APPROVED 1988														36845
	WAT															145
LEASE TOTAL	GAS															82800
	WAT															836
DOME NAVAJO 18-26-12																
1M1826N12W	GAS	PLUGGING APPROVED 1989														52872
	WAT															928
FREW-FED																
7M1926N12W	GAS	PLUGGING APPROVED 1987														1386
FUSSELMAN FEDERAL																
2D1726N12W	GAS	PLUGGING APPROVED 1980														42796
KIRBY GALLEGOS																
2M2627N13W	GAS	PLUGGING APPROVED 1985														20149
COMPANY TOTAL	GAS															212879
	WAT															1406
MAX D. WEBB																
FEDERAL																
3P2727N13W	GAS	344	235	601	292	326	446	904	256	576	979	869		5828	S	275741
	WAT															2883
FEDERAL 27																
6M2727N13W	GAS	107	121	293	241	138	129		80	220	120	150		1599	S	328030
7E2727N13W	GAS	92	55	138	84	120	127	168	39	120	119	100	73	1235		110833
LEASE TOTAL	GAS	199	176	431	325	258	256	168	119	340	239	250	73	2834		438863
FEDERAL 34																
1A3427N13W	GAS	322	330	1231	1186	625	742	1026	233	305	791	775	5	7571		346662
2I3427N13W	GAS	99	33	224	317	244	307	480	205	311	502	438	17	3177		34891
	WAT															4676
LEASE TOTAL	GAS	421	363	1455	1503	869	1049	1506	438	616	1293	1213	22	10748		381553
	WAT															4676
STATE																
1 2226N13W	GAS	174	164	391	348	244	294	366	158	313	379	314	159	3304		194180
COMPANY TOTAL	GAS	1138	938	2878	2468	1697	2045	2944	971	1845	2890	2646	254	22714		1290337
	WAT															7361

WILD HORSE GALLUP (GAS) GP 7N TO 8N

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1991 PROD	PP	ACCUM
JEROME P. MCHUGH																
APACHE																
1O1826N 3W	GAS	877	693	394	203	205	358	315	379	288	366	423	689	5210		178362
	OIL	14	15	18	18	20	14	18	30	18	12	35	33	245		9395
	WAT	3	3	3	5		3	4	4	4	2	2	3	38		749
E 1A1926N 3W	GAS	2377	2043	2269	2275	1854	1936	1879	2196	1760	1756	1736	2100	24169		222179
	OIL	33	30	14	27	22	31	23	30	25	21	27	34	317		3416
	WAT	3	2	5	3	2	3	2	3	4	3	2	2	34		362
2I1926N 3W	GAS	LAST PROD. PRIOR TO 6/73													S	51796
	OIL															737
3?1926N 3W	GAS	LAST PROD. DATE 01/89													S	1495760
	OIL															16116
	WAT															523
E 3H1926N 3W	GAS	LAST PROD. DATE 09/83													S	170
	OIL															60
4I1926N 3W	GAS	LAST PROD. DATE 06/88													S	366774
	OIL															5183
	WAT															10
COMPANY TOTAL	OIL	47	45	32	45	42	45	41	60	43	33	62	67	562		35707
	GAS	3254	2736	2663	2476	2059	2294	2196	2565	2048	2142	2159	2789	29379		2315041
	WAT	6	5	10	8	2	6	6	7	8	5	4	5	72		1553
MERIDIAN OIL INCORPORATED																
JICARILLA A 103																
E 11F1926N 4W	GAS			654	1172	10009		1872	10824	10391	321	9947	1783	46973		68088
	OIL				62					134		79		275		347
12A1726N 4W	GAS			1156					1988	2038		2029	1154	8365		98237
	OIL			59						90		33		182		2337
	WAT															40
M 12I1726N 4W	GAS					112	6		94	155	130	128	112	737		1165
	OIL					1			11					12		16
13C2026N 4W	GAS					341	63		371	506	108		300	1689		2487
	OIL															
COMPANY TOTAL	OIL			59	62	1			11	224		112		469		2599
	GAS			1810	1172	10462	69	1872	13277	13090	559	12104	3349	57764		170776
	WAT															60
SNYDER OIL CORP. - N.M.																
TRIBAL 5																
4M 426N 3W	GAS															143009
	OIL						2							2		2786
	WAT												4	4		2535
E 6M 526N 3W	GAS	153				1313	554	518	374	454	29	1046	553	4995		42671
	OIL	13			15	29	29	30	27	23		27	32	225		1242
	WAT					15	12	14	9	11		12	11	84		85
A 9D 726N 3W	GAS				110	1167	647	422	322	520	219	197	406	4010		78907
	OIL				7	1	1	1	2		1		1	14		139
	WAT											4	8	12		96
COMPANY TOTAL	OIL	13			22	30	32	31	29	23	1	27	33	241		4187
	GAS	153			110	2480	1201	940	696	974	248	1243	959	9004		264398
	WAT					15	12	14	9	11		16	23	100		2715
SOUTHERN UNION EXPLORATION CO.																
JICARILLA A																
9E2326N 4W	GAS					10418					155	126		10699	S	3530980
	OIL															28033
11J1426N 4W	GAS	6484	6435	7189	7408	7644	2999				7262	4056	2642	52119		1588540
	OIL	96	44	52	67	56	28				63	38	13	457		10786
	WAT															10
12D2426N 4W	GAS	2797	13506	15238	14935	17335	8081			3738	19033	14959	6279	116201		2396146
	OIL	91	172	200	226	218	57			94	179	170	60	1467		11355
	WAT															25

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1992 PROD	PR	ACCUM
2B 225N12W	GAS	4826	6039	6093	5174	2751	4586	4113	4060	3512	4614	4409	4009	54186		832133
LEASE TOTAL	GAS	9038	10672	10922	9478	6779	7874	8390	8767	7552	9212	6858	8539	104081		1424262
NTB STATE																
1C3226N12W	GAS	5722	5856	5397	4461	4297	3120	4727	5736	4929	5436	5415	5170	60246		1142196
PHILLIPS FEDERAL																
1E 925N12W	GAS	117	103	118	112	106	94	125	119	108	151	163	145	1461		33374
	WAT															3
CHRISTOPHER RAY COUM																
1A 525N12W	GAS	729	1054	1129	1019	1099	1096	1151	1175	1054	1138	851	882	12377		139554
	WAT															2
COMPANY TOTAL	GAS	21834	22372	24208	22041	18623	18038	20861	26205	18663	24105	21954	23882	262786		7360835
	WAT															5593
NIXON DEVELOPMENT CO.																
CHACO WASH COM																
J 1I3226N12W	GAS	PLUGGING APPROVED 1983														
NIXON FEDERAL																
1G 425N12W	GAS	ZONE ABANDONED														2381
R 1G 425N12W	GAS	PLUGGING APPROVED 1984														5538
LEASE TOTAL	GAS															8219
IN NI DA PAH																
1I 425N12W	GAS	ZONE ABANDONED														15992
R 1I 425N12W	GAS	ZONE ABANDONED														3236
	WAT															2
LEASE TOTAL	GAS															19228
	WAT															2
NA DA PAH																
1M 125N12W	GAS	RECOMPLETED TO BISTI FARMINGTON (GAS)														17776
VIRGINIA STATE																
3M 225N12W	GAS	PLUGGING APPROVED 1990														7449
COMPANY TOTAL	GAS															52572
	WAT															2
JEROME P. MCHUGH																
CHACO PLANT																
3B2026N12W	GAS	PLUGGING APPROVED 1979														566
4M1626N12W	GAS	LAST PROD. DATE 05/81													D	14313
5E2126N12W	GAS	LAST PROD. DATE 08/88													D	63395
	WAT															23
6O 526N12W	GAS	PLUGGING APPROVED 1979														806
9H 526N12W	GAS	PLUGGING APPROVED 1979														160
12I2226N12W	GAS	LAST PROD. DATE 06/88													S	16331
19K2226N12W	GAS	PLUGGING APPROVED 1988														10314
	WAT															1
R 19N2226N12W	GAS	PLUGGING APPROVED 1988														67685
	WAT															25
20M2726N12W	GAS	LAST PROD. DATE 08/81													D	13449
35J2726N12W	GAS	PLUGGING APPROVED 1988														396166
36F3626N12W	GAS	LAST PROD. DATE 03/82													T	93134
COMPANY TOTAL	GAS															675174
	WAT															49
MERIDIAN OIL INCORPORATED																
FREW-FED																
6F1926N12W	GAS	LAST PROD. DATE 05/85													S	61683
	WAT															308
J R																
1F3027N12W	GAS	161	134	147	147	154	131	153	142	100	115	122	142	1648		24526
COMPANY TOTAL	GAS	161	134	147	147	154	131	153	142	100	115	122	142	1648		86369
	WAT															308
MERRION OIL AND GAS CORPORATION																
BARTLESVILLE																
1C 226N13W	GAS	53	53	59	84	87	84	87	87	84	87	84	87	936		63513
CHACO																
1F1826N12W	GAS		209											2095		102522
2N 726N12W	GAS	RECOMPLETED TO BASIN FRUITLAND COAL (GAS)														33515
R 2K 726N12W	GAS	241	209	116	8	193	280	231	370	226	479	413	298	3064		46384
3M1226N13W	GAS	LAST PROD. DATE 11/91													S	42899
	WAT															1192
4D 726N12W	GAS	79		18	49	89	96	96	96	37	62	59	82	757		200665
5P 126N13W	GAS	49				6	1	1	6	6	19	9	13	110		143727
11E 126N13W	GAS	359	88	28	231	333	216	105	209	389	373	341	233	2905		308624
13I1026N13W	GAS	LAST PROD. DATE 05/86													S	23841
14K1026N13W	GAS	LAST PROD. DATE 05/86													S	2839
LEASE TOTAL	GAS	728	506	162	288	621	591	431	679	658	933	822	626	7045		904586
	WAT															1192
CHACO LIMITED																
1M 126N13W	GAS	LAST PROD. DATE 02/89													S	38586
	WAT															1590
J 1K 126N13W	GAS			117	8		357	2		59			73	616		12383
2G 126N13W	GAS	LAST PROD. DATE 04/85													S	12015
	WAT															67
J 2B 126N13W	GAS	54		51	158	154	153	153	153	179	164	157	165	1541		36550
	WAT															131
3F1226N13W	GAS	438	485	528	455	491	463	488	546	826	860	839	829	7248		54525
	WAT															51
J 3E1226N13W	GAS	656	727	792	682	737	695	731	818	551	574	560	553	8076		74526
	WAT															39
LEASE TOTAL	GAS	1148	1212	1488	1303	1382	1668	1374	1517	1615	1598	1556	1620	17481		228385
	WAT															1848
DOME FEDERAL 07-27-13																
1E 727N13W	GAS	872	552	430		713	410	426	494	301	317	374	258	5147		52420
	WAT															398
DOME FEDERAL 08-27-13																
1M 827N13W	GAS	LAST PROD. DATE 08/90													S	11473
	WAT															217
DOME FEDERAL 14-26-13																
1P1426N13W	GAS	LAST PROD. DATE 01/87													S	19956
	WAT															1
2M1426N13W	GAS					3								3	S	256366
	WAT															2555
3F1426N13W	GAS	LAST PROD. DATE 03/90													S	59571
	WAT															1007
LEASE TOTAL	GAS					3								3		335893
	WAT															3563
DOME FEDERAL 17-27-13																
2M1727N13W	GAS	1813	2176	1534	777	1408	1872	1828	1951	1985	2002	2001	1175	20522		251164
	WAT															3550
DOME FEDERAL 18-27-13																
2F1827N13W	GAS	9	456	122	78	41	40	69	48	44	59	62	352	1380		352573
	WAT															7
DOME FEDERAL 21-27-13																
1E2127N13W	GAS	PLUGGING APPROVED 1990														8453
	WAT															6511
DOME FEDERAL 25-26-13																
1M2526N13W	GAS	108	312	350	106	251	243	243	243	263	255	194	11	2579		21384
	WAT															1277
FEDERAL 19																
1I1827N13W	GAS	LAST PROD. DATE 08/82													S	529
FEDERAL 24																
1P2426N13W	GAS	LAST PROD. DATE 07/90													S	22746
	WAT															4
FREW-FED																
1J2026N12W	GAS	197	255	230	78	164	141	168	146	136	171	247	274	2207		111342
	WAT															1940
2M2026N12W	GAS							729	766	1968	1508	1356	1110	7437		243122
	WAT															535
3B2926N12W	GAS	LAST PROD. DATE 06/90													S	212752
4C2926N12W	GAS	284										511		795	S	1031138
5A1926N12W	GAS	59	700	845	168	176	511	1152	1044	925	925	147	270	6922		86575
	WAT															162
8J1926N12W	GAS	55	39	13		25	1				9	140	74	356		63395
	WAT															251
9M3026N12W	GAS			36				71	4	133	18		120	382		70110
	WAT															534
10F3026N12W	GAS	PLUGGING APPROVED 1991														2398
12P3026N12W	GAS	LAST PROD. DATE 01/91													S	141469
	WAT															523
13N2926N12W	GAS											272		272		37790
	WAT															993
15P2926N12W	GAS	184	55	88	73	27	18	18	15	635	287		291	1694		33509
	WAT															1364
16K1926N12W	GAS	LAST PROD. DATE 04/86													S	5789
LEASE TOTAL	GAS	779	1049	1212	319	392	671	2138	1975	3800	2910	2673	2139	20065		2038559
	WAT															5902
FUSSELMAN FEDERAL																
1L1726N12W	GAS	RECOMPLETED TO BASIN FRUITLAND COAL (GAS)														103383
	WAT															2574
R 2E1726N12W	GAS	LAST PROD. DATE 11/88													D	65737
	WAT															1988
LEASE TOTAL	GAS															169120
	WAT															4562

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1992 PROD	MP	ACCUM
MANLAD FEDERAL																
2A 31 26N 12W	GAS		32	20						2				545		46059
	WAT															1219
HIGH ROLL																
# 1O 35 27N 13W	GAS				86	87	84	87	87	84	82	84	82	771		60251
2K 35 27N 13W	GAS	606	328	331	360	383	299	294	296	491	405	333	332	4459		262173
3 35 27N 13W	GAS	LAST PROD. DATE 03/90													S	129970
4 35 27N 13W	GAS	987	827	489	821	890	810	834	1626	2830	2191	2172	2019	16496		450241
	WAT															3
LEASE TOTAL	GAS	1593	1155	820	1265	1360	1193	1215	2009	3405	2683	2589	2438	21725		902135
	WAT															3
HIGH ROLL METER RUN																
1O 35 27N 13W	GAS	PLUGGING APPROVED 1982														92583
HIGH LAKE																
1M 34 27N 13W	GAS	PLUGGING APPROVED 1985														22535
	WAT															5
SMITHLAND																
1K 3 26N 13W	GAS	400	561	543	363	317	343	493	537	524	621	652	597	5951		99491
	WAT															7
Y 2O 3 26N 13W	GAS	240	337	326	218	190	206	295	323	105	124	130	119	2613		49424
	OIL															1
	WAT															20
3C 10 26N 13W	GAS	160	225	217	145	127	137	197	215	209	249	261	239	2381		53197
	OIL															1
	WAT															19
4A 9 26N 13W	GAS	LAST PROD. DATE 02/89													S	23290
	WAT															953
5G 11 26N 13W	GAS	LAST PROD. DATE 01/86													S	50112
	OIL															1
	WAT															20
6M 10 26N 13W	GAS	558	785	761	507	445	480	689	753	942	1118	1172	1076	9286		209244
	OIL															1
	WAT															20
7O 11 26N 13W	GAS	240	337	326	218	190	206	295	323	315	373	391	358	3572		81774
	OIL															1
	WAT															19
LEASE TOTAL	OIL															5
	GAS	1598	2245	2173	1451	1269	1372	1969	2151	2095	2485	2606	2389	23903		557151
	WAT															568
SUSCO FEDERAL																
1J 9 26N 12W	GAS	PLUGGING APPROVED 1990														11510
COMPANY TOTAL	OIL															5
	GAS	8701	9748	8370	5671	7527	8144	9780	11154	14252	13337	12961	11095	120740		6082141
	WAT															31317
P-R-O MANAGEMENT, INC.																
NAVAJO 9																
1E 4 25N 12W	GAS	1474	554	1121	900	1253	969	663	256	1801	1838	1137		11966		1009777
TEXACO EXPLORATION & PRODUCTION INC. N.M.																
DOME FEDERAL 07-27-13																
2O 7 27N 13W	GAS	156	361	432	166	260	8	357	385	474	155	275	236	3265		31155
	WAT	31		31	30	31	30	31	31	30	31		31	307		1240
TEXACO INC.																
DOME FEDERAL 07-27-13																
3G 7 27N 13W	GAS	RECOMPLETED TO BASIN FRUITLAND COAL (GAS)														4937
DOME FEDERAL 24-26-13																
1H 24 26N 13W	GAS	PLUGGING APPROVED 1987														8259
	WAT															42
DOME NAVAJO 13-26-13																
2G 13 26N 13W	GAS	PLUGGING APPROVED 1988														49755
	WAT															571
4M 13 26N 13W	GAS	PLUGGING APPROVED 1988														36645
	WAT															145
LEASE TOTAL	GAS															82330
	WAT															836
DOME NAVAJO 19-26-12																
1M 19 26N 12W	GAS	PLUGGING APPROVED 1989														52372
	WAT															328
FREM-FED																
7M 19 26N 12W	GAS	PLUGGING APPROVED 1987														1386
FUSSELMAN FEDERAL																
2O 17 26N 12W	GAS	PLUGGING APPROVED 1980														42796
KIRBY GALLEGOS																
2M 26 27N 13W	GAS	PLUGGING APPROVED 1985														20149
COMPANY TOTAL	GAS															212379
	WAT															1936
MAK D. WEBB																
FEDERAL																
1P 27 27N 13W	GAS	1001	1085	478	715	949	644	840	1188	966	792	758	782	10198		285939
	WAT															2385
FEDERAL 27																
6N 27 27N 13W	GAS	433	144		86	70	47	152			29		35	996		329326
7E 27 27N 13W	GAS	144	132	142	76	85	98	106	127	55	32	43	62	1102		111335
LEASE TOTAL	GAS	577	276	142	162	155	145	258	127	55	61	43	97	2098		440661
FEDERAL 34																
1A 34 27N 13W	GAS	1708	1275	1359	925	1007	678	765	1237	941	1019	1249	1058	13221		359993
2I 34 27N 13W	GAS	378	278	269	275	205	235	244	265	253	289	250	133	3074		37763
	WAT															4476
LEASE TOTAL	GAS	2086	1553	1628	1200	1212	913	1009	1502	1194	1308	1499	1191	16295		397549
	WAT															4476
STATE																
1A 2 26N 13W	GAS	412	341	333	351	360	340	328	335	313		347	382	3842		199322
COMPANY TOTAL	GAS	4076	3255	2581	2423	2676	2042	2435	3152	2528	2161	2647	2452	32433		1322770
	WAT															7361

WILD HORSE GALLUP (GAS) GP 7N TO 9M

WELL S T R		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1992 PROD	MP	ACCUM
JEROME P. MCHUGH																
APACHE																
1O 19 26N 3W	GAS	490	555	736	478	394	414	444	417	288	362	349	485	5412		183674
	OIL	23	22	25	25	13	10	10	12	[illegible]	18	14	1	181		9576
	WAT	4	5	5	3	3	3	2	4	3	3	3	1	38		787
E 1A 18 26N 3W	GAS	1820	1671	1776	1782	1927	1470	1786	2599	1665	1712	1976	2173	22367		246526
	OIL	73	24	26	23	26	21	23	23	20	19	24	16	268		4384
	WAT	3	3	5	3	2	4	2	3	3	3	4	3	38		400
2L 18 26N 3W	GAS	LAST PROD. PRIOR TO 6/73													S	51766
	OIL															737
1O 17 26N 3W	GAS										266	299	191	746		1496406
	OIL															16315
	WAT															523
F 3M 19 26N 3W	GAS	LAST PROD. DATE 09/83													S	120
	OIL															60
4L 19 26N 3W	GAS									30	47	57	43	177		367151
	OIL															5103
	WAT															19
COMPANY TOTAL	OIL	46	46	51	48	39	31	33	35	28	37	38	17	449		36156
	GAS	2310	2226	2512	2260	2321	1884	2230	3006	1983	2357	2691	2082	28682		2343723
	WAT	7	8	10	6	5	7	4	7	6	5	7	4	76		1779
MERIDIAN OIL INCORPORATED																
JICARILLA 103																
E 11 18 26N 4W	GAS	10644	6760	479	3604	6433	2612	1631	9106	4696	4701	7533	9812	68011		136899
	OIL	80	80			71			78		79		80	468		915
1M 17 26N 4W	GAS	1674	1992	1523	1245	1558	1504	1395	1531	1385	1192	1521	1136	17546		115783
	OIL	17	23	35	25	23	30	28	24	38	16	30	31	320		2557
	WAT															60
M 12L 17 26N 4W	GAS	111	24	108	80	117	144	107	141	117	91	91	83	1204		2348
	OIL			8										8		22
13C 20 26N 4W	GAS	32	28	304	279	304	316	292	296	297	306	174	228	2856		5543
	OIL				1									1		2
COMPANY TOTAL	OIL	97	103	43	26	94	30	28	102	38	95	30	111	797		3496
	GAS	12461	8694	2414	5208	8412	4576	3425	11074	6495	6290	9319	11259	89617		260393
	WAT															60
SNYDER OIL CORP. - N.M.																
TRIBAL C																
E 4M 6 26N 3W	GAS				290	50	75	33	59	31	65	34	69	706		143726
	OIL															2796
	WAT				29	7	11	7	7	7	7	7	7	88		2523
T 4M 5 26N 3W	GAS	704	366	466	459	499	490	683	695	650	512	501	814	6954		49159
	OIL	29	20	13	25	17	16	11	8	10	2	14	7	174		1536
	WAT	13	9	8	9	9	12	12	12	13	10	10	13	130		214
A 9O 7 26N 3W	GAS	466	323	507	291	512	259	625	420	481	287	506	551	5028		83135
	OIL			8		3	1	1	2	1	1	1		18		157
	WAT	10	7	10	8	12	9	6	11	12	9	11	12	116		217
COMPANY TOTAL	OIL	29	20	23	25	20	17	12	10	11	3	15	7	192		4179
	GAS	1170	689	973	1039	1061	824	1151	1176	1162	984	1061	1434	12592		276120
	WAT	23	16	18	45	28	30	28	30	32	24	28	32	334		3369

STATE OF NEW MEXICO
ENERGY & MINERALS DEPARTMENT

AMENDED

OPERATOR'S MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2088, SANTA FE, NEW MEXICO 87504

OPERATOR: MERRION OIL & GAS CORPORATION ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: JANUARY, 1993 PG 6 OF 8

API #	WELL No.	U S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	PRODUCTION BARRELS OIL/COND PRODUCED	PRODUCTION BARRELS OF WATER PRODUCED	PRODUCTION GAS PRODUCED (MCF)	DAYS PROD	DISPOSITION OF GAS SOLD	TRANS-POR-TER	OTHER	CODE	DISPOSITION OF OIL OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANS-PORTER	TRANS-POR-TER	OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																			
SNAKE EYES DAKOTA																			
Escovada		Lease NM-66124																	
30-045-28629	#1	N 08-21N-08W	P			8	630	681	20	581	GNM	100	U	203	0	NOI	0		211
Santa Fe 20		Lease Fee	** NOTE: NAMED CHANGED FROM SNAKE EYES NO. 2, APPROVED BY NMOCD ON 1/5/93.																
30-045-20955	#7 **	K 20-21N-08W	S			0	0	0	0	0	GNM	0	U						
30-045-27342	#4	I 20-21N-08W	S			0	0	0	0	0	GNM	0	U						
30-045-22568	#3	H 20-21N-08W	P			249	35,617	1,560	13	963	GNM	597	U						
			Battery Total			249	35,617	1,560		963		597		181	0	NOI	0		430
			FIELD TOTALS			257	36,247	2,241		1,544		697		384	0		0		641
UNDESIGNATED GALLUP																			
Chaco Wash		Lease NO692081236																	
30-031-20975	#1	J 13-20N-06W	S			0	0	0	0	0		0	U	49	0	NOI	0		49
WAW FRUITLAND SAND PICTURED CLIFFS																			
Armour Federal		Lease NM-0559974																	
30-045-22076	#1Y	C 04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Bartlesville		Lease Fee/E9707																	
30-045-23127	#1	C 02-26N-13W	F			0	0	87	1	87	EPG	0		0	0		0		0
Chaco		Lease NM-22046																	
30-045-22309	#1	F 18-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23691	#2R	K 07-26N-12W	F			0	0	238	31	238	EPG	0		0	0		0		0
Chaco		Lease SF-080238A																	
30-045-22410	#4	D 07-26N-12W	F			0	0	67	1	67	EPG	0		0	0		0		0
30-045-22411	#5	P 01-26N-13W	F			0	0	70	31	70	EPG	0		0	0		0		0
30-045-22686	#11	E 01-26N-13W	F			0	0	227	15	227	EPG	0		0	0		0		0
30-045-23923	#13	I 10-26N-13W	PLUGGED & ABANDONED ON 1/4/93.			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23924	#14	K 10-26N-13W	PLUGGED & ABANDONED ON 1/13/93.			0	0	0	0	0	EPG	0		0	0		0		0

RECEIVED
MAR - 9 1993
OIL CON. DIV
DIST. 3

DISTRIBUTION
Original OCD Santa Fe
One Copy OCD Dist Office in which lease is located
One Copy to Transporter(s)

DATE DUE:
To be received by 24th day of next succeeding month.

STATUS CODE
F...FLOWING
P...PUMPING
G...GAS-LIFT
S...SHUT-IN
T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

"OTHER" GAS DISPOSITION CODE
X....USED OFF LEASE
D...USED FOR DRILLING
G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OF PRESSURE MAINTENANCE
V...VENTED

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature]

State of New Mexico
Energy & Minerals Department

AMENDED

OPERATOR'S MONTHLY REPORT
Form C115

OIL CONSERVATION DIVISION
P.O. Box 2088 Santa Fe, New Mexico 87504

Operator: Merrion Oil & Gas Corporation   Address: P.O. Box 840, Farmington, NM 87499   For Month/Year of: January 1993   Pg 7 of 8

Pool Name (Underline) / Lease Name / API # Well No.	U S-T-R	Well Status	Injection Volume	Injection Press.	Production Barrels Oil/Cond Produced	Production Barrels of Water Produced	Production Gas Produced (MCF)	Production Days Prod	Disposition of Gas Sold	Disposition of Gas Transporter	Disposition of Gas Other	C O D E	Disposition of Oil: Oil on Hand at Beg of Month	Disposition of Oil: Barrels to Transporter	Disposition of Oil: Transporter	Disposition of Oil: Other	C O D E	Oil on Hand at End of Month
** GAS SECTION**																		
Chaco Limited	Lease SF-080238A																	
30-045-22429 #1	N 01-26N-13W	PLUGGED & ABANDONED ON 1/2/93.			0	0	0	0	0	EPG	0		0	0		0		0
30-045-25134 #1J	K 01-26N-13W	F			0	0	435	1	435	EPG	0		0	0		0		0
30-045-23594 #2	G 01-26N-13W	PLUGGED & ABANDONED ON 1/2/93.			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23593 #2J	B 01-26N-13W	F			0	0	166	31	166	EPG	0		0	0		0		0
30-045-24612 #3	F 12-26N-13W	F			0	0	799	30	799	EPG	0		0	0		0		0
30-045-24611 #3J	E 12-26N-13W	F			0	0	532	30	532	EPG	0		0	0		0		0
Dome Federal 7-27-13	Lease NM-8409																	
30-045-23397 #1	E 07-27N-13W	F			0	0	503	31	503	EPG	0		0	0		0		0
Dome Federal 8-27-13	Lease NM-8409																	
30-045-23398 #1	N 08-27N-13W	PLUGGED & ABANDONED ON 1/13/93.			0	0	0	0	0	EPG	0		0	0		0		0
Dome Federal 14-26-13	Lease NM-31059																	
30-045-23526 #2	H 14-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23525 #3	F 14-26N-13W	PLUGGED & ABANDONED ON 1/15/93.			0	0	0	0	0	EPG	0		0	0		0		0
Dome Federal 17-27-13	Lease NM-9787																	
30-045-23401 #1	E 17-27N-13W	PLUGGED & ABANDONED ON 1/5/93.			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23402 #2	N 17-27N-13W	F			0	0	2,041	31	2,041	EPG	0		0	0		0		0
Dome Federal 18-27-13	Lease NM-8409																	
30-045-23404 #2	G 18-27N-13W	F			0	0	36	17	36	EPG	0		0	0		0		0
Dome Federal 25-26-13	Lease NM-7787																	
30-045-23305 #1	H 25-26N-13W	F			0	0	16	1	16	EPG	0		0	0		0		0
Federal 18	Lease NM-8409																	
30-045-23188 #1	I 18-27N-13W	PLUGGED & ABANDONED ON 1/4/93.			0	0	0	0	0	EPG	0		0	0		0		0
Federal 24	Lease NM-7787																	
30-045-23187 #1	P 24-26N-13W	PLUGGED & ABANDONED ON 1/11/93.			0	0	0	0	0	EPG	0		0	0		0		0
Frew Federal	Lease NM-0560223																	
30-045-22052 #1	J 20-26N-12W	F			0	0	145	31	145	EPG	0		0	0		0		0
30-045-22477 #2	N 20-26N-12W	F			0	0	547	11	547	EPG	0		0	0		0		0

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R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
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L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

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ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature]

SIGNATURE   DATE

AMENDED

OPERATOR'S MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2008 SANTA FE, NEW MEXICO 87501

OPERATOR: MERRION OIL & GAS CORPORATION ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: JANUARY, 1993

POOL NAME (UNDERLINE) Lease Name API #	WELL No.	U	S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	BARRELS OIL/COND PRODUCED	BARRELS OF WATER PRODUCED	GAS PRODUCED (MCF)	DAYS PROD	SOLD	TRANS-POR-TER	OTHER	CODE	OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANS-PORTER	TRANS-POR-TER	OTHER	CODE	OIL ON HAND AT END OF MONTH
								** GAS SECTION**												
30-045-22479	#4	C	29-26N-12W	PLUGGED & ABANDONED ON 1/2/93			0	0	0	0	0	EPG	0		0	0		0		0
30-045-22476	#5	A	19-26N-12W	F			0	0	399	31	399	EPG	0		0	0		0		0
30-045-22651	#8	J	19-26N-12W	F			0	0	19	5	19	EPG	0		0	0		0		0
30-045-22655	#9	H	30-26N-12W	F			0	0	96	31	96	EPG	0		0	0		0		0
30-045-22657	#12	P	30-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23529	#15	P	29-26N-12W	F			0	0	288	31	288	EPG	0		0	0		0		0
				Lease Total			0	0	1,494		1,494		0		0	0		0		0
Hanlad Federal			Lease NM-16473																	
30-045-22658	#2	A	31-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
Hi Roll			Lease NM-33047																	
30-045-23694	#1R	O	35-27N-13W	F			0	0	87	1	87	EPG	0		0	0		0		0
30-045-23033	#2	K	35-27N-13W	F			0	0	315	31	315	EPG	0		0	0		0		0
30-045-23034	#3	G	35-27N-13W	PLUGGED & ABANDONED ON 1/12/93.			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23032	#4	D	35-27N-13W	F			0	0	1,904	31	1,904	EPG	0		0	0		0		0
				Lease Total			0	0	2,306		2,306		0		0	0		0		0
Kirby Federal			Lease NM-308																	
30-045-22143	#1	C	05-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Ross Federal 1			Lease NM-11775																	
30-045-22484	#1	A	04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-24307	#2	J	04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Southland			Lease NM-12235																	
30-045-23409	#1	K	03-26N-13W	F			0	0	516	31	516	EPG	0		0	0		0		0
30-045-23760	#2Y	O	03-26N-13W	F			0	0	103	31	103	EPG	0		0	0		0		0
30-045-23596	#3	C	10-26N-13W	F			0	0	207	31	207	EPG	0		0	0		0		0
30-045-23595	#4	A	09-26N-13W	PLUGGED & ABANDONED ON 1/14/93.			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23886	#5	G	11-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23803	#6	H	10-26N-13W	F			0	0	929	31	929	EPG	0		0	0		0		0
30-045-23894	#7	O	11-26N-13W	F			0	0	310	1	310	EPG	0		0	0		0		0
				Lease Total			0	0	2,065		2,065		0		0	0		0		0
				FIELD TOTALS			0	0	11,082		11,082		0		0	0		0		0

RECEIVED
MAR - 9 1993
OIL CON. DIV.
DIST. 3

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"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

: I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS
: TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.
:
: ESTHER J. [illegible] (505) 327-9801
: OPERATIONS TECH

DATE DUE:

STATE OF NEW MEXICO
ENERGY & MINERALS DEPARTMENT

AMENDED

OPERATOR'S MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2088 SANTA FE, NEW MEXICO 87501

OPERATOR: MERRION OIL & GAS CORPORATION ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: JANUARY, 1993 PG 2 OF 8

POOL NAME (UNDERLINE) Lease Name API # WELL No.	U S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	PRODUCTION BARRELS OIL/COND PRODUCED	PRODUCTION BARRELS OF WATER PRODUCED	PRODUCTION GAS PRODUCED (MCF)	PRODUCTION DAYS PROD	DISPOSITION OF GAS SOLD	DISPOSITION OF GAS TRANS-POR-TER	DISPOSITION OF GAS OTHER	CODE	DISPOSITION OF OIL OIL ON HAND AT BEG OF MONTH	DISPOSITION OF OIL BARRELS TO TRANS-PORTER	DISPOSITION OF OIL TRANS-POR-TER	DISPOSITION OF OIL OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																		
Canada Mesa Com	Lease Fee/NMA44																	
30-039-23183 #4	A 10-24N-06W	F			0	0	1,661	31	1,599	EPG	62	U	148	0	MOI	0		148
30-039-23057 #4E	F 10-24N-06W	F			3	0	76	10	56	EPG	20	U	162	0	MOI	0		165
Carnahan Com	Lease Fee/NMA95																	
30-045-25844 #2	P 35-30N-12W	F			27	0	1,620	31	1,558	EPG	62	U	136	0	MOI	0		163
Federal 20	Lease SF-078530																	
30-045-26204 #1E	G 20-25N-09W	F			7	12	1,598	31	1,536	EPG	62	U	65	0	MOI	0		72
30-045-25012 #1R	J 20-25N-09W	F			11	11	2,745	28	2,689	EPG	56	U	180	0	MOI	0		191
Federal 28	Lease SF-078309																	
30-045-05238 #1	A 28-25N-09W	S			0	0	0	0	0	EPG	0	U	0	0	MOI	0		0
30-045-25420 #2	E 28-25N-09W	F			19	35	1,427	19	1,389	EPG	38	U	132	0	MOI	0		151
30-045-26205 #2E	L 28-25N-09W	F			14	54	358	19	320	EPG	38	U	151	0	MOI	0		165
Federal 29																		
30-045-25052 #1	B 29-25N-09W	F			43	23	1,881	19	1,843	EPG	38	U	136	0	MOI	0		179
30-045-26999 #1E	J 29-25N-09W	F			11	17	164	31	102	EPG	62	U	93	0	MOI	0		104
Old Rock Com	Lease Fee/SW672																	
30-039-20549 #2	P 28-25N-06W	F			0	0	822	1	820	EPG	2	U	23	0	MOI	0		23
		FIELD TOTALS			194	152	27,650		26,996		654		1,774	0		0		1,968
BASIN FRUITLAND																		
Chaco	Lease NM-22046																	
30-045-22310 #2	N 07-26N-12W	S			0	0	0	0	0	NER	0	V	0	0		0		0
Chaco	Lease SF-080238A																	
30-045-22343 #3	H 12-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Da On Pah	Lease 25-7472																	
30-045-23692 #1	H 35-27N-12W	F			0	0	1,001	31	1,001	EPG	0		0	0		0		0
Frew Federal	Lease NM-0560223																	
30-045-22478 #3	B 29-26N-12W	F			0	0	245	28	245	EPG	0		0	0		0		0

OIL CON. DIV.
DIST. 3
MAR 2 5 1993
RECEIVED

DISTRIBUTION
Original [illegible] Santa Fe
One Copy [illegible] District Office
[illegible] Lease is located
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STATUS CODE
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"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
[illegible]
S...SEDIMENTATION [illegible]
E...EXPLANATION ATTACHED

: I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS
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:
: ESTHER [illegible] GREYEYES (505) 327-9801
: OPERATIONS TECH

POOL NAME (UNDERLINE) Lease Name API # WELL No.	U S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	PRODUCTION BARRELS OIL/COND PRODUCED	PRODUCTION BARRELS OF WATER PRODUCED	PRODUCTION GAS PRODUCED (MCF)	PRODUCTION DAYS PROD	DISPOSITION OF GAS SOLD	DISPOSITION OF GAS TRANS-POR-TER	DISPOSITION OF GAS OTHER	CODE	DISPOSITION OF OIL OIL ON HAND AT BEG OF MONTH	DISPOSITION OF OIL BARRELS TO TRANS-PORTER	DISPOSITION OF OIL TRANS-POR-TER	DISPOSITION OF OIL OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																		
Fusselman Federal	Lease NM-0560222																	
30-045-22051 #1	L 17-26N-12W	F			0	0	338	31	338	EPG	0		0	0		0		0
Hickman	Lease SF-080384B																	
30-045-25656 #7R	A 03-26N-12W	F			0	0	110	1	110	EPG	0		0	0		0		0
Pete	Lease NOOC-14-20-7471																	
30-045-25663 #1R	I 35-27N-12W	F			0	0	80	1	80	EPG	0		0	0		0		0
Serendipity	Lease NM-33031																	
30-045-25679 #1	J 26-26N-13W	S			0	0	0	0	0		0		0	0		0		0
Sullivan	Lease SF-080384																	
30-045-28047 #9	K 15-26N-12W	S			0	0	0	0	0		0	V	0	0		0		0
Susco	Lease NM-63320																	
30-045-28166 #3	N 09-26N-12W	S			0	0	0	0	0		0	V	0	0		0		0
	FIELD TOTALS				0	0	1,774		1,774		0		0	0		0		0
BLANCO MESAVERDE																		
North Lindrith Com A	Lease NM-014733																	
30-039-21850 #1	D 20-26N-02W	P			0	24	30	6	0	EPG	30	U	- 159	0	NOI	0		159
BLANCO PICTURED CLIFFS, SOUTH																		
Badlands Flats	Lease 09-000163																	
30-043-20494 #1	L 24-23N-02W	F			0	0	263	31	263	EPG	0		0	0		0		0
30-043-20495 #2	O 24-23N-02W	F			0	0	315	31	315	EPG	0		0	0		0		0
John F. Brown	Lease Fee																	
30-039-05314 #1	C 27-24N-02W	F			0	0	3	1	3	EPG	0		0	0		0		0
Cat	Lease NM-40642																	
30-039-2369 #1	A 35-24N-02W	S			0	0	0	0	0		0		0	0		0		0

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OPERATIONS TECH

[signature]

OPERATOR'S MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2088 SANTA FE, NEW MEXICO

... CORPORATION ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: FEBRUARY PG OF

POOL NAME (UNDER...) Lease Name API # Well No.	U S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	PRODUCTION BARRELS OIL/COND PRODUCED	PRODUCTION BARRELS OF WATER PRODUCED	PRODUCTION GAS PRODUCED (MCF)	PRODUCTION DAYS PROD	DISPOSITION OF GAS SOLD	DISPOSITION OF GAS TRANS-POR-TER	DISPOSITION OF GAS OTHER	C O D E	DISPOSITION OF OIL OIL ON HAND AT BEG OF MONTH	DISPOSITION OF OIL BARRELS TO TRANS-PORTER	DISPOSITION OF OIL TRANS-POR-TER	DISPOSITION OF OIL OTHER	C O D E	OIL ON HAND AT END OF MONTH
						** GAS SECTION**												
30-045-24517 #3	F 12-26N-13W	F			0	0	730	28	730	EPG	0		0	0		0		0
30-045-24511 #33	E 12-26N-13W	F			0	0	486	28	486	EPG	0		0	0		0		0
Dome Federal 7-27-13	Lease NM-8409																	
30-045-23397 #1	E 07-27N-13W	F			0	0	548	28	548	EPG	0		0	0		0		0
Dome Federal 14-26-13	Lease NM-31059																	
30-045-23526 #1	F 14-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Dome Federal 17-27-13	Lease NM-9787																	
30-045-23403 #2	K 17-27N-13W	F			0	0	1,796	26	1,796	EPG	0		0	0		0		0
Dome Federal 18-27-13	Lease NM-8409																	
30-045-23404 #2	G 18-27N-13W	F			0	0	20	22	20	EPG	0		0	0		0		0
Dome Federal 25-26-13	Lease NM-7787																	
30-045-23305 #1	H 25-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Frew Federal	Lease NM-0560223																	
30-045-22052 #1	J 20-26N-12W	F			0	0	189	28	189	EPG	0		0	0		0		0
30-045-22477 #2	K 20-26N-12W	F			0	0	242	18	242	EPG	0		0	0		0		0
30-045-22476 #5	A 19-26N-12W	F			0	0	283	28	283	EPG	0		0	0		0		0
30-045-22651 #8	J 19-26N-12W	F			0	0	4	1	4	EPG	0		0	0		0		0
30-045-22655 #9	H 30-26N-12W	F			0	0	114	28	114	EPG	0		0	0		0		0
30-045-22657 #12	P 30-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23529 #15	P 29-26N-12W	F			0	0	252	28	252	EPG	0		0	0		0		0
		Lease Total			0	0	1,084		1,084		0		0	0		0		0
Hanlad Federal	Lease NM-16473																	
30-045-22658 #2	A 31-26N-12W	F			0	0	2	1	2	EPG	0		0	0		0		0
Hi Roll	Lease NM-33047																	
30-045-23694 #1R	D 35-27N-13W	F			0	0	79	1	79	EPG	0		0	0		0		0
30-045-23033 #2	K 35-27N-13W	F			0	0	324	28	324	EPG	0		0	0		0		0
30-045-23032 #4	D 35-27N-13W	F			0	0	2,245	28	2,245	EPG	0		0	0		0		0
		Lease Total			0	0	2,648		2,648		0		0	0		0		0
Kirby Federal	Lease NM-308																	

DISTRIBUTION
Original OCD Santa Fe
One Copy OCD Dist Office in which lease is located
One Copy to Transporter(s)

DATE DUE:
To be postmarked by 24th of next succeeding month.

STATUS CODE
F...FLOWING
P...PUMPING
G...GAS-LIFT
S...SHUT-IN
T...TEMP. ABAND.
I...INJECTION
D...DISCONT.INJEC

"OTHER" GAS DISPOSITION CODE
X....USED OFF LEASE
D...USED FOR DRILLING
G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E..EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature] 3/24/...
SIGNATURE DATE

ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: FEBRUARY, 1993 PG 6 OF 6

API NO. / WELL NO. / LEASE NAME	ULSTR	WELL STATUS	BARRELS OIL/COND PRODUCED	BARRELS OF WATER PRODUCED	GAS PRODUCED (MCF)	DAYS PROD	[illegible]	TRANSPORTER	OTHER	OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANSPORTER	TRANSPORTER	OTHER	OIL ON HAND AT END OF MONTH
** GAS SECTION**														
30-045-[illegible] #[illegible]	[illegible] 05-26N-13W	[illegible]	0	0	0	0	0	EPG	0	0	0		0	0
Koss Federal 1	Lease NM-11775													
30-045-22484 #1	A 04-26N-13W	S	0	0	0	0	0	EPG	0	0	0		0	0
30-045-24307 #2	J 04-26N-13W	S	0	0	0	0	0	EPG	0	0	0		0	0
Southland	Lease NM-12235													
30-045-23409 #1	A 03-26N-13W	F	0	0	464	28	464	EPG	0	0	0		0	0
30-045-23760 #2Y	G 03-26N-13W	F	0	0	93	28	93	EPG	0	0	0		0	0
30-045-23596 #3	C 10-26N-13W	F	0	0	185	28	185	EPG	0	0	0		0	0
30-045-23886 #5	G 11-26N-13W	S	0	0	0	0	0	EPG	0	0	0		0	0
30-045-23803 #6	H 10-26N-13W	F	0	0	834	28	834	EPG	0	0	0		0	0
30-045-23894 #7	[illegible] 11-26N-13W	F	0	0	278	28	278	EPG	0	0	0		0	0
		Lease Total	0	0	1,854		1,854		0	0	0		0	0
		FIELD TOTALS	0	0	10,119		10,119		0	0	0		0	0

DISTRIBUTION
Original OCD Santa Fe
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One Copy to Transporter(s)

DATE DUE:
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STATUS CODE
F...FLOWING
P...PUMPING
G...GAS-LIFT
S...SHUT-IN
T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

"OTHER" GAS DISPOSITION CODE
X....USED OFF LEASE
D...USED FOR DRILLING
G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OF PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E..EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

Esther J. Greyeyes 3/24/93
SIGNATURE DATE

State of New Mexico
Energy & Minerals Department

OPERATOR'S MONTHLY REPORT
FORM C115

Oil Conservation Division
P.O. Box 2088 Santa Fe, New Mexico 8750[illegible]

OPERATOR: MERIDIAN OIL & GAS CORPORATION   ADDRESS: P.O. Box 840, Farmington, NM 87499   FOR MONTH/YEAR OF: FEBRUARY, 1993   PG 2 OF 6

POOL NAME (UNDERLINE) / Lease Name / API # WELL NO.	U - S - T - R	WELL STATUS	INJECTION: VOLUME	INJECTION: PRESS.	PRODUCTION: BARRELS OIL/COND PRODUCED	PRODUCTION: BARRELS OF WATER PRODUCED	PRODUCTION: GAS PRODUCED (MCF)	PRODUCTION: DAYS PROD	DISPOSITION OF GAS: SOLD	DISPOSITION OF GAS: TRANS-PORTER	DISPOSITION OF GAS: OTHER	CODE	DISPOSITION OF OIL: OIL ON HAND AT BEG OF MONTH	DISPOSITION OF OIL: BARRELS TO TRANS-PORTER	DISPOSITION OF OIL: TRANS-PORTER	DISPOSITION OF OIL: OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																		
Canada Mesa Com	Lease Fee/NMA44																	
30-039-23183 #4	A 10-24N-06W	F			0	0	3,132	20	3,092	EPG	40	U	148	0	NOI	0		148
30-039-23057 #4E	F 10-24N-06W	F			27	0	292	28	236	EPG	56	U	165	0	NOI	0		192
Carnahan Com	Lease Fee/NMA95																	
30-045-25844 #2	F 35-30N-12W	F			8	0	1,300	26	1,244	EPG	56	U	163	0	NOI	0		171
Federal 20	Lease SF-078530																	
30-045-26204 #1E	G 20-25N-09W	F			10	8	36	15	6	EPG	30	U	72	0	NOI	0		82
30-045-25012 #1R	J 20-25N-09W	F			13	7	1,352	16	1,320	EPG	32	U	191	100	NOI	0		104
Federal 28	Lease SF-078309																	
30-045-05238 #1	A 28-25N-09W	S			0	0	0	0	0	EPG	0	U	0	0	NOI	0		0
30-045-25420 #2	E 28-25N-09W	F			21	20	2,023	28	1,967	EPG	56	U	151	0	NOI	0		172
30-045-26205 #2E	L 28-25N-09W	F			10	4	315	12	291	EPG	24	U	165	0	NOI	0		175
Federal 29																		
30-045-25052 #1	B 29-25N-09W	F			43	21	1,707	14	1,679	EPG	28	U	179	100	NOI	0		122
30-045-26999 #1E	J 29-25N-09W	F			21	8	32	16	0	EPG	32	U	104	0	NOI	0		125
Old Rock Com	Lease Fee/SW672																	
30-039-20549 #2	P 28-25N-06W	F			0	0	20	1	18	EPG	2	U	23	0	NOI	0		23
		FIELD TOTALS			254	74	24,908		24,226		682		1,968	200		0		2,022
BASIN FRUITLAND																		
Chaco	Lease NM-22046																	
30-045-22310 #2	N 07-26N-12W	S			0	0	0	0	0	MER	0	V	0	0		0		0
Chaco	Lease SF-080238A																	
30-045-22343 #3	H 12-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Da On Pah	Lease 25-7472																	
30-045-23692 #1	H 35-27N-12W	F			0	0	826	26	826	EPG	0		0	0		0		0
Frew Federal	Lease NM-0560223																	
30-045-22475 #3	B 29-26N-12W	F			0	0	188	28	188	EPG	0		0	0		0		0

DISTRIBUTION:
Original OCD Santa Fe
One Copy OCD Dist Office
in which lease is located
One Copy to Transporter(s)

[illegible]
[illegible] postmarked by 24th

STATUS CODE
F...FLOWING
P...PUMPING
G...GAS-LIFT
S...SHUT-IN
T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

"OTHER" GAS DISPOSITION CODE
U...USED OFF LEASE
D...USED FOR DRILLING
G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OR PRESSURE MAINTENANCE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature] 3/24/93

STATE OF NEW MEXICO
ENERGY & MINERALS DEPARTMENT

OPERATOR'S MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2088 SANTA FE, NEW MEXICO 87501

OPERATOR: MERRION OIL & GAS CORPORATION ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: FEBRUARY 199[illegible] PG 3 OF [illegible]

POOL NAME (UNDERLINED) / Lease Name / API # WELL No.	U S - T - R	WELL STATUS	INJECTION: VOLUME	INJECTION: PRESS.	PRODUCTION: BARRELS OIL/COND PRODUCED	PRODUCTION: BARRELS OF WATER PRODUCED	PRODUCTION: GAS PRODUCED (MCF)	PRODUCTION: DAYS PROD	DISPOSITION OF GAS: SOLD	DISPOSITION OF GAS: TRANS-PORTER	DISPOSITION OF GAS: OTHER	CODE	DISPOSITION OF OIL: OIL ON HAND AT BEG OF MONTH	DISPOSITION OF OIL: BARRELS TO TRANS-PORTER	DISPOSITION OF OIL: TRANS-PORTER	DISPOSITION OF OIL: OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																		
Fusselman Federal	Lease NM-0560222																	
30-045-22051 #1	L 17-26N-12W	F			0	0	182	28	182	EPG	0		0	0		0		0
Hickman	Lease SF-0803848																	
30-045-25656 #7R	A 03-26N-12W	F			0	0	99	1	99	EPG	0		0	0		0		0
Pete	Lease NOOC-14-20-747[illegible]																	
30-045-25663 #1F	J 35-27N-12W	F			0	0	73	1	73	EPG	0		0	0		0		0
Serendipity	Lease NM-33031																	
30-045-25679 #1	J 26-26N-13W	S			0	0	0	0	0		0		0	0		0		0
Sullivan	Lease SF-080384																	
30-045-28047 #9	K 15-26N-12W	S			0	0	0	0	0		0	V	0	0		0		0
Susco	Lease NM-63320																	
30-045-28166 #3	K 09-26N-12W	S			0	0	0	0	0		0	V	0	0		0		0
	FIELD TOTALS				0	0	1,368		1,368		0		0	0		0		0
BLANCO MESAVERDE																		
North Lindrith Com A	Lease NM-014733																	
30-039-21850 #1	D 20-26N-02W	S			0	0	0	0	0	EPG	0	U	159	0	NOI	0		159
BLANCO PICTURED CLIFFS, SOUTH																		
Badlands Flats	Lease 09-000163																	
30-043-20494 #1	L 24-23N-02W	F			0	0	250	28	250	EPG	0		0	0		0		0
30-043-20495 #2	G 24-23N-02W	F			0	0	315	28	315	EPG	0		0	0		0		0
John F. Brown	Lease Fee																	
30-039-05314 #1	C 27-24N-02W	F			0	0	2	1	2	EPG	0		0	0		0		0
Cot	Lease NM-40642																	
30-039-2369 #1	A 35-24N-02W	S			0	0	0	0	0		0		0	0		0		0

DISTRIBUTION
Original OCD Santa Fe
One Copy OCD Dist Office in which lease is located
One Copy to Transporter(s)

DATE DUE:
To be postmarked by 24th day of the succeeding month.

STATUS CODE
F...FLOWING
P...PUMPING
G...GAS-LIFT
S...SHUT-IN
T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

"OTHER" GAS DISPOSITION CODE
X...USED OFF LEASE
D...USED FOR DRILLING
G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature] 3/24/93

SIGNATURE DATE

[illegible] CORPORATION ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: FEBRUARY, 1993 PG 6 OF F

API #	WELL NO.	U - S - T - R	WELL STATUS	VOLUME	PRESS.	BARRELS OIL/COND PRODUCED	BARRELS OF WATER PRODUCED	GAS PRODUCED (MCF)	DAYS PROD	SOLD	TRANSPORTER	OTHER	CODE	OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANSPORTER	TRANSPORTER	OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																			
Escovada		Lease NM-66124																	
30-045-28629	#1	N 08-21N-08W	P			1	284	507	9	462	GNM	45	U	211	0	NOI	0		212
Santa Fe 20		Lease Fee																	
30-045-20955	#7	K 20-21N-08W	S			0	0	0	0	0	GNM	0	U						
30-045-27342	#4	I 20-21N-08W	S			0	0	0	0	0	GNM	0	U						
30-045-27568	#3	H 20-21N-08W	P			581	58,976	5,812	26	4,656	GNM	1,156	U						
			Battery Total			581	58,976	5,812		4,656		1,156		430	877	NOI	0		134
			FIELD TOTALS			582	59,260	6,319		5,118		1,201		641	877		0		346
UNDESIGNATED GALLUP																			
Chaco Wash		Lease NOG92081236																	
30-031-20975	#1	J 13-20N-06W	S			0	0	0	0	0		0	U	49	0	NOI	0		49
WAW FRUITLAND SAND PICTURED CLIFFS																			
Armour Federal		Lease NM-0559974																	
30-045-22076	#1Y	C 04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Bartlesville		Lease Fee/E9707																	
30-045-23127	#1	C 02-26N-13W	F			0	0	79	28	79	EPG	0		0	0		0		0
Chaco		Lease NM-22046																	
30-045-22309	#1	F 18-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23691	#2R	K 07-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
Chaco		Lease SF-080238A																	
30-045-22410	#4	D 07-26N-12W	F			0	0	71	28	71	EPG	0		0	0		0		0
30-045-22411	#5	P 01-26N-13W	F			0	0	80	28	80	EPG	0		0	0		0		0
30-045-22686	#11	E 01-26N-13W	F			0	0	382	28	382	EPG	0		0	0		0		0
Chaco Limited		Lease SF-080238A																	
30-045-25134	#1J	K 01-26N-13W	F			0	0	199	1	199	EPG	0		0	0		0		0
30-045-23593	#2J	E 01-26N-13W	F			0	0	140	28	140	EPG	0		0	0		0		0

DISTRIBUTION
Original OCD Santa Fe
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One Copy to Transporter(s)

DATE DUE:
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STATUS CODE
F...FLOWING
P...PUMPING
G...GAS-LIFT
S...SHUT-IN
T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

"OTHER" GAS DISPOSITION CODE
X....USED OFF LEASE
D...USED FOR DRILLING
G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

: I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS
: TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.
: ESTHER J. GREYEYES (505) 327-9801
: OPERATIONS TECH
: Esther J. Greyeyes 3/24/93
: SIGNATURE DATE

OI[illegible] [illegible]RVATI[illegible] [illegible]ISION
P.O. BOX 2088 SANTA FE, NEW MEXICO 8750[illegible]

[illegible] OPER[illegible] MONT[illegible] PORT
FORM C115

[illegible] OIL & GAS CORPORATION ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: MARCH, 1993 PG 7 OF 7

API # / Well No.	U S - T - R	Well Status	Injection Volume	Injection Press.	Production: Barrels Oil/Cond Produced	Production: Barrels of Water Produced	Production: Gas Produced (MCF)	Production: Days Prod	Disposition of Gas: Sold	Disposition of Gas: Transporter	Disposition of Gas: Other	Disposition of Gas: Code	Disposition of Oil: Oil on Hand at Beg of Month	Disposition of Oil: Barrels to Transporter	Disposition of Oil: Transporter	Disposition of Oil: Other	Disposition of Oil: Code	Oil on Hand at End of Month
** GAS SECTION**																		
Hi Roll	Lease NM-33047																	
30-045-23694 #1R	O 35-27N-13W	F			0	0	87	31	87	EPG	0		0	0		0		0
30-045-23033 #2	K 35-27N-13W	F			0	0	352	31	352	EPG	0		0	0		0		0
30-045-23032 #4	D 35-27N-13W	F			0	0	377	31	377	EPG	0		0	0		0		0
		Lease Totals			0	0	816		816		0		0	0		0		0
Kirby Federal	Lease NM-308																	
30-045-22143 #1	C 05-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Ross Federal 1	Lease NM-11775																	
30-045-22484 #1	A 04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-24307 #2	J 04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Southland	Lease NM-12235																	
30-045-23409 #1	K 03-26N-13W	F			0	0	601	31	601	EPG	0		0	0		0		0
30-045-23760 #2Y	O 03-26N-13W	F			0	0	120	31	120	EPG	0		0	0		0		0
30-045-23596 #3	C 10-26N-13W	F			0	0	240	31	240	EPG	0		0	0		0		0
30-045-23886 #5	G 11-26N-13W	PLUGGED AND ABANDONED ON 3/10/93			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23803 #6	H 10-26N-13W	F			0	0	1,081	31	1,081	EPG	0		0	0		0		0
30-045-23894 #7	D 11-26N-13W	F			0	0	360	31	360	EPG	0		0	0		0		0
		Lease Totals			0	0	2,402		2,402		0		0	0		0		0

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R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E..EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature] 4/26/93

SIGNATURE DATE

OPERATOR'S MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2088 SANTA FE, NEW MEXICO 8750[illegible]

… GAS CORPORATION   ADDRESS: P.O. Box 840, Farmington, NM 87499   FOR MONTH/YEAR OF: MARCH, 1993   PG 2 OF 7

API # / WELL No. (Lease Name underlined)	U S - T - R	WELL STATUS	INJECTION: VOLUME	INJECTION: PRESS.	PRODUCTION: BARRELS OIL/COND PRODUCED	PRODUCTION: BARRELS OF WATER PRODUCED	PRODUCTION: GAS PRODUCED (MCF)	PRODUCTION: DAYS PROD	DISPOSITION OF GAS: SOLD	DISPOSITION OF GAS: TRANSPORTER	DISPOSITION OF GAS: OTHER	CODE	DISPOSITION OF OIL: OIL ON HAND AT BEG OF MONTH	DISPOSITION OF OIL: BARRELS TO TRANSPORTER	DISPOSITION OF OIL: TRANSPORTER	DISPOSITION OF OIL: OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																		
Carnahan Com	Lease Fee/NMA95																	
30-045-25844 #2	P 35-30N-12W	F			44	0	1,516	31	1,454	EPG	62	U	171	0	MOI	0		215
Federal 20	Lease SF-078530																	
30-045-26204 #1E	G 20-25N-09W	F			0	0	42	1	40	EPG	2	U	82	0	MOI	0		82
30-045-25012 #1R	J 20-25N-09W	F			0	0	40	20	0	EPG	40	U	104	0	MOI	0		104
Lease Totals					0	0	82		40		42		186	0		0		186
Federal 28	Lease SF-078309																	
30-045-05238 #1	A 28-25N-09W	S			0	0	0	0	0	EPG	0	U	0	0	MOI	0		0
30-045-25420 #2	E 28-25N-09W	F			50	17	2,885	31	2,823	EPG	62	U	172	186	MOI	0		36
30-045-26205 #2E	L 28-25N-09W	F			17	0	354	25	304	EPG	50	U	175	37	MOI	0		150
Federal 29																		
30-045-25052 #1	B 29-25N-09W	F			23	0	30	15	0	EPG	30	U	122	0	MOI	0		145
30-045-26999 #1E	J 29-25N-09W	F			0	0	6	3	0	EPG	6	U	125	0	MOI	0		125
Lease Totals					85	17	3,275		3,127		148		594	223		0		456
Old Rock Com	Lease Fee/SW672																	
30-039-20549 #2	P 28-25N-06W	F			0	0	1,413	28	1,357	EPG	56	U	23	0	MOI	0		23
BASIN FRUITLAND																		
Chaco	Lease NM-22046																	
30-045-22310 #2	M 07-26N-12W	S			0	0	0	0	0	NER	0	V	0	0		0		0
Chaco	Lease SF-080238A																	
30-045-22343 #3	M 12-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Da On Pah	Lease 25-7472																	
30-045-23692 #1	M 35-27N-12W	F			0	0	837	31	837	EPG	0		0	0		0		0
Frew Federal	Lease NM-0560223																	
30-045-22478 #3	B 29-26N-12W	F			0	0	19	1	19	EPG	0		0	0		0		0
Fusselman Federal	Lease NM-0560222																	
30-045-22051 #1	L 17-26N-12W	F			0	0	265	31	265	EPG	0		0	0		0		0
Hickman	Lease SF-080384B																	
30-045-25656 #7R	A 03-26N-12W	F			0	0	110	1	110	EPG	0		0	0		0		0

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T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

"OTHER" GAS DISPOSITION CODE
X....USED OFF LEASE
D...USED FOR DRILLING
G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

SIGNATURE   DATE 5/3/93

Pool / Lease Name / API # / Well No.	U-S-T-R	Well Status	Injection Volume	Injection Press.	Barrels Oil/Cond Produced	Barrels of Water Produced	Gas Produced (MCF)	Days Prod	Gas Sold	Gas Transporter	Gas Other	Code	Oil on Hand at Beg of Month	Barrels to Transporter	Oil Transporter	Oil Other	Code	Oil on Hand at End of Month
							** GAS SECTION**											
Pete	Lease NOOC-14-20-7471																	
30-045-25663 #1E	35-27N-12W	F			0	0	80	1	80	EPG	0		0	0		0		0
Serendipity	Lease NM-33031																	
30-045-25679 #1	J 26-26N-13W	S			0	0	0	0	0		0		0	0		0		0
Sullivan	Lease SF-080384																	
30-045-28047 #9	K 15-26N-12W	S			0	0	0	0	0		0	V	0	0		0		0
Susco	Lease NM-63320																	
30-045-28166 #3	N 09-26N-12W	S			0	0	0	0	0		0	V	0	0		0		0
BLANCO MESAVERDE																		
North Lindrith Com A	Lease NM-014733																	
30-039-21850 #1	D 20-26N-02W	P			0	0	205	31	50	EPG	155	U	159	0	NOI	0		159
BLANCO PICTURED CLIFFS, SOUTH																		
Badlands Flats	Lease 09-000163																	
30-043-20494 #1	L 24-23N-02W	F			0	0	267	31	267	EPG	0		0	0		0		0
30-043-20495 #2	O 24-23N-02W	F			0	0	320	31	320	EPG	0		0	0		0		0
John F. Brown	Lease Fee																	
30-039-05314 #1	C 27-24N-02W	F			0	0	4	2	4	EPG	0		0	0		0		0
Cot	Lease NM-40642																	
30-039-2369 #1	A 35-24N-02W	S			0	0	0	0	0		0		0	0		0		0
East Lindrith	Lease NM-03992																	
30-039-22021 #1	A 22-24N-02W	F			0	0	559	31	559	EPG	0		0	0		0		0
30-039-22449 #6	K 26-24N-02W	F			0	0	428	31	428	EPG	0		0	0		0		0
30-039-22429 #7	C 35-24N-02W	F			0	0	627	31	627	EPG	0		0	0		0		0
		Lease Totals			0	0	1,614		1,614		0		0	0		0		0
East Lindrith	Lease Fee/SCR269																	
30-039-22168 #2	B 27-24N-02W	S			0	0	0	0	0	EPG	0		0	0		0		0
East Lindrith	Lease NM-03992/SRM1490																	
30-039-22023 #3	I 27-24N-02W	F			0	0	342	31	342	EPG	0		0	0		0		0

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T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

"OTHER" GAS DISPOSITION CODE
X....USED OFF LEASE
D...USED FOR DRILLING
G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E..EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

Esther J. Greyeyes 4/26/93
SIGNATURE DATE

STATE DEPARTMENT

OPERATOR'S MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2088 SANTA FE, NEW MEXICO 87501

OPERATOR: MERRION OIL & GAS CORPORATION — ADDRESS: P.O. Box 840, Farmington, NM 87499 — FOR MONTH/YEAR OF: MARCH, 1993 — 1 5 ... 7

POOL NAME (UNDERLINE) Lease Name / API # WELL No.	U S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	BARRELS OIL/COND PRODUCED	BARRELS OF WATER PRODUCED	GAS PRODUCED (MCF)	DAYS PROD	DISPOSITION OF GAS: SOLD	TRANS-PORTER	OTHER	CODE	OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANS-PORTER	TRANS-PORTER	OTHER	CODE	OIL ON HAND AT END OF MONTH
							** GAS SECTION**											
ROSA GALLUP																		
Gibbons	Lease NM-0558223																	
30-039-07999 #1	L 20-32N-05W	S			0	0	0	0	0	EPG	0	U	0	0		0		0
RUSTY CHACRA																		
Alemita	Lease NM-4565																	
30-043-20315 #2	C 28-22N-07W	S			0	0	0	0	0	EPG	0	U	0	0		0		0
SNAKE EYES DAKOTA																		
Escovada	Lease NM-66124																	
30-045-28629 #1	N 08-21N-08W	S			0	0	0	0	0	GNN	0	U	[illegible]	[illegible]	NOI	0		212
Santa Fe 20	Lease Fee																	
30-045-20955 #7	K 20-21N-08W	S			0	0	0	0	0	GNN	0	U						
30-045-27342 #4	I 20-21N-08W	S			0	0	0	0	0	GNN	0	U						
30-045-22568 #3	N 20-21N-08W	P			710	64,755	6,731	29	5,559	GNN	1,172	U						
		Battery Total			710	64,755	6,731		5,559		1,172	U	134	453	NOI	0		391
UNDESIGNATED GALLUP																		
Chaco Wash	Lease NOG92081236																	
30-031-20975 #1	J 13-20N-06W	S			0	0	0	0	0		0	U	49	0	NOI	0		49
WAW FRUITLAND SAND PICTURED CLIFFS																		
Armour Federal	Lease NM-0559974																	
30-045-22076 #1Y	C 04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Bartlesville	Lease Fee/E9707																	
30-045-23127 #1	C 02-26N-13W	F			0	0	87	31	87	EPG	0		0	0		0		0
Chaco	Lease NM-22046																	
30-045-22309 #1	F 18-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23691 #2R	K 07-26N-12W	F			0	0	189	31	189	EPG	0		0	0		0		0

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"OTHER" GAS DISPOSITION CODE
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G...GAS LIFT
L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

SIGNATURE — 4/29/93 — DATE

OPERATOR'S MONTHLY REPORT
FORM C-...

OIL CONSERVATION DIVISION
P.O. BOX 2088 SANTA FE, NEW MEXICO 87501

OPERATOR: MERIDIAN OIL & GAS CORPORATION
ADDRESS: P.O. Box 845, Farmington, NM 87499
FOR MONTH/YEAR OF: MARCH, 1993
PG 6 OF 7

POOL NAME (UNDES INE) Lease Name / API #	WELL No.	U S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	BARRELS OIL/COND PRODUCED	BARRELS OF WATER PRODUCED	GAS PRODUCED (MCF)	DAYS PROD	GAS SOLD	GAS TRANSPORTER	GAS OTHER	C O D E	OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANSPORTER	TRANSPORTER	OIL OTHER	C O D E	OIL ON HAND END OF MONTH
** GAS SECTION**																			
Chaco		Lease SF-080238A																	
30-045-22410	#4	D 07-26N-12W	F			0	0	68	31	68	EPG	0		0	0		0		0
30-045-22411	#5	P 01-26N-13W	F			0	0	92	31	92	EPG	0		0	0		0		0
30-045-22686	#11	E 01-26N-13W	F			0	0	37	31	37	EPG	0		0	0		0		0
Chaco Limited																			
30-045-25134	#1J	K 01-26N-13W	F			0	0	125	31	125	EPG	0		0	0		0		0
30-045-23593	#2J	B 01-26N-13W	F			0	0	164	31	164	EPG	0		0	0		0		0
30-045-24612	#3	F 12-26N-13W	F			0	0	826	31	826	EPG	0		0	0		0		0
30-045-24611	#3J	E 12-26N-13W	F			0	0	550	31	550	EPG	0		0	0		0		0
			Lease Totals			0	0	1,862		1,862		0		0	0		0		0
Dome Federal 7-27-13		Lease NM-8409																	
30-045-23397	#1	E 07-27N-13W	F			0	0	526	31	526	EPG	0		0	0		0		0
Dome Federal 14-26-13		Lease NM-31059																	
30-045-23526	#2	H 14-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Dome Federal 17-27-13		Lease NM-9787																	
30-045-23402	#2	M 17-27N-13W	F			0	0	1,875	31	1,875	EPG	0		0	0		0		0
Dome Federal 18-27-13		Lease NM-8409																	
30-045-23404	#2	G 18-27N-13W	F			0	0	46	1	46	EPG	0		0	0		0		0
Dome Federal 25-26-13		Lease NM-7787																	
30-045-23305	#1	H 25-26N-13W	F			0	0	63	23	63	EPG	0		0	0		0		0
Frew Federal		Lease NM-0560223																	
30-045-22052	#1	J 20-26N-12W	F			0	0	183	27	183	EPG	0		0	0		0		0
30-045-22477	#2	N 20-26N-12W	F			0	0	658	31	658	EPG	0		0	0		0		0
30-045-22476	#5	A 19-26N-12W	F			0	0	359	31	359	EPG	0		0	0		0		0
30-045-22651	#8	J 19-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-22655	#9	M 30-26N-12W	F			0	0	125	31	125	EPG	0		0	0		0		0
30-045-22657	#12	P 30-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23529	#15	P 29-26N-12W	F			0	0	286	31	286	EPG	0		0	0		0		0
			Lease Totals			0	0	1,611		1,611		0		0	0		0		0
Hanlad Federal		Lease NM-16473	PLUGGED AND ABANDONED ON 3/10/93																
30-045-22658	#2	A 31-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0

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DIST. 3

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"OTHER" GAS DISPOSITION CODE
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L...LOST (MCF ESTIMATED)
E...EXPLANATION ATTACHED
R...REPRESSURING OR PRESSURE MAINTENANCE
V...VENTED
U...USED ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

SIGNATURE: [signature] DATE: 5/3/93

ENERGY AND MINERALS DEPARTMENT | OPER MONTHLY REPORT | OIL CONSERVATION DIVISION
FORM C115 | P.O. BOX 2088 SANTA FE, NEW MEXICO 87504

OPERATOR: [illegible] OIL & GAS CORPORATION   ADDRESS: Box 840, Farmington, NM 87499   FOR MONTH/YEAR OF: APRIL, 1993   PG 6 OF 7

** GAS SECTION **

POOL NAME (UNDERLINE) / Lease Name / API # WELL No.	U S - T - R	WELL STATUS	VOLUME	PRESS.	BARRELS OIL/COND PRODUCED	BARRELS OF WATER PRODUCED	GAS PRODUCED (MCF)	DAYS PROD	SOLD	TRANS-PORTER	OTHER	C O D E	OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANS-PORTER	TRANS-PORTER	OTHER	C O D E	OIL ON HAND AT END OF MONTH
Chaco	Lease NM-22046																	
30-045-22309 #1	F 18-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-23691 #2R	K 07-26N-12W	F			0	0	482	30	482	EPG	0		0	0		0		0
Chaco	Lease SF-080238A																	
30-045-22410 #4	D 07-26N-12W	F			0	0	63	30	63	EPG	0		0	0		0		0
30-045-22411 #5	P 01-26N-13W	F			0	0	86	30	86	EPG	0		0	0		0		0
30-045-22686 #11	E 01-26N-13W	F			0	0	208	30	208	EPG	0		0	0		0		0
Chaco Limited																		
30-045-25134 #1J	K 01-26N-13W	F			0	0	216	30	216	EPG	0		0	0		0		0
30-045-23593 #2J	B 01-26N-13W	F			0	0	147	30	147	EPG	0		0	0		0		0
30-045-24612 #3	F 12-26N-13W	F			0	0	761	30	761	EPG	0		0	0		0		0
30-045-24611 #3J	E 12-26N-13W	F			0	0	507	30	507	EPG	0		0	0		0		0
	Lease Totals				0	0	1,988		1,988		0		0	0		0		0
Dome Federal 7-27-13	Lease NM-8409																	
30-045-23397 #1	E 07-27N-13W	F			0	0	493	27	493	EPG	0		0	0		0		0
Dome Federal 14-26-13	Lease NM-31059																	
30-045-23526 #2	H 14-26N-13W	F			0	0	0	10	0	EPG	0		0	0		0		0
Dome Federal 17-27-13	Lease NM-9787																	
30-045-23402 #2	K 17-27N-13W	F			0	0	1,528	27	1,528	EPG	0		0	0		0		0
Dome Federal 18-27-13	Lease NM-8409																	
30-045-23404 #2	G 18-27N-13W	F			0	0	114	9	114	EPG	0		0	0		0		0
Dome Federal 25-26-13	Lease NM-7787																	
30-045-23305 #1	H 25-26N-13W	F			0	0	175	30	175	EPG	0		0	0		0		0
Frew Federal	Lease NM-0560223																	
30-045-22052 #1	J 20-26N-12W	F			0	0	128	27	128	EPG	0		0	0		0		0
30-045-22477 #2	N 20-26N-12W	F			0	0	388	30	388	EPG	0		0	0		0		0
30-045-22476 #5	A 19-26N-12W	F			0	0	279	30	279	EPG	0		0	0		0		0
30-045-22651 #8	J 19-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-22655 #9	H 30-26N-12W	F			0	0	121	30	121	EPG	0		0	0		0		0
30-045-22657 #12	P 30-26N-12W	F			0	0	0	30	0	EPG	0		0	0		0		0
30-045-23529 #15	P 29-26N-12W	F			0	0	268	30	268	EPG	0		0	0		0		0
	Lease Totals				0	0	1,184		1,184		0		0	0		0		0

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[illegible]ITION CODE
OFF LEASE
R DRILLING
..GAS LIFT
ESTIMATED)
N ATTACHED
SSURING OR
AINTENANCE
V...VENTED
D ON LEASE

"OTHER" OIL DISPOSITION CODE
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E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature] 5/21/93
SIGNATURE DATE

New Mexico
[illegible] & Minerals Department

OPERA[illegible] MONTH[illegible] REP[illegible]
Form C115

OIL [illegible]VATIO[illegible]SION
P.O. BOX 2088 SANTA FE, NEW MEXICO 875[illegible]

OPERATOR: MERRION OIL & GAS CORPORATION   ADDRESS: P.O. Box 840, Farmington, NM 87499   FOR MONTH/YEAR OF: APRIL, 1993   PG 7 OF 7

POOL NAME (UNDERLINE) / Lease Name / API #	WELL No.	U S-T-R	WELL STATUS	[illegible] VOLUME	[illegible] PRESS.	PRODUCTION: BARRELS OIL/COND PRODUCED	PRODUCTION: BARRELS OF WATER PRODUCED	PRODUCTION: GAS PRODUCED (MCF)	PRODUCTION: DAYS PROD	DISPOSITION OF GAS: SOLD	DISPOSITION OF GAS: TRANS-POR-TER	DISPOSITION OF GAS: OTHER	DISPOSITION OF GAS: CODE	DISPOSITION OF OIL: OIL ON HAND AT BEG OF MONTH	DISPOSITION OF OIL: BARRELS TO TRANS-PORTER	DISPOSITION OF OIL: TRANS-POR-TER	DISPOSITION OF OIL: OTHER	DISPOSITION OF OIL: CODE	DISPOSITION OF OIL: OIL ON HAND AT END OF MONTH
** GAS SECTION**																			
Hi Roll		Lease NM-33047																	
30-045-23694	#1R	O 35-27N-13W	F			0	0	84	1	84	EPG	0		0	0		0		0
30-045-23033	#2	K 35-27N-13W	F			0	0	378	30	378	EPG	0		0	0		0		0
30-045-23032	#4	D 35-27N-13W	F			0	0	954	30	954	EPG	0		0	0		0		0
			Lease Totals			0	0	1,416		1,416		0		0	0		0		0
Kirby Federal		Lease NM-308																	
30-045-22143	#1	C 05-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Ross Federal 1		Lease NM-11775																	
30-045-22484	#1	A 04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
30-045-24307	#2	J 04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Southland		Lease NM-12735																	
30-045-23409	#1	K 03-26N-13W	F			0	0	536	30	536	EPG	0		0	0		0		0
30-045-23760	#2Y	O 03-26N-13W	F			0	0	107	30	107	EPG	0		0	0		0		0
30-045-23596	#3	C 10-26N-13W	F			0	0	214	30	214	EPG	0		0	0		0		0
30-045-23803	#6	H 10-26N-13W	F			0	0	965	30	965	EPG	0		0	0		0		0
30-045-23894	#7	D 11-26N-13W	F			0	0	321	30	321	EPG	0		0	0		0		0
			Lease Totals			0	0	2,143		2,143		0		0	0		0		0

DISTRIBUTION
Origin[illegible] OCD Santa Fe
One C[illegible] OCD Dist Office
in wh[illegible] lease is located
One Copy to Transporter(s)

DATE DUE:
To be postmarked by 24th
day of next succeeding month.

STATUS CODE
F...FLOWING
P...PUMPING
G...GAS-LIFT
S...SHUT-IN
T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

[illegible]TION CODE
[illegible] OFF LEASE
[illegible]R DRILLING
[illegible]..GAS LIFT
[illegible] ESTIMATED)
[illegible]N ATTACHED
[illegible]SSURING OR
[illegible]AINTENANCE
V...VENTED
[illegible]D ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (PS&W)
E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature] 5/21/93
SIGNATURE DATE

…EXICO
… MINERALS DEPARTMENT

OPERATOR'S MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2008 SANTA FE, NEW MEXICO 87501

OPERATOR: MERRION OIL & GAS CORPORATION ADDRESS: P.O. Box 840, Farmington, NM 87499 FOR MONTH/YEAR OF: APRIL, 1993 PG 2 OF 7

POOL NAME (UNDERLINE) Lease Name / API #	WELL No.	U S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	PRODUCTION BARRELS OIL/COND PRODUCED	PRODUCTION BARRELS OF WATER PRODUCED	PRODUCTION GAS PRODUCED (MCF)	PRODUCTION DAYS PROD	DISPOSITION OF GAS SOLD	DISPOSITION OF GAS TRANS-POR-TER	DISPOSITION OF GAS OTHER	CODE	DISPOSITION OF OIL OIL ON HAND AT BEG OF MONTH	DISPOSITION OF OIL BARRELS TO TRANS-PORTER	DISPOSITION OF OIL TRANS-POR-TER	DISPOSITION OF OIL OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																			
30-039-23057	#4E	F 10-24N-06W	F			7	0	3,228	25	3,178	EPG	50	U	192	0	NOI	0		199
Carnahan Com		Lease Fee/NMA95																	
30-045-25844	#2	P 35-30N-12W	F			10	0	1,652	30	1,592	EPG	60	U	215	0	NOI	0		225
Federal 20		Lease SF-078530																	
30-045-26204	#1E	G 20-25N-09W	F			0	0	88	1	86	EPG	2	U	82	0	NOI	0		82
30-045-25012	#1R	J 20-25N-09W	F			28	17	3,207	30	3,147	EPG	60	U	104	0	NOI	0		132
			Lease Totals			28	17	3,295		3,233		62		186	0		0		214
Federal 28		Lease SF-078309																	
30-045-05238	#1	A 28-25N-09W	S			0	0	0	0	0	EPG	0	U	0	0	NOI	0		0
30-045-25420	#2	E 28-25N-09W	F			53	41	3,227	30	3,167	EPG	60	U	36	0	NOI	0		89
30-045-26205	#2E	L 28-25N-09W	F			6	0	795	10	775	EPG	20	U	150	44	NOI	0		112
Federal 29																			
30-045-25052	#1	B 29-25N-09W	F			71	17	2,914	25	2,864	EPG	50	U	145	179	NOI	0		37
30-045-26999	#1E	J 29-25N-09W	F			7	6	1,103	20	1,063	EPG	40	U	125	0	NOI	0		132
			Lease Totals			137	64	8,039		7,869		170		456	223		0		370
Old Rock Com		Lease Fee/SW672																	
30-039-20549	#2	P 28-25N-06W	F			0	0	1,545	26	1,493	EPG	52	U	23	0	NOI	0		23
BASIN FRUITLAND																			
Chaco		Lease NM-22046																	
30-045-22310	#2	N 07-26N-12W	S			0	0	0	0	0	NER	0	V	0	0		0		0
Chaco		Lease SF-080238A																	
30-045-22343	#3	H 12-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Da On Pah		Lease 25-7472																	
30-045-23692	#1	H 35-27N-12W	F			0	0	997	30	997	EPG	0		0	0		0		0
Frew Federal		Lease NM-0560223																	
30-045-22478	#3	B 29-26N-12W	S			0	0	0	0	0	EPG	0		0	0		0		0
Fusselman Federal		Lease NM-0560222																	
30-045-22051	#1	L 17-26N-12W	F			0	0	292	30	292	EPG	0		0	0		0		0

DISTRIBUTION
Original OCD Santa Fe
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To be postmarked by 24th
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G...GAS-LIFT
S...SHUT-IN
T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

…ITION CODE
…OFF LEASE
…R DRILLING
…GAS LIFT
…ESTIMATED
…N ATTACHED
…SSURING OR
…AINTENANCE
V...VENTED
…D ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

I HEREBY CERTIFY THAT THE INFORMATION GIVEN IS TRUE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

SIGNATURE DATE

POOL NAME (UNDES. INC) Lease Name API # WELL No.	U S - T - R	WELL STATUS	VOLUME	PRESS.	BARRELS OIL/COND PRODUCED	BARRELS OF WATER PRODUCED	GAS PRODUCED (MCF)	DAYS PROD	SOLD	TRANS-POR-TER	OTHER	CODE	OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANS-PORTER	TRANS-POR-TER	OTHER	CODE	OIL ON HAND AT END OF MONTH
							** GAS SECTION**											
Hickman	Lease SF-080384B																	
30-045-25656 #7R	A 03-26N-12W	F			0	0	106	1	106	EPG	0		0	0		0		0
Pete	Lease NOOC-14-20-7471																	
30-045-25663 #1R	I 35-27N-12W	F			0	0	77	1	77	EPG	0		0	0		0		0
Serendipity	Lease NM-33031																	
30-045-25679 #1	J 26-26N-13W	S			0	0	0	0	0		0		0	0		0		0
Sullivan	Lease SF-080384																	
30-045-28047 #9	K 15-26N-12W	S			0	0	0	0	0		0	V	0	0		0		0
Susco	Lease NM-63320																	
30-045-28166 #3	K 09-26N-12W	S			0	0	0	0	0		0	V	0	0		0		0
BLANCO MESAVERDE																		
North Lindrith Com A	Lease NM-014733																	
30-039-21850 #1	D 20-26N-02W	P			41	32	2,708	30	2,558	EPG	150	U	159	0	NOI	0		200
BLANCO PICTURED CLIFFS, SOUTH																		
Badlands Flats	Lease 09-000163																	
30-043-20494 #1	L 24-23N-02W	F			0	0	207	30	207	EPG	0		0	0		0		0
30-043-20495 #2	O 24-23N-02W	F			0	0	266	30	266	EPG	0		0	0		0		0
John F. Brown	Lease Fee																	
30-039-05314 #1	C 27-24N-02W	F			0	0	1	30	1	EPG	0		0	0		0		0
Cot	Lease NM-40642																	
30-039-2369 #1	A 35-24N-02W	S			0	0	0	0	0		0		0	0		0		0
East Lindrith	Lease NM-03992																	
30-039-22021 #1	A 22-24N-02W	F			0	0	300	30	300	EPG	0		0	0		0		0
30-039-22449 #6	K 26-24N-02W	F			0	0	328	30	328	EPG	0		0	0		0		0
30-039-22429 #7	C 35-24N-02W	F			0	0	442	30	442	EPG	0		0	0		0		0
	Lease Totals				0	0	1,070		1,070		0		0	0		0		0

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T...TEMP. ABAND.
I...INJECTION
D...DISCONTINUED

ITION CODE
OFF LEASE
R DRILLING
..GAS LIFT
ESTIMATED)
N ATTACHED
SSURING OR
AINTENANCE
V...VENTED
D ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

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ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

[signature]
SIGNATURE

5/21/93
DATE

OPERATOR MONTHLY REPORT
FORM C115

OIL CONSERVATION DIVISION
P.O. BOX 2088 SANTA FE, NEW MEXICO 875..

OPERATOR: MERRION OIL & GAS CORPORATION   ADDRESS: P.O. Box 840, Farmington, NM 87499   FOR MONTH/YEAR OF: APRIL, 1993   PG 5 OF 7

POOL NAME (UNDERLINED) Lease Name / API # WELL No.	U S - T - R	WELL STATUS	INJECTION VOLUME	INJECTION PRESS.	BARRELS OIL/COND PRODUCED	BARRELS OF WATER PRODUCED	GAS PRODUCED (MCF)	DAYS PROD	DISPOSITION OF GAS SOLD	TRANS-POR-TER	OTHER	CODE	OIL ON HAND AT BEG OF MONTH	BARRELS TO TRANS-PORTER	TRANS-POR-TER	OTHER	CODE	OIL ON HAND AT END OF MONTH
** GAS SECTION**																		
Fields Com	Lease NM-010458																	
30-039-20216 #1	F 31-26N-06W	F			0	0	3,125	30	3,125	EPG	0		0	0		0		0
Lease Totals					0	0	6,256		6,256		0		0	0		0		0
ROSA GALLUP																		
Gibbons	Lease NM-0558223																	
30-039-07999 #1	L 20-32N-05W	S			0	0	0	0	0	EPG	0	U	0	0		0		0
RUSTY CHACRA																		
Alemita	Lease NM-4565																	
30-043-20315 #2	C 28-22N-07W	S			0	0	0	0	0	EPG	0	U	0	0		0		0
SNAKE EYES DAKOTA																		
Escovada	Lease NM-66124																	
30-045-28629 #1	N 08-21N-08W	S			0	0	0	0	0	GNN	0	U	212	0	NOI	0		212
Santa Fe 20	Lease Fee																	
30-045-20955 #7	K 20-21N-08W	S			0	0	0	0	0	GNN	0	U						
30-045-27342 #4	I 20-21N-08W	S			0	0	0	0	0	GNN	0	U						
30-045-22568 #3	H 20-21N-08W	P			635	63,573	7,148	30	5,970	GNN	1,178	U						
Battery Total					635	63,573	7,148		5,970		1,178		391	675	NOI	0		351
UNDESIGNATED GALLUP																		
Chaco Wash	Lease NO692081236																	
30-031-20975 #1	J 13-20N-06W	S			0	0	0	0	0		0	U	49	0	NOI	0		49
WAW FRUITLAND SAND PICTURED CLIFFS																		
Armour Federal	Lease NM-0559974																	
30-045-22076 #1Y	C 04-26N-13W	S			0	0	0	0	0	EPG	0		0	0		0		0
Bartlesville	Lease Fee/E9707																	
30-045-23127 #1	C 07-26N-13W	F			0	0	84	30	84	EPG	0		0	0		0		0

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I...INJECTION
D...DISCONTINUED

..TION CODE
..OFF LEASE
..R DRILLING
..GAS LIFT
..ESTIMATED)
..N ATTACHED
..SSURING OP
..AINTENANCE
V...VENTED
..D ON LEASE

"OTHER" OIL DISPOSITION CODE
C...CIRCULATING OIL
L...LOST
S...SEDIMENTATION (BS&W)
E...EXPLANATION ATTACHED
T...THEFT

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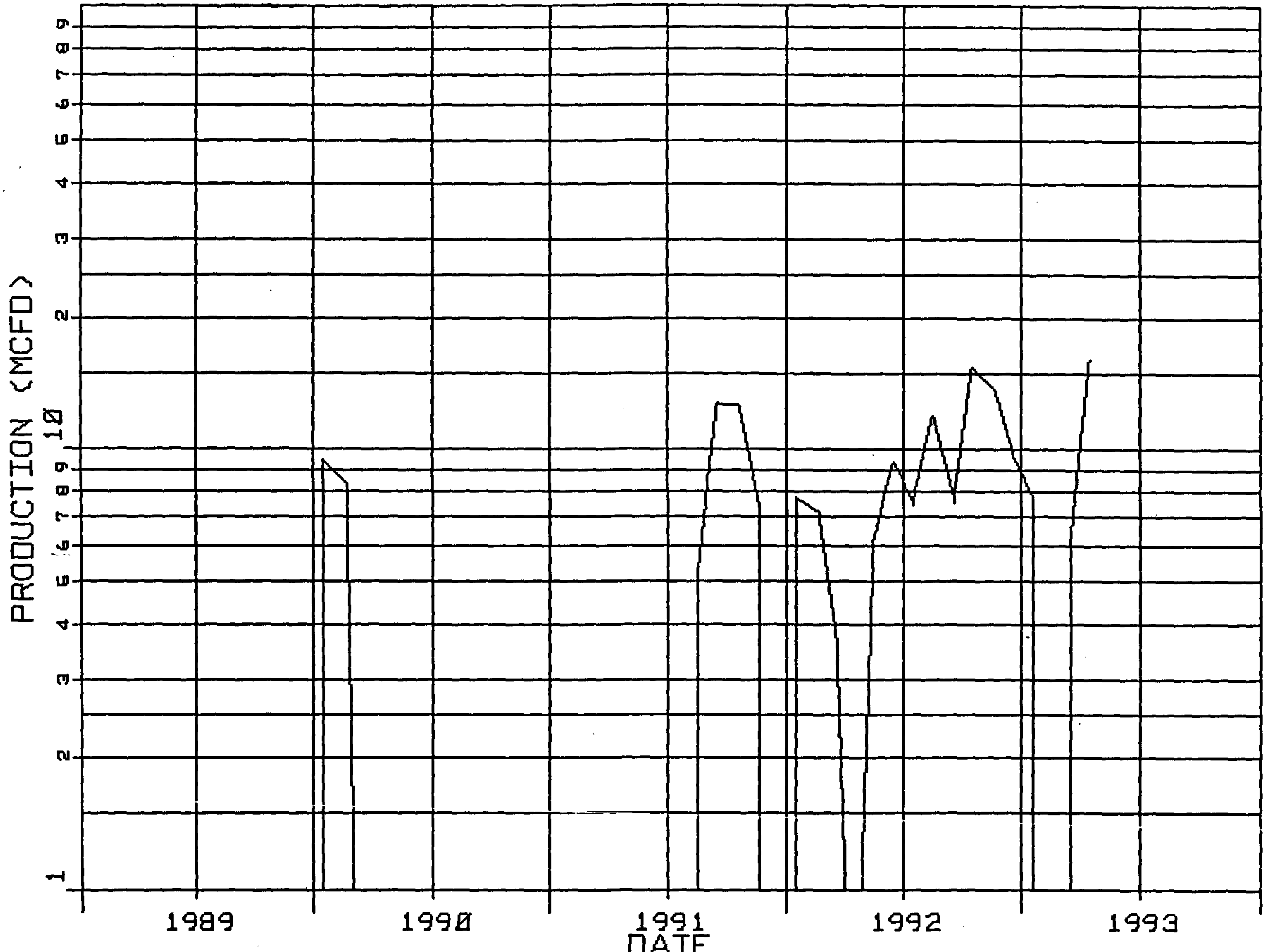
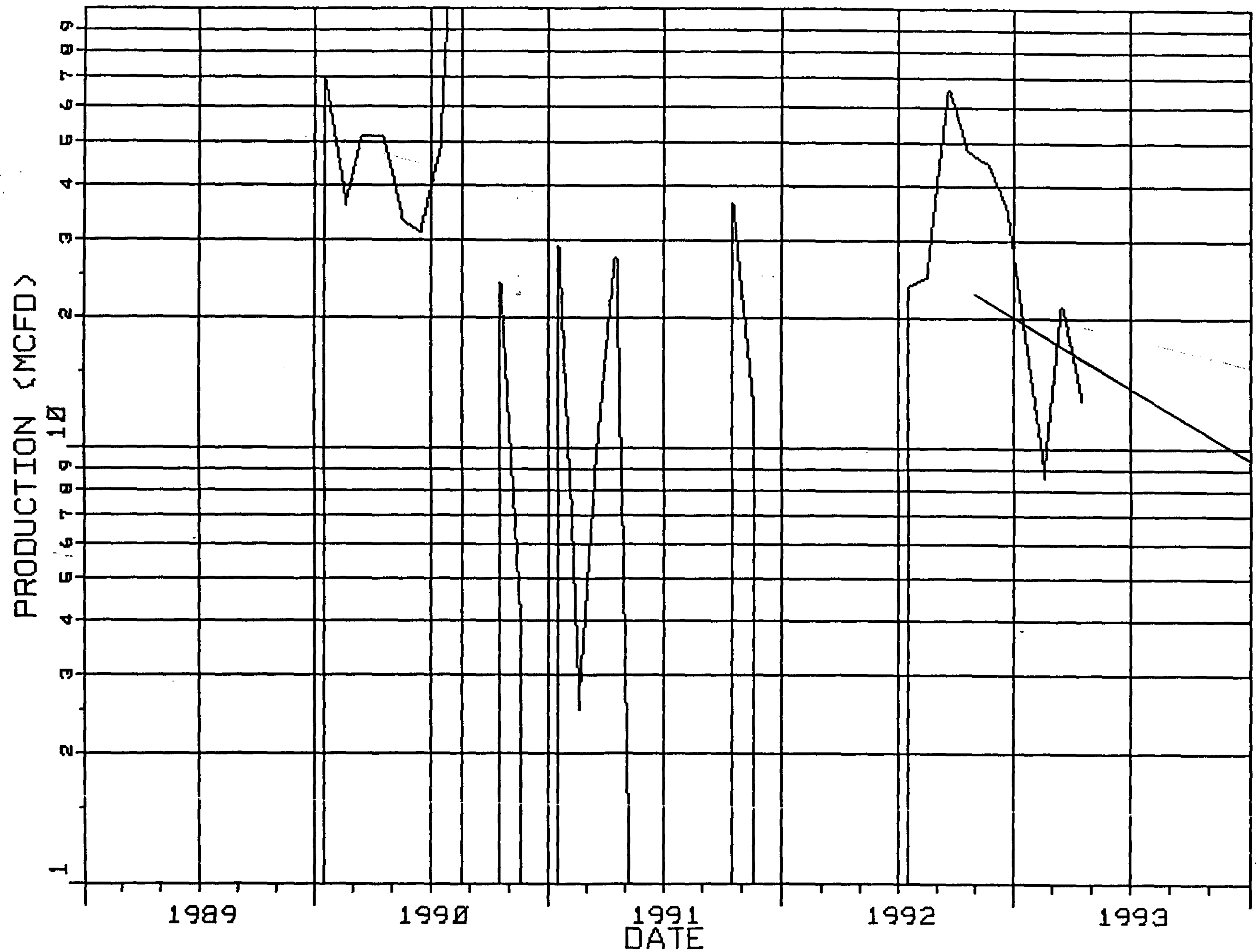
ESTHER J. GREYEYES (505) 327-9801
OPERATIONS TECH

SIGNATURE [signature]   DATE 5/21/93

CHACO NO. 2R
PRODUCTION HISTORY



FREW FEDERAL #2
PRODUCTION HISTORY

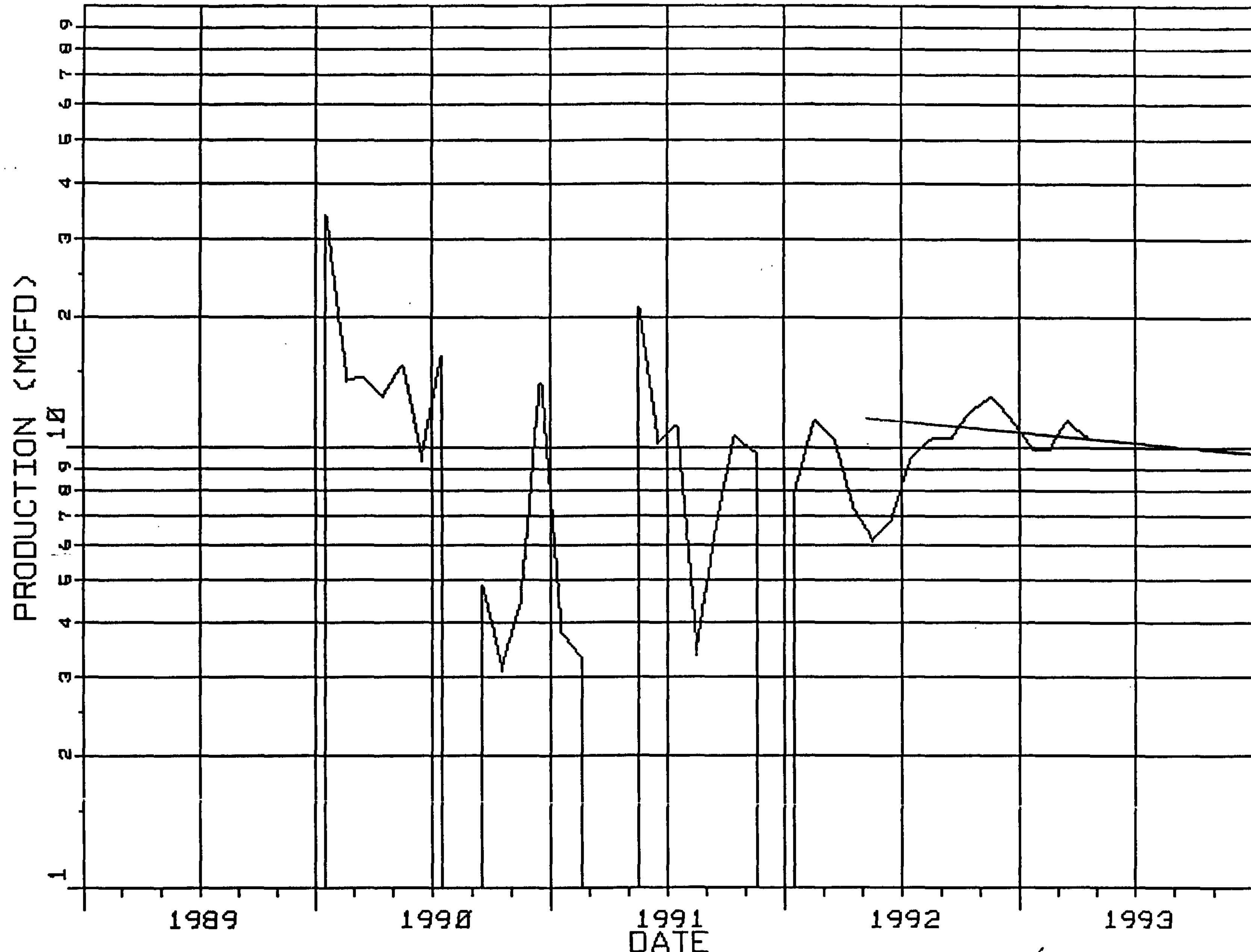


5 = 2.35
10 = 1.78
15 = 1.56
20 = 1.37
25 = 1.22
30 = 1.09

$D = \ln\left(\frac{20}{9.5}\right) = .744$

$D = \ln(\ldots) = 0.272$

SOUTHLAND #7
PRODUCTION HISTORY

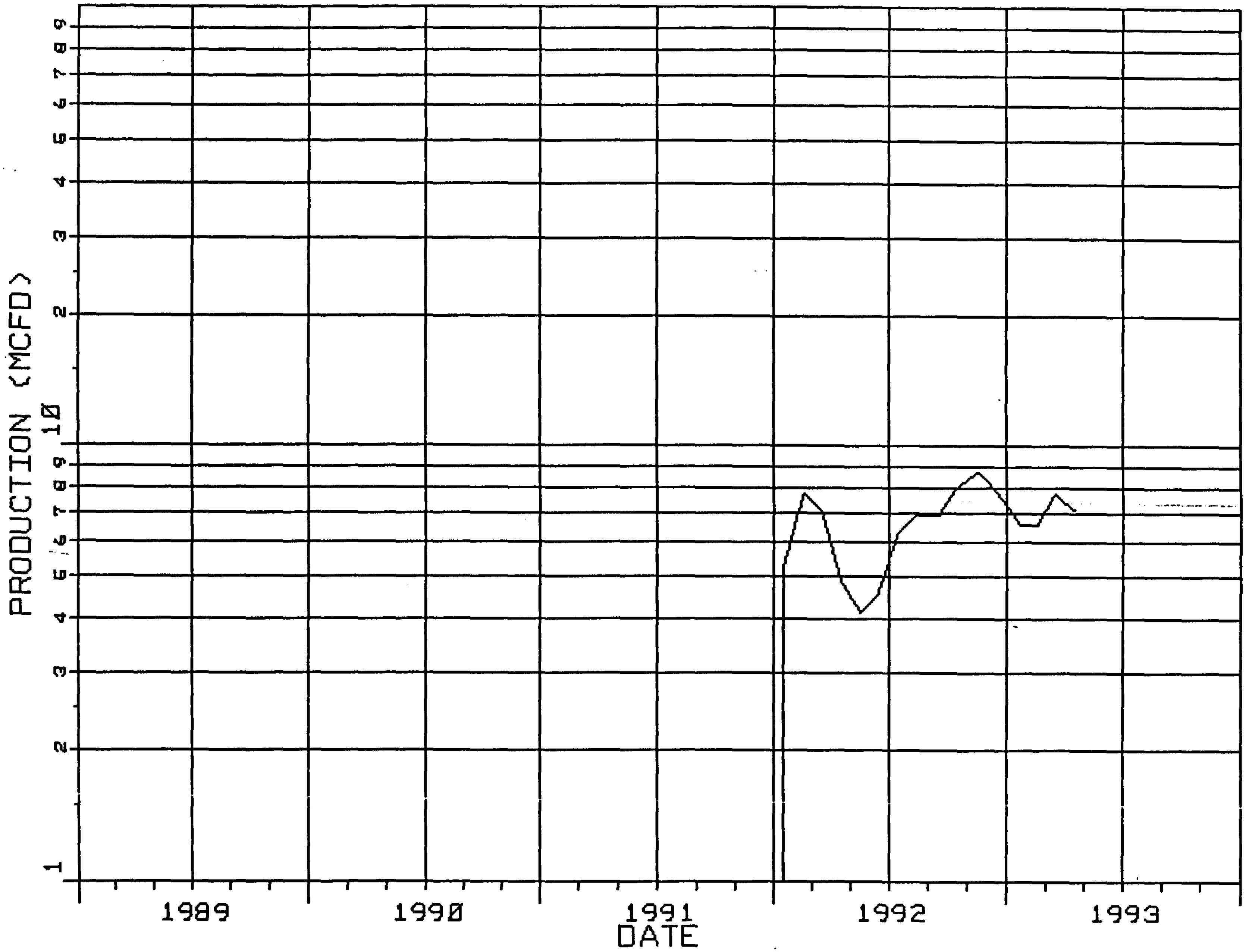


15 = 0.21
20 = 0.19
30 = 0.15

$D = \ln\left(\frac{12}{9.8}\right) = .202$

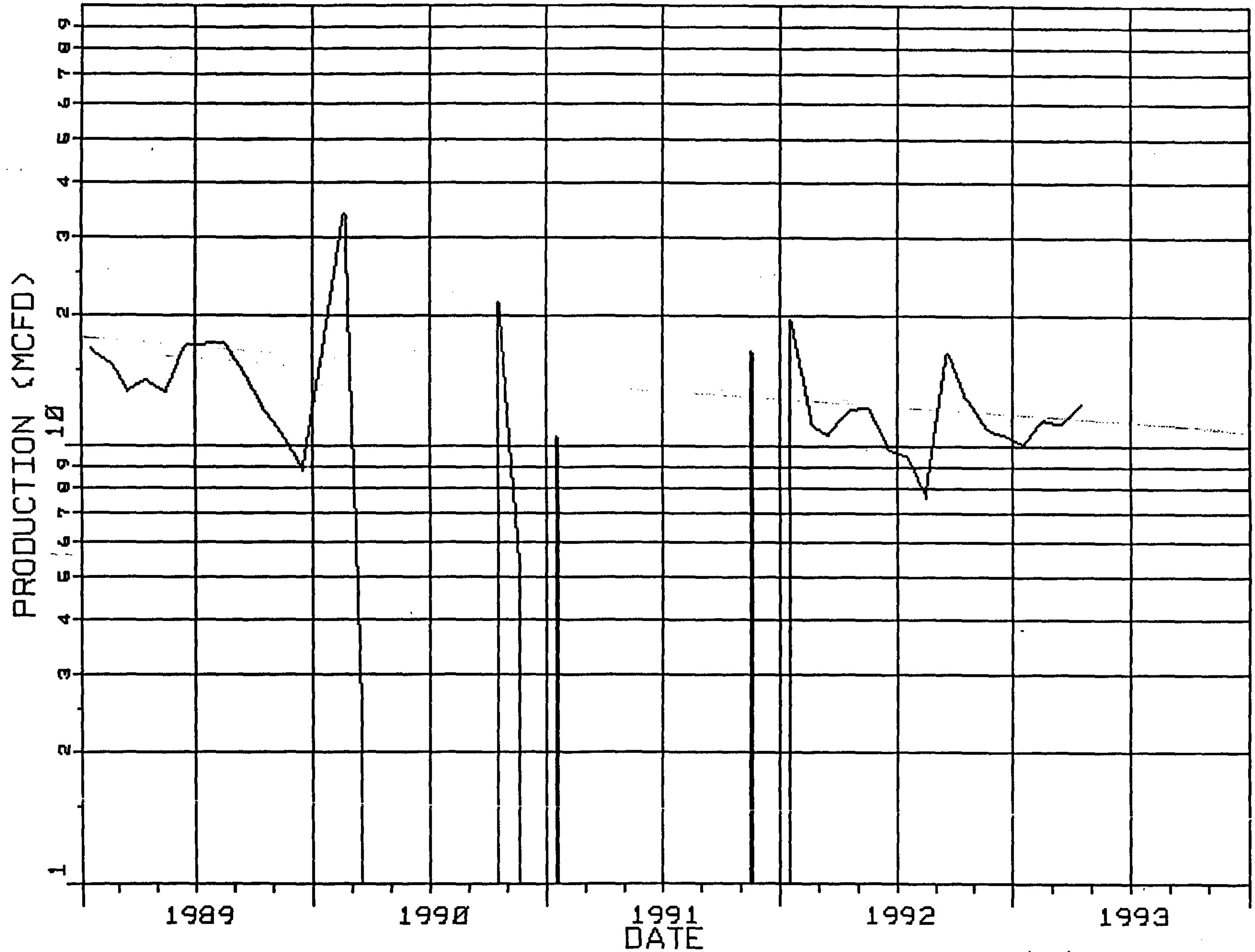
N69

SOUTHLAND #3
PRODUCTION HISTORY

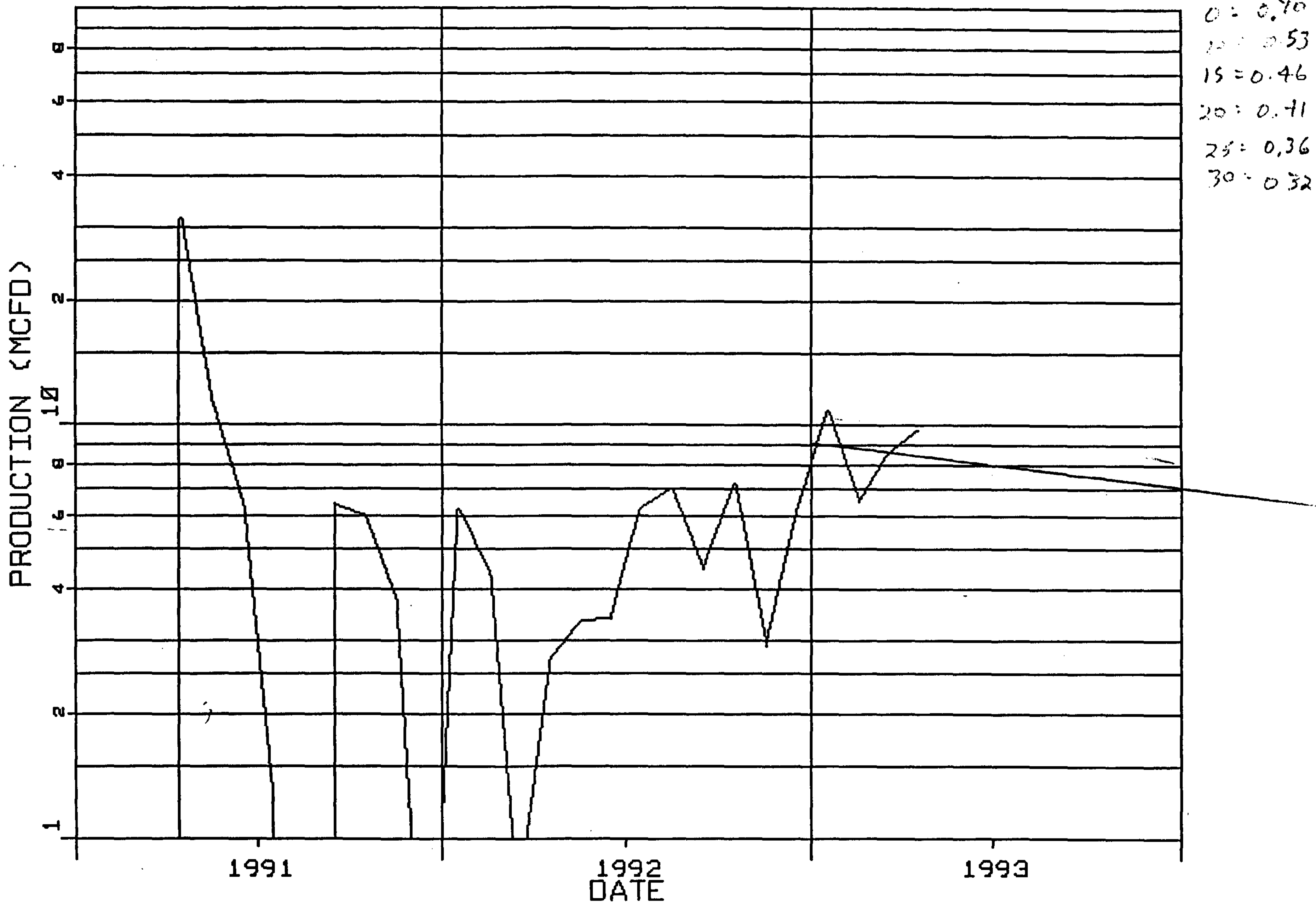


0 = 0.70
10 = 0.58
15 = 0.53
20 = 0.49
25 = 0.45
30 = 0.42

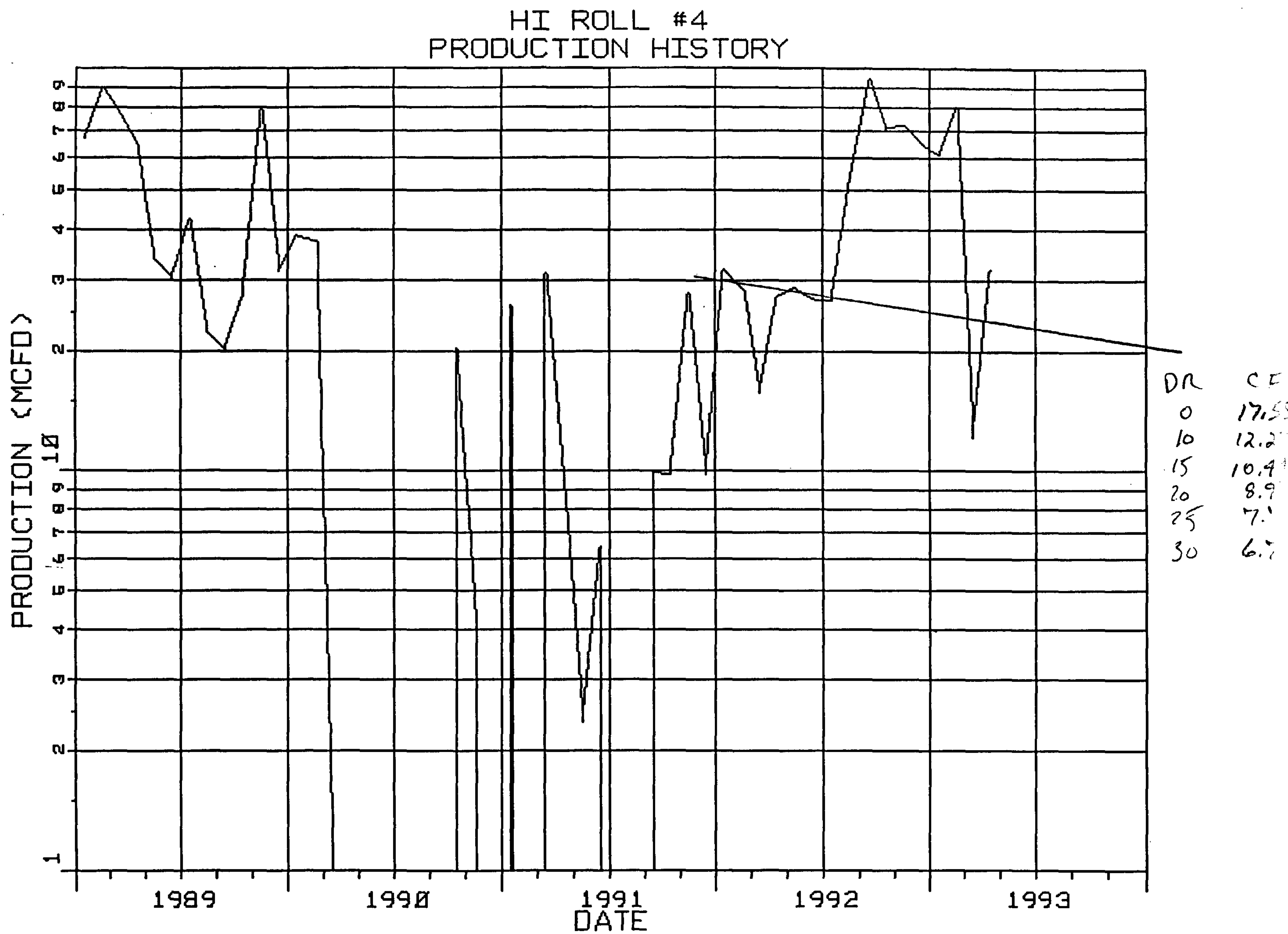
HI ROLL #2
PRODUCTION HISTORY



FUSSELMAN FEDERAL NO. 1
PRODUCTION HISTORY

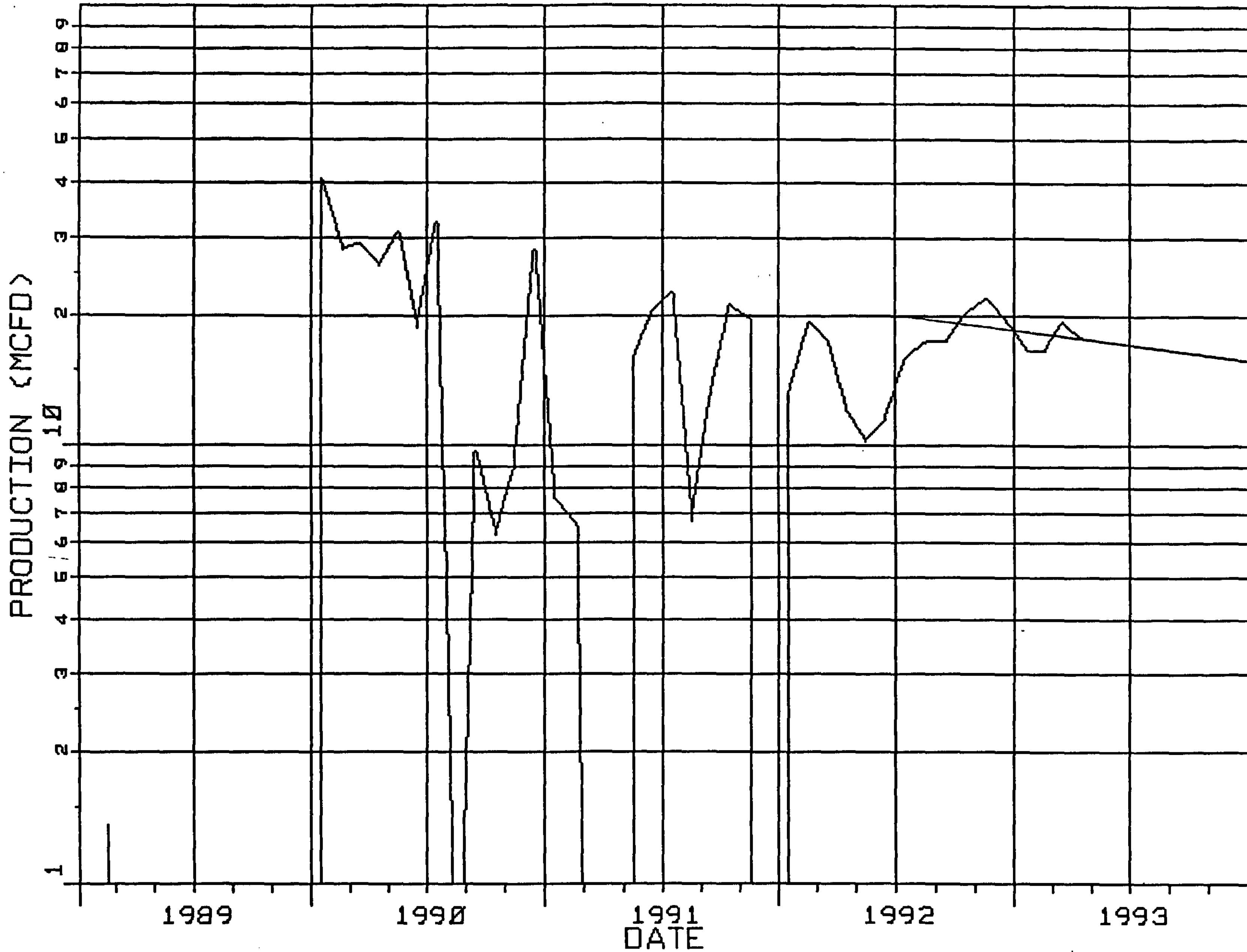


$D = \ln(9.1/7) = .26$



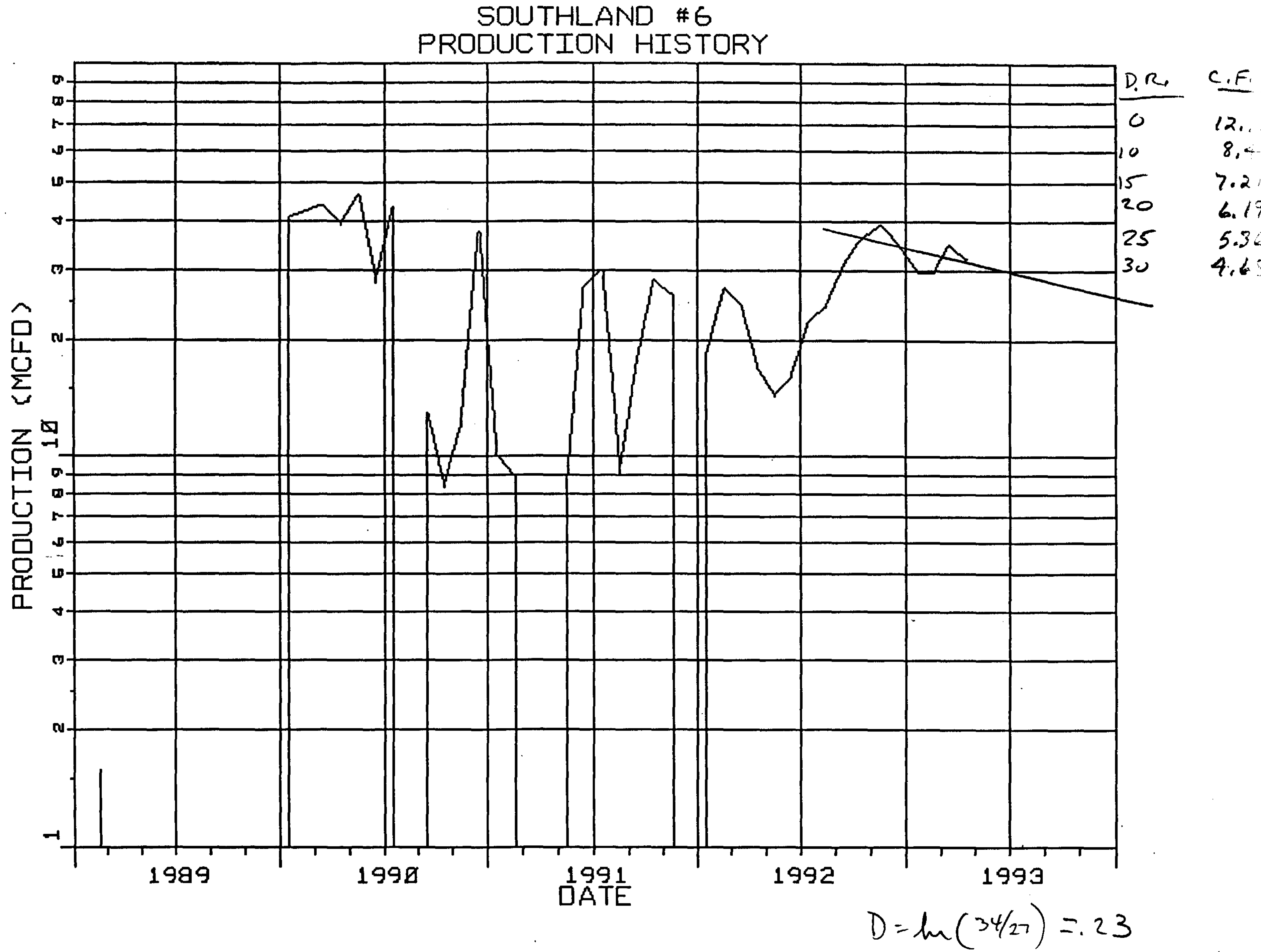
D = ln (25/20.5) = .198

SOUTHLAND #1
PRODUCTION HISTORY



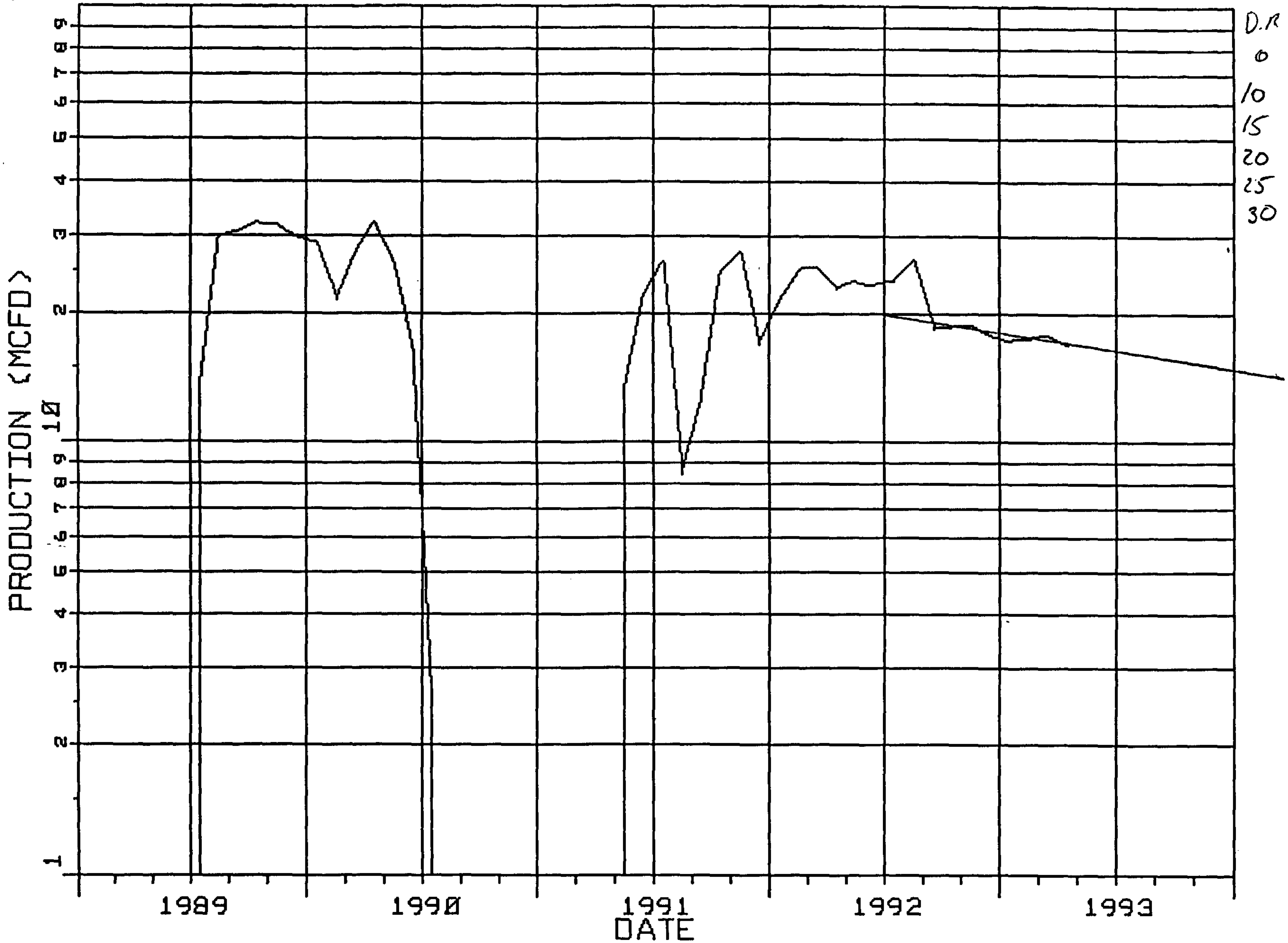
DR	CF
0	7.9
10	5.2
15	4.3
20	3.6
25	3.14
30	2.7

$D = \ln(18/16) = .117$



SOUTHLAND #6
PRODUCTION HISTORY
PRODUCTION (MCFD)
1
2
3
4
5
6
7
8
9
10
1989
1990
1991
1992
1993
DATE
D.R.
0
10
15
20
25
30
C.F.
8,
7.2
6.19
5.36
4.6
D = ln(34/27) = .23

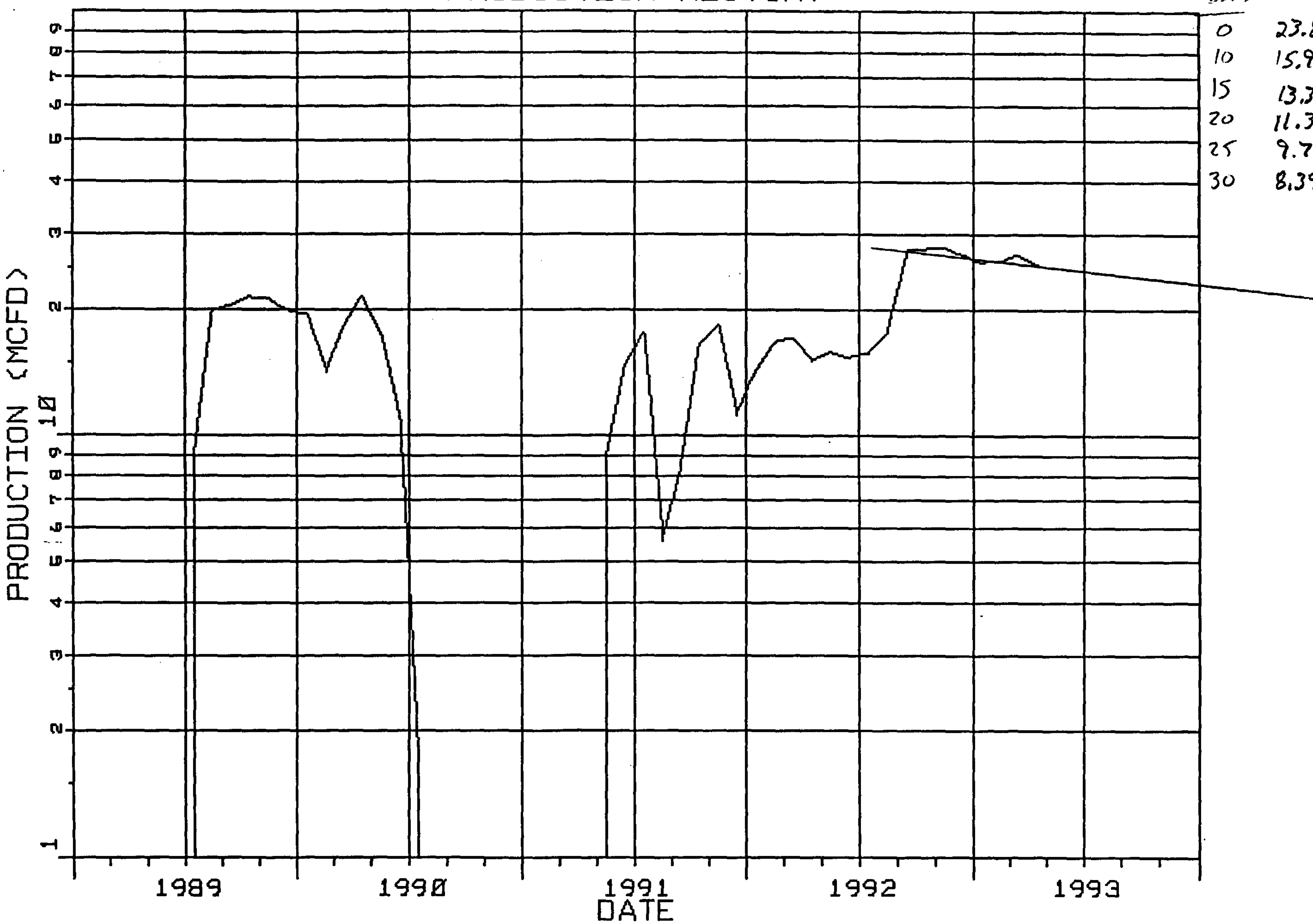
CHACO LIMITED #3J
PRODUCTION HISTORY



D.R	CASH
0	12.79
10	8.60
15	7.20
20	6.10
25	5.22
30	4.51

$D = \ln(18/16) = .1178$

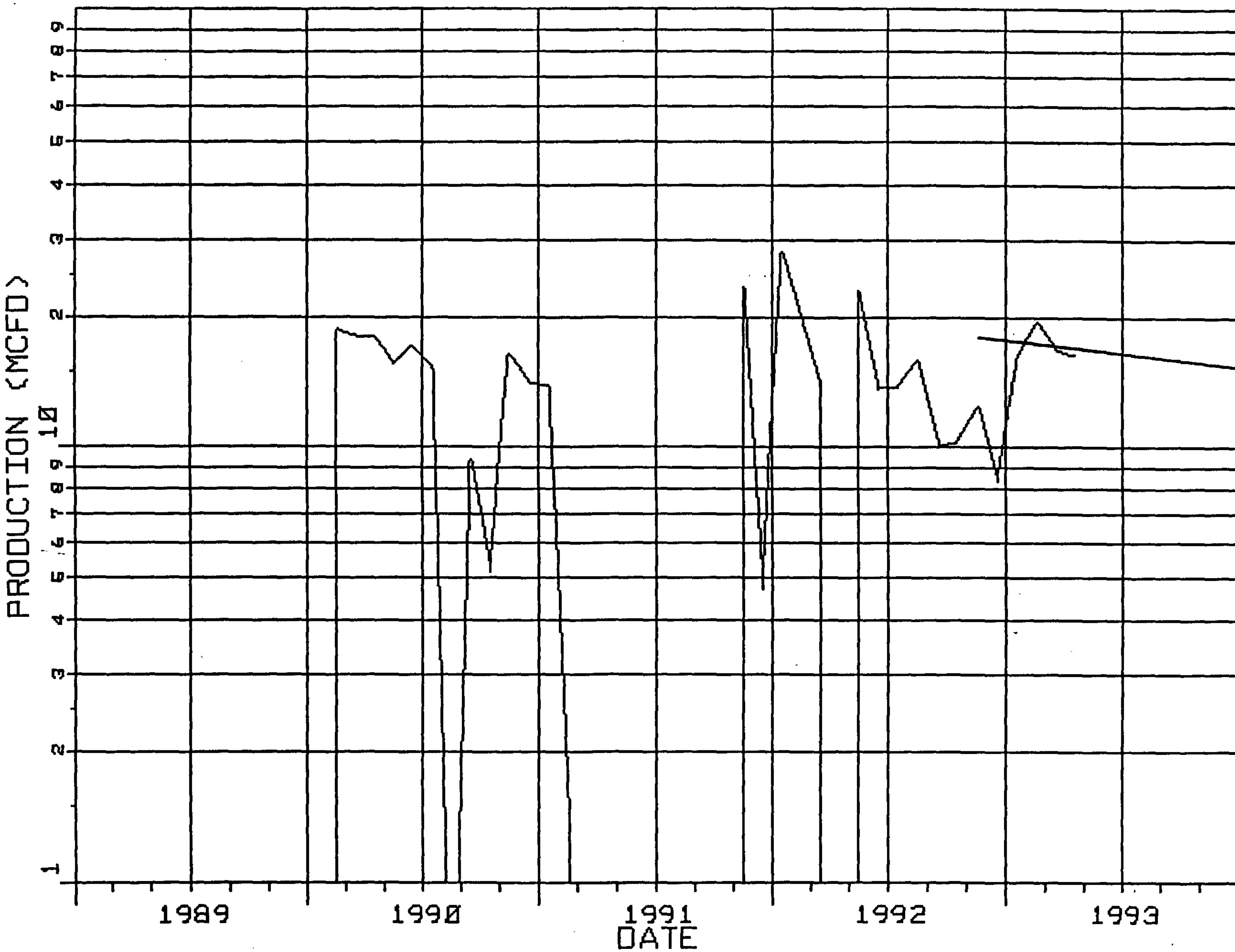
CHACO LIMITED #3
PRODUCTION HISTORY



D.n.	
0	23.85
10	15.99
15	13.38
20	11.33
25	9.70
30	8.39

$D = \ln(26.5/22.5) = .164$

DOME FEDERAL 7-27-13 #1
PRODUCTION HISTORY



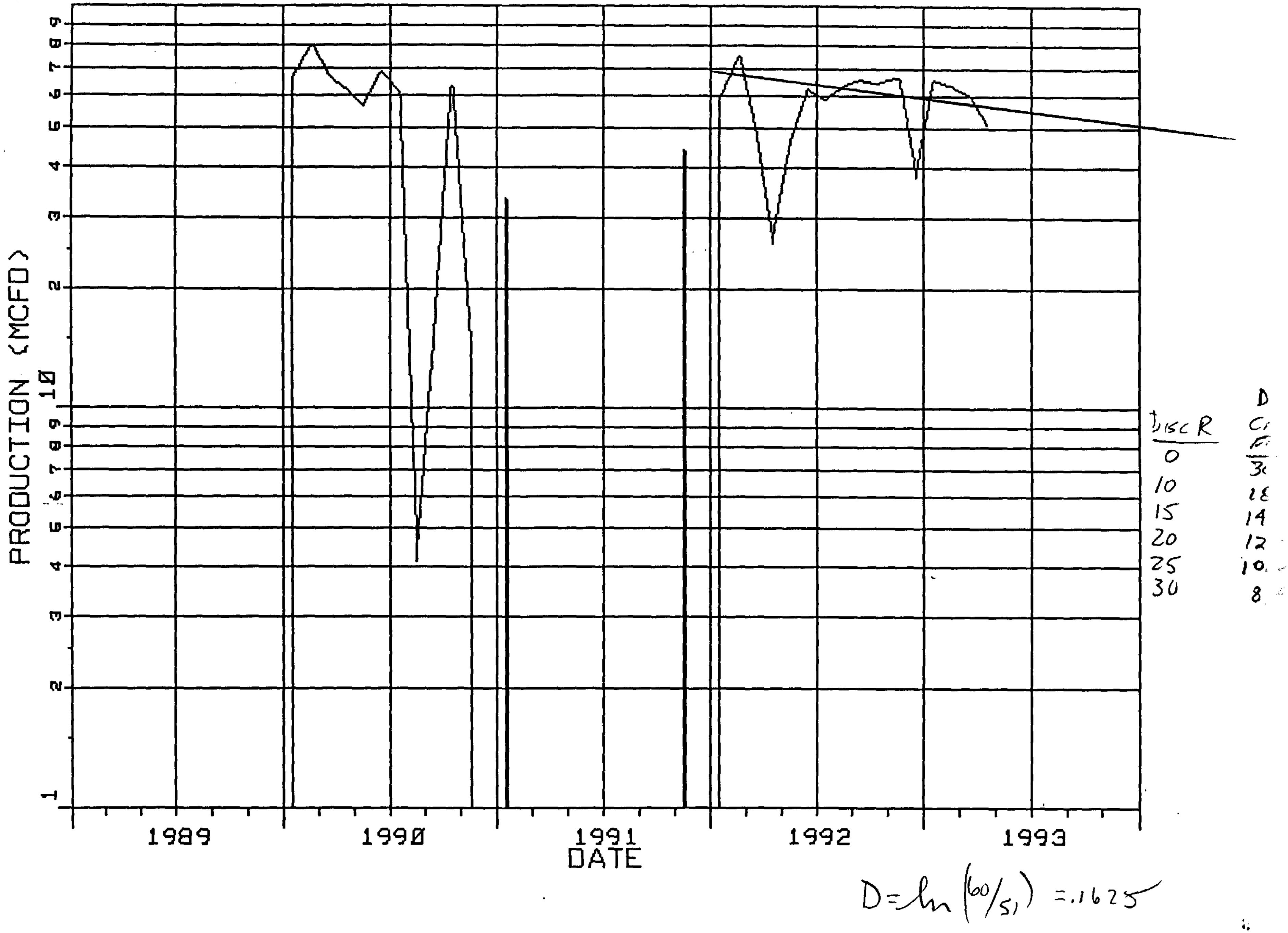
Disc R	
0	15.2
10	10.12
15	8.43
20	7.11
25	6.07
30	5.23

W.I = 60

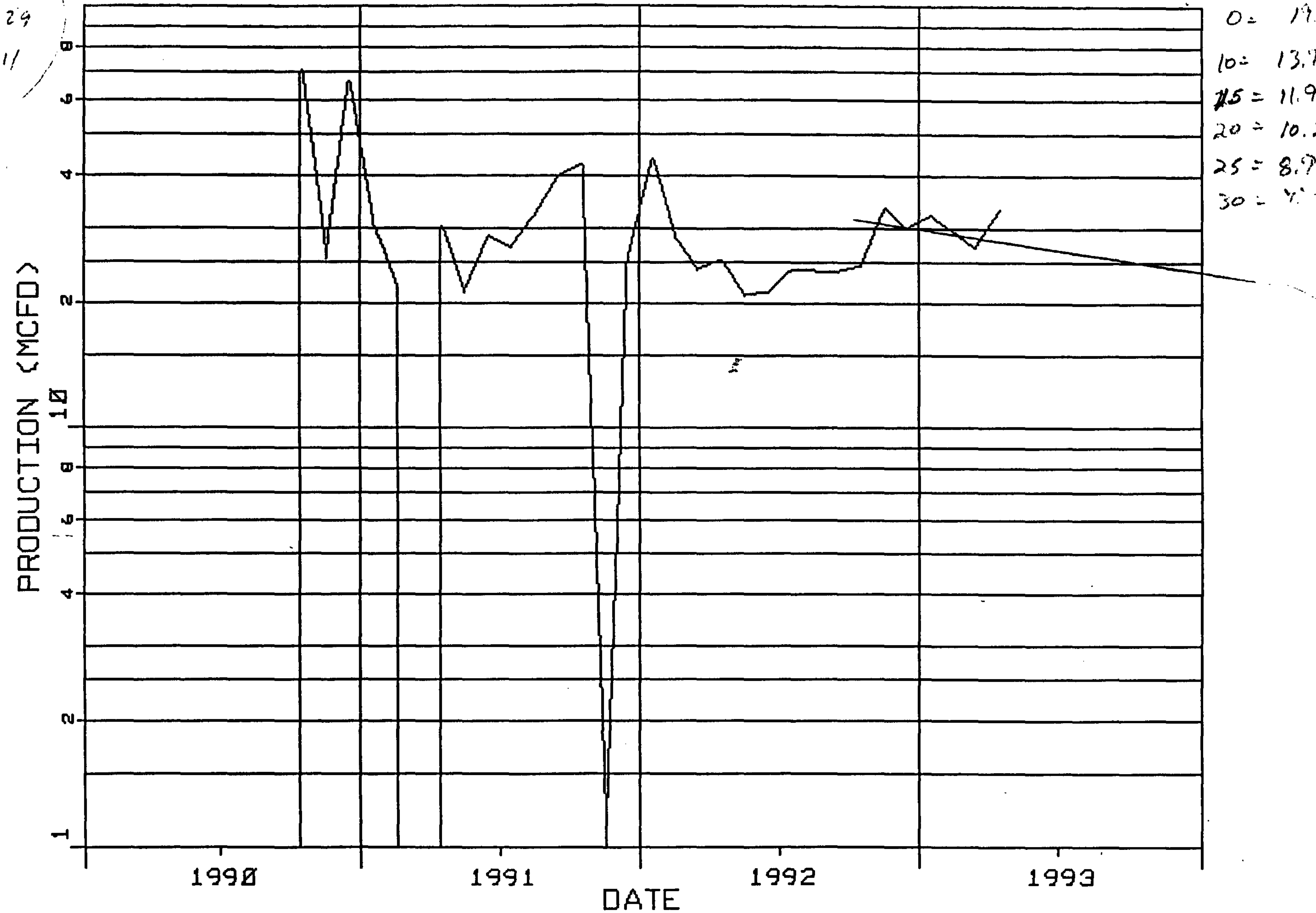
0 =	9.25
10 =	6.14
15 =	5.11
20 =	4.31
25 =	3.68
30 =	3.17

$D = \ln(18/16) = .117$

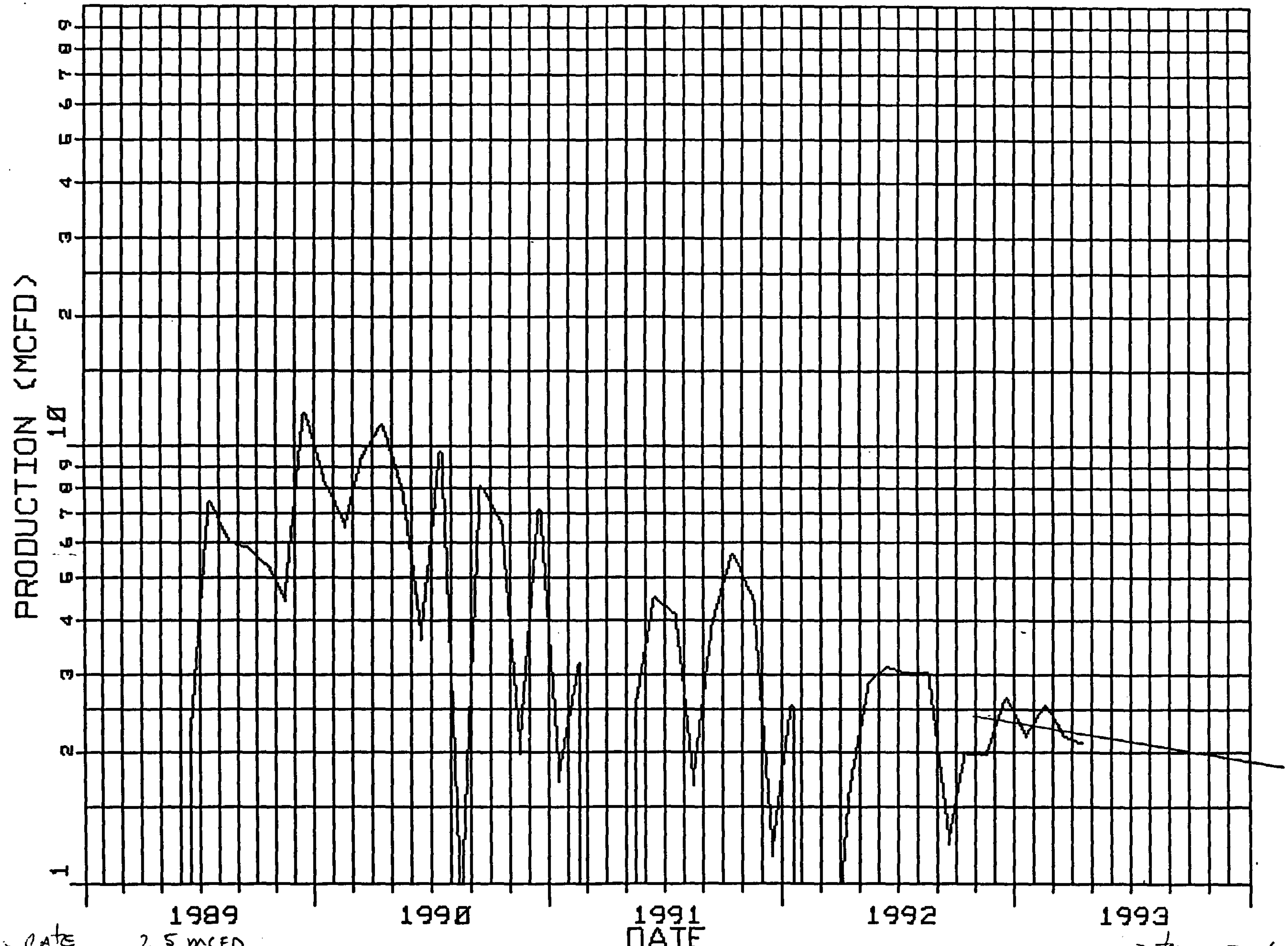
DOME FEDERAL 17-27-13 #2
PRODUCTION HISTORY



DA ON PAH NO. 1
PRODUCTION HISTORY



CHACO NO. 4
PRODUCTION HISTORY



Starting Rate 2.5 MCFD

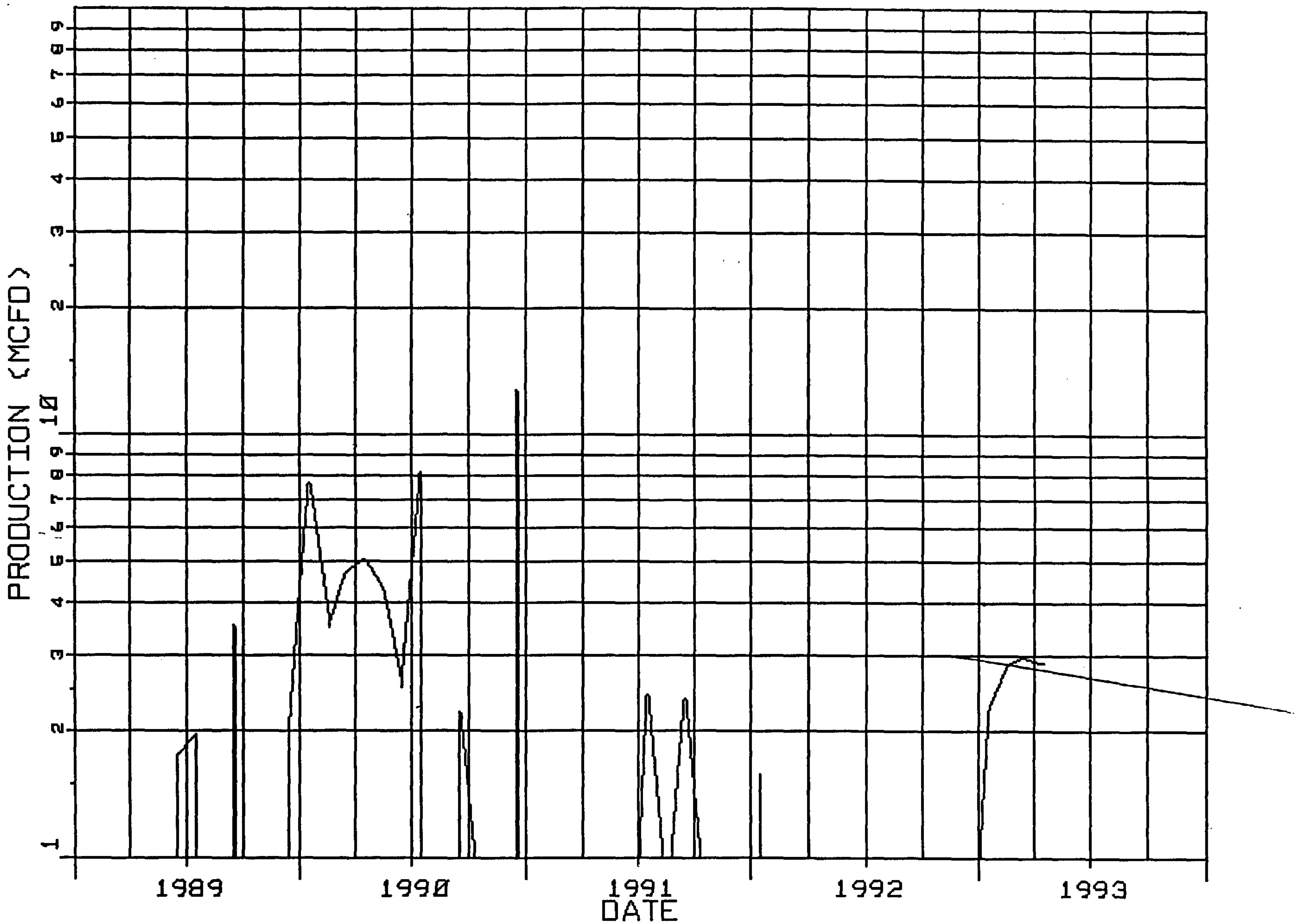
exp. Decline Rate/yr D = ln (2.3/1.85) = .218

F2 Same

Rate of Return

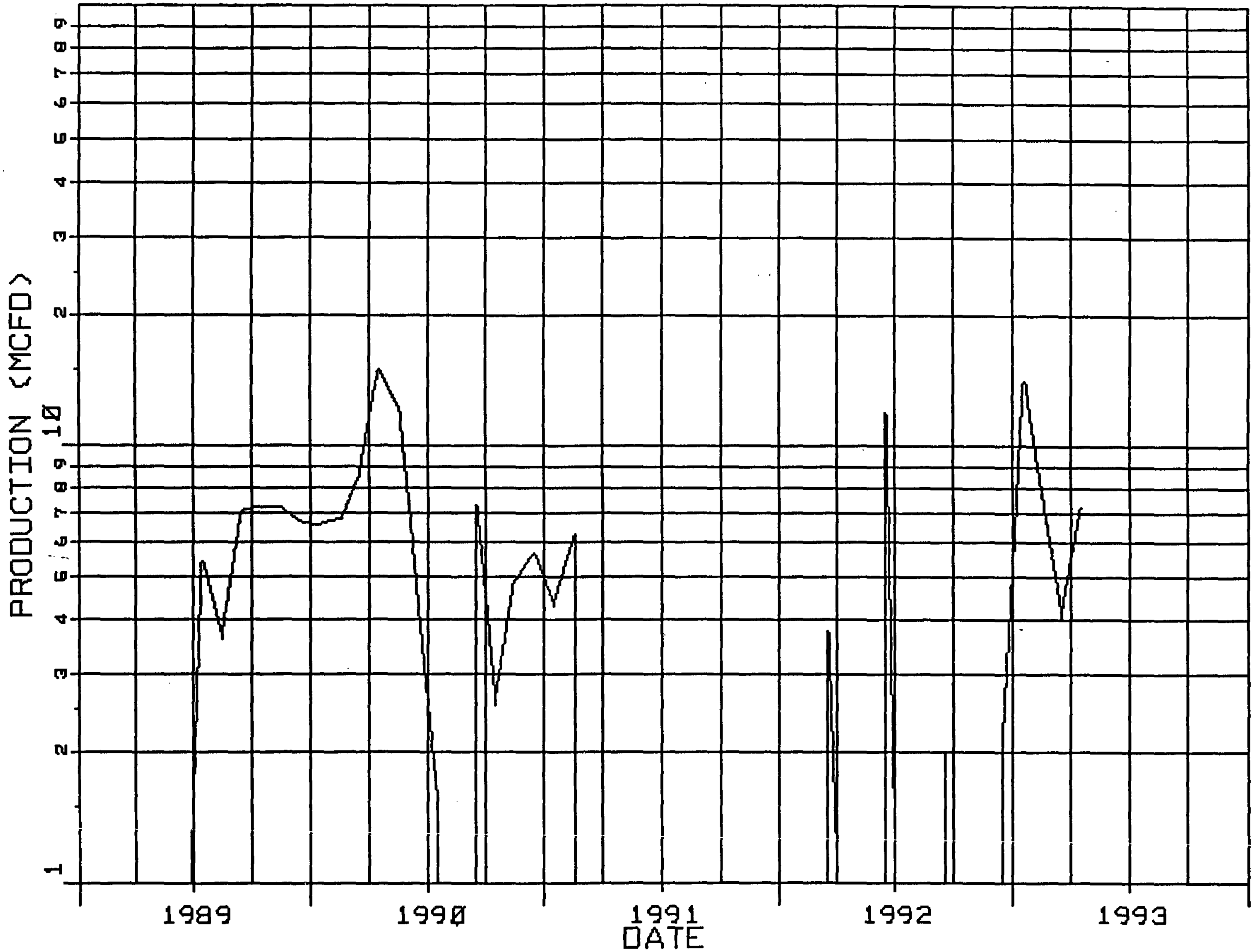
10 —
20 —
30 —
35 —

CHACO NO. 5
PRODUCTION HISTORY

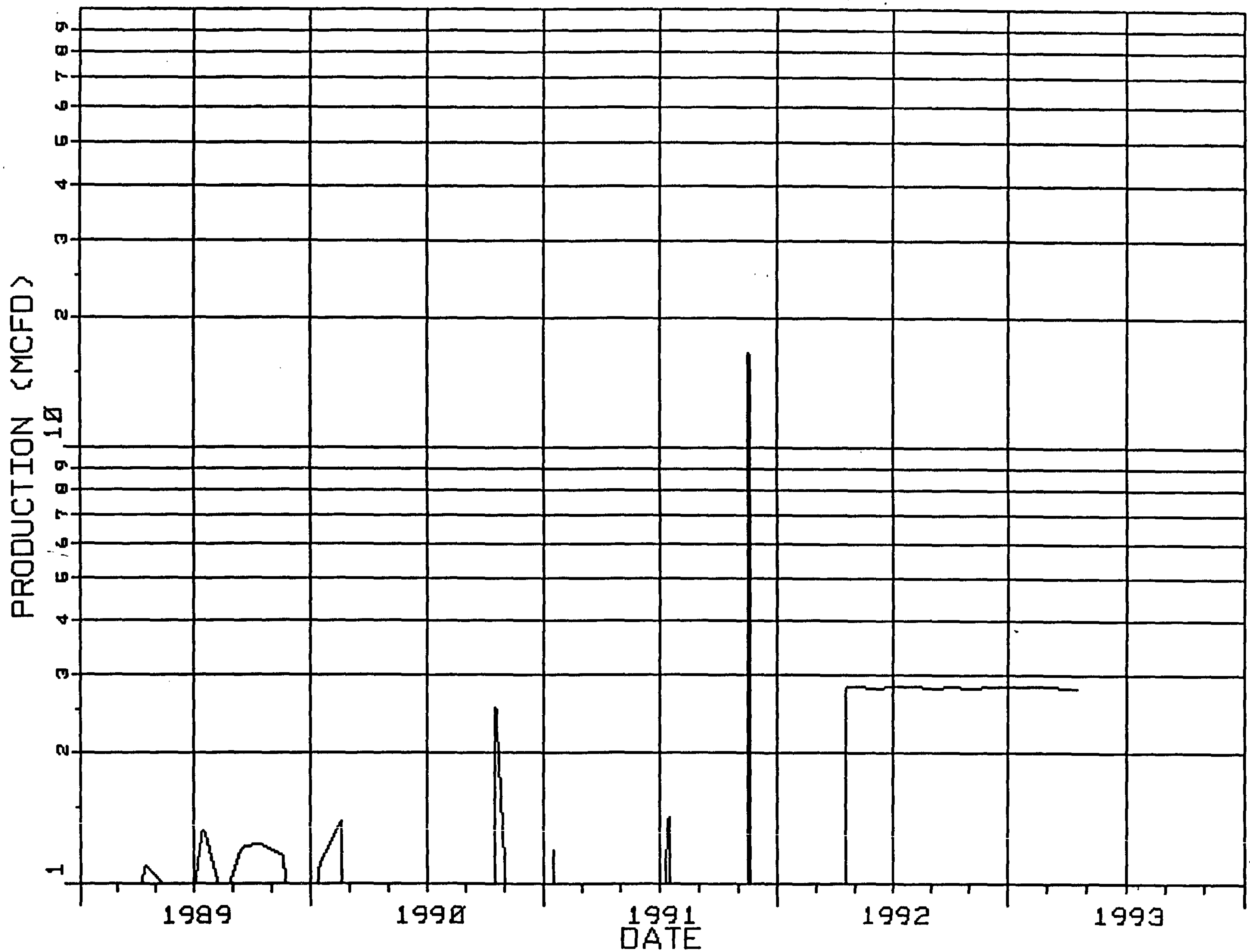


$D = \ln(2.9/2.7) = .0714$

CHACO LIMITED NO. 1J
PRODUCTION HISTORY

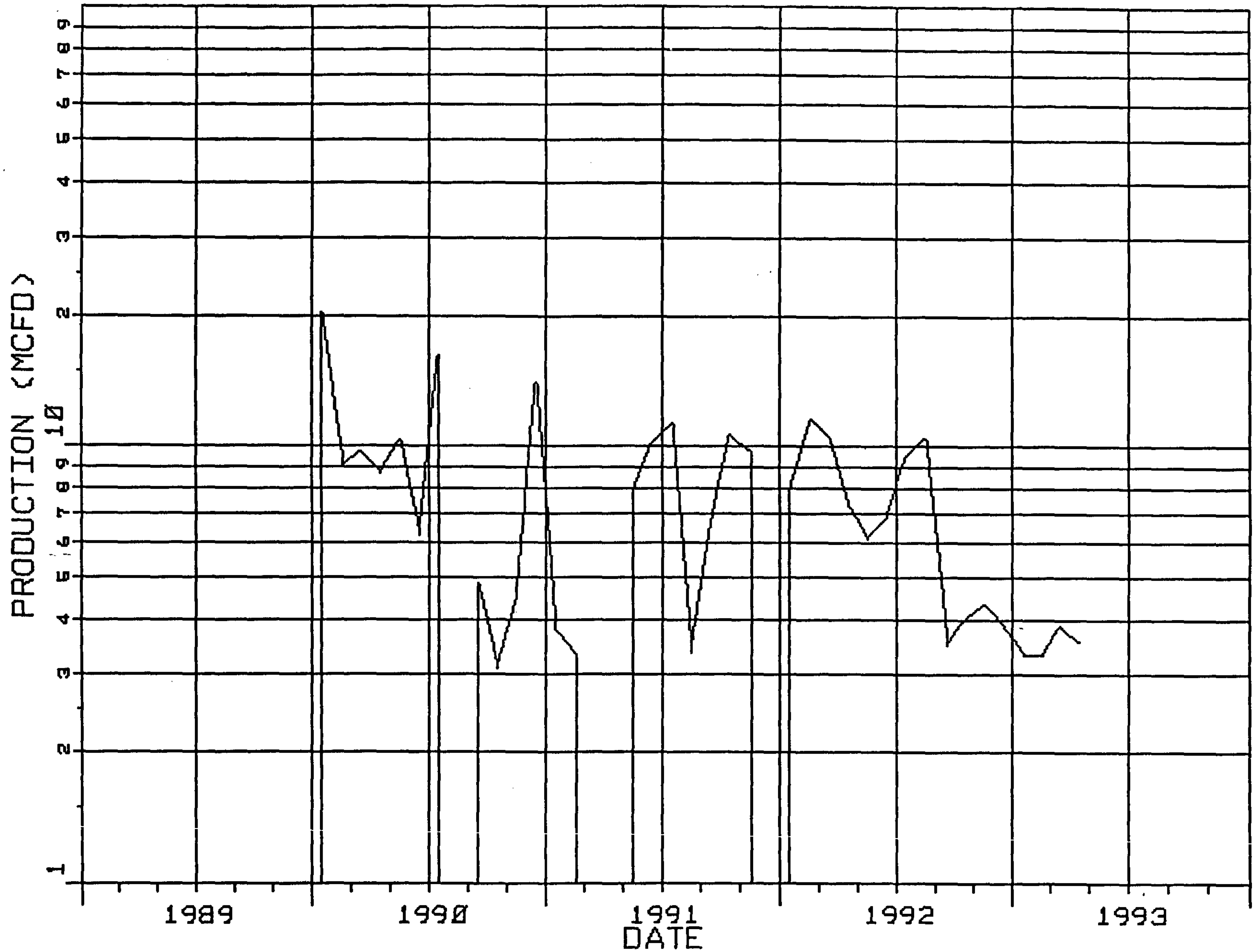


HI ROLL #1
PRODUCTION HISTORY



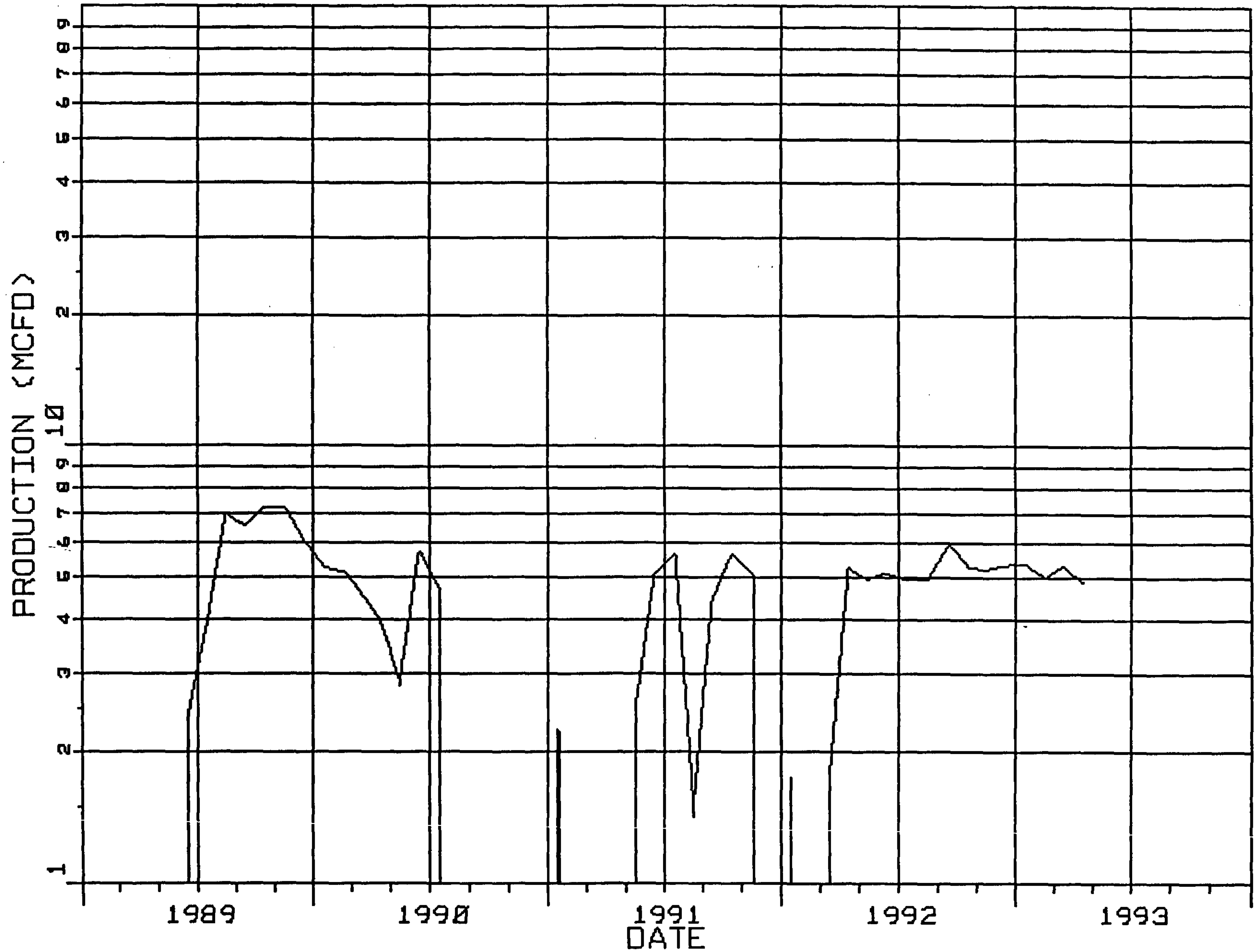
Ney

SOUTHLAND #2Y
PRODUCTION HISTORY

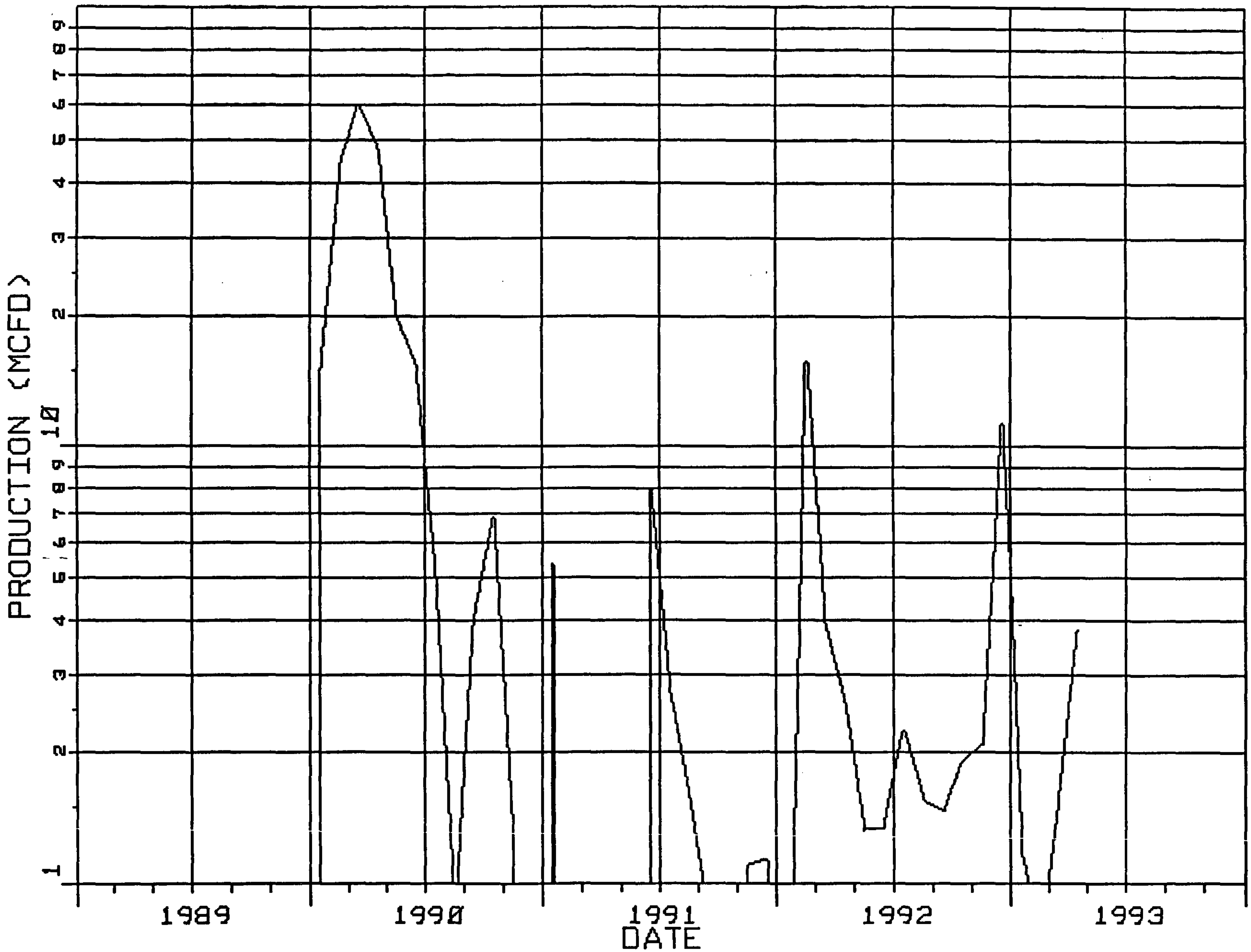


N 5j

CHACO LIMITED #2J
PRODUCTION HISTORY



DOME FEDERAL 18-27-13 #1
PRODUCTION HISTORY



N67

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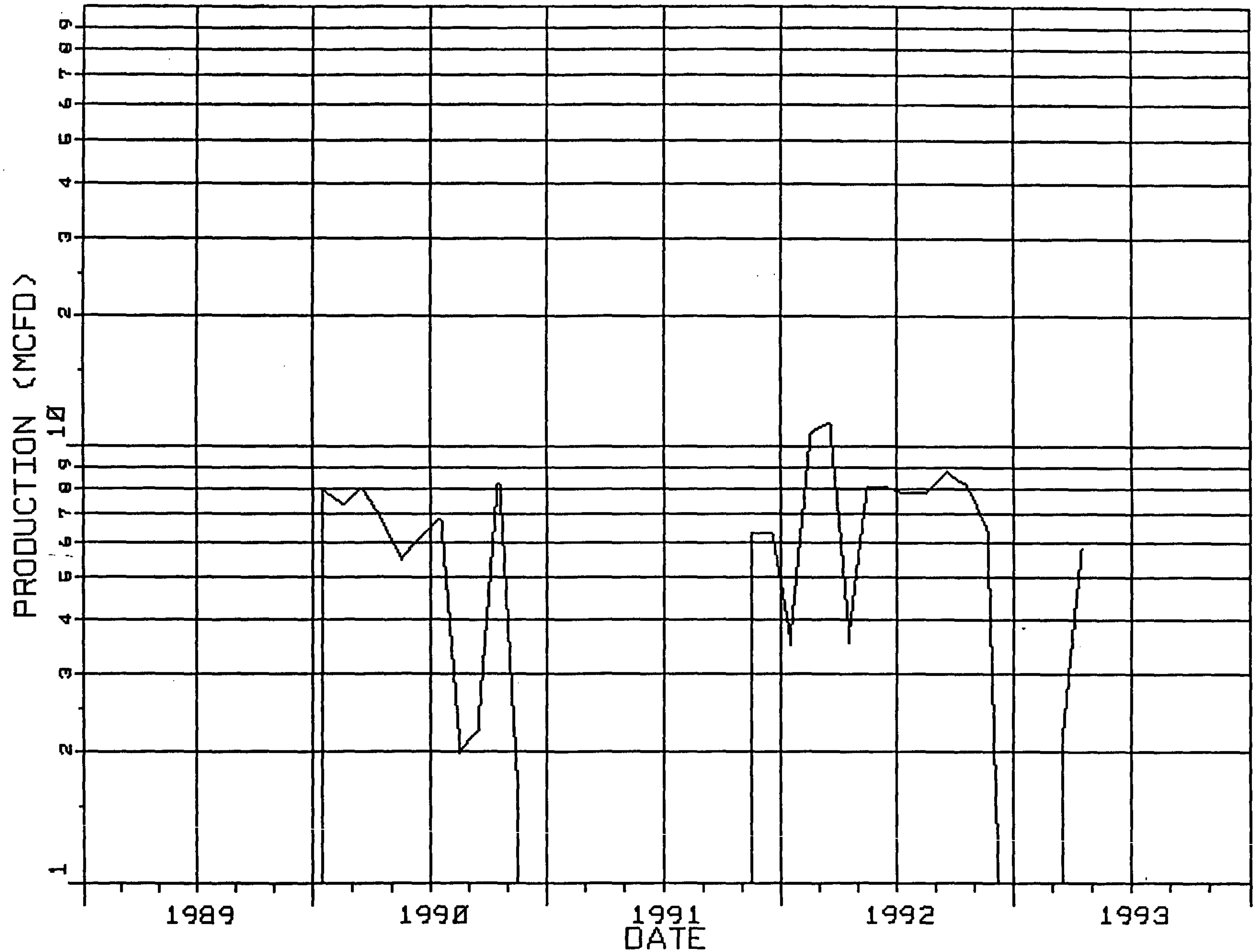
PRODUCTION HISTORY



N39

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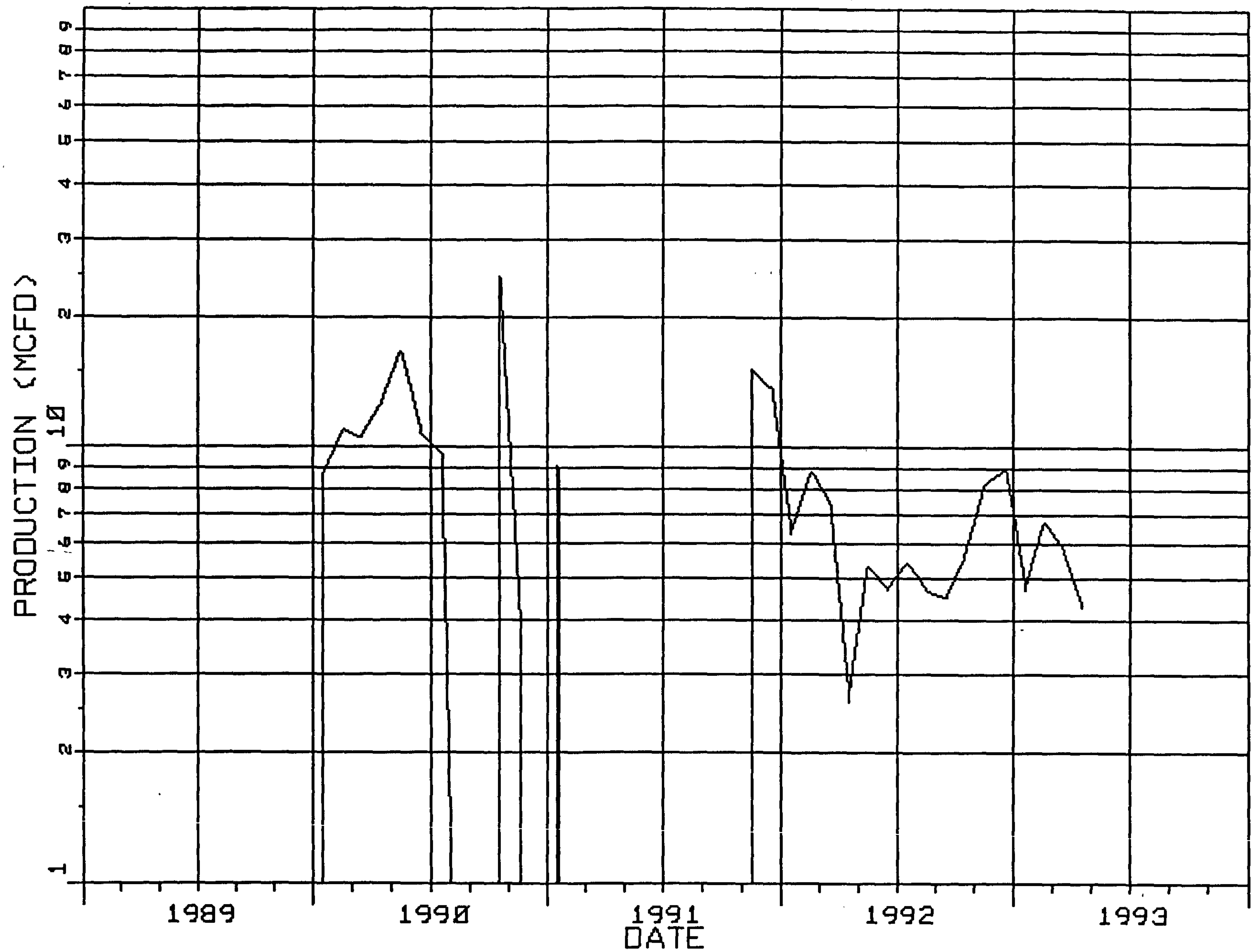
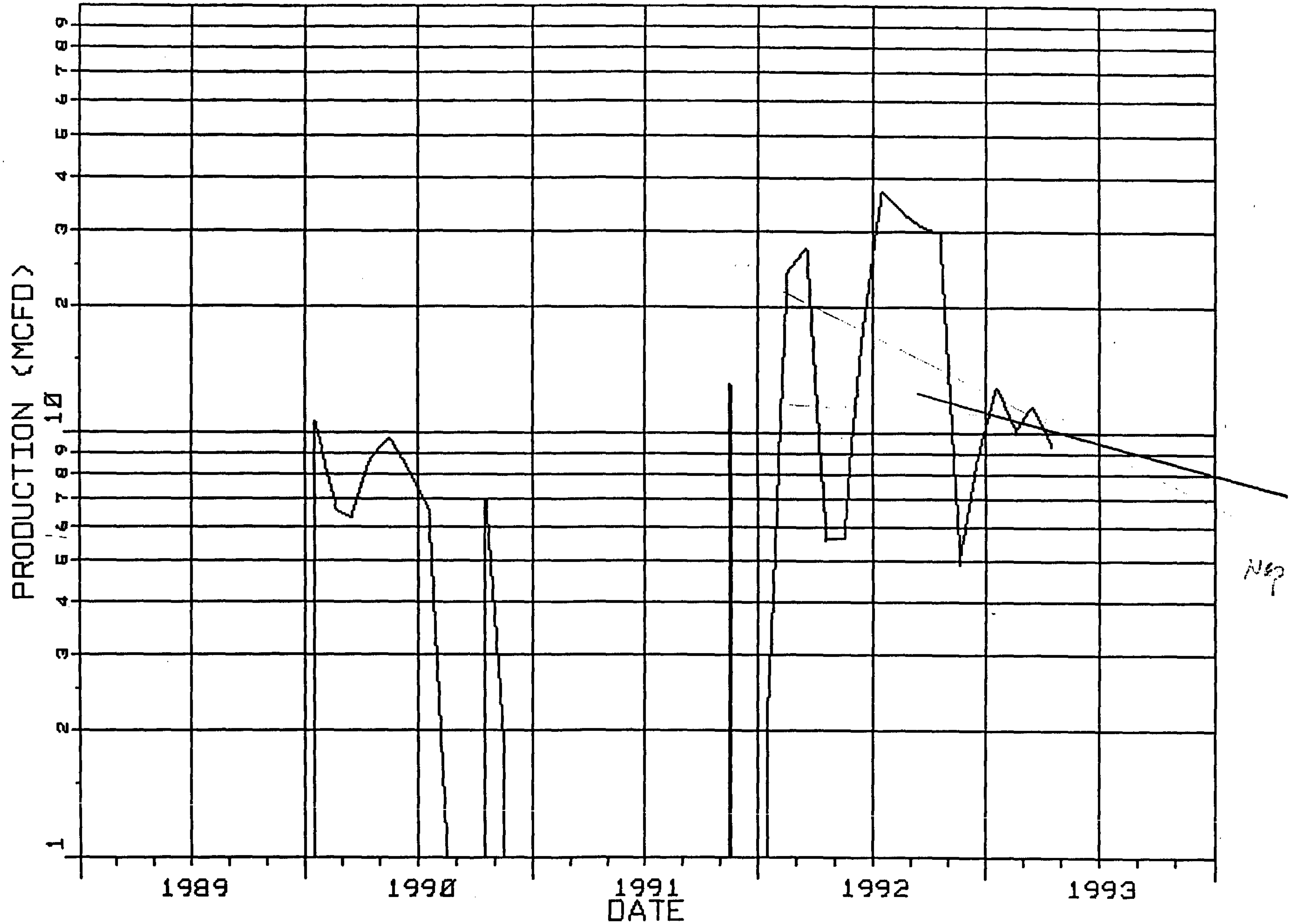


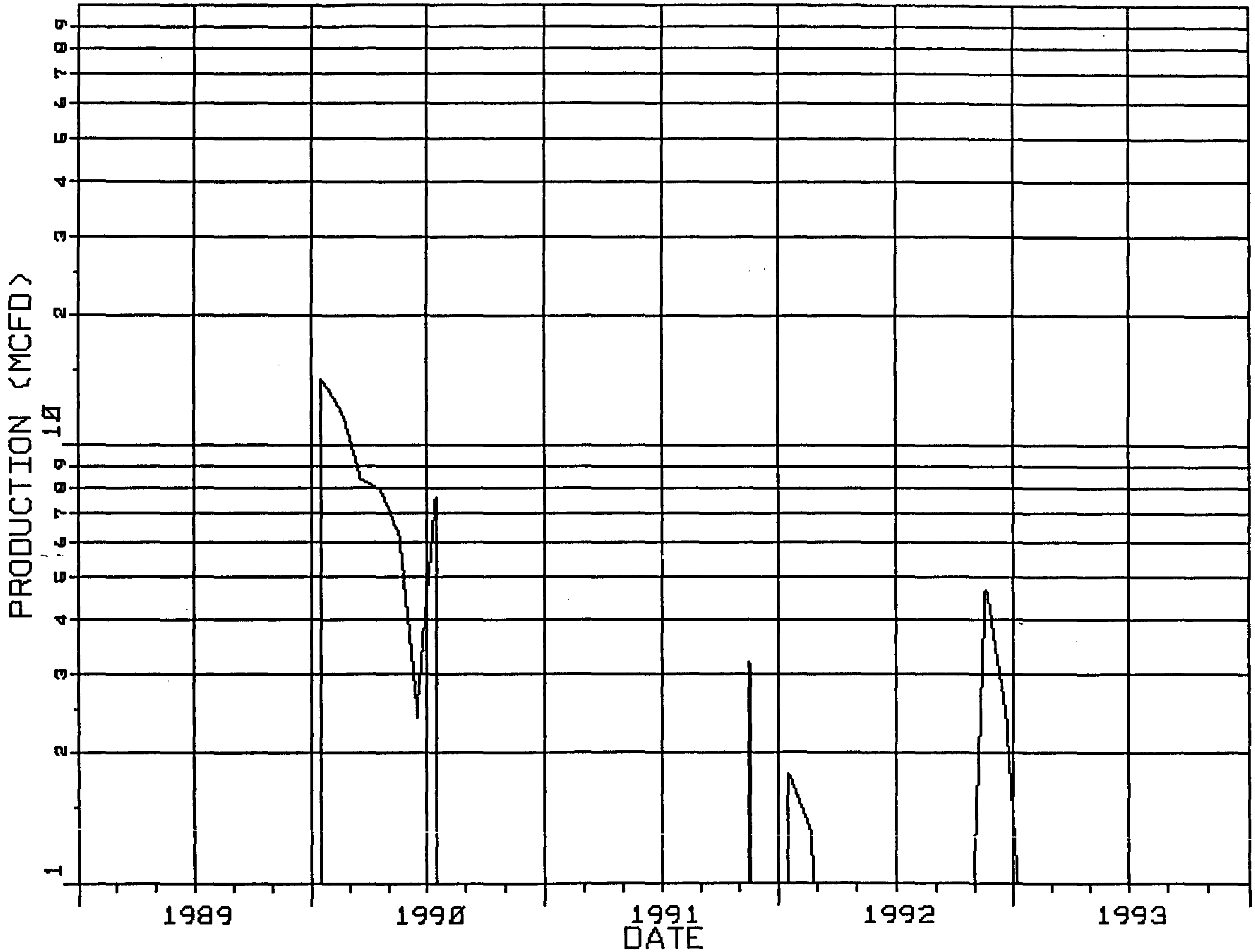
NEY

FREW FEDERAL #5
PRODUCTION HISTORY



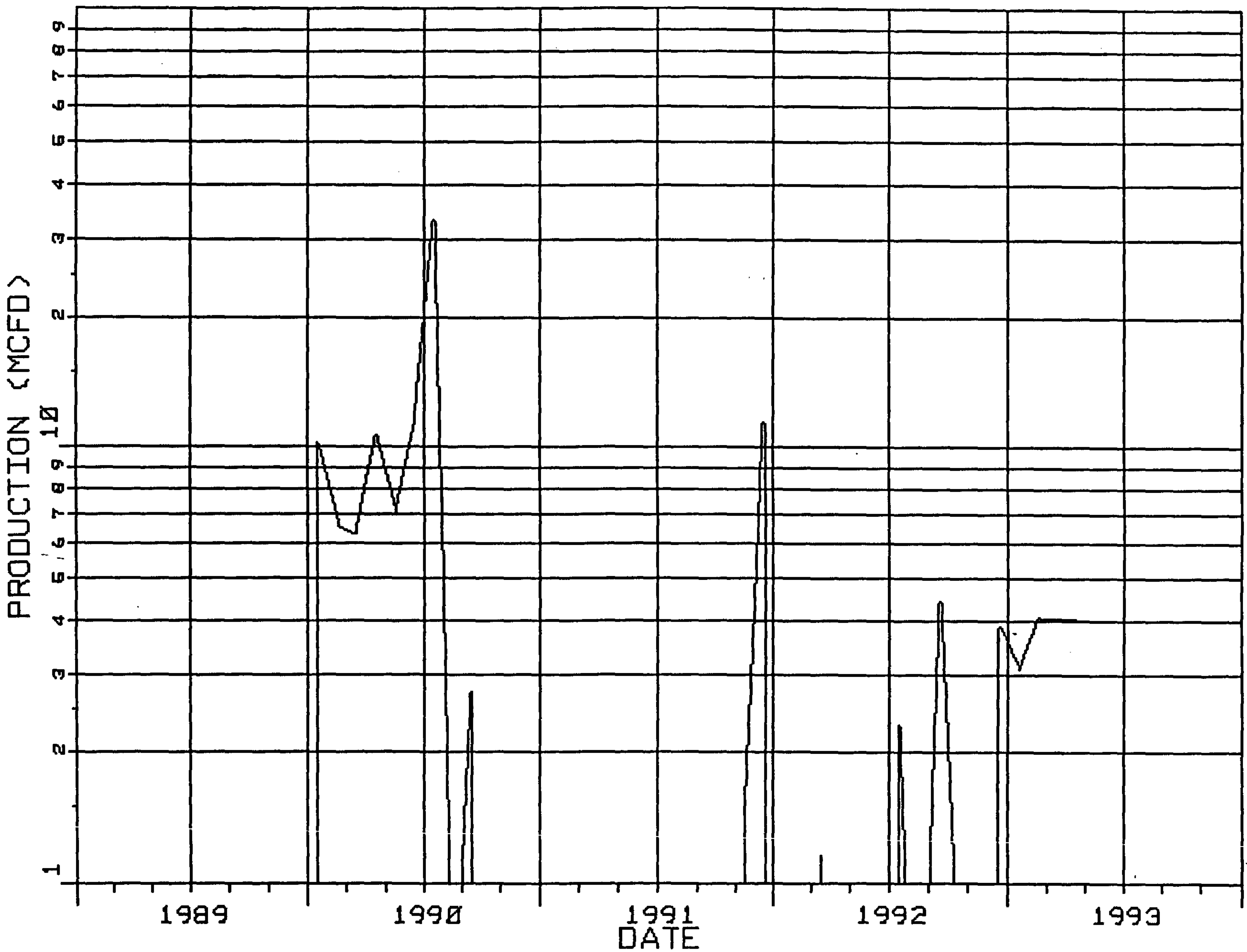
$D = \ln\left(\frac{11.5}{8}\right) = .36$

FREW FEDERAL #8
PRODUCTION HISTORY



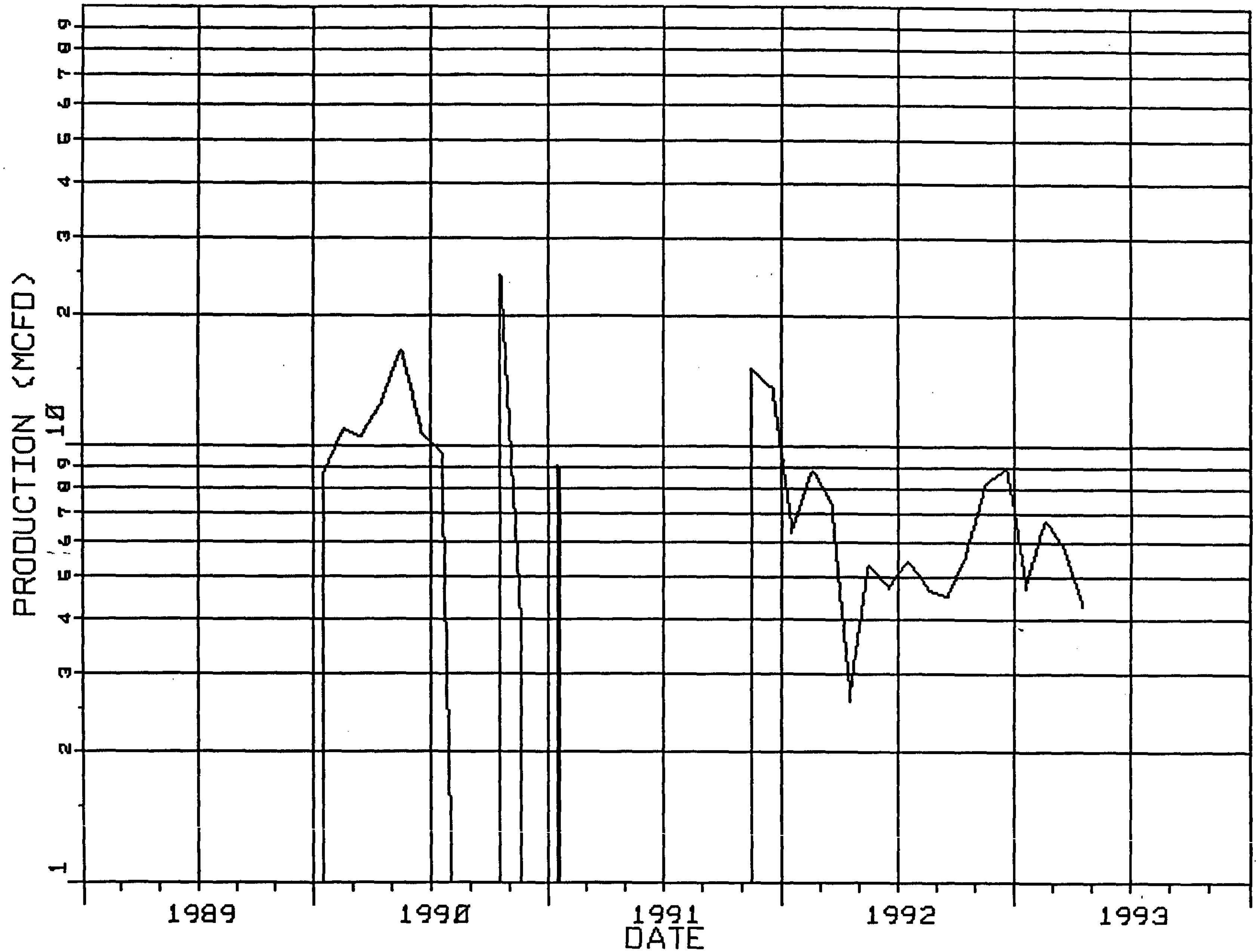
Unoc

FREW FEDERAL #9
PRODUCTION HISTORY



UMEC

FREW FEDERAL #15
PRODUCTION HISTORY

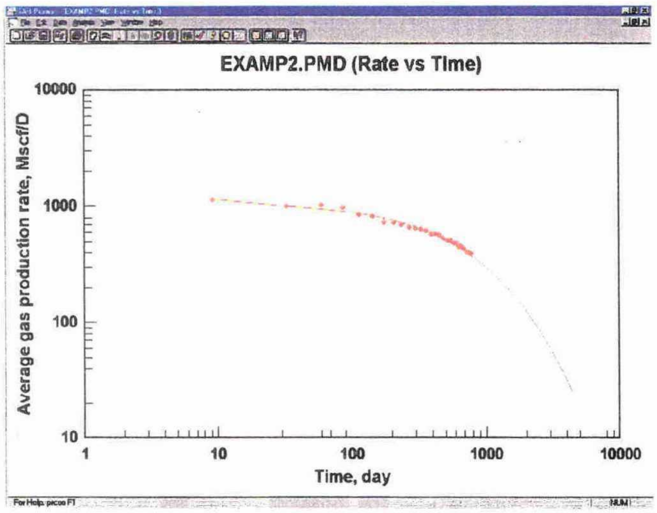


PROMAT™

...Have Production Data? Engineer Your Reservoir!

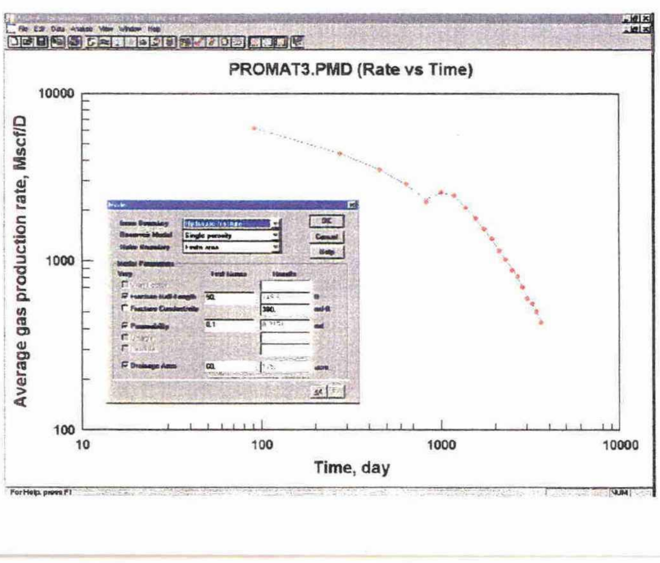
What is PROMAT™?

PROMAT™ is a single-phase production data analysis and forecasting tool. With it, you can automatically history match existing production data to estimate reservoir properties such as permeability, drainage area, skin factor, and fracture half-length or conductivity. ***PROMAT*** lets you forecast well performance based on the results of the history match or using independent estimates of reservoir properties when production data are not available.



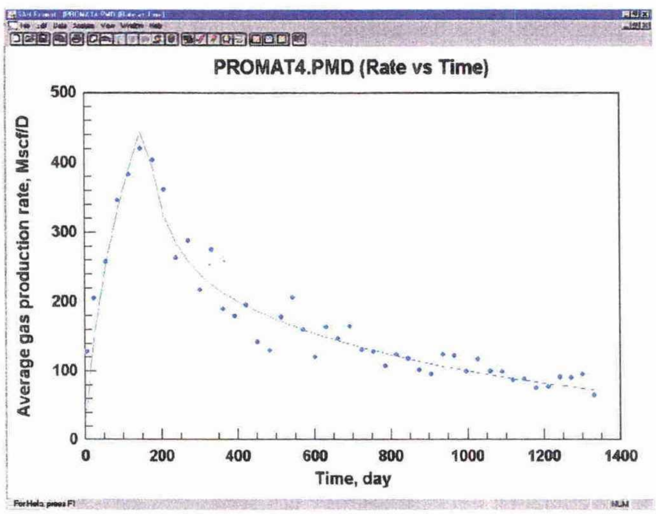
Major Features of PROMAT™

- ***PROMAT*** models both radial flow (with varying degrees of damage or stimulation) and hydraulically fractured wells from either infinite-acting or bounded reservoirs.

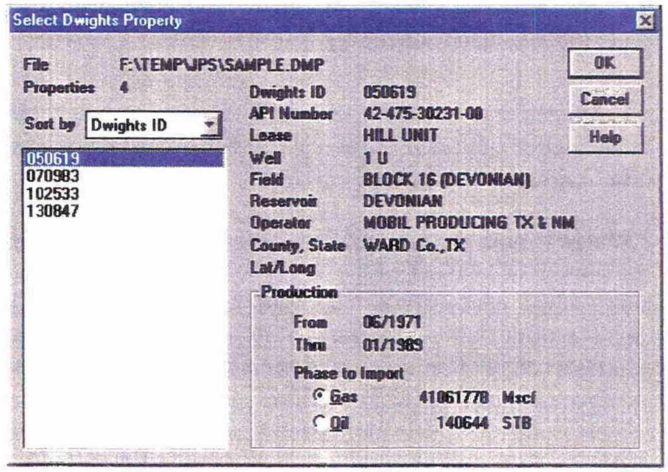


- ***PROMAT*** includes a variety of reservoir types, from conventional depletion drive gas reservoirs to coalbed methane and fractured shale reservoirs.

- ***PROMAT*** accounts for both constant and variable bottomhole pressure history, allowing you to evaluate the impact of operational changes such as curtailment or compressor installation.

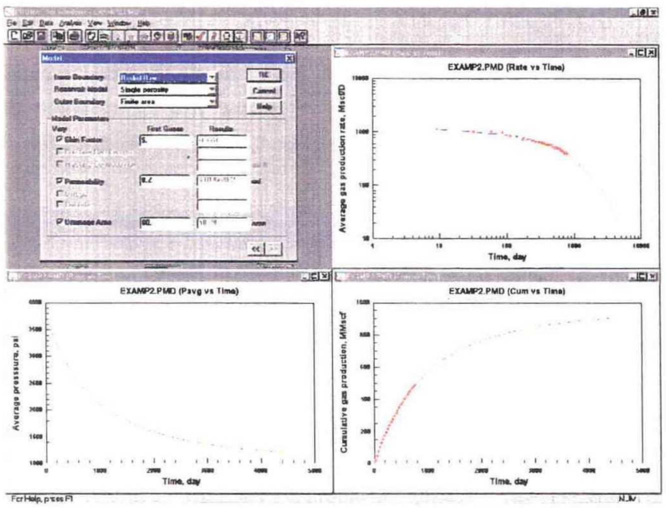


- ***PROMAT*** can import production data from a variety of commonly used formats, including *Dwights™ PCD* files and *Petroleum Information™ 98* files. Flow rate versus time results can be exported in an *Aries™*-compatible format for economic analysis.



- ***PROMAT*** accurately reflects changes in gas properties with time, something that decline curves or type curves cannot do easily.

- ***PROMAT's*** Windows®-based user interface allows you to edit data and reports easily, customize units systems, open multiple views simultaneously, and access on-line help.



PROMAT™ Applications & Advantages

Major producers, small to large independents, gas transmission companies, service companies, and foreign national oil companies use ***PROMAT*** routinely to

- Estimate reserves and forecast well performance for annual reserves reporting and evaluation of acquisitions.

- Evaluate infill drilling programs.

- Analyze post-fracture production data to evaluate the effectiveness of stimulation treatments.

- Optimize fracture half-length and well spacing to maximize project economics.

- Quantify reservoir permeability for "tight gas" classification (to qualify for severance tax relief in states like Texas, for example).

PROMAT provides a superior alternative to conventional decline curve analysis and material balance techniques for forecasting performance of depletion drive gas and undersaturated oil reservoirs. Unlike a material balance program, ***PROMAT*** does not require an input value for average reservoir pressure. Thus, in addition to being a valuable tool in higher-permeability oil and gas reservoirs and gas storage fields, it is particularly useful in lower-permeability reservoirs where static pressure measurements do not provide accurate estimates of average drainage area pressure. ***PROMAT*** also generates a production forecast rather than only the cumulative reserves estimate provided by material balance.

Users find ***PROMAT*** to be highly reliable and quick and easy to use, a combination that is hard to beat in today's leaner operating environment. For simple, single-phase problems, ***PROMAT's*** results are comparable to those obtained through numerical simulation, but require much less time and input data.

Hardware & Software Requirements

PROMAT™ requires a 486-25 (minimum) PC with 2 MB hard drive space, 4 MB RAM, and Microsoft Windows® 3.1 or higher.

For More Information...

To find out more about ***PROMAT™***, contact Bill Powell at (281) 558-9120 or David Lancaster or John Spivey at (409) 764-1122.

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email: 104551.1722@compuserve.com

E-Mail: info@holditch.com
http://www.holditch.com/

S. A. Holditch & Associates

PETROLEUM ENGINEERING & GEOSCIENCE SERVICES

PROMAT™

...Have Production Data? Engineer Your Reservoir!

What is PROMAT™?

PROMAT™ is a single-phase production data analysis and forecasting tool. With it, you can both manually and automatically history match existing production data to estimate reservoir properties such as permeability, drainage area, skin factor, and fracture half-length or conductivity. ***PROMAT***™ lets you forecast well performance based on the results of the history match or using independent estimates of reservoir properties when production data are not available.

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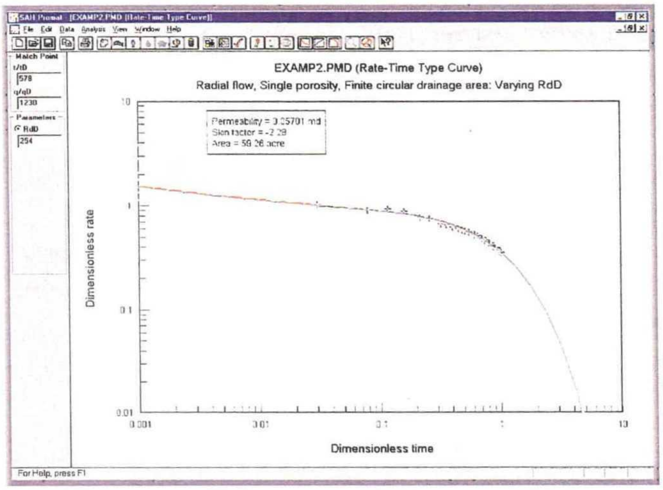

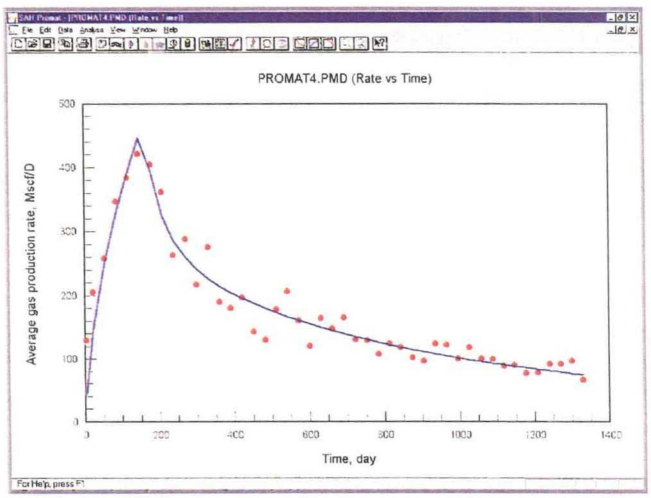

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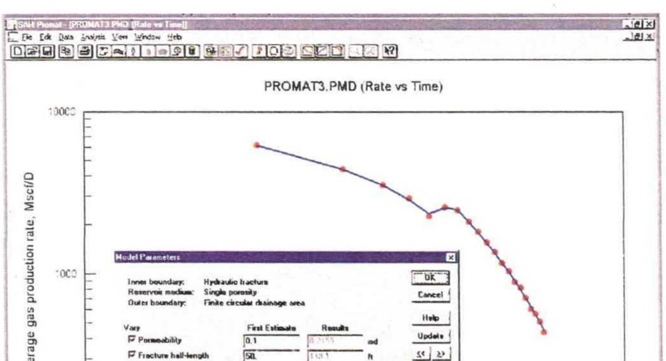

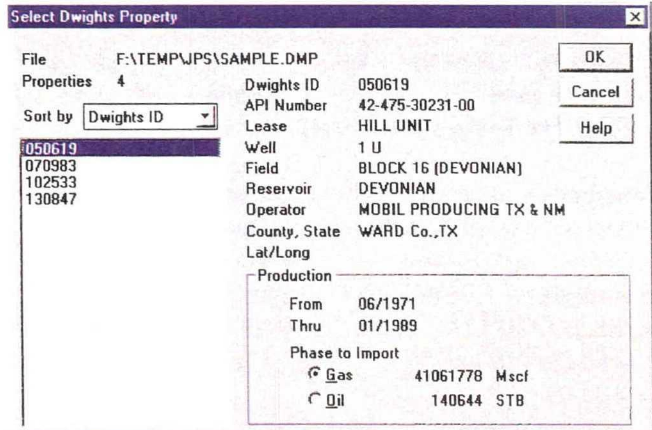

S. A. Holditch & Associates

PETROLEUM ENGINEERING & GEOSCIENCE SERVICES

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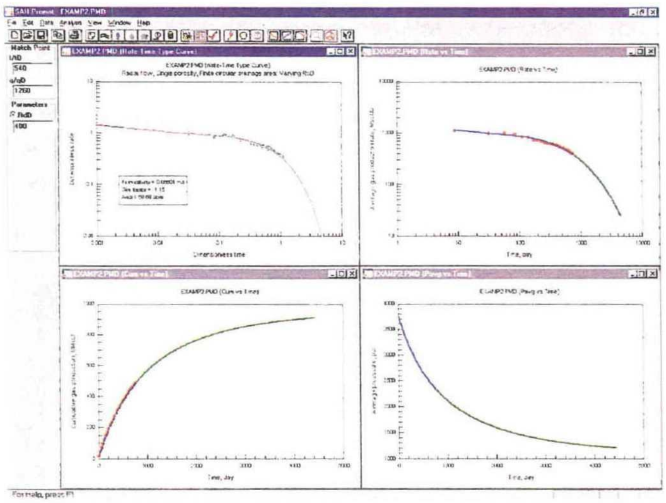

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PROMAT™

PROMAT™ is a single-phase production data analysis and forecasting tool. PROMAT provides a superior alternative to conventional decline curve analysis and material balance for forecasting performance of depletion drive gas and undersaturated oil reservoirs.

PROMAT™ Version 5 is the latest version of S. A. Holditch & Associates, Inc.'s (HOLDITCH's) production data analysis software, originally released in 1987. PROMAT Versions 3.2.2 and earlier were developed, in part, through research performed by HOLDITCH for the Gas Research Institute (GRI), Chicago, IL under GRI Contract No. 5084-213-0980. Development and applications of PROMAT are documented in several SPE papers, journal publications (attached), and GRI reports.

Analysis capabilities

Unlike conventional decline curve analysis, PROMAT™ predicts performance using the physical properties of the formation, such as net pay, porosity, permeability, and drainage area. Since most of these physical properties can be measured or estimated without a production history, PROMAT allows the engineer to make preliminary forecasts of well performance for wells without production. If production history is available, PROMAT can estimate formation properties such as permeability and drainage area with automatic history-matching. Further, PROMAT enables the engineer to estimate the effect of stimulation treatments or compressor installation.

PROMAT™ does not require knowledge of average reservoir pressure, unlike material balance analysis. This is particularly important in lower-permeability reservoirs, where static pressure measurements are not accurate estimates of average drainage area pressure. Further, PROMAT provides a production forecast over time, rather than the single reserves estimate provided by material balance analysis.

Reservoir models

PROMAT™ supports a number of different reservoir models, including conventional depletion drive gas and oil reservoirs, dual porosity reservoirs, and dewatered coalbed methane and naturally fractured shale reservoirs. PROMAT can model both radial flow and hydraulically fractured wells. PROMAT can model production from both infinite-acting reservoirs and from bounded reservoirs.

Importing and exporting

PROMAT™ can import production data in a variety of formats, including PROMAT for DOS data files, Dwight's ™ PCD files, and Petroleum Information™ 98 format files. PROMAT can also export files in Aries™ compatible format. In addition, PROMAT provides clipboard support for copying data from, and pasting results to, other applications.

PROMAT™ is used by more than 75 organizations in the petroleum industry, some of whom use the software at multiple sites. The following is list of the types of user groups and, under each, a sample listing of the user companies.

MAJOR OIL / GAS COMPANIES

- ***Amoco***
- ***Chevron***
- ***Texaco***

INDEPENDENT OIL COMPANIES

- ***Cabot Oil and Gas Corporation***
- ***Coastal Natural Gas Company***
- ***Burlington Resources (formerly Meridian Oil Corparation)***
- ***NorAm Gas Transmission***
- ***Oxy USA Inc.***
- ***Pogo Producing Company***
- ***Santa Fe Energy Resources, Inc.***
- ***Sanchez O'Brien***
- ***TransTexas Gas Corporation***

SERVICE COMPANIES

- ***Halliburton Energy Services***
- ***Schlumberger Dowell***

PETROLEUM CONSULTING FIRMS

- ***Doran & Associates***
- ***Ely Associates Inc.***
- ***Flack Petroleum Consultants***
- ***Gary Bagwell, Consultant***
- ***Huddleston & Company***
- ***Integrated Petroleum Technologies***
- ***Jim Murtha***
- ***Pinnacle Technologies***
- ***S. A. Holditch & Associates***

RESEARCH INSTITUTIONS AND UNIVERSITIES

- ***Gas Research Institute***
- ***Institut Teknolgi Bandung***
- ***Marietta College***
- ***New Mexico Tech***
- ***Porous Media Institute***
- ***Texas A&M University***
- ***University of Alaska***
- ***University of Arizona***
- ***West Virginia University***

INTERNATIONAL ENTITIES

- *British Gas*
- *Cat Oil GmbH*
- *PEMEX Exploracion y Produccion*
- *Petroleos de Venezuela S.A. (Corpoven, Lagoven, Maraven)*
- *Saudi Arabian Texaco Inc.*
- *Texaco Kuwait*
- *Virginia Indonesia Company*

New PRODUCTS & SERVICES

The following information describes new, recently revised, or historically popular GRI products and services. Any inquiries regarding additional details, ordering instructions, or applicability to a particular problem should be directed to the listed contacts. In addition, the 1995-1996 Natural Gas Supply Product & Services Guide highlights 77 products and contact points for additional information. A copy of the guide can be obtained by calling Brian Gahan at 312/399-5481, or by contacting either of the GRI Information Centers listed on page 38.

PROMAT™ for Windows™ Now Available

The Windows™ version of the popular DOS-based PROMAT™ software developed by *S. A. Holditch & Associates, Inc. (SAH)* for GRI, is now commercially available. PROMAT for Windows™ is a single-phase production data analysis and forecasting tool. With it, users can automatically history-match existing production data to estimate reservoir properties such as permeability, drainage area, skin factor, and fracture half-length or conductivity. PROMAT also allows users to forecast well performance based on the results of the history match or using independent estimates of reservoir properties when production data are not available.

PROMAT for Windows provides a superior alternative to conventional decline curve analysis and material balance techniques for forecasting performance of depletion drive gas and undersaturated oil reservoirs. Unlike a material balance program, PROMAT for Windows does not require an input value for average reservoir pressure. Thus, although it can be applied in a variety of depletion drive reservoirs, it is particularly useful in lower-permeability reservoirs where static pressure measurements do not provide accurate estimates of average drainage area pressure. Additionally, the software generates a production forecast rather than the cumulative reserves estimate provided by material balance.

This product uses analytical solutions and an automatic history-matching algorithm to analyze existing production data and forecast well performance. For simple, single-phase problems, PROMAT's results are comparable to those obtained through numerical simulation, but require much less time and input data. Although earlier versions of the software could be used only for constant bottomhole pressure production, PROMAT for Windows permits the user to model a variable bottomhole pressure history. This allows engineers to evaluate the impact of operational changes such as curtailment or compressor installation.

PROMAT for Windows models a variety of reservoir types, from conventional depletion drive gas reservoirs to coalbed methane and fractured shale reservoirs. The software can model both radial flow (with varying degrees of damage or stimulation) and hydraulically fractured wells from either infinite-acting or bounded reservoirs. In addition, PROMAT for Windows accurately reflects changes in gas properties with time, something that decline curves or type curves cannot do easily.

This version of PROMAT offers a number of enhancements over the previous DOS-based product. First, the software can now import production data from a variety of commonly used formats, including *Dwights™ PCD* files and *Petroleum Information™ 98* files. Flow rate versus time results can be exported in an Aries™-compatible format for economic analysis. Conventional oilfield or SI units can be used, or users may customize the unit's system to fit their needs. Graphics options are substantially improved and PROMAT for Windows offers all the advantages of other Windows software, including clipboard support for copying data from and pasting results to other Windows applications, as well as the ability to open multiple views.

About 150 installations of PROMAT are currently in use by more than 60 companies, including major producers, small to large independents, gas transmission companies, service companies, and foreign national oil companies. These companies use PROMAT to:

- Estimate reserves and forecast well performance for annual reserves reporting and evaluation of acquisitions
- Evaluate infill drilling programs
- Optimize fracture half-length and well spacing to maximize economics
- Analyze post-fracture production data to evaluate the effectiveness of stimulation treatments
- Assess the impact of compression on long-term well performance
- Quantify reservoir permeability to qualify for tight gas classification (to receive severance tax relief in states like Texas, for example).

Although PROMAT for Windows is well suited for solving engineering problems related to lower-permeability reservoirs, it is also a valuable tool for higher-permeability, conventional oil and gas reservoirs, and storage fields.

Glenn Sliva, Consulting Reservoir Engineer for *Sanchez O'Brien* in Houston, is using PROMAT for Windows to forecast well performance on all new wells drilled in South Texas. Sliva finds PROMAT to be highly reliable and very quick and easy to use, a combination that's hard to beat in today's leaner operating environment. *Sanchez O'Brien* has also used PROMAT successfully to obtain severance tax relief from the state of Texas on a number of low-permeability gas wells in South Texas, resulting in a tax savings of $9 million through 1995.

Stan Shaw, a reservoir engineer with *Columbia Gas Transmission* in Charleston, WV, uses PROMAT for Windows routinely to identify deliverability problems in gas storage wells. PROMAT for Windows allows Shaw to predict well performance under different stimulation scenarios, based on the data from a single well test. With these predictions, *Columbia* can choose the stimulations that give the best overall deliverability increase for the money. Shaw completed a study of 200 wells in 1995 and plans to test another 600 wells in 1996.

Brian Ault is a senior reservoir engineer with *Meridian Oil Corporation* in Farmington, NM. Most recently, Ault has been using PROMAT for Windows to evaluate infill drilling prospects in reservoirs in the San Juan Basin. Using PROMAT to estimate reservoir properties, particularly permeability and drainage area, he has identified reservoirs where infill wells are needed. One of the advantages of PROMAT is that it is less data-intensive than other models, an important feature in an area were pressure data is scarce and production is the typical history-matching parameter. "We're currently using a very sophisticated simulator to model these reservoirs right along side PROMAT," says Ault. "So far, we have been very pleased with how well PROMAT results compare with the more elaborate model's predictions. We hope to gain enough confidence to replace the expensive model completely in the next few months."

Although PROMAT for Windows has been available only a short time, another significant enhancement to the product is planned for the summer of 1996. That release, already in beta test, will include numerous type curve analysis options, in addition to the currently available automatic history-matching capability. Future plans include adding the capability for modeling layered reservoirs and two-phase systems.

For more information about PROMAT for Windows, or to obtain a free demo version of the software, please contact David Lancaster with *S. A. Holditch & Associates*, Inc. at 409/764-1122, by FAX at 409/764-8157, or by e-mail at del@holditch.com. ■

Electronic Flow Measurement Device Delivers Speed and Accuracy at Low Cost

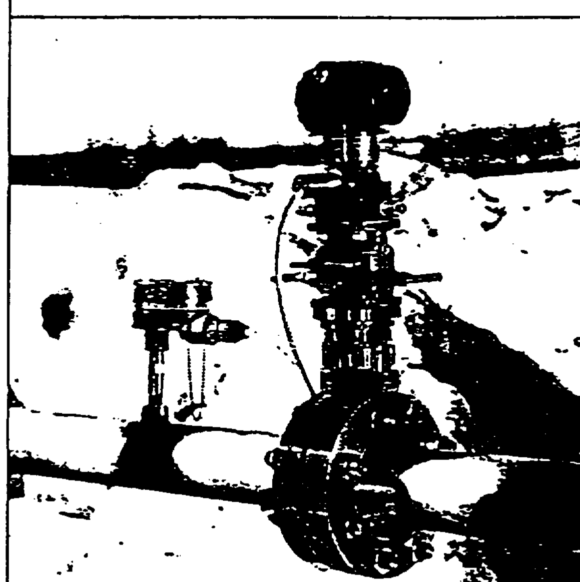
How is open access affecting your measurement practices? FERC Order 636 requires not only quick and accurate tracking of gas volumes, but also a clear audit trail for custody transfer settlements. However, heightened competition means that any product that meets this need must also be available at reasonable cost.

In response, Gas Research Institute (GRI), in collaboration with *Rosemount Inc.*, has developed a low-cost, electronic flow measurement device (EFM), Model 3095FT. In the past, orifice meters using circular chart recorders were the standard gas measurement device. The charts were gathered and interpreted by hand, a labor-intensive process that sometimes caused delays in processing gas transactions. EFM units, on the other hand, while fast and accurate, were often too expensive to warrant use at other than the largest meter stations.

In contrast, the Model 3095FT delivers speed and accuracy at a cost suited even for low-volume, remote installations. At a list price of less than $2,000, the device will have a total installed cost 30 to 50 percent less than many existing EFM systems. The price is also competitive with chart recorders (about $1,800 to $2,000 installed).

Advances in sensor technology, solid-state electronics and microprocessor technology allow the integration of multiple sensors into a single compact housing. The Model 3095FT houses the most accurate differential and absolute pressure sensors available in this platform and receives input from an RTD temperature sensor. The Model 3095FT also supports calculation of orifice meter flow rate and total volume

Electronic Flow Measurement Device Model 3095FT



according to the American Gas Association (A.G.A.) Report No. 3 and American Petroleum Institute Chapter 14.3 standard (1992), as well as A.G.A. Report No. 8 (1992).

In addition, the Model 3095FT meets the data logging, audit trail, and security requirements of the API Chapter 21.1 EFM standard. Hourly audit-trail data can be stored for 35 days and transmitted by means of a serial output for real-time information. The power requirements for the Model 3095FT are modest, about 0.1 watt on a 12-volt system. A small solar panel and a rechargeable battery can supply the needed energy, making remote installation possible.

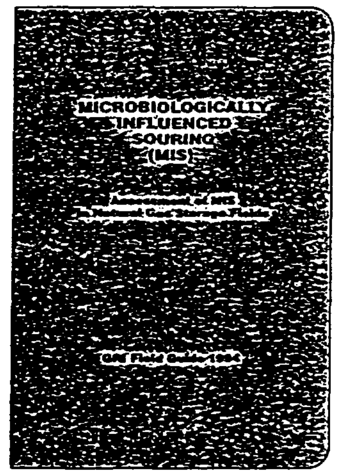
At the March 1996 Energy Telecommunications and Electrical Association Conference (ENTELEC) in Dallas, *Rosemount Inc.* introduced the Model 3095FB. This device measures the differential pressure, absolute or gauge pressure, and process temperature and communicates this information in real time to a connected Remote Terminal Unit (RTU). The RTU uses this process variable information to calculate flow, and communicates this information back to the user's host system.

Integrating the Model 3095FB into a natural gas measurement solution provides savings in several ways. Three process variables are handled through the purchase of one device, net purchase price and installation costs are lower, and fewer pipe penetrations (important for minimizing fugitive emissions) are required. In addition, if all of the process variables are available simultaneously from the transmitter, installation costs are further reduced by minimizing the amount of wiring required.

For more information on these products call 1-800-685-8254, or write: *Rosemount* Measurement Customer Central, 8200 Market Blvd., Chanhassen, MN 55317. ■

Field Guide Provides for Early Detection of Reservoir Souring

A user-friendly field guide, *Microbiologically Influenced Souring (MIS): Assessment of MIS in Natural Gas Storage Fields,* is designed to help gas industry personnel detect and differentiate MIS from nonbiological souring. The guide provides information on the key microbiological and chemical parameters necessary for the diagnosis of MIS, and contains a systematic, stepwise approach for assessing MIS in gas storage reservoirs.



Additionally, the guide contains several "souring scenarios," which include chemical and microbiological data representative of certain types of souring problems, along with a brief interpretation of each data set. The user can apply the field guide's diagnostic process to these results and derive the interpretation, prior to doing an actual field assessment.

One of the advantages of using the field guide is detection of MIS in the very early stages of development (i.e., before the gas becomes sour). This enables the user to remediate the problem more effectively.

Liz Niemtschik of *Public Service Company of Colorado* is using the guide to determine if there is MIS, or potential for its occurrence, in certain reservoirs and surface distribution systems. Rick Gomez and Tom Watts at *Northern Natural Gas*, an affiliate of *Enron Corp.*, are using the diagnostic approach to determine if one specific formation within a storage reservoir has potential for developing MIS.

The field guide can be used for assessing MIS in aquifer-storage as well as depleted-oil-and-gas-storage reservoirs. Additionally, the information contained in it has been used by technical personnel for investigating souring in produced-water systems and even potable water wells.

Copies of the field guide can be obtained from *Bioindustrial Technologies, Inc.* 40105 Industrial Park Circle, Georgetown, Texas 78626. Contact Melanie Bouffard at 512/869-0580 or FAX at 512/863-8097. ■

Improving Fracturing Results In The Clinton Sandstone

By Robert Henry Jacot—*The purpose of this column is to describe several cost-effective methods to evaluate current stimulation treatments. The methodology I describe uses a production data analysis program and 3D fracture simulator. The production data analysis program is used to evaluate the stimulation effectiveness (fracture half-length) and reservoir quality (permeability). A 3D fracture design simulator is used to calculate the fracture height, length, width, and proppant distribution within the fracture.*

Historical production data was analyzed using the program and the results suggested that effective fracture half-lengths were much less than expected. The stimulation treatment pumped on those wells was simulated with the 3D fracture model, which showed the fracturing sand settled below the pay zone because of poor proppant transport and downward growth of the hydraulic fracture.

This methodology presented is simple and applicable to other tight gas formations in Ohio and throughout the Appalachian Basin. The process does not require large data collection and thus is cost effective to apply.

Introduction

The Clinton sandstone is characterized as a fine grain sandstone with low matrix permeability averaging less than .10 millidarcies. Core data of the Clinton reveal that the primary reason for low permeability is secondary quartz overgrowths creating narrow, slot like apertures in the pore throats. Besides the secondary quartz overgrowth, permeability is reduced even further by pore bridging illite clay and compaction of narrow pore throats. Due to the tight nature the Clinton sandstone must be hydraulically fractured to improve flow rates and economic performance. The Clinton sandstone exhibits widely varying reservoir characteristics such as permeability, porosity, and extent of the sand lenses. Because of the heterogeneity, most operators have developed a "cookbook" type frac that is pumped in the wells, ac-

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cording to D.J. Mack and R.A. Mason. ("Individualizing Fracturing Treatment Design Benefits Clinton Sands" presented at the 1985 Eastern Regional Meeting in Morgantown, WV.) Many different types of stimulation treatments have been pumped in the Clinton. These different type jobs include crosslink gel, foam fracs, gelled lease crude, linear gel, and slick water. Pumping a gel pad followed by slick water is a common type treatment in Ohio. Fluid volumes range from 1500 bbl to 5000 bbl of fluid and pump rates vary between 20 and 60 bpm. Typical proppant volumes range between 30,000 and 60,000 lbs. of 20/40 Ottawa fracturing sand. Some operators choose to use no proppant.

It is generally assumed that good production rates are related to natural fractures or good permeability. Stimulation effectiveness is seldom considered a factor in good production because changes in fracture treatments seldom result in better production.

Production Data Analysis

The production data analysis program used in this study was developed in part by funding from the Gas Research Institute. The program, PROMAT™ as defined by S.A. Holdtich & Associates, Inc. (*"A Production Data History Matching and Performance Forecasting Program for Oil and Gas Wells"*) is based on a type curve first suggested by M.J. Fetkovich in *"Decline Curve Analysis Using Type Curves."* Type curves are graphic solutions to the equations describing fluid flow in a porous medium. PROMAT™ is an analytical production data analysis program that automates the history matching process. This was also explained at the 1985 Eastern Regional Meeting by J.M. Gatens, III, W.J. Lee and Z. Rahim in "Application of an Analytical Model to History Match Devonian Shales Production Data." Besides history matching, PROMAT™ was used to make production forecasts based on different fracture half-lengths.

Net Pay	25 ft.
Average Porosity	7.5%
Reservoir Pressure	1400 psi
Bottomhole Flowing Press.	500 psi
Water Saturation	30%
Permeability	.02 md
Drainage Area	40 acres

TABLE 1: Summary of reservoir properties used for production forecast

The reservoir properties listed in Table 1 were used for the simulation. The production was discounted at 10% over ten years and multiplied by a gas price of $2.25/mcf to give discounted revenue.

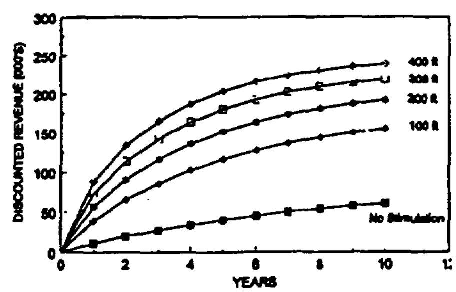

FIG. 1: Effect of fracture half-length on discounted revenue.

The results in Figure 1 show the economic implications of obtaining a 100 ft. vs 400 ft. fracture. The discounted revenue for the 100 ft. fracture is $155,318 and $239,187 for the 400 ft. fracture. This results in a 54% increase in discounted revenue.

Figure 2 illustrates the importance of permeability on well productivity. One well has a permeability of .001 millidarcies and an effective fracture half-length of 600 ft. The other well has a permeability of .10 millidarcies and an effective fracture half-length of 50 ft. Cumulative production after

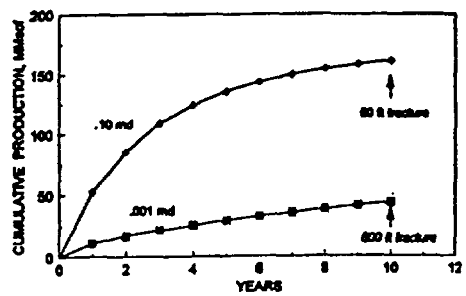

FIG. 2: Effect of permeability on cumulative production

ten years for the well with .001 md. is 43,798 mcf and 161,010 mcf for the well with .10 md. This is one possible explanation why fracturing treatments with little or no sand result in good wells.

PROMAT™ was used to historically match the production data from five wells to determine the fracture half-length and reservoir permeability. All of the wells analyzed were infinite acting; boundary effects were not evident. This can be determined by plotting production rate vs time on a log-log scale. Once the boundary of the well has been observed, the drainage size or gas-in-place can be determined.

Well	Permeability (md)	Fracture Half-Length (ft)	Permeability Thickness Product (md-ft)
1	.018	195	.390
2	.012	43	.295
3	.001	125	.042
4	.008	146	.256
5	.067	44	2.077

TABLE 2: Summary of production data analysis results for five study wells

The results listed in Table 2 indicated the fracture half-lengths were shorter than desired. Figure 3 is an example of a history match on a well. The estimated fracture half-length is 43 ft. and the permeability is .012 md. To illustrate the economic importance of pumping a more effective stimulation treatment, Figures 4 and 5 compare predicted well perfor-

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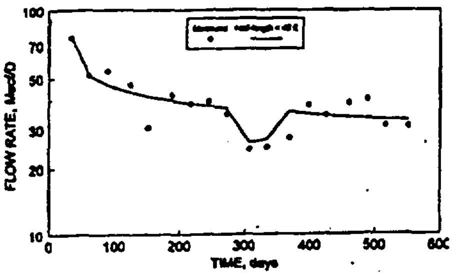


FIG. 3: History match of actual production with the production data analysis program

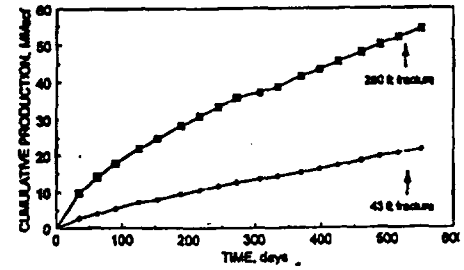


FIG. 5: Comparison of measured to predicted cumulative production for a 250 ft fracture half-length

mance to actual well performance assuming an effective fracture half-length of 250 ft. could be

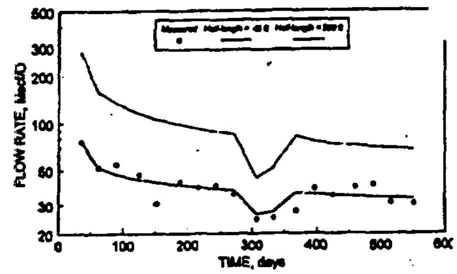


FIG. 4: Comparison of measured to predicted flow rates for a 250 ft fracture half-length

achieved. The longer fracture half-length could have more than doubled the production (22 to 54 MMscf) for the same producing time and conditions. Because the fracture half-lengths were less than desired, the treatments were modified using the fracture simulator as a design tool. Some changes included pumping the sand with a higher viscosity fluid (20 to 30 cp) and increasing the sand concentrations to 4 lb./gal. The new design was pumped on eight wells and the production data over 3 to 12 months was analyzed. Gas volumes, days on line, and flowing pressure histories were analyzed using PROMAT™.

Well	Permeability (md)	Fracture Half-Length (ft)	Permeability Thickness Product (md-ft)
8	.22	25	6.377
9	.098	27	1.666
12	.086	80	3.870
11	.07	50	1.890
7	.047	255	1.219
6	.027	108	1.080
10	.011	288	.336
13	.009	224	.126

TABLE 3: Summary of production data analysis results for eight study wells

Table 3 lists the eight wells with estimates of permeability and fracture half-length. The data from the new wells with permeabilities less than .05 millidarcies showed improved fracture half-lengths of up to 288 ft. The wells with permeability of more than .07 millidarcies had much shorter effective fracture half-lengths than expected. The modified stimulation design was reviewed with the fracture simulator for possible explanations of the short fractures. The simulator showed that sand concentrations of up to 7 lb./gal would be necessary to achieve sufficient conductivity contrast for the higher permeability wells. This points out the importance of obtaining a prefracture estimate of permeability.

3D Fracture Simulation

In 1983 the Gas Research Institute initiated a program to study the factors that control the successful application of hydraulic fracturing in tight gas sands. The program has included four Stage Field Experiments, cooperative wells and R&D wells. Some important conclusions from this work are: (1) hydraulic fractures are taller, wider and shorter than previously thought; (2) in-situ stress is an important factor controlling the height of an induced fracture; and (3) proppant transport is affected by convection rather than particle settling. Because in-situ rock stresses are important factors controlling fracture height, 3D fracture design models have become necessary to accurately determine created fracture geometry. The different layers of rock stress, Young's modulus and Poisson's ratio are put into the simulator and the fracture model calculates fracture width, height and length based on different pump rates and fluid viscosities. The mechanical properties of the different rock layers can by obtained by running mechanical property logs or the in-situ stress can be measured by a stress test of the reservoir rock and the bounding rock layers.

Depth (ft)	Stress (psi)	Frac Gradient (psi/ft)	Young's Modulus (psi)	Poisson's Ratio
5500	4200	.76	5e06	.25
5530	3000	.54	4e06	.20
5570	4000	.72	5e06	.25
5580	3200	.57	4e06	.20
5900	4100	.69	5e06	.25

TABLE 4: Summary of mechanical properties

Table 4 lists mechanical rock properties for the simulation of two different fracture treatments. The fracture simulation in Case #1 consists of a 15,000-gallon 30/lb. gel pad followed by slick water carrying 20/40 Ottawa fracturing sand at a maximum concentration of 1 1/2 lb./gal.

Rate (bpm)	Type Fluid	Fluid Volume (gals)	Sand Conc. (lb/gal)	Sand Volume (lb)
35	30# Gel	15,000	0	0
35	Slick Water	20,000	1/2	10,000
35	Slick Water	20,000	1	20,000
35	Slick Water	20,000	1-1/2	30,000
	Total	75,000		60,000

TABLE 5: Treatment schedule for case #1

Table 5 lists the pumping schedule for Case #1. The 3D fracture simulator used in these examples is MFRAC-II™ as defined by Meyer & Associates, Inc. in *"A Three Dimensional Fracture Design Simulator."* In Case #1 and Case #2 the fracture is initiated between 5500 and 5530 ft. with 30 .39" perforations.

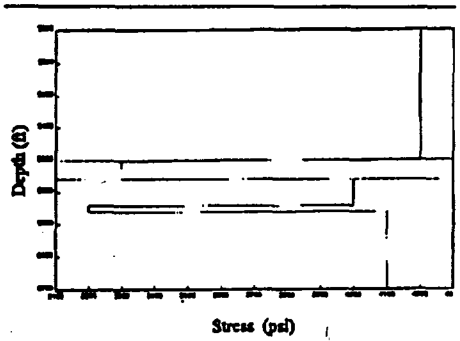


FIG. 6: Stress profile for Case #1 and Case #2

Figure 6 is a stress profile using the stress data in Table 4.

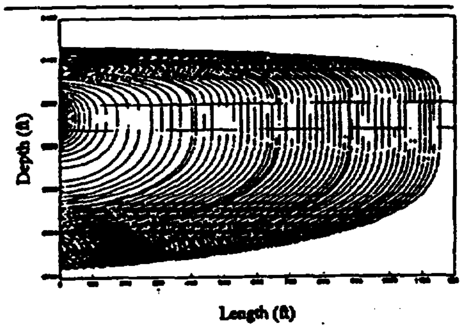


FIG. 7: Fracture profile for Case #1

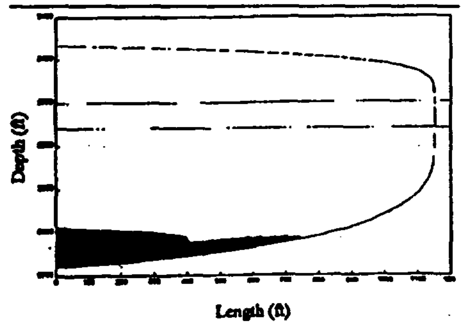


FIG. 8: Proppant profiles at closure for Case #1

Figure 7 shows the fracture grows upward and downward from the pay interval. Because of the high stress contrasts of 1100 and 1200 psi, this is possibly a best case scenario. The actual in-situ stress contrast could be much lower resulting in a larger fracture height. Figure 8 shows the proppant distribution in the fracture. All of the fracturing sand is below the pay zone. This is one possible explanation why operators that do not use fracturing sand have the same results as those who run sand.

Case #2 was simulated with the same mechanical properties as Case #1. The treatment schedule for Case #2 is listed in Table 6.

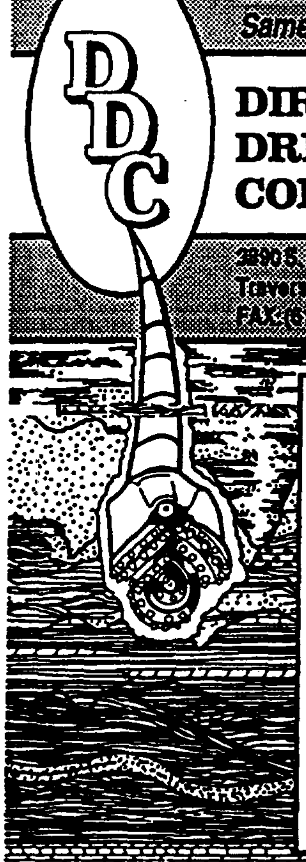
This treatment was simulated with a 6000-gallon pad of slick water followed by 30,000 gal. of 30 lb. gel carrying sand at 4 lb./gal. Total sand volume is 120,000 lbs. The fracture profile and pro The proppant is placed across the pay zone. In comparison, Case #1 has a longer fracture length but Case #2 should result in a more effective stimulation treatment because the proppant is across the pay zone.

Rate (bpm)	Type Fluid	Fluid Volume (gals)	Sand Conc. (lb/gal)	Sand Volume (lb)
35	Slick Water	6,000	0	0
35	30# Gel	30,000	4	120,000
	Total	36,000		120,000

TABLE 6: Treatment schedule for case #2

Summary

Production data analysis and 3D fracture simulation can be used together as tools to evaluate and improve current simulation treatments. This process provides the same information as more costly bottomhole pressure buildups. To eliminate any non-unique answers, a prefracture estimate of permeability should be obtained.



An Analytical Model for History Matching Naturally Fractured Reservoir Production Data

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W. John Lee, SPE, Texas A&M U.; and **Zillur Rahim,** SPE, S.A. Holditch & Assocs.

Summary. This paper presents a method for analyzing production data from naturally fractured gas reservoirs. A normalized time is used to modify analytical solutions to model gas flow in finite, dual-porosity reservoirs. Procedures for validating the dual-porosity reservoir model, determining the suitability of simpler reservoir models, and determining the best parameter estimates are illustrated with field data from naturally fractured reservoirs.

Introduction

Naturally fractured reservoirs typically are characterized as having two distinct porosity systems: a primary system associated with the reservoir matrix and a secondary system associated with the fractures. An idealized reservoir model developed by Warren and Root,[1] in which the reservoir is represented by a regular fracture system that is superimposed on the primary porosity system, has formed the basis for many investigations into the performance of naturally fractured reservoirs. This dual-porosity model is also adopted in our study.

A key exercise in reservoir engineering is forecasting the response of a producing well. Production data can be important sources of information for determining reservoir properties for use in simulations of reservoir behavior and well response. We address the estimation of reservoir properties from production data for naturally fractured reservoirs and the subsequent forecasts of well response.

Finite-difference reservoir simulators, configured as dual-porosity reservoir models,[2,3] can be used to analyze production data. Analytical solutions, however, may be obtained for certain idealized situations.[1,4-8] In such cases, analytical solutions provide a number of advantages over finite-difference simulators. Typically, they provide solutions comparable with finite-difference simulations in a fraction of the computing time. Grid breakup, which normally affects the accuracy and stability of finite-difference simulators, is not required for the analytical solutions. Consequently, data input for a reservoir simulator that uses analytical solutions can be greatly simplified compared with finite-difference simulators.

The basic assumptions currently required for availability of an analytical solution are that only a single fluid phase is flowing and that reservoir properties are spatially uniform. When such a simple model is adequate for describing reservoir behavior, the production data can be analyzed very efficiently.

In this paper, we present an analytical dual-porosity reservoir model for forecasting production. We also present methods to validate the model with production data and to estimate reservoir properties for forecasting production. The analytical reservoir production model has been used successfully with the data analysis procedures presented here to analyze more than 500 Devonian shale gas wells.[9]

Dual-Porosity Model

The dual-porosity reservoir model introduced by Warren and Root[1] and discussed by Odeh[4] has been extended by a number of authors. In developing their analytical models, Warren and Root and Odeh represented matrix flow as a pseudosteady state. Kazemi[2] used a finite-difference simulator to introduce transient flow in the matrix, and de Swann-O.[6] presented an analytical model that included transient matrix flow. Mavor and Cinco-Ley[7] presented an analytical dual-porosity model based on a constant-bottomhole-pressure (BHP) production boundary condition, and Serra *et al.*[5] and Da Prat *et al.*[8] developed solutions for bounded reservoirs.

Our reservoir production model uses the analytical model developed by Serra *et al.* The constant-BHP production boundary condition is most suitable for analyzing Devonian shale production data. We include as options the finite- and infinite-acting solutions, and either the dual-porosity or standard single-porosity reservoir model may be selected. We normally use slab matrix geometry, although any standard matrix geometry may be selected.

An important new feature in our reservoir production model is the use of a new time function to account for gas properties changing with pressure. All the previous analytical models are based on the assumption that the fluid is slightly compressible. We found that large errors can be encountered in computing production from gas wells when the change of gas properties with pressure is not considered.

Fraim and Wattenbarger[10] found that pseudopressure[11] and a new time function, which we call normalized time, can be used to account for changing gas properties in the analysis of constant-BHP production by use of type curves similar to those of Fetkovich.[12] Normalized time is defined by

$$\bar{t}_n = \sum_{j=1}^{n} \frac{(\mu_g c_t)_{p_i}}{(\mu_g c_t)_{\bar{p}_j}} \Delta t_j, \qquad (1)$$

where $(\mu_g c_t)_{p_i}$ and $(\mu_g c_t)_{\bar{p}_j}$ are the gas-viscosity/total-compressibility product evaluated at initial reservoir pressure, p_i, and average reservoir pressure at the end of the jth timestep, $\bar{p}_j$. The normalized time, $\bar{t}_n$, is always less than or equal to real time. When the reservoir is infinite-acting and when average reservoir pressure is close to the initial pressure, $\bar{t}_n$ is approximately equal to real time. The procedure described in Refs. 10 and 13 is used to implement normalized time.

The importance of accounting for changing gas fluid properties is shown in **Fig. 1.** The reservoir parameters in **Table 1** are used to simulate the production by three different methods: (1) a numerical simulator,[14] (2) the analytical reservoir production model (with normalized time), and (3) the analytical reservoir production model without normalized time. The results when the numerical simulator and analytical reservoir production model are used compare very well. The results with the analytical model without normalized time deviate significantly from the other cases, except for early times when the reservoir models are infinite-acting.

Production Data Analysis

We developed a procedure to analyze production data from a well for which we believe a dual-porosity model, or a simpler single-porosity model, is a suitable candidate for representing the measured reservoir production. The objective of the analysis is to determine whether one of the analytical models is appropriate and to determine a suitable set of reservoir parameters that can be used for subsequent forecasting. Our data analysis procedure is based on sound statistical theory for mathematical modeling. It is designed (1) to determine the suitability of the production models to charac-

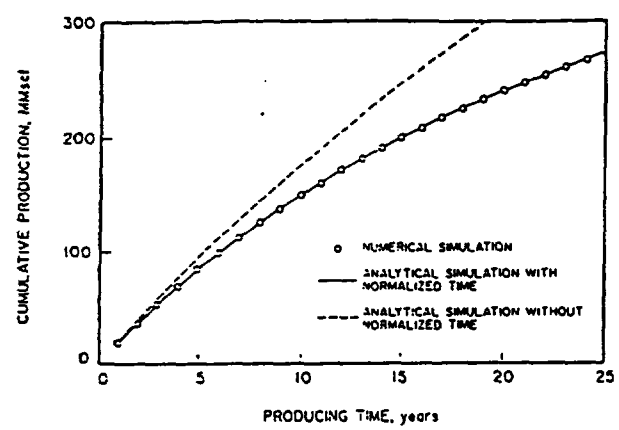

Fig. 1—Comparison of production simulations.

TABLE 1—INPUT DATA FOR SIMULATION OF FIG. 1

k, md	0.1
ϕ	0.06
r_e, ft	1,053
s	0
h, ft	100
r_w, ft	0.26
S_w	0.3
p_i, psia	600
p_{wf}, psia	70
γ_g	0.6
T_r, °F	100

TABLE 2—INPUT DATA REQUIRED FOR HISTORY-MATCHING MODEL

Unknown Parameters Estimated in History Match
Effective permeability, $\bar{k}$
Porosity, ϕ
Storage capacity ratio, ω
Interporosity flow coefficient, λ
Drainage radius, r_e
Skin, s
Parameters Specified From Independent Information
Net pay thickness, h
Wellbore radius, r_w
Initial reservoir pressure, p_i
Constant flowing BHP, p_{wf}
Reservoir temperature, T_r
Wet gas gravity, γ_g
Water saturation, S_w

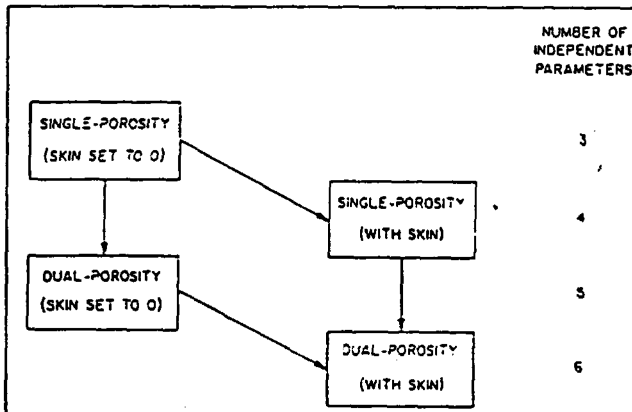

Fig. 2—Hierarchy of models for history matching.

terize a given set of production data, (2) to select the most appropriate production model, and (3) to determine the best estimates of reservoir parameters for the selected model. To select models and parameter estimates with confidence, several history matches are required for a given set of production data. The efficiency of the analytical production model is an important feature in enabling the procedure presented here to be implemented readily for analysis of long-term production data.

The methodology we developed uses a history-matching procedure based on certain statistical criteria to ensure that we obtain the best estimates of reservoir properties, a multistart method to obtain the global solution to the history-matching problem, and a model-selection procedure to ensure that the most appropriate reservoir model is selected.

History Matching. There are six independent groups of parameters in the reservoir model[15]: storage and transmissibility terms for each of the two porosity systems, skin, and drainage radius (or reservoir extent). At best, we can determine uniquely six parameters through history matching; the other parameters must be specified independently. Table 2 lists the parameters specified through independent means and the unknown parameters to be estimated through history matching. The information available for assigning values to the specified parameters is discussed elsewhere.[16]

The reservoir model parameters are obtained by minimizing the performance index,

$$J=[\vec{G}_p^o-\vec{G}_p^c(\vec{\beta})]^T\mathbf{W}[\vec{G}_p^o-\vec{G}_p^c(\vec{\beta})], \quad (2)$$

where $\vec{G}_p^o$ is the set of observed, or measured, cumulative production data and $\vec{G}_p^c$ is the set of corresponding quantities calculated from the reservoir model with the set of reservoir parameters $\vec{\beta}$. The weighting matrix is given by[17]

$$\mathbf{W}=\mathbf{A}^T\mathbf{A}, \quad (3)$$

where $\mathbf{A}=$

$$\begin{bmatrix} t_1^{-1/2} & 0 & \cdots & 0 & 0 \\ -(t_2-t_1)^{-1/2} & (t_2-t_1)^{-1/2} & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & -(t_{n_p}-t_{n_{p-1}})^{-1/2} & (t_{n_p}-t_{n_{p-1}})^{-1/2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & -(t_{n_p}-t_{n_{p-1}})^{-1/2} & (t_{n_p}-t_{n_{p-1}})^{-1/2} \end{bmatrix}. \quad (4)$$

The numerical minimization of Eq. 2 is performed with a trust-region implementation of the Marquardt-Levenberg method that includes linear inequality constraints on the unknown parameters.[18]

To ensure that we obtain the parameters corresponding to the global minimum of Eq. 2, we developed a multistart method for history matching.[19] Many sets of parameter values (on the order of 50 to 100) are generated as candidates for the initial parameter estimates required for the history-matching algorithm. The performance index (Eq. 2) is evaluated for each set. Three or four of these candidate parameter sets corresponding to the lowest values of the performance index are used as starting points for the history matches. We then evaluate whether we believe we have obtained the global minimum of Eq. 2. If the algorithm produces a common local minimum from all the starting points, we are fairly confident that this minimum is also the global minimum. If, on the other hand, the minimizations produce more than one local minimum from the different starting points, more effort may be required to determine the global minimum. If the fit corresponding to the smallest value of the performance index is fairly precise, we may be satisfied with that solution. Otherwise, we use an additional three or four initial guesses to investigate whether other minima corresponding to

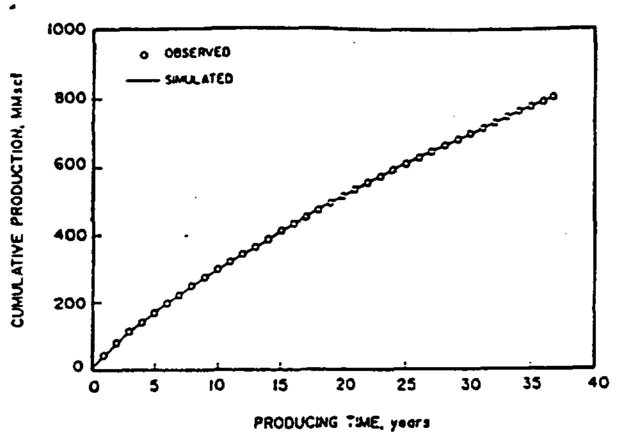

Fig. 3—Measured and calculated production for Case 1.

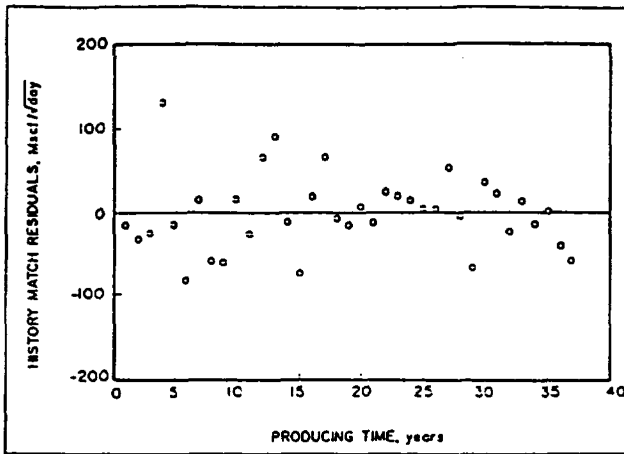

Fig. 4—History-matching residuals for Case 1.

smaller values of the performance index may be found. We normally will perform three to five history matches (i.e., minimizations of Eq. 2 from different initial values) for each candidate reservoir model in analyzing data from a single well. Each history match is relatively efficient, normally requiring less than 20 iterations, because reasonably good initial guesses usually are obtained from the multistart method.

Model Selection. Our objective is to select the model with the smallest number of independent parameters that fully describes the data and is consistent with all other knowledge we may have about the reservoir. We use a hierarchical approach to model selection.[20] The hierarchy includes the most complex reservoir model, in terms of the greatest number of independent parameters, that we intend to consider as a candidate for modeling the reservoir. Other models in the hierarchy are simpler reservoir models that may be obtained from the most complex model by specifying values for certain reservoir parameters. For the particular case discussed here, the hierarchy is quite simple, and is given in Fig. 2. If desired, infinite-acting models may be included in the hierarchy,[20] although we find they are rarely suitable for describing long-term production data.

In our model-selection procedure, we first determine whether the most complex reservoir model fully describes the data. A most desirable situation is that the lack of fit between measured and calculated data is attributable to random errors, which can be determined by residual analysis. This test is fairly stringent, however, because its use requires some assumptions regarding the manner in which errors arise from data measurement or modeling. If the residual analysis does not support the reservoir model, the reason could be that a contradiction of those assumptions about the errors exists. Finally, even if the reservoir model does not fully describe the data, it may still provide suitable predictions, although little physical significance should be attached to the reservoir parameters in such a situation. The alternative would then be a more complete and detailed reservoir study.

If the most complex reservoir model is satisfactory, then other models within the hierarchy may also be suitable. We used an F test to determine the suitability of simplified reservoir models.[20] A feature of this selection procedure is that we do not require estimates for any reservoir parameters that are not identifiable from the data.

Case Studies

The analytical reservoir production model and data analysis procedures are illustrated by history matching Devonian shale production data. Case 1 used production data from a well in Pike County, KY. Fig. 3 shows the measured production data and the cumulative production predicted using our production model. Table 3 lists the parameters obtained through history matching.

As Fig. 3 shows, a very precise match of the data was obtained. This indicates that the reservoir model accounts for all the significant features represented by the data. A further test of the model is provided by residual analysis. Basically, this involves the detection, through visual examination of a plot or statistical tests, of serial correlation of the residuals—the differences between observed and calculated data values at the conclusion of the history match.[17] On the basis of our error model for cumulative production,[17] we expect the residuals given by

$$\vec{r}=\mathrm{A}[\vec{G}_p^o-\vec{G}_p^c(\vec{b})] \quad \text{(5)}$$

to be independent random variables.

Fig. 4 plots the residuals for Case 1. A serial correlation of the residuals is not indicated by the plot—no definite pattern to the residuals is apparent. This observation is substantiated by the Durbin-Watson test,[17] which accepts, at the 95% confidence level, the hypothesis that the residuals are not correlated. This suggests that the dual-porosity reservoir model is appropriate for this set of production data and that nothing would be gained by relaxing assumptions associated with the reservoir model, such as spatial homogeneity of the properties.

We now investigate whether a simpler model is adequate for representing the data. The history match is performed with both the dual-porosity model with skin set to zero and the single-porosity model. Table 4 summarizes the use of the F test in the model-selection procedure. Evidently, skin can be identified from the data, and use of the more complete dual-porosity model, rather than the simpler single-porosity model, is justified.

Case 2 used production data from another well in Pike County. Fig. 5 shows the measured production data along with the corresponding values calculated with the single-porosity model, and Table 3 lists the corresponding parameter estimates. A fairly precise match is obtained. In this case, the dual-porosity model did not lead to a more precise match. The results from the model selection procedure, summarized in Table 4, indicate that only a single-porosity

TABLE 3—PARAMETER ESTIMATES FOR EXAMPLES

Case	Model	J (Mscf²/D)	R^2	k (md)	ϕ	ω	λ	s	r_e (ft)
1	Dual porosity	7.52×10^4	0.981	4.67×10^{-2}	0.119	3.83×10^{-4}	2.63×10^{-6}	−5.29	1,240
2	Single porosity	5.86×10^4	0.990	3.02×10^{-2}	0.229	—	—	−3.74	377
3A	Single porosity	2.80×10^2	0.970	8.72×10^{-3}	0.224	—	—	−2.15	185
3B	Single porosity	2.05×10^3	0.944	8.23×10^{-3}	0.246	—	—	−2.26	181

TABLE 4—APPLICATION OF F TEST

Case	Full Model	Reduced Model	F	$F_{0.9}(u,n-n_p)$	Conclusion
1	Dual porosity	Single porosity	26	2.5	Two porosity systems are identified
1	Dual porosity	Dual porosity/zero skin	15	2.9	Skin is nonzero
2	Dual porosity	Single porosity	0	2.5	Two porosity systems not identified
2	Single porosity	Single porosity/zero skin	13	2.9	Skin is nonzero

system is identified. It does not, however, necessarily follow that the reservoir does not have two porosity systems. The ability to detect two porosity systems, when they exist, depends on a number of factors, including the ranges of time over which the data are available and the frequency and accuracy with which the data are measured. For example, it is known that for certain ranges of time (namely very early or very late times), production from a dual-porosity reservoir model can be represented by a single-porosity model.[2,15] The discrete, noisy nature of measured data tends to hinder the identification of a second porosity system. Of course, it may be desirable to use the more complex model should there be independent information that confirms the presence of a dual-porosity system. Nevertheless, the example clearly illustrates that long-term production data can be reconciled with a relatively simple reservoir model.

We next illustrate the use of our reservoir production model for forecasting production. For Cases 3A and 3B, we used production data from a well located in Mingo County, WV. In Case 3A, we history matched production data for the first 20 years. The single-porosity model, with parameter estimates listed in Table 3, was selected. We then used those parameters to forecast production for the next 15 years. Fig. 6 shows the forecast and the actual production. Fig. 6 illustrates that after 5 or 6 years, the production model forecast begins to underestimate production somewhat. Nevertheless, the predictions are quite accurate, being within 5 to 10% even after about 15 years.

To illustrate the predictive capability of the reservoir production model further, we analyze only the first 10 years of history in Case 3B. A single-porosity model was again selected by our model-selection procedure; Table 3 lists the parameter estimates. Using those parameters, we then forecast production for the next 25 years. Fig. 7 shows the results. As expected, the forecast for production in the interval between 20 and 35 years is not as accurate as the previous case that used 20 years of production data in the history match. Nevertheless, the predictions are remarkably good and are quite accurate for the first 10 years after the history-matching period. These examples illustrate that excellent forecasts can be obtained when these simple production models are used with our method of production data analysis.

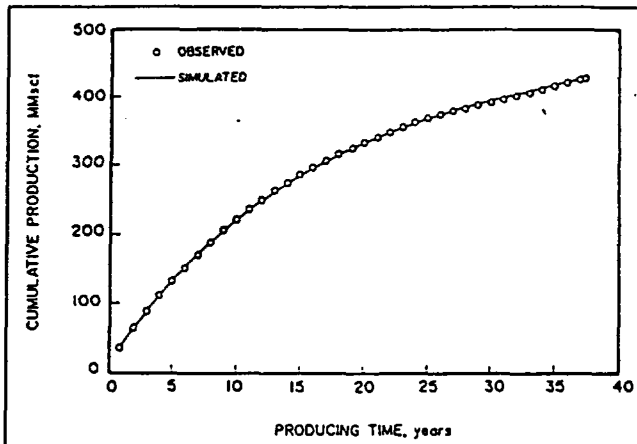

Fig. 5—Measured and calculated production for Case 2.

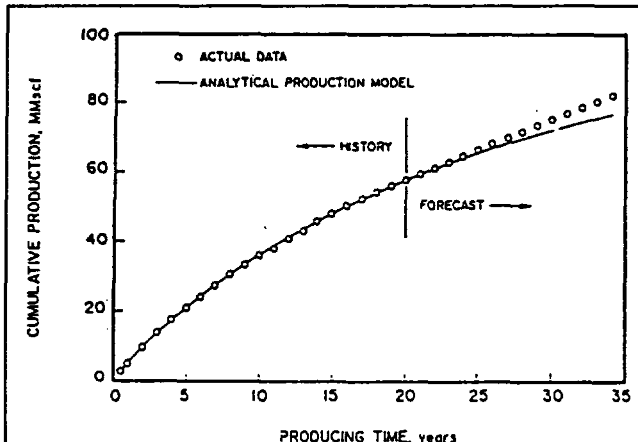

Fig. 6—History match and forecast for Case 3A.

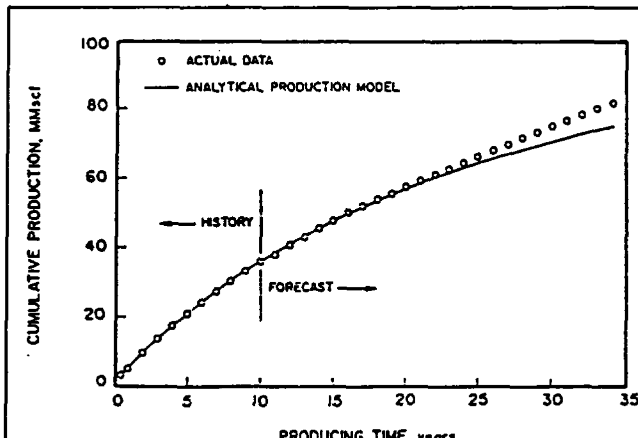

Fig. 7—History match and forecast for Case 3B.

Conclusions

1. Analytical reservoir production models for history matching and forecasting production were presented. Both single- and dual-porosity reservoir models can be used.
2. The methodology for analyzing production data is presented. The method includes procedures for validating the reservoir models, choosing the most appropriate reservoir model, and obtaining the best estimates of reservoir parameters in the selected model.
3. Long-term production data can be suitably analyzed with the analytical production models and data analysis method presented.
4. A normalized time is used in the reservoir production model to account for gas properties changing with pressure.

Nomenclature

$\underline{A}$ = transformation matrix
$\overline{b}$ = estimates for reservoir parameters
c_t = total compressibility, psi^{-1} [kPa^{-1}]
F = F-test statistic calculated from data
$F_{1-\alpha}$ = tabulated F value at $(1-\alpha)100\%$ confidence level
$\overline{G}_p^c$ = calculated cumulative gas production, Mscf [std m^3]
$\overline{G}_p^o$ = measured cumulative gas production, Mscf [std m^3]
h = net pay thickness, ft [m]
J = performance index, Mscf/D [std m^3/d]

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k = permeability, md
n = number of time intervals
n_p = number of production data
$\bar{p}$ = average reservoir pressure, psia [kPa]
p_i = initial reservoir pressure, psia [kPa]
p_{wf} = flowing BHP, psia [kPa]
$\bar{r}$ = history matching residuals, Mscf^2/D$^{1/2}$ [(std m^3)^2/d$^{1/2}$]
r_e = drainage radius, ft [m]
r_w = wellbore radius, ft [m]
R^2 = correlation coefficient
s = skin factor, dimensionless
S_w = water saturation, fraction
t = time, days
$\bar{t}_n$ = normalized time, days
T_r = reservoir temperature, °F [°C]
W = weighting matrix
$\bar{\beta}$ = reservoir parameter
γ_g = wet gas gravity, dimensionless
λ = interporosity flow coefficient based on bulk properties, dimensionless
μ_g = gas viscosity, cp [Pa·s]
ϕ = porosity, fraction
ω = fracture storativity based on bulk properties, dimensionless

Superscript
T = transpose operator

Acknowledgments

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SI Metric Conversion Factors

ft	× 3.048*	E−01	=	m
ft^3	× 2.831 685	E−02	=	m^3
°F	(°F−32)/1.8		=	°C
md	× 9.869 233	E−04	=	μm^2
psi	× 6.894 757	E+00	=	kPa

*Conversion factor is exact.

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Production Data Analysis for Wells That Have Been Subject to Periodic Curtailment

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ABSTRACT

Gas wells are often subject to periodic or cyclic curtailment. Currently available methods are poorly suited for analyzing production data from these wells. Using methods presented in this paper, an equivalent continuous flowing pressure can be calculated from pressures measured at the end of the flow and shutin periods during each cycle. This equivalent continuous flowing pressure is then used for production data analysis in conjunction with the average flow rate. This method is applicable for boundary dominated flow, transient radial flow, and transient linear flow of slightly compressible liquids in a homogeneous formation. The method may be applied to gas well production data through the use of pseudopressure or normalized pressure.

INTRODUCTION

Production data analysis is often used for reserves estimation and performance prediction, and for estimating reservoir characteristics such as permeability, drainage area, and degree of stimulation. Current methods of analyzing production data assume either constant flowing bottomhole pressure or production at constant rate. Simultaneously varying bottomhole pressure and rate may be taken into account by using either special plotting functions or superposition. Use of either special plotting functions or superposition requires detailed historical flowing bottomhole pressures and rates.

Gas wells are often subject to cyclic production for a variety of reasons. Often, monthly production is limited by market demand. Under these circumstances, a well may be open to flow until its allocated production is achieved, then shut in for the remainder of the month. In other cases, wells are open to flow only part of each year because of seasonal market demand. Still other gas wells cannot flow continuously because of liquid loadup. These wells may be produced until they load up, then shut in to allow the reservoir pressure to build up high enough near the well to allow the accumulated wellbore liquids to be lifted.

Current production analysis methods cannot readily account for the cyclic nature of production from these wells. In this paper, we present a method for obtaining an equivalent continuous flowing bottomhole pressure from measurements of the flowing pressure at the end of the flow period and the shutin pressure at the end of the shutin period. This continuous flowing bottomhole pressure is then combined with the average flow rate over the entire production cycle for use in existing production data analysis methods.

In the next section, we briefly review the production data analysis literature. We also present a qualitative motivation for the new method, define terminology, and discuss the results of our investigation. The following section presents an example of the use of the new averaging method. The final section presents the conclusions reached in this study.

DISCUSSION

Review of Literature

In 1973, Fetkovich[1] presented dimensionless rate-time type curves combining transient, radial flow solutions to the diffusivity equation with Arps' empirical decline curve equations[2]. The Fetkovich type curves assume constant pressure production. Early time data were

References at end of paper.

characterized by a dimensionless drainage radius stem r_D, and the late time data were characterized by Arps' b exponent.

Carter[3] then presented similar type curves for gas reservoirs, with the dimensionless drawdown as a correlating parameter. Carter's type curves also assume production at constant bottomhole pressure.

Carter's type curves differ from Fetkovich's because of the non-linearity of the real gas flow equation. Another approach to this problem was provided by the introduction of the real gas pseudopressure[4], p_p:

$$p_p \equiv 2\int_0^p \frac{pdp}{\mu(p)z(p)} \quad \text{.......... (1)}$$

Other authors have defined a normalized pressure[5]:

$$p_n \equiv \frac{\mu_i z_i}{p_i}\int_0^p \frac{pdp}{\mu(p)z(p)} \quad \text{.......... (2)}$$

The normalized pressure has the advantage that it may be used directly in equations developed for slightly compressible liquids.

Fraim and Wattenbarger[6] showed that the Fetkovich type curves could be used for gas reservoirs by using pseudopressure and normalized time, defined in terms of the average drainage area pressure, $\bar{p}$:

$$t_n \equiv \mu_i c_{ti}\int_0^t \frac{dt}{\mu(\bar{p})c_t(\bar{p})}, \quad \text{.......... (3)}$$

For volumetric gas reservoirs, the graph of production rate versus normalized time follows the $b=0$ late time stem of the Fetkovich type curve.

Blasingame and Lee[7] developed a constant rate analog time plotting function to allow variable rate production to be analyzed using methods developed for constant rate production, provided that "changes in flow rate do not dominate the influence of the outer boundary." Blasingame, McCray, and Lee[8] then developed a constant pressure analog time function to allow variable pressure production data to be analyzed using constant pressure methods. The recommended procedure for calculating the constant pressure analog time function requires the constant rate analog time function to be calculated first.

Spivey, Gatens, Semmelbeck, and Lee[9] then presented a new family of cumulative production type curves to supplement the Fetkovich type curves. They presented plotting functions to allow the new type curves to be used for gas or oil, constant or variable flowing bottomhole pressure. Their variable pressure plotting functions were based on Blasingame's constant pressure analog time.

Blasingame's constant rate analog time[7] and constant pressure analog time[8] functions appear to be the best methods currently available for analyzing variable rate, variable bottomhole pressure production using constant rate or constant pressure solutions. However, these plotting functions work best with either smoothly varying rates and pressures, or with data with a small number of discrete changes in rate or pressure. They do not appear to be as useful for analysis of periodically curtailed production data.

Monthly production data from wells which have been subject to periodic curtailment often appear as if the well were producing continuously against a higher backpressure during the time curtailment was in effect. This observation suggests the possibility of calculating an equivalent continuous flowing pressure from pressure measurements easily obtained during the curtailment cycle.

Qualitative arguments

Figs. 1 and 2 show the normalized pressure profile at two different times for a gas reservoir which has been subject to periodic curtailment for two years. Profiles are shown for the end of the flow period and for the end of the shutin period. In Fig. 1, the curtailment cycle consisted of equal length, fifteen day flow and shutin periods; in Fig. 2, the cycle consisted of a five day flow period followed by a twenty-five day shutin period. For both of these figures, the well was operated at constant flowing wellbore pressure during the flow period. In both cases, the pressure transients caused by rate variations during the curtailment cycle do not extend beyond a certain point in the reservoir. Beyond this point, the reservoir responds as if the well were producing at a constant, average rate. The lines labeled "average" in Figs. 1 and 2 suggest that it should be possible to extrapolate the pressure gradient beyond the transient drainage radius back to the wellbore to give an equivalent continuous flowing wellbore pressure.

Definition of terms

The weight factors will be derived from the diffusivity equation for slightly compressible liquids in which pressure is the dependent variable. The extension to analysis of gas wells is made by substituting normalized pressure for pressure in the appropriate equations.

The duration of one cycle, consisting of a flow period followed by a shutin period, is denoted by the symbol T. The well is assumed to produce at constant rate q during the flow period. The length of the flow period is a fraction x of the total cycle length, T. This results in an average flow rate xq over the cycle. The number of cycles that have elapsed at any point in time is denoted by N.

With these definitions, weight factors are developed in the Appendix for three conditions: 1) boundary-dominated flow; 2) transient radial flow; and 3) transient linear flow.

Weight factors for boundary dominated flow

The simplest case occurs when both the flow and shutin periods are longer than the time required to reach pseudosteady state flow in the reservoir. In this case, the pseudosteady state flow equation may be applied, and the equivalent continuous flowing wellbore pressure may be obtained from the following equation:

$$p_{wefc} = w_{wf}\, p_{wf} + w_{ws}\, p_{ws}\text{, where}$$

$$w_{wf} = x\text{, and } w_{ws} = (1-x)\text{.} \quad \text{.............................. (4)}$$

This equation is simply a time-weighted average of the shutin and flowing wellbore pressures. Note that the derivation of Eq. 4 does not depend on the reservoir shape or on the production history of the well prior to the current curtailment cycle.

Although Eq. 4 was developed for boundary dominated flow, it provides a good approximation for transient radial and linear flow, as will be seen in the next section.

Weight factors for transient radial flow

The well is assumed to be periodically curtailed, with identical curtailment cycles. During the flow period of each cycle, the well produces at constant rate q. The well is assumed to be in the center of an infinite, circular reservoir. For gas wells, it is also assumed that the real gas flow equation is adequately linearized by the use of normalized pressure and real time.

With these assumptions, the following equation is developed in the Appendix:

$$\Delta p_{wecf} = w_{wf}\Delta p_{wf} + w_{ws}\Delta p_{ws}\text{, where}$$

$$w_{wf} = x\text{, } w_{ws} = x\frac{a_N(1-x)}{a_N(x)}\text{, and}$$

$$a_N(x) \equiv \sum_{j=1}^{N}\ln\left(\frac{j}{j-x}\right)\text{.} \quad \text{.................................... (5)}$$

The flowing pressure weight factor is x, the fraction of the cycle during which the well is open to flow, as in the case of boundary-dominated flow. The shutin pressure weight factor, however, is a function of both x and N, as shown in Fig. 3.

Note that the sum of these weight factors is 1.0 only for the case of equal length flow periods. This makes it necessary to apply the weight factors to Δp_{wf} and Δp_{ws}, rather than to p_{wf} and p_{ws} directly.

For the special case of equal length flow and shutin periods, the shutin pressure weight factor reduces to 0.5, independent of N.

Weight factors for transient linear flow

For an infinite linear system, the equation corresponding to Eq. 5 is

$$\Delta p_{wecf} = w_{wf}\Delta p_{wf} + w_{ws}\Delta p_{ws}\text{, where}$$

$$w_{wf} = x\text{, } w_{ws} = x\frac{b_N(1-x)}{b_N(x)}\text{, and}$$

$$b_N(x) \equiv \sum_{j=1}^{N}\left\{j^{1/2} - (j-x)^{1/2}\right\}\text{.} \quad \text{............................ (6)}$$

The weight factor for the flowing pressure is again found to be x, while the shutin pressure weight factor is a function of x and N, as shown in Fig. 4. As with the transient radial flow weight factors, the transient linear weight factors must be applied to Δp_{wf} and Δp_{ws}, rather than to p_{wf} and p_{ws} directly. Again, the shutin pressure weight factor reduces to 0.5, independent of N, for the special case of equal length flow and shutin periods.

Time-weighted average

In order to choose the appropriate weight factors to use for any given well, the appropriate flow regime (boundary-dominated, transient radial, or transient linear) must be identified. This requires a knowledge of the formation permeability, the drainage area of the well, and the degree of stimulation, any or all of which we hope to determine from production data analysis. Thus, we are forced to assume a particular flow regime in order to begin the analysis. Since the weight factors for boundary dominated flow correspond to a simple time-weighted average, and since the transient radial and linear weight factors reduce to a time-weighted average for equal length flow and shutin periods, the time-weighted average is a logical starting point for analysis when the flow regime is not known.

To determine the error involved in using a time-weighted average for transient radial and linear flow, we calculated both the exact pressure and the time-weighted average pressure. The error, e, involved in using a time-weighted average was defined as

$$e \equiv \frac{\Delta p_{wavg} - \Delta p_{wefc}}{\Delta p_{wefc}}\text{, where}$$

$$p_{wavg} = x p_{wf} + (1-x)p_{ws}\text{,} \quad \text{................................ (7)}$$

and where Δp_{wecf} is calculated using the appropriate weight functions for transient radial or linear flow.

Figs. 5 through 8 show the results of these calculations.

Figs. 5 and 6 show the error incurred in using a time-weighted average pressure for transient radial flow. Fig. 5 shows the error following twelve flow/shutin cycles, as a function of the duration of the flow period relative to the production cycle. For radial flow the error also depends on the dimensionless cycle length, defined as

$$T_D = \frac{0.0002637kT}{\phi\mu c_t r_w^2} . \quad (8)$$

Fig. 6 shows the error for a dimensionless cycle length of 1.0×10^5 as a function of the number of elapsed cycles, for various length flow periods. Note that the error is not a strong function of number of elapsed cycles.

It is unlikely that an economically viable, unstimulated well would have a dimensionless cycle length lower than 1.0×10^5 or 1.0×10^6 for a 30 day flow/shutin cycle. Thus, the error incurred in using the time-weighted average pressure should be no more than 5 to 10% whenever the well is open to flow at least 10% of the total flow/shutin cycle.

Figs. 7 and 8 show the error in using a time-weighted average pressure for transient linear flow. Fig. 7 shows the error as a function of flow period length. For the transient linear flow case, the error is independent of the dimensionless cycle length. As with the transient radial flow case, the error is greatest for short flow periods, and decreases as the duration of the flow period increases relative to the production cycle. Fig 8 shows the error for transient linear flow as a function of the number of elapsed cycles. For linear flow, the error is a fairly strong function of cycle number during the first dozen cycles.

For transient linear flow, the error incurred in using the time-weighted average pressure is less than 10% whenever the well is open to flow at least 25% of the total flow/shutin cycle.

Analysis of synthetic production data

We generated six sets of production data with a commercial finite-difference simulator to test the proposed method. Formation and fluid properties for the six cases are given in Table 1; operating conditions and the results of the analysis for each case are listed in Table 2. The formation permeability for Cases 1, 2, 5, and 6 was 5 md; the permeability for Cases 3 and 4 was 0.1 md. Figs. 9 and 10 show the type curve match obtained for Case 2; Fig. 11 shows a comparison of the time-weighted average pressure for Case 5 with the pressure from a simulator run where the well was produced at a constant average rate during each curtailment cycle.

In Case 1, equal length flow and shutin periods, analysis using the time weighted average pressure gave excellent results for both drainage area and pressure. For Case 2, unequal length flow and shutin periods, analysis using the time weighted average pressure gave the best estimate of the drainage area, while analysis using the transient radial flow weight factors gave the best estimate of formation permeability. Analysis of Cases 3 and 4 using either time-weighted averaging or transient linear weight factors underestimates the drainage area. In Case 5, we made two simulation runs. First, we produced the well at constant pressure for two years, then curtailed the well with a 5/25 day cycle. Next, we used the average rate for each month during curtailment as the constant flow rate for that month and produced the well at that constant average rate. The resulting pressure is compared with the calculated average pressure in Fig. 11. In Case 6, during the first curtailment cycle, the well was produced for 7 days, then shut in for 23 days. Each subsequent cycle had one additional day of production, so that after 24 cycles the well was producing continuously. Here the estimated area is roughly 7% too low, while the permeability is about 14% too high. While not as good agreement as was obtained with some of the other cases, this is still acceptable accuracy for many applications.

EXAMPLE

To illustrate the application of the new method, we present the analysis for Case 2 in some detail. The well was operated for 2 years with a production cycle consisting of a 5 day flow period at a constant production rate of 5500 Mscf/D, followed by a 25 day shutin period. This well is in a formation of moderate permeability, and has not been fractured. Thus, we present the calculation using weight factors for both boundary dominated flow and for transient radial flow.

For this example x is 5/30, or 0.16667. Table 3 shows the details of the calculations for the first twelve cycles. The cycle number, the elapsed time at the end of each cycle, the cumulative gas production, and the flowing and shutin wellbore pressures are first tabulated in columns 1 through 5. The normalized flowing and shutin pressures are then calculated and tabulated in columns 6 and 7, using Eq. 2.

The normalized equivalent continuous flowing wellbore pressure for boundary dominated flow is calculated using Eq. 4, and the result is given in column 8. The corresponding real pressure is given in column 9. The analysis then proceeds as if the well were continuously flowing, using columns 2 and 3 to obtain flow rate, and treating column 9 as a smoothly declining pressure.

The equivalent continuous flowing wellbore pressure assuming transient radial flow is calculated in columns 10 through 14. Columns 10 and 11 show the logarithm summation terms and column 12 shows the weight function for the shutin pressure from Eq. 5. The normalized equivalent continuous flowing wellbore pressure is then calculated from

$$p_{nefcl} = p_{ni} - \left[x\left(p_{ni} - p_{nwf}\right) + w_{ws}\left(p_{ni} - p_{nws}\right)\right] \ldots (9)$$

and is tabulated in column 13. Finally, the corresponding real pressure is given in column 14.

The resulting pressure vs. time and rate vs. time were then analyzed with Blasingame's constant pressure analog time[8] function and Spivey's cumulative production type curves[9]. The type curve analysis is shown in Figs. 9 and 10.

CONCLUSIONS

1. We have developed a method for use in analyzing production data from wells which have been subject to periodic curtailment. The method requires the flowing pressure at the end of the production period and the shutin pressure at the end of the shutin period, the number of days on-line, and the total gas volume produced during the production cycle. The method uses weight factors to compute an equivalent continuous flowing pressure for use with the average monthly production rate.
2. We have developed exact weight factors for boundary dominated flow from a reservoir of arbitrary shape, and for transient flow from both unfractured wells and fractured wells. The exact weight factors for boundary dominated flow correspond to time-weighted averaging. An engineer can use a time-weighted average pressure with less than 10% error for transient radial flow, provided the dimensionless cycle time is 1.0×10^5 or greater, and that the flow period is at least one-tenth of the total cycle length. The time-weighted average pressure can be used with less than 10% error for transient linear flow, provided the flow period is at least one-fourth of the total cycle length. For both transient radial and linear flow, the exact weight factors reduce to the time-weighted average weight factors when flow and shutin periods are of equal length.
3. If field conditions meet all the assumptions used in developing the exact weight factors for transient radial or linear flow, the exact weights should be used. If the assumptions are not met, the time-weighted average pressure may be used as a reasonable engineering approximation.

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NOMENCLATURE

- a_N - sum of N logarithm terms
- A - drainage area, acres
- b - Arps' hyperbolic decline curve exponent
- b_N - sum of N square root terms
- B - formation volume factor, RB/STB or RB/Mscf
- C - radial flow rate constant
- C_A - drainage area shape factor
- C_l - linear flow rate constant
- D - radial flow time constant
- D_l - linear flow time constant
- h - net pay thickness, feet
- i,j - summation indices
- k - permeability, md
- N - number of curtailment cycles
- p - pressure, psia
- $\overline{p}$ - average reservoir pressure, psia
- p_p - pseudopressure, psia²/cp
- q - flow rate during the flow period, STB/D or Mscf/D
- r_w - wellbore radius, feet
- s - skin factor
- t - time, hours
- T - duration of a curtailment cycle consisting of a flow period followed by a shutin period, hours
- w - weight factor
- x - ratio of the duration of the flow period to that of the curtailment cycle.
- μ - viscosity, cp

Subscripts

- avg - average value
- b - boundary-dominated flow
- D - dimensionless variable

l - linear flow

n - normalized variable

r - radial flow

wecf - equivalent continuous flow

wf - end of flow period

ws - end of shutin period.

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APPENDIX

Consider a well which is subject to periodic curtailment. We assume that the curtailment cycles are of equal length T, and that the well produces at a constant rate q during the flow portion of each cycle. We further assume that the well is opened to production at the beginning of each cycle, and is allowed to produce for the same fraction x of each cycle.

With these definitions, we may calculate the average flow rate during a cycle:

$$q_{avg} = qx + 0(1-x) = qx. \quad \text{(A-1)}$$

In the following sections, we derive weight factors for boundary dominated flow, transient radial flow, and transient linear flow.

Weight factors for boundary dominated flow

When the flow and shutin periods are each longer than the time required to reach pseudosteady state flow, the appropriate weight factors are obtained simply as follows. The pressure at the end of the flow period is given by

$$p_{wf} = \bar{p} - \frac{141.2qB\mu}{kh}\left[\frac{1}{2}\ln\left(\frac{10.06A}{C_A r_w^2}\right) - \frac{3}{4} + s\right] \quad \text{(A-2)}$$

The wellbore pressure at the end of the shutin period is equal to the average reservoir pressure at the end of the period:

$$p_{ws} = \bar{p} \quad \text{(A-3)}$$

Since there is no fluid withdrawn during the shutin period, the average reservoir pressure at the end of the shutin period is the same as that at the end of the flow period.

The wellbore pressure for continuous flow at the average flow rate xq during the cycle is given by

$$p_{wecf} = \bar{p} - \frac{141.2xqB\mu}{kh}\left[\frac{1}{2}\ln\left(\frac{10.06A}{C_A r_w^2}\right) - \frac{3}{4} + s\right]. \quad \text{(A-4)}$$

Taking the time weighted average of the flow and shutin pressures, we have

$$\begin{aligned}(1-x)p_{ws} + xp_{wf} &= (1-x)\bar{p} + x\bar{p} - \frac{141.2xqB\mu}{kh}\left[\frac{1}{2}\ln\left(\frac{10.06A}{C_A r_w^2}\right) - \frac{3}{4} + s\right] \\ &= \bar{p} - \frac{141.2xqB\mu}{kh}\left[\frac{1}{2}\ln\left(\frac{10.06A}{C_A r_w^2}\right) - \frac{3}{4} + s\right] \\ &= p_{wecf} \quad \text{(A-5)}\end{aligned}$$

Thus, the desired weight factors for boundary dominated flow are

$$w_{wf} = x \text{ and}$$

$$w_{ws} = (1-x) \quad \text{(A-6)}$$

Weight factors for transient radial flow

For the Nth cycle, the time, t_{wfN}, at the end of the flow period is given by

$$t_{wfN} = (N-1+x)T, \quad \text{(A-7)}$$

and the time, t_{wsN}, at the end of the shutin period is given by

$$t_{wsN} = NT. \quad \text{(A-8)}$$

At the end of the Nth cycle, the pressure is given as the superposition of terms for all preceding flow and shutin periods. The contribution to the pressure drop at the end of the Nth cycle, due to turning the well on at the beginning of the ith cycle, is given by

$$\Delta p_{ws1} = Cq\ln\left(D\{N-(i-1)\}T\right), \quad \text{(A-9)}$$

where C and D are defined as

$$C \equiv \frac{70.6B\mu}{kh} \text{ and } D \equiv \frac{k}{1{,}688\phi\mu c_t r_{wa}^2}. \quad \text{(A-10)}$$

Similarly, the contribution to the pressure drop at the end of the Nth cycle, due to shutting in the well at the end of the flow period during the ith cycle, is given by

$$\Delta p_{ws2} = -Cq\ln\left(D\{N-(i-1+x)\}T\right). \quad \text{(A-11)}$$

Thus, the total pressure drop at the end of the Nth cycle is seen to be

$$\begin{aligned}\Delta p_{ws} &= Cq\left[\sum_{i=1}^{N}\ln\left(D\{N-(i-1)\}T\right) - \sum_{i=1}^{N}\ln\left(D\{N-(i-1+x)\}T\right)\right] \\ &= Cq\left[\sum_{i=1}^{N}\ln\left(\frac{\{N-(i-1)\}}{\{N-(i-1+x)\}}\right)\right] \\ &= Cq\sum_{j=1}^{N}\ln\left(\frac{j}{j-x}\right) \\ &= Cqa_N(x), \quad \text{(A-12)}\end{aligned}$$

where

$$a_N(x) \equiv \sum_{j=1}^{N}\ln\left(\frac{j}{j-x}\right). \quad \text{(A-13)}$$

At the end of the flow period during the Nth cycle, the pressure drop due to turning the well on production at the beginning of the ith cycle is given by

$$\begin{aligned}\Delta p_{wf1} &= Cq\ln\left(D\{(N-1+x)-(i-1)\}T\right) \\ &= Cq\ln\left(D\{(N+x)-i\}T\right). \quad \text{(A-14)}\end{aligned}$$

Similarly, the pressure drop due to shutting in the well during the ith cycle is given by

$$\begin{aligned}\Delta p_{wf2} &= -Cq\ln\left(D\{(N-1+x)-(i-1+x)\}T\right) \\ &= -Cq\ln\left(D\{N-i\}T\right). \quad \text{(A-15)}\end{aligned}$$

Thus, the total pressure drop at the end of the flow period during the Nth cycle is

$$\begin{aligned}\Delta p_{wf} &= Cq\left[\sum_{i=1}^{N}\ln\left(D\{(N+x)-i\}T\right) - \sum_{i=1}^{N-1}\ln\left(D\{N-i\}T\right)\right] \\ &= Cq\left[\sum_{i=1}^{N}\ln\left(D\{(N+x)-i\}T\right) - \sum_{i=1}^{N}\ln\left(D\{N-i+1\}T\right) + \ln(DNT)\right] \\ &= Cq\left[\ln(DNT) + \sum_{i=1}^{N}\ln\left(\frac{\{(N+x)-i\}}{\{N-i+1\}}\right)\right] \\ &= Cq\left\{\ln(DNT) + \sum_{j=1}^{N}\ln\left(\frac{j-(1-x)}{j}\right)\right\} \\ &= Cq\left\{\ln(DNT) - a_N(1-x)\right\}. \quad \text{(A-16)}\end{aligned}$$

The pressure drop after N cycles due to a constant average flow rate xq is given by

$$\Delta p_{wcf} = Cxq\ln(DNT). \quad \text{(A-17)}$$

Forming a linear combination of the pressures at the end of the flow and shutin periods,

$$\begin{aligned}x\Delta p_{wf} + x\frac{a_N(1-x)}{a_N(x)}\Delta p_{ws} &= Cxq\left\{\ln(DNT) - a_N(1-x)\right\} + x\frac{a_N(1-x)}{a_N(x)}Cqa_N(x) \\ &= Cxq\ln(DNT) \\ &= \Delta p_{wcf}. \quad \text{(A-18)}\end{aligned}$$

Thus, the appropriate weighting factors for determining the equivalent continuous flowing pressure at the end of the Nth curtailment cycle for transient radial flow are

$w_{wf} = x$, and

$$w_{ws} = x\frac{a_N(1-x)}{a_N(x)}. \quad \text{(A-19)}$$

Weight factors for transient linear flow

The derivation of the weight factors for transient linear flow follows very closely that for the transient radial flow weight factors.

At the end of the Nth cycle, the pressure is given as the superposition of terms for all preceding flow and shutin periods. The contribution to the pressure drop at the end of the Nth cycle, due to turning the well on at the beginning of the ith cycle, is given by

$$\Delta p_{ws1} = C_l q\left(D_l\{N-(i-1)\}T\right)^{1/2}, \quad \text{(A-20)}$$

where C_l and D_l are defined for formation linear flow into an infinite conductivity vertical fracture of half length L_f as

$$C_l \equiv \frac{4.064B}{hL_f} \text{ and } D_l \equiv \frac{\mu}{k\phi c_t}. \quad \text{(A-21)}$$

Similarly, the contribution to the pressure drop at the end of the Nth cycle, due to shutting in the well at the end of the flow period during the ith cycle, is given by

$$\Delta p_{ws2} = -C_l q\left(D_l\{N-(i-1+x)\}T\right)^{1/2}. \quad \text{(A-22)}$$

Thus, the total pressure drop at the end of the Nth cycle is seen to be

$$\begin{aligned}\Delta p_{ws} &= C_l q\left[\sum_{i=1}^{N}\left(D_l\{N-(i-1)\}T\right)^{1/2} - \sum_{i=1}^{N}\left(D_l\{N-(i-1+x)\}T\right)^{1/2}\right] \\ &= C_l q(D_l T)^{1/2} b_N(x), \quad \text{(A-23)}\end{aligned}$$

where

$$b_N(x) \equiv \sum_{j=1}^{N}\left\{j^{1/2}-(j-x)^{1/2}\right\}. \quad \text{(A-24)}$$

At the end of the flow period during the Nth cycle, the pressure drop due to turning the well on production at the beginning of the ith cycle is given by

$$\Delta p_{wf1} = C_l q\left(D_l\{(N+x)-i\}T\right)^{1/2}. \quad \text{(A-25)}$$

Similarly, the pressure drop due to shutting in the well during the ith cycle is given by

$$\Delta p_{wf2} = -C_l q\left(D_l\{N-i\}T\right)^{1/2}. \quad \text{(A-26)}$$

Thus, the total pressure drop at the end of the flow period during the Nth cycle is

$$\begin{aligned}\Delta p_{wf} &= C_l q\left[\sum_{i=1}^{N}\left(D_l\{(N+x)-i\}T\right)^{1/2} - \sum_{i=1}^{N-1}\left(D_l\{N-i\}T\right)^{1/2}\right] \\ &= C_l q(D_l T)^{1/2} \times \left\{N^{1/2} + \sum_{j=1}^{N}\left[\{j-(1-x)\}^{1/2} - j^{1/2}\right]\right\} \\ &= C_l q(D_l T)^{1/2}\left\{N^{1/2} - b_N(1-x)\right\}. \quad \text{(A-27)}\end{aligned}$$

The pressure drop after N cycles due to a constant average flow rate xq is given by

$$\Delta \bar{p}_{wf} = C_l xq(D_l NT)^{1/2}. \quad \text{(A-28)}$$

Forming a linear combination of the pressures at the end of the flow and shutin periods,

$$\begin{aligned}x\Delta p_{wf} + x\frac{b_N(1-x)}{b_N(x)}\Delta p_{ws} &= C_l xq(D_l T)^{1/2}\left\{N^{1/2} - b_N(1-x)\right\} + x\frac{b_N(1-x)}{b_N(x)}C_l q(D_l T)^{1/2} b_N(x) \\ &= C_l xq(D_l NT)^{1/2} \\ &= \Delta p_{wecf}. \quad \text{(A-29)}\end{aligned}$$

Thus, the appropriate weighting factors for determining the equivalent continuous flowing pressure at the end of the Nth curtailment cycle for transient linear flow are

$w_{wf} = x$, and

$$w_{ws} = x\frac{b_N(1-x)}{b_N(x)} \quad \text{(A-30)}$$

Table 1 - Fluid and Formation Properties	
Net pay	50 feet
Initial pressure	2400 psia
Gas porosity	0.052
Formation temperature	178 deg F.
Wellbore radius	0.23 feet
Gas gravity	0.615 (air=1.0)

Table 2 - List of Cases

Case	Description	Analysis Method	A (acres)	k (md)
1	Constant rate production at 3 MMscf/D for 15 days followed by 15 day shutin.	Actual input	592.34	5
		Time-weighted average	598.8	5.172
2	Constant rate production at 5.5 MMscf/D for 5 days followed by 25 day shutin.	Actual input	592.34	5
		Time-weighted average	597.4	5.492
		Transient radial flow average	479.5	5.011
3	L_f=500 ft. Constant pressure production at 500 psia for 15 days followed by 15 day shutin.	Actual input	450	0.1
		Time weighted average	416.6	0.1079
4	L_f=500 ft. Constant pressure production at 500 psia for 5 days followed by 25 day shutin.	Actual input	450	0.1
		Time-weighted average	407.8	0.116
		Transient linear flow average	406.2	0.1156
5	Constant pressure production at 500 psia for two years, then curtailed for two years, with 5 days production at 500 psia followed by 25 day shutin.	Actual input	592.34	5
6	Constant pressure production at 500 psia. The first cycle has 7 days production, 23 days shutin. Each succeeding cycle has one additional day of production and one fewer day shutin.	Actual input	592.34	5
		Time-weighted average	552.8	5.733

Table 3 - Example Calculation, Case 2

(1) N	(2) t (days)	(3) G_p (MMscf)	(4) p_{wf} (psi)	(5) p_{ws} (psia)	(6) p_{nwf} (psi)	(7) p_{nws} (psi)	(8) p_{nefcb} (psi)	(9) p_{efcb} (psia)	(10) $a_N(x)$	(11) $a_N(1-x)$	(12) w_{ws}	(13) p_{nefcr} (psi)	(14) p_{efcr} (psia)
1	30	27.5	1825	2392	803	1324	1237	2304	0.1823	1.7918	1.6379	1231	2298
2	60	55.0	1816	2386	796	1317	1230	2298	0.2693	2.3308	1.4423	1222	2289
3	90	82.5	1808	2379	789	1311	1224	2291	0.3265	2.6562	1.3559	1213	2279
4	120	110.0	1801	2373	783	1304	1217	2284	0.3691	2.8898	1.3051	1205	2271
5	150	137.5	1793	2366	777	1298	1211	2277	0.4030	3.0721	1.2707	1196	2262
6	180	165.0	1785	2359	770	1291	1204	2271	0.4311	3.2216	1.2454	1188	2254
7	210	192.5	1777	2353	764	1285	1198	2264	0.4552	3.3484	1.2259	1180	2245
8	240	220.0	1769	2347	758	1279	1192	2258	0.4763	3.4584	1.2102	1172	2237
9	270	247.5	1762	2339	751	1272	1185	2250	0.4950	3.5556	1.1972	1163	2228
10	300	275.0	1754	2333	745	1265	1178	2244	0.5118	3.6426	1.1863	1155	2219
11	330	302.5	1746	2327	739	1259	1172	2237	0.5270	3.7214	1.1768	1147	2211
12	360	330.0	1738	2320	733	1253	1166	2231	0.5410	3.7933	1.1686	1140	2203

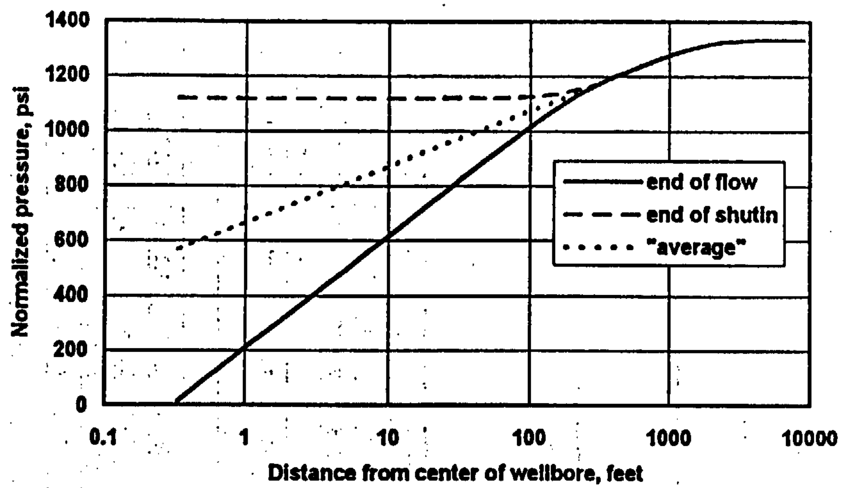

Fig. 1 - Normalized pressure profile after two years production, 15 day flow period followed by 15 day shutin period.

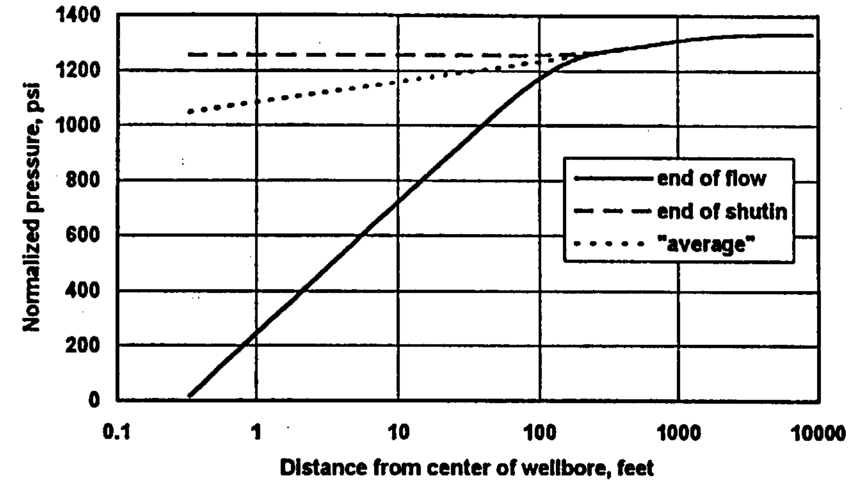

Fig. 2 - Normalized pressure profile after two years production, 5 day flow period followed by 25 day shutin period.

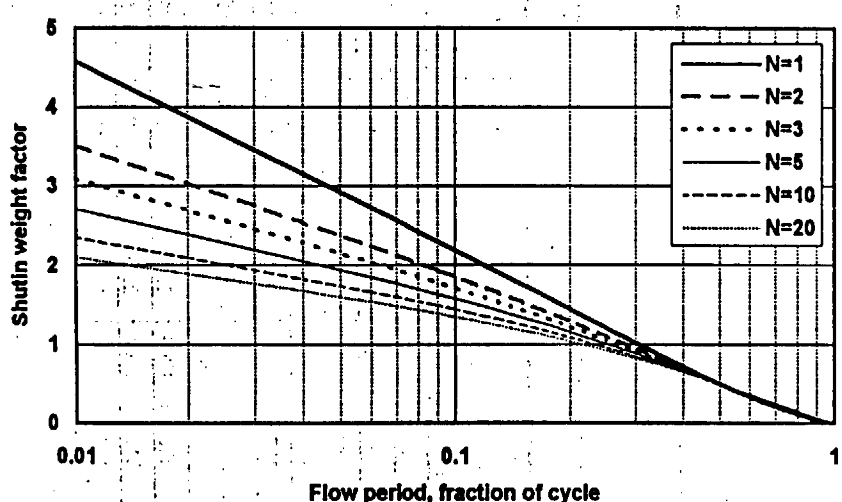

Fig. 3 - Shutin pressure weight factors for transient radial flow.

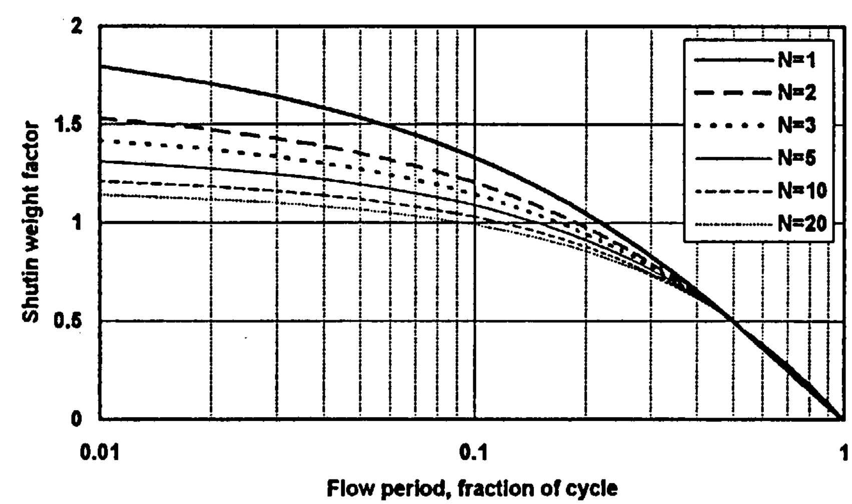

Fig. 4 - Shutin pressure weight factors for transient linear flow.

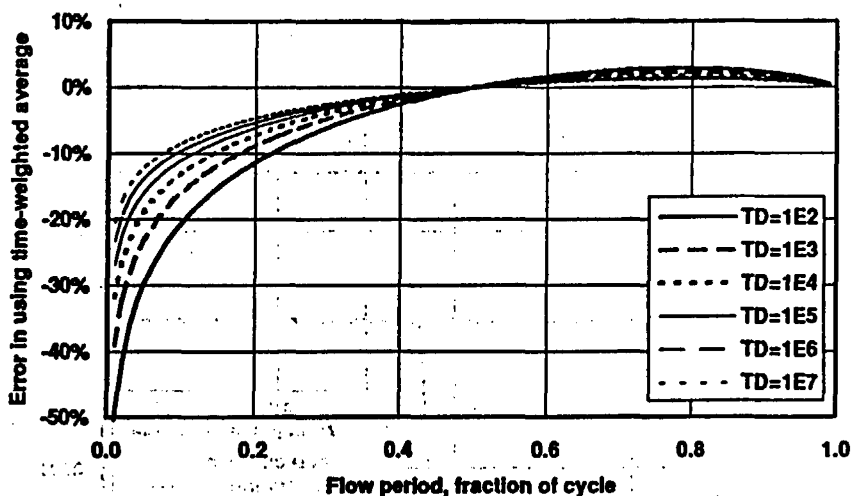

Fig. 5 - Error in pressure calculated using time-weighted average, radial flow, at end of twelve production/shutin cycles.

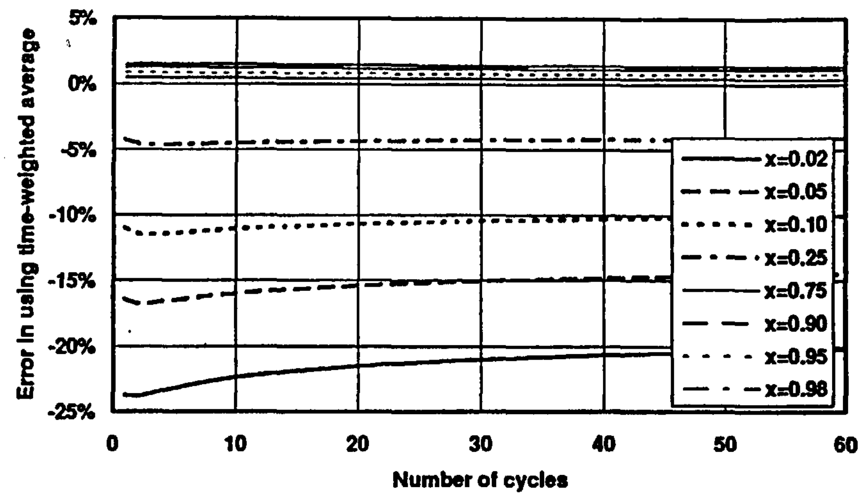

Fig. 6 - Error in pressure calculated using time-weighted average, radial flow, dimensionless cycle length $=1.0\times10^5$.

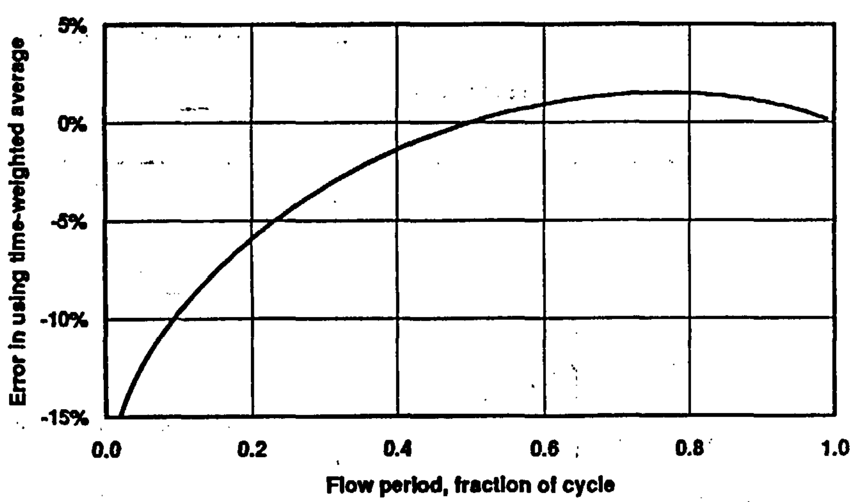

Fig. 7 - Error in pressure calculated using time-weighted average, linear flow, at end of twelve production/shutin cycles.

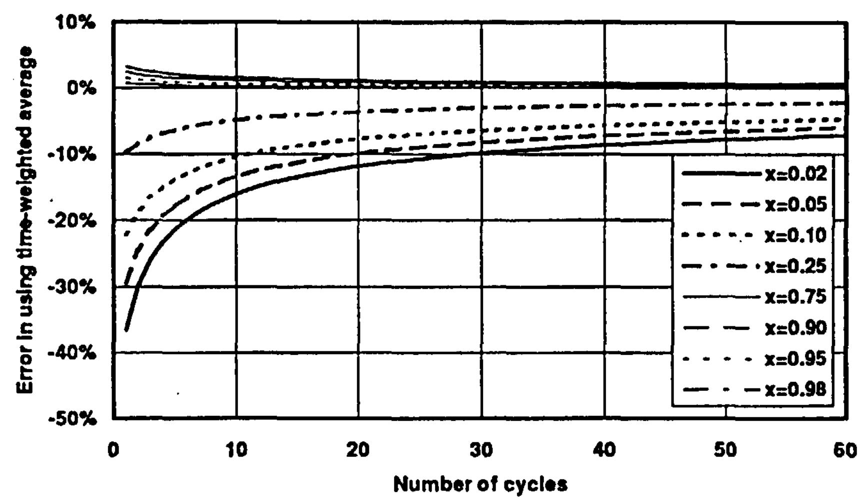

Fig. 8 - Error in pressure calculated using time-weighted average, linear flow.

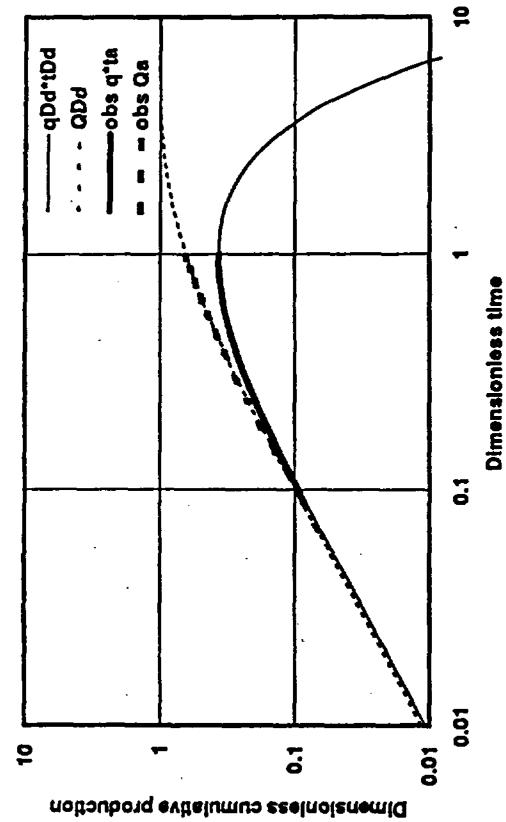

Fig. 10 - Cumulative production match, Case 2.

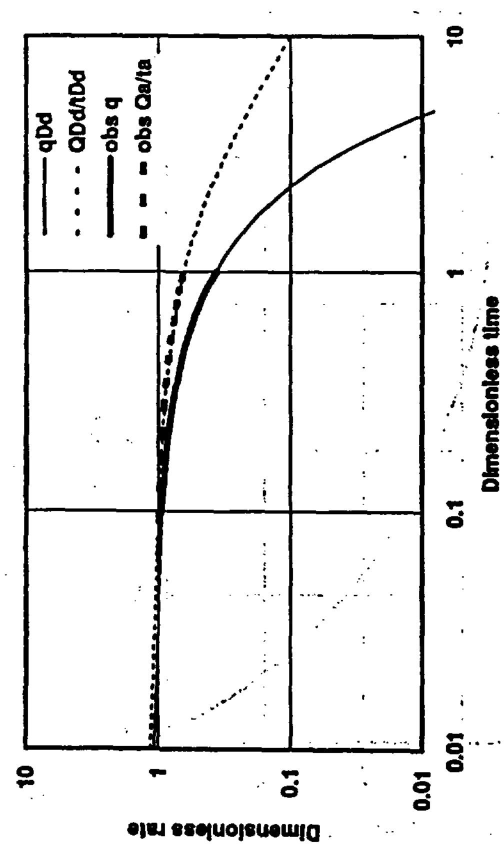

Fig. 9 - Production rate match, Case 2.

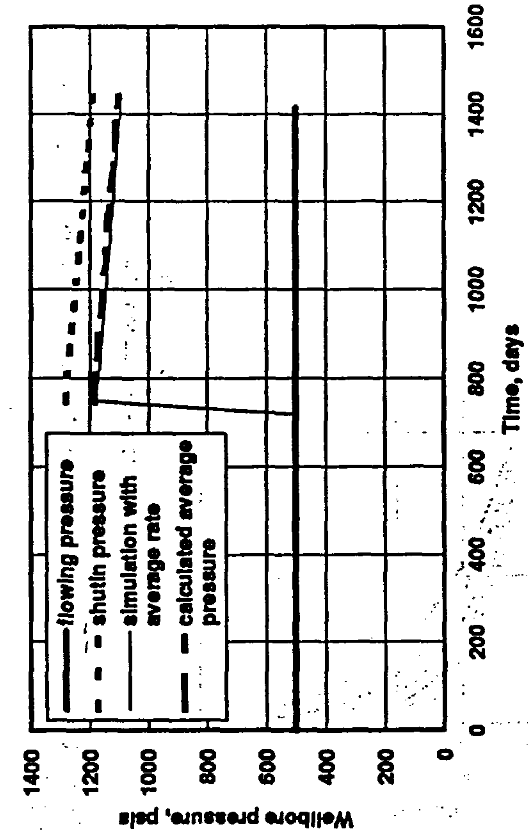

Fig. 11 - Comparison of pressure from simulator with time-weighted average pressure, Case 5.

SPE 29167

History Matching Production Data Using Analytical Solutions for Linearly Varying Bottomhole Pressure

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ABSTRACT

Performance of gas wells is often modeled using analytical solutions which are based on the assumption of constant pressure production at the wellbore. A variable pressure history can be modeled by using superposition of these constant pressure solutions. Unfortunately, each pressure change results in a spike in the resulting production rate. In practice, wells are often operated such that pressure declines slowly and smoothly until line pressure is reached. Thus, superposition of constant pressure solutions does not accurately model production in real wells. In this paper we present a procedure for calculating production rate and cumulative production using superposition of solutions for bottomhole pressure which varies linearly with time. These solutions for linearly varying bottomhole pressure may be easily obtained from the constant pressure solution for the same reservoir geometry. Rates calculated using superposition of linear pressure solutions model actual production data more faithfully than do those calculated using superposition of constant pressure solutions.

INTRODUCTION

Wells are often operated in a manner such that pressure declines slowly and smoothly until line pressure is reached. This may be done for a variety of reasons. First, there may be an early period of curtailment due to deliverability being higher than sales contract commitments. Second, controlled flowback is often used to prevent proppant crushing and embedment in hydraulically fractured wells[1]. Finally, cleanup of mud filtrate or hydraulic fracture fluids may result in increasing production rate and decreasing effective back pressure during the first few days of production of a well.

References at end of paper.

Figs. 1, 2, and 3 show pressure and production histories for three different wells that exhibit characteristic behavior. The production histories show several similarities as well as some interesting differences. For all three wells, the pressure decreased initially, then leveled off at a fairly constant rate. The period in which the pressure was decreasing ranged from approximately one month for Well B to as much as six months for Wells A and C. There are several disadvantages to using constant pressure solutions to model rates and pressure histories like these. These disadvantages can be reduced or eliminated through the use of the linear pressure solutions presented in this paper.

In this paper, we present a general method for obtaining the solution to the diffusivity equation for a linearly varying wellbore pressure from the constant pressure solution for the same reservoir geometry. We also present the necessary equations for modeling an arbitrary, piecewise linear pressure history using superposition of these linear pressure solutions.

In the next section, we review the literature on solutions to the diffusivity equation for boundary conditions other than constant rate or constant pressure. In the following section, we discuss the problems that arise when using superposition of constant pressure solutions and illustrate the benefits to be gained by using the new linear pressure solution. In the remaining sections, we present the linear pressure solution in terms of the constant pressure solution in both the time domain and the Laplace domain. We also show how to apply the linear pressure solution to gas reservoirs. We then validate the linear pressure solution by comparison with the constant pressure solution. We conclude the paper with a field example illustrating the advantages of the linear pressure solution.

LITERATURE REVIEW

In 1949, Van Everdingen and Hurst presented the basic equations for superposing constant pressure solutions in order to predict well performance.[2] In 1980, Filippi presented solutions for varying rate histories including linearly varying rate, exponentially varying rate, and hyperbolic varying rate.[3] Streltsova presented in 1988 a wide range of solutions for varying rate histories including linear, quadratic, and higher order polynomial rate histories, exponentially declining rate, and periodically varying histories such as sinusoidal and square wave pressure histories.[4] In 1993, Raghavan presented a convolution integral to calculate the production rate that would result from a variable bottomhole pressure history.[5]

Blasingame and Lee defined a constant rate analog time to allow the engineer to analyze reservoir limits with variable rate histories, using methods which have been developed under the assumption of constant rate production.[6,7] Blasingame, McCray, and Lee then presented a method for calculating an equivalent constant pressure analog time for allowing production data taken under varying pressure conditions to be analyzed using methods that were developed for constant pressure production.[8]

DISCUSSION

A major disadvantage of constant pressure solutions is that each pressure change results in an infinite rate "spike". These spikes are present no matter how closely spaced the pressure steps are. For the linear pressure solution, on the other hand, the production rate is a continuous function of time, with only a discontinuity in the slope of the calculated rate.

Second, it may take a large number of pressure changes to provide a reasonable model of the early pressure history for a well where the pressure is declining slowly and smoothly. If the pressure history of the well can be easily approximated by a piecewise linear pressure history, we will be able to reduce the number of superposition terms needed to model the performance.

Finally, early production data is very important in determining the degree of wellbore damage or stimulation from the analysis of production data. If only late time data is available then it may not be possible to distinguish between permeability effects in the formation and the near wellbore condition. Unfortunately, this is the time during which the pressure is most likely to be changing. So, we hope to be able to more accurately model early pressure behavior with linear pressure solutions, and thus obtain better estimates of the degree of wellbore damage or stimulation and formation permeability.

For a well producing at constant rate in an infinite reservoir, the wellbore pressure should decline as a logarithmic function of time. Fig. 4 shows such a pressure history modeled using both superposition of constant pressure solutions and superposition of linear pressure solutions. The same number of superposition terms is used for each case. The scalloped appearance of the linear pressure history arises because we are superposing pressure responses which are linear with time to model a pressure response which is linear in the logarithm of time.

Fig. 5 shows the rate history that we would compute corresponding to the two pressure histories given on the previous figure. Here we see that even though we have used a fairly short pressure interval for the constant pressure solution, the rate spikes at each pressure change. On the other hand, the linear pressure history gives a rate which is continuous. Both the constant pressure and the linear pressure solutions give very similar results for the cumulative production curve, shown in Fig. 6.

DEVELOPMENT OF LINEAR PRESSURE SOLUTIONS

In Appendix A we show that the dimensionless production rate for linear bottomhole pressure production is related to that for the constant bottomhole pressure solution by

$$q_{DLinear}(t_D) = \int_0^{t_D} q_D(\tau)d\tau \quad \text{.......(1)}$$

where $q_{DLinear}$ is defined as

$$q_{DLinear} \equiv \frac{C_q C_t q_{linear}(t)}{dp_{wf}/dt} \quad \text{.......(2)}$$

In field units, C_t and C_q are

$$C_q \equiv \frac{141.2\mu B}{kh} \quad \text{.......(3)}$$

$$C_t \equiv \frac{0.00633k}{\phi\mu c_t r_w^2} \quad \text{.......(4)}$$

The cumulative production solution for linear bottomhole pressure is then obtained by integrating the production rate solution:

$$Q_{DLinear}(t_D) = \int_0^{t_D} q_{DLinear}(\tau)d\tau \quad \text{.......(5)}$$

where $Q_{DLinear}$ is defined as

$$Q_{DLinear} \equiv \frac{C_q C_t^2 Q_{Linear}(t)}{dp_{wf}/dt} \quad \text{.......(6)}$$

These relationships are even simpler expressed in the Laplace domain. The Laplace domain solution for linearly varying pressure is

$$\tilde{q}_{Dlinear}(u)=\frac{\tilde{q}_D(u)}{u},\qquad(7)$$

while the Laplace transform of the cumulative production for linear pressure is

$$\tilde{Q}_{Dlinear}(u)=\frac{\tilde{q}_{Dlinear}(u)}{u}.\qquad(8)$$

As noted in Appendix A, the above results are completely general. No assumption has been made about the reservoir geometry or outer boundary condition. Thus, these results should apply to vertical wells and to wells with finite conductivity hydraulic fractures, to transient or pseudosteady-state dual porosity systems as well as to single porosity systems, and to reservoirs which are either infinite acting or finite acting.

For the examples given in this paper, we used Eqs. 7 and 8 along with the Stehfest inversion algorithm[9] to compute the linear pressure solution. Evaluation of the linear pressure solution in the Laplace domain requires only one more division than does the constant pressure solution. This represents a negligible increase in computer time compared to that required to evaluate the constant pressure solution. Thus, reducing the number of superposition terms will result in a comparable reduction in computer time, at least for slightly compressible liquids.

Figs. 7 and 8 show the dimensionless rate and the dimensionless cumulative production, respectively, for a finite, radial, single porosity system produced at constant bottomhole pressure. Figs. 9 and 10 show the dimensionless rate and the dimensionless cumulative production for the same system produced at a bottomhole pressure which decreases linearly with time. Fig. 7 shows the typical rate response for any finite system produced at constant pressure - at late times, the production rate declines exponentially with time. In Fig. 8, the cumulative production approaches a constant value, as the average reservoir pressure approaches the constant flowing bottomhole pressure.

The dimensionless production rate for a linear bottomhole pressure, shown in Fig. 9, has the same shape as the dimensionless cumulative production for a constant bottomhole pressure shown in Fig. 8. However, the physical explanation of the behavior is different. Here, as the reservoir approaches pseudosteady-state, the production rate approaches a constant value. At pseudosteady-state conditions, the pressure at every point in the reservoir declines at the same rate as the imposed wellbore pressure. The cumulative production for a linear bottomhole pressure system, shown in Fig. 10, approaches a unit-slope line on log-log coordinates at late times.

In Appendix B we compare the superposition equation for constant pressure solutions with that for linear pressure solutions.

Although we have presented this development in terms of analysis of production data, the new linear pressure solution is also applicable to transient water influx calculations for material balance.

Application to Gas Reservoirs

Both linear pressure and constant pressure solutions are based on the assumption of flow of a slightly compressible liquid. We are also interested in analyzing production data from single phase gas wells so we need to be able to take into account the variation of gas properties with pressure. To do this, we extend the method developed by Fraim and Wattenbarger[10] for constant pressure production to the linear pressure solutions. In this method, we use adjusted pressure as the dependent variable:

$$p_a\equiv\frac{(\mu z)_i}{p_i}\int_0^p\frac{p\,dp}{\mu z}\qquad(9)$$

As the independent variable, we use an adjusted time where the fluid properties are calculated at an average drainage area pressure:

$$t_a\equiv(\mu c_t)_i\int_0^t\frac{dt}{\mu(\bar{p})c_t(\bar{p})}\qquad(10)$$

Unfortunately, the use of adjusted time based on average drainage area pressure requires the use of an iterative method to solve for adjusted time, production rate, and cumulative production. Appendix C outlines one method of performing this iteration.

For gas systems, the dimensionless production rate must be defined in terms of the new independent and dependent variables:

$$q_{Dlinear}\equiv\frac{C_q C_t q_{linear}(t)}{dp_{awf}/dt_a}\qquad(11)$$

C_t and C_q must also be written in terms of fluid properties evaluated at the initial reservoir pressure:

$$C_q\equiv\frac{141.2\mu_i B_i}{kh}\qquad(12)$$

$$C_t\equiv\frac{0.00633k}{\phi\mu_i c_{ti} r_w^2}\qquad(13)$$

Because the dimensionless solution is written in terms of the slope of adjusted pressure with respect to adjusted time, Because the dimensionless solution is written in terms of the slope of adjusted pressure with respect to adjusted time, we now have to iterate on the adjusted times corresponding to the known pressure points, as described in Appendix C.

This need to iterate tends to offset the time savings expected from the need for fewer superposition terms. A net savings in computer time will be achieved for three cases: (1) undersaturated oil reservoirs; (2) infinite-acting gas reservoirs; and (3) gas reservoirs where most of the production history occurs under constant bottomhole pressure conditions. In Cases (1) and (2), iteration on adjusted time is not required. In Case (3), the derivative dp_{wf}/dt_a will be zero for each constant pressure interval, independent of the estimate of t_a, again eliminating the need to iterate.

For a gas system, the dimensionless cumulative production is no longer proportional to the true cumulative production. Instead, the dimensionless cumulative production is a constant multiple of the integral of production rate with respect to adjusted time, which we call the adjusted cumulative production:[11]

$$Q_a \equiv \int_0^{t_a} q\,dt_a = \int_0^t \frac{\mu_i c_{ti}}{\mu(\bar{p})c_t(\bar{p})} q\,dt \quad \text{.....(14)}$$

With this definition of adjusted cumulative production, the dimensionless cumulative production becomes:

$$Q_{DLinear} \equiv \frac{C_q C_t^2 Q_a(t)}{dp_{awf}/dt_a} \quad \text{.....(15)}$$

VALIDATION OF LINEAR PRESSURE SOLUTIONS

In order to validate the linear pressure solutions, we compared production calculated using a two-term superposition of linear pressure solutions with production calculated using a single term constant pressure solution. The long term behavior should be the same whether the pressure at the wellbore drops from initial pressure to its final value instantly, as the constant pressure solution assumes, or if it falls from initial pressure to constant value over some finite period of time that is short in comparison to the duration of the forecast.

Using the linear pressure solutions, we used superposition to model wells where we allowed the pressure to decline linearly from initial pressure to its final value over 0.1 day, then held pressure constant for the rest of a 10,000 day forecast. We compared the resulting forecast with one obtained using a constant pressure solution for the same reservoir description. We did this for a number of different cases including radial flow with or without skin factor, hydraulically fractured wells with finite conductivity fractures, single porosity systems, transient and pseudosteady-state dual porosity systems and finite- and infinite-acting systems. Figs. 11 through 14 show several of the cases we considered.

Radial flow

Fig. 11 shows a comparison between the results for the constant pressure solution and the linear pressure solution for a infinite radial system. The calculated rates agree very closely, even after only 1 day. Fig. 12 shows the comparison for a radial unsteady state dual porosity system. Again, the two solution methods give almost indistinguishable results.

Hydraulically fractured wells

Fig. 13 shows the two solutions for a finite single porosity system with a finite conductivity vertical fracture. Again, the comparison is very good over the entire forecast. The final example is for a hydraulically fractured well in a finite, pseudosteady-state dual porosity system, shown in Fig. 14. As with the preceding cases, the linear pressure solution agrees very closely with that for the constant pressure solution.

FIELD EXAMPLE

We analyzed Well A using both constant pressure and linear pressure solutions. Fig. 15 shows the results of matching production data from Well A using a three step, constant pressure superposition. Here, we get a good agreement during the latter part of the data but the agreement between the observed rate and the rate predicted by the constant pressure solution during the first six months is very poor. In Fig. 16, we have increased the number of superposition terms in the constant pressure solution to seven. Even with the additional terms we still did not get a good match with the production data during the earliest times. In Fig. 17, we have used a two point superposition with linear pressure solutions. In this case we get a good match of virtually all of the data even though we have used fewer superposition terms than with either of the constant pressure cases.

CONCLUSIONS

We draw the following conclusions from this study.

1. For a given reservoir geometry, the solution for linear bottomhole pressure is easily obtained from the constant pressure solution for the same reservoir geometry.

2. Linear pressure solutions may be superimposed to model varying pressure histories.

3. Linear pressure solutions may be applied to gas reservoirs through the use of adjusted pressure and adjusted time.

4. In many cases, rates calculated from superposition of linear pressure solutions match field data better than those computed using constant pressure solutions.

5. Use of the linear pressure solution allows the use of significantly fewer superpositions terms than would be needed by the constant pressure solution.

6. Under certain conditions, the linear pressure solution will save computer time compared to the constant pressure solution.

NOMENCLATURE

Latin symbols

B = formation volume factor, RB/STB for oil; RB/Mscf for gas

c_t = compressibility, psi^{-1}

C_q = $\frac{141.2\mu B}{kh}$, for oil

= $\frac{141.2\mu_i B_i}{kh}$, for gas

C_t = $\frac{0.00633k}{\phi\mu c_t r_w^2}$, for oil

= $\frac{0.00633k}{\phi\mu_i c_a r_w^2}$, for gas

h = net pay thickness, ft

k = in-situ permeability, md

p_i = initial pressure, psi

p_{wf} = flowing wellbore pressure, psi

p_a = adjusted pressure, psi

p' = rate of change of wellbore pressure, psi/D

q = production rate, STB/D for oil, Mscf/D for gas

q_D = dimensionless production rate

$\tilde{q}_D$ = Laplace transform of the dimensionless rate

Q = cumulative production, STB for oil, Mscf for gas

Q_a = adjusted cumulative production, Mscf

Q_D = dimensionless cumulative production

$\tilde{Q}_D$ = Laplace transform of dimensionless cumulative production

r_w = wellbore radius, ft

t = time, days

t_a = adjusted time, days

t_D = dimensionless time

u = Laplace domain independent variable

z = real gas deviation factor, dimensionless

Greek symbols

ϕ = porosity, fraction

μ = viscosity, cp

τ = time integration variable, days

Subscripts

a = adjusted variable

D = dimensionless

i = evaluated at initial conditions

linear = for linearly varying bottomhole pressure

var = for varying bottomhole pressure

wf = evaluated at flowing wellbore conditions

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Appendix A - Development of solutions for linearly varying pressure from solutions for constant pressure

Consider a general continuous pressure history $p_{Dvar}(t)$. If this pressure history is approximated by a piecewise constant pressure history,

$$p_{Dvar}(t_D) \cong p_j \equiv p_{Dvar}(t_j), \quad t_j < t_D \le t_{j+1}, \quad \text{(A-1)}$$

where the t_j's are evenly spaced,

$$t_j \equiv \frac{j}{N} t_{D\alpha}, \quad \text{(A-2)}$$

then we have

$$\begin{aligned} q_{Dvar}(t_D) &\cong \sum_{j=0}^{N-1} (p_j - p_{j-1}) q_D(t_D - t_{j-1}) \\ &= \sum_{j=0}^{N-1} \frac{(p_j - p_{j-1})}{(t_j - t_{j-1})} q_D(t_D - t_{j-1})(t_j - t_{j-1}) \end{aligned} \quad \text{(A-3)}$$

If we now take the limit as the number of subdivisions increases without bound, we have

$$q_{Dvar}(t_D) = \int p'_{Dvar}(\tau) q_D(t_D - \tau) d\tau \quad \text{(A-4)}$$

For a linearly varying pressure we may take $p'_{Dvar} = p'_{Dlinear} = 1$ and we have

$$\begin{aligned} q_{Dlinear}(t_D) &= \int_0^{t_D} q_D(t_D - \tau) d\tau \\ &= \int_0^{t_D} q_D(\tau) d\tau \end{aligned} \quad \text{(A-5)}$$

If the Laplace transform of q_D is available, then the transform of $q_{Dlinear}$ may be trivially obtained as

$$\tilde{q}_{Dlinear}(u) = \frac{\tilde{q}_D(u)}{u} \quad \text{(A-6)}$$

where u is the Laplace domain variable.

The Laplace transform of the dimensionless cumulative production $Q_{Dlinear}$ is then obtained as

$$\tilde{Q}_{Dlinear}(u) = \frac{\tilde{q}_{Dlinear}(u)}{u} \quad \text{(A-7)}$$

To tie the dimensionless solutions to dimensional variables, we proceed as follows. For flow at constant flowing bottomhole pressure, the dimensionless time t_D is defined as

$$t_D = C_t t, \quad \text{(A-8)}$$

the dimensionless rate q_D corresponding to the pressure difference $(p_i - p_{wf})$ is defined as

$$q_D \equiv \frac{C_q q(t)}{p_i - p_{wf}}, \quad \text{(A-9)}$$

and the dimensionless cumulative production is defined as

$$Q_D \equiv \frac{C_q C_t Q(t)}{p_i - p_{wf}}. \quad \text{(A-10)}$$

For linearly decreasing bottomhole pressure,

$$p(t) = p_i - t\left|\frac{dp_{wf}}{dt}\right| = p_i - t|p'| \quad \text{(A-11)}$$

Now we have

$$q_{Dlinear} \equiv \frac{C_q C_t q_{linear}(t)}{p'} \quad \text{(A-12)}$$

and

$$Q_{Dlinear} \equiv \frac{C_q C_t^2 Q_{linear}(t)}{p'} \quad \text{(A-13)}$$

Note that the preceding development is completely general. It applies equally to infinite- and finite-acting reservoirs, single- and dual-porosity systems, and to radial flow and flow to a finite conductivity vertical fracture.

Appendix B - Comparison of superposition for constant flowing bottomhole pressure with superposition for linearly varying flowing bottomhole pressure

Superposition for constant flowing bottomhole pressure

Let the pressure history be given by

$$p_{wf}(t)=\begin{cases} p_i, t\le 0 \\ p_1, 0<t\le t_1 \\ \dots \\ p_n, t_{n-1}<t\le t_n \end{cases} \qquad \text{(B-1)}$$

Then the corresponding production rate q is given by

$$q(t)=\frac{1}{C_q}\sum_{j=1}^{l-1}\left[(p_j-p_{j-1})q_D\left(C_t\left(t-t_{j-1}\right)\right)\right],\ t_{l-1}<t\le t_l \qquad \text{(B-2)}$$

Similarly, the cumulative production Q is given by

$$Q(t)=\frac{1}{C_qC_t}\sum_{j=1}^{l-1}\left[(p_j-p_{j-1})Q_D\left(C_t\left(t-t_{j-1}\right)\right)\right],\ t_{l-1}<t\le t_l \qquad \text{(B-3)}$$

Superposition for linearly varying flowing bottomhole pressure

Let the pressure history be given by

$$p_{wf}(t)=\begin{cases} p_i, t\le 0 \\ p_i+\dfrac{p_1-p_i}{t_1}t, 0<t\le t_1 \\ \dots \\ p_{n-1}+\dfrac{p_n-p_{n-1}}{t_n-t_{n-1}}(t-t_{n-1}), t_{n-1}<t\le t_n \end{cases} \qquad \text{(B-4)}$$

If we introduce the following notation,

$$p'_j\equiv\frac{p_j-p_{j-1}}{t_j-t_{j-1}}, \qquad \text{(B-5)}$$

we may write the resulting rate as

$$q(t)=\frac{1}{C_qC_t}\sum_{j=1}^{l-1}\left[(p'_j-p'_{j-1})q_{Dlinear}\left(C_t\left(t-t_{j-1}\right)\right)\right],\ t_{l-1}<t\le t_l \qquad \text{(B-6)}$$

and the cumulative production as

$$Q(t)=\frac{1}{C_qC_t^2}\sum_{j=1}^{l-1}\left[(p'_j-p'_{j-1})Q_{Dlinear}\left(C_t\left(t-t_{j-1}\right)\right)\right],\ t_{l-1}<t\le t_l \qquad \text{(B-7)}$$

Appendix C - Application to gas wells

In this section, we present a method for applying both constant pressure and linear pressure solutions to gas reservoirs.

Constant pressure solutions:

We write the problem in the form of a pair of coupled, first order, ordinary differential equations:

$$\frac{dt_a}{dt}=\frac{\mu_i c_{ti}}{\mu(\bar{p})c_t(\bar{p})} \qquad \text{(C-1)}$$

$$\frac{dQ}{dt}=q(t_a) \qquad \text{(C-2)}$$

Eqs. C-1 and C-2 are then solved using a general-purpose ODE solver.[12]

Linear pressure solutions:

For gas wells, the independent variable is adjusted time, while the dependent variable is adjusted pressure. Thus, use of the linear pressure solution for gas wells implies that adjusted pressure is a linear function of adjusted time. Thus, we have to iterate to determine the variation of adjusted pressure with adjusted time. Fixed point iteration is satisfactory for this calculation, using the following procedure. We assume that we know pressure p_1 and p_2 at times t_1 and t_2, respectively. We also assume that we have already calculated the adjusted time t_{a1} corresponding to time t_1.

1. Calculate the adjusted pressures p_{a1} and p_{a2} corresponding to pressures p_1 and p_2.

2. Estimate the adjusted time corresponding to time t_2 using gas properties evaluated at the current average drainage area pressure:

$$t_{a2}^0\cong t_{a1}+\frac{\mu_i c_{ti}}{\mu(\bar{p})c_t(\bar{p})}(t_2-t_1) \qquad \text{(C-3)}$$

3. Estimate the slope of adjusted pressure vs adjusted time,

$$p'_a\cong\frac{p_{a2}-p_{a1}}{t_{a2}^0-t_{a1}} \qquad \text{(C-4)}$$

4. Integrate Eqs. C-1 and C-2 from time t_1 to time t_2.

5. Recalculate the slope of adjusted pressure vs adjusted time, using the new estimate of adjusted time t'_{a2}:

$$p'_a\cong\frac{p_{a2}-p_{a1}}{t_{a2}^1-t_{a1}} \qquad \text{(C-5)}$$

6. Repeat steps 4 and 5 to convergence.

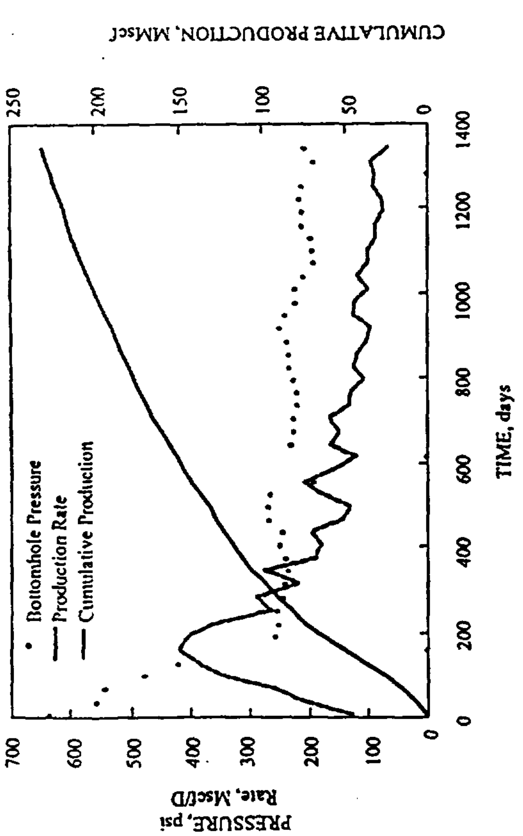

Fig. 1 - Production and pressure history, Well A.

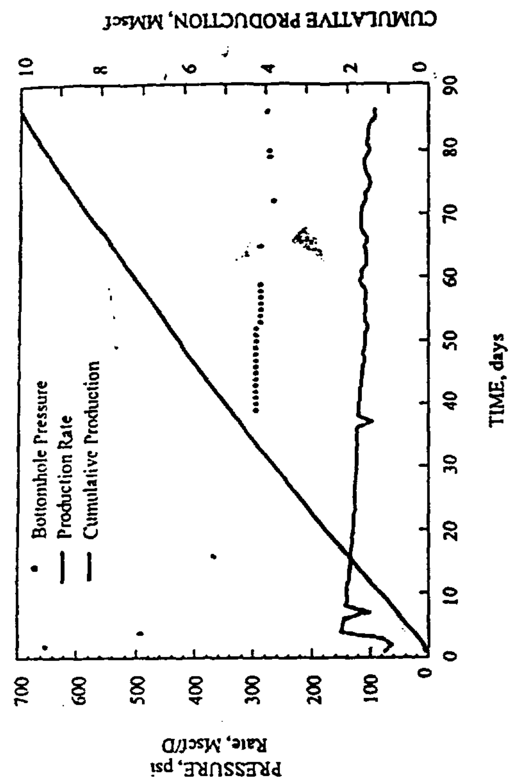

Fig. 2 - Production and pressure history, Well B.

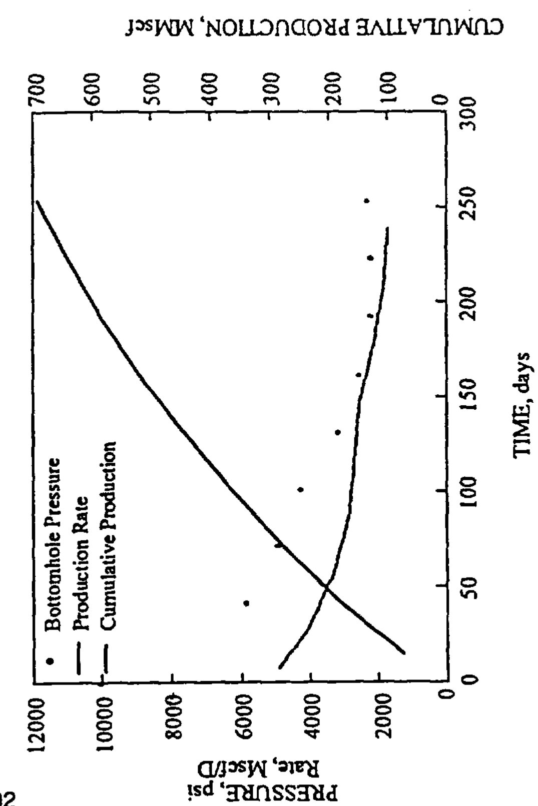

Fig. 3 - Production and pressure history, Well C.

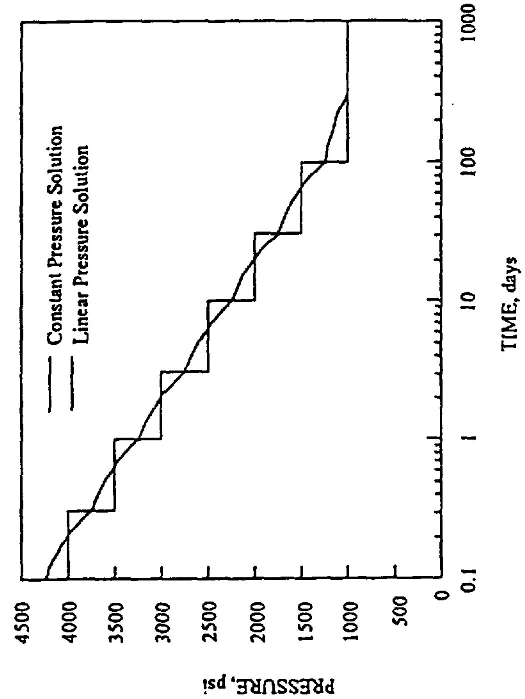

Fig. 4 - Modeling a varying bottomhole pressure history using superposition of constant pressure and linear pressure solutions.

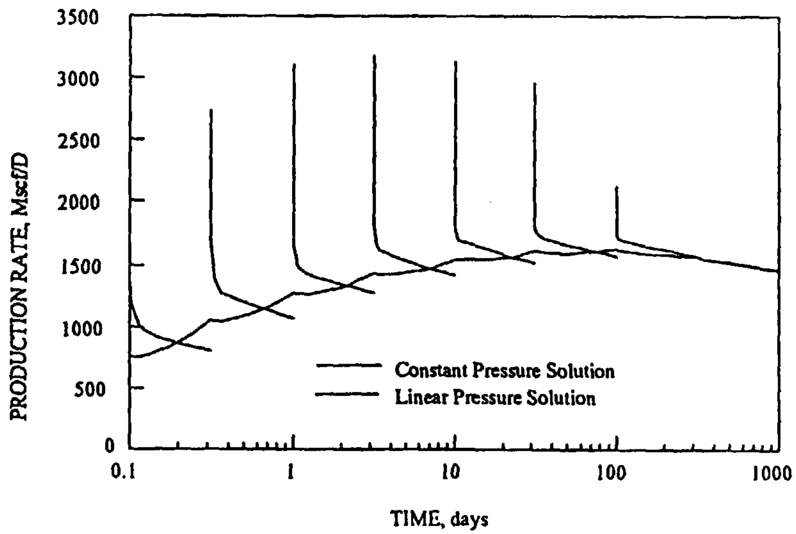

Fig. 5 - Comparison of production rates calculated using superposition of constant pressure and linear pressure solutions.

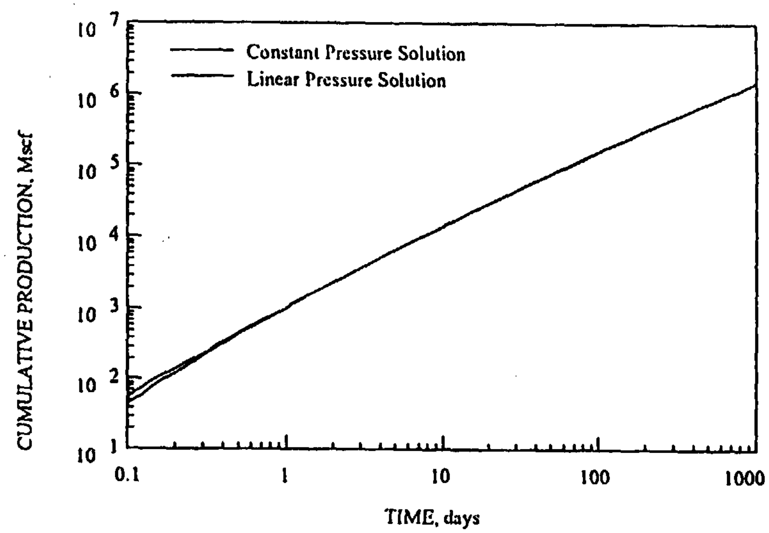

Fig. 6 - Comparison of cumulative production calculated using superposition of constant pressure and linear pressure solutions.

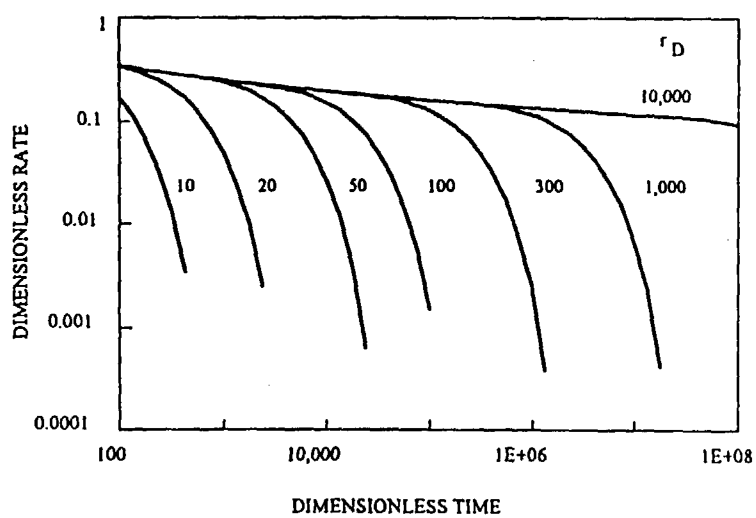

Fig. 7 - Dimensionless production rate for a finite radial system produced at constant wellbore pressure.

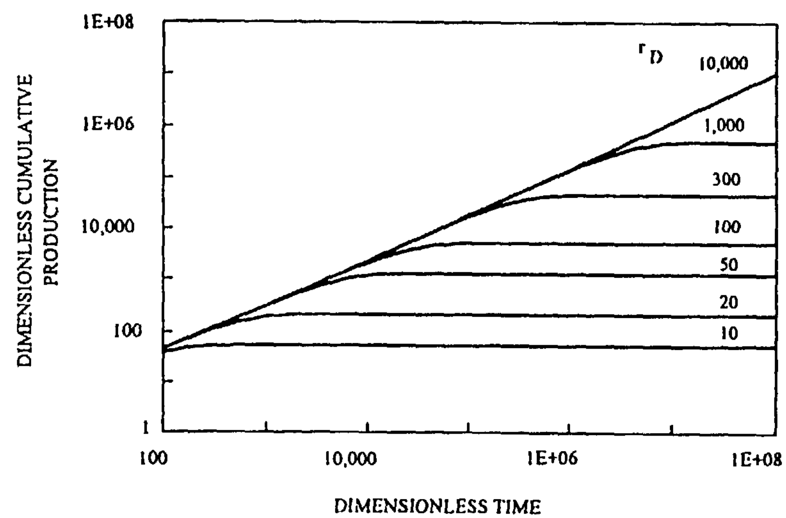

Fig. 8 - Dimensionless cumulative production for a finite radial system produced at constant wellbore pressure.

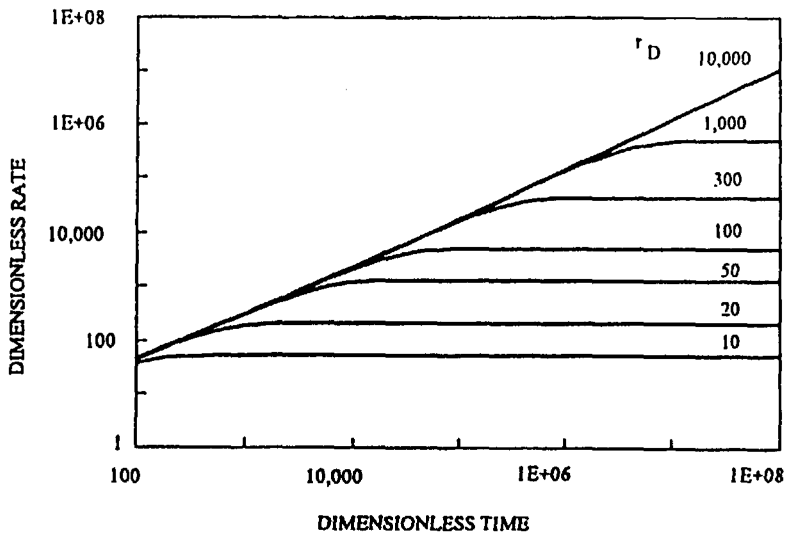

Fig. 9 - Dimensionless production rate for a finite radial system produced at linearly decreasing wellbore pressure.

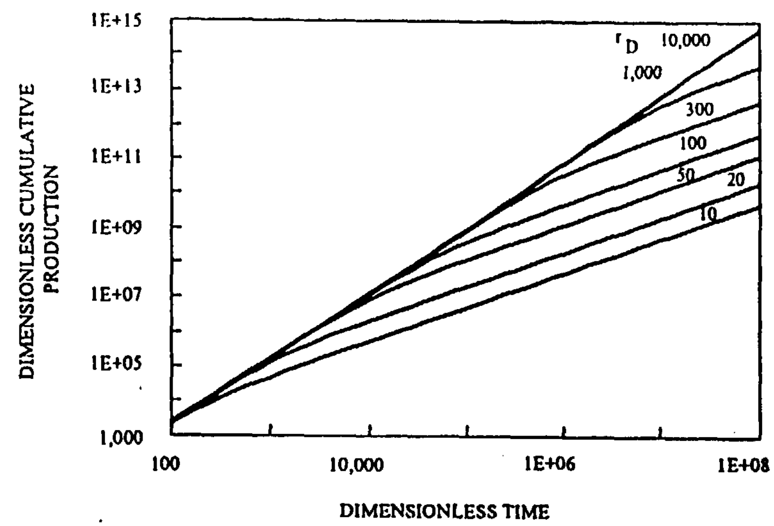

Fig. 10 - Dimensionless cumulative production for a finite radial system produced at linearly decreasing wellbore pressure.

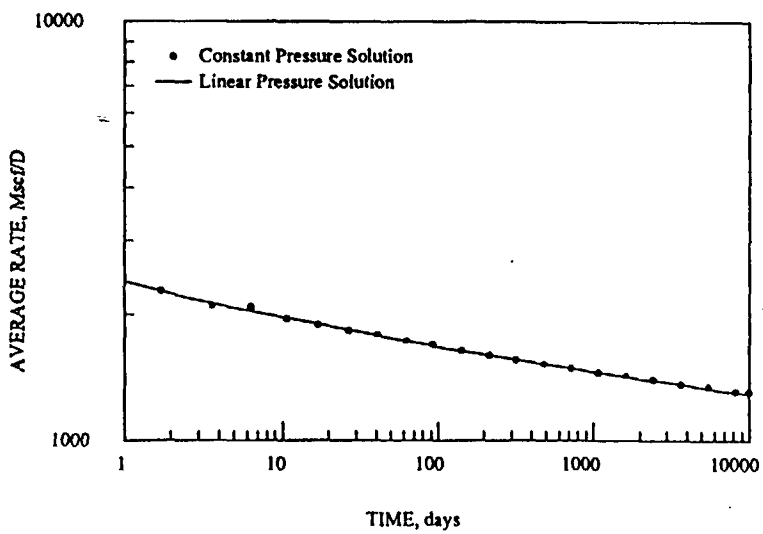

Fig. 11 - Comparison of rates computed using linear and constant pressure solutions, radial flow in an infinite single porosity system.

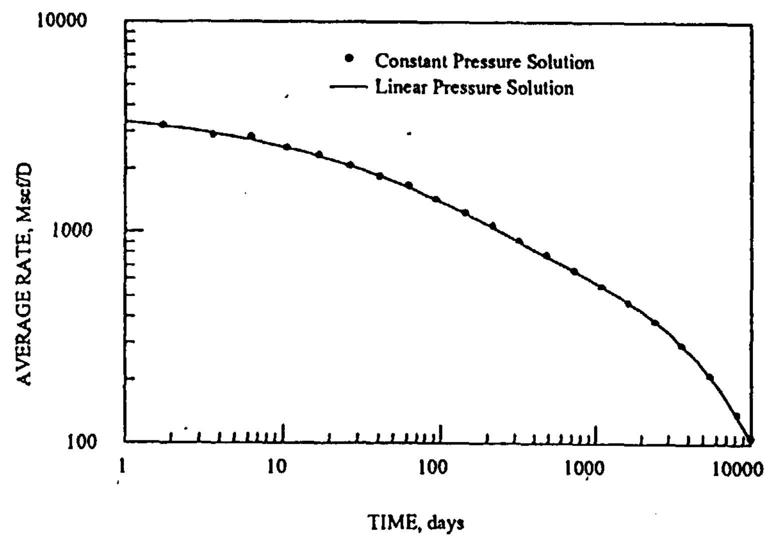

Fig. 12 - Comparison of rates computed using linear and constant pressure solutions, radial flow in a finite transient dual porosity system.

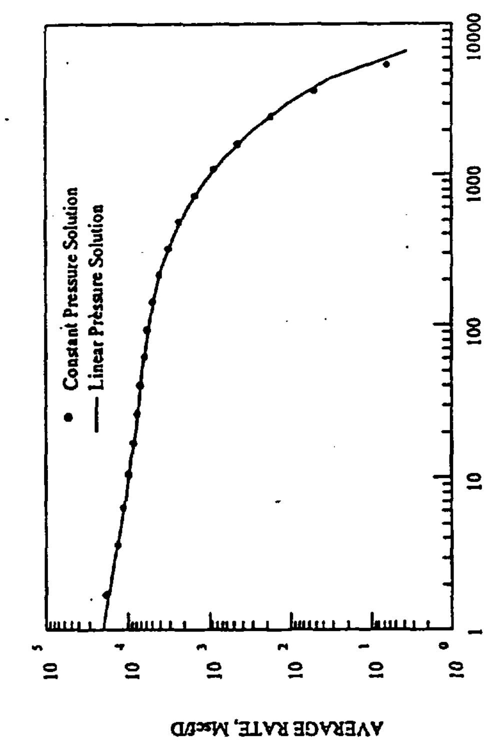

Fig. 13 -Comparison of rates computed using linear and constant pressure solutions, finite conductivity fracture in a finite single porosity system.

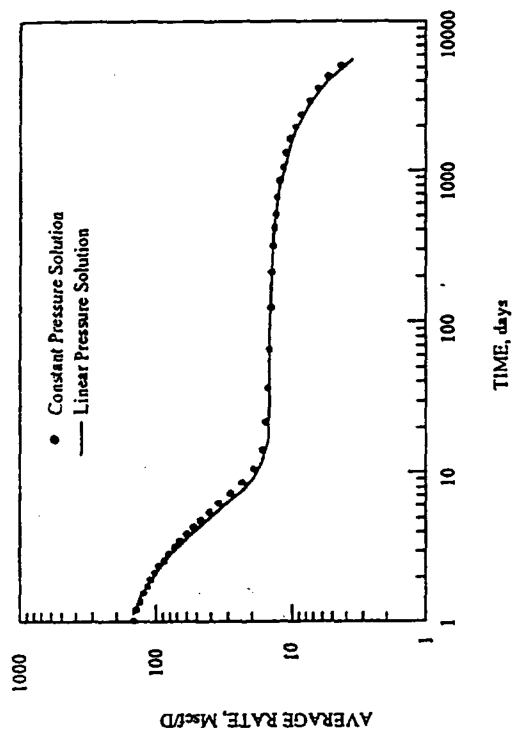

Fig. 14 -Comparison of rates computed using linear and constant pressure solutions, finite conductivity fracture in a finite pseudosteady-state dual porosity system.

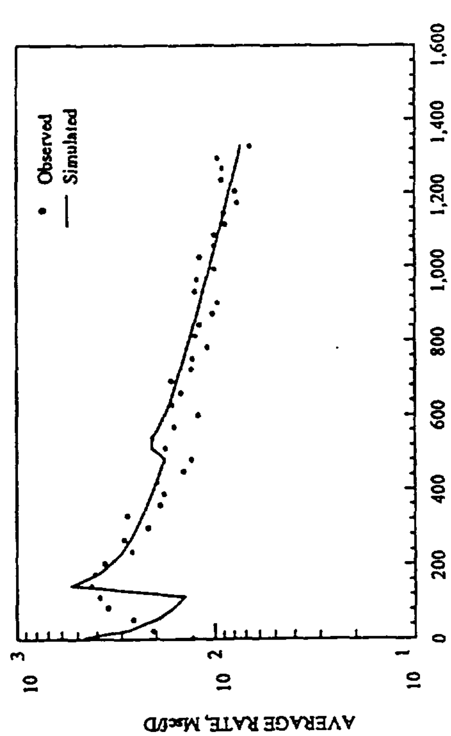

Fig. 15 -History match of Well A using the constant pressure solution with three superposition terms.

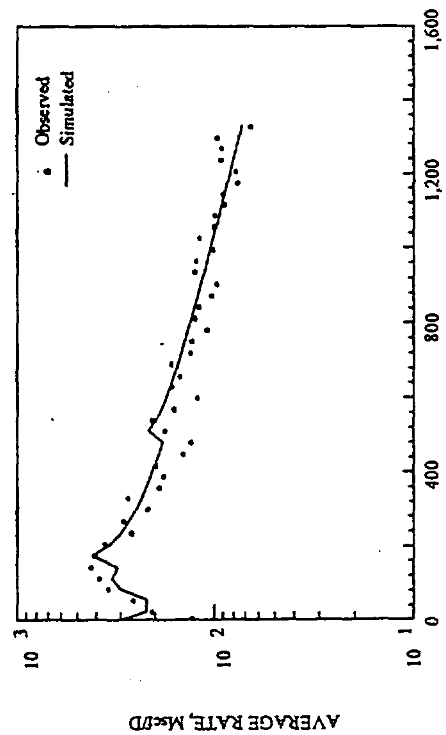

Fig. 16 -History match of Well A using the constant pressure solution with seven superposition terms.

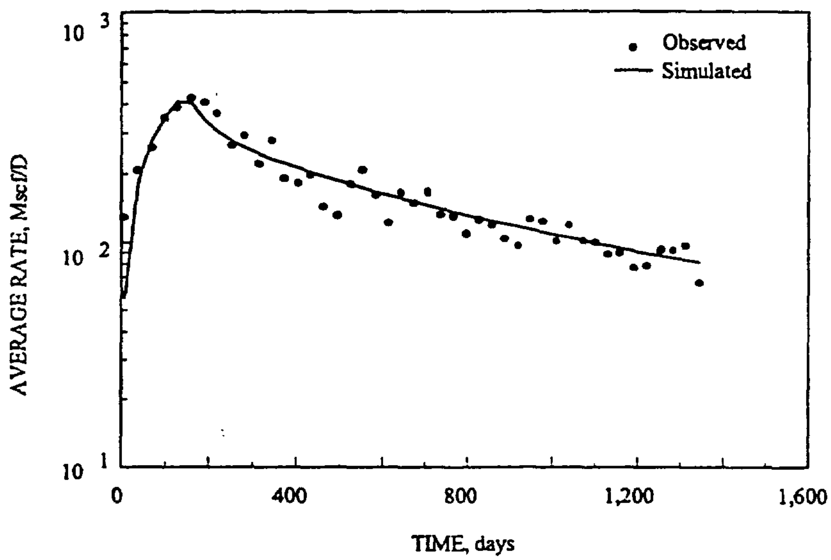

Fig. 17 -History match of Well A using the linear pressure solution with two superposition terms.

SPE 29580

Forecasting Long-Term Gas Production of Dewatered Coal Seams and Fractured Gas Shales

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ABSTRACT

A procedure is presented which allows forecasting long range performance of dewatered coal and fractured gas shale reservoirs having nonlinear adsorption isotherms, using constant pressure solutions to the flow equation for slightly compressible liquids. A correlation is presented to show the range of applicability of this procedure.

INTRODUCTION

Production decline curves are routinely used by engineers to predict the future performance of oil and gas wells. Because the results of decline curve predictions are used for calculating asset value and estimating future revenue, they are one of the most important tools reservoir engineers use. There are numerous variations on the basic exponential or hyperbolic decline analysis method. Fetkovitch[1] and others[2] have extended the decline curve analysis method to handle gas wells properly and to be able to estimate reservoir properties from the analysis of these data. However, there has been considerable drilling activity in the last 10 years into unconventional reservoirs whose wells do not follow the traditional production decline characteristic shapes. Among these problem reservoirs are coalbed methane and fractured shale reservoirs.

Two factors complicate the prediction of future gas production rates in many coalbed methane and fractured shale reservoirs such as the Devonian Shale of the Appalachian Basin, the Antrim Shale of Michigan and the New Albany Shale in Indiana. The first factor common in Antrim and New Albany reservoirs is high initial water saturation and essentially zero gas flow rate at the beginning of production. The second factor common to all fractured gas shales is desorption of gas from organic material within the reservoir rock. Both of these factors can result in well behavior that is not properly predicted by conventional decline curve methods.

Because of the complex production behavior of coalbed methane and fractured gas shale wells, the best way to predict performance is to use a numerical reservoir simulator which accounts for all of the mechanisms occurring during production. However, use of reservoir simulation may not be practical for all situations, particularly when many wells must be analyzed rapidly or when reservoir simulation is not available. This paper presents a rapid analytical solution that can account for production from reservoirs undergoing desorption. One extension of this method over others presented in the literature is that it accounts for nonlinear Langmuir sorption isotherms.

References at end of paper.

DISCUSSION

Previous Work

A number of authors have considered the problem of forecasting production from gas reservoirs using analytical solutions developed for slightly compressible liquids.

In 1987, Fraim and Wattenbarger[2] developed a procedure which predicts production rate as a function of time for gas reservoirs produced at constant flowing bottomhole pressure. This procedure accounts for both transient flow and boundary dominated flow with a single model. It also allows gas production to be forecast using any of numerous analytical solutions which have been developed for slightly compressible liquids.

In 1988, McKee and Bumb[3] developed an expression for the total compressibility for coalbed methane reservoirs which includes the effects of desorption using a Langmuir isotherm. They applied this compressibility term to pressure transient test analysis in coalbeds.

In 1991, J. P. Seidel[4] presented a calculation procedure for predicting stabilized flow rate as a function of time for coal reservoirs. This procedure combined the pseudosteady-state deliverability equation in terms of pseudopressure with a material balance equation taking into account both gas expansion and gas desorption. Seidel compared a forecast using his method to that obtained using a numerical reservoir simulator and found very good agreement during the boundary dominated flow period. This calculation procedure, however, is applicable only for boundary dominated flow since he used a pseudosteady-state deliverability equation to calculate the gas production rate.

The new solution presented in this paper has been applied to layered reservoirs by Gao, *et. al.*[5]

Reservoir Models

Coal

In coals much of the gas is found adsorbed on the surface of the coal rather than as free gas within a conventional porosity system. This adsorbed gas content may be described by the Langmuir isotherm which relates the adsorbed gas volume to the pressure of the gas phase:

$$V = \frac{V_L p}{p_L + p} \quad \text{.......(1)}$$

Coals vary widely in their adsorbed gas content. Sorbtion isotherms for coal may have a Langmuir volume, V_L, of 200 to 800 scf/ton and a Langmuir pressure 100 to 500 psi. The matrix density for coal ranges from 1.2 to 1.45 g/cm³.

Naturally Fractured Shale

Naturally fractured shales are characterized by a network of natural fractures, which provides virtually all of the flow capacity, yet provides only a small fraction of the storage capacity, of the reservoir rock. Most of the gas content in a naturally fractured shale is found either as free gas in a conventional porosity system within the matrix, or as gas adsorbed on surfaces of organic material within the shale. Adsorbed gas content of shale is much lower than that of coal.

As the reservoir is produced, gas desorbs from the shale into the matrix porosity system. It then flows through the matrix to the natural fracture system, then through the fracture system to the wellbore, as in a conventional dual porosity system.

A number of different dual porosity models have been presented in the literature. Warren and Root[6] noted that dual-porosity behavior must be characterized by two parameters in addition to those required for single porosity systems. The first of these parameters is the storativity ratio, ω, which is defined as

$$\omega \equiv \frac{(\phi c_t)_f}{(\phi c_t)_f + (\phi c_t)_m} \quad \text{.......(2)}$$

The second parameter is the interporosity flow coefficient, λ, defined as

$$\lambda \equiv \frac{\alpha k_m r_w^2}{k_f} \quad \text{.......(3)}$$

The term α is defined as

$$\alpha \equiv \frac{4n(n+2)}{L_m^2} \quad \text{.......(4)}$$

In this study, we assumed slab matrix elements (n=1), as shown in Fig. 1. This model is described in more detail by Kazemi[7] and de Swaan.[8]

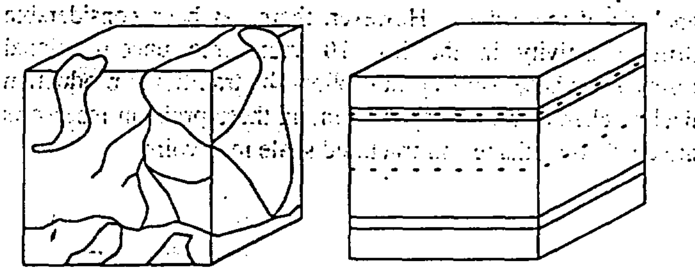

Fig. 1 - Comparison of naturally fractured reservoir and idealized slab reservoir model.

As with coalbed methane reservoirs, much of the gas content in naturally fractured shales is present as adsorbed gas. Sorbtion isotherms for shale may have a Langmuir volume of 60 to 200 scf/ton and a Langmuir pressure of 400 to 600 psi. The matrix density for shale is about 2.45 g/cm^3.

Analytical Solution

The solution proposed in this paper combines the method presented by Fraim and Wattenbarger[2] for predicting gas production rate using analytical solutions for slightly compressible liquids with the expression for total system compressibility in the presence of desorbtion presented by Bumb and McKee.[3]

Fraim and Wattenbarger[2] showed that solutions to the flow equation for slightly compressible liquids could be applied to gas reservoirs if the dimensionless time and rate are defined in terms of adjusted time and adjusted pressure, respectively. Adjusted time and adjusted pressure are defined as:

$$t_a \equiv \mu_i c_{ti} \int_0^t \frac{dt}{\mu(\bar{p}) c_t(\bar{p})} \quad \text{.....(5)}$$

$$p_a \equiv \mu_i z_i \int_0^p \frac{p\,dp}{\mu z} \quad \text{.....(6)}$$

The dimensionless time and dimensionless production rate are then defined as

$$t_D = \frac{0.0002637 k t_a}{\phi \mu_i c_{ti} r_w^2} \quad \text{.....(7)}$$

and

$$q_D = \frac{141.2 q B_{gi} \mu_i}{kh(p_{ai} - p_{awf})} \quad \text{.....(8)}$$

With these two definitions, the gas flow rate can be calculated from the solution to the diffusivity equation for production rate at constant pressure.

Fraim and Wattenbarger[2] noted that an iterative procedure must be used to predict the gas production rate, since the average reservoir pressure used in the definition of adjusted time, Eq. 5, is itself a function of the cumulative production.

Bumb and McKee[3] showed that the total compressibility for coals must be modified to include a term accounting for desorption of gas from the coal:

$$c_t = S_w c_w + (1 - S_w) c_g + \frac{p_{sc} V_L p_L T z}{\phi p T_{sc} z_{sc} (p_L + p)^2} \quad \text{.....(9)}$$

where V_L is expressed in scf/rcf.

The procedure presented in this paper incorporates the total compressibility from Eq. 9 in the definition of adjusted time given in Eq. 5. A more rigorous derivation is given in the paper by Gao, *et. al.*[5] The iterative procedure for calculating gas production rate is outlined in Appendix A.

Throughout this study we use the analytical solution for radial flow of a slightly compressible liquid to a well centered in a bounded circular reservoir, producing at constant flowing bottomhole pressure. This analytical solution is discussed in Appendix B.

In principal, the procedure presented in this paper can be extended to analytical solutions for any geometry, such as wells with vertical hydraulic fractures or horizontal wellbores.

Computer Simulation Sensitivity Runs

For this study we made a large number of computer simulation runs, varying the drainage radius, r_d; the dual porosity parameters storativity, ω and interporosity flow coefficient, λ; the Langmuir volume, V_L; and the flowing bottomhole pressure, p_{wf}. We compared the production rate predicted by the analytical solution to the results of the simulation runs. Using the production rate from the simulation as the reference, we calculated the error in the production rate from the analytical solution using the following expression:

$$e = \frac{q_{ana} - q_{sim}}{q_{sim}} \quad \text{.....(10)}$$

Table 1 - Base values used for all simulation runs

Property	Value	Units
Net pay	100	ft
Wellbore radius	0.25	ft
Skin factor	0	
Bulk porosity	5	%
Permeability	5	md
Initial pressure	700	psi
Langmuir pressure	200	psi
Matrix density	2.45	g/cm^3
Formation temperature	120	deg F
Gas gravity	0.55	(air=1.0)
Formation compressibility	4×10^{-6}	psi^{-1}

There were a number of parameters that were held constant throughout the simulation runs, as shown in Table 1. Table 2 shows the range of values for those parameters which were varied during the study.

Table 2 - Parameters varied during simulation runs

Property	Base value	Other values used	Units
Drainage radius	750	250, 2500, 7500, 25000	ft
Lambda	10^{-9}	1, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}	
Omega	10^{-3}	10^{-2}, 10^{-4}	
Langmuir volume	800	0, 100, 200, 400	scf/ton
Flowing wellbore pressure	35	175, 350, 525, 665	psi

Effect of Drainage Radius

In the first two series of runs, we varied the drainage radius r_d from 250 ft to 25,000 ft, corresponding to drainage areas of 4.5 acres to 45,000 acres.

For the first series of runs, we used a Langmuir volume V_L of 200 scf/ton and an interporosity flow coefficient λ of 10^{-6}. Results from this series of runs are shown in Fig. 2. For this series of runs, we found the maximum error in the analytical solution to be about 9%, for drainage radii r_d of 250 ft and 750 ft. For the other drainage radii the maximum error is less than 2%.

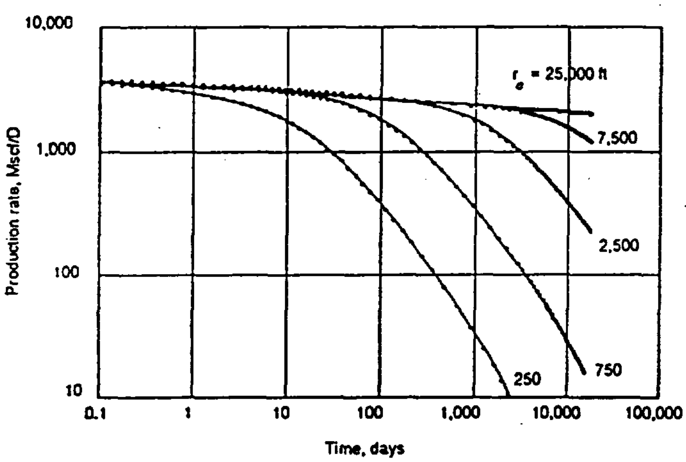

Fig. 2 - Effect of r_d on production rate, Series 1: V_L = 200 scf/ton, $\lambda = 10^{-6}$, $\omega = 10^{-3}$.

For the second series of runs, we used a Langmuir volume V_L of 800 scf/ton and an interporosity flow coefficient λ of 10^{-8}. Results from these runs are shown in Figs. 3 and 4. In this series, we found that the maximum error in the analytical solution (28%) occurred for a drainage radius of 250 ft., while the second largest error (15%) occurred for a drainage radius of 750 ft. The maximum error for all the remaining runs was less than 2%.

Thus, we conclude that the error in the analytical solution can be as high as 30% for system with small drainage areas. Other factors such as Langmuir volume V_L and interporosity flow coefficient λ also influence the error. For a given set of conditions there appears to be a threshold drainage radius. Above this threshold, the error in the analytical solution is fairly small; below the threshold, the error increases significantly with decreasing drainage radius.

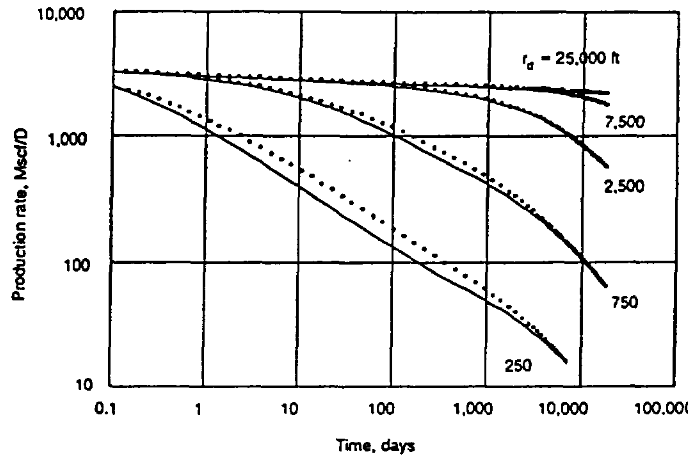

Fig. 3 - Effect of r_d on production rate, Series 2: V_L = 800 scf/ton, $\lambda = 10^{-8}$, $\omega = 10^{-3}$.

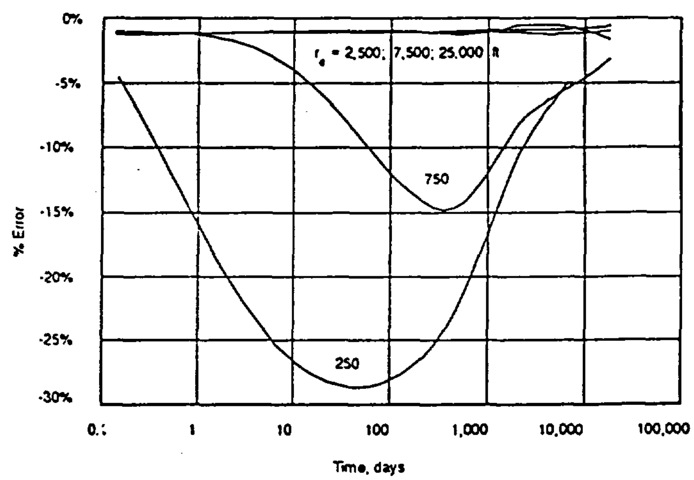

Fig. 4 - Effect of r_d on error in analytical solution, Series 2: V_L = 800 scf/ton, $\lambda = 10^{-8}$, $\omega = 10^{-3}$.

Effect of Interporosity Flow Coefficient

In the next two series of runs, we varied λ from 10^{-4} to 10^{-7}.

In the third series of runs, we used a Langmuir volume of 200 scf/ton and a drainage radius of 2500 ft. The results are shown in Figs. 5 and 6. In this series of runs, we found the maximum error was 11% for an interporosity flow coefficient λ of 10^{-9}. The maximum error for the other runs in this series was less than 3%.

The results for the fourth series of runs, with a Langmuir volume of 800 scf/ton and a drainage radius of 750 ft., are shown in Figs. 7 and 8. We found that the maximum error (28%) occurred with the interporosity flow coefficient λ of 10^{-9} while the second highest error (15%) occurred for a λ of 10^{-8}. The maximum error for the remaining runs, with interporosity flow coefficient λ ranging from 10^{-4} to 10^{-7}, was 3%. We made another run (not shown) with λ set to 1, representing production from a coalbed methane reservoir. The maximum error for this case was also less than 3%.

We conclude that the interporosity flow coefficient, λ, influences the error as much as does the drainage radius, and in much the same fashion. For a given set of conditions, there appears to be a threshold value of λ above which the error in the analytical solution is fairly small, and below which the error increases significantly with decreasing λ.

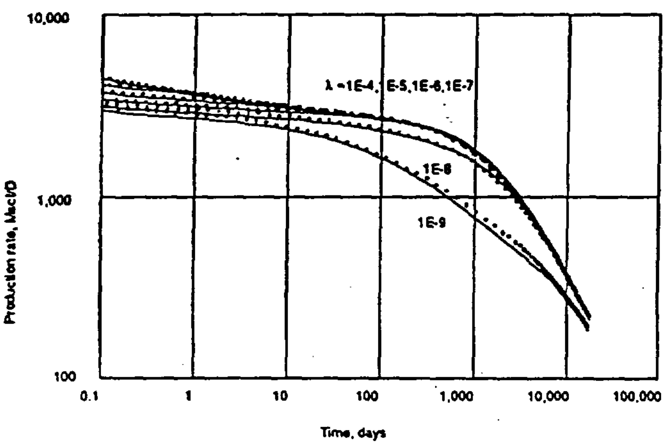

Fig. 5 - Effect of λ on production rate, Series 3: V_L = 200 scf/ton, r_d = 2500 feet, $\omega = 10^{-3}$.

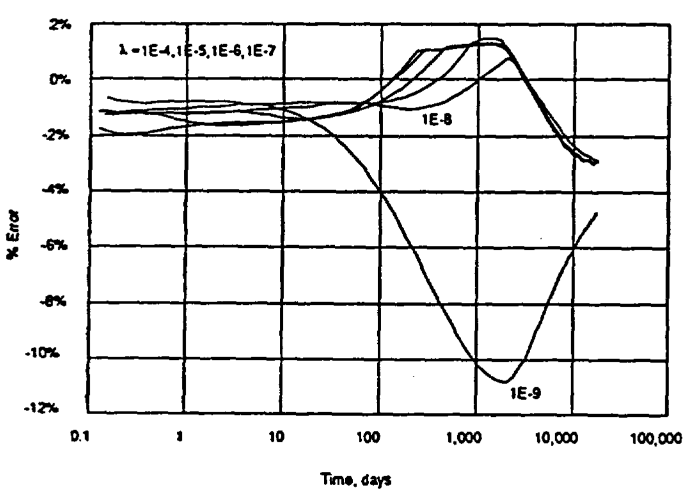

Fig. 6 - Effect of λ on error in analytical solution, Series 3: V_L = 200 scf/ton, r_d = 2500 feet, $\omega = 10^{-3}$.

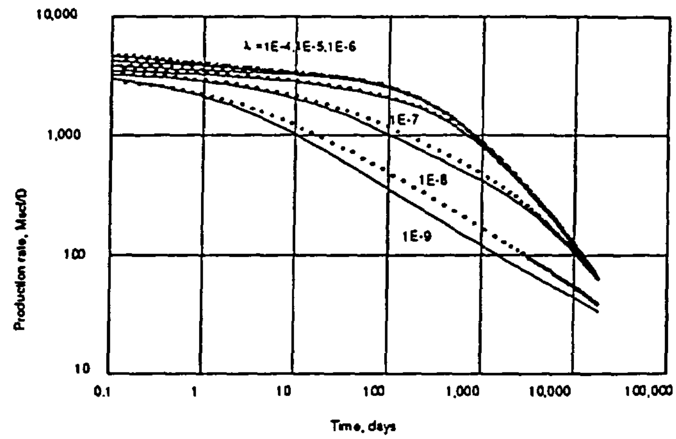

Fig. 7 - Effect of λ on production rate, Series 4: V_L = 800 scf/ton, r_d = 750 feet, $\omega = 10^{-3}$.

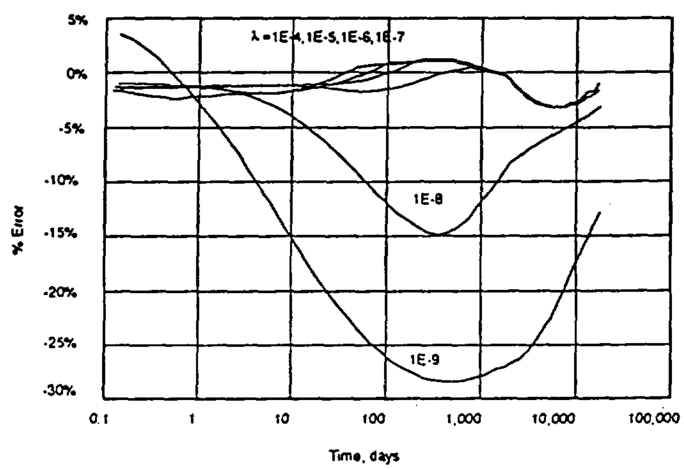

Fig. 8 - Effect of λ on error in analytical solution, Series 4: V_L = 800 scf/ton, r_d = 750 feet, $\omega = 10^{-3}$.

<u>Effect of Storativity Ratio</u>

For the next series of runs, shown in Figs. 9 and 10, we varied the storativity ratio, ω, from 10^{-2} to 10^{-4}. We used a Langmuir volume of 800 scf/ton, a drainage radius of 750 ft, and an interporosity flow coefficient of 10^{-9}. The maximum error for these runs ranges from 28 to 33%, showing only a weak dependence on the storativity ratio, ω.

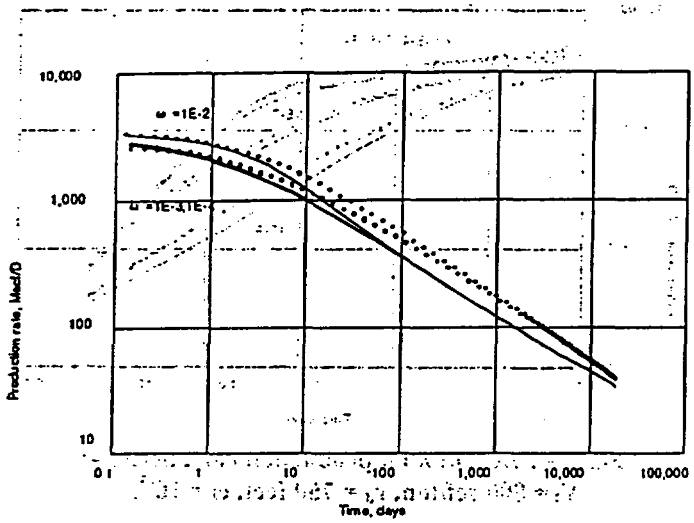

Fig. 9 - Effect of ω on production rate, Series 5: V_L = 800 scf/ton, r_d = 750 feet, $\lambda = 10^{-9}$.

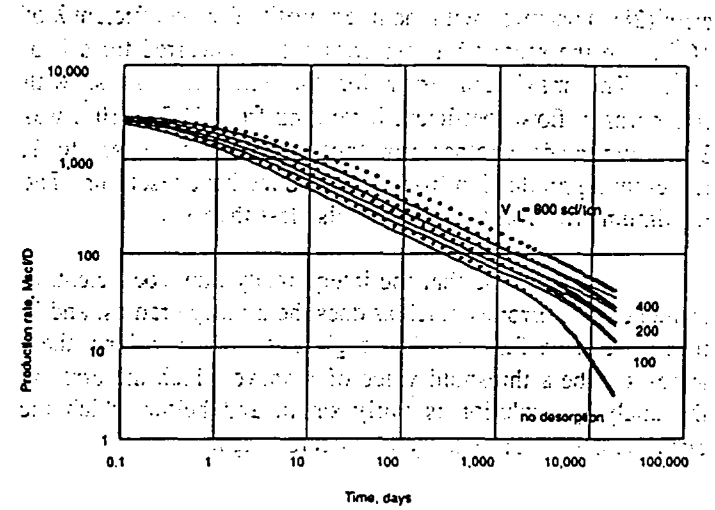

Fig. 11 - Effect of V_L on production rate, Series 6: r_d = 750 feet, $\lambda = 10^{-9}$, $\omega = 10^{-3}$.

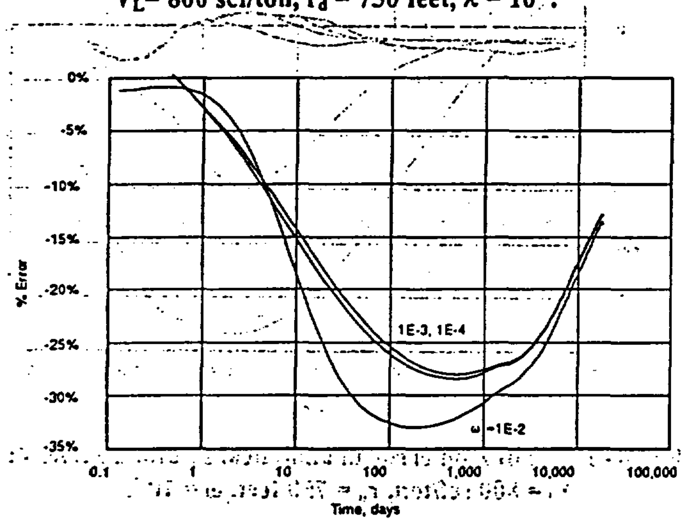

Fig. 10 - Effect of ω on error in analytical solution, Series 5: V_L = 800 scf/ton, r_d = 750 feet, $\lambda = 10^{-9}$.

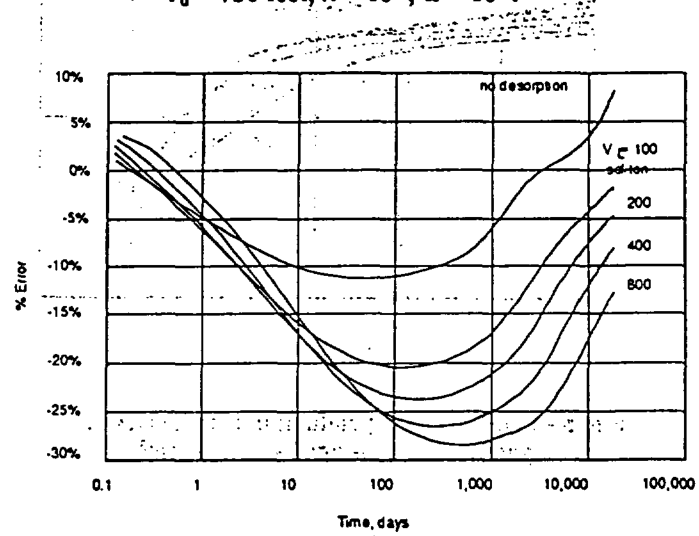

Fig. 12 - Effect of V_L on error in analytical solution, Series 6: r_d = 750 feet, $\lambda = 10^{-9}$, $\omega = 10^{-3}$.

Effect of Langmuir Volume

In the sixth series of runs, we varied Langmuir volume V_L from 0 to 800 scf/ton. We held the drainage radius constant at 750 ft, the storativity ratio, ω, at 10^{-3}, the interporosity flow coefficient, λ, at 10^{-9}. For this series of runs the maximum error ranged from 11%, for a Langmuir volume of 0 (corresponding to a conventional dual porosity system without desorption) to 28%, for a Langmuir volume of 800 scf/ton. Thus, even in the absence of desorption the nonlinearity in the gas flow equation results in a significant departure from the solution obtained with a finite difference simulator. All other factors being equal, this error increases with increasing adsorbed gas content.

Effect of Flowing Bottomhole Pressure

In the seventh series of runs, shown in Figs. 13 and 14, we varied the flowing bottomhole pressure, p_{wf}, from 35 psi to 665 psi, representing drawdowns of 95% to 5% of initial pressure, respectively. For this series of runs we used a Langmuir volume of 800 scf/ton, a drainage radius of 750 ft, a storativity ratio of 10^{-3}, and an interporosity flow coefficient of 10^{-9}. For this series of runs, the error ranged from about 4% for a flowing bottomhole pressure of 665 psi, to 28% for a flowing wellbore pressure of 35 psi. For even a moderate drawdown of 50% (a flowing bottomhole pressure of 350 psi), the maximum error was 16%.

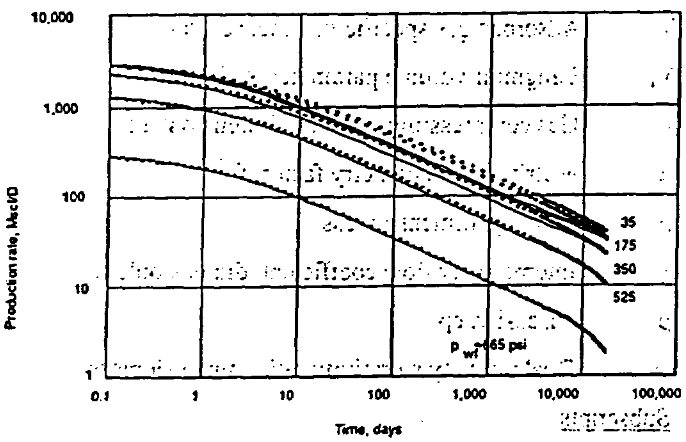

Fig. 13 - Effect of p_{wf} on production rate, Series 7: V_L= 800 scf/ton, r_d = 750 feet, $\lambda = 10^{-9}$, $\omega = 10^{-3}$.

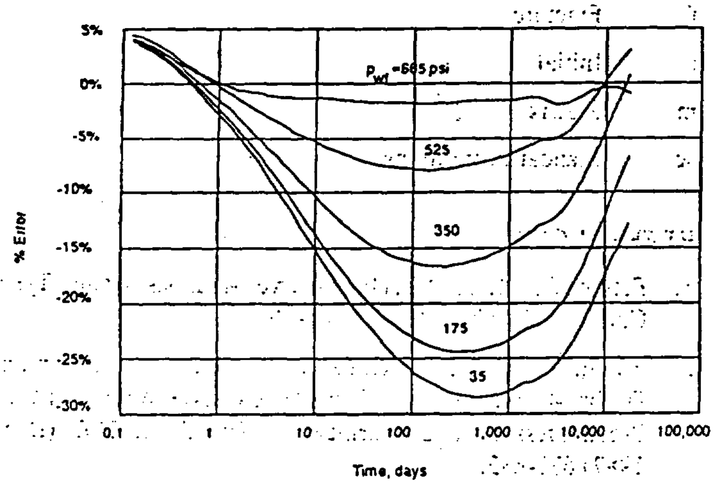

Fig. 14 - Effect of p_{wf} on error in analytical solution, Series 7: V_L= 800 scf/ton, r_d = 750 feet, $\lambda = 10^{-9}$, $\omega = 10^{-3}$.

Error Correlation

As part of this study, we were interested in establishing the range of validity of the proposed solution. Ideally, we would like to be able to estimate the level of accuracy to be expected without having to use the numerical simulator for comparison. In this section, we propose a simple condition for determining whether or not the solution is expected to be accurate.

Of the parameters varied during this study, the interporosity flow coefficient λ, the drainage radius r_d, and the flowing bottomhole pressure, p_{wf} had the largest effect on the error. Two of these three parameters, the interporosity coefficient λ and the drainage radius r_d, have very similar effects on the error. We found that we can combine these two parameters into a single group as follows.

The interporosity flow coefficient λ is defined in Eq. 3. The dimensionless drainage radius is defined as:

$$r_{dD} \equiv \frac{r_d}{r_w} \quad \text{(11)}$$

We can combine these two dimensionless parameters into a third dimensionless group, λr_{dD}^2, which is independent of the wellbore radius, r_w.

Fig. 15 shows the maximum error for each run as function of this new dimensionless group. Note that only two runs having $\lambda r_{dD}^2 \geq 1$ have an error higher than 4%. In both cases, the error is still less than 9%. These two runs had a Langmuir volume of 200 scf/ton, a storativity ratio of 10^{-3}, a interporosity flow coefficient of 10^{-6}, and drainage radii of 250 ft and 750 ft. Only two runs having $\lambda r_{dD}^2 \leq 0.1$ had an error less than 10%. These two cases both had low drawdowns, with flowing wellbore pressures of 665 psi, (5% drawdown, 4% error) and 525 psi, (25% drawdown, 8% error), respectively.

Note that these conclusions are based on a transient dual-porosity reservoir model with slab geometry matrix elements. Dual porosity models with matrix blocks of different shapes such as columns or cubes may exhibit somewhat different behavior, although we still expect the error to be correlated with λr_{dD}^2.

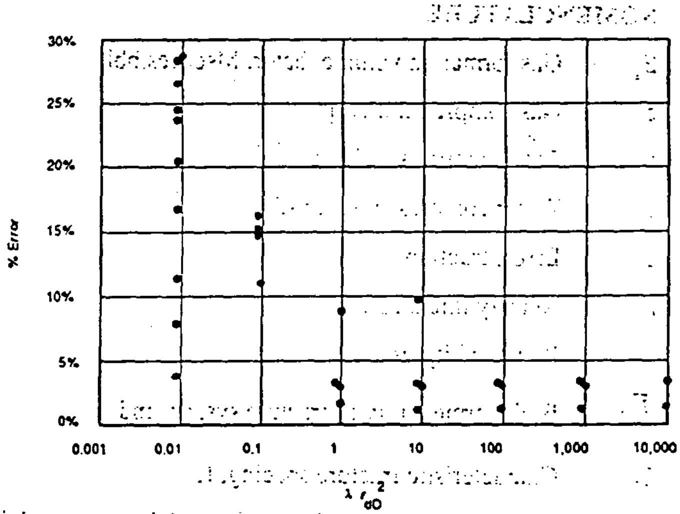

Fig. 15 - Correlation of error in analytical solution.

Advantages of Proposed Solution

The proposed solution accounts for transient flow in the matrix, so it can be applied to coals and shales which have not initial water production to predict both production during the transient period as well as during the boundary dominated flow period. It can be expanded to a wide variety of reservoir geometries including wells which have been hydraulically fractured and wells in reservoirs where the outer boundaries have shapes other than cylindrical. This solution uses a formulation which is very similar to analytical models of conventional gas reservoirs thus it can be easily incorporated into a general purpose analytical gas reservoir simulator. The analytical model is much faster to use than finite difference simulation of hydraulically fractured coal and shales and thus may be more practical to use with fracture optimization programs.

CONCLUSIONS

As a result of this study we have reached the following conclusions.

1. The proposed analytical solution accurately models gas flow in the presence of desorption for a wide range of parameters.

2. For coals, the new solution is expected to be less than 5% in error compared to single phase numerical reservoir simulation.

3. For naturally fractured shales, using a slab geometry dual porosity model, where the dimensionless group $\lambda r_{dD}^2 \geq 1$, the error in the proposed solution is expected to be less than 10%, with a more typical value being 2 to 3%. For shales where the drawdown is 25% or less of initial pressure, the error in the new solution is expected to be less than 10%.

NOMENCLATURE

B_g	Gas formation volume factor, Mscf/res.bbl
c_g	Gas compressibility, psi^{-1}
c_t	Total compressibility, psi^{-1}
c_w	Water compressibility, psi^{-1}
e	Error, fraction
h	Net pay thickness, ft
k	Permeability, md
$\bar{k}_f$	Bulk permeability of fracture system, md
L_m	Characteristic fracture spacing, ft
n	Number of orthogonal sets of parallel fractures (1,2 or 3)
p	Pressure, psia
$\bar{p}$	Average drainage area pressure, psia
p_L	Langmuir pressure parameter, psi
q	Flow rate, Mscf/day
r	Radius, ft
r_w	Wellbore radius, ft
S_w	Water saturation, dimensionless
t	Time, hours
V	Adsorbed gas specific volume, scf/ton
V_L	Langmuir volume parameter, scf/ton
z	Gas compressibility factor, dimensionless
α	Matrix block geometry factor, ft^{-2}
ϕ	Porosity, dimensionless
λ	Interporosity flow coefficient, dimensionless
μ	Viscosity, cp
ω	Dual porosity storativity ratio, dimensionless

Subscripts

a	Adjusted
D	Dimensionless
d	Drainage area
f	Fracture
i	Initial
m	Matrix
sc	Standard conditions

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APPENDIX A

In this appendix we outline a robust method for iteratively calculating the adjusted time and gas production rate.

First, we take the derivative of both sides of Eq. 5 with respect to time:

$$\frac{dt_a}{dt} = \frac{\mu_i c_{ti}}{\mu(\bar{p})c_t(\bar{p})} \quad \text{(A-1)}$$

Next, we write the production rate as the time derivative of the cumulative production

$$\frac{dQ}{dt} = q(t_a) \quad \text{(A-2)}$$

Eqs. A-1 and A-2 are a desired pair of coupled, first order, ordinary differential equations (ODE) which may be solved using any general-purpose ODE solver.[9] The independent variable is time, and the dependent variables are adjusted time and cumulative production. These two equations are coupled through the material balance relationship between the average reservoir pressure in Eq. A-1 and the cumulative production in Eq. A-2. These two equations are quite general, and apply to slightly compressible liquids, conventional gas reservoirs, and gas reservoirs with desorption, provided appropriate expressions are used for total compressibility and material balance.

To take into account the effects of desorption, we write the total compressibility as suggested by McKee & Bumb:[3]

$$c_t = S_w c_w + (1-S_w)c_g + \frac{p_{sc} V_L p_L T z}{\phi p T_{sc} z_{sc} (p_L + p)^2} \quad \text{(A-3)}$$

The material balance equation including the effects of desorption is

$$V = V_{free} + V_{adsorbed}, \quad \text{(A-4)}$$

where

$$V_{free} = \phi \frac{T_{sc} z_{sc}}{p_{sc}} \frac{p}{Tz}, \quad \text{(A-5)}$$

and

$$V_{adsorbed} = \frac{V_L p}{(p_L + p)} \quad \text{(A-6)}$$

V and V_L are in scf/rcf.

APPENDIX B

For this study, we assumed radial flow to a well centered in a circular reservoir, produced at constant flowing bottomhole pressure, with uniform initial pressure, and closed outer boundaries. For slightly compressible liquids, the analytical solution for the flow equation for these initial and boundary conditions is given in the Laplace domain by:

$$\tilde{q}_D = \frac{u\left[I_1(ur_{eD})K_1(u) - K_1(ur_{eD})I_1(u)\right]}{s\left[K_1(ur_{eD})I_0(u) + I_1(ur_{eD})K_0(u)\right]} \quad \text{(B-1)}$$

where

$$u = \sqrt{sf(s)} \quad \text{(B-2)}$$

For a conventional single porosity reservoir,

$$f(s) = 1 \quad \text{(B-3)}$$

For a transient dual porosity reservoir with slab matrix elements,[10]

$$f(s) = \omega + \sqrt{\frac{\lambda(1-\omega)}{3s}} \tanh\sqrt{\frac{3(1-\omega)s}{\lambda}} \quad \text{(B-4)}$$

In this study, we used the Stehfest algorithm[11] to numerically invert Eq. B-1.

9. [illegible] Tsolakay [illegible] W.T., and [illegible] SPE [illegible] Transport [illegible] Mechanics [illegible] Journal [illegible]

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APPENDIX A

In this appendix we outline a robust method for accurately calculating the adsorbed gas and gas production rate.

First, we take the derivative of both sides of Eq. 5 with respect to time:

$$[illegible] \qquad (A-1)$$

[illegible] the production rate as the time derivative of the [illegible]:

$$[illegible] \qquad (A-2)$$

[illegible] independent variables are [illegible] time and cumulative production. These two equations are coupled through the material balance relationship between [illegible] average reservoir pressure in Eq. [illegible] and the cumulative production in Eq. A-[illegible]. These two equations are quite general and apply to slightly compressible liquids, conventional gas reservoirs, and gas reservoirs with desorption, provided appropriate expressions are used for total compressibility and material balance.

To take into account the effects of desorption, we write the material balance [illegible] as presented by [illegible] as follows:

$$[illegible] \qquad (A-3)$$

[illegible]

$$[illegible] \qquad (A-4)$$

$$[illegible] \qquad (A-5)$$

$$[illegible] \qquad (A-6)$$

and

$$[illegible] \qquad (A-7)$$

V and V_L are in scf/ton.

APPENDIX B

For this study, we assumed radial flow to a well centered in a circular reservoir, produced at constant flowing bottomhole pressure, with uniform initial pressure, and closed outer boundaries. For slightly compressible liquids, an analytical solution for the flow equation for these initial and boundary conditions is given in the Laplace domain by:

$$\bar{q}_D = \frac{u\left[I_1(ur_{eD})K_1(u) - K_1(ur_{eD})I_1(u)\right]}{s\left[K_1(ur_{eD})I_0(u) + I_1(ur_{eD})K_0(u)\right]} \qquad (B-1)$$

where

$$u = \sqrt{s f(s)} \qquad (B-2)$$

[illegible]

$$[illegible] \qquad (B-3)$$

[illegible]

$$f(s) = \omega + \sqrt{\frac{\lambda(1-\omega)}{3s}}\tanh\sqrt{\frac{3(1-\omega)s}{\lambda}} \qquad (B-4)$$

In this study, we used the Stehfest algorithm[11] to numerically invert Eq. B-1.

RESERVOIR MANAGEMENT/PC Program Predicts Production.

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Summary

A computer program, PROMAT, has been developed by S.A. Holditch & Associates, Inc. sponsored by Gas Research Institute, to take some of the risks out of reservoir management. Designed to help petroleum engineers analyze long-term production data from oil or gas wells, PROMAT may be used to automatically history-match existing production data to estimate reservoir properties and then predict well performance, or to predict well performance given specific reservoir properties. It is designed to predict performance from single- and dual-porosity reservoirs, both gas and oil. The most recent version of PROMAT (of March 1992) includes several enhancements, such as the ability to accommodate multiple bottomhole flowing pressures during the production period, derive the half-length of a hydraulic fracture and its conductivity from production data, and predict performance under prescribed fractured-well conditions.

Full Text:

In a time of low gas prices, production companies can't afford to make assumptions that involve taking risks. You can't assume that an offset well will be as productive as any of the others in the field. You can't assume that a hydraulic fracture design that worked on one well will work in another nearby well. And, just because you've always used a tried-and-true method of developing your field, you can't assume it's the best method for every field.

In reality, no producing company takes excessive risks and stays in the business. But your company just might be making some assumptions, based on past performance, that aren't in sync with state-of-the-art production practices and unnecessarily increase your risks.

A recent GRI-sponsored computer program, PROMAT, has been developed to take some of the assumptions out of reservoir management. Designed to help petroleum engineers analyze long-term production data from oil or gas wells, PROMAT may be used to automatically history-match existing production data to estimate reservoir properties and then predict well performance. Or, you could use PROMAT to predict well performance given specific reservoir properties.

Although it was originally designed to analyze production data from Devonian shale wells, PROMAT--developed by S.A. Holditch & Associates, Inc. (SAH)--should be useful in evaluating well performance from all types of pressure-depletion reservoirs.

Larry Hairgrove, Senior Petroleum Engineer for Cabot Oil & Gas Corporation, has used PROMAT extensively on tight gas sandstone formations in the Appalachian Basin. "We typically use decline curves to evaluate future well performance and couple this with our geologic maps to justify additional wells," says Hairgrove. "But, PROMAT has caused us to consider all sorts of factors that influence production in a particular field.

"For example, we had logs from wells in the same field that looked the same, but their decline curves showed us that they were performing altogether differently. Using PROMAT, we were able to compare things like the skin factors and permeabilities of the two wells and determine if the production anomalies were related to completion efficiency or were truly an indication of reservoir quality. With this information, we could determine if offset drilling was indicated.

"PROMAT has also helped us determine if additional wellhead compression is justified because of its ability to predict future performance at various flowing pressures. This is especially useful in the kind of tight reservoirs we have."

PROMAT is designed to predict performance from single- and dual-porosity reservoirs, both gas and oil. The most recent version of PROMAT (released in March 1992) includes several enhancements, including the ability to 1) accommodate multiple bottomhole flowing pressures during the production period, 2) derive the half-length of a hydraulic fracture and its conductivity from production data, and 3) predict performance under prescribed fractured-well conditions.

PROMAT has been sold to about 30 companies including several independents in the Appalachian Basin, gas transmission companies, major producers, and foreign national oil companies. SAH has also used the software extensively to project future gas reserves, to quantify reservoir properties (e.g., permeability) for purposes such as tight gas classifications, and to identify well productivity problems for its clients in gas reservoirs all over the country.

PROMAT runs on IBM and IBM-compatible personal computers with a minimum of 640K RAM, hard disk, a math coprocessor, and an enhanced graphics monitor (for optimal performance). PROMAT comes with a user's guide, including several sample applications. Production data can be entered using the input data screens or can be read directly from existing files. PROMAT also offers a variety of options for plotting and reporting the results. The production data may be plotted along with the history-match results and the future performance predictions.

To ORDER A COPY OF PROMAT, contact David Lancaster, Vice President, S.A. Holditch & Associates, Inc., 900 Southwest Parkway East, Suite 200, College Station, TX 77840 (409/764-1122; FAX 409/764-8157).

For MORE R&D INFORMATION ON THE SOFTWARE, contact David Hill, GRI's Project Manager, Devonian Shale Research (312/399-5434).

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FRACPRO®

FRACPRO® is widely accepted and used in the petroleum industry. There are several fracture design programs on the market. However, FRACPRO is the main design and evaluation program used by Halliburton Energy Services, one of the largest stimulation service companies in the world. Another major service company, BJ Services, uses several programs including FRACPRO. Operators from majors, such as Texaco, to independents, like Union Pacific Resources, use FRACPRO to evaluate their fracture treatments.

Fracture stimulation consulting companies, like S.A. Holditch & Associates also use FRACPRO, including Branagan & Associates, (Las Vegas), Integrated Petroleum Technologies (Denver), Pinnacle Technologies (San Francisco) and Ely and Associates (Houston). Due to high usage of FRACPRO among the service and consulting companies, most of the fracture treatments performed in the petroleum industry are designed and evaluated with FRACPRO.

FRACPRO is a 3-Dimensional fracture developed in the mid 1980's based on joint research conducted under the direction of the Gas Research Institute, an organization funded by the petroleum industry. The model continues to be updated incorporating new correlations developed by the industry.

The engineering results of designing and analyzing fracture treatments with FRACPRO have been published throughout the petroleum industry. The following list contains several papers published on the application of FRACPRO.

1. Johnson, D.E., Wright, C.A., Stachel, A., Schmide, H. and Cleary, M.P.: "On-Site Real-Time Analysis Allows Optimal Propped Fracture Stimulation of a Complex Gas Reservoir," paper SPE 25414 presented at the 1993 Production Operations Symposium, Oklahoma City, OK, Mar. 21-23.

2. Cipolla, C.L., Meehan, D.N., and Stevens. P.L.: "Hydraulic Fracture Performance in the Moxa Arch Frontier Formation," paper SPE 25918 presented at the 1993 SPE Rocky Mountain Regional Meeting/Low Permeability Reservoirs Symposium, Denver, Apr. 16-28.

3. Johnson, D.E., Wright, T.B., Tambini, M., Maroli, R., Cleary, M.P.: "Real-Data On-Site Analysis of Hydraulic fracturing Generates Optimum Procedures for Job Design and Execution," paper SPE 25920 presented at the 1993 SPE Rocky Mountain Regional/Low Permeability Reservoirs Symposium, Denver, Apr. 12-14.

4. Davidson, B.M., Saunders, B.F., and Robinson, B.M.: "Analysis of Abnormally High Fracture Treating Pressures Caused by Complex Fracture Growth," paper SPE 26154 to be presented at the 1993 SPE Gas Technology Symposium, Calgary, Jun. 28-10.

5. Arihara, N., Abbaszadeh, M., Wright, C.A., and Hyodo, M.: "Integration of Fracturing Dynamics and Pressure Transient Analysis for Hydraulic Fracture Evaluation," paper SPE 36551 presented at the 1996 SPE Annual Technical Conference and Exhibition, Denver, Oct. 6-9.

6. Harkrider, J.D., Middlebrook, M.L., Huffman, C.H., Aud, W.W., Teer, G.A., and Hansen, J.T.: "Completion Optimization Through Advanced Stimulation Technology and Reservoir Analysis: A Case Study in the Red fork Formation, Okeene Field, Major County, Oklahoma," paper SPE 37429 presented at the 1997 SPE Production Operations Symposium, Oklahoma City, Mar. 9-11.

7. Davidson, B.M., Franco, V.H., Gonzalez, S., and Robinson, B.M.: "Stimulation Program in High Permeability Oil Sands - Case Study," paper SPE 39050 presented at the 1997 Fifth Latin American and Caribbean Petroleum Engineering Conference - V LACPED, Rio de Janeiro, Aug. 30 - Sept. 3.

SPE 25414

On-Site Real-Time Analysis Allows Optimal Propped Fracture Stimulation of a Complex Gas Reservoir

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This paper was prepared for presentation at the Production Operations Symposium held in Oklahoma City, OK, U.S.A., March 21-23, 1993.

ABSTRACT

In order to increase gas production in an under-producing formation, the German utility/energy company RWE-DEA stimulated the Wardboehmen Z1 well with a propped fracture treatment on December 6, 1991. Two days prior to the main fracture treatment, a step-rate test and mini-fracture were pumped for the purpose of evaluating more accurately the characteristics of the reservoir, including closure stress, leak-off rates, and permeability (and stress) profile. This information was then used to substantially improve the originally proposed design, provided by the service company, in order to create an effective/optimal propped fracture in this reservoir, incidentally also producing major savings in job cost. For the first time in Germany, electronic bottomhole pressure-measuring equipment with surface readout was used, during the minifrac. Availability of the bottommhole pressure data in the minifrac and repeated abrupt flow-rate changes, including shut-ins of about one minute, during both the minifrac and main fracture treatment allowed realistic simulation of fracture development with an on-site real-data 3D simulator. It was possible to determine the continually changing friction losses in the near-wellbore vicinity of the perforations: this tortuosity was very high initially but reached acceptable values after pumping the re-designed pad volume. This finding was important because it minimized the risk of a premature near-wellbore screen-out resulting from the planned proppant concentrations, up to 1,250 g/l (10 ppg). The fracture treatment led to a consistent four-fold increase in the gas production rate. This success was due, at least partly, to careful planning and use of novel technology in the fracture treatment, which allowed the on-site determination of actual reservoir conditions, with growth influenced by extremely variable permeability as against idealized models used for initial design.

INTRODUCTION

Many man-years have been invested in theoretical and laboratory investigations of hydraulic fracturing (e.g. Refs. 1–4), including field and laboratory R&D (e.g. Refs. 1, 4) and commercial field efforts (e.g. Refs. 5–8) all aimed toward advancing the technology. These efforts have produced a unique technology (i.e. the Gas Research Institute (GRI) fracture simulator, a true 3D, real-data, real-time hydraulic fracture simulator for design and on-site analysis). Our many novel conclusions from such data analysis have included: shorter, wider fractures than those predicted by other simulators, which do not consistently match measured pressures; frequent occurrence of a significant level of near-wellbore friction, due to near-wellbore fracture tortuosity, which must be subtracted from measured (downhole) pressure data for correct interpretation; relative insensitivity of fracture width to frac-fluid rheology; dominant effects of permeability variation, in contrast to existing theories; and dangerously fast convection (versus settlement) of proppant in imperfectly-contained fractures. We have recommended that many of the existing approaches to fracture design and execution be revised. We have also demonstrated, with numerous case studies, that a higher degree of treatment optimization can be achieved by more careful on-site analysis; our approach is to arrive at the optimum fracture treatment design by making use of flexible field operations, and real-time, real-data analyses of suitably designed minifrac tests with an appropriate fracture simulator and data-acquisition software package. Our normal requirement is to match measured net-fracture pressure (on-site, real-time) on all such carefully designed minifracs with the unique real-data simulator developed for GRI, then design the main fracture treatment, with the understanding that details may change as larger injection volumes experience new conditions in the reservoir.

THE SPE IMAGE LIBRARY SEARCH RESULTS REPORT

Paper Number	Author	Year
25414	1Johnson, D.E.; Wright, C.A.; Stachel, Alfred ; Schmidt, Holger; Cleary, M.P.	1993

On-Site Real-Time Analysis Allows Optimal Propped Fracture Stimulation of a Complex Gas Reservoir

The purpose of this paper is to provide a simple description and case-study illustration of the methodology and to document some of our primary conclusions and recommendations (Appendix).

TREATMENT MONITORING AND ANALYSIS

Since autumn 1988, the Wardböehmen Z1 well has produced gas from the Schneverdinger Sandstone layer of 50m thickness at a depth of 4,900 m (Fig. 1), having an effective permeability average of 0.2 mD in the drainage area of the well. Steady decline of the production rate had occurred, from an initial 9,000 to 4,000 m^3 (Vn)/h at a wellhead flowing pressure of 120 bars.

To improve the flowrate, a high-volume fracture treatment was carried out in December 1991. In preparation for the treatment, a so-called data frac (step-rate test and breakdown/minifrac) was pumped to determine the actual reservoir parameters relevant to fracturing, in order to optimize the propped fracture treatment and decide on the definitive fracture design.

A three-dimensional fracture simulation program was used during all operations. The measured data were fed directly and continuously into the simulation program, which computed forecasts of pressure and fluid losses, growth of fracture during treatment, proppant transport and fracture packing etc. It was also the first time in Germany that a true 3D simulator was used, including on-site real-time analysis.

Step-Rate-Test and Minifrac Data

During the step-rate test, mini-fracture and main fracture, the following data were recorded:

Data Recorded
Tubing pressure
Annulus pressure (isolated)
Bottomhole pressure (Minifracs only)
Bottomhole temperature (Minifracs only)
Flow rate
Slurry density

But Figs. 2 and 3 show the merged step-rate data as recorded by both service companies. Although both companies recorded in metric units, the GRI fracture simulator converted the data to oil-field units for its fracture-geometry calculations. The data shown in Figs. 2 and 3 were output from the simulator and are thus given in oil-field units (a metric option for the simulator will be available in the future). From Fig. 2(a) it is clear that a significant amount of near-wellbore/perf friction exists at the end of the last stage of the step-rate test. This is manifest in the sudden drop in bottomhole pressure (by 4.4 MPa-640 psi) at shut-in. Using this measured value of near-wellbore/perf friction, it was possible to calculate the friction drop down the wellbore of the YF650HT gel, which filled the wellbore at the end of pumping. The total friction drop in surface (tubing) pressure was about 14.2 MPa (2,060 psi). Subtracting the near-wellbore friction from this value, the total friction pressure drop for the gel was 9.79 MPa (1,420 psi), at 4.0 m^3/min (25.2 bpm) (the main-fracture pumping rate), which was reasonably close to the value implied from the service company's handbook of friction data; however, in general, service-company friction data may not be relied upon, e.g. to extract tortuosity by subtracting assumed pipe friction.

The total fluid pumped during the step-rate test consisted of approximately 2.8 m^3 (738 gal) of 2% KCl water, followed by 52 m^3 (13,720 gal) of YF650HT (the pad fluid). The reservoir caught pressure and began fracturing just after the start of pumping of KCl water at 0.5 m^3/min (3.15 bpm). The step-rate test showed that the (then) unknown payzone stress was no greater than 71.5 MPa (10,400 psi), the pressure at which the fracture began to propagate. A square-root-time plot of the shut-in pressure at the end of the step-rate test (shown in Fig. 2(b)) suggested closure was between 66 MPa (9,600 psi) and 64 MPa (9,300 psi), with the actual value probably about 65.3 MPa (9,500 psi). Service company personnel independently estimated this same closure-stress value. This agreement gave confidence as to the actual closure stress (±0.34 MPa ~ ±50 psi).

After the fracture created by the step-rate test was determined to be well past closure, the mini-fracture treatment began. It consisted of 42.0 m^3 (11,080 gal) of YF650HT fluid pumped at 4.0 m^3/min (25.2 bpm) (with this same fluid already in the wellbore from the step-rate test), followed by a wellbore flush of 38.0 m^3 (10,030 gal) of KCl fluid, also at 4.0 m^3/min (25.2 bpm). The data are shown in Fig. 3(a). The shut-in at the end of pumping reveals that significant levels of near-wellbore/perf friction were still present (2.7 MPa-400 psi), although the level had dropped by 1.4 MPa (200 psi) since the end of the step-rate test. The friction drop measured in the surface pressure was 18.3 MPa (2,660 psi). Subtracting near-wellbore friction from this value gave a friction pressure drop down the wellbore of 15.5 MPa (2,260 psi) at 4.0 m^3/min (25.2 bpm) for the KCl water (which filled most of the wellbore).

Judging from the recorded treatment data shown in Fig. 3(a), gas evidently entered the wellbore after the end of the minifrac. This would explain the different rates of pressure decline observed between the bottomhole pressure and the surface pressure (plotted on the same relative scale in Fig. 3(a): the hydrostatic head was reduced as gas displaced the liquid in the wellbore column of fluid. After 20 minutes of shut-in pressure decline, the bottomhole pressure had dropped 1.27 MPa (185 psi) more than the surface-pressure drop.

When the bottomhole pressure-decline data were plotted on a square-root-time plot, shown in Fig. 3(b), closure stress was determined to fall between 65 MPa (9,400 psi) and 66 MPa (9,600 psi), with the probable value about 65.3 MPa (9,500 psi). This agreed well with the value of closure stress estimated from the first shut-in to closure which followed the step-rate test. A Nolte plot suggested closure at about 62 MPa (9,000 psi), which is much lower than what is probably the actual value. If this were the true closure stress, then a matching of net pressures would yield a fracture that was on the order of 15% shorter and wider, and also much more efficient (in contradiction of later observations). We do not often find success with the Nolte methodology under most typical stratified reservoir conditions (see also Ref 3.)

Pressure Analysis

Background Information

As background to the discussion of the (net) pressure analyses, we present the following brief summary (see Refs. 2, 5, 6 for more discussion). For accurate simulation of the hydraulic fracturing process, bottomhole pressure, $P_{bottomhole}$, must be known with considerable accuracy. Bottomhole pressure, when not measured directly, can be calculated using the following formula:

$$P_{bottomhole} = P_{surface} + P_{head} - P_{friction} \quad (1)$$

$P_{surface}$ is the treating pressure measured at the surface; P_{head} is the hydrostatic head, or weight, of the fluid in the wellbore; and $P_{friction}$ is the head-loss due to friction in the pipe. Once bottomhole pressure is known, the net fracturing pressure (P_{net}, which is the pressure in the fracture above closure stress, $P_{closure}$) can be calculated by subtracting the closure stress and any pressure loss due to perf and/or near-wellbore friction, $P_{perf/near-wellbore}$, from the bottomhole pressure:

$$P_{net} = P_{bottomhole} - P_{closure} - P_{perf/near-wellbore} \quad (2)$$

Frictional losses in the wellbore and/or in the perf/near-wellbore region, the major unknowns in the equations above, are very difficult to *predict*, but they are relatively simple to *measure*, in most treatments. If flow-rate changes and/or shut-ins are incorporated into the treatment design, any error in the real-time calculation of net pressure by the GRI fracture simulator will manifest itself as sudden jumps or spikes (either up or down, depending upon whether too much or too little friction is being subtracted) in the net-pressure calculation, whenever the flow rate is changed. This simple and inexpensive technique is essential if the frictional effects are to be confidently and accurately subtracted from the net-pressure calculations.

The GRI 3D real-data fracture simulator uses the measured flow rate, and proppant concentration, along with fluid and reservoir descriptions, to predict net fracture pressure. This predicted net pressure can be compared, in a history-matching process, to the "observed" value of net pressure described in Eqn. (2). Unknown or uncertain reservoir properties, upon which the fracture growth (and therefore, pressure response) depends, can be changed and the simulator re-run until the observed and predicted net pressures match. A good match of net pressures will result in a good estimation of fracture extent and proppant placement. Obviously, the more accurately bottomhole pressure is known, the more accurately the true net pressure in the fracture can be calculated; thus, the more accurate will be the fracture geometry predicted from the net pressure matching process.

Minifrac History Match

The minifrac for this job was pumped down tubing, with two bottomhole gauges (one real-time and one memory) monitoring pressure and temperature. Table 1 gives the values of Young's Modulus used for the Schneverdinger sandstone and the bounding shales. These values were taken from measured core data for the sandstone (with values ranging from 23 GPa (3.3 x 10^6 psi) to 45 GPa (6.6 x 10^6 psi)), and from measured core values in another Rotliegendes formation (the Soltlingen gas field in the Hamburg-Hanover area) for the shale modulus. Poisson's Ratio is also shown in Table 1.

The stress profile used in matching both the minifrac and the main fracture treatment is shown in Table 2. These values were originally estimated from a lithology log (shown in Fig. 1(c)) for the pre-frac design simulations. The profile was altered on the day of the minifrac based on the measured value of confining stress in the payzone, and on other observations from the minifrac data indicating the extent of containment provided by stress barriers (especially the shale immediately above the Schneverdinger sandstone).

The net-pressure history match for the minifrac is shown in Fig. 4(a). The predicted net pressure does not match the steep pressure decline which occurs during the first four minutes of the minifrac, according to the observed net pressure. After four minutes the observed net pressure rises at a fast rate before leveling off eight minutes later. Although (Nolte-Smith) analysis of this observed pressure data would suggest an initial radial fracture which becomes almost completely contained after four minutes, it is difficult to imagine any realistic stress (or permeability) profile which would give this sort of drastic transition. It is most likely, in fact, that the early rapid pressure decline during the first four minutes of the minifrac is due to changing friction in the near-wellbore region as the gel first enters the fracture. The near-wellbore friction level for KCl was 4.1 MPa (600 psi), measured at the end of the step-rate test. Since the wellbore was full of YF650HT gel at the end of the step-rate test, it is quite possible that the friction level increased briefly as the gel first flowed through the near-wellbore region, and then decayed to a level of about 2.7 MPa (400 psi), measured at the end of pumping (at 4.0 m^3/min-25.2 bpm). If this was indeed what had happened, then the actual observed net pressure would be generally rising in time (indicative of a well-contained fracture), rather than falling and then rising.

Table 1: Three-layer model for Young's Modulus and Poisson's Ratio.

	Depth[1] (feet)	Young's Modulus (psi)	Poisson's Ratio
Upper Layer	0 to 15,990 (0-4,875 m)	7.0×10^6 (48 GPa)	0.20
Middle Layer	15,990 to 16,243 (4,875-4,952 m)	5.0×10^6 (34 GPa)	0.20
Lower Layer	16,243 to TD (4,952 m to TD)	7.0×10^6 (48 GPa)	0.20

[1] Depths are given as log depth.

About half way through the minifrac pumping, the levels of model and observed net pressures agree, as does the rapid falloff in pressure during shut-in. The pressure decline at the end was matched the day of the minifrac by inputting the log-derived core permeability, K_p (as listed in Table 2) in the GRI Fracture Simulator's reservoir screen, and varying the (unknown) ratio of pore-fluid permeability (K_p) to leak-off-fluid permeability (K_l). This ratio affects the value of the total leak-off coefficient, which determines the leak-off rates in the fracture. The ratio which matched the rate of pressure decline in the minifrac is shown in Table 3, along with several other reservoir parameters. All the values shown in Table 3 are used in calculating the total leak-off coefficient for each permeable layer, given in Table 2. The values given in Tables 2 and 3 are the same as those used in the final pressure match during the main fracture treatment. (Note that it is the total leak-off coefficient which is important to evaluate for the purposes of determining fluid leak-off into the formation. Even if some of the values given in Table 3 are not correct they do at least give the correct *total* leak-off coefficient needed to match the net pressures for the minifrac.)

In the plot of observed net pressure shown in Fig. 4(a), the near-wellbore friction has been taken out, based on the values measured at each flow-rate change and at the final shut-in. At the beginning and end of each flow-rate change (and also at the very end of pumping) the observed net pressure shows a spike (up or down). These spikes are actually due to inaccurate friction values during the transient time from one flow rate to another. It can be determined that the friction was subtracted from the data correctly by comparing the level of observed net pressure just *before the flow-rate change to the level of observed net pressure* just after the transition to a new flow-rate: when friction is subtracted correctly, the levels of observed net pressure before and after the transition will be essentially the same. This same idea also holds true of ISIP (zero flow rate). Fig. 4(b) illustrates early deceiving variations of $P_{near-wellbore}$ (Eqn. (2)).

Table 2: Reservoir leak-off properties.

Leak-off Properties		
Depth[1] (ft)	Permeability[2] (mD)	Leak-off Co. ft / (min)[½]
0	0.00	0.0
15,793 (4,815 m)[3]	2.00	6.56×10^{-3}
15,819 (4,823 m)	0.00	0.0
15,990 (4,875 m)[4]	0.31	2.65×10^{-3}
16,039 (4,890 m)	0.00	0.0
16,062 (4,897 m)	0.61	3.62×10^{-3}
16,105 (4,910 m)	0.00	0.0
16,124 (4,916 m)	1.00	4.63×10^{-3}
16,144 (4,922 m)	0.03	8.10×10^{-4}
16,170 (4,930 m)	0.15	1.81×10^{-3}
16,184 (4,934 m)	0.61	3.62×10^{-3}
16,216 (4944 m)	1.53	5.73×10^{-3}
16,229 (4948 m)	0.03	8.10×10^{-2}
16,243 (4952 m)	0.00	0.0

[1] Values of depth are given as log depth.
[2] Permeability values are for gas in the reservoir, and are taken from log-derived core values.
[3] Lower half of the Wustrow sandstone (with higher permeability).
[4] Top of the Schneverdinger sandstone.

The hydraulic dimensions corresponding to the net-pressure match shown in Fig. 4(a) are given in Fig. 4(b) which also displays the stress profile and the permeability layers. Fig. 4(b) shows the effect of containment which the stress barrier above the Schneverdinger sandstone has, as well as the containment effect caused by the higher permeability zone in the lower half of the sandstone.

Matching and analysis of the minifrac pressure data led to several conclusions about the reservoir conditions:

1) The level of net pressure at end of pumping (4.8 MPa-700 psi) indicated that the fracture was well-contained by stress above and (higher) permeability contrast below.
2) The rate of leak-off into the formation of the fracturing fluid, which was unknown before the step-rate test and minifrac, was determined through matching the rate of pressure decline during shut-in for the minifrac test.
3) The linear fall-off characteristic of the pressure during shut-in implied the existence of a large stress barrier which pinched back the fracture tip during shut-in. Otherwise, the pressure would have fallen off at a rate closer to $\sqrt{time}$.
4) The closure stress was much lower than had been originally expected. The closure-stress gradient reported by the service company was 16.5 kPa/m (0.73 psi/ft), whereas the measured closure-stress gradient was only 13.8 kPa (0.61 psi/ft). The lower stress level was possibly due to the partial depletion of the reservoir from production.

These observations and conclusions from the minifrac data led to an attempt to justify the existence of a large stress barrier in the upward direction (which was initially thought not to exist). It was known before the minifrac that the high permeability layers in the lower half of the Schneverdinger sandstone would provide downward fracture containment; however, it was expected that the stress barrier above the sandstone would offer only moderate containment. Yet, the minifrac data made it clear that upward growth was contained, as well as downward growth. When RWE-DEA informed us that the pore pressure was lower than that reported in the service company's original design (by 5.6 MPa-810 psi), this helped to explain the higher-than-expected stress barriers: the partially depleted reservoir meant that the stress contrast effectively was greater by about 60% of the decrease in pore pressure, i.e. by almost 3.4 MPa (500 psi).

Main Fracture Data

Although bottomhole pressure could not be recorded during the main fracture treatment, it proved extremely valuable to have during the minifrac for the following reasons:

1) It allowed the accurate measurement of the wellbore hydrostatic head for both the KCl water and the YF650HT gel. For such a deep well as this one, even a small error in wellbore head can translate to a serious error in calculating the observed net pressure from surface pressure;

Table 3: Leak-off parameters used in calculating leak-off coefficients.

(Pore Fluid Perm.) (K) / (Leakoff Fluid Perm.) (K')	84
Reservoir Pore Pressure	7,150 psi (49.1 MPa)
Initial Fracture Pressure	10,000 psi (68.7 MPa)
Reservoir Fluid Compressibility	1.0×10^{-4} 1/psi (1.46×10^{-4} 1/MPa)
Cold Leakoff Viscosity	1.0 cp
Hot Leakoff Viscosity	0.33 cp
Cold Reservoir Fluid Viscosity	0.03 cp
Hot Reservoir Fluid Viscosity	0.03 cp
Porosity	0.10

2) Similarly, knowing bottomhole pressure accurately allowed a more confident determination of closure stress when analyzing the pressure fall-off data;
3) Recorded bottomhole pressure allowed for the measurement of near-wellbore friction as distinct from wellbore friction. ISIPs recorded only from surface pressure give total friction levels, but do not allow for the determination of wellbore friction vs. near-wellbore friction;
4) In this particular instance, having bottomhole pressure data showed that the wellbore head changed in time during shut-in, evidently as gas entered the column of fluid (a common observation). Had only surface pressure been available for analysis, a lower level of fluid leak-off into the formation might have been calculated based on the (false) assumption that the wellbore head remained constant during shut-in. Knowing the leak-off accurately was critical in determining the correct pad volume for the main fracture treatment.

The original design agreed upon by DEA and the service company was to pump 950 m³ (251,000 gal) of pad into the formation for a period of four hours, followed by proppant stages varying from 0.25 kg/l (2 ppg) to 1.25 kg/l (10 ppg), pumping a total of 200 metric tons (441,000 lb) of proppant. Based on an analysis of the minifrac data (Figs. 4(a), 8), even considering the higher permeability zones down lower, we determined that pumping at most one half of the pad size originally proposed would be sufficient—in fact, necessary—to create a high-conductivity fracture with minimal downward growth and ideal proppant placement. Based on these considerations, the job was pumped with half the originally planned pad volume and with all the originally specified sand volume (plus a 5% excess volume of sand, which was on location during the job). The result was a fracture which had a good packoff of sand and closed only 25 minutes after the end of pumping. This packoff and fast closure of the fracture helped to minimize proppant convection--which can be detrimental to proppant placement[4].

The main fracture treatment was pumped two days following the minifrac, on December 6,1991. Fig. 5(a) shows the main-fracture treatment data as recorded by the service company. The treatment was pumped down the tubing (with annulus sealed off), with bottomhole pressure being deduced from the tubing pressure plus the hydrostatic head of the fluid, minus the wellbore friction.

Fig. 5(a) shows also the response of treatment pressure to the two ISIPs during the pad stage, and to the shut-in at the end of the job. The data show that there was a significant amount of total friction (in the wellbore and/or near-wellbore region), which apparently remained constant throughout most of the job after falling early on, due to tortuosity removal, as observed on the minifrac. The two ISIPs during the pad gave total friction levels of 11.3 MPa (1,640 psi) and 11.4 MPa (1,650 psi), respectively, thus implying constant (unchanging) near-wellbore tortuosity. Subtracting out the expected value of wellbore friction for the gel (measured at the end of the step-rate test) gave a near-wellbore friction level of approximately 1.6 MPa (230 psi), which was 2.8 MPa (410 psi) lower than the level measured at the end of the step-rate test.

The total friction drop at the end of pumping, with KCl filling most of the wellbore, was 10.4 MPa (1,520 psi). The lengthy shut-in time which followed was used to determine the time for the fracture to close on proppant.

Main Fracture History Match

The main fracture treatment was pumped two days following the minifrac. The final treatment schedule was chosen on the evening of the minifrac, after the service company had time to analyze the minifrac data. All agreed to cut the pad by 50%, based on the minifrac data which had an efficiency at end of pumping of about 40%. We were satisfied with this level of reduction, based on our prediction that the final efficiency at the end of the main fracture would in fact be much lower (closer to 20%) as the fracture grew into the higher permeability lower zone.

All of the reservoir properties used in the minifrac analysis (see Tables 1-3) were used in analyzing the main fracture treatment data. These values are nearly identical to the values selected on-site during the analysis of the minifrac.

The match of predicted versus observed net pressures is shown in Figs. 5(b), 5(c). Most of the friction (wellbore and near-wellbore) was removed from the observed net pressure shown in Fig. 5(b). Pressure spikes (up or down) in the observed net pressure at the beginning and end of each ISIP are again due to inaccurate calculation of changing friction levels during the transition from beginning of ISIP to end (and vice versa). To see that the correct level of friction has been subtracted from the data, note that the pressure levels just before the flow-rate goes to zero, and just after it goes to zero, are very close to the same value. If too much or too little friction had been taken out, the levels would not have been the same. Of course, it is possible to remove all the friction, by forcing a perfect match, but this is usually time consuming and uninformative. It also helps to leave the early (variable) tortuosity, which emphasizes the errors commonly made when interpreting this as "breakdown" and/or unconfined growth.

During the first 30 minutes of pumping (approximately), the observed net pressure shown in Figs. 5(b), 5(c) shows a continual decline. Though a typical interpretation of such a decline would be "initiation" or "breakdown" and radial growth, it is clear from the later minifrac data that such growth is not occurring. The pressure decline is almost certainly an error in subtracting (constant) friction from the data. Because there were no ISIPs or flow rate changes (FRCs) during the first 30 minutes of pumping, it is impossible to say definitively what the levels of friction in the wellbore and near-wellbore region were—they could only be assumed to be constant, as measured a little later during the job, at the first ISIP.

At the beginning of the 1.0 kg/l (8.4 ppg) proppant stage, just as the proppant passed through the perfs, the pressure increased by 0.7 MPa (100 psi) within a three-minute period. This pressure rise was obviously a near-wellbore effect, where there was possibly some bridging of proppant as it flowed from some of the perfs to the main fracture body.

The pressure rise in observed net pressure toward the end of the job may have indicated that the proppant had started to reach critical volume fraction in the fracture and that additional sand being pumped was forming an effective packoff in the fracture. The GRI fracture simulator suggests the beginning of the packoff, but does not model (in sufficient detail) the near-wellbore tortuosity restriction, which is also clearly a part of the later pressure rise: tortuosity plays a strong role when concentrations of order 8 ppg are reached.

The initial rapid pressure decline just after shut-in was also not matched by the predicted net pressure. The pressure drop probably results from an equilibration of pressure in the proppant-packed fracture at the end of pumping, and not pressure decline due to leak-off. The fast falloff to closure, after the initial equilibration, may still represent a component of fracture-pressure equilibration since the fracture was packed off so well. The GRI fracture simulator's predicted net pressure does not match the exact rate of observed-pressure falloff to closure. This is due primarily to the approximation made in the model that the ratio of pore-fluid permeability to leak-off fluid permeability (K_p/K_l in Table 3) was assumed constant for the entire reservoir. In fact, it is more probable that the relative permeability to water for the lower half of the Schneverdinger sandstone is higher (i.e. the ratio K_p/K_l is lower) because of the higher water saturation in that region. Modelling a higher relative permeability to water in the lower zone would have increased the overall leak-off rate at the end of the job and matched the leak-off at the end slightly better. Fig. 5(c) shows the effect of lowering the K_p/K_L ratio for the lower half of the payzone. While this match is obviously better than the one shown in Fig. 5(b), the latter has been included to illustrate the advantages of on-site fracture analysis, since the reservoir parameters used in the match are those chosen on-site from the minifrac analysis.

The hydraulic-fracture dimensions corresponding to the pressures predicted in Fig. 5(c)are shown in Fig. 5(d), a 2D view showing a profile of the stresses, as well as the permeability profile in the reservoir. It is evident from Fig. 5(d) that downward growth was restricted by the higher permeability layers in the lower half of the Schneverdinger sandstone, while upward growth was constrained by the shale barrier above. The shale barrier above prevented the fracture from intersecting the permeable section of the Wustrow sandstone.

Fig. 5(d) also shows the concentration of proppant in the fracture at the point of closure on proppant. The profile represents the effect which proppant convection has on the overall proppant-concentration profile. For this fracture, convection was minimized, both because the fracture was well-contained and, more importantly, because the pad volume had been dramatically reduced from the volume originally designed.

Fracture Design With 25% of Original Pad Size

The pad volume chosen for this propped fracture treatment was only 50% of the volume originally agreed upon by the service company and RWE-DEA. The new value was selected after an analysis of the minifrac data: it was, in our opinion, a conservative pad size for this job, but the decision not to try for an aggressive packoff was made for (at least) three reasons:

1) This was the first job we had done for RWE-DEA, and a screen-out (even if unrelated to pad volume) could have created doubts about our credibility;
2) Because this was the first frac job RWE-DEA had done in this formation (and no other fracture treatment data from other companies were available to analyze), there was a higher degree of uncertainty which existed relating to possibility of a screen-out;
3) The unavailability of downhole or reflected pressure data for more precise real-time determination of net pressure during the main frac made it unwise for us to take the risk without the feedback needed to respond to a developing screen-out.

However, in the interest of analyzing what may have happened had a much smaller pad size been pumped, the GRI fracture simulator was used to model the results of pumping a fracture treatment where only 25% of the originally proposed service-company pad volume was used. The same reservoir conditions used in matching both the minifrac and the main frac were assumed in this simulation (see Tables 1–3). Fig. 6(a) shows the net pressure prediction for such a scenario. The net pressure continually rises as sand is pumped into the formation, creating an effective packoff. The efficiency at the end of pumping is 20%, 4% higher than in the actual frac job, where there was twice as much pad. Complete closure occurs about 40 minutes after shut-in. Fig. 6(b) gives the propped dimensions for the net pressure plot shown in Fig. 6(a).

Table 4 offers a comparison between the fracture actually created using 50% of the originally proposed pad, and the design simulation assuming only 25% of the originally proposed value.

Table 4: Comparison of fracture sizes, assuming 25% vs. 50% of the originally proposed pad size.

	25% Pad Volume	50% Pad Volume
Propped Length	140 m (460 ft)	177 m (581 ft)
Propped Upper Height	29 m (95 ft)	28 m (93 ft)
Propped Lower Height	46 m (151 ft)	50 m (164 ft)
Aspect Ratio	3.78	4.52
Efficiency[1]	0.21	0.16
Average Proppant Concentration	12.4 kg/m³ (2.54 lb/ft³)	9.83 kg/m³ (2.01 lb/ft³)

[1] Efficiency at end of pumping.

From Table 4 it is clear that, although both fractures have similar dimensions, the average proppant concentration is higher (by 25%) for the smaller pad volume. The fracture with the smaller pad volume has the particular advantage of having 4 m (13 ft) less growth in the downward direction, where water saturations are higher. If near-wellbore tortuosity were not problem such that there had been a real fear of near-wellbore screen-out, then the smaller pad volume may have produced the more optimal fracture for the given amount of proppant pumped: a slightly shorter frac with 25% higher average proppant concentrations.

For this fracture treatment in the Wardboehmen Z1 well, it is not certain that pumping a smaller volume would have, in fact, been the better treatment. The results of gaining a 25% higher conductivity fracture would have to be weighed against the possible increased likelihood of near-wellbore screen-out before all the sand was pumped into the formation. Convection was not considered a major problem, because of the downward (increasing) permeability barrier. However, for jobs in other reservoirs, the safest approach may be to gradually cut back on the size of the pad for each successive job, rather than cutting the pad all the way to 25% of the size originally proposed on this present treatment: in fact, the only way to truly test the limits in any reservoir is to pump increasingly aggressive jobs with careful monitoring and on-site analysis.

CONCLUSIONS AND RECOMMENDATIONS

The fracture stimulation of the Schneverdinger sandstone in the Wardboehmen Z1 well proved quite successful in producing an almost optimal propped fracture in this reservoir for the total amount of sand pumped. The success of the fracture treatment was aided by our analysis of a minifrac pumped two days prior to the main fracture treatment, in conjunction with data provided by the calibrated permeability log. The minifracture was pumped for the explicit purpose of evaluating more accurately the characteristics of the reservoir, including closure stress, leak-off rates, and stress (and permeability) profile, in order to optimize the pad volume for the main fracture treatment. The availability of measured bottomhole pressure increased the accuracy and confidence of the analysis made using the minifrac data.

The analysis of the minifrac yielded an estimated fracture efficiency of 40% at the end of pumping. However, the fracture efficiency at end of pumping for the main fracture was only 16%, substantially different from the minifrac. Because the GRI fracture simulator was able to model the variable high-permeability layers in the payzone and those immediately below it, we had anticipated the drastic reduction in efficiency and determined a pad volume based on this estimate. Had the pad volume been chosen based only on the efficiency of the minifrac at the end of pumping (as would have been the case using a 2D simulator, for example), the final pad volume selected may have been far too small, increasing the chances for screen-out to occur. On the other hand, the originally proposed pad volume was far too large.

Using the diagnostics (i.e. ISIPs and FRCs) which we requested be implemented during both the minifrac and the main fracture treatment, we were able to monitor accurately the changing near-wellbore tortuosity (the near-wellbore friction). Based on our analysis of the diagnostics, we were able to determine that near-wellbore tortuosity—which was quite high at first—decreased to marginally acceptable levels before the start of proppant. This observation was significant, because it gave increased confidence that there was less likelihood of a near-wellbore screen-out resulting from high proppant concentrations flowing along a tortuous pathway near the wellbore. Had the high levels of near-wellbore friction remained as the pad was pumped, an alternative to the proposed treatment schedule would have needed to be discussed—in particular, a decision would have been necessary on whether or not to pump the last stage of proppant with the highest proppant concentration (1.25 kg/l–10.4 ppg). This stage would have been in greatest danger of causing a screen-out at the wellbore. Future jobs may allow the use of our proppant slug technique to reduce or to eliminate this tortuosity problem.

We were able to monitor the fracture growth in real time by interfacing the GRI fracture simulator with the service company's serial port and receiving pressure, flow, and density data as it was recorded. Predicting fracture size in real time allowed us to estimate how much downward growth had occurred as the job progressed. Using the real-time data, the GRI fracture simulator matched the approximate levels of net pressure throughout the job. The GRI fracture simulator also predicted closure of the fracture on proppant within 15 minutes of the actual closure time, after a pumping time of nearly four hours had elapsed. In fact, the only major difference between the observed net pressure and the best estimate from the GRI fracture simulator can most reasonably be explained as being due to near-wellbore resistance to proppant injection: instead of a gradual build ("quadratic backfill") in the pressure profile, it turns sharply upward when a new high concentration (8 ppg) hits the near-wellbore region. This is a clear indication of the potential for reducing such effects in future jobs with proppant slugs, as already conducted by us on recent jobs [Refs. 6, 7]. This would then allow a better pack-off (with higher concentration) and minimize convection [Ref. 4].

More general conclusions and recommendations are provided in the Appendix and in Refs. 6, 7; some of these apply directly to this job, which is now part of our extensive database.

ACKNOWLEDGEMENTS

The authors are grateful to the management of RWE-DEA for permission to publish the case study. Appreciation is also expressed to the service company personnel for their co-operation on the job. Finally, the Gas Research Institute is acknowledged for supporting the development of the real-time analysis system and many other field applications—some of which have been published, but many remain to be published in future papers.

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APPENDIX

Conclusions and Recommended Procedures for Hydraulic Fracturing Developed on the Basis of GRI Research (1983-1992).

These have been discussed already in Refs. 4, 6 (the latter also defines the benefits and cost-savings). These are truncated here, with some minor additions concerning foam:

1. A dominant mechanism is convection[4], presently not even visualized by industry designs and associated simulators. This not only controls achievable propped fracture lengths opposite pay (often as a small fraction of created length) but also requires use of minimal fluid volume. Many jobs (especially in tight formations) contain too much volume, especially too much pad. Use of foam jobs makes it even more difficult to avoid convection, which may damage production from uncontained fractures, by failing to effectively prop payzones. Operators who still use foam may consider a lower foam quality for tail-in stages.

2. Experience with data shows that optimal treatment volumes and staging often differ dramatically from those currently employed, because of many inadequacies in simulators used.

3. The essential feature of a successful fracturing treatment is an effective pack-off at the end of the job. This is even more important in low-permeability reservoirs to achieve a reasonable propped fracture length opposite pay. Indeed, considerations such as water-sensitivity and/or low pressure have led to the selection of foam jobs in many reservoirs, contrary to this primary consideration: we have increasing evidence that water damage has limited effects and is far less a consideration than placing the proppant opposite selected pays—which is much more difficult to achieve with (more expensive) foam jobs.

4. The common use of flowback at the end of jobs should only be justified when a pack-off is not achieved and we have then used limited flowback to retain proppant in the wellbore as a supply to the near-perforation region as convection removes proppant from there before closure.

5. Many premature screen-outs may be avoided and optimal fracture designs may be achieved by performing some relatively straightforward diagnostics, mainly during pre-pad and/or pad stages (on the morning of the job), if necessary using the injection of proppant "slugs" during such (equivalent) minifracs to check for, and design against, near-wellbore tortuosity and potential screen-out.

6. The acquisition of adequate data and proper determination of net-pressure behavior continually during the job is needed for essential (on-site) redesign and fracture optimization. It is not realistic in general to claim effective fracture execution on the basis of pre-frac designs, even if calculated with realistic models, from log and core data or even from small minifracs.

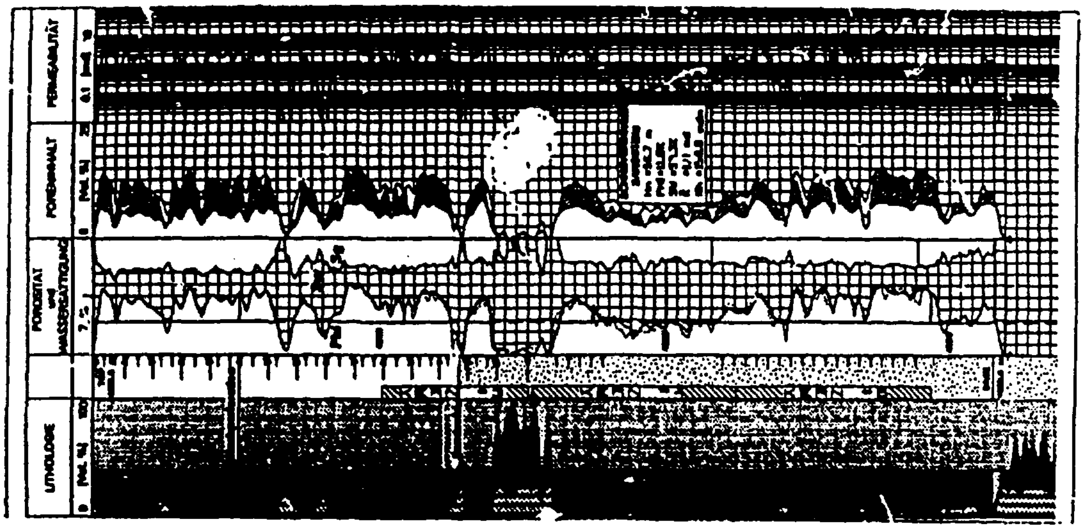


Figure 1(c): Lithology log for the Wardboehmen Z1 well.

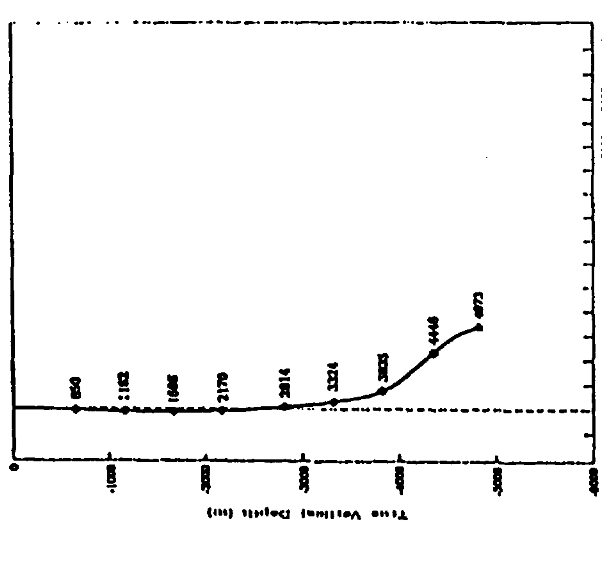


Figure 1(a): Vertical projection of the Wardboehmen Z1 well.

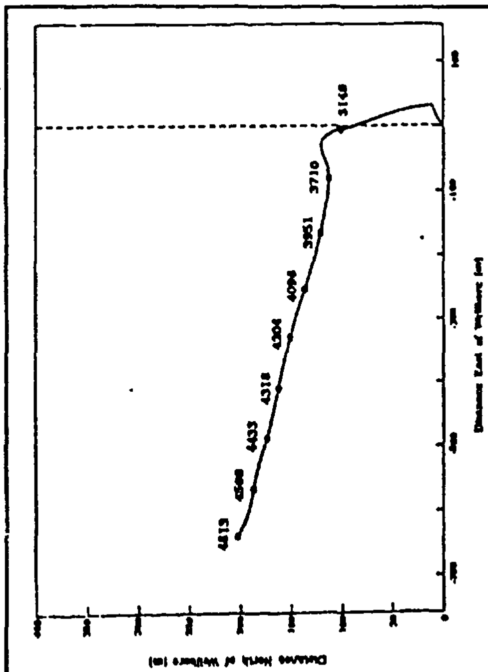


Figure 1(b): Horizontal projection of the Wardboehmen Z1 well.

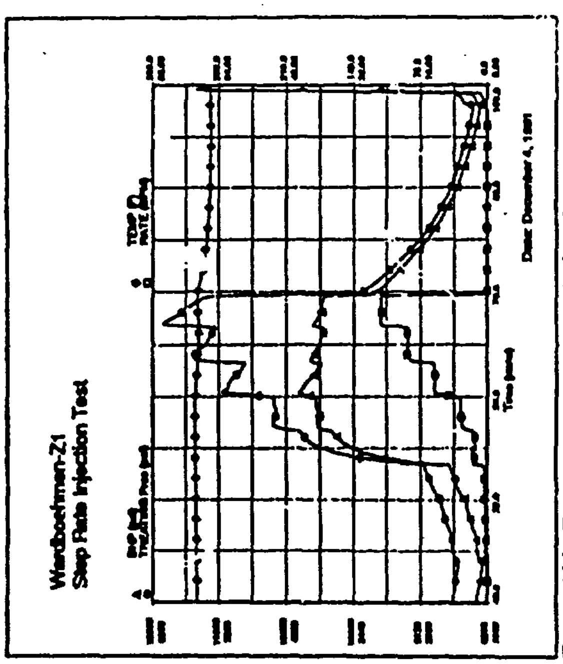


Figure 2(a) Database data recorded during the step-rate test.

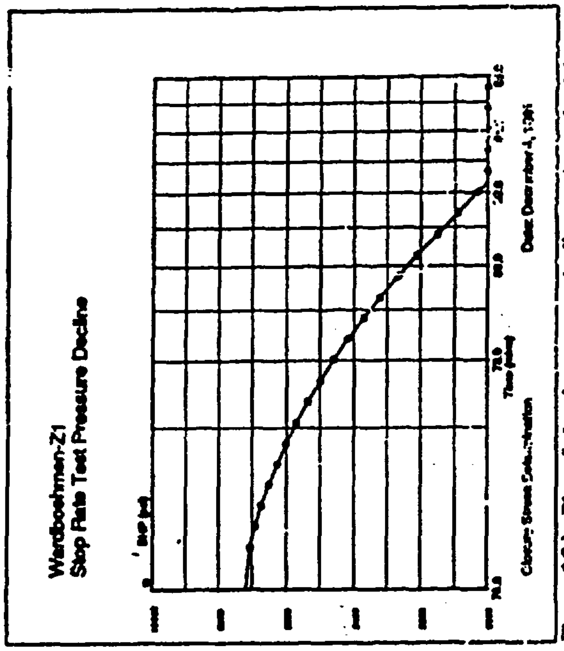


Figure 2(b) Plot of shut-in pressure decline at the end of the step-rate test, plotted on a square-root-time scale.

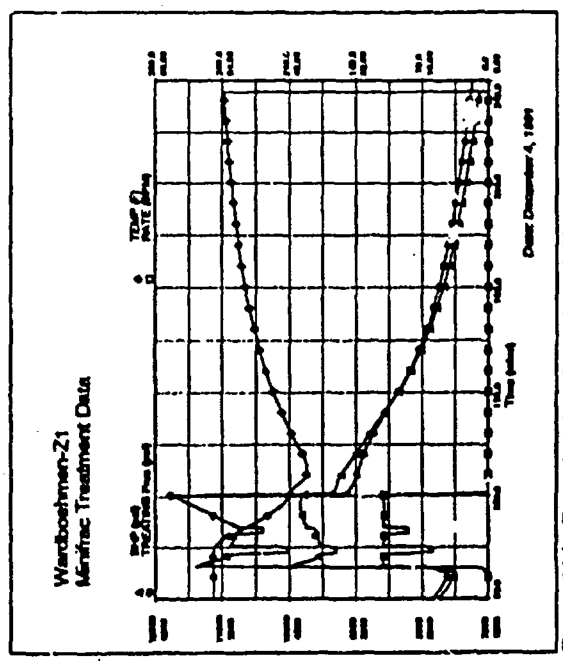


Figure 3(a) Recorded data from the minifrac treatment.

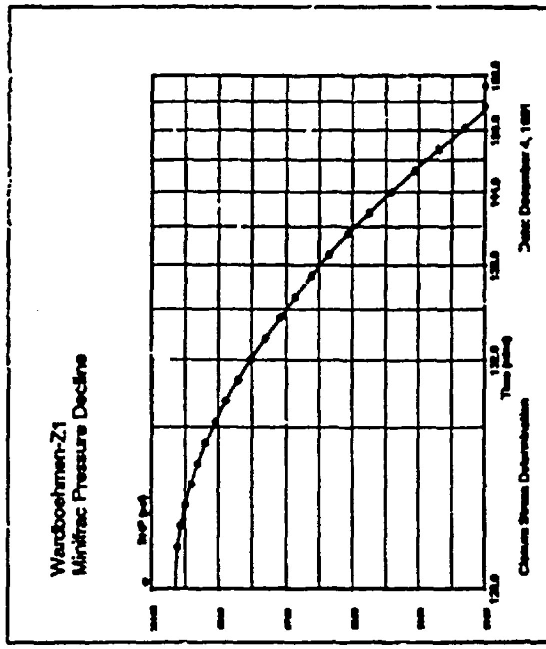


Figure 3(b) Plot of bottomhole pressure for minifrac on a square-root-time plot.

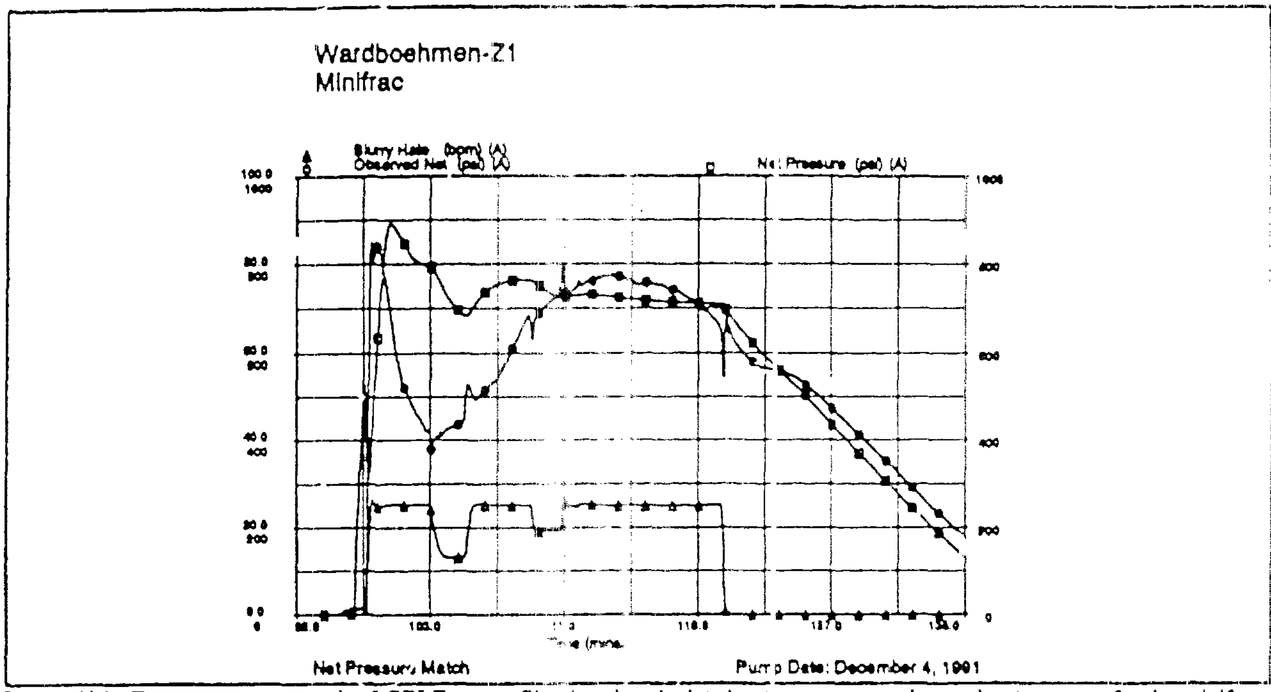


Figure 4(a) Excess-pressure match of GRI Fracture Simulator's calculated net pressure vs. observed net pressure for the minifrac.

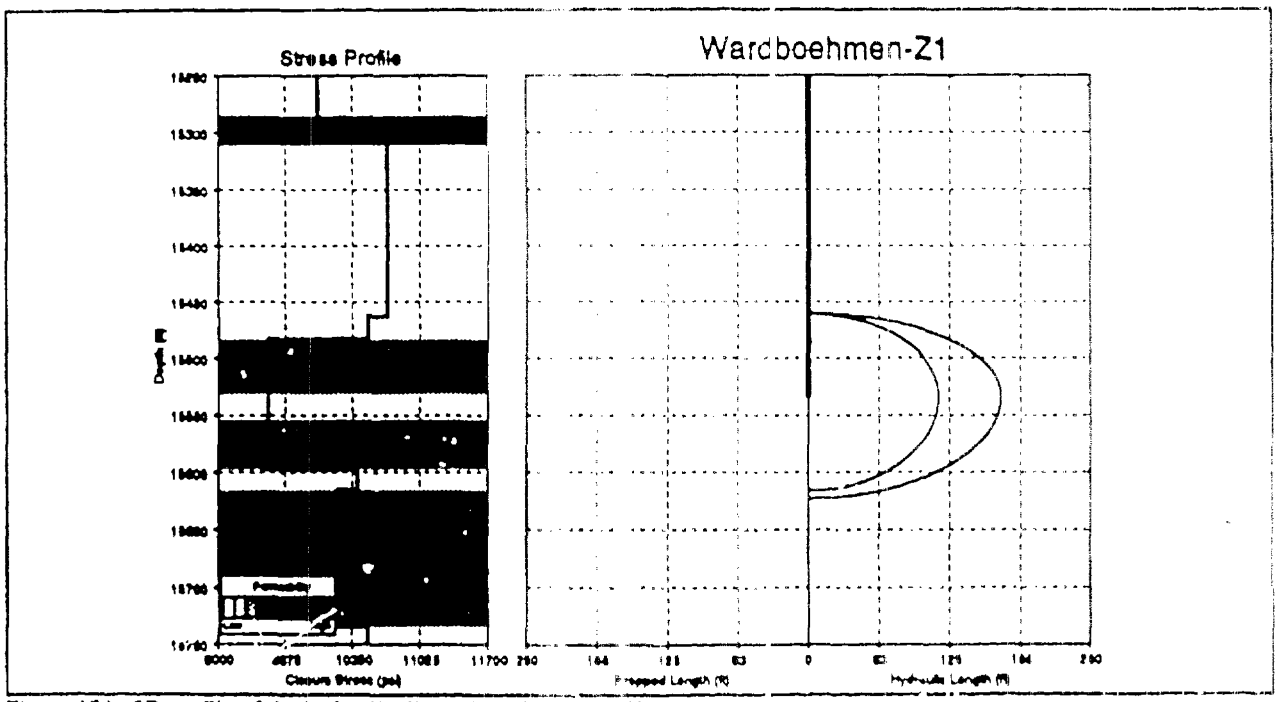


Figure 4(b) 2D profile of the hydraulic dimensions for the minifrac.

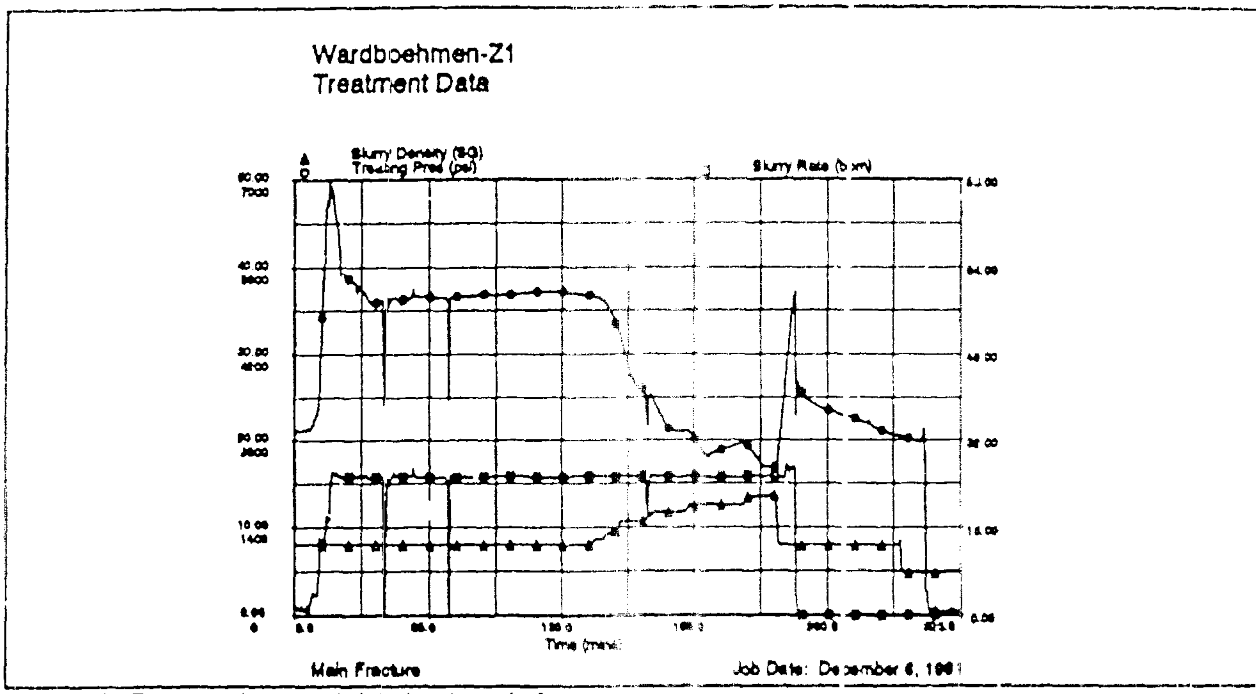


Figure 5(a) Treatment data recorded during the main fracture treatment.

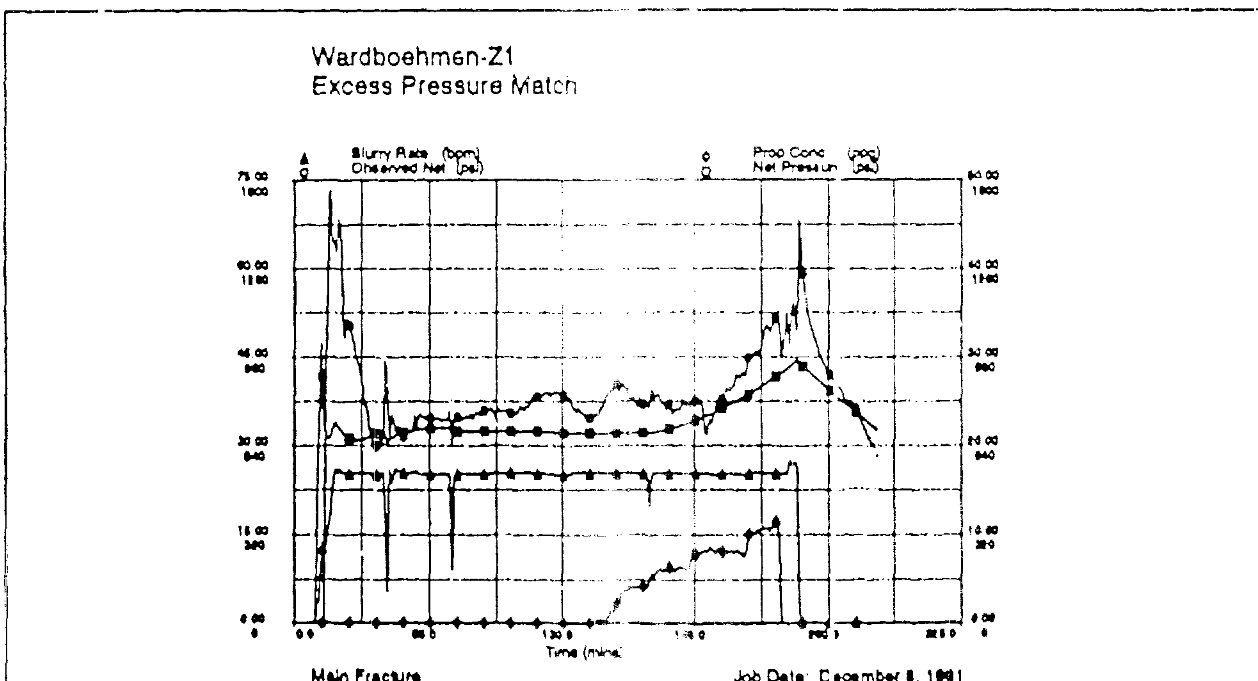


Figure 5(b) Excess pressure match for the main fracture treatment using minifrac-derived reservoir parameters.

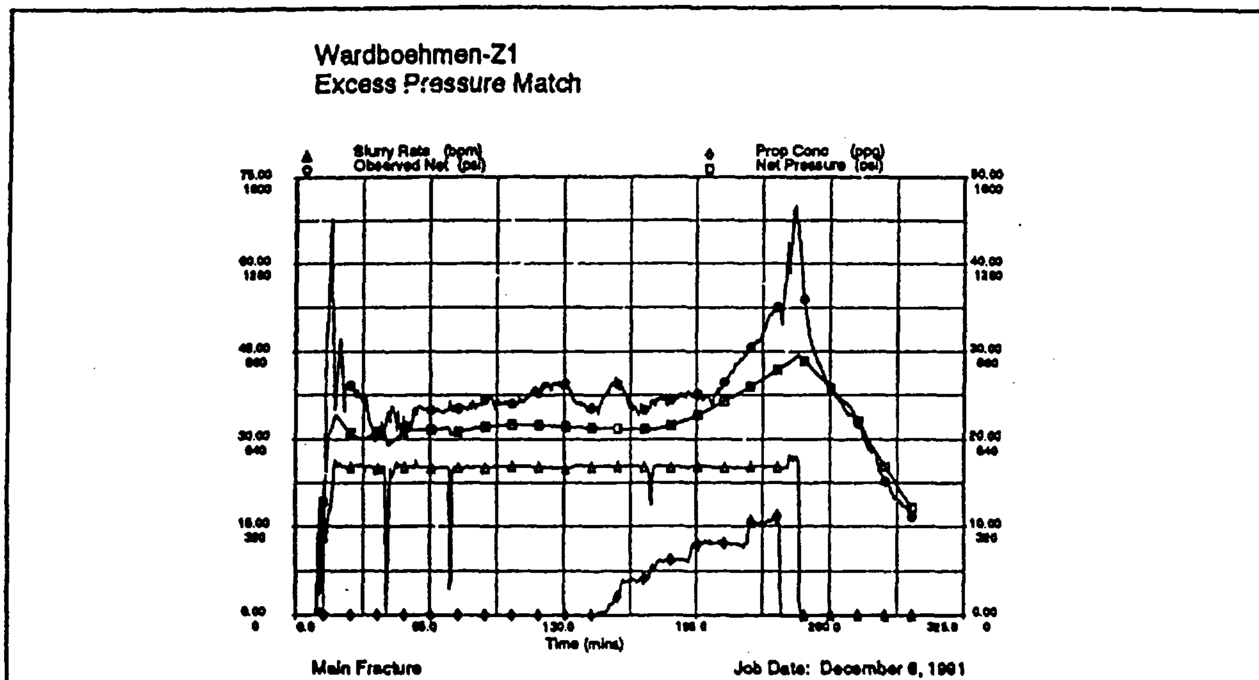
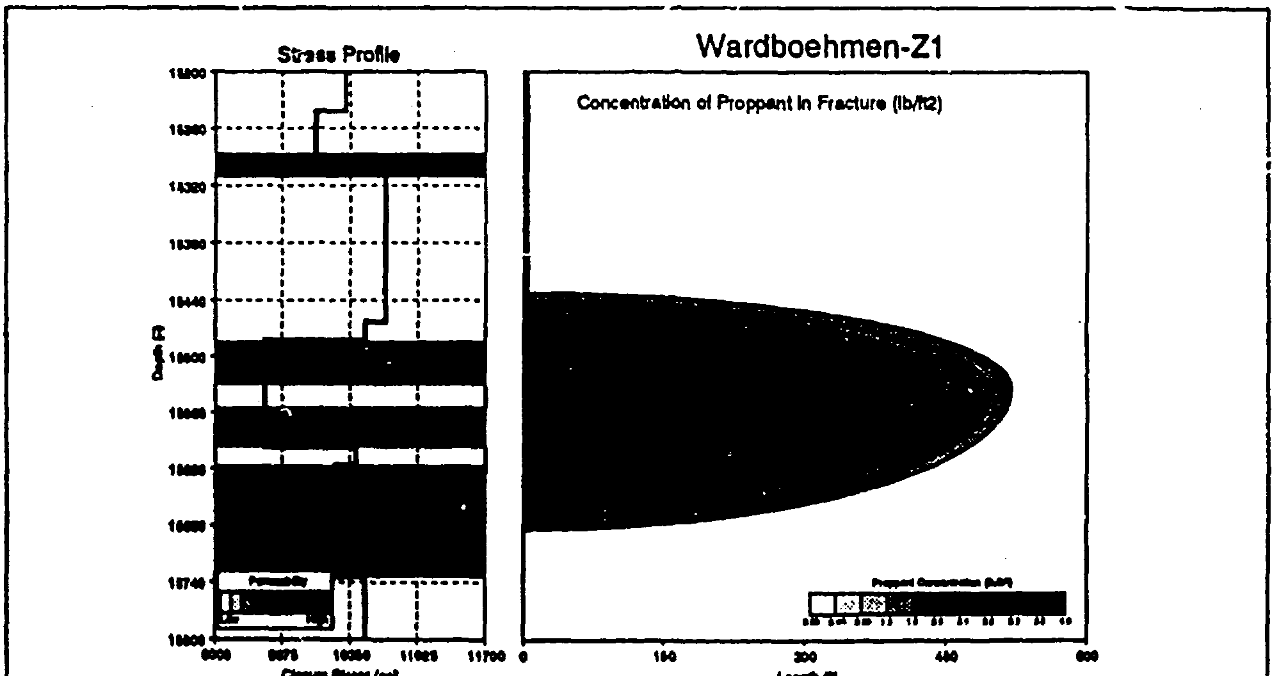


Figure 5(c) Excess pressure match for the main fracture treatment (higher permeability lower zone).



5(d) 2D view of the concentration of proppant in the fracture (lb/ft^2) for the main fracture (higher permeability lower zone).

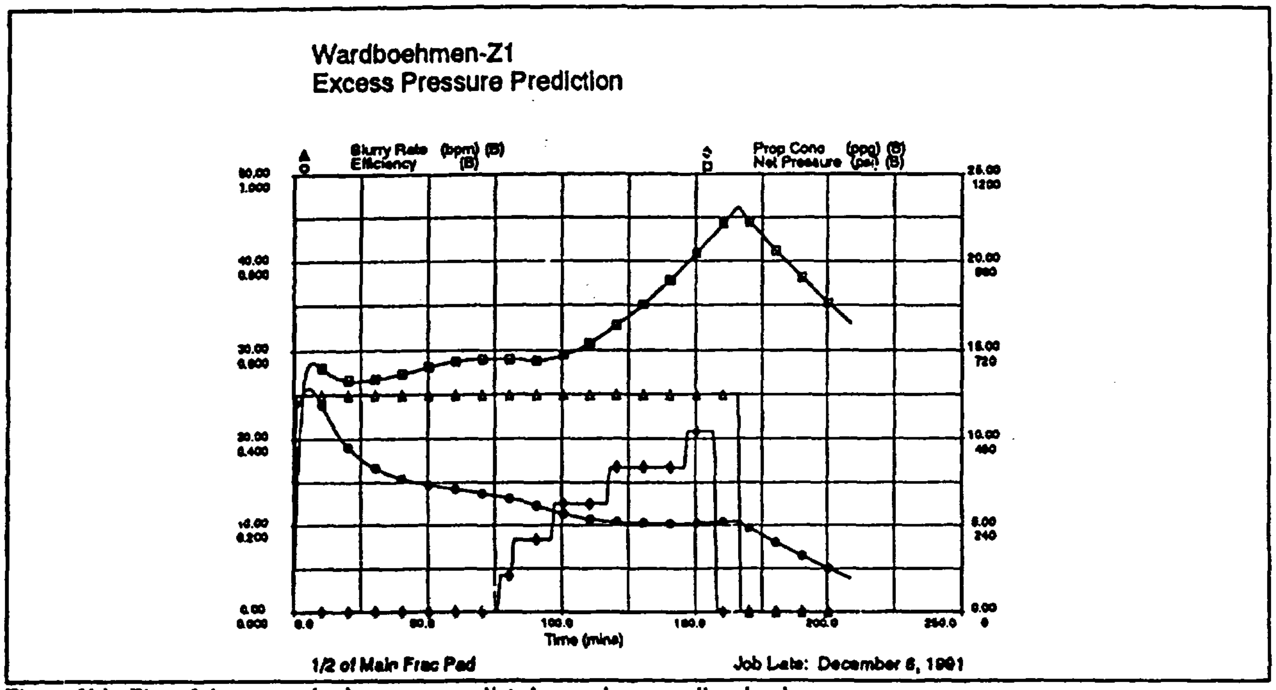


Figure 6(a) Plot of the excess (net) pressure predicted assuming a small pad volume.

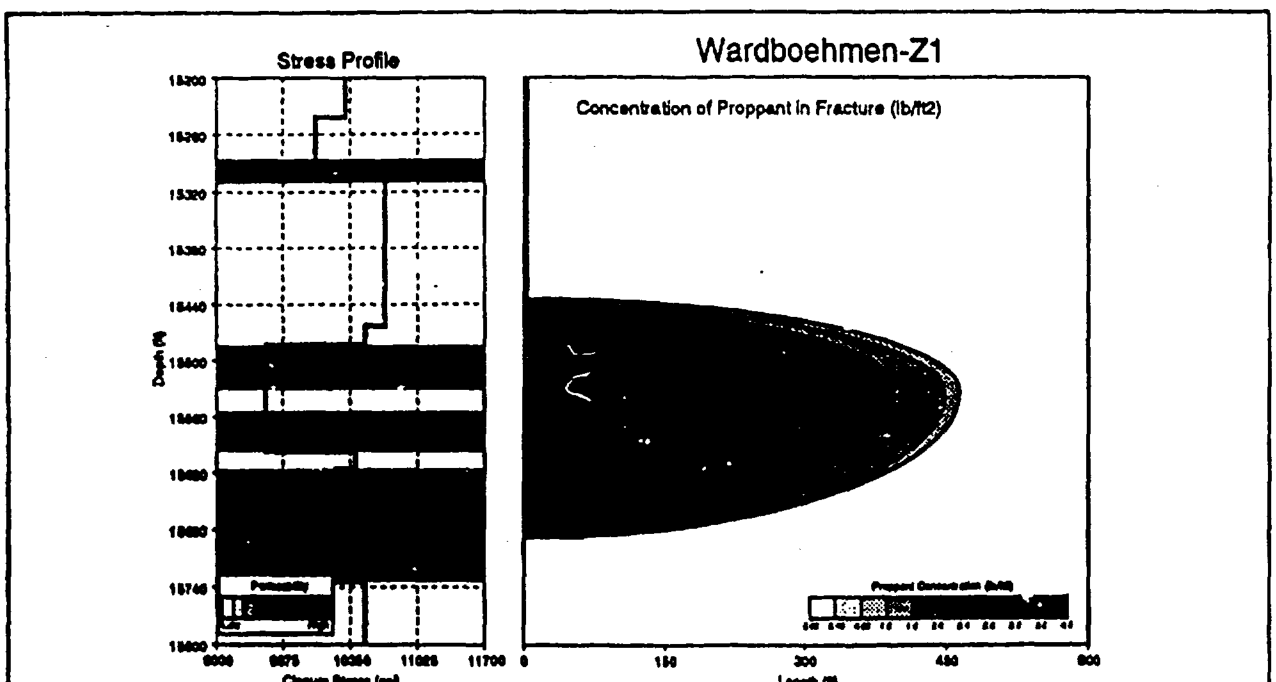


Figure 6(b) Proppant profile predicted assuming a small pad volume.

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Hydraulic Fracture Performance in the Moxa Arch Frontier Formation

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SPE Members

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ABSTRACT

A comparison of hydraulic fracture performance during the initial development of the Moxa Arch Frontier sandstone in southwestern Wyoming (1975-85) through infill development in 1989-91 (320 acre spacing) and 1992 (160 acre spacing) is presented. The evaluation includes 3D hydraulic fracture modeling of reflected bottom hole pressures measured on 36 wells completed in 1992. In addition, *in situ* stress test results from two wells are integrated with 3D fracture modeling and reservoir simulation of post-fracture well performance to evaluate the evolution of fracture treatments over 17 years of development.

The results from over 200 fracturing treatments were used to quantify the effect of treating fluid and proppant type on well performance. Detailed 3D fracture modeling illustrates the effects of *in situ* stress and leakoff properties on fracture geometry. The results from 3D fracture modeling of 33 mini-fracs indicates vastly different fluid loss behavior from well-to-well and a variation of *in situ* stress within the Moxa Arch. The performance of 1992 infill wells stimulated with guar-based gels (borate & zirconium crosslinked) and sand is similar to initial development wells stimulated using guar-based crosslinked polymers and sand; however, the performance of 1989-91 infill wells stimulated using CO_2 foam and intermediate strength ceramic proppants (ISP) did not perform as well as the water-based fluids and sand treatments. Fracturing net pressure data are presented that illustrate excess pressures due to "proppant effects" and breakdown of stress barriers during fracturing that occurs in many treatments.

INTRODUCTION

The Moxa Arch is located in the Green River Basin in southwestern Wyoming at the intersection of Lincoln, Uinta, and Sweetwater counties. The development of the Moxa Arch Frontier was made possible through the advent of massive hydraulic fracturing (MHF) techniques in the late 1970's. Stimulations during initial development consisted of water-based fluids (210 Kgal) and 20/40 mesh sand (450 Klbs) with sporadic use of other fluids (emulsions and oil-based) and sintered bauxite. During 1989-91 infill drilling, the majority of the fracture treatments utilized CO_2 foam (180 Kgal) and intermediate strength proppants (ISP, 440 Klbs). Based on the performance of the 1989-91 treatments, current designs utilize water-based gels crosslinked with borate or zirconium (170 Kgal) and sand proppants (560 Klbs).

Initial field development was on 640 acre spacing with most drilling completed by 1982. Increased density drilling was initiated in 1989 with the drilling of an additional well on each 640 acre spacing unit. This infill program was completed in 1991. In December 1991 the Wyoming Oil & Gas Conservation Commission authorized further infill development by granting an optional third and fourth well per spacing unit in a limited area of the Moxa Arch. This program was essentially completed in 1992.

Union Pacific Resources drilled 70 wells in the area designated for 160 acre development and acquired a significant data base of hydraulic fracture treatment behavior and well performance. This study covers hydraulic fracture performance in the area

IN SITU STRESS

In situ stresses in selected intervals were measured in two wells[4,5] to develop stress profiles for subsequent 3D fracture modeling. The Fabian Ditch (FD) 3-2 and 4-34 were selected to provide stress data in the northern end of the 160 acre development area. *In situ* stress data was already available on two wells in the southern part of the study area.[6,7,8] The results of the stress tests are summarized in Table 2. The results from the Fabian Ditch 3-2 are depth shifted to the Fabian Ditch 4-34 log depth for comparison.

Table 2 - Stress Test Results

	Gradient, psi/ft		
Depth	FD 4-34	FD 3-2	Zone
11463		0.85	shale
11563		0.77	fluvial sand
11602	0.82		fluvial siltstone
11623	0.74	0.70	marine sand
11661	0.84		shale
11693	0.84		shale
11757		0.82	shale
11780	0.82		shale
11887	0.79		shale

The stress test results indicate stress gradients above the Frontier sand of about 0.85 psi/ft. The stress gradient in the fluvial sands/siltstones ranges from 0.77 to 0.82 psi/ft. The shales below the Frontier exhibit stress gradients of 0.79 to 0.84 psi/ft. It is important to emphasize that the stress gradients measured in the marine sandstone ranged from 0.70 to 0.74 psi/ft with the wells only 1,800 ft apart. This difference cannot be linked to current reservoir pressure variations as test data indicates essentially identical pressures[9,10] in these two wells. Therefore, it is probable that *in situ* stress varies as much as 500 psi locally within the Frontier sands.

In addition, dipole sonic logs were run in the two stress test wells to acquire reliable shear wave transit time that could be used (along with compressional wave transit time) to calculate Poisson's ratio using the following equation.[11]

$$\mu = (0.5 \cdot \Delta T_s^2 - 1)/((\Delta T_s/\Delta T_c)^2 - 1) \quad \text{.............(1)}$$

where: ΔT_s = shear wave transit time
ΔT_C = compressional wave transit time
μ = Poisson's ratio

The measured stresses were used to calibrate log calculated *in situ* stress gradients using the following equation.[12]

$$S_h = \frac{\mu}{(1-\mu)}(S_v - P) - P + C \quad \text{.................(2)}$$

where: S_h = horizontal stress, psi/ft
S_v = overburden stress = 1.1 psi/ft
C = constant = 0.04 psi/ft
P = pore pressure = 0.58 psi/ft

Figure 2 compares the log-calculated stress gradients to the measured data. A good correlation between log-calculated stress and measured stress was obtained using Equation 2 with the above values for S_v, P, and C. The log-calculated stress profile for the Fabian Ditch 4-34 is presented in Figure 3.

The stress data (both measured and calculated) indicates a slightly decreasing stress gradient from 11,600 ft to 12,000 ft. This may indicate a tendency for preferential downward fracture growth.

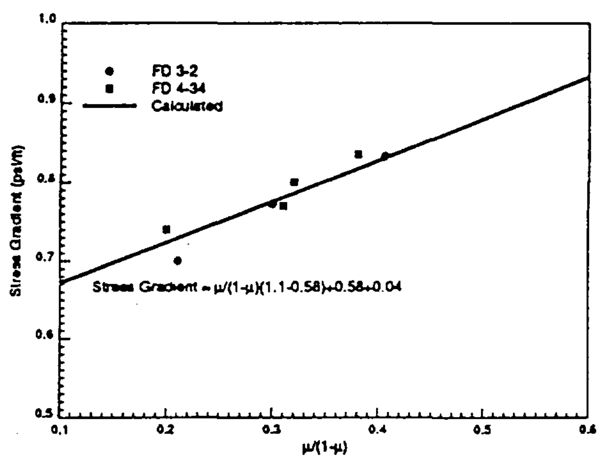

Figure 2 - Log-Calculated & Measured Stresses

FRACTURE PERFORMANCE

The results from hydraulic fracturing treatments on 160 acre development wells were compared with the performance of previous treatments on 320 acre development wells and initial development wells to evaluate the effectiveness of various stimulation fluids and proppants. The analysis includes detailed 3D hydraulic fracture modeling of measured net pressures from 36 wells and mini-frac data from 33 wells.

Net pressure data was obtained by stimulating the wells down the annulus of 5-1/2" casing and 2-3/8" tubing ("dead-string") while monitoring the tubing pressure. The tubing was initially displaced with 1.5 tubing volumes of water to ensure an accurate

The model predicted hydraulic fracture length is 750 ft, with a propped length of 700 ft. The estimated fracture height is about 600 ft at the wellbore, with about 550 ft propped. The history match indicates an average proppant concentration in the fracture of 1.2 lb/ft.[2] Figure 6 illustrates the model predicted fracture geometry and proppant distribution.

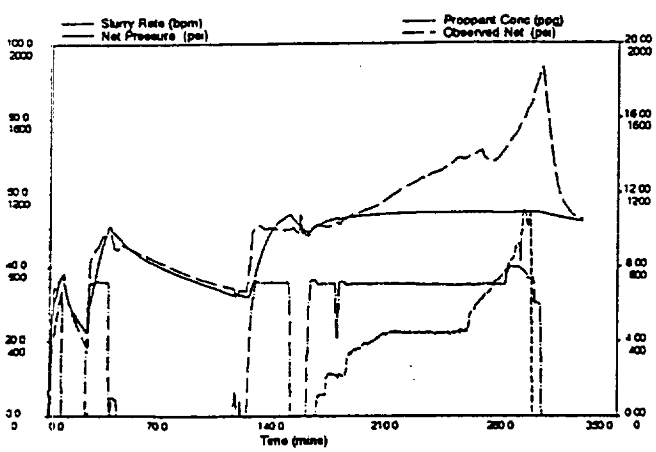

Figure 5 - Fabian Ditch 4-34 Net Pressure Match

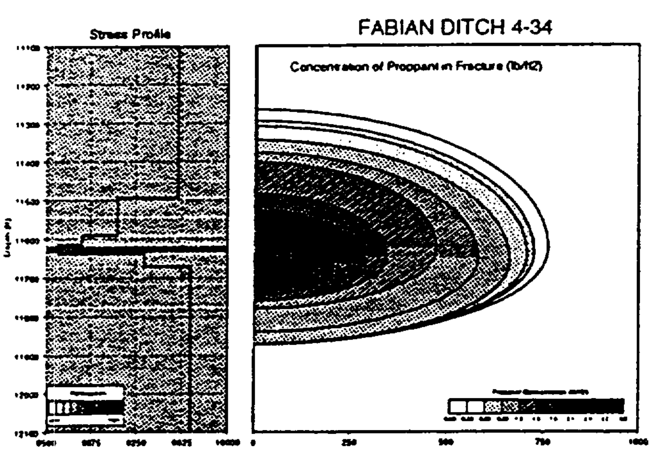

Figure 6 - Fabian Ditch 4-34 Fracture Geometry

Proppant Effect

The net pressure increase when proppant reaches the perforations will be referred to as the "proppant effect." This phenomenon is not believed to be a classical "tip-screenout", but probably a concentration of proppant that extends from the near-wellbore area into the fracture. The treating behavior of the Fabian Ditch 4-34 was not unique and was frequently identified with "dead string" pressures in other wells. Figure 7 compares the measured net pressures from the Fabian Ditch 4-34 and 3-34. These wells are diagonal 160 acre offsets. The figure shows similar net pressure behavior for the two wells, with pressures increasing sharply when proppant reaches the perforations.

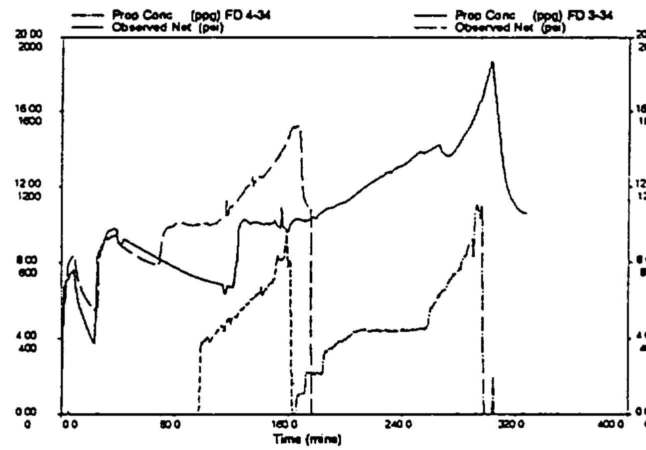

Figure 7 - FD 4-34 & FD 3-34 Net Pressures

This effect is currently being studied and detailed evaluation is beyond the scope of this text. However, several observations can be made:

- excess pressures due to "proppant effects" dissipate in 10 to 30 minutes after pumping.
- net pressures after pumping can be accurately matched after the "proppant effects" dissipate.
- "proppant effects" are present in about 50% of the wells treated.
- many treatments pressure-out due to this effect; of which some appear to be wellbore/perf "screen-outs."

Some possible explanations for this effect are:

- ineffective near-wellbore proppant transport caused by delayed crosslinkers that result in essentially linear gel entering the perforations,[19]
- proppant "filtering" through narrow passages created by higher stress regions above and/or below the Frontier sandstone (premature screen-outs have been attributed to this effect in previous modeling[7]),
- near-wellbore width restrictions caused by fracture initiation in a direction away from the preferred orientation.

The "proppant effect" complicates the net pressure behavior of many wells. However, predicted fracture geometry should be

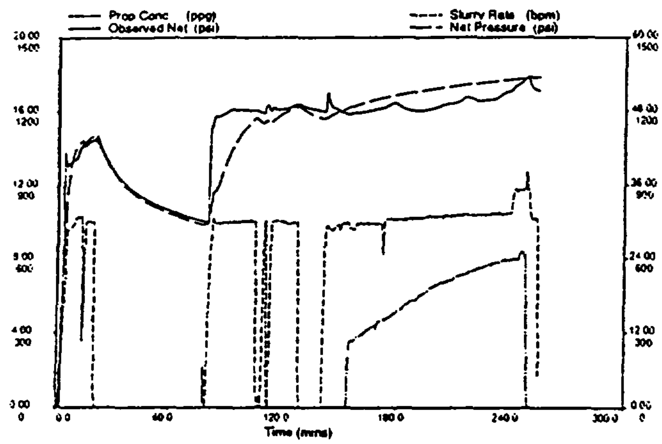

Figure 10 - 285 I-3 Net Pressure Match

Permeability was adjusted in the reservoir model until the simulated production profile accurately matched the available production data. The propped fracture length and conductivity profile were not changed from the geometry predicted by the fracture model. Figure 11 compares the actual production history to the model predicted flow rates using a reservoir permeability of 0.0085 mD (essentially that measured by the pre-frac well test). The figure shows two curves, one without any cleanup effects and one with an analytical cleanup model.[23] "Clean up" effects are discussed later, but it suffices to say they are commonly observed and suppress early time production. The figure shows that without any cleanup effects the initial production predicted by the model is significantly overestimated (3,000 MCFD versus 1,000 MCFD). However, after 80 days of production the model predicted flow rate and actual production virtually overlay.

The production history can be more accurately simulated by including cleanup effects. The second simulation (lower curve) shown in Figure 11 assumes that the 4,560 bbls of fracturing fluid injected will result in both temporary and permanent reservoir/fracture damage and requires a prolonged period to cleanup. The actual production response can be matched using a cleanup model that assumes a filtrate viscosity of 5 cp that requires 30 pore-volumes of production to cleanup to 50% of its original permeability. A permanent 50% damage factor was used for both the invaded-reservoir area and fracture. These cleanup values are consistent with model derived values on many other Moxa Arch Frontier wells.

It should be emphasized that regardless of cleanup effects the actual production history can be matched using the predicted fracture length and conductivity from the fracture model along with the well test permeability. It has been previously shown that long-term production history (8-12 yrs) from Moxa Arch Frontier wells can be reliably predicted (after the normal 1-3 month cleanup period) using these fracture and reservoir modeling techniques.[1]

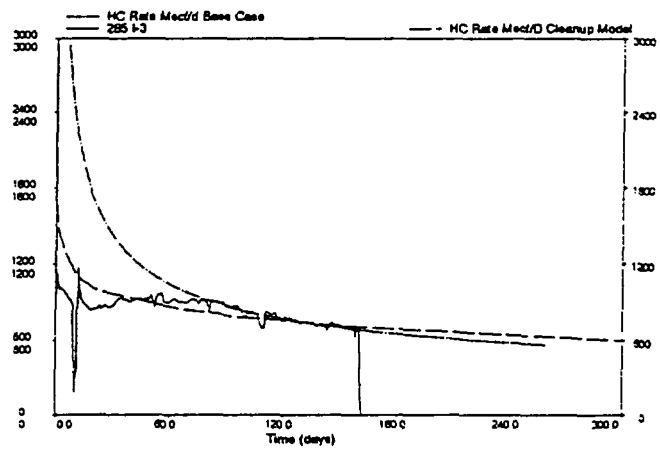

Figure 11 - 285 I-3 Production History Match

Sampson Fed. #2-14

The Sampson Federal #2-14 fracture treatment was selected to illustrate both "proppant effects" and probable barrier breakthrough. This well is located on the southwestern edge of Bruff Field, near the western limit of current economic production (ref. Fig. 1). This well was stimulated using 168 Kgals of a LPH fluid carrying 400 Klbs of sand and 50 Klbs of RCS. The bottom hole pressures measured using a "dead string" were significantly higher than typical Moxa Arch wells located in the center of the field.

The fracture modeling of measured net pressures indicated that the sand stress gradient was approximately 0.77 psi/ft, somewhat higher than values measured in stress tests on the Fabian Ditch 3-2 and 4-34 (0.70-0.74 psi/ft). However, stress data from wells located farther south indicate a sand stress gradient of 0.75 to 0.78 psi/ft.[6,7,8] The ability to estimate sand stress was greatly enhanced by pumping a small-volume (8 Kgal) water mini-frac. This procedure induces a small hydraulic fracture using a well-defined low viscosity fluid that is normally confined to the lower stress reservoir sands.

The water mini-frac and the subsequent 20 Kgal LPH fluid mini-frac were accurately modeled using a leakoff coefficient of 0.0005 ft/min.$^{1/2}$ The magnitude of net pressures during the two mini-fracs required a shale gradient of 0.93 psi/ft, much higher actual production is consistent with expected (simulated) production. The "cleanup" effect dissipates as injected fluids are produced and fracturing gel residue degrades. Figure 14 shows cleanup periods of 60 to 90 days for four wells. However, the 149 H-3 is still cleaning up after 150 days. This classic cleanup behavior is only present in about 25% of the Moxa Arch Frontier wells. However, it is probable that all wells experience these typical cleanup periods and as a result initial production rates are suppressed. It should be noted that two of the example wells were stimulated with LPH fluids (Fed 3-6 & 149 H-3), while the other two were borate treatments. There does not appear to be any difference between the cleanup behavior of these two fluid systems.

The effects of fracture and reservoir cleanup emphasize the importance of evaluating both initial and long-term production behavior. Evaluating the initial 30 to 90 days of production can lead to erroneous conclusions of both hydraulic fracture and reservoir characteristics.

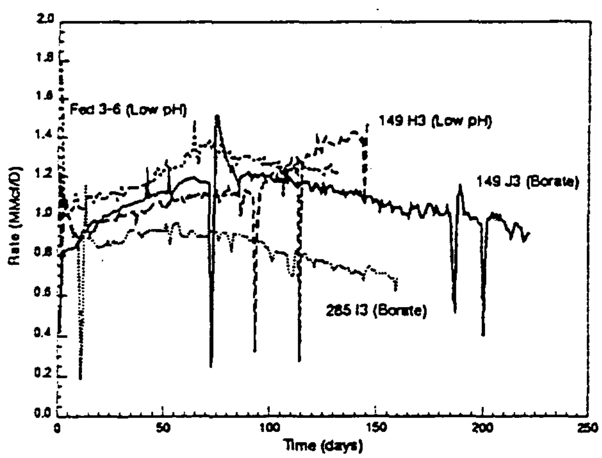

Figure 14 - Illustration of Well "Cleanup"

STIMULATION RESULTS

Stimulation treatments during the development of the Moxa Arch have changed significantly in an attempt to optimize fracture performance. Initial treatments (1975-85) utilized crosslinked water-based fluids and sand proppants. During the 1989-91 infill program, wells were treated with 70% CO_2 foams and ISP proppants. This resulted in fracture treatment costs of over $300,000 in 1991. Based on 3D fracture modeling and well performance, 1992 treatments returned to water based fluids and sand proppants, reducing fracture treatment costs by about $150,000.

Due to the very heterogeneous nature of the Frontier, simple offset well comparisons are not valid and statistical averages and distributions are required to accurately compare well/stimulation performance.[1] Therefore, stimulation treatments from 1975-85, 1989-91, and 1992 are compared based on average well performance.

Figure 15 compares average production from wells located in the area designated for 160 acre development. These averages are based on 38 wells drilled during initial development, 36 wells from the 1989-91 320 acre infill program, and 24 wells from the 160 acre development in 1992. The figure shows that the 640 acre development wells performed better initially than the subsequent infill wells. However, the 1992 infill wells exhibit essentially the same performance after the third month of production. The 1989-91 infill wells were stimulated using 70% CO_2 foams and performed consistently below the original wells.

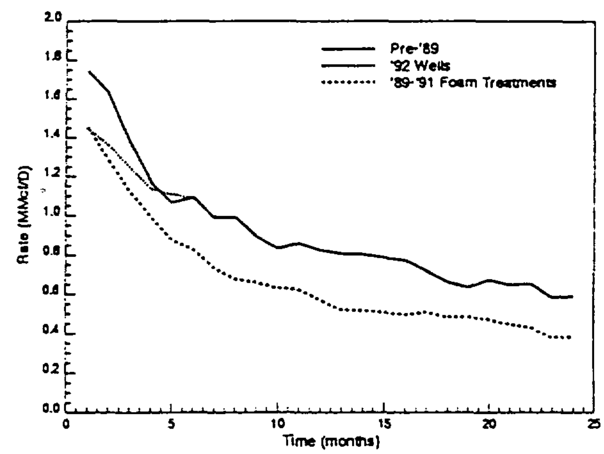

Figure 15 - Comparison Monthly Production

It is suggested that the poor performance of the foam treatments is due to ineffective proppant placement, resulting in shorter fracture lengths compared to crosslinked water-based fluids. The foam treatments were routinely shut-in overnight, which could aggravate any proppant settling problem. The "cleanup" effect appears to be more severe in the 1992 infill wells, as evidenced by the lower initial production rates compared to 640 acre developments wells. This is consistent with the more viscous fluids used in 1992 and lower reservoir pressure in some areas. Figure 15 shows only 6 months of production from the 1992 wells: further production data may show additional cleanup effects and better performance from the 1992 wells.

The variation in reservoir properties in the Moxa Arch Frontier results in a wide distribution of production. Figure 16 compares the distribution of second month production for the 640, 320, and 160 acre development wells. The figure shows that stress in the Frontier is about 7,500 psi (assumes a 1,000 psi p_{net}). Therefore, it is sometimes assumed that sand proppants will not supply adequate conductivity. However, based on current 3D modeling of actual net pressures combined with a better understanding of the *in situ* stress distribution in the Moxa Arch, 20/40 Ottawa sand should provide adequate fracture conductivity for most Moxa Arch Frontier wells.

The fracture length from this study averaged about 465 ft. The required fracture conductivity ($k_f w_f$) can be estimated using the dimensionless fracture conductivity (C_r) as defined by Cinco *et al*[29]

$$C_r = k_f w_f / \pi x_p k_g \quad \text{.....................(3)}$$

A C_r of ten indicates efficient fracture flow capacity. With an average reservoir permeability of 0.009 mD, the required fracture conductivity is about 130 mD-ft to achieve a dimensionless conductivity of 10. The fracture modeling predicted fracture conductivities of 140 mD-ft using 20/40 sand (about 1.9 lb/ft^2), resulting in a C_r value of 10.8. This assumes only proppant adjacent to the productive pay (30 ft median thickness) contributes to fracture flow capacity. However, the average treatment placed over 550 Klbs of sand into the fracture, or about 20 lbs/ft^2 based on 30 ft of net pay. This significant propped fracture volume could potentially increase apparent fracture conductivity by a factor of 2 to 5, resulting in effective C_r values of 20 to 50 using sand.[30] Therefore, sand should provide sufficient fracture conductivity even in the presence of non-Darcy flow, fracture fluid damage, and proppant crushing.

Based on 1992 stimulation results, borate or LPH fluids are preferred to foams. Due to the variation in *in situ* stress and reservoir properties throughout the Moxa Arch, fracture treatments should be optimized for each well. However, reservoir permeability and detailed stress data are normally not available. Therefore, two fracture optimizations are presented, one for an 800 psi stress contrast and one for an 1,100 psi stress contrast. The simulations assume 160 acre spacing and are based on median Moxa Arch Frontier properties (Table 1) and C_t=0.001 ft/min.$^{1/2}$ The optimizations assume a \$1.45/MCF net gas price, \$1,500/month operating cost, \$750,000 base well cost plus stimulation costs. Stimulation costs are calculated based on \$30,000 fixed cost and \$0.75/gal variable costs. Prices and costs are escalated at 5% per year and net present value (NPV) is calculated at a 15% discount rate. The fracture designs assume a maximum blender proppant concentration of 8 ppg (ramped 3 to 8 ppg) and a 35% pad volume.

Figure 19 compares the NPV versus total injected volume for the two cases. The amount of proppant can be estimated based on 150 lbs/bbl of injected fluid for reference. The 800 psi case shows an optimum treatment size of about 4,500 bbls (about 190 Kgals, 675 Klbs sand), while the 1,100 psi case shows an optimum treatment size of about 7,000 bbl (294 Kgals, 1,050 Klbs sand). The results from the optimization runs emphasize the importance of accurate stress data. The optimizations do not address complications such as barrier breakthrough, "proppant effects", and reservoir heterogeneities[31] which can significantly affect optimum treatment volumes.

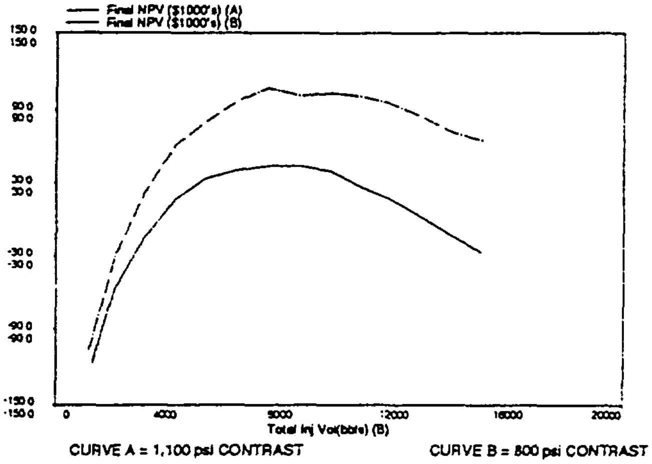

Figure 19 - Fracture Optimization, NPV vs Volume

SUMMARY

The results from 3D fracture modeling of 36 wells are listed in Table 3. The results indicate relatively short propped fractures averaging about 465 ft. However, average proppant concentrations are high at 1.88 lb/ft.^{2} The leakoff coefficients averaged 0.001 ft/min.$^{1/2}$ but ranged from 0.0002 to 0.0025 ft/min.$^{1/2}$ This 12:1 span is expected based on the range of reservoir permeability encountered in this area (reference Table 1). This variability emphasizes the need for real-time evaluation of mini-frac data to optimize treatment design.

Stress tests and fracture modeling indicate that sand stress gradients range from 0.70 to 0.78 psi/ft. The sand stress gradients appear to be higher in the southern and flank areas of the Moxa Arch. Shale stress gradients range from 0.80 to 0.85 psi/ft in the northern portion of the study area, and increase to 0.85 to 0.90 psi/ft in the southern flank areas of the Moxa Arch. This variation in stress profile can significantly influence optimum fracture design.

Table 3 - 3D Fracture Model Summary

	Average	Min.	Max.
x_f	533	330	870 ft
x_p	465	280	700 ft
PC	1.88	0.7	2.8 lbs/ft^2
C_t	0.001	0.0002	0.0025 ft/min$^{1/2}$

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SPE 25920

Real-Data On-Site Analysis of Hydraulic Fracturing Generates Optimum Procedures for Job Design and Execution

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SPE Members

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ABSTRACT

This paper demonstrates our methodology and capabilities for effective on-site real-time analysis, re-design and execution of hydraulic fracturing treatments. This unique technology has been developed over many years of research and development, sponsored primarily by the Gas Research Institute (GRI). Ten years of field implementation in the stimulation of gas- and oil-well production have led to conclusions and recommendations which involve major changes from conventional concepts about hydraulic fracturing. Most of our recommendations are relatively simple, low-cost procedures for adequate data collection, such as the use of flow-rate changes and/or multiple injection/shut-in cycles for stringent model evaluation of recorded data. Proper implementation of our recommendations is demonstrated by a case study in a commercial field situation, where the fracture treatment was drastically redesigned as a result of on-site analysis, and executed on the same day. This job showed that treatment cost/benefit optimization can be achieved by careful on-site analysis and more flexible field execution schedules.

INTRODUCTION

Many man-years have been invested in theoretical and laboratory investigations of hydraulic fracturing[1-2], as well as in R&D[3-10] and commercial field efforts[11-14] aimed toward advancing the technology. These efforts have led to a number of conclusions and recommendations, and they have also produced a unique technology (i.e., the Gas Research Institute fracture simulator, a true 3-D, real-data, real-time hydraulic-fracture simulator for design and analysis) that has made significant benefits and cost savings possible for many users on both oil and gas applications, even without on-site implementation.

R&D efforts have included the analysis of many fracturing jobs, including those pumped as part of experimental investigations[4-9], and also many "routine" commercial fracture treatments[10-14]. Our conclusions from such data analysis have included: shorter, wider fractures than those predicted by other simulators, which do not consistently match measured pressures; frequent occurrence of a significant level of near-wellbore friction, due to near-wellbore fracture tortuosity, which must be subtracted from measured (downhole) pressure data for correct interpretation; relative insensitivity of fracture width to frac-fluid rheology; and dangerously fast convection (versus settlement) of proppant in imperfectly-contained fractures. We have recommended that many of the existing approaches to fracture design and execution be reconsidered. We have also demonstrated, with numerous case studies, that a higher degree of treatment optimization can be achieved by more careful on-site analysis; our approach is to arrive at the optimum fracture-treatment design by making use of flexible field operations, and real-time, real-data analyses of suitably-designed tests with an appropriate engineering-oriented software package, incorporating at least a realistic reservoir/fracture simulator interfaced to data-acquisition. Our normal requirement is to match measured net fracture pressure (on-site, real-time), on carefully designed minifracs with the GRI simulator, then continuously redesign the main frac as needed, e.g. to achieve pack-off, understanding that details may change as larger injection volumes experience new reservoir conditions.

The purpose of this paper is to provide a simple description and a unique case study illustrating our approach to on-site fracture redesign, and to document some primary conclusions and recommendations (App. 1), as well as benefits and cost-savings (App. 2) which our GRI/Industry co-operative efforts have generated.

Paper Number	Author	Year
25920	Johnson, D.E.; Wright, T.B.; Tambini, Mauro; Maroli, Renato; Cleary, M.P.	1993

Real-Data On-Site Analysis of Hydraulic Fracturing Generates Optimum Procedures for Job Design and Execution

METHODOLOGY FOR REAL-DATA ANALYSIS

A schematic of the equipment layout on-site is provided in Fig. 1, including the presence of a (portable) computer system which analyzes actual data (e.g. Table 1). As background to the discussion of the pressure analyses for our case study, we present the following brief summary. Accurate simulation of the hydraulic fracturing process requires that bottomhole pressure, $P_{bottomhole}$, must be known with considerable accuracy. Bottomhole pressure, when not measured directly, can be calculated using the following formula:

$$P_{bottomhole} = P_{surface} + P_{head} - P_{friction} \quad (1)$$

$P_{surface}$ is the treating pressure measured at the surface, P_{head} is the hydrostatic head, or weight, of the fluid in the wellbore, and $P_{friction}$ is the pressure drop due to friction in the pipe (which is zero during shut-ins and/or if surface pressure is measured in a dead-string annulus or tubing). Once bottomhole pressure is known, the net fracturing pressure (P_{net}, which is the pressure in the fracture above closure stress, $P_{closure}$) can be calculated by subtracting the closure stress and any pressure loss due to perforation and/or near-wellbore friction, $P_{perf/near-wellbore}$, from the bottomhole pressure:

$$P_{net} = P_{bottomhole} - P_{closure} - P_{perf/near-wellbore} \quad (2)$$

Table 1: Data channels recorded during the job.

Data Recorded (Minifracs & Main Frac)
Bottomhole Pressure
Bottomhole Temperature
Surface Tubing Pressure (damped)
Surface Tubing Pressure (undamped)
Annulus Pressure (isolated)
Surface Gel Rate
Backup Gel Rate
Surface N_2 Rate
Density (High-Pressure Side)
Density (Low-Pressure Side)
Calculated Proppant Concentration at Perforations*
Calculated Bottomhole Foam Rate*

* Transmitted on-line from service company

Frictional losses in the wellbore and/or in the perforation/near-wellbore region, the major unknowns in the above equations, are very difficult to *predict*, but they are relatively simple to *measure*, in most treatments[8, 10-14].

The GRI fracture simulator uses the measured flow rate (of specified/known fluid rheology), proppant concentration and reservoir description to predict the net fracture pressure, which can then be compared, in a pressure-matching process, to the observed value of net pressure, as in Equation (2). Unknown or uncertain reservoir properties, upon which the fracture growth (and, therefore, pressure response) depends, can be modified, within a reasonable range, re-running the simulator until the net pressures match. A good match of model and observed net pressures should result in a good estimation of fracture geometry and proppant placement. Of course, there is a strong element of experience and human intelligence in the process. The simulator allows the engineer to study all reasonable scenarios, but common sense must guide the final interpretation.

CASE STUDY: A LOW PRESSURE GAS WELL

To illustrate the methodology, we have chosen a unique case study in which many complexities were present but, nevertheless, the job was completely executed in one day, from breakdown through minifrac and main frac, with continuous on-site redesign of our original schedule. The original design, optimization, and implementation of the stimulation treatment for this gas producing well were dictated by a number of constraints. For instance, fracture size was effectively limited by an undesirable zone that contained impure gas (CO_2), close to the zones to be stimulated. (See Fig. 2 for a schematic of the reservoir environment.) Also, the liquid-sensitive low-pressure formation led the service company to recommend a (N_2) foam job, i.e. in order to use the smallest possible amount of liquid, and to produce back from the formation (any liquid) as quickly as possible. Lastly, a lack of any previous fracturing data from the area necessitated a fairly large amount of pre-stimulation fracture testing e.g., logs, cores and extensive minifrac evaluation.

Minimum and maximum treatment volumes were set during pre-job meetings (based on an economics study using the GRI fracture simulator, with an embedded reservoir simulator). A tentative plan of action for fracture testing and stimulation were discussed and adopted. Most importantly, all operations were left very flexible so that on-site decisions could be made, based on the observation of the measured data and the simulator matches of observed minifrac net pressures. Prestimulation testing was to include a breakdown test and a step-rate re-opening test, both using liquid. The minifrac objectives were to diagnose any near-wellbore tortuosity problems, and to measure reservoir fluid-leakoff characteristics. The pre-frac design schedule is shown in Table 2, indicating two critical decision points at which minor or major changes to the schedule could be adopted. In fact, there were many more major decision points on this job, which we find to be necessary on most jobs, as the growing fracture encountered conditions substantially different from those assumed beforehand and even different to those determined in the minifrac treatment.

Table 2: Schematic of flexible design schedule on which service company based cost proposal, allowing for variation of volumes and staging determined at Decision Points, based on real-data analysis.

Stg #	Total Rate (bpm)	Volume (gal)	Comments
1	20 (average)	2,100 gals. (2 WB Vol.)	Liquid breakdown (50 lb. gel); max rate; include step-rate test on shut-down.
2	---	---	Shut-In; monitor tortuosity and liquid leak-off past closure.
Decision Point 1			
3	20	200 gals. (approx.)	Perform step-rate re-opening (consider possibility to pump small proppant slug if tortuosity appears a risk); stage to test closure pressure and acceptance of proppant by fracture.
4	---	---	Shut-in; monitor pressure well past closure.

Stg #	Down-Hole Rate (bpm)	Down-Hole Conc (ppg)	Slurry-Foam Vol (kgal)	N_2 Rate (scfm)	Surface Slurry Rate (bpm)	Surface Prop Conc (ppg)
5	20	0	8–16	19,460	5.00	0.00
6	Shut-in					
Decision Point 2						
7	20	0	48–56	19,460	5.00	0.00
8	20	2	2.7	17,230	6.65	7.35
9	20	4	2.9	15,390	8.10	13.55
10	20	5	6.6	14,580	8.70	16.30
11	20	~ 6	6.6	~ 13,120	10.10	16.30
12	20	~ 7	6.6	~ 11,700	11.25	16.30
13	20	~ 8	6.6	~ 10,100	12.10	16.30
14	20	0	0.770	19,460	5.00	0.00

- Total gel 24,400 gal
- Total proppant 122.5 klbs (maximum 164 klbs.)
- Total foam 93,240 gal

(~ Indicates possible higher concentrations/foam-quality reduction to achieve pack-off.)

Logistics and Execution of Fracture Treatment

Based on extensive discussions in meetings with personnel from the service company, a plan was also developed for the main fracturing treatment, as outlined in Table 2. Extremely flexible options were retained to allow major changes on the basis of on-site measurement of reservoir response. This flexibility proved to be essential for successful execution of the job. In particular, the following aspects of the design were fully exploited to optimize data gathering and job schedule:

a) The pad and proppant volumes were kept flexible until just before the fracture treatment. It was decided to mix only 30 kgals (approximately 100 m^3) of WG-11, HPG linear gel unless the leakoff was found to be higher than expected. As well, only 120 klbs (~ 55 tonnes) of proppant was placed in the silos until just before the job. The final design chosen (see Figs. 6, 7 later) was based on our criterion of packing off the fracture (App. 1), which made the pad much smaller than that originally proposed in Table 2, since foam leak-off was actually found to be less than originally expected.

b) Although substantial tortuosity was not expected[11], our schedule was designed to handle it if it was found. However, not only was one proppant slug pumped, but it was also followed by two more slugs, to evaluate/alleviate the problem. The result of this unique effort was both avoidance of premature screen-out and proper evaluation of leak-off.

c) The major reason for making the proppant slugs of minimum size is the short extent of the "rat-hole" above the sand-plug (top at 1,485 m in Fig. 2). The first slug was to serve also as a "marker" to indicate approximately which perforations were accepting fluid and/or resisting proppant.

d) The whole job, including breakdown and testing cycles, was conducted in a single day. This was very desirable in avoiding water damage to this sensitive formation, but it also demonstrated (for the first time) the ability to perform the required analyses and decision-making on a commercial schedule, even on complex jobs, within the same day.

Break-Down Test

In an attempt to minimize the number of fractures initiating from the wellbore and, hence, to minimize near-wellbore tortuosity, 50# gel was circulated to the perforations so that the formation was broken down with a relatively viscous fluid. Breakdown and fracture extension pressures were much higher than expected (see first injection in Fig. 3(a, b)). Perforation/near-wellbore friction was measured at different flow rates and was considered to be at a borderline[11] danger level i.e., 400 psi total near-wellbore friction. Calculations made on-site indicated that the perforation and near-wellbore pressure losses varied as flow rate to the 3/4 power (Fig. 3(d)); such a variation is indicative of tortuosity pressure losses (caused by an inefficient connection between wellbore and fracture), rather than perforation pressures losses, which should vary as flow rate squared[11]; this level of near-wellbore friction (tortuosity) suggested re-oriented/multiple fractures[11], perhaps connecting to the main fracture.

A simple plot of pressure decline versus the square root of shut in time was used to estimate closure pressure (Fig. 3(c)). The closure-stress/leakoff rate were much higher/lower than expected, indicating a permeability substantially lower than the value estimated from pre-treatment-production matches. It was decided that such an extremely low permeability was probably not realistic, and that the near-wellbore region may have closed before the fracture itself and at least partially isolated the wellbore from the fracture. As such, the true leakoff character of the formation was not being seen in the pressure-decline data.

Step-Rate Reopening Test

A step-rate test (second injection, Fig. 3(a)) was performed next, primarily to reconfirm the closure stress and leakoff character seen in the breakdown test. From the re-opening and pressure decline data, a similar far-field closure stress was observed and permeability was again gauged to be much lower than expected.

One-ppg Test

This was, to our knowledge, the first use of such a technique[11]: a small "slug" of 1-ppg slurry fluid was pumped to prop open the near-wellbore region in an attempt to more accurately measure the leakoff character of the reservoir (see Fig. 4(a) and third injection in Fig. 3(a)). The early-time pressure decline data in this test were similar to those of the previous two, but the later-time pressure data declined at a faster rate than before. Simulator matching of the pressure decline data indicated a permeability at least six times that obtained in the earlier two tests. We believe the proppant kept the near-wellbore region open (even though we slightly over-displaced the slug into the formation), such that a better picture of the reservoir's leakoff character was seen.

One- and Three-ppg Test

A definite "kick" (~ 150 psi) in bottomhole pressure was seen during the previous 1-ppg test when the proppant slug hit the perforations. To determine whether there would be problems injecting proppant during the actual stimulation treatment, another test was done with 1- and 3-ppg proppant "slugs" to see if they would pass through the near-wellbore region (see Fig. 4(c) and fourth injection shown in Fig. 3(a)). No pressure "kick" was seen for either proppant concentration and the deduced permeability was 10 times higher again than in the previous test. Others may believe that the near-wellbore region is eroded by the slurry[11] but, at least in this case, there is little doubt that the mechanism of near-wellbore friction reduction was that of certain fracture(s) being propped by the previous 1-ppg test: only these were reopened upon re-injection. The perforation/near-wellbore[11] pressure losses were significantly less for the rest of the job, and proppant was accepted during the main treatment with no difficulty: the result is a new technique for avoiding near-wellbore screen-outs using prior placement of proppant slugs.

Foam Minifrac
To determine the reservoir's response to the foam that would be used in the propped-fracture treatment, a 75-quality foam minifrac was pumped (see Fig. 5 and final injection shown in Fig. 3(a)). As expected, the leakoff was reduced, ostensibly by the more efficient foamed fluid. The net-pressure response (see Fig. 6(a) for the foam minifrac net-pressure match) showed no indication of any significant stress barriers that might contain fracture growth. A small, low-concentration proppant stage was included at the end of the minifrac to again prop the near-wellbore region. Closure pressure was difficult to discern from the pressure-decline data and a very low leakoff was deduced.

Net-Pressure Match of All Tests & Minifracs
Fig. 6(a) shows the varying degree of net-pressure match for the foam minifrac, as well as all other tests. Optimal use of the information gained from all the tests and the minifrac was made in the process of determining the reservoir characteristics that facilitated the pressure match shown in Fig. 6(a). The leakoff character of the reservoir was determined (due to the propping of the near-wellbore region), closure stress was estimated, and the near-wellbore region's ability to accept proppant was confirmed.

Propped-Fracture Treatment
The reservoir description determined from various test and minifrac net-pressure matches (e.g., Fig. 6(b)) was then used to run different scenarios in order to find the optimal job design. We aggressively designed for a proppant pack-off, (Fig. 6(c)). Fig. 7(a) shows the recorded treatment data. The treatment was ended prematurely due to an equipment failure after most of the proppant (75 tonnes) had been pumped. Fig. 7(b) shows the model predicted and measured net pressures, which were strikingly similar to pre-job predictions (Fig. 6(c)). Corresponding to the pressure match in Fig. 7(b), Figs. 7(c, d) shows a schematic representation of the fracture. The initial pressure decline was fast; (at least partial) closure on proppant *may* have occurred after 10–20 minutes, which would have reduced convection[11].

Case Study Summary and Conclusions
We believe that the optimal treatment was designed on-site for this situation. The very flexible field operations, in combination with the GRI fracture simulator system, were indispensable in the process. The design strategy was successfully implemented, except for a premature treatment termination caused by excessive sand concentrations in the blender (i.e. foam quality was not reduced, as designed by us to prevent such an occurrence). Otherwise, the job execution was generally excellent and incorporated at least three procedures which were performed for the first time (to our knowledge):

1) The use of proppant slugs to test allowable concentrations, and, more importantly, to remove much of the tortuosity threatening near-wellbore screen-out;
2) Propping of the near-wellbore region with low-concentration proppant slugs for the purpose of monitoring leak-off and closure in the fracture, rather than isolating the fracture by closure of the near-wellbore/perforation region only; and
3) Same-day implementation of minifracs (acting also as a pad) with on-site extremely aggressive redesign of the pad/proppant schedule.

Because this well exhibited moderate levels of tortuosity-induced near-wellbore friction[11], all three procedures (above) were necessary to achieve an optimal propped fracture, without premature termination due to near-wellbore screenout.

The use of proppant slugs (point 1) was essential to estimate how much proppant would pass through the perforation/near-wellbore region without screening out at the wellbore. It was intended to estimate the greatest concentration which would pass into the fracture, in order to design the best treating schedule, using that proppant concentration as a maximum. However, the more dramatic result was the determination that the tortuosity could be removed, not by near-wellbore erosion (as commonly assumed), but rather by biasing the reopening toward the one (or more) fractures being wedged open by proppant from a previous injection. Thus, the initial resistance to a proppant slug of only 1 ppg was completely removed, and no further near-wellbore inhibition was observed for any concentrations, at least up to the maximum that we could pump.

The tortuosity also produced a near-wellbore closure tendency which thus also required the use of proppant slugs placed into the near-wellbore region to ensure that the wellbore remained in contact with the fracture during shut-in (point 2). The first two minifracs (breakdown and step-rate test) were pumped without proppant slugs having been placed in the near-wellbore region. The resulting pressure declines implied an extremely low estimated pore permeability (of order 0.002 mD). When the third and fourth minifracs were pumped, with low-concentration proppant slugs placed in the near-wellbore region just before the start of shut-in, the implied pore permeability was much higher (of order 0.1 mD). The proppant slugs maintained communication between the wellbore and the main fracture body, allowing the true pressure response due to leak-off to be observed.

Based on the true leak-off behavior of the liquid and foam minifracs, which were matched on-site using the GRI simulator, an optimal job design was determined, and the simulator was used to predict the pressure response and fracture dimensions for the main treatment. The low leak-off of the foam caused us to design an extremely aggressive treatment. The GRI fracture simulator predicted a fracture packoff and corresponding significant pressure rise for this design (Fig. 6(c)). A remarkably similar response (to that predicted) was seen in the field, up until the point of blender screen-out, and job termination (Fig. 7(a, b)).

GENERAL CONCLUSIONS

The major conclusion from many field jobs is that on-site real-time analysis is an indispensable tool for proper effective execution of hydraulic fracture treatments. We believe that it is simply impractical, and certainly far from an optimum engineering approach, to design jobs on the basis of laboratory and/or theoretical estimates of reservoir conditions. Many new conditions appear, especially in new environments, but even from well to well within a given environment. For instance, the major findings on this job were as follows:

- High apparent tectonic (stress) effects with associated high fracture pressures;
- Near-wellbore tortuosity, perhaps due to near-wellbore turning into a more favorable fracture direction, but apparently also due to the initiation of multiple fractures around the wellbore, the number of which was later apparently reduced by the placement of proppant slugs, which biased the response toward reopening of the propped fracture segments only[11];
- Estimated pore permeability (to gas) of order 0.1 mD; although in the "ballpark" of prior estimates, it was important to know the actual leak-off behavior of the fracturing fluid (i.e. K_f/K_L): we generally avoid often misleading use of leakoff coefficients (although calculated);
- Maximum propped fracture lengths of order 140 ft (40 m), with substantial fracture height growth; however, placement of the proppant is not certain because of possible convection before closure;
- An average proppant concentration of about 1.7 lb/ft^2, which would be adequate for good production and economic return on the fracturing operation if properly placed;
- Use of foam made it extremely difficult to achieve a fracture pack, because of the greater fluid efficiency, density contrast, and the lower maximum proppant concentration that could be pumped with a foam system.

Since a simple effective system is able to extract such information very easily and quickly on any job, we believe that it should always be used. A number of additional conclusions and recommendations are made in App. 1 in order to improve on the procedures for hydraulic fracture treatments. Using an embedded reservoir simulator, we have been matching production data as it becomes available, in order to complete the optimization process. By such comprehensive analysis of (many) wells, we are gradually isolating the primary actual causes of successes and failures. By this means, we are able to generate substantial savings and economic benefits for operators (e.g. App. 2).

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The authors are grateful to the management of Agip S.p.A. and Edison Gas for permission to publish the case study. Appreciation is also expressed to the service company personnel, especially George York and Klaas Giltenbeek, for their superb co-operation before and during the job. Finally, the Gas Research Institute is acknowledged for supporting the development of the real-time analysis system and many other field applications—some of which have been published, but many of which remain to be published in future papers.

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Appendix 1.
Conclusions and Recommended Procedures for Hydraulic Fracturing Developed on the Basis of GRI Research (1983-1992).

Some of these have been discussed in Ref. 9 and only a truncated version of our general story is presented here:

1. A dominant mechanism is convection*, presently not even visualized by industry designs and associated simulators. This not only controls achievable propped fracture lengths opposite pay (often as a small fraction of created length) but also requires use of minimal fluid volume. Many jobs (especially in tight formations) contain too much volume, especially too much pad. Use of foam jobs makes it even more difficult to avoid convection, which may damage production from uncontained fractures, by failing to effectively prop payzones. effectively. Operators who still use foam may consider a lower foam quality for tail-in stages.

2. Experience with data shows that optimal treatment volumes and staging often differ dramatically from those currently employed, because of many inadequacies in simulators used.

3. The essential feature of a successful fracturing treatment is an effective pack-off at the end of the job. This is even more important in low-permeability reservoirs to achieve a reasonable propped fracture length opposite pay. Indeed, considerations such as water-sensitivity and/or low pressure have led to the selection of foam jobs in many reservoirs, contrary to this primary consideration: we have increasing evidence that water damage has limited effects and is far less a consideration than placing the proppant opposite selected pays—which is much more difficult to achieve with (more expensive) foam jobs.

4. The common use of flowback at the end of jobs should only be justified when a pack-off is not achieved and we have then used limited flowback to retain proppant in the wellbore as a supply to the near-perforation region as convection removes proppant from there before closure.

5. Many premature screen-outs may be avoided and optimal fracture designs may be achieved by performing some relatively straightforward diagnostics, mainly during pre-pad and/or pad stages (on the morning of the job), if necessary using the injection of proppant "slugs" during such (equivalent) minifracs to check for, and design against, near-wellbore tortuosity and potential screen-out.

6. The acquisition of adequate data and proper determination of net-pressure behavior continually during the job is needed for essential (on-site) redesign and fracture optimization. It is not realistic in general to claim effective fracture execution on the basis of pre-frac designs, even if calculated with realistic models, from log and core data or even from small minifracs.

Appendix 2.
Realized and Potential Benefits/Cost-Savings from Real-Data Analysis

Although a formal procedure has long existed for "fracture optimization" (based on Net Present Value, NPV, and Return on Investment, ROI), it has been based on extremely idealized approximations to the components involved: idealized fracture and reservoir models, assuming ideal wellbores, with little coupling to fracture process; and little or no attempt to document the statistics of such individual isolated studies for each wellbore. The capabilities (being) developed for GRI, with input from numerous member companies[11], and based on efforts like the present paper, is aimed at overall realistic optimization of wellbore operations. However, some immediate benefits have already resulted:

1. Modify (generally reduce) job volume and staging/composition:
   A. Direct savings on job cost (e.g., cheaper fluids and appropriate use of rheology).
   B. Minimize damage and clean-up time. Check the use of additives.
   C. Minimize convection— optimize proppant placement (see 2.).
2. Optimize Proppant Placement:
   A. Place most proppant opposite pay-zone(s). This is what counts in NPV/RoI.
   B. Avoid propping other (e.g., water-bearing) zones.
   C. Minimize proppant production and damage to separation equipment (or tubulars).
3. Optimize number of treatments and/or wellbores:
   A. Realistic estimates of kH and fracture dimensions achievable, hence realistic economics.
   B. Rational choice of number of (staged) treatments, e.g. for multiple pay zones.
   C. Ability to correctly determine/implement optimum fracs vs. (infill) drilling programs.
4. Minimize/reduce the number of operational problems:
   A. Reduce risk of screen-out, avoiding (e.g., coiled-tubing) wellbore clean-out.
   B. Replace expensive and uninformative/misleading procedures (e.g. "frac-height" logs).
5. Optimize upstream activities (e.g. drilling & completions):
   A. Modify cementing and perforating procedures, e.g., based on (tortuosity) measurement.
   B. Optimize (e.g., horizontal) wellbore orientation, based on realistic model of fracturing.
   C. Openhole completions, when possible e.g. cheaper and less (tortuosity) problems.

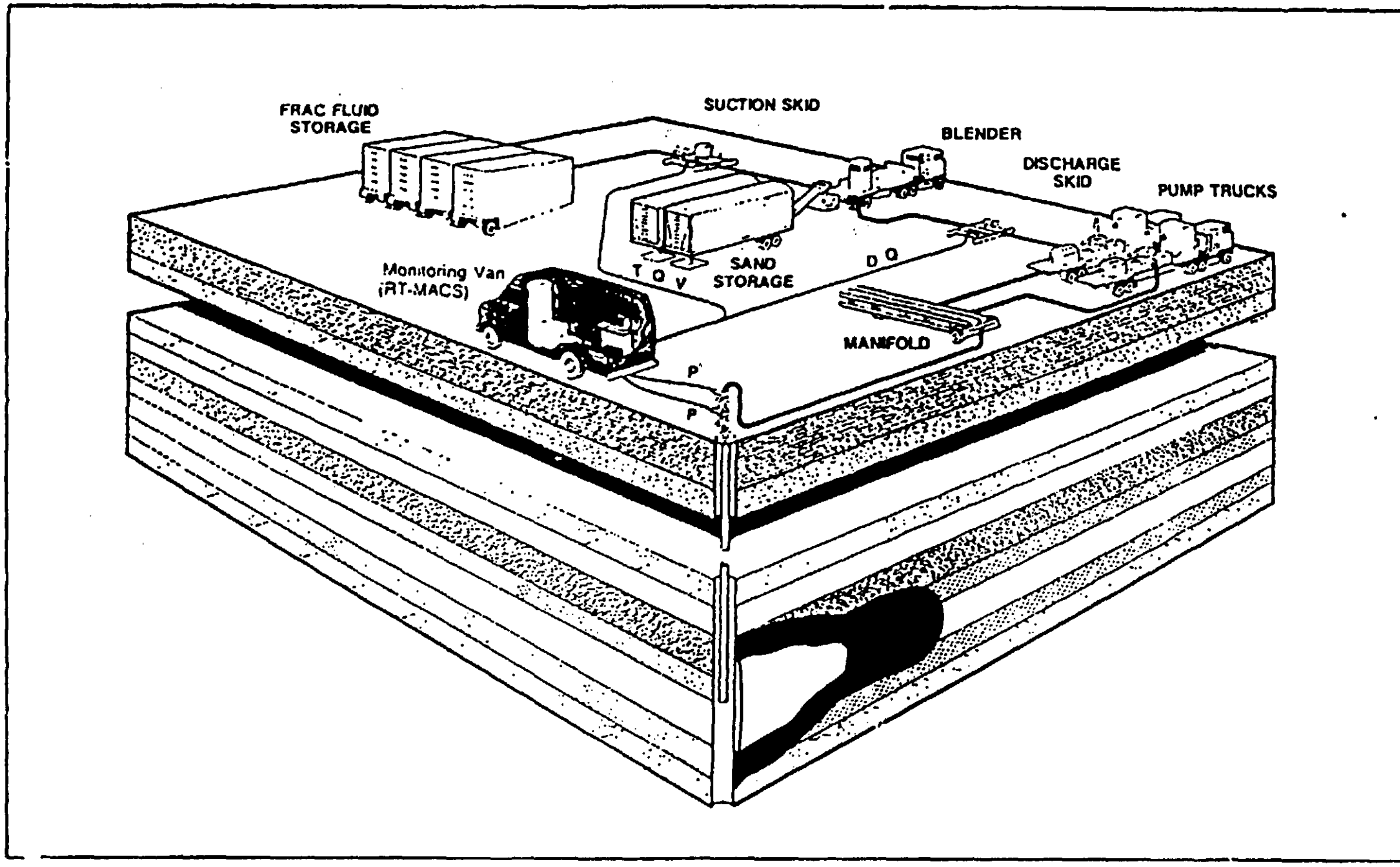


Figure 1. Schematic of on-site equipment and instrumentation required to perform an adequate/optimum fracture treatment. The computerized system shown is designated RT-MACS (Real-Time Monitoring, Analysis and Control Systems) by the non-profit industry agency, Gas Research Institute (GRI), which supported its development; its application is now being expanded to complete wellbore design and (on-site) analysis of drilling, completions and production operations. Current usage requires only a portable computer interfaced with the on-site data-acquisition units supplied by most service companies.

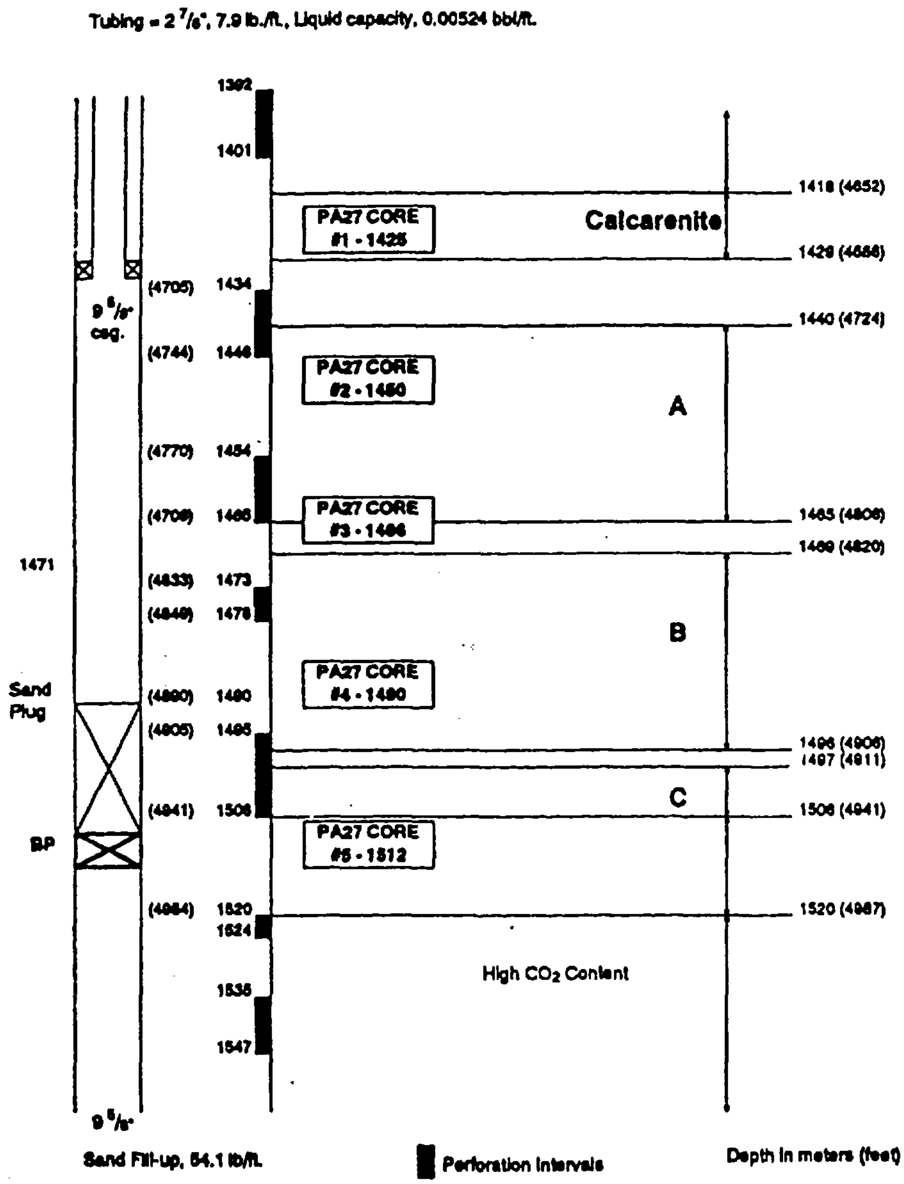


Figure 2 Schematic of completion associated with case study presented: A & B are target strata for fracturing.

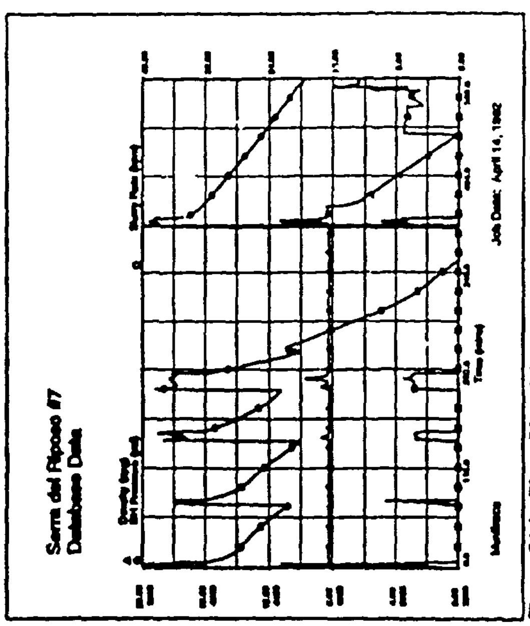


Figure 3(a) Plot of breakdown, step-rate re-opening, "1 lb slug" test, "1 & 3 lb slug" test, and the foam mini-frac.

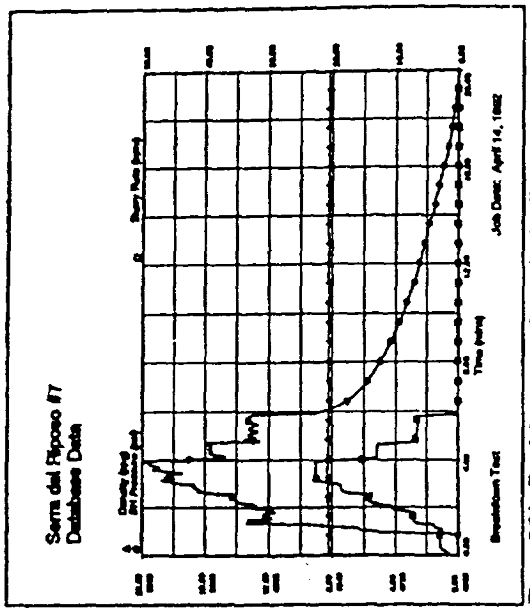


Figure 3(b) Breakdown test, shown in detail.

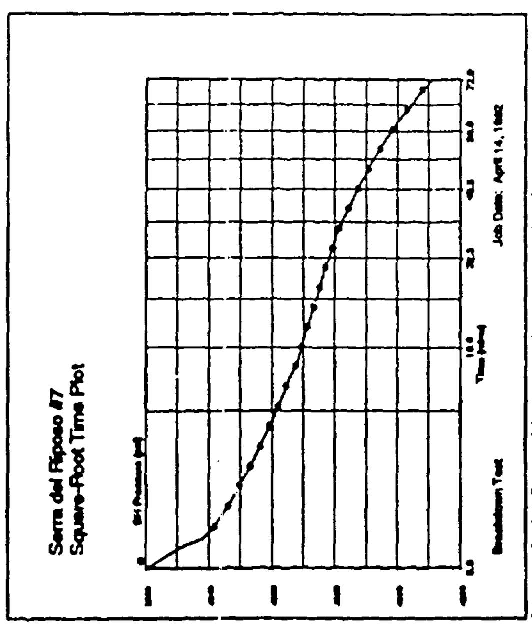
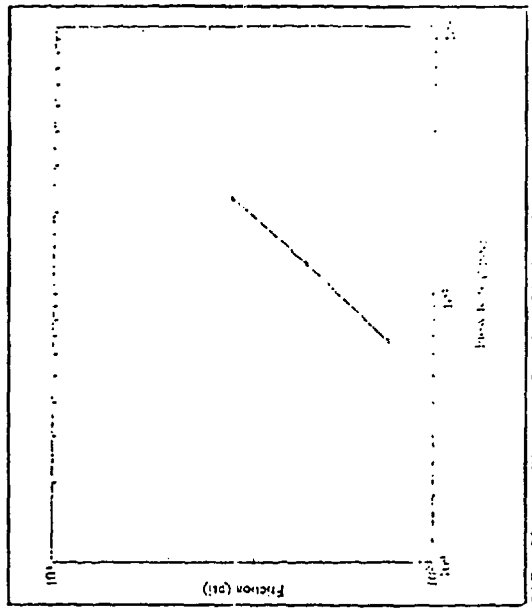


Figure 3(c) Plot of bottomhole pressure decline during shut-in of breakdown test, on a square-root of time plot.



3(d) Near-wellbore/perforation friction plotted versus flow rate. Friction goes as flow-rate to the 3/4 power.

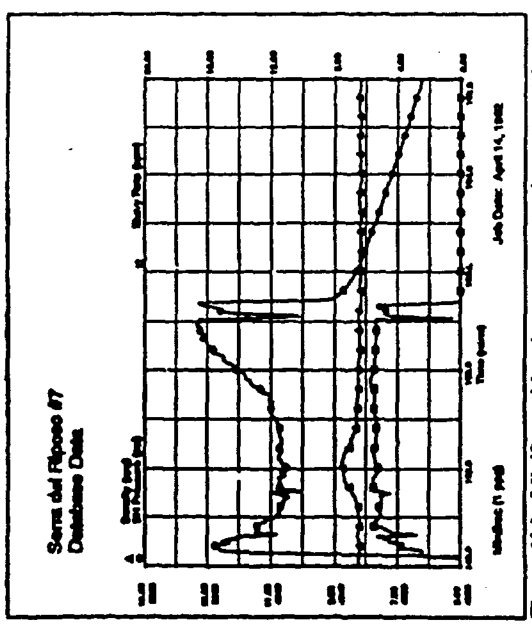


Figure 4(a) Minifrac with a 1 ppg proppant slug pumped into the near-wellbore region just before shut-in.

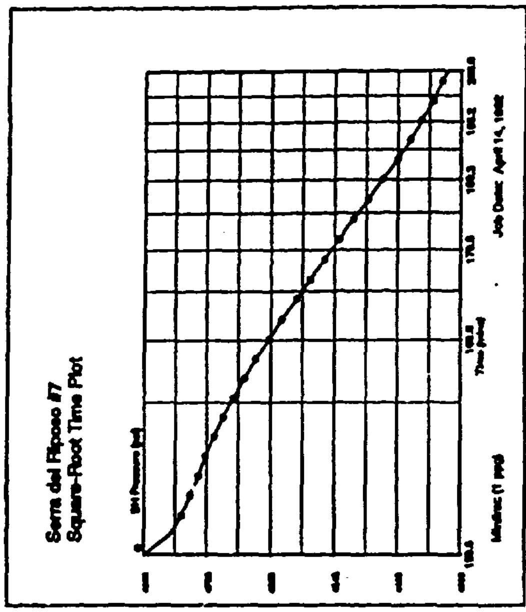


Figure 4(b) Plot of bottomhole pressure decline during shut-in of 1-ppg-slug minifrac.

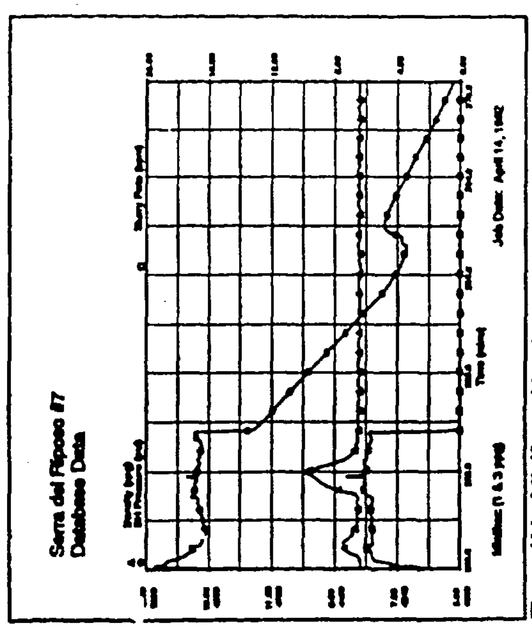


Figure 4(c) Minifrac with a 1 ppg proppant slug, followed by a 3 ppg proppant slug pumped into the near-wellbore region just before shut-in.

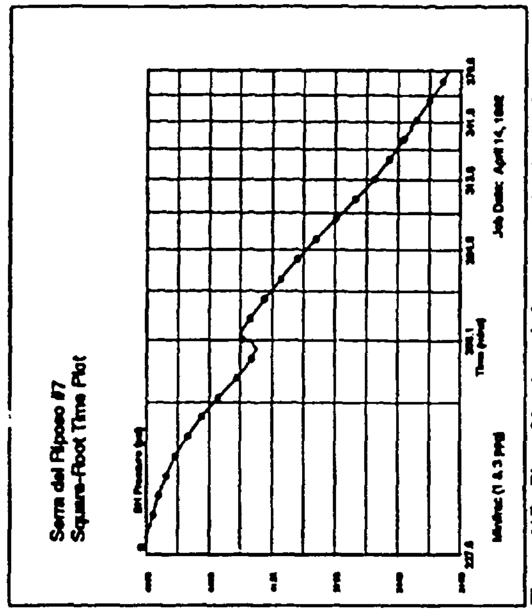


Figure 4(d) Plot of bottomhole pressure decline during shut-in of the one- and three-ppg-slug minifrac.

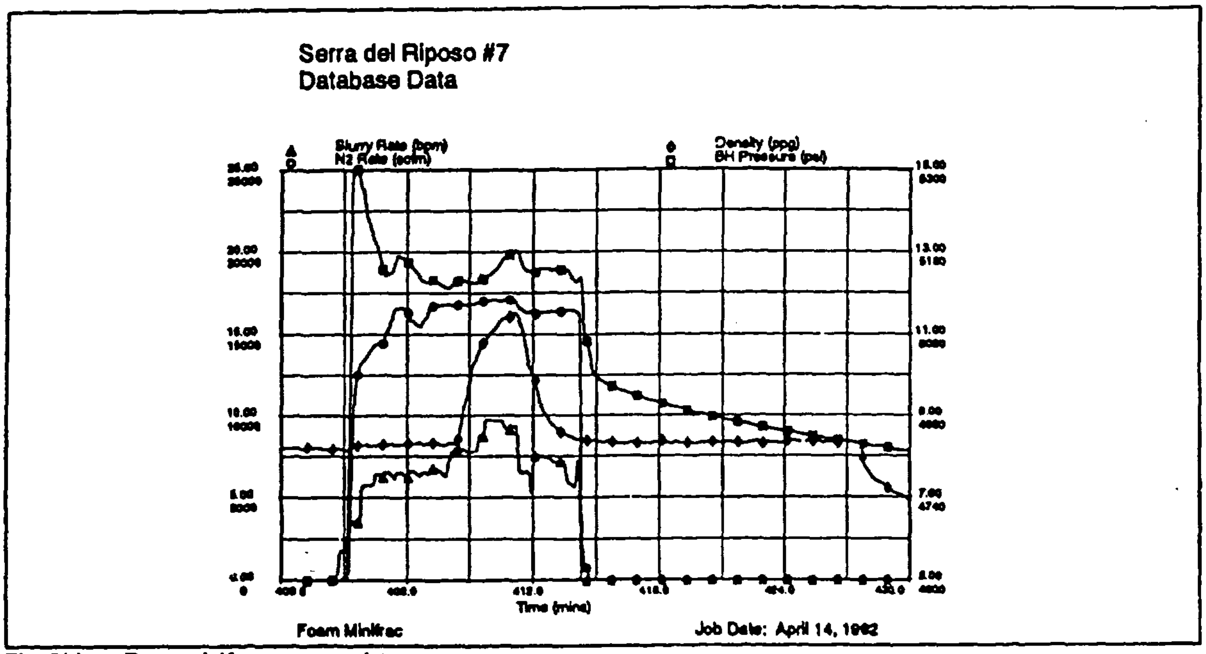


Fig. 5(a) Foam minifrac treatment data.

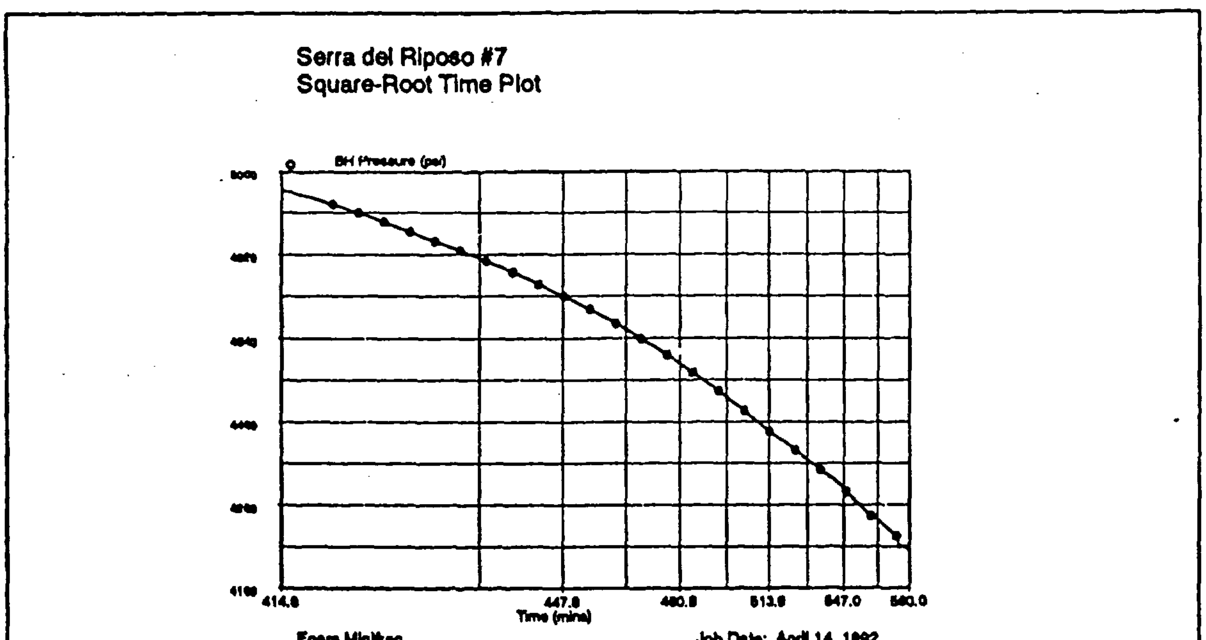


Fig. 5(b) Pressure decline of the foam minifrac, plotted on a square-root time of plot.

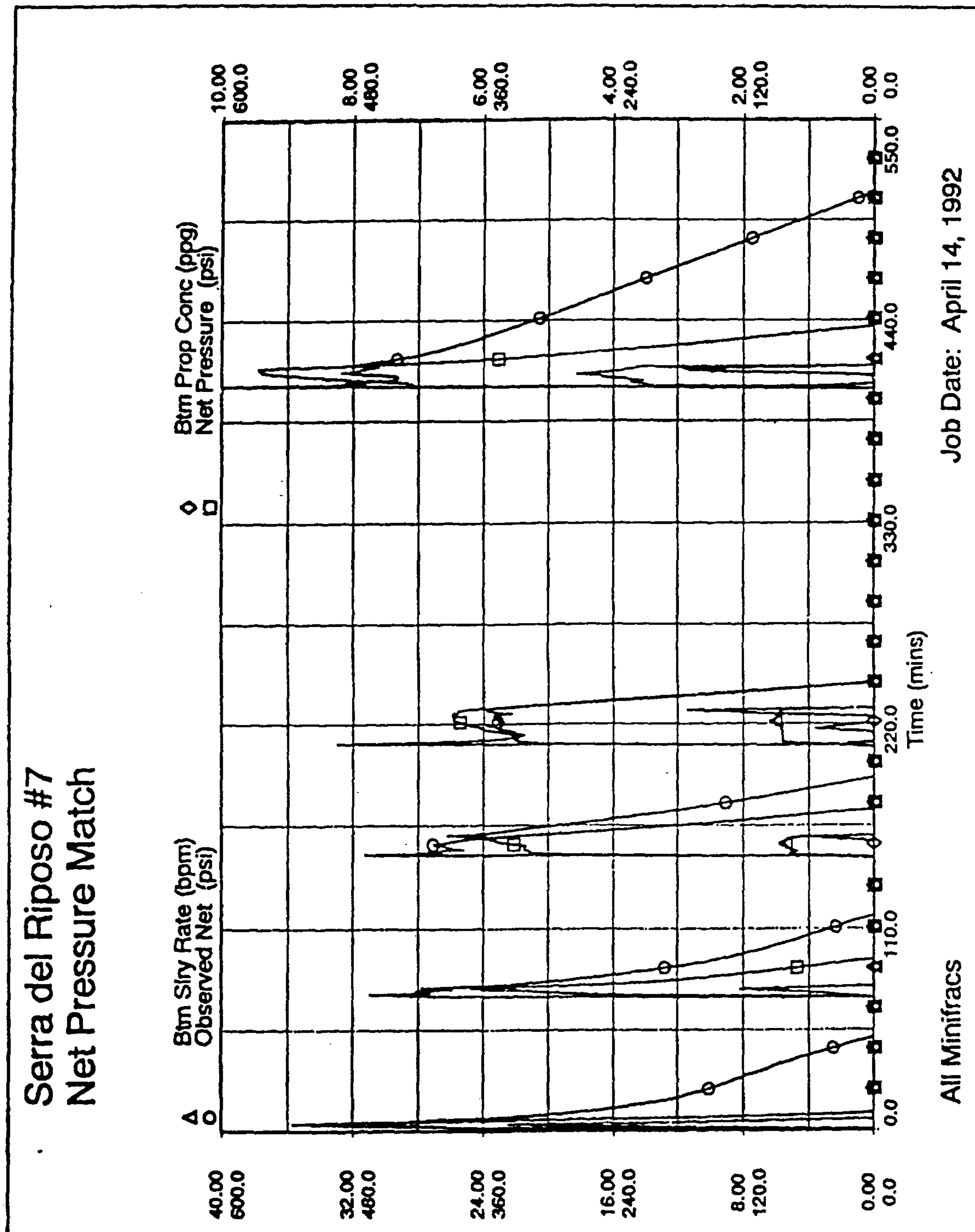


Figure 6(a) Net-pressure match of breakdown test, step-rate test, and gel and foam minifracs.

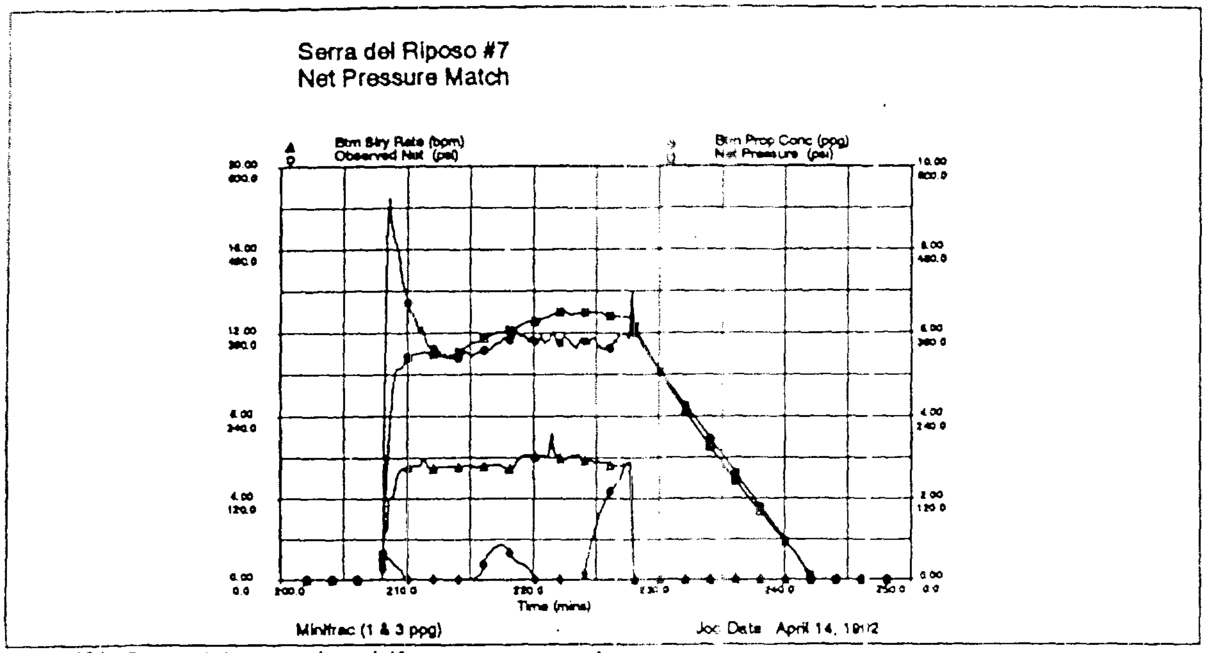


Figure 6(b) One- and three-ppg slug minifrac net-pressure match.

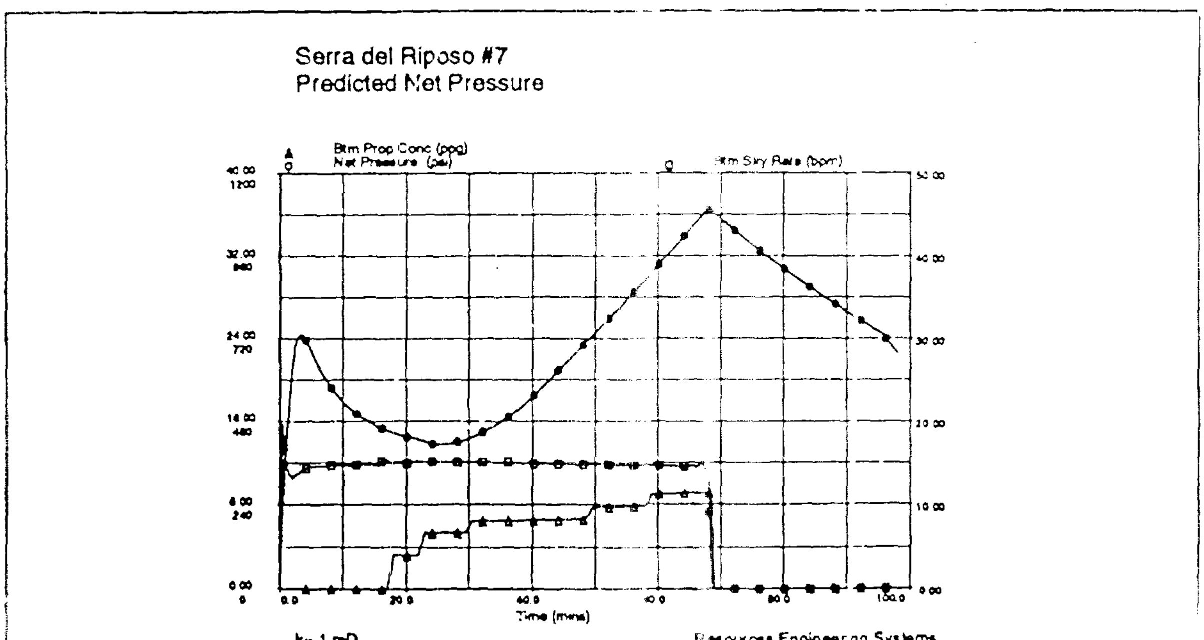


Figure 6(c) Final design of the proppant fracture treatment and the predicted net pressure.

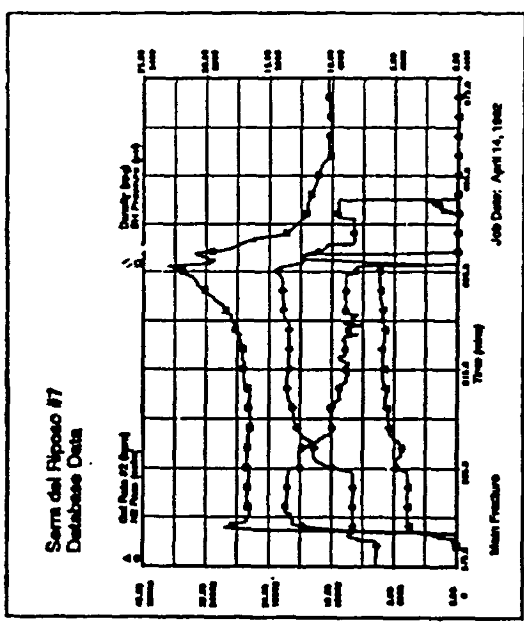


Figure 7(a) Main fracture treatment data, including the early shut-in behavior.

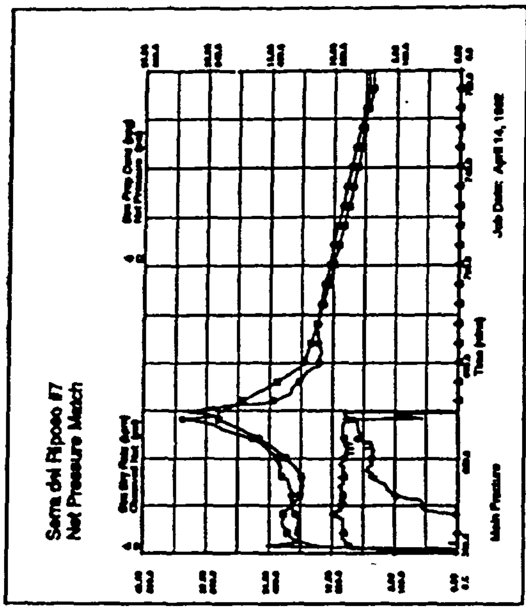


Figure 7(b) Net-pressure match of main fracture treatment.

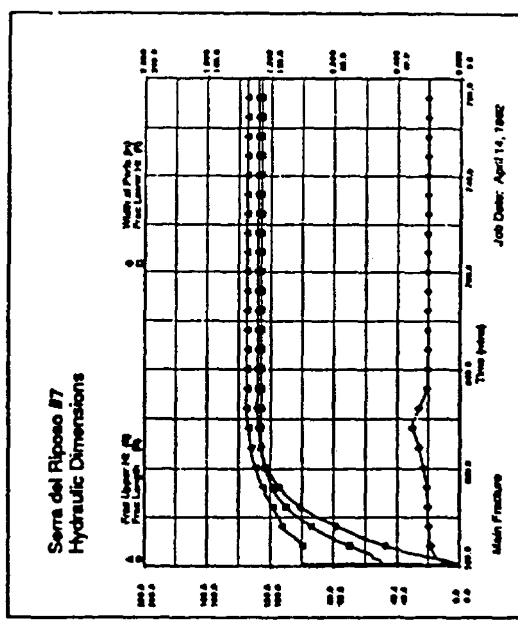


Figure 7(c) Hydraulic dimensions for main frac, assuming 4,300 psi closure stress.

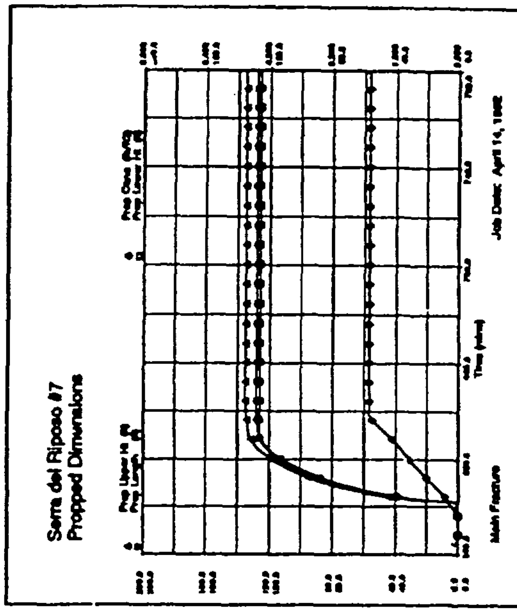


Figure 7(d) Propped dimensions for main frac, assuming 4,300 psi closure stress.

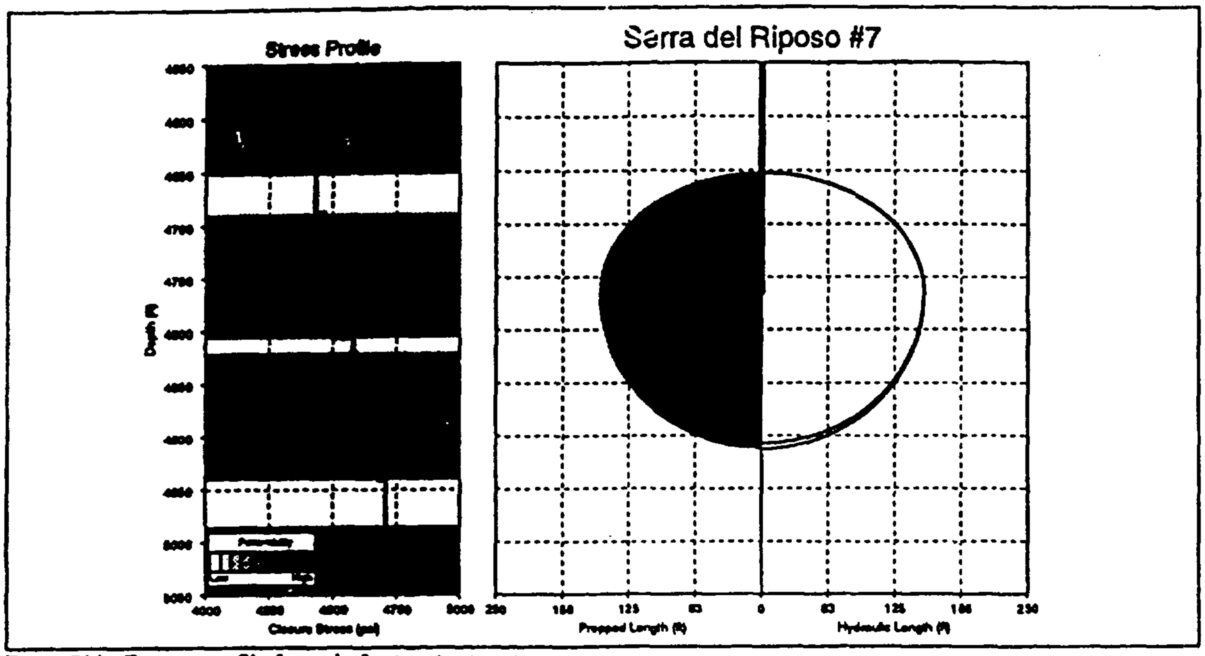


Figure 7(e) Fracture profile for main fracture treatment.

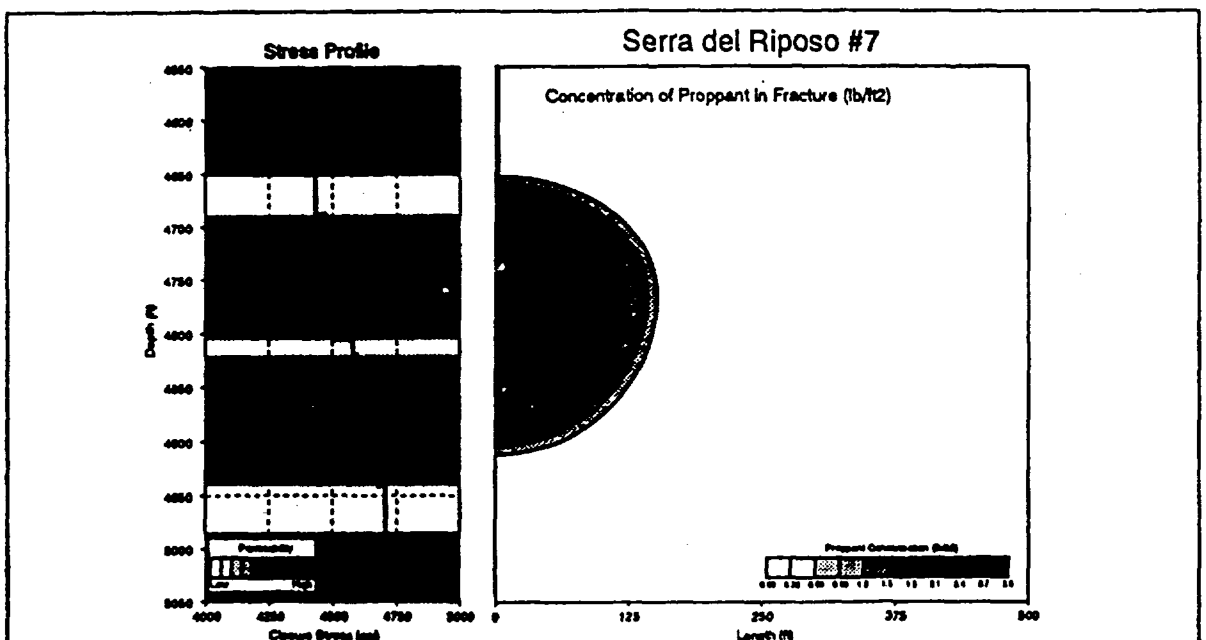


Figure 7(f) Proppant profile for main fracture treatment.

SPE 26154

Analysis of Abnormally High Fracture Treating Pressures Caused by Complex Fracture Growth

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INTRODUCTION

The Gas Research Institute's (GRI) fourth Staged Field Experiment (SFE No. 4) well was drilled as part of a field-based research program that has been conducted in the Frontier formation of southwest Wyoming. During this experiment, data were collected from whole cores, multiple sets of openhole logs, in-situ stress measurements, microseismic surveys, and multiple injection (mini-frac) tests.[1] These comprehensive data sets have been used to fully describe the Frontier sandstone. This paper summarizes the analysis of abnormally high fracture treating pressures that were observed on SFE No. 4.

Over the past two decades, the analysis of the net or excess pressure has become an important diagnostic tool for the petroleum engineer to evaluate hydraulic fracture treatments. The technique was introduced to the industry by Nolte and Smith[2] and has been used in many situations to diagnose fracture growth patterns. Net pressure analysis can also be used to categorize formation types based on their net pressure response.[3] Abnormally high fracture pressures encountered in certain formations have also been evaluated with this method[4]

It was evident from the initial injection tests on SFE No. 4 that the injection pressure was noticeably higher than other wells in the area.[5-9] Due to this high injection pressure, a series of diagnostic injection tests was developed to evaluate the cause of the high pressure. These tests indicated the high injection pressures were caused in part by high near wellbore friction. We also saw evidence of high net pressures in the fracture, indicating that multiple fractures were propagating simultaneously.

This paper presents a detailed evaluation of the data from three of the mini-fracs. Also included is a brief summary of the three treatments and a description of the methodology used to analyze the data and determine the reservoir situation.

DESCRIPTION OF THE MINI-FRACTURE INJECTION TESTS

As shown in Table 1 (at the end of this paper), we attempted a total of fourteen (14) injection tests. The data from every injection (mini-frac) tests were analyzed in this project. However, the results from only the June 5, August 5, and August 10 injection tests will be discussed in detail in this paper. These treatments were selected for the following reasons: (1) the bottomhole treating pressure was measured with a downhole gauge, (2) surface data were recorded with the GRI Treatment Analysis Unit (TAU), and (3) large fluid volumes were injected. The knowledge gained by analyzing the data from all 14 tests was invaluable in determining the cause(s) for the abnormally high fracture treating pressure. We can state conclusively that the results obtained from the three injection treatments we describe in this paper are consistent with the analyses from all of the injection tests.

At the start of the June 5 injection test, the tubing-casing annulus contained 2 percent KCL water (280 bbls) from a previous injection. The pumping schedule on June 5 consisted of 750 bbls of 40 lb/1000 gal crosslinked gel displaced with 260 bbls of 2 percent KCL water. Numerous flow rate changes and shut-ins were performed to gather data that we could use to evaluate friction pressures in the near wellbore vicinity.

References at end of paper.

The August 5 injection test was designed to calibrate the three-dimensional fracture propagation model by injecting a viscous fluid at the tip of the fracture. Unlike previous injection tests, the crosslinked gel (600± bbls) was pumped into the formation without being preceded by a significant volume of low viscosity fluid (2 percent KCL water). This was accomplished by circulating and filling the tubing-casing annulus with crosslinked gel before injecting into the formation. Therefore, only 10 bbl of 2 percent KCL water remained in the casing and preceded the crosslinked gel into the hydraulic fracture.

Evaluating the injection pressure response at high injection rates was the primary purpose of the August 10 injection test. Multiple rates ranging from 5 to 40 BPM were pumped during this injection test. The highest previous injection rate was 22 BPM during the May 16 injection test. The injection rates were increased in 5 or 10 BPM increments, after which the pressure was allowed to stabilize. By changing the injection rates, we generated data to correlate bottomhole injection pressure with injection rate. These data could then be analyzed with a three-dimensional fracture model. A second goal of this treatment was to investigate the effect that different fracturing fluids had on the injection pressure. The treatment, conducted solely with 2 percent KCL water, could be compared directly to the August 5th injection in which only crosslinked gel was used. A total of 1160 bbls of fluid were pumped during the August 10 injection test.

ANALYSIS METHODOLOGY

The mini-fracture treatment data measured in SFE No. 4 indicated that complex mechanisms were affecting the pressure profile in the fracture. Even though it was apparent that conventional analysis techniques or simple models probably would not adequately describe the observed pressures, conventional analyses should be performed as a first step in the evaluation process. In many instances, qualitative observations can be made that can assist the engineer in interpreting the data. A more complex analyses can then be performed depending upon the amount and quality of the injection data. In the SFE program, a primary objective is to collect comprehensive data sets so that complex methods can be applied in the analysis of fracture treatment data.

To begin our conventional analyses, we use a log-log graph of the change in pressure after shut-down vs. shut-in time. The purpose of this graph is to identify wellbore storage, bilinear flow, and linear flow regimes. These different flow regimes are characterized by the slope of the data. A unit slope line suggests wellbore storage, a one-quarter slope indicates bilinear flow, and a one-half slope indicates formation linear flow.[10] The existence of a bilinear flow region is associated with a low or finite-conductivity hydraulic fracture. The duration of bilinear flow is very short. Following a transition period, formation linear flow can often be identified. When a high conductivity hydraulic fracture is created, bilinear flow may not be observed and only linear flow is seen.

A graph of pressure change vs. the square root of shut-in time is one graph that can be used to determine fracture closure pressure. During linear flow when the created fracture is open, the change in pressure should be linear when graphed vs. the square root of shut-in time. As the fracture closes, the data will deviate from the straight line.[11] Fracture closure pressure and in-situ stress gradient are two variable names that are commonly used to depict the pressure where the fracture closes.

Near wellbore friction pressure was measured on each treatment by varying the injection rates and recording the instantaneous changes in downhole pressure. The pressure drop after a rate change can be graphed vs. change in rate for each of these injections. The near wellbore friction pressure can then be computed and subtracted from the measured bottomhole treating pressure to generate estimates of the true pressure in the fracture away from the wellbore.

After our conventional analyses were performed, we used a three-dimensional fracture propagation to analyze the injection tests. Net pressure is calculated by subtracting the fracture closure pressure, which was 6800 psi on SFE No. 4, from the true bottomhole pressure inside the fracture near the wellbore.[2] In all cases, the observed pressures during the injection tests were higher than the values predicted by the model. This indicated that the input parameters in the model were not correct. To evaluate which parameters should be changed, it was necessary to change each parameter one at a time, within an acceptable range, to determine the impact of each parameter on net pressure and the resulting fracture geometry. In essence, we performed a parametric study while history matching the actual net pressures.

CONVENTIONAL ANALYSIS

Fig. 1 presents the pressure decline during a shut-in period for the June 5 injection test. We can determine that the instantaneous shut-in pressure (ISIP) is 8320 psi and the near wellbore friction pressure was 345 psi. The log-log graph of these same data, Fig. 2, indicates a brief period, between one and two minutes, when the slope is 0.25 following a brief wellbore storage period. The slope (represented by the derivative points) then declines below a value of 0.2. However, the slope increases to almost 0.5 after approximately one hour of shut-in time. The shape of the graph in Fig. 2 implies both bilinear and formation linear flow may be present in the falloff data and that a low conductivity fracture was created and remains open for the duration of the falloff evaluation. An extended period of linear flow seems reasonable since a large volume of crosslinked gel was pumped. The viscous fluid did not readily leak off to the formation and the fracture is kept open.

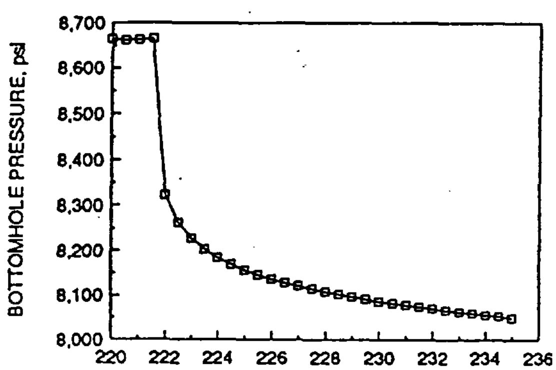

Fig. 1 - Pressure Decline at End of Injection, June 5, 1991

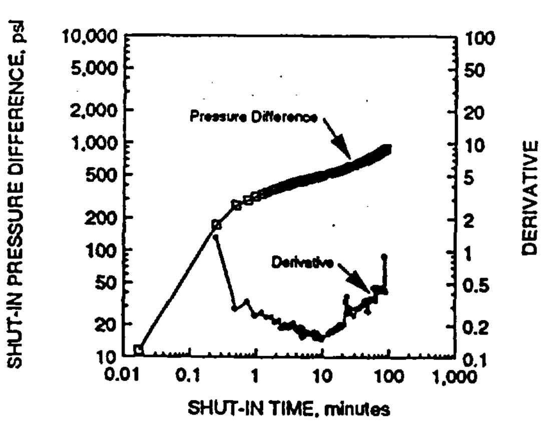

Fig. 2 - Log-Log Graph of Pressure Difference and Derivating at End of Injection, June 5, 1991

The ISIP was determined to be 8310 psi on the August 5 treatment as shown in Fig. 3. The near wellbore friction pressure was estimated to be 190 psi. This indicates the near wellbore friction pressure decreased between the June 5 and August 5 injection tests. Thus, it was obvious that whatever mechanisms was causing the excessive friction pressure, was slowly eroded during the injection tests. Fig. 4 shows the square-root-of-time graph for the pressure falloff data measured on the August 5 treatment. The pressure falloff data form a straight line from approximately 60 to 120 minutes. At slightly less than 7000 psi, the pressure falloff data begin to deviate from the straight line. This derivation occurs at a value that is close to the value of closure pressure in the Second Frontier that we derived from in-situ stress tests.[5] A second straight line could possibly exist from about 2 to 6 minutes. This subtle change in the pressure decline occurs at a value of approximately 8,100 psi. It is possible that we are seeing multiple fractures closing at different values of in-situ stress.

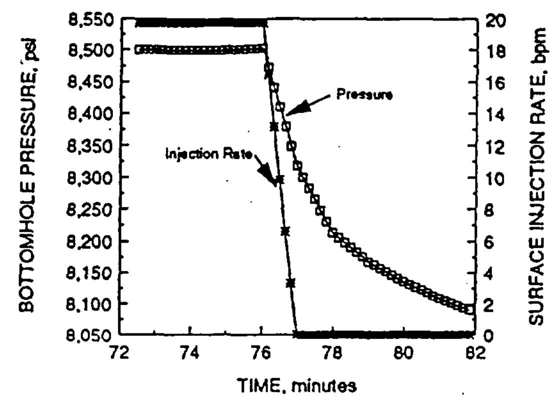

Fig. 3 - Pressure Decline at End of Injection, August 5, 1991

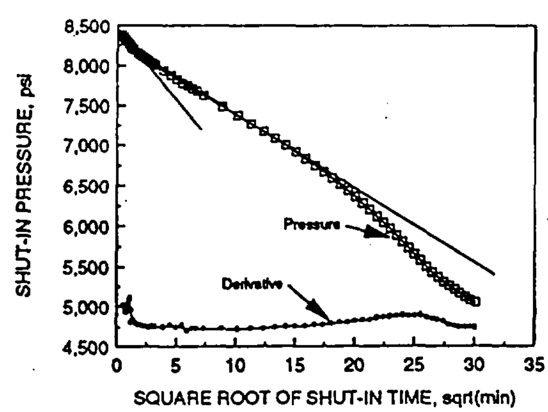

Fig. 4 - Pressure Decline Vs. Square-Root-of-Time at End of Injection, August 5, 1991

A graph of the pressure falloff for the August 10 injection test is shown in Fig. 5. We estimate the ISIP value to be 8,320 psi. The near wellbore friction pressure was 655 psi. This value of near wellbore friction is significantly higher than the value measured during the previous injection tests. However, the final injection rate was 41 BPM, as compared to previous injections which were pumped at approximately 20 BPM. To compare these values on an equal injection rate basis, we calculated the near wellbore friction pressure when the injection rate was about 20 BPM. A value of 415 psi was calculated (versus 190 psi at 20 BPM on August 5). Therefore, the viscosity of the injected fluid is clearly affecting the near wellbore friction pressure.

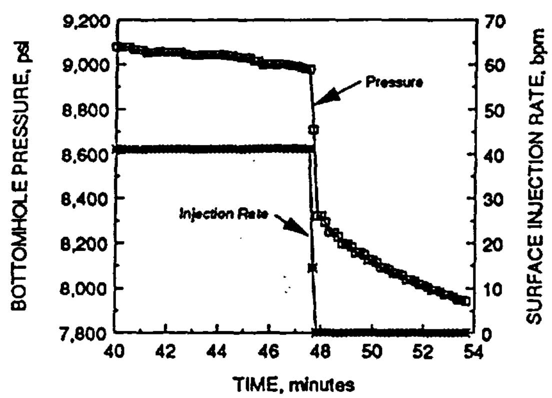

Fig. 5 - Pressure Decline at End of Injection, August 10, 1991

NEAR WELLBORE PRESSURE

Near wellbore friction pressure can be caused by several phenomenon. One cause could be high pressure drop through the perforations. If the perforation holes are too small or too few holes are open, then a large pressure drop will be observed. In SFE No. 4, we reperforated the formation and performing ballout treatments with no change in the downhole injection pressures.

Near wellbore friction pressure can also be caused by tortuosity. Fractures will initiate based upon perforation orientation, wellbore stresses and natural fractures. Sometimes the fractures leave the wellbore, then turn based upon the farfield stresses. If the perforations are not aligned in the same direction as the fracture orientation, then the fracture must open against a horizontal stress that is greater than the minimum horizontal stress (σ_{Hmin}). Depending upon the perforation orientation, this could be as high as the maximum horizontal stress (σ_{Hmax}) or some magnitude between the maximum and minimum horizontal stress. Fig. 6 illustrates the tortuous pathway that can result when this occurs.

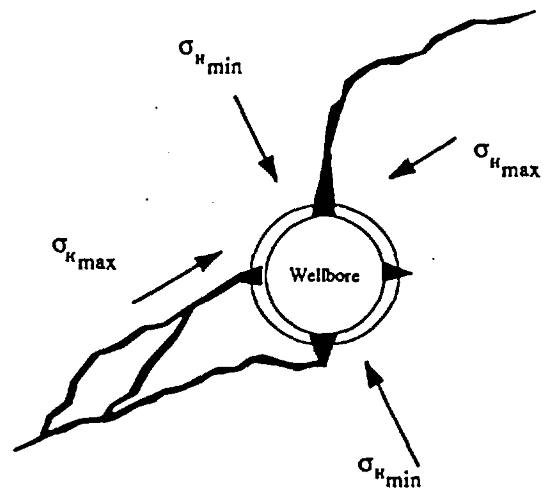

Fig. 6 - Near Wellbore Tortuosity

The near wellbore friction pressure can be estimated by analyzing the changes in downhole pressure that occur when injection rates are changed instantaneously. The friction pressures, when the injection rate was changed rapidly from 20 to 0 BPM for a series of injection tests, are shown in Table 2. The near wellbore friction pressure was higher when injecting 2 percent KCL water. The near wellbore friction pressure decreased when crosslinked gel was used.

Table 2 - Near Wellbore Friction Pressure at 20 BPM

Date	Fluid Type	Volume (bbls)	Near Wellbore Friction (psi)	ISIP (psi)
5/16/91	2% KCl	280	820	8140
	Crosslinked Gel	260	650	8200
6/5/91	Crosslinked Gel	1040	345	8320
8/5/91	Crosslinked Gel	600	190	8310
8/7/91	2% KCl	280	490	8140
8/9/91	2% KCl	200	530	8120
8/10/91	2% KCl	340	415	8320
8/13/91	Crosslinked Gel	885	310	8330

The measured values of near wellbore friction pressure from the May 16 treatment are shown in Fig. 7. The relationship for conventional perforation friction is also included on this graph. It is obvious from this graph the near wellbore friction pressure is not the result of perforations. Therefore, this friction pressure cannot be modeled with the perforation friction equation. To determine the magnitude of this friction pressure, rapid rate changes and multiple ISIP's are required. These types of injection data were recorded for each of the mini-frac treatments so that the true bottomhole treating pressure could be determined.

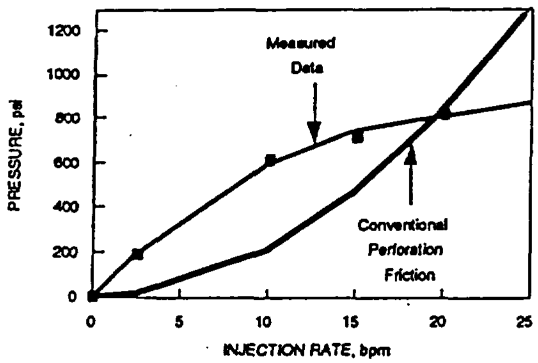

Fig. 7 - Measured Near Wellbore Friction Vs. Injection Rate With 2% KCL Water, May 16, 1991

In comparing several injection tests, it appeared that the near wellbore pressure drop decreased as fluid volume increased. **Fig. 8** shows the lower near wellbore friction at 10 BPM when compared to 20 BPM. **Fig. 8** also indicates the friction pressure decline as fluid volume increased. Analysis of these data clearly shows the near wellbore pressure drop does not adhere to classical orifice flow theory. As such, we believe the behavior can be explained by tortuosity caused by misalignment of the main fracture(s) with the direction of fluid leaving the wellbore.

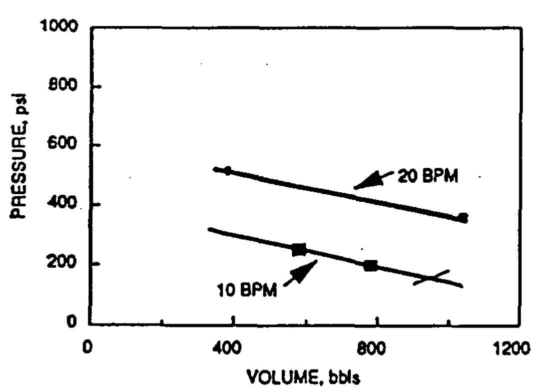

Fig. 8 - Measured Near Wellbore Friction Vs. Injection Rate, June 5, 1991

Quantifying the near wellbore pressure drop and subtracting it from the measured bottomhole treating pressure reveals the true pressure in the fracture near the wellbore. **Fig. 9** illustrates how we can determine net pressure for the June 5 injection test. We made such calculations for every injection test so we could determine the "true" values of net pressure in the fracture that are controlling fracture propagation.

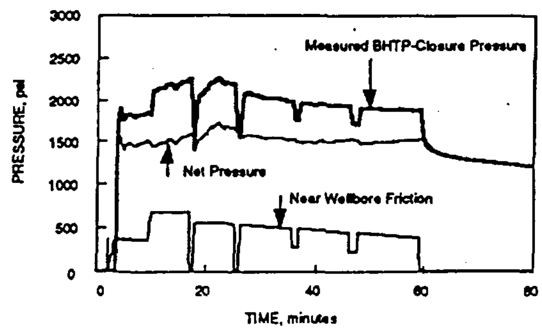

Fig. 9 - Effect of Near Wellbore Friction on Net Pressure, June 5, 1991

FRACTURE MODELING

The in-situ stresses measured on SFE No. 4 were larger than 0.9 psi/ft in the Frontier formation. Other wells in this area have in-situ stresses of 0.75 - 0.8 psi/ft.[5-9] The higher in-situ stress obviously will result in a higher bottomhole treating pressure (BHTP). However, the net pressures we encountered were higher than would be expected even from the higher in-situ stress profile.

A three-dimensional fracture propagation model, *FRACPRO*,[13,14] was used to evaluate the bottomhole treating pressure observed during the injection tests. The observed pressures were higher than the values predicted by the model, indicating we were not modeling the fracture growth correctly. **Fig. 10**, which is the net pressure from the June 5 injection tests, illustrates a typical discrepancy.

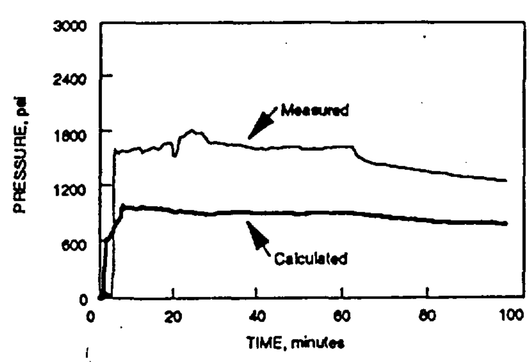

Fig. 10 - Net Pressure Graph for June 5, 1991 Mini-Frac

There were several methods evaluated to increase the calculated bottomhole treating pressure in the model so we could match the field pressures. Two of these methods involved the stress profile. First, the stress profile was increased by 500 psi in every zone. This increased the net pressure calculated in the model and the match in **Fig. 11** was obtained. Shifting the stress profile results in calculated values of net pressure that were about the correct order of magnitude. However, the shape and character of the two pressure curves are distinctly different. Thus, we did not consider this approach acceptable. Even if a reasonable match had been obtained, arbitrarily shifting the in-situ stress profile is hard to justify because it was based on actual in-situ stress tests.

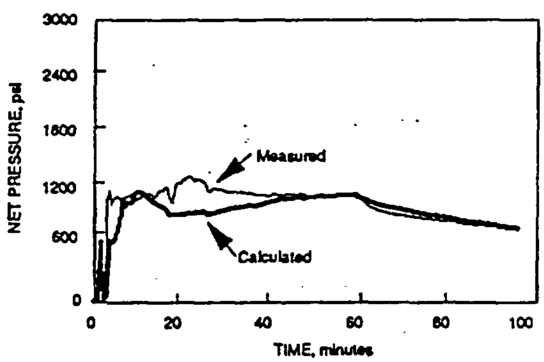

Fig. 11 - Net Pressure Graph for June 5, 1991 Using Increased Stresses

A second approach was to add high stress barriers above and below the fractured interval. We know there are several bentonite stringers in the Frontier section.[5] Since these bentonite beds are soft, they could have horizontal stresses essentially equal to the vertical stress. The stress in these bentonite beds were increased until the history match shown in Fig. 12 was obtained. This match, as the previous one, was not considered acceptable because the shape and character of the calculated pressure values do not match the actual data.

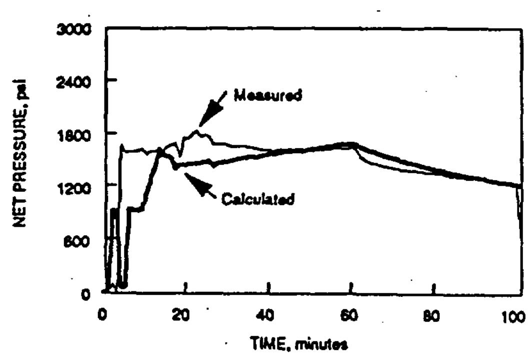

Fig. 12 - Net Pressure Graph for June 5, 1991 Using High Stress Barriers

The possibility of multiple hydraulic fractures was also evaluated. Multiple fractures have been found to occur in formations that contain natural fractures, like the Frontier Sandstone.[5] The existence of multiple fractures created during the hydraulic fracturing process has been documented in the literature.[15,16] The growth of multiple fractures can occur in several ways, as illustrated in Fig. 13. Each fracture could be propagating independently from the wellbore, originating from a different series of perforations. It is also possible that one main fracture may be extended from the wellbore and a secondary fracture may split off, forming a fracture splay. The presence of multiple hydraulic fractures influences the net pressure. The effect has been investigated both with field data[17] and laboratory tests.[18] Several pressure correlations have been developed to evaluate the effect of multiple fractures on net pressures.[19,20]

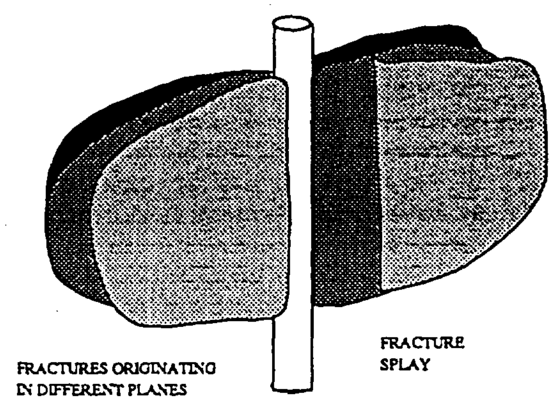

Fig. 13 - Diagram of Multiple Fractures

While maintaining the integrity of the stress profile and other reservoir input data, the high pressure response could be simulated by increasing the number of fractures that are propagated. The three-dimensional fracture propagation model, *FRACPRO*, used in this analysis calculates the pressure response of multiple fractures using three coefficients.[14,20] These include the volume factor, leakoff factor, and opening factor. The volume factor divides the injected fluid equally between each of the created fractures. The leakoff factor increases the surface area of the fracture face by the number of fractures. The opening factor increases the apparent stiffness or toughness of the formation due to the competing fractures.

Increasing the number of fractures increased the calculated net pressure. However, on most of the treatments, it was also necessary to increase the fluid friction in the fracture using the channel flow coefficient.[14] This coefficient is a correction for deviation from laminar, parallel plate flow theory and, in effect, increases the pressure drop down the fracture due to wall roughness. The overall effect of this coefficient is more pronounced when using a conventional rheology model than when using a model where tip effects dominate the pressure response. In our study, both types of models were used to evaluate the net pressure behavior of every injection test.

We matched the data in Fig. 14 by allowing *FRACPRO* to have three fractures growing simultaneously. The channel flow coefficient was increased from the default value in the model. This increase in friction may be the result of initiating the fracture with a large volume (260 bbls) of 2 percent KCL water before the gel was injected.

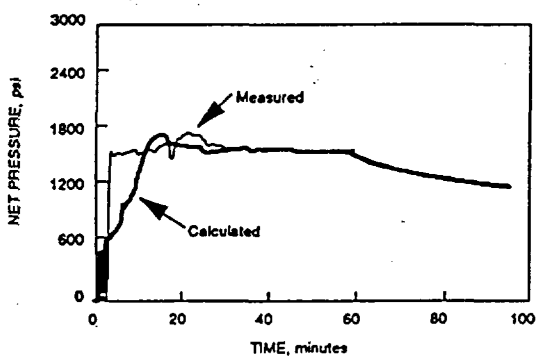

Fig. 14 - Net Pressure Graph for June 5, 1991 Using Multiple Fractures

The August 5 injection test was also analyzed using multiple propagating fractures. Consistent and reasonable results were obtained when multiple fractures were modeled. The best history match was obtained using three fractures, as illustrated in Fig. 15. The fluid friction coefficient was not altered (from the model default value), indicating the model was properly simulating fluid friction in the fracture, with crosslinked gel throughout most of the injection. There is some discrepancy during the early part of the injection which could be related to modeling a fracture being initiated with crosslinked gel when, in fact, a fracture was already created (from previous injections) and was just being refilled with the fluid.

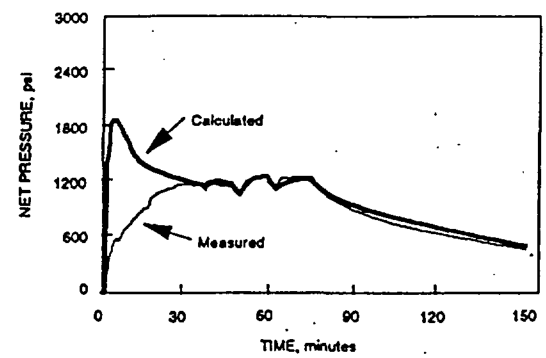

Fig. 15 - Net Pressure Graph for August 5, 1991 Using Multiple Fractures

The August 10 injection test was evaluated using the same methodology as the previous two treatments. The in-situ stresses were adjusted until our best match of the pressure response was achieved. Even though these adjustments generated the same magnitude of pressure, like the previous attempts, they did not result in a reasonable match. The best match was obtained by increasing the number of fractures to 10, as illustrated in Fig. 16. Along with the increase in the number of fractures, the fluid friction in the fracture was also increased from the high value on the June 5 injection test. This is probably due to the fact that the only fluid injected on this treatment was 2 percent KCL water. The higher number of fractures, compared to the previous injections, is difficult to explain. However, it may be easier for the thinner fluid to enter and propagate more fractures than the thicker gel. The increased friction in the fracture may be the result of more fractures taking fluid, thus generating more friction pressure in the fracture.

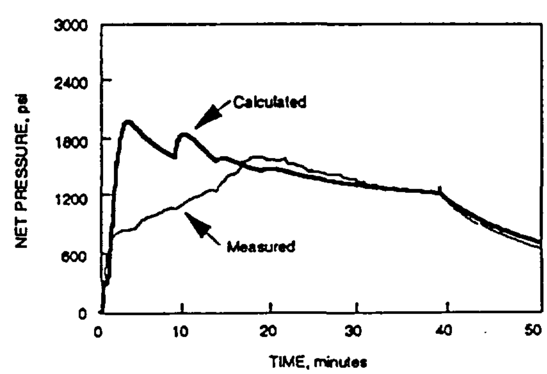

Fig. 16 - Net Pressure Graph for August 10 Using Multiple Fractures

An excellent match was achieved except for the first 12 to 13 minutes where the calculated model pressures are higher than the measured pressures. As previously mentioned, this may be the result of modeling new fracture growth when, in fact, numerous fractures may already exist that are being refilled. Once the injection rate is increased to 20 bbl/min, the net pressures agree very well.

CONCLUSIONS

Based on our analysis of this data, we have reached the following conclusions:

1. There were two major causes of high treating pressure in SFE No. 4. First, near wellbore tortuosity caused excessive near wellbore pressure drop. Second, multiple hydraulic fractures propagating in parallel significantly increased the net fracturing pressures.

2. Near wellbore pressure drop resulting from tortuosity cannot be modeled as conventional perforation friction. The near wellbore pressure drop is not a function of the rate squared but, instead, is a complex phenomenon that must be measured from injection rate changes and multiple ISIP's.

3. Removing the near wellbore pressure drop to obtain the "true" pressure in the fracture near the wellbore is critical to proper analysis of fracture treatments.

4. Modeling of the net pressure response during the SFE No. 4 injection tests could only be accomplished by simulating multiple fractures.

5. Injecting 2 percent KCL water at a higher rate apparently caused more multiple fractures to be propagated when crosslinked gel was used during the injection test.

ACKNOWLEDGMENT

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Table 1 - Treatment Summary

Injection Test No.	Date	Description Of Treatment	Fluid Type*	Injection Rate, BPM	Treatment Volume, bbl
1	11/14/90	Teledyne mini-frac: 1st attempt	2% KCl	9 - 3	230
2	11/15/90	Teledyne mini-frac: 2nd attempt after reperforating	2% KCl	3	40
3	5/15/91	Step rate injection/falloff tests	2% KCl	0.5 - 10	155
4	5/16/91	Step rate injection/mini-frac	2% KCL X-linked Gel	5 - 22	540
5	6/5/91	Teledyne mini-frac; wellbore filled with 2% KCl water	2% KCl X-linked Gel	10 - 20	1,010
6	8/5/91	Step rate injection test (circulate well with X-linked gel)	X-linked Gel	0.5 - 20	600
7	8/7/91	Step rate injection test	2% KCl	0.5 - 20	255
8	8/8/91	Spinner survey during injection	2% KCl	1 - 11	120
9	8/9/91 (am)	Injection and flowback with spinner	2% KCl	1 - 20	115
10	8/9/91 (pm)	Multiple injection and flowback with spinner	2% KCl	20	130
11	8/10/91	Multirate mini-frac	2% KCl	5 - 40	1,160
12	8/11/91	Injected 100 mesh sand	2% KCl	10 - 20	640
13	8/13/91 (am)	Teledyne mini-frac; test aborted - lubricator malfunction	2% KCl X-linked Gel	20	480
14	8/13/91 (pm)	Teledyne mini-frac	2% KCl X-linked Gel	20	405

*Fluid injected into the formation.

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Integration of Fracturing Dynamics and Pressure Transient Analysis for Hydraulic Fracture Evaluation

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Abstract

This paper presents pre- and post-fracture pressure transient analysis, combined with net fracture pressure interpretation, for a well in a naturally fractured geothermal reservoir. Integrated analysis was performed to achieve a consistent interpretation of the created fracture geometry, propagation, conductivity, shrinkage, reservoir flow behavior, and formation permeability characteristics. The interpreted data includes two-rate pre-frac injection tests, step-rate injection tests, a series of pressure falloff tests, and the net fracturing pressure from a massive fracture treatment. Pressure transient analyses were performed utilizing advanced well test interpretation techniques and a thermal reservoir simulator with fracture propagation option. Hydraulic fracture propagation analysis was also performed with a generalized 3-D dynamic fracture growth model simulator.

Three major conclusions resulted from the combined analysis: 1) that an increasing number of hydraulic fractures were being simultaneously propagated during the fracture treatment, 2) that the reservoir behaved as a composite reservoir with the outer region permeability being greater than the permeability of the region immediately surrounding the wellbore, and 3) that the created fractures extended into the outer region during the fracture treatment but retreated to the inner region several days after stimulation had ceased. These conclusions were apparent from *independent* pressure transient analysis and from *independent* hydraulic fracture propagation analysis. Integrated interpretation, however, increased the confidence in these conclusions and greatly aided the quantification of the created hydraulic fracture geometry and characterization of the reservoir permeability.

Introduction

Hydraulic fracturing is an effective way of well stimulation in tight oil and gas reservoirs. Development of geothermal systems including hot dry rock reservoirs also employs this technology[1,2]. Hydrothermal energy extraction is typically controlled by the conductivity of the natural fracture system intersected by a wellbore. Hydraulic fracture stimulation is often applied to less prolific producers to enhance productivity by establishing the communication with nearby natural fracture systems[3].

Effective hydraulic fracture stimulation primarily depends on the modeling and diagnostic capability required to optimally design field operations and to reliably estimate the created geometry and dimensions of the induced hydraulic fracture systems. Realistic three-dimensional fracture models are necessary tools for these purposes. The required functions to be possessed by models are such that formation is characterised by rock and fluid parameters including stress, modulus, permeability, pressure, fluid satuaration, etc., that physical mechanisms of fracture initiation, fluid leakoff, fracture propagation and closing are modeled, and that observed well pressures can be reproduced by simulating a single fracture or multiple fractures.

Well testing is another indispensable tool which is normally conducted before and after hydraulic fracturing in order to obtain data for fracture evaluation. Analysis of injection and falloff tests in a fractured well can possibly be complicated by several effects including the multiphase effect[4] and temperature effect[5]. Another complexity in injection and falloff tests is caused by dynamic behaviors of the fractured well. Dynamic opening and closing of fractures are amplified in the case of an unpropped fracturing treatment. Because injection rate is usually very high in geothermal well testing, dynamic fractures can be easily initiated from natural fractures. Effects of propagating fractures on pressure-transient injection and falloff data have been analysed by several authors[6,7] for determining key parameters such as fracture propagation characteristics, reservoir and fluid properties, and temperature and saturation profiles.

The principal objectives of this paper are to interpret pre- and post-fracturing pressure transient tests and net fracturing treatment pressures for a well in a naturally fractured geothermal reservoir, and to evaluate physical mechanisms governing growth and closure of unpropped hydraulic fracturing in this system. Net fracturing pressures were first analyzed by a dynamic fracture modeling system which determined the fracture geometry, the number of openings of multiple fractures, as a function of both time and formation permeability[8]. Formation parting pressure was estimated by interpreting two-rate pre-frac injection tests and step-rate injection tests. A series of pressure falloff tests were then analyzed to estimate changing fracture lengths and evaluate permeability of different zones surrounding the well. A series of transient injectivity data from the massive fracture treatment were interpreted applying the multirate analysis method. Hydraulic fracture propagation analysis was also performed with a thermal reservoir simulator with a fracture propagation option.

Analyses by individual tools were then combined to reach a consistent interpretation of the created fracture geometry and dimensions, reservoir flow behavior, and formation permeability characteristics. Integrated interpretation increased the confidence in quantification of the created hydraulic fracture geometry and characterization of the reservoir permeability.

Field Test Operation

Background. The tested well TG-2 was drilled next to the Matsukawa geothermal field under a plan to produce steam after creating communication with the Matsukawa reservoir by hydraulic fracturing. The well is deviated and open hole over the interval 710 - 1298 m depth. The target zone for hydraulic fracturing consists mainly of naturally fractured silt and tuff formations. Mutiple-step rate tests of fresh water and injection tests by different gels were first carried out to choose an injection fluid and to evaluate reservoir properties for hydraulic fracturing. Analysis of a BHTV log run before and after the gel injection tests indicated that most of the created hydraulic fractures were in the zone between 1100 - 1180 m.

After having decided to use fresh water for testing and fracturing, pre-fracturing well tests, a massive hydraulic fracturing (MHF) treatment, and post-fracturing well tests were performed sequentially. All the well tests conducted were injection and falloff tests. In all the tests, memory gauges were stationed at bottomhole to record pressure and temperature, or production logging was run to survey injection profiles, to measure pressure and temperature gradients during the injection period, and to monitor falloff pressures when the tool was stationed at a fixed depth. Spinner analysis indicated that a limited number of fuild entry depths with narrow intervals were located between 1080 and 1190 m.

Test Procedure. Testing and operation at the TG-2 well consisted of four parts:

(1) Two multiple step rate tests (MSRT-1, and MSRT-2) with fresh water and three gel injection tests were conducted on January 23 through 26, 1992, to choose a fracturing fluid and to evaluate formation properties. Pressure and rate data of MSRT-1 and MSRT-2 are shown in Fig. 1. In MSRT-1, the rate was increased by ten steps from 0 to 12 BPM for 54.5 minutes. In MSRT-2, the rate was increased by nine steps from 0 to 16 BPM for 50.0 minutes. Three gel injection tests were performed with YF-650, YF-660 and PSS polymers respectively, each at about 10 BPM for about 50 minutes.

(2) Two injection-falloff tests with fresh water were conducted in sequence on September 22, 1992, to evaluate pre-fracturing properties of the formation. The first injection (IT-1) continued at about 0.88 BPM (1261 BPD) for 48 min. and was followed by a falloff test. The second injection test (IT-2) was at about 9.42 BPM (13562 BPD) for 75 min. and a longer falloff test followed immediately after injection.

(3) The MHF treatment was performed with fresh water on November 24 and 25, 1992. Pressure and rate records are shown in Fig. 2. The injection rate was initially increased stepwise to a maximum rate 25.4 BPM and kept between 25.4 and 24.5 BPM. Injection was interrupted four times, each time for about 30 min. Cumulative injected water was 27,400 Bbls. A pressure falloff test followed the 24 hours injection.

(4) Two post-fracturing injection-falloff tests were conducted on November 27 and 29, 1992, respectively. Fresh water was injected at a rate of 9.44 BPM for 4.14 hours and 1.87 hours before the November 27 and the November 29 falloff tests, respectively.

Hydraulic Fracture Analysis

Fracture Model Development. For nearly fifty years hydraulic fracture stimulation has been widely used to stimulate production from all types of reservoirs. There has not, however, been a commensurate level of rigorous engineering applied to the process. At its inception, hydraulic fracturing practice was strictly empirical. In the 1960's and 1970's 2-D fracturing models[9,10] were introduced in an attempt to add quantitative engineering tools to the process. The early 1980's saw the emergence of simplified 3-D models[11,12], which at least offered the hope of providing realistic tools for modeling (understanding) hydraulic fracture growth. The optimism of the early 1980's, however, was quickly dashed by parallel efforts at careful collection of fracture treatment data sets which clearly showed that the predictions of the early ("conventional") 3-D fracture models agreed very poorly with actual measured fracture treatment data sets[1,13,14]. It soon became abundantly clear that without the ability to model and explain real field fracturing data, it simply would not be possible to understand fracture treatment results or to know how to change a fracture design to improve treatment success.

Net Pressure Analysis. To achieve confidence in the predictions of any hydraullic fracture simulator requires that the net fracturing pressure (fracturing fluid pressure above formation closure stress) predicted by the model match the observed net fracturing pressure on the treatment. The net fracturing pressure can be calculated by subtracting the formation closure stress and any pressure loss due to perforation and/or near-wellbore friction, $p_{perf/near-wellbore}$, from the bottomhole pressure:

$$p_{net} = p_{bottomhole} - p_{closure} - p_{perf/near-wellbore}$$

Frictional losses in the wellbore and/or the perf/near-wellbore region, the major unknowns in the equations above, are very difficult to *predict*, but they are relatively simple to *measure*, using abrupt flow-rate changes and shut-ins.

Hydraulic Fracture Model. Extensive net pressure analysis conducted over the last five to ten years has revealed dramatic differences between the observed fracturing response and the response predicted by the conventional, elastic, 3-D hydraulic fracture models: observed net pressure response was simply vastly different from what the "simplified" 3-D fracture models predicted. A host of mechanisms, which were not previously accounted for, were found to often play dominant roles in hydraulic fracture growth, including: complex rock behavior near the fracture tip[14], fracture containment due to permeability barriers; near-wellbore fracture tortuosity, and, perhaps most significantly, the simultaneous propagation of multiple hydraulic fractures.

In response to these complexities, generalized and modular "lumped parameter" 3-D fracture models were developed because they allow for the approximate handling of the complex fracture mechanisms mentioned above[13,15-17], in addition to rigorously modeling the impacts on fracture growth of variable (with depth) reservoir stress, modulus, and permeability. In exchange for this great model flexibility, the models sacrifice any attempt at rigorous calculation of the precise shape of the fracture perimeter that might be achieved with a fully 3-D finite element model. Instead, the fracture dimensions are approximated by two half ellipses.

Simultaneous Propagation of Multiple Hydraulic Fractures. In general, hydraulic fractures tend to initiate where there is a pre-existing crack from a natural fracture or a perforation-induced crack. Fractures initiate at points of pre-existing cracks because these are structually the weakest points. Hydraulic fracture initiation results when the stress intensity at a fracture tip rises above the material's critical stress intensity level, usually referred to as the "fracture toughness". In a typical reservoir environment, hydraulic fractures may initiate from one or several perforations or existing cracks along an openhole interval, and then coalesce into one (or a few) dominate fracture(s) at some distance away from the wellbore. In naturally fractured reservoirs, however, hydraulic fracture initiation may occur wherever a natural fracture intersects the wellbore or is intersected by a growing hydraulic fracture. In naturally fractured reservoirs, therefore, multiple hydraulic fractures are typically initiated and propagated, often in increasing numbers as more natural fractures are intersected by the growing hydraulic fractures. This process is self reinforcing as the propagation of multiple hydraulic fractures tends to elevate the net fracturing pressure, which in turn makes it easier to initiate hydraulic fracture propagation at newly intersected natural fractures due to the increased stress intensity level that can be achieved with the elevated net pressures.

Evidence from coring through propped hydraulic fracture treatments in naturally fractured reservoirs has confirmed the simultaneous growth of multiple hydraulic fractures[18,19]. In fact, almost all investigations of in situ hydraulic fractures (through coring, minebacks, etc.) have revealed the presence of multiple hydraulic fractures. The simultaneous growth of multiple hydraulic fractures should be expected when stimulating naturally fractured reservoirs, and the number and nature of the multiple fracturing can be estimated by net pressure matching of the observed fracturing data.

MHF Treatment Data Analysis. The treating and net pressure response observed on the 27,400 Bbl MHF (see Fig. 2) displayed the same type of behavior that was observed on all previous injections into the tested well:

- Gradually rising pressures when pumping at a constant injection rate, and
- Significant treating (and net) pressure sensitivity to fluid injection rate.

Both of these characteristics are contrary to the expected behavior for a single (radial) fracture growing in a homogeneous reservoir. Simple radial fracture growth displays net fracturing pressure that is (nearly) independent of fluid injection rate and falls gradually ($t^{-1/3}$) with injection time. The two observed characteristics are, however, quite typical for hydraulic fracturing in a reservoir where multiple parallel hydraulic fractures are generated. The propagation of an increasing number of hydraulic fractures keeps the pressure from falling because as more fractures open there is increased "competition" for opening space (width). Iterative matching of the observed net fracturing pressure resulted in an estimate of the hydraulic fracture growth behavior versus time (results in Fig. 2).

Fig. 3 shows a plot of the pressure decline data versus the square-root shut-in time for IT-1. There is a significant deviation from the linear slope behavior at a bottomhole (at 1000 m) pressure of approximately 2000 psi. This point is believed to represent closure of the created hydraulic fractures. Similar analysis was performed on the pressure decline data from the two step-rate tests (MSRT-1 and MSRT-2), as well as the gel injection tests and IT-2. All of these analyses showed fracture closure in the range 2000 psi +/- 200 psi. Fracture closure did not appear as distinct as it often does. it is believed that this is due to the fact that many hydraulic fractures are closing and that the individual fracture closures are probably occurring over a few hundred psi range. For the sake of the net pressure analysis, a formation closure stress of 2000 psi was used.

In addition to the level and character of the net fracturing pressure, the other major unknown that would significantly affect the rate of fracture growth is the "apparent" reservoir permeability. An increase in an encountered reservoir permeability - as the fracture grew nearer to the highly permeable Matsukawa geothermal reservoir - would slow the fracture radius growth due to a reduction in the fracture efficiency caused by the increasing leakoff of fluid out of the hydraulic fracture system. As can be seen in **Fig. 2**, several thirty to sixty minute shut-ins were scheduled during the MHF treatment to allow determination of the average encountered reservoir permeability versus fracture size (injected fluid volume). Careful matching of the net fracturing pressure during all of the shur-ins during the MHF resulted in an estimation of the increase in encountered reservoir permeability versus time for the injection. The formation permeability was initially assumed to be the same as the value determined from the earlier smaller volume injection tests. **Table 1** shows the results of the net pressure analysis, including estimates of the number of propagating hydraulic fractures and the relative increase in reservoir permeability.

Fig. 2 shows the net fracturing pressure match with the number of "equivalent" propagating hydraulic fractures versus time. From this figure it can be seen that the rate of generation of new "equivalent" hydraulic fractures gradually slows with time, and that there is a total of about 19 "equivalent" fractures after pumping the total 27,400 Bbl MHF. **Fig 2** also shows the fracture radius and the fracture width of each individual fracture versus time: with final values of 310 feet and 0.12 inches, respectively. Note how close the fracture modeling's predicted fracture length versus time matches the independent predictions from the pressure transient analysis. As explained in the following sections, the apparent increase in encountered reservoir permeability is also remarkably similar from both the hydraulic fracture analysis and the pressure transient analysis.

Step Rate Tests Analysis

Bottom-hole flowing pressures of MSRT-1 and MSRT-2 are graphed against injection rate as shown in **Fig. 4**. The plotted pressures are taken at the end of each rate hike during each test. It is seen that linear increases in pressure break twice at about 2,000 and 2,250 psia in both tests as injection rate increases. Therefore, fracture started parting at 2,000 psia and another fracture was induced at 2,250 psia, and both kept propagating above 2,250 psia.

Fig. 5 shows also bottom-hole flowing pressures vs. injection rate for the first five stages in the MHF treatment. Although conclusive interpretation is not reached because of scarce data points, the pressure does not break sharply but gradually bends between about 2,200 and 2,700 psia. This suggests that multiple fractures were induced sequentially. Another observation is that the parting and propagating pressures are much higher than those of MSRT-1 and MSRT-2, which indicates that the fractures created by the MHF propagated into zones of different rock properties.

Injection pressures of IT-1 and IT-2 are interpreted by the method proposed by Singh and Agarwal[20]. **Fig. 6** shows a plot of the rate normalized pressure function $\Delta p/\Delta q$ against the multirate equivalent time function assuming radial flow, where $\Delta p = p_{wf_n}(\Delta t) - p_{wf_{n-1}}(t_{n-1})$ and $\Delta q = q_{n-1} - q_n$. Here, pressures of IT-1 are well below an estimated fracture parting pressure, and therefore can be taken as the baseline data. Data for the two steps coincide as long as the fracture parting pressure (FPP) is not exceeded. When the FPP is exceeded during the second step IT-2, the IT-2 data beyond this time will deviate from the baseline IT-1 data with a smaller slope. From **Fig. 6**, the FPP is estimated to be 2,038 psia at an equivalent time of about 0.014 hours.

Pressure Transient Analysis

Injectivity Test Interpretation. The pressure transient data during the very first injection stage of 33 minutes of the MHF treatment operation (labeled as 1 in **Fig. 2**) can be interpreted as shown in **Fig. 7**. Because the pressures during this injection stage are lower than the level of fracture parting pressures, these data are considered to reflect the formation property near the wellbore. Although the pressure derivative curve fluctuates as seen in **Fig. 7**, the latter portion seems to approach radial flow, from which formation permeability is estimated as 0.546 md.

Falloff Test Interpretation. Six falloff tests are interpreted: four mini-falloff tests during the injection stages (**Figs. 8** through **11**), the long falloff test data after the stage-8 injection (**Fig. 12**), and the falloff test conducted two days after the MHF treatment (**Fig. 13**). All the mini-falloff tests and the long falloff test exhibit clearly a half-slope line behavior which is a feature of an infinite conductivity fracture, but all the tests terminate during the linear flow period. Meaningful interpretations of these falloff tests require a formation permeability estimate which has to be obtained from other tests including a radial or pseudo-radial flow period. A good estimate for permeability is 0.546 md obtained from the injectivity test as discussed above.

The falloff test conducted two days after the MHF treatment is also interpretable to estimate formation permeability. The data are matched by nonlinear regression with an infinite conductivity fractured well model. From reasonably good matches of pressure and derivative curves as seen in **Fig. 13**, the formation permeability is estimated as 1.573 md.

Two values of formation permeability have been obtained, 0.546 md and 1.573 md. The former is based on the injectivity test which tends to reflect the near wellbore region, while the latter is obtained from the falloff test which detects the formation property ahead of the front of injected water. Reservoir rock, therefore, changes from a zone of 0.546 md immediately surrounding the wellbore to a zone of 1.573 md farther into formation.

Now, the mini-falloff tests and the long falloff test can be interpreted using the formation permeability values as obtained above. Consistent interpretations are made by applying the lower permeability to the first mini-falloff test, and the higher permeability to the other falloff tests based on the trends on pressure and levels of pressure derivative. The interpreted results are summarized in **Table 2**. The table shows that fractures extended into the higher permeability zone during and after the second mini-falloff.

Fracture Closure or Shrinkage Effects. In many unpropped fracturing treatment jobs, the created fractures begin to close once the pressure inside the fracture falls below the parting pressure of formation rock. This phenomenon causes a change in fracture geometry in the form of reduction in fracture width (narrowing) or reduction in fracture length (shrinkage). Both of these geometrical alterations will affect pressure falloff data, and thus can be identified on pressure transient tests.

Koning provides a model for fracture closure by accounting for changing fracture width at a fixed fracture length through the concept of fracture storage[7]. This model assumes that the created fracture path remains in the formation as an infinite conductivity fracture of nearly zero width upon the fracture closure. Several models for propagating fractures have been proposed by various investigators, with the simplest of them given by Larsen-Bratvold[6] who consider that a fracture grows proportional to square root of injection time.

We use the simple model of Larsen-Bratvold for a falloff test and assume that the shrinkage in fracture length occurs proportional to the square root of shut-in time, similar to fracture propagation:

$$x_f(\Delta t) = x_f(t_p) - a\sqrt{\Delta t} \qquad (1)$$

where, $x_f(t_p)$ is the fracture length at the time of shut-in and "a" is the proportionality constant. For simplification purposes, it is also assumed that the parting pressure is equal to initial reservoir pressure, so that a fracture is created at the instant of injection. Thus, dimensionless falloff pressure may be expressed by superposition as:

$$p_{wD}(\Delta t_D) = p_D^f\left[\Delta t_D, x_f(\Delta t_D)\right] - p_D^f\left[(t_p+\Delta t)_D, x_f(t_{pD})\right] + p_D^f\left[t_{pD}, x_f(t_{pD})\right] \qquad (2)$$

and, p_D^f is the infinite-conductivity fracture solution given by[21]:

$$p_D^f(t_D) = \frac{1}{2}\sqrt{\pi t_D}\left[erf\left(\frac{0.866}{\sqrt{t_D}}\right) + erf\left(\frac{0.134}{\sqrt{t_D}}\right)\right] - 0.433Ei\left(-\frac{0.75}{t_D}\right) - 0.067Ei\left(-\frac{0.018}{t_D}\right) \qquad (3)$$

where,

$$p_{wD}(\Delta t_D) = \frac{kh\left[p_{wf}(t_p) - p_{ws}(\Delta t)\right]}{141.2qB\mu} \qquad (4)$$

$$t_D = \frac{0.000263kt}{\phi\mu c_t x_f^2} \qquad (5)$$

The second and the third terms in Eq. 2 are based on fixed fracture length of $x_f(t_p)$; but the first term should be computed at dimensionless shut-in time based on fracture length given by Eq. 1:

$$x_f(\Delta t) = \left(1 - a_D\sqrt{\Delta t_D}\right)x_f(t_p) \qquad (6)$$

where,

$$a_D = \frac{a}{\sqrt{0.000263k/\phi\mu c_t}} \qquad (7)$$

Fig. 14 shows log-log plots of pressure and pressure derivative for three falloff tests using the above fracture shrinkage model at a_D = 0, 1 and 2. a_D = 0 represents the familiar constant fracture length case, which starts as one-half slope lines for the formation linear flow followed by the pseudoradial flow. The case of a_D > 0, initially exhibits the one-half slope line behavior when the shrinkage in the fracture length is not significant. At late times, both pressure and pressure derivative increase above the one-half slope line level, indicating onset of fracture closure or shrinkage.

This theoretical investigation provides an explanation for the upward trending of pressure derivative curve that is seen in several mini-falloff tests conducted during the MHF treatment in this study. In fact, the time of departure from the one-half slope line may be used as an indicator of the start of fracture closure or shrinkage effects. We have checked the pressures corresponding to these departure times and they agree closely with the FPP calculated before.

Multirate Analysis. As seen in **Fig. 2**, the MHF treatment is a multirate test where the injection rate was successively increased from 0 to the final rate ranging between 25.4 BPM and 24.5 BPM. **Fig. 15** is a rate normalized multirate plot of injection periods. The straight line portions of the data suggest infinite acting radial flow in an apparent homogeneous formation. The slopes of the straight lines correspond to effective permeabilities, and the distance between the parallel straight lines indicates the magnitude of skin factor. Several important characteristics can be interpreted from this multirate plot. Assuming apparent reservoir homogeneity, the effective permeability progressively increases from the injection stage-1 through stage-4 as the slopes of straight lines decrease, and then remains about the same from stage-4 through stage-8. It may be inferred from these increased effective permeability that formation permeability is improved by the creation and propagation of multiple and distributed fractures. The fact that enhanced effective permeability is determined from injectivity tests is not surprising because it is well documented in the literature[4,22] that in moving boundary problems, such as those in injection tests, pressure transients during injection period show reservoir behavior behind the flood front, while falloff tests investigate regions ahead of the front. Thus, permeability calculated from multirate analysis would represent an apparent permeability in the injected fluid bank, including the effect of multiple fractures in the invaded zone. **Table 1** shows that after 340 minutes (Falloff Test #2 corresponding to stage-5), generally the number of propagating fractures is significant enough to give an appearance of an effective enhanced permeability.

The parallel lines of stage-4 through stage-8 suggest constant effective permeability and decreasing skin. As apparent homogeneity is assumed, decreasing skin in this case corresponds to increasing fracture length x_f.

The data of stages-1 and -2 coincide until the time function value $f(q,t)$ of -1, and then they deviate from each other, indicating fracture initiation. From the pressure function of 0.11 at this separation point, the fracture parting pressure is interpreted to be 2015 psia.

Synergism of Fracturing and Transient Analysis

Fracture Initiation (Parting Pressure). Based on multistep rate test analysis, the formation has a range of fracture parting pressures. The range is evaluated to be of order 200 - 300 psi, which is not large enough to dramatically affect the fracture modeling results. This, however, supports interpretation that multiple hydraulic fractures are initiated and propagated in increasing numbers as more natural fractures are intersected by the growing hydraulic fractures.

Fracture Lengths. The fracture model assumes fracture profile of circular plane geometry for uniform rock stress distribution, and estimates the fracture radius, the number of equivalent hydraulic fractures, and total hydraulic width, all as function of time. Pressure transient analysis, on the other hand, estimates the fracture length of a single equivalent hydraulic fracture. Both of these are therefore avaraged fracture length and can be compared. The fracture lengths estimated by the fracture model and pressure transient analysis are plotted in **Fig. 2**. The results are generally in good agreement.

Closure Behavior. As discussed in the foregoing, the pressure transient tests can detect fracture closure behaviors with a good sensitivity. Based on the falloff test interpretation, the fractures created by the MHF treatment (a single fracture of 312 ft length) mostly closed in two days, and only a part of the fractures (a single fracture of effective length of 31 ft length) was reopened when injectivity and falloff tests were carried out after 56 hours. However, there may have remained a narrow passage of almost zero width connecting the fracture with the outer region of higher permeability, as is evident from the falloff behavior of **Fig. 13**.

In the hydraulic fracture model, fracture closure phenomena are modeled mainly in terms of the fracture width. Simulated closure behavior is presented in **Fig. 2**. The fracture length was kept constant after the injection stages, while the width at the wellbore shrinks quickly. Rapid decreases in the fracture width are also seen after the first two shut-ins. These simulation results are very consistent with the pressure transient analysis as seen in **Figs. 8** through **12**. The first and the second mini-falloff tests clearly show upward bending behavior of pressure derivative curve (**Figs. 8** and **9**), which is interpreted as a sign of fracture closing. The third and the fourth mini-falloff tests, however, do not show this behavior as the falloff pressures remain above the FPP (**Figs. 10** and **11**). The last falloff test shows again fracture closing as seen in **Fig. 12**.

Permeability Zones. The existence of two permeability zones is confirmed both by well test analysis and by fracture model analysis. As listed in **Table 1**, the leakoff coefficient is estimated to increase by 60 % implying a 2.5 fold increase in reservoir permeability. Pressure transient analysis shows a quite similar 2.6 fold increase in the reservoir permeability (0.6052 md to 1.573 md). The transition zone is estimated to exist not far, around 150 ft., from the wellbore, because both fracture model and pressure transient analysis estimate a permeability change between the first and second mini-falloff tests, or during the fifth stage of injection. Recall from **Table 2** that the fracture half-length from the first and second falloff tests are 138 and 169 ft, respectively.

Multiple Fractures. In fracture model simulation, the number of fractures must be explicitly specified for matching the measured pressures. Corresponding to the continuous increase of the net pressure during the injection stages, the number of required hydraulic fractures being propagated continues to increase. **Table 1** and **Fig. 2** show the specified numbers of fractures necessary for obtaining a good match to measured pressures. Multirate analysis of pressure transient of the eight injection stages only suggests multiple fractures by an increase in effective permeability in the invaded zone assuming apparent reservoir homogeneity.

The MHF treatment has been simulated by a two-dimensional areal model using a thermal oil recovery simulator which has a dynamic fracture growth/shrinkage option. This option is enabled essentially by four parameters: (a) fracture opening pressure, (b) a range of pressure over which fracture opens, (c) maximum transmissibility multiplier to be applied for fully open fracture, and (d) location of fracture. In order to reproduce the pressure behavior as shown in Fig. 16, the parameters (a), (b) and (c) were set as 2500 psi, 100 psi, and 10,000, respectively. For (d) fracture locations, extensive dynamic fracturing needed to be assumed to sustain increasing pressures during the latter injection stages. For a reasonable match, areal propagation covering the 410 ft x 410 ft square zone with the well at center was assumed in addition to linear propagation of two vertical fractures. Fig. 17 shows the acoustic emission recorded during the MHF treatment, which can be referred to for qualitative verification of the geometry and dimension of fracture propagation. From the planview map, a general direction of hydraulic fractures is evaluated to be in the NE - SW direction. A three-dimensional distribution of the AE events also suggests that multiple fractures were created and extended into shallower zones.

Conclusions

1. Analysis of the multiple-step rate test data shows that the formation has a range of fracture parting pressures with an estimated order of several hundred psi.

2. An increasing number of hydraulic fractures were being simultaneously propagated during the fracture treatment. Multirate analysis suggests multiple fractures by an increase in effective permeability in the flooded region assuming apparent homogeneity, while the hydraulic fracture model provides a number of 'equivalent' hydraulic fractures with a total hydraulic width.

3. The reservoir behaved as a composite reservoir where the outer region permeability being greater than the permeability of the region immediately surrounding the wellbore. During MHF, fractures penetrated into the high permeability region but retreated back during subsequent falloff.

4. Fracture growth and shrinkage are better quantified by integrated interpretation of fracture model simulation and pressure transient analysis.

Acknowledgments

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A hydraulic fracture modeling system, FRACPRO was used for fracture analysis. Well test analysis was accomplished by Automate, the well test interpretation system. The reservoir simulation model used is STARS developed by Computer Modelling Group in Calgary, Canada. We thank H. Kikuchi of Teikoku Oil Co. for his additional help with FRACPRO.

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SI Metric Conversion Factors

ft × 3.048*	E-01	= m
bbl × 1.589 873	E-01	= m^3
md × 9.869 233	E-04	= μm^2
psi × 6.894 757	E+00	= kPa

*Conversion factor is exact

Table 1—Apparent Number of Propagating Hydraulic Fractures and Leakoff/Permeability Multipliers Versus Injection Progression

	Time (min. on Fi. 3)	# of Fracs	Leakoff Multiplier	Permeability Multiplier
Injections 1-4	NA	3-4	1.0	1.0
Falloff Test #1	180	5	1.3	1.69
Falloff Test #2	340	8	1.4	1.96
Falloff Test #3	600	11	1.6	2.56
Falloff Test #4	850	14	1.6	2.56
Falloff Test #5	1500	19	1.6	2.56

Table 2—Results of Falloff Test Interpretation

	$x_f h\sqrt{k}$ $md^{1/2}ft^2$	k md	x_f ft
Falloff Test #1	40910	0.6052	138
Falloff Test #2	81330	1.604	169
Falloff Test #3	95950	1.594	200
Falloff Test #4	102200	1.605	212
Falloff Test #5	149700	1.595	312
Falloff Test #6	14600	1.573	31

$x_f h\sqrt{k}$ from linear flow analysis
h = 380 ft.

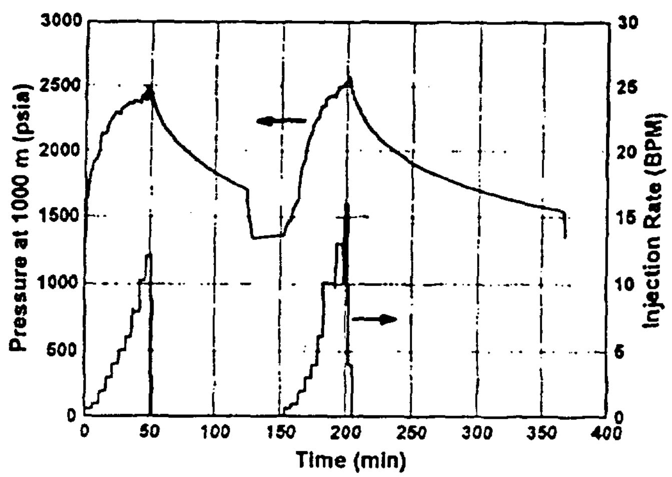

Fig. 1 – Pressure and injection data of multiple-step rate tests MSRT-1 and -2, and falloff tests

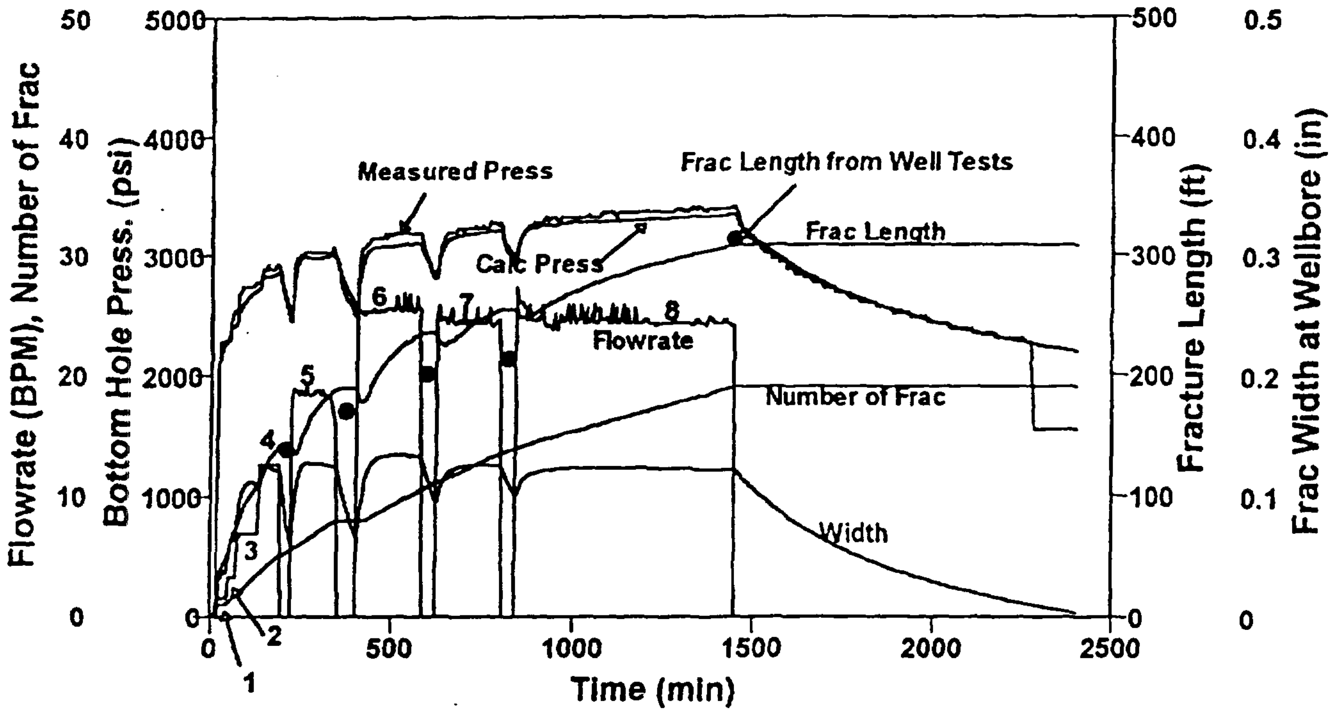

Fig. 2 Pressure and rate data of the MHF treatment, overlaid with FRACPRO calculations of pressure, number of fractures, fracture length, and fracture width at wellbore. Filled circles are fracture lengths estimated by pressure transient analysis of falloff tests. Numbers 1 through 8 indicate injection stages.

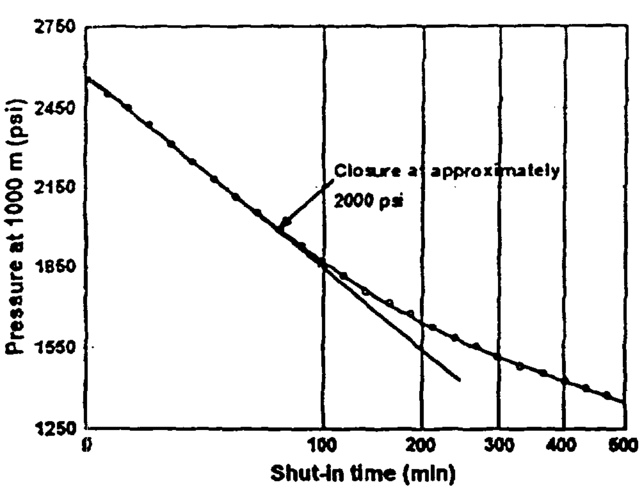

Fig. 3 Pressure decline analysis for injection test IT-1.

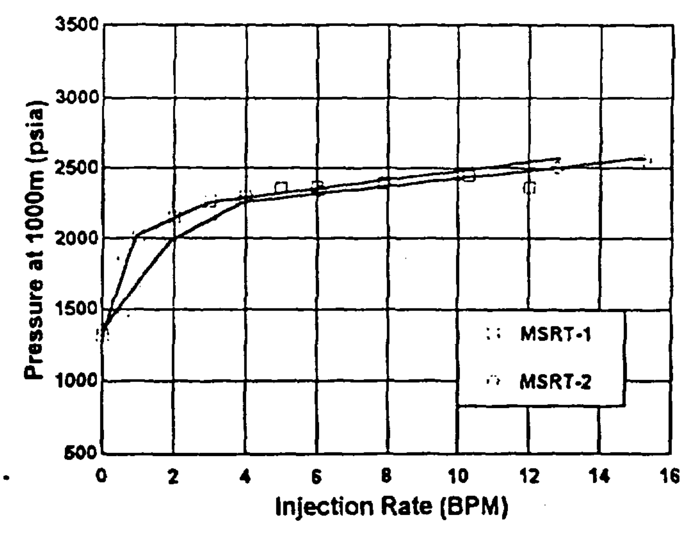

Fig. 4 Pressure vs. rate plot for multistep-rate test, MSRT-1 and MSRT-2.

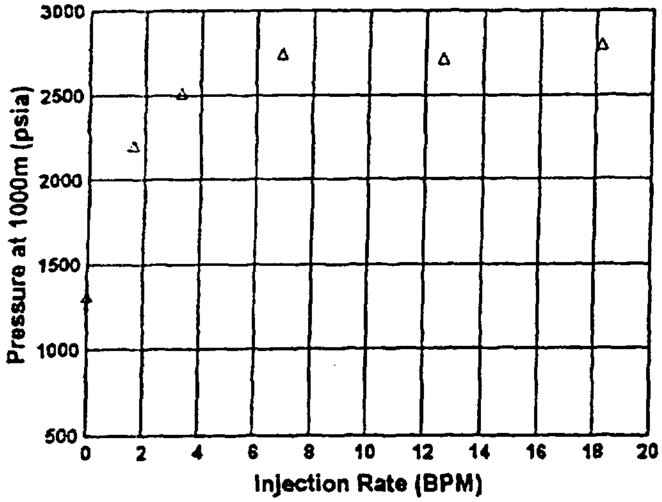

Fig. 5 – Pressure vs. rate plot for the first six injection stages during the MHF treatment.

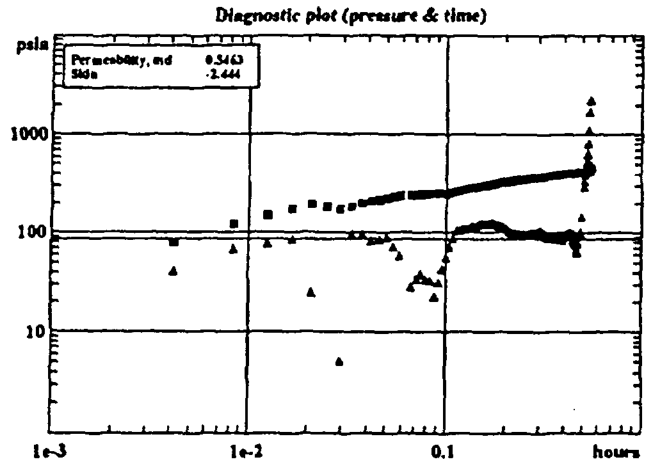

Fig. 7 – Pressure and pressure derivative for the first injection stage in the MHF treatment.

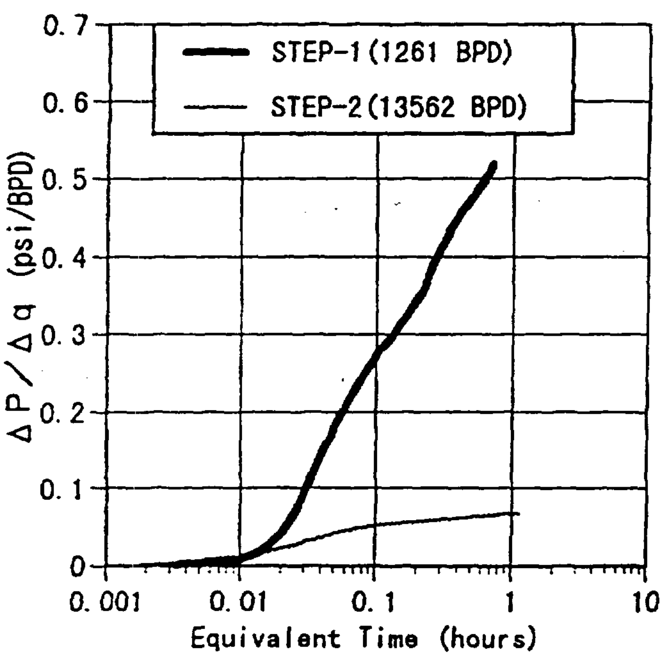

Fig. 6 – Radial-flow multirate equivalent-time analysis for two-step-rate test (IT-1, IT-2).

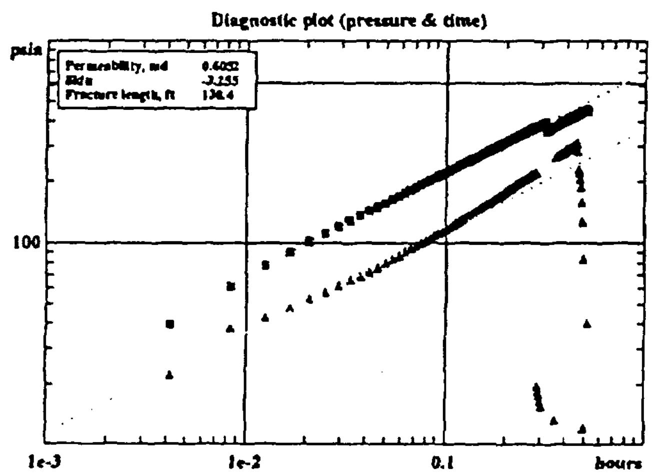

Fig. 8 – Pressure and pressure derivative for the first mini-falloff test in the MHF treatment.

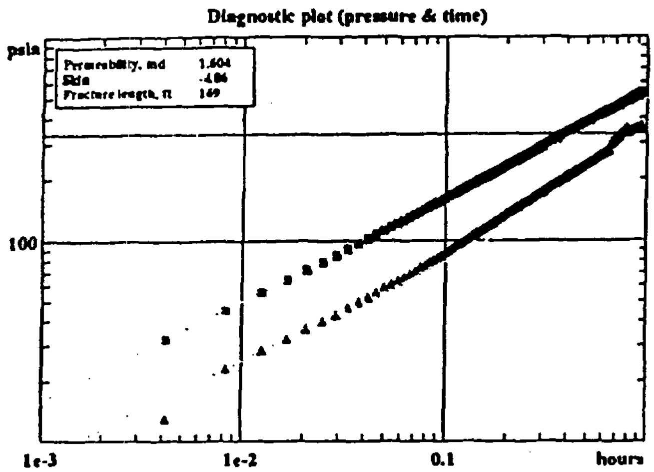

Fig. 9 – Pressure and pressure derivative for the second mini-falloff test in the MHF treatment.

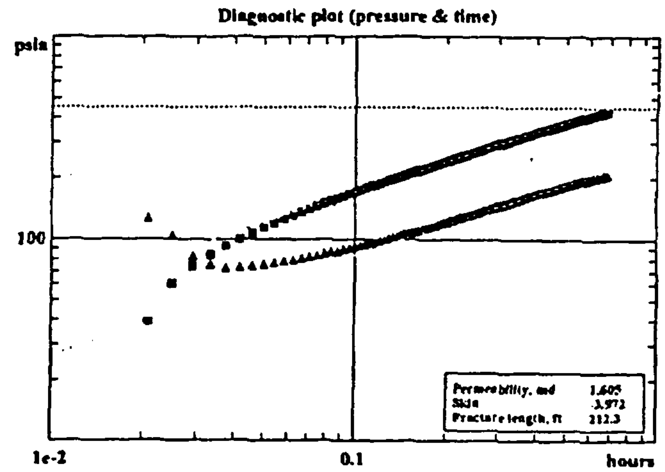

Fig. 11 – Pressure and pressure derivative for the fourth mini-falloff test in the MHF treatment.

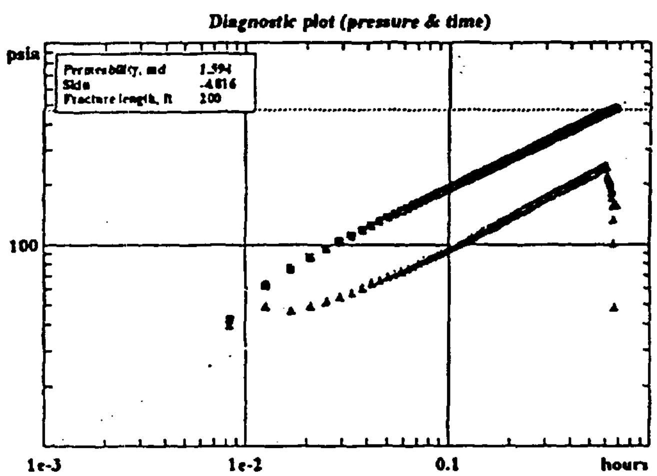

Fig. 10 – Pressure and pressure derivative for the third mini-falloff test in the MHF treatment.

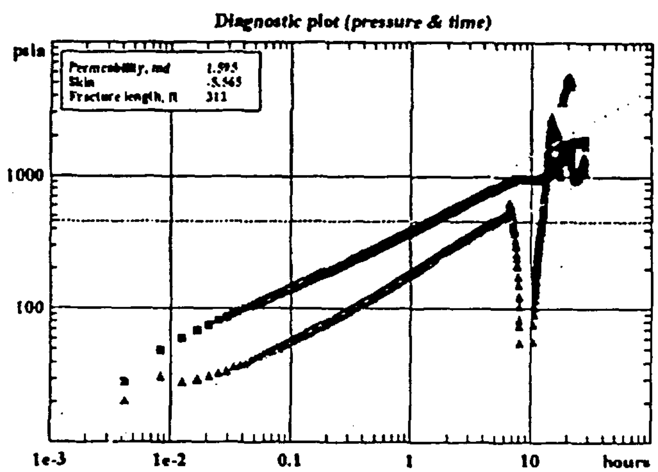

Fig. 12 – Pressure and pressure derivative for the last falloff test in the MHF treatment.

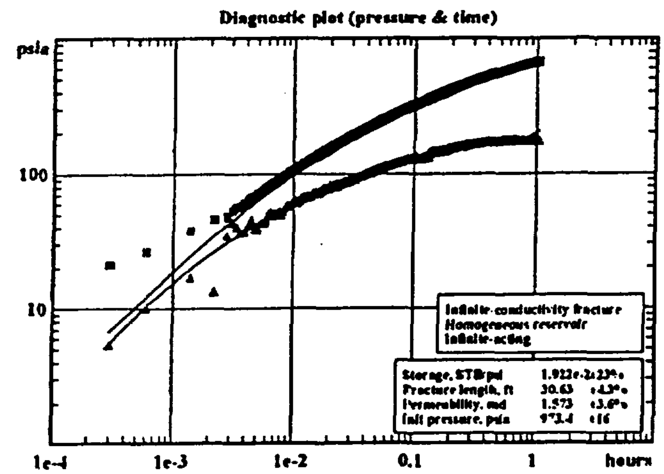

Fig. 13 – Pressure and pressure derivative for the falloff test conducted two days after the MHF treatment.

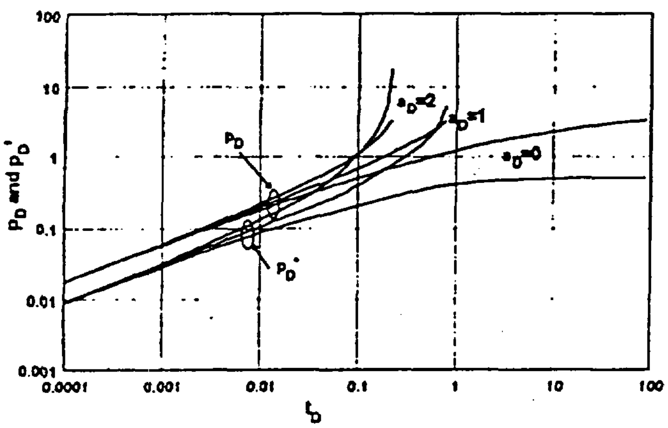

Fig. 14 Pressure and pressure derivative for falloff tests in fracture shrinkage model.

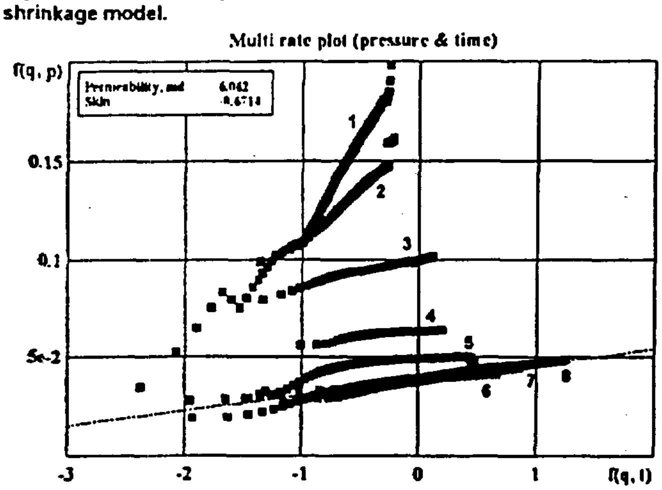

Fig. 15 Multirate plot of eight injection stages in the MHF treatment, numbers 1 - 8 correspond to the injection stages in Fig. 2.

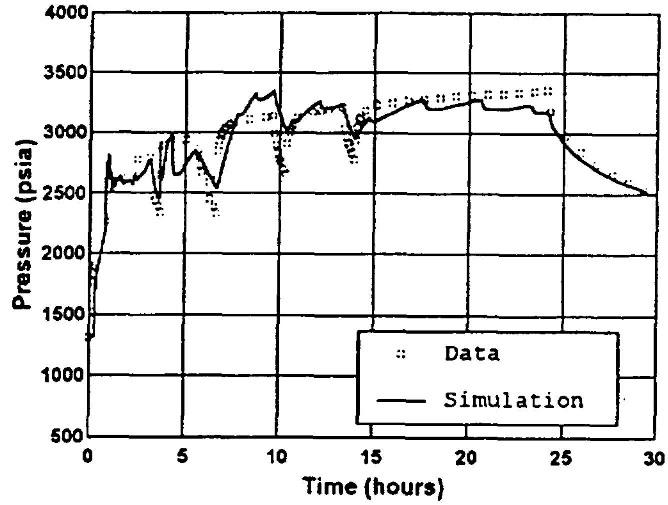

Fig. 16 Matching of bottomhole pressure of the MHF treatment using STARS with dynamic fracture option.

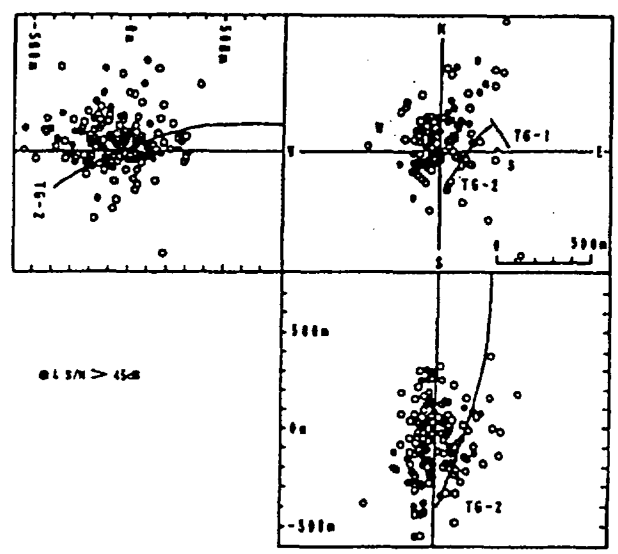

Fig. 17 Epicenter plot of acoustic emission events during the MHF treatment (Filled circles are AE of S/N higher than 45 dB).

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Completion Optimization Through Advanced Stimulation Technology and Reservoir Analysis: A Case Study in the Red Fork Formation, Okeene Field, Major County, Oklahoma

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Abstract

This paper illustrates the use of advanced stimulation technologies coupled with reservoir analysis to improve gas production from a low permeability formation. Modern stimulation techniques used include real-time treatment data analysis, stress profiling, three dimensional fracture modeling and fluid quality control procedures. Implementation of these technologies was based on an evaluation of previous and current completion and stimulation approaches in the study area. A statistical review was performed to characterize the reservoir and establish a baseline from which to compare results and quantify benefits of the completion optimization process.

Part of the project was performed under the Gas Research Institute Advanced Stimulation Technology Deployment Program.[1] Through the use of modern completion and stimulation practices, the operator was able to nearly double the average initial production rate in the Red Fork formation from 300 Mscf/d to over 600 Mscf/d. Ten year reserve estimates have increased about 38% from 390 MMscf to over 540 MMscf. Acceleration of reserves has allowed the operator to produce in less than 5 years the same amount of gas that was previously recovered in 13 years. The combination of improved reserve recovery and accelerated production has increased the discounted cashflow about 43%.

Introduction

This project, from the beginning to the end, attempted to integrate the complete package of engineering practices to optimize costs and results. A multi-phase program was outlined and included an initial phase of evaluating previous completion and stimulation approaches in the area.[2-6] The following technologies and techniques were implemented in baselining previous results:

- Integration of practical and theoretical considerations to evaluate prior completions.
- Advanced 3-D fracture modeling of breakdown and fracture treatment pressure responses.
- Reservoir simulation of production and pressure responses.
- Iteration between fracture treatment and production response on all wells to achieve consistency of overall interpretation.
- Establishment of a production response baseline from offset well history.

Once the baseline analysis was completed, field deployment was implemented and included a continued evaluation and evolution of approaches. This phase employed the following technologies and techniques:

- Intense surface and in-situ fluid and equipment quality control before and during each fracture treatment.
- Advanced real-time evaluation of the treating pressure response on all treatments.
- On-site, real-time integration of fluid and equipment quality control with pre-treatment diagnostics and main fracture treatment execution.
- Pre-treatment diagnostics to identify closure pressure of the Red Fork and adjacent layers, observe the leakoff response of various fluids and determine the quality and complexity of the near-wellbore and far-field fracture geometry.
- Real-time execution of fracture treatments to optimize near-wellbore and far-field proppant placement/conductivity.
- A coupled approach to acquire both post-treatment pressure decline data, which yields a better understanding of the fracture treatment, and rapid flowback to enhance fracture conductivity and minimize formation damage.

The final phase of the project was a cost benefit analysis. This comparative analysis of wells using modern completion practices to the offset production baseline quantified the benefits of optimization. The following were used in this phase of the project:

- Comparison of long-term production response on new wells to previous wells.

The following were used in this phase of the project:

- Comparison of long-term production response on new wells to previous wells.

- Reservoir simulation and analytical evaluation of production and pressure buildup response to confirm propped fracture dimensions and reservoir characteristics.
- 3-D fracture modeling to ensure consistency of propped fracture dimensions with reservoir simulation.
- Development of a relationship between fracture treatment leakoff coefficients, in-situ reservoir permeability and production responses.

The project area is the Okeene Field, located on the northern shelf of the Anadarko Basin. Figure 1 shows the four township area that straddles the Blaine-Major County line. The Red Fork, in the project area, is a thin sandstone/shale sequence deposited during the Pennsylvania period of basin subsidence and filling. The gross interval thickness ranges from about 40 to 110 feet thick with sandstone thickness ranging up to 100 feet. The dominant Red Fork lithology is a silty shale that coarsens upward with a channel or bar sandstone at the top of the sequence. This sandstone reservoir produces gas with very little oil from stratigraphic traps at drill depths ranging from 7,000 to 8,000 feet. The best well in the area has reportedly produced about 4 BCF from the Red Fork. The average (calculated) Red Fork porosity is 12-14% with effective permeabilities ranging from 0.04 to 0.30 md.

Evaluation of Prior Approaches

The initial phase of the project incorporated advanced techniques to characterize the reservoir and fracturing aspects by reviewing experiences of the past.[2-6] Ideally, this process utilizes modern engineering tools (i.e., 3-D fracturing models and reservoir simulators), a practical as well as theoretical background and, perhaps most important, uses a precise methodology. Many projects have failed or stumbled because the learning curve is established by "re-inventing the wheel" on the higher economic risk, newly drilled wells.

To optimize the overall economic and engineering process, prior completion and stimulation approaches were rigorously evaluated. A baseline was developed by screening the details of daily completion reports, modeling the treating pressure responses with advanced 3-D models and history matching of the production and pressure buildup responses. Typically, with persistence and patience, a significant volume of data can be derived from old well files. Also, and perhaps more beneficial, is that older wells have a long-term production response which provides an excellent data-set to evaluate the character of the reservoir. Each well is evaluated in this manner until a consistent interpretation is developed that encompasses most of the well responses in the data-set. From this process, the unknown variable and/or uncertainties are identified and the completion process on subsequent wells can be tailored to resolve the unknowns. This sets a stage for an ongoing evolution of improved results.

The proximity of several hydrocarbon bearing formations within the Okeene Field resulted in the commingling of a variety of intervals. In the four township project area, twenty-nine wells were identified as Red Fork-only completions and were used for establishing the initial production baseline. Figure 2 shows the baseline production data as a logarithmic (probability) plot for the twenty-nine Red Fork-only completions. The average monthly gas production is plotted against the highest consecutive three months of production and shows a good log-normal distribution (solid line). This indicates that the average production is not disproportionately weighted by a few very good or very poor producers. Analysis of the data reveals an average monthly (baseline) production of 13.8 MMscf with a median monthly production of 11.2 MMscf.

Besides a statistical review of previous Red Fork completions, the baseline study included a historical analysis of prior completion practices. Understanding how formations were completed in the past is a key part of any effort to quantify the benefits of new completion approaches. Table 1 outlines the relative differences between "typical" completions of the past and the newer completions using modern technology. On the downside, the new approaches increased costs about $25,000 per well. Of the cost increase, about 50% was associated with higher proppant volumes (185,000 vs 30,000 lbs.) while 10% was due to increased fluid volumes (40,000 vs 30,000 gals). The remaining 40% cost increase was due to higher hydraulic horsepower of pumping down tubing and the use of higher viscosity fluids. Recently, horsepower requirements have been reduced as most Red Fork treatments are now pumped at 8-10 bpm.

Stimulation designs of previous Red Fork completions typically consisted of high injection rates, low viscosity fluid and limited proppant concentrations. Historically, there was a problem successfully placing proppant concentrations above 4 or 6 ppg in the fracture.[7] Using modern techniques[8], the new fracture treatments consistently (100% success rate) placed most of the proppant at 8 to 12 ppg, even at lower injection rates.

Though additional discussion will be presented in the following sections, Figure 3 is the probability plot of the twenty-nine previous completions along with eleven wells using these modern techniques. The figure continues to show the statistical consistency of the study area but also shows the influence of the project wells. The average production response of the forty well dataset was 16.5 MMscf, up from 13.8 MMscf for the twenty-nine well average, while the median month production increased from 11.2 MMscf to 14.1 MMscf.

Field Implementation and Continued Evaluation and Evolution of Approaches

The second part of the project was field deployment. This phase was intended to integrate the conclusions of the baseline analysis into a completion approach that would improve far-field proppant placement and ultimately production responses.

Each new well completion was preceded by a design iteration to determine the economically optimal treatment size and fracture length. As the project developed, a continuous re-evaluation and evolution of completion approaches was incorporated into the design philosophy. This included the refinement of the stress and leakoff data, reservoir parameters and economic considerations after each well. Risk analysis was performed to determine the relative cost and benefit of incremental propped fracture length. This process established a range of propped fracture length economically justified in the Red Fork interval.

An example of a simplified economic optimization approach is shown in Figure 4. It shows the un-risked net present value (NPV) for each fracture length. The data corresponds to the Harland #1-22, one of the first project wells. Based on a risk assessment, the recommended fracture half-length was 240 ft. Though the peak of the NPV curve in Figure 4 is around 350 feet, the minimal increase in NPV is not compensated by the increased risk and treatment costs to achieve the added length beyond 240 ft.

After establishing a methodology that incorporated an understanding of the fracturing processes and reservoir characteristics of the Red Fork, the next part of the project was field deployment. This included intense treatment fluid testing at both surface and in-situ conditions, field equipment testing/calibration and real-time evaluation of the treating pressure responses. A unique, on-site and real-time process of integrating fluid and equipment testing with the associated treating pressure response was used to discern the effectiveness of each treatment. Finally, analysis of diagnostic pump-in stages provided the ability to determine key fracturing mechanisms that may have prevented/limited the placement of the recommended treatment design.

Fluid and Equipment Quality Control Procedures. Fluid and equipment quality control should be an integral part of all hydraulic fracture treatments. This ensures that the viscosity of the fluid entering the perforations, the proppant transport character and the fluid break profile are refined for specific treatment conditions. Tailoring the fluid character to address the fracture geometry identified from pre-treatment diagnostics and actual job execution ensures optimum results.

There are at least two important issues associated with the integration of fluid and equipment quality control with real-time evaluation and execution. The first has been documented in the literature and concerns the fluid viscosity entering the perforations.[8] Based on the fracture treatment pressure response, the fluid rheology may be modified to improve the fracture dimensions and optimize proppant transport and placement/conductivity in the near-wellbore and far-field fracture(s). The second issue involves the fluid break profile. If proppant is effectively placed while pumping the fracture treatment, the fluid break profile can be designed to maximize the fracture cleanup response and conductivity. This breaker design approach is in contrast to other, less effective approaches that delay the fluid break profile, hoping to suspend the proppant until fracture closure occurs.

Real-time Fracture Treatment Diagnostics. Well-to-well variations often require on-site re-evaluation and possible re-optimization either after pre-treatment diagnostics or as the treatment is being pumped. Specific procedures may be used during the treatment to facilitate these changes. Table 2 provides a breakdown of several modern fracture treatment diagnostics and the purpose of each test.

An example showing the utilization of these diagnostic tests is presented in Figure 5. The figure shows a net pressure history match performed on location during the Harland #1-22 fracture treatment. Note the two pressure peaks or pump-in/shut-in stages pumped before the proppant-laden stage. These front-end stages are specific, diagnostic features for determining key fracturing parameters critical to successful execution of the proppant-laden stages.

The first pump-in typically consists of pumping a small volume of wellbore fluid (approximately 250 to 1,000 gallons) and monitoring the pressure falloff response to fracture closure. Besides verifying the design closure pressure, this stage may provide an indication of the stress contrast. It should be noted, that sound engineering practices should be used in interpreting the pressure falloff response as this directly relates to net pressure modeling and fracture geometry predictions.[9]

The second pump-in typically consists of a larger volume (1,500 to 3,000 gallons) of linear gel. This stage shows the leakoff response of the linear gel and typically provides a relative indication of formation permeability. Also, a rate step-down test is performed at the end of this diagnostic pump-in. Based on the relationship between flowrate changes and the associated pressure drops, the connection between the near-wellbore and the formation is characterized. Finally, the two initial pump-in/shut-in stages are used to evaluate the complexity of the far-field fracture geometry (i.e., fracture growth profile, multiple fractures, etc.).

Based on the actual fracturing characteristics of the well, such as the leakoff response, fracture geometry and near-wellbore connectivity, the fracture treatment is re-designed in real-time. This re-design process is composed of practical approaches that are meshed with real-time (forward modeling) simulation processes that optimize the pad volume and proppant concentration schedule. If a near-wellbore connection problem is identified, a proppant slug may be included to mitigate the potential problem. This approach minimizes risk of premature screenout and optimizes both near-wellbore and far-field proppant placement.

In this fracture treatment, a higher leakoff and more complex fracture geometry (multiple fractures) occurred than was anticipated. This was identified on the pre-treatment diagnostics and accounted for in the re-design and execution process.

Figure 5 shows a 700 to 800 psi net pressure increase during the proppant-laden stages and a gradual pressure decline following the shut-down. Because of the higher leakoff and multiple fracturing, the effective fracture length was approximately 162 ft. This net pressure increase suggests good proppant placement throughout the body of the fracture. Because of the gradual proppant induced pressure increase, sufficient friction was developed within the fracture to preclude proppant movement down away from the pay interval. Thus, near-wellbore and far-field proppant placement/conductivity is expected to be good. Past treatments did not exhibit this pressure behavior nor the far-field fracture conductivity.

Typical of this project, Figure 5 shows that approximately 30 minutes of pressure decline data were recorded after the treatment. These data were obtained to improve the characterization of the fracture geometry and proppant distribution within the fracture. Because the proppant was effectively placed during the treatment, it was not necessary to perform instant flowback (i.e., "forced closure") to attempt to salvage the results of the fracture treatment. Also, the viscosity profile of the fluid was designed to maximize proppant transport while pumping and improve flowback with an adequate break character. Flowback of the fracture was initiated immediately after recording the pressure decline data to enhance the fracture conductivity, minimize formation damage and use the hydraulic energy from the fracturing operation to improve the cleanup response. Also, once flowback began, the well was continuously produced until most of the fluid was recovered. Shutting-in the well after a "forced closure" procedure and soaking the formation overnight was avoided.

Final Phase: Quantifying the Benefits

The final phase of the project was to quantify the benefits of applying advanced completion techniques to the Red Fork completions in the Okeene Field. The primary markers of the project's success were the tangible, financial benefits realized by the operator. The most influential, obviously is the improved production response and incremental reserve increase and acceleration. Though successful field implementation is often a subtle benefit, the ability to show tangible improvements reinforces the technical merit of the new technologies. A final benefit of using modern tools was the development of a relationship between fracture treatment leakoff responses, in-situ reservoir permeability and production responses.

Red Fork Production Comparison. Besides the probability analysis presented in Figure 3, a comparison between the twenty-nine previous Red Fork completions and the eleven new completions corroborates the benefits. Figure 6 compares the average daily production rate of the twenty-nine older wells to the eleven new wells and shows a substantial production improvement using modern technology. After ten months, the average daily rate of the eleven new wells was about 310 Mscf/d while the twenty-nine well baseline average was only 200 Mscf/d. This reflects a 55% increase in the average daily rate. Note on Figure 6 the increase in the production after ten months is associated with a drop in the total new well count. As with most programs, the anticipated better performers (in this case, due to more net pay) are completed earlier in the program while the "poorer" performers (less net pay) are completed later. This explains the drop in the average daily rate with the addition of more wells. But as discussed earlier, the log-normal distribution in Figure 3 suggests a statistical consistency within the study area.

Figure 7 is a plot of the average gas rate versus cumulative production on a monthly basis. Each marker along the curves represents one month. The figure demonstrates the accelerated production that is occurring by achieving longer effective fracture lengths. As depicted on the figure, the average new well reached a cumulative production of ~160 MMscf in about one year while the average baseline well took about two years to produce a similar amount of gas.

Production History Matching. Reservoir simulation and analytical evaluation of production and pressure buildup responses were performed to quantify the added reserves and acceleration of production. Using a single phase, two dimensional reservoir simulator, each individual well's production response was history matched. With few exceptions, the production character was affected by a channel deposition. Consistent with the geologic interpretation of the Red Fork in this area, the channel width was discernible in most cases.

As an example, the production history match for the Harland #1-22 well is shown in Figure 8 while Figure 9 shows the associated bottomhole pressure match. Based on a fracture half-length predicted from the net pressure history match (~162 feet), simulation of the production response was obtained with a permeability of 0.08 md, a net pay of 24 ft and a channel width of 240 ft. The history match shows good agreement of observed and predicted rates and pressure through 210 days. Taking a conservative approach on the drainage area (80 acres), the estimated ultimate recovery in this well is approximately 1,072 Mmscf. These drainage areas and ultimate recoveries are consistent with reservoir simulation of the older producing wells. The improved reserve recovery is primarily associated with the longer effective propped fracture lengths.

Using this approach on each of the eleven new wells, the recovery estimate for each project well is approximately 540 MMscf. This reflects an improvement of about 38% as compared to the estimated average recovery of the baseline group of 390 MMscf. Acceleration of reserves is an important component of the project with the previous 390 MMscf, that was produced over 13 years, being recovered in less than 5 years. This improvement in reserve recovery coupled with the acceleration of reserves increases the discounted cashflow by about 43%.

Relationship of Leakoff Coefficients, Reservoir Permeability and Production Responses. Besides providing fracture geometry/complexity information, small volume diagnostic pump-ins can provide excellent data in developing a predictive reservoir/production tool. By modeling the pressure falloff response, a leakoff value was determined from which an in-situ reservoir permeability can be derived. A study showing the relationship between the leakoff coefficient value, the pump-in derived reservoir permeability and the post-treatment production response was then performed.

A basic search for many reservoir engineers is to understand the flow potential of a reservoir. Though several factors influence the well's productivity after a fracture treatment, in-situ reservoir permeability dictates the relative magnitude of the production response. Conventional methods of determining in-situ permeability include sidewall or whole cores, pre-frac pressure build-up tests and long term production tests. Though these methods can provide quality data, they are usually limited. Analyses of whole cores are costly and only provide a micro-sampling (± 4-6 inches) of the rock. Though pre-frac pressure build-up tests can provide good estimates, erroneous in-situ permeability values may result due to poor communication with the reservoir. Also, in low permeability reservoirs, the testing times can be cost prohibitive, resulting in a micro sampling of the rock. Long-term production tests typically provide the best data for in-situ permeability estimations especially when combined with a pressure build-up test. Unfortunately, this macro sampling of the rock may require 3 to 6 months of production and can also be costly (especially with a pressure build-up test).

Analysis of a small volume pump-in stage ahead of the proppant-laden stages eliminates the problems associated with these conventional methods. The advantages of a small volume pump-in stage are: (1) it provides a direct measurement of in-situ permeability on a macro-scale, (2) eliminates wellbore connectivity problems of pre-frac PBU tests, (3) a larger area (h^*X_f) is contributing to the measurement, (4) negligible cost when pumped ahead of the proppant-laden stages. However, using this method to determine in-situ permeability requires an understanding of fracture geometry, analysis of the pressure falloff transient and 3-D fracture treatment modeling.

The relationship between the leakoff coefficient used in hydraulic fracture modeling and reservoir permeability is defined in the literature.[10] The intent of this discussion is not to review the theoretical equations relating the two but rather to provide data to show a unique way of predicting production responses after a fracture treatment.

Detailed 3-D modeling of the pressure falloff analysis was performed on seventeen wells in the study area. From this analysis, leakoff values and the associated in-situ reservoir permeability were estimated. The results were then normalized with net pay and plotted against production. Figure 10 is a plot of the pump-in derived Kh versus the first three months of production. Figure 11 plots the pump-in leakoff coefficient value versus the first three months of production/net pay. The groupings shown in the plots suggests that small volume pump-ins can provide a relative estimate for the effective productive capacity of the interval. In addition, when compared to the falloff response at the end of the treatment, can provide a relative indicator of rock quality with distance.

Conclusions

Applying modern techniques and technology in this program was directed towards reducing the cost of producing gas from the Red Fork formation. In today's cost cutting environment, the front-end costs of drilling and completing a low permeability gas well typically justifies or kills the project at the outset. Therefore, increasing the fracture treatment cost by $25,000 per well had to be justified by production response improvement. One common hindsight comment about this project is that large jobs obviously would achieve improved results. Unfortunately, there are ample examples where larger treatments were not optimally placed and improved results were not achieved. It took a comprehensive analysis to optimize the treatments performed and achieve the production responses. The total benefit observed is a product of the complete, not partial, coupling of these modern technologies and techniques. Major conclusions from this study are:

- A statistical review of previous approaches establishes a baseline from which evolutionary steps in optimizing completion practices can be quantified.
- Real-time evaluation of diagnostic pump-ins quantifies key fracturing parameters from which adjustments can be made to optimize far-field proppant placement/conductivity.
- A review of post-treatment production responses justifies the modern completion approaches used in this study.
- Use of modern stimulation practices has improved Red Fork production by 55% and the ultimate recovery by 38%.
- Analysis of pre-treatment pump-in pressure decline data yields a cost effective measurement of in-situ reservoir permeability.

Acknowledgements

The authors would like to acknowledge the Gas Research Institute, Lomak Petroleum, Inc., and the engineering staff at Integrated Petroleum Technologies, Inc., for their support in pursuing the evaluation and application of these modern techniques. In addition, special recognition is given to the many individuals and companies involved with the implementation of these procedures in the field.

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Table 1: Average Completion Approach Comparison

	Previous Approach	New Approach
Perforation Scheme	Phased Perforations	Zero Degree Phasing
Operations		
Proppant Volume	30,000 lbs	185,000 lbs
Fluid Volume	15,000 gallons	40,000 gallons
Fluid Type	Linear Gel/Foam	35# Borate Crosslink
Maximum Proppant Concentration	4 ppg	8-12 ppg
Injection Rate	>20 bpm	8-20 bpm
Treatment Configuration	Tubing or Casing	Tubing
Treatment Results		
Propped half-length	< 100 ft	200 ft
Proppant Concentration	< 0.5 lbs/ft^2	1.5 lbs/ft^2
Estimated Treatment Cost	$10,000 to $15,000	$35,000 to $40,000

Table 2: Fracture Treatment Diagnostic Tests

Test	Purpose
Rate Step-Down	Evaluation of Tortuosity and Perforation Friction
Multiple Initial Shut-in Pressures (ISIPs)	Verification of Pipe Friction, Near-Wellbore Friction, "True" Net Pressure and Estimation of Fracture Complexity
Pump-In/Shut-In Pressure Decline	Estimation of Pay Zone Closure Pressure and Evaluation of Fluid Efficiency for Treatment Optimization

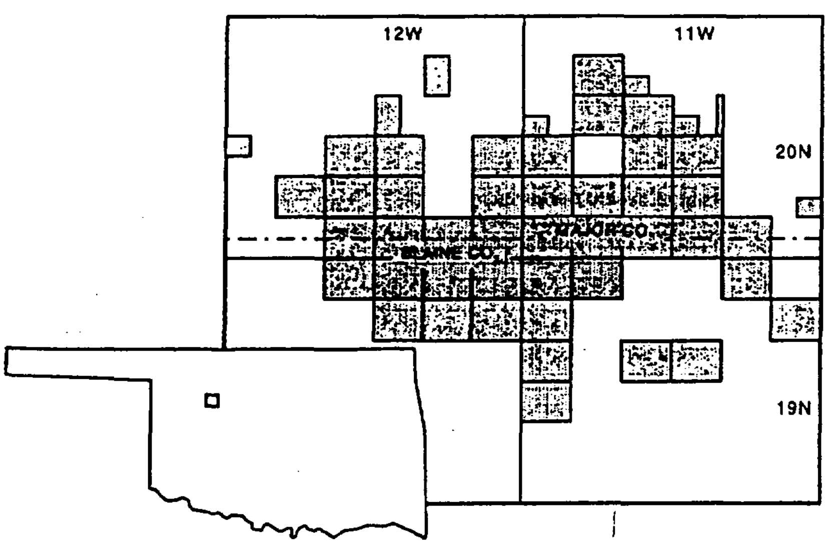


Fig. 1- Project area (Okeene Field, Major County, Oklahoma).

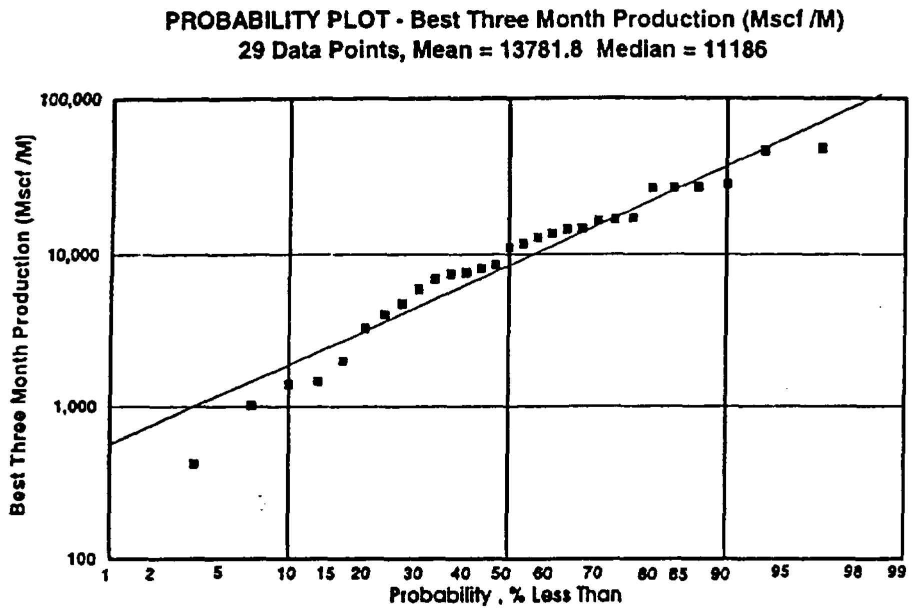


Fig. 2 - Best three months probability plot for previous wells.

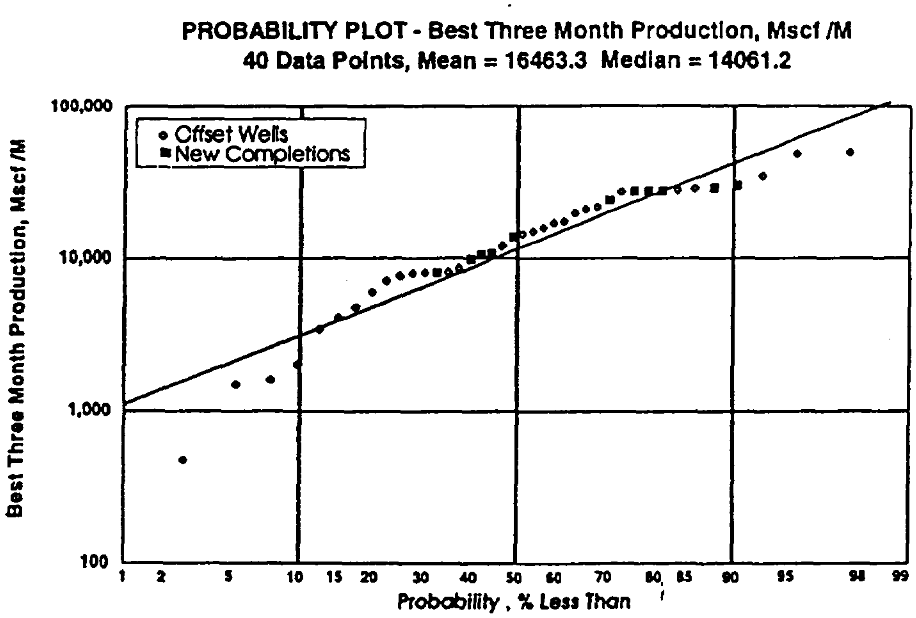


Fig. 3 - Best three months probability plot for new and previous wells.

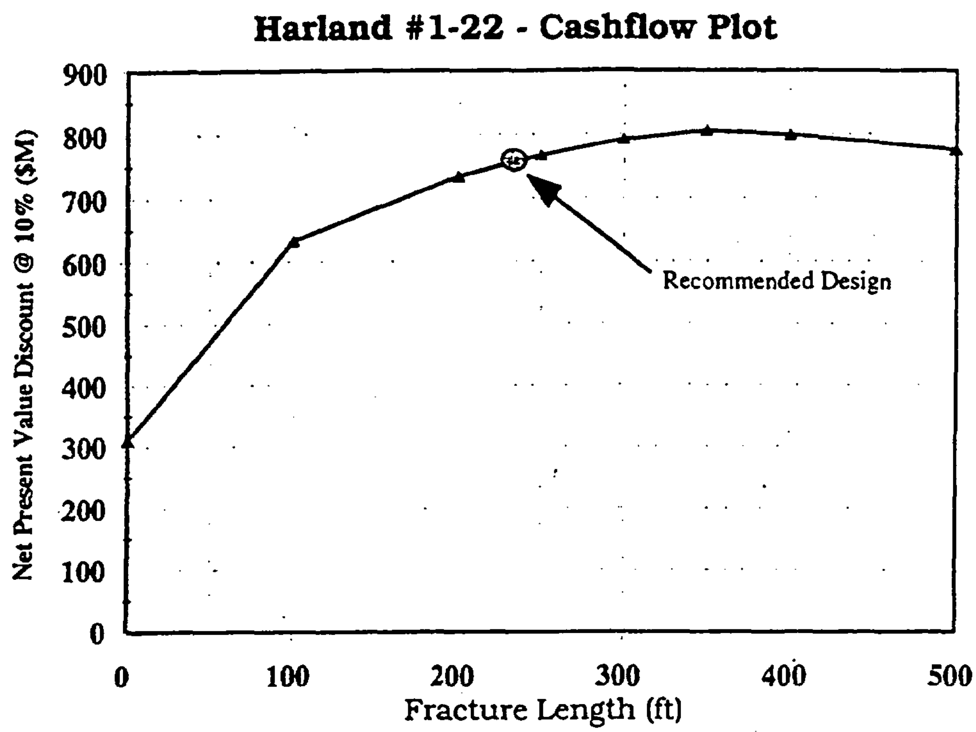


Fig. 4 - Fracture treatment cashflow plot.

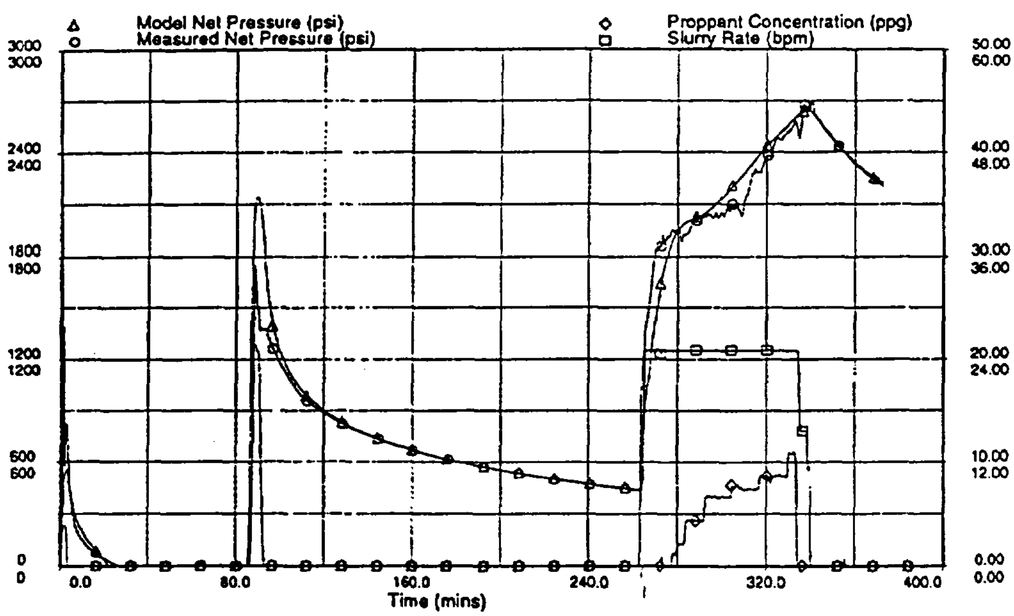


Fig. 5 - Net pressure history match for Harland #1-22.

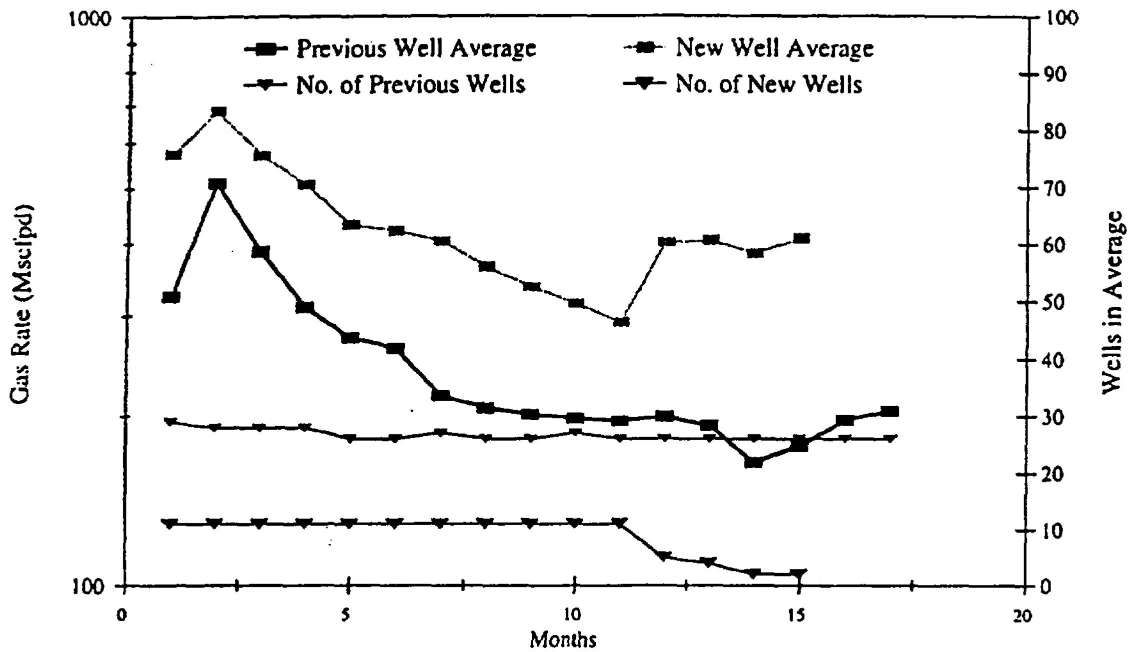


Fig. 6 - Red Fork production data comparison - daily production.

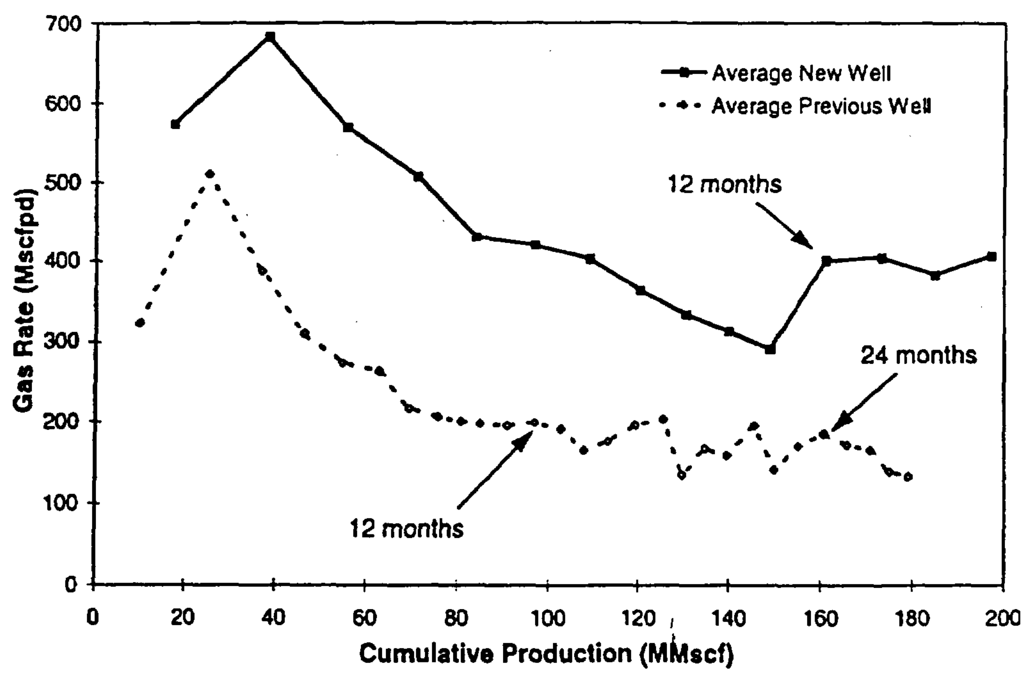
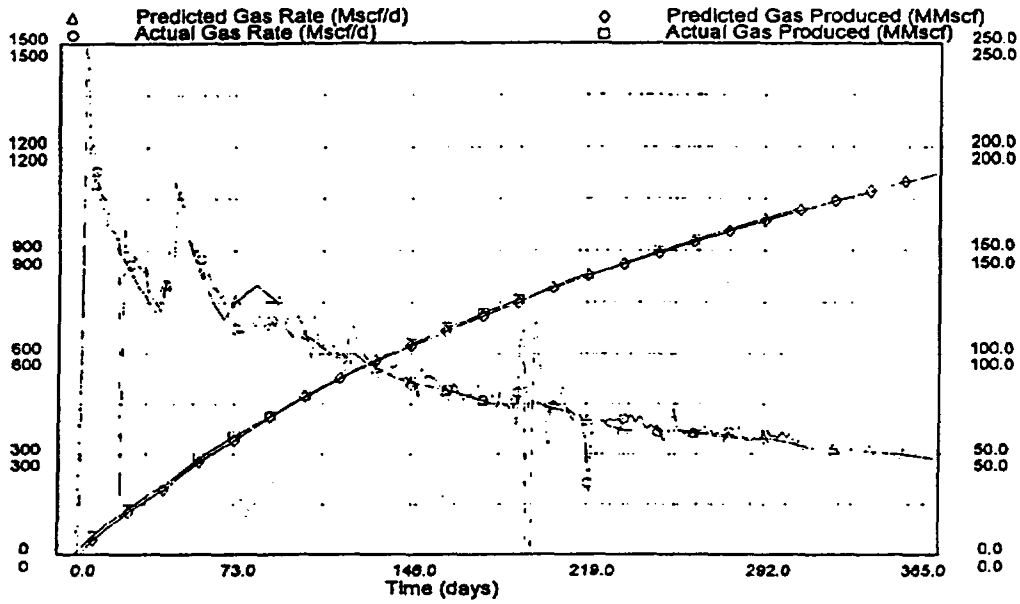


Fig. 7 - Red Fork production comparison - cumulative production.



Pi = 3,000, K = 0.08, H = 24, Area = 80 Ac Phi = 0.15, Sw = 0.20, Xf =162

Fig. 8 - Harland #1-22 production rate and cumulative production prediction.

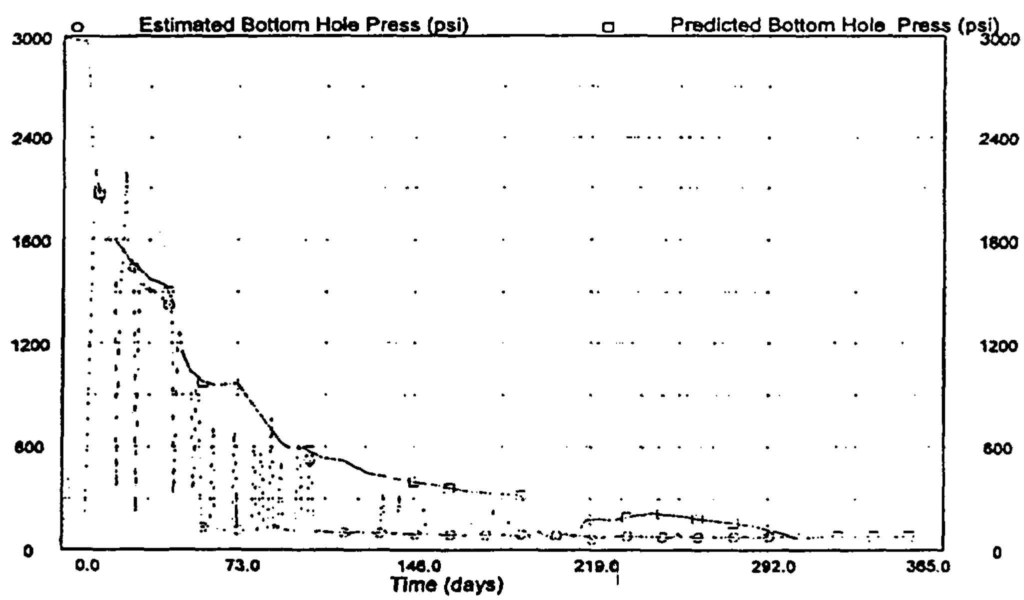


Fig. 9 - Harland #1-22 bottom-hole pressure match.

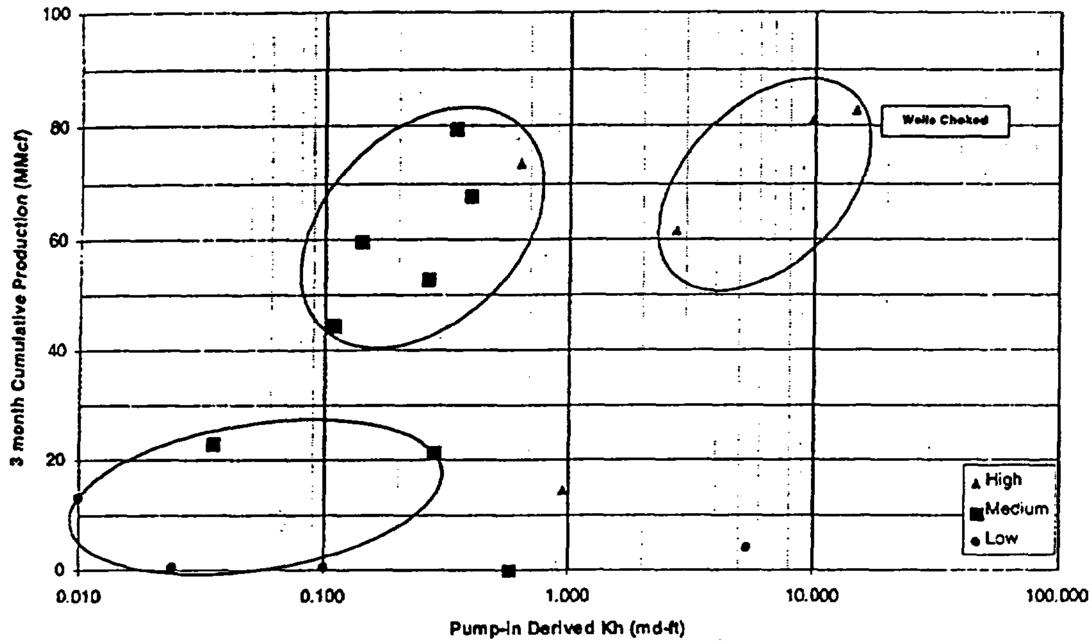


Fig. 10 - Kh versus three month production plot.

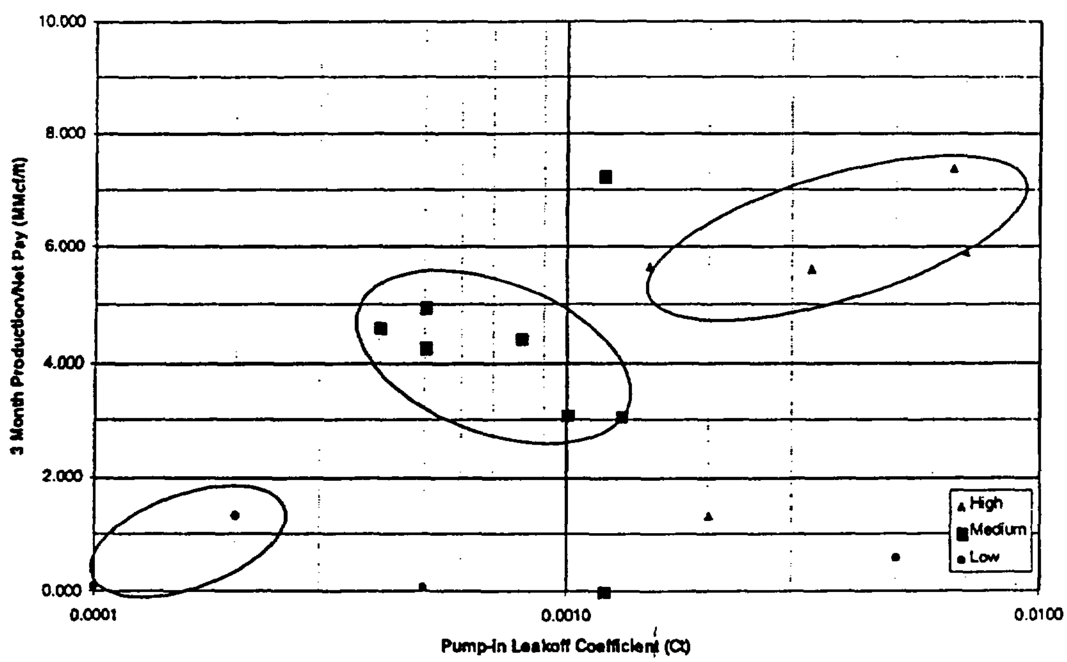


Fig. 11 - Leakoff coefficient versus three month production/net pay plot.

Society of Petroleum Engineers

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Stimulation Program In High Permeability Oil Sands - Case Study

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Abstract

Argosy International operates several oil fields in southern Colombia, South America that were experiencing a significant decline in productivity. A study of numerous wells in these fields revealed the decrease in productivity was due to increasing skin damage near the wellbore. Lab tests and field observations indicated that fines migration and asphaltine deposition were the most likely causes. Several types of treatments were performed during a pilot program to overcome the near wellbore damage, including acid treatments, xylene treatments, clay stabilizer treatments, high pressure gas fracturing and hydraulic fracturing. The hydraulic fracture treatments provided the best results and justified the economics of implementing a major stimulation program. A total of 17 fracture treatments have been performed on 10 different wells. As a result, the productivity of the wells has increased by 2-3 fold, the total field production has increased substantially. As of February 1997 an additional 2,700,000 bbls of oil has been produced as a result of the fracturing program. The implementation of quality control and real-time analysis using a 3-Dimensional fracture model has allowed for on-site revisions of the fracture treatments. The amounts of pad and proppant volumes were optimized to achieve a proppant pack off in the fracture at the end of the flush.

Introduction

Argosy operates several fields in the Putumayo Basin in southern Colombia. These fields include the Toroyaco, Linda, Mary, and Miraflor fields. The main producing intervals in these fields are the Villeta U and T Sands. The formations vary in reservoir properties from well to well as indicated in Table 1. There is a strong water drive present in all of the fields for each formation. Therefore, the location of the oil-water contact is of great concern and is mapped very carefully.

Most of the wells have very severe near wellbore formation damage. There is initial damage from drilling operations due to the high mud weight of 11 to 11.5 lbs/gal that is required to prevent the shales from sloughing into the wellbore. The excessive mud weight damages the formations which range in permeability from 120 to 1664 md. The amount of skin damage also increases over time, reducing the productivity. Several types of treatments have been performed to minimize the amount of damage and to lower the skin values. These treatments include pumping acids, solvents, and performing hydraulic fracture treatments. Based on an evaluation of the results of the treatments, hydraulic fracturing was determined to be the best method for overcoming the damage. To date, there have been 17 fracture treatments performed on 10 different wells.

The fracture treatments have been performed in three phases. First was the Toroyaco No. 3 pilot well in January 1995. The second phase involved a 7 well, 12 treatment program between October 1995 and February 1996. The third phase included the stimulation of the Toroyaco No. 4 and Linda No. 4 upon initial completion in December 1996. The total proppant volume pumped during the 7 well program was 247,000 lbs. As a result, when the program was completed, it was one of the largest stimulation program performed in Colombia. This paper summarizes the results of the fracturing program.

Declining Productivity

Argosy has a very good reservoir management program. As a result, accurate and current data are available for the effective permeability, skin factor, and reservoir pressure. Production tests are performed to calculate the productivity index for the different intervals over the life of the well. Pressure buildups are also performed on a regular basis. Both the pressure buildups and production tests indicate the near wellbore skin damage was increasing with time. This was evident in the calculation of both the skin factor and the productivity index. Fig. 1 is a graph of the productivity index versus time for the T sand formation, prior to stimulation, in several wells.

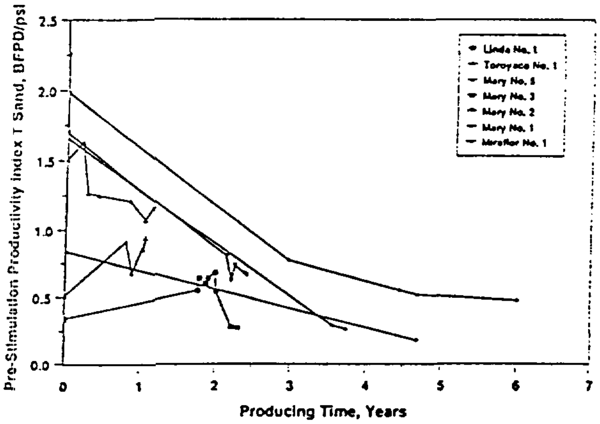

Fig. 1 - Pre-stimulation productivity index versus time for the T Sand.

Originally, the increasing skin values and decreasing productivity index were thought to be the result of two items: (1) plugging of the near wellbore area by organics, such as asphaltene and paraffin and (2) plugging of the pore throats due to migrating clays. The oil gravity is approximately 25-30 ° API with an in-situ viscosity of about 5-10 cp. The paraffin and asphaltene content are significant. The paraffin averages approximately 17 % while the asphaltene is 6 %.

A significant amount of work has been performed by the petroleum industry to understand the mechanics of the deposition and to develop methods of prevention.[1-7] During various workover operations, there was no sign of organic deposits on the tubulars or bottom hole assemblies. Also, solvent treatments were pumped on several of the wells with limited success. Therefore, plugging due to deposition of asphaltene is probably not a major problem.

The effect of fines migration on productivity is also well documented in the petroleum literature.[8-14] To evaluate the potential for fines migration, a series of critical velocity tests were conducted. Based on these tests, fines migration caused plugging of the pore throats at higher flow rates. A lower permeability sample, 20.72 md, indicated a fines plugging problem from kaolinite platelets at 3.5 ml/min on a 1-inch diameter core. A higher permeability sample, 115.7 md, did not indicate a fines plugging problem up to the maximum rate tested of 10 ml/min. However, fines were moving since the fluid recovered from this core indicated the presence of kaolinite platelets. Therefore, the fines generated during the test were apparently small enough to pass through the pore throats.

Stimulation Program

To remove the near wellbore damage, several different types of treatments were performed. These treatments included acidizing, clay stabilization, solvent, and hydraulic fracturing.

The results from hydrochloric acid and hydrofluoric acid treatments were disappointing. Due to the high paraffin content of the reservoir fluid, a sludge was formed. Production from wells following the treatments was actually lower than production prior to the treatments. Several clay stabilization treatments were performed with a blend of surfactants and clay stabilizers. The results were inconsistent, therefore, it was not considered to be a viable alternative. Several solvent treatments were pumped to remove any organic deposits. Unfortunately, the production response was disappointing.

The Viletta T and U sands of the Toroyaco No. 3 well were fracture stimulated on January 29 and February 2, 1995. The results were significant, increasing the oil production from 438 to 1,908 bbl/day. The productivity index increased from 0.31 to 1.81 BFPD/psi, resulting in almost a 6-fold increase in productivity. As a result of this pilot test, 7 additional wells were treated with 12 fracture treatments in both the Viletta T and U sands from October 10, 1995 to February 26, 1996. These treatments placed over 247,000 lbs of proppant in the formation. Since that time, two additional wells, Toroyaco No. 4 and Linda No. 4, were fracture stimulated upon original completion.

Quality control is an important aspect of fracture treatments to ensure that the fracture fluids behave as designed. There has been a lot of work performed in the petroleum industry documenting the benefits of quality control.[15-20] The fluid must have a high viscosity to transport the proppant into the fracture while pumping and degrade into a low viscosity fluid following the treatment so that it can be recovered from the formation. To ensure the fluid achieved these objectives on the Argosy fracture treatments, laboratory tests were conducted on the fluid to determine the appropriate chemical concentrations. These tests were repeated on location prior to the fracture treatment to confirm that the fluids would perform as designed.

One of the most critical aspects of using a viscous fracture fluid is to ensure that the fluid will degrade in viscosity following the treatment so it can be produced from the fracture. Therefore, tests are necessary to evaluate the concentration of breaker required to reduce the viscosity. These tests were performed with water samples from each of the rivers. The tests were performed at 170°F for comparison purposes, even though the actual reservoir temperatures ranged from 174°F to 223°F

Because recommended breaker concentrations, based on laboratory tests, may not affect fluid mixed on location in the same manner, it is critical to perform breaker tests in the field prior to the treatment to ensure the fluid will break properly. These tests were performed on location with the actual fluid to be used for each treatment. During the fracture treatment, samples of the fluid were caught "on the fly" and placed in the hot water bath to confirm the fluid pumped in the formation was breaking as indicated during the pre-job tests.

The Toroyaco No. 3 was the first well fracture treated (January 1995). The proppant used on this treatment was a 20/40 light weight ceramic proppant. Since the well has been put back on production following the fracture treatments, there have been problems with proppant being produced from the fracture. Therefore, to reduce this problem, the 20/40 light weight ceramic proppant used on the remaining treatments was coated with a 2% phenolic resin designed to bond proppant particles together in the fracture, and prevent proppant flow-back.

Mini-frac Treatments

Mini-frac treatments were performed for several reasons: (1) evaluate communication between the tubing and the annulus prior to the introduction of proppant to the wellbore, (2) determine the surface treating pressure at the designed injection rate, and (3) evaluate fracture properties such as closure pressure and fracture fluid efficiency.

To accurately optimize any fracture treatment, it is critical to evaluate the fracture fluid efficiency. This value is the amount of fluid that is retained in the fracture, i. e., fluid that does not leakoff into the matrix of the rock. Fluid efficiency is even more critical in a high permeability well where fluid leakoff can be excessive. To perform an effective fracture stimulation on a high permeability well, a tip screen-out and proppant pack should be achieved. Therefore, to optimize the fracture treatment volumes, (i.e., pad volume, proppant laden volume, and proppant concentration), it is critical to measure the fracture fluid efficiency.

An analysis of fluid efficiency was performed on location for each treatment with the three-dimensional fracture model, by history matching the pressure falloff response after pumping the mini-frac fluid. **Fig. 2** illustrates a history match of the pressure decline for the mini-frac performed on the Linda No. 1, U sand treatment. When the model calculated pressure matches the actual pressure decline, then one can be more confident that the leakoff rate is being modeled correctly.

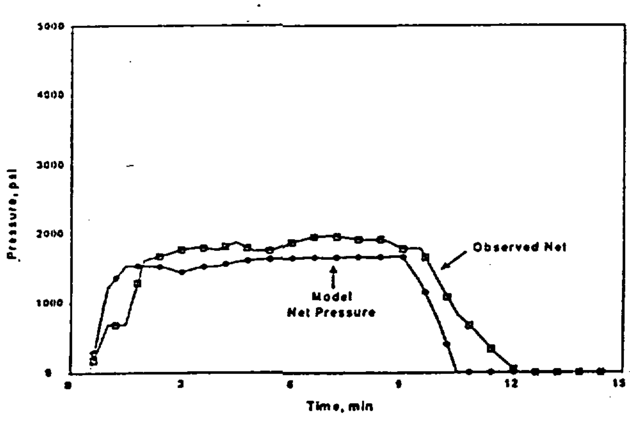

Fig. 2 - History match of the mini-frac performed on Linda No. 1, U sand.

The pressure decline was also analyzed to determine the fracture closure pressure. The closure pressure was determined by graphing the shut-in pressure versus the square root of time as shown in Fig. 3 for the Linda No. 1, U sand treatment.

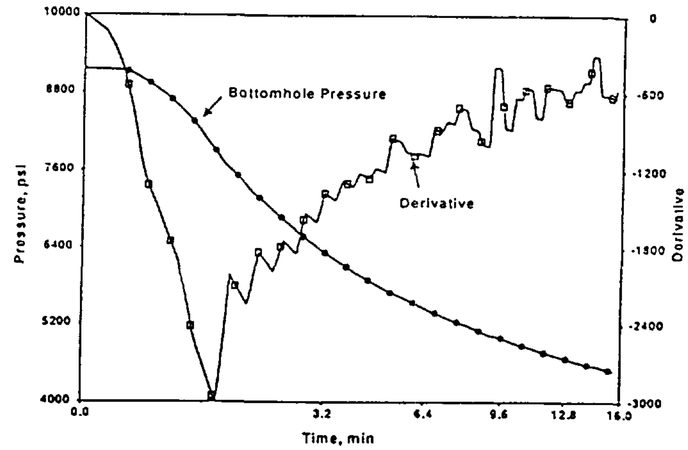

Fig. 3 -Shut-in pressure decline on the Linda No. 1, U sand.

Closure pressure occurs when the pressure deviates from a straight line. The straight line indicates linear flow from a fracture. The derivative, which represents the change in slope, is included on the graph to help determine when the pressure deviates from a straight line. The analysis of the shut-in data was performed on each mini-frac. **Table 2** summarizes the closure pressure and fluid efficiency determined for each mini-frac treatment.

As can be seen in Table 2, the closure pressure and fracture fluid efficiency varied over a wide range. The closure pressure gradient ranged from 0.52 to 0.72 psi/ft. Fracture fluid efficiencies ranged from a low of 2.5% to a high of 27%. The wide range indicates the importance of measuring these values on each interval.

Fracture Treatment Summary

As stated earlier, the fracture treatments were designed for a tip screen-out in order to achieve a high conductivity fracture. In almost every case, based on the mini-frac analysis, it was necessary to redesign the treatment schedules on location to achieve a tip screen-out.

Net pressure is the difference between the bottomhole treating pressure (BHTP) and the closure pressure, (Net pressure = BHTP - Closure pressure). The BHTP was determined from the surface treating pressure, fluid rheology, injection rate, and tubing configuration. The closure pressure was determined from an analysis of the pressure decline following the mini-frac. The net pressure is important in the evaluation of fracture treatments because the magnitude and the trend of net pressure indicate different types of fracture geometry and the major factors influencing fracture growth. **Fig. 4** illustrates the history match of the net pressure on the Linda No. 1, U sand and **Fig. 5** displays the predicted fracture geometry. **Table 3** summarizes the estimated fracture geometry for each treatment.

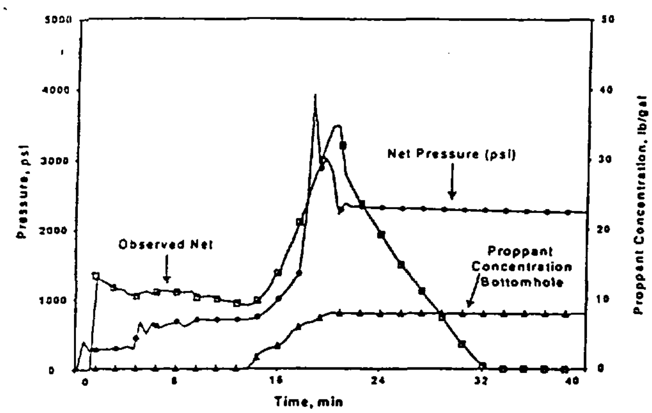

Fig. 4 - Net pressure history match on the Linda No. 1, U sand.

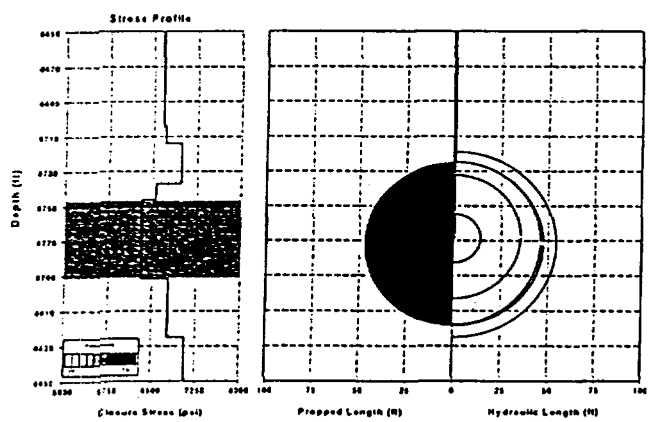

Fig. 5 - Predicted geometry Linda No. 1, U sand.

History matching the pressure data required simulating multiple fractures on many of the treatments. Multiple fractures can be initiated and propagated in any reservoir. However, they are more common in naturally fractured reservoirs and in deviated wellbores. Based on the current technology developed from fracture treatment evaluation, it appears that the occurrence of multiple fractures is far more common than previously thought.[21-25] There have even been horizontal cores through a fractured zone where fourteen (14) individual fractures were observed.[26] Typically, propagating multiple fractures will increase the bottomhole treatment pressure and the net pressure. The propagation of multiple fractures is of concern because it reduces the fracture width making it more difficult to place proppant in the fracture. In a high permeability reservoir, it is even more critical because the fracture width is already narrow due to the low fluid efficiency. Therefore, when multiple fractures were suspected, steps were taken to minimize their existence. One of the most important design changes was to initiate the fracture with a viscous gel pill.

Production Data

The increased production from the stimulation program has been significant. As can be seen in Fig. 6 approximately 50 percent of the current production can be attributed to the fracture treatments, resulting in over 2,700,000 bbs of increased reserves.

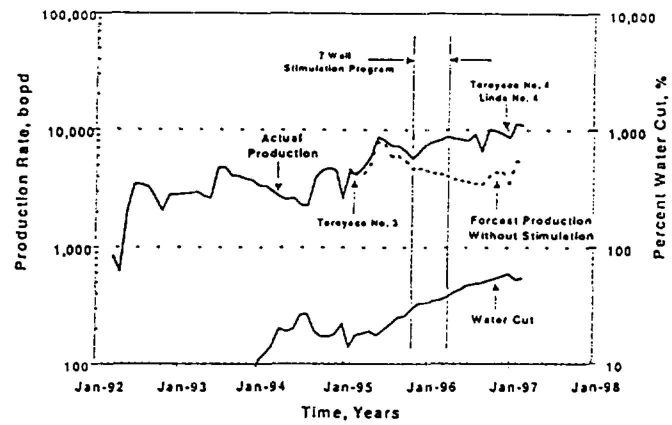

Fig. 6 - Production history before and after stimulation program.

The Viletta T and U sands are pressure supported by a very strong aquifer. Prior to performing the initial fracture treatment, there was concern that the fracture would penetrate the water leg of the reservoir and substantially increase the water production. However, the percent water cut has not increased at a faster rate, Fig 6. In fact the rate of increase has been slightly less after the stimulation program. It is not surprising that the hydraulic fractures could reduce the effects if water coning. Since the first work performed by Muskat in 1948 [27] the mechanics of water coning have been studied extensively by the petroleum industry. [28-37] It is well understood that hydraulic fracturing will reduce the pressure gradients that cause water coning.

Analysis of Production Response

The oil production increase was significant on most of the wells. Table 4 is a summary of the production rates of oil and water for each of the wells that were fracture stimulated. The production is based on the monthly production rates.

To evaluate the increased productivity of the wells, several parameters were reviewed. These included the net production increase and the fold increase in production. Fig. 7 is a graph of the net increase in production of oil and water. The average increase was a total of 1440 bbls/day. Of this amount, 770 bbls/day were oil and 660 bbls/day were water.

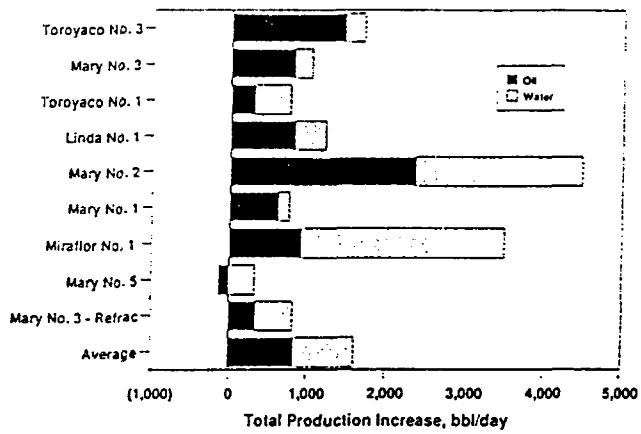

Fig. 7 - Net production rate increase.

The increase in productivity index (J) is normally used to evaluate the effectiveness of stimulation treatments. The index is defined by the following equation:

$$J = \frac{Q}{p_s - p_{wf}}$$

where

J = Productivity Index, BFPD/psi
Q = Production Rate, bbl/day
p_s = Static Reservoir Pressure. psi
p_{wf} = Flowing Bottomhole Pressure, psi

Since the productivity index was determined both before and after the fracture treatments, a comparison of the productivity index can be made. The fold increase in the productivity index was determined by dividing the post-stimulation productivity index by the pre-stimulation productivity index (J/J_o). Some of the productivity indices were determined for individual sands while others were for commingled production. If a pre- and post-stimulation productivity index was available for an individual sand, those values were used to determine the fold increase. However, if individual tests were not available, the commingled value was assigned to both of the sands. The productivity index used to evaluate the fracture treatment is graphed in Fig. 8.

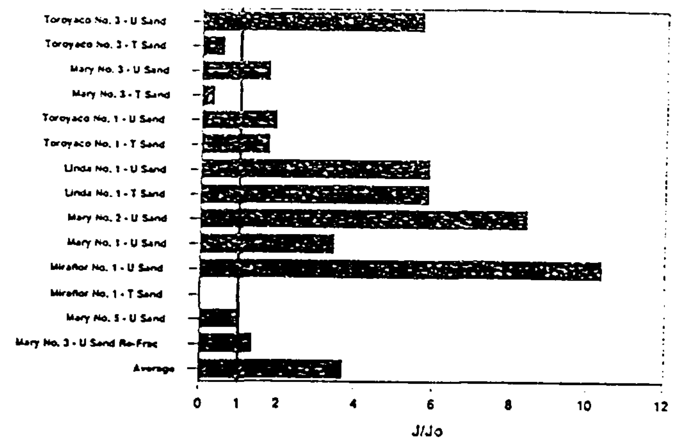

Fig. 8 - Fold increase in productivity index.

Evaluation of Fracture Parameters That Affect Productivity Increase

Several of the wells responded very well to fracture stimulation and some of the wells resulted in only a modest increase. To evaluate what factors had the most control over the success of the fracture treatments, we compared the productivity increase to several different parameters. The Miraflor No. 1 well was not used in any of the attempts to correlate these parameters due to the abnormally high J/J_o increase.

As can be seen in Fig. 9, there is a relationship between the larger proppant volume results in a higher value of J/J_o. The r-squared of 0.58 is not definitive; however, due to the small data set, it is a reasonable correlation.

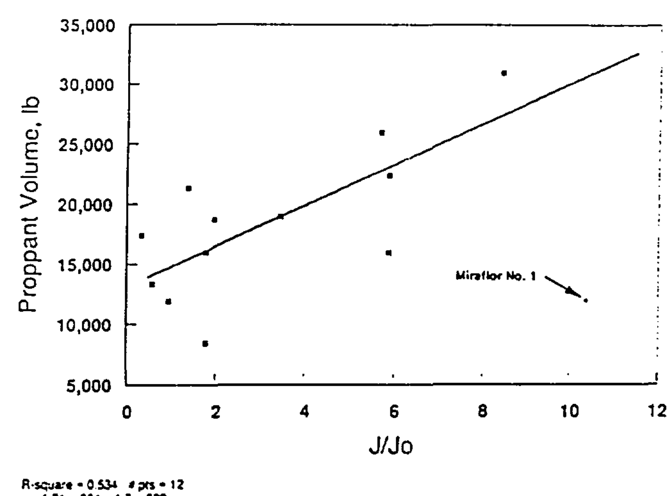

Fig. 9 - Proppant volume

Since the total proppant volume seems to influence the increase in productivity, other proppant parameters were also evaluated. The average proppant concentration was calculated for each fracture treatment by dividing the total proppant volume by the total fluid volume pumped for each treatment.

As can be seen in Fig. 10, the higher proppant concentrations also correlate to improved production.

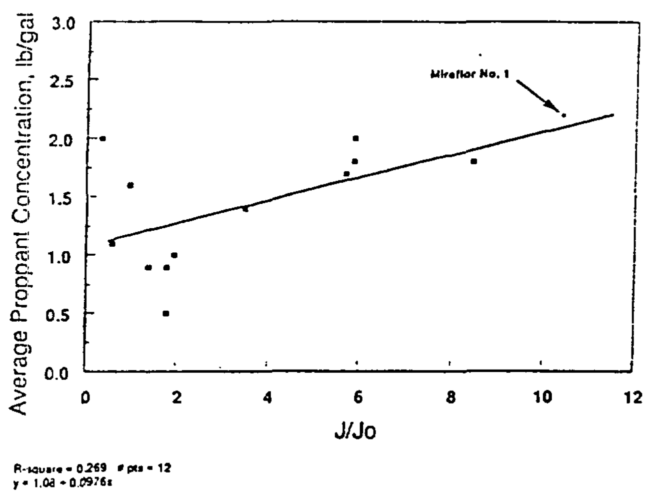

Fig. 10 - Proppant concentration.

These average values are based on the proppant concentrations at the surface and do not account for the fracture geometry or fluid efficiency in the fracture. Therefore, the values may not totally represent the actual proppant concentration in the fracture. As discussed earlier, fracture modeling was performed on every fracture treatment. History matching the pressure data was performed in order to predict the actual fracture geometry. Based on this modeling, the fracture conductivity, in md-ft, was determined for each fracture treatment. As can be seen in Fig. 11, there is a reasonable correlation between J/J_0 and the fracture conductivity indicating the higher conductivity fractures resulted in a larger increase in J/J_0.

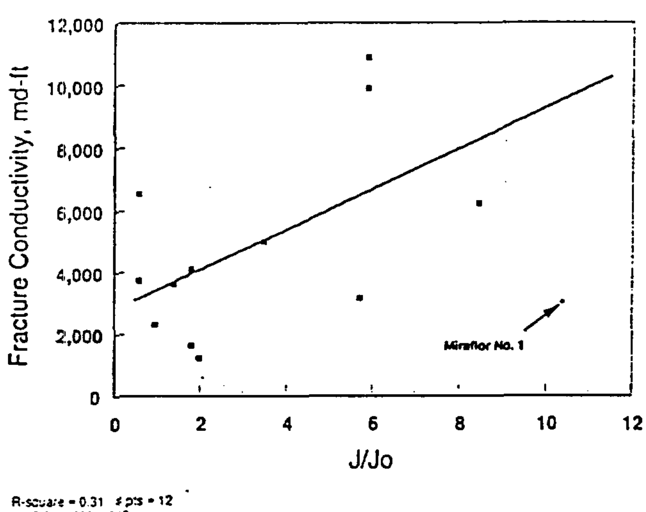

Fig. 11 - Fracture conductivity.

The fracture length calculated from the 3-Dimensional fracture model was also compared to J/J_0 to evaluate the effect of propped length on productivity. As can be seen in Fig. 12, there was no apparent correlation. In high permeability reservoirs, one would expect that the propped fracture length would have little or no influence on the productivity of the well. This observation is assuming, of course, the length was sufficient to reach past any damaged area.

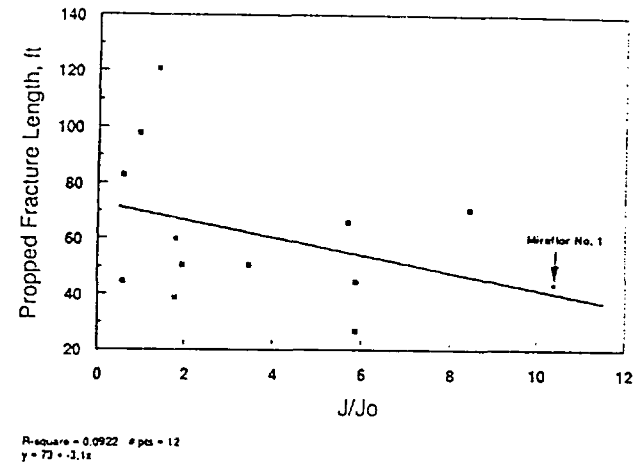

Fig. 12 - Propped fracture length.

To obtain higher conductivity, we attempt to achieve a tip screen out so that proppant can be packed in a wide fracture. Under a screen-out condition, the net pressure increases substantially. Therefore, a comparison was performed on the increase in net pressure and J/J_0. As can be seen in Fig. 13, there is a trend with a higher increase in net pressure resulting in a higher J/J_0.

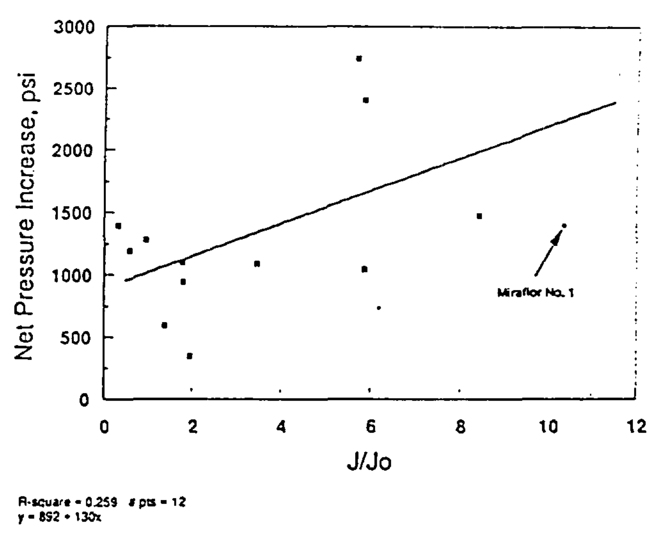

Fig. 13 - Increase in net pressure.

The correlation between the net pressure increase and J/Jo indicated the importance of achieving a tip screen-out and a high conductivity proppant pack.

The success of the stimulation program can be attributed to the application of quality control and real time evaluation of the mini-frac and fracturing data. If each of the fracture treatments had not been optimized on location based on observed data the dramatic results would not have been acheived

Conclusions

1. Performing quality control ensured the fracture fluids performed as designed.
2. Measuring the closure pressure and fracture fluid efficiency was critical to designing for a tip screen-out and maximizing fracture conductivity. Most of the treatment schedules were modified, based on the mini-frac data, to achieve a tip screen-out.
3. The average oil production rate increased from 614 bbl/day to 1461 bbl/day. This is an average increase of 847 bbl/day or 2.6 fold increase.
4. The productivity index increased from an average of 0.42 to 1.47 BFPD/psi, a fold increase of 3.5.
5. Water cut, in percent, was not increased over the normal trend in the field.
6. Currently, about half of the total oil production in the field can be attributed to the stimulation treatments.

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Table 1 - Reservoir Properties

Well	Interval	Average Depth (ft)	Perm (md)	Net Pay (ft)	kh (d-ft)	Skin Factor	Reservoir Pressure (psi)	BHT (Deg F)
Toroyaco No. 3	T Sand	9,256	310	36	11	6	3,600	210
	U Sand	9,081	500	16	8	21	3,800	205
Mary No. 3	T Sand	7,608	304	60	18	33	3,210	195
	U Sand	7,428	778	83	65	108	2,971	192
Toroyaco No. 1	T Sand	9,216	1,664	33	55	25	3,427	211
	U Sand	9,044	721	52	37	60	3,499	211
Linda No. 1	T Sand	8,948	120	46	6	16	3,900	220
	U Sand	8,769	409	46	19	19	3,609	223
Mary No. 2	U Sand	7,495	952	68	65	15	3,142	193
Mary No. 1	U Sand	7,578	210	70	15	22	3,182	195
Miraflor No. 1	T Sand	6,775	891	40	36	15	2,785	174
	U Sand	6,488	883	75	66	39	2,319	176
Mary No. 5	U Sand	7,439	472	84	40	10	3,010	190
Mary No. 3	U Sand	7,683	778	83	65	Unknown	2,971	192
Toroyaco No. 4	T Sand	9,258	185	50	9	17	3,445	210
	U Sand	9,080	258	26	7	5	2,850	210
Linda No. 4	U Sand	8,723	193	31	6	17	3,230	200
Average (Mean)		8,228	566	53	31	27	3,232	200
Median		8,723	472	50	19	18	3,210	200
Minimum		6,488	120	16	6	5	2,319	174
Maximum		9,258	1,664	84	66	108	3,900	223

Table 2 - Analysis of Mini-frac Treatments

Well	Interval	Closure Gradient (psi/ft)	Time (min)	Fluid Efficiency (%)
Toroyaco No. 3	T Sand	0.65	9.9	6.0
	U Sand	0.57	10.0	9.0
Mary No. 3	T Sand	0.72	6.3	22.0
	U Sand	0.59	0.7	2.5
Toroyaco No. 1	T Sand	0.60	1.3	9.0
	U Sand	0.62	0.8	6.0
Linda No. 1	T Sand	0.72	9.5	6.0
	U Sand	0.72	3.2	8.0
Mary No. 2	U Sand	0.52	3.8	27.0
Mary No. 1	U Sand	0.60	4.5	4.5
Miraflor No. 1	T Sand	0.65	3.5	7.0
	U Sand	0.70	3.0	7.0
Mary No. 5	U Sand	0.58	1.0	11.5
Mary No. 3 (Re-frac)	U Sand	0.58	2.2	12
Toroyaco No. 4	T Sand	0.64	1.9	3.0
	U Sand	0.72	1.2	3.0
Linda No. 4	U Sand	0.75	2.0	3.0
Average (Mean)		0.64	3.8	8.6
Median		0.64	3.0	7.0
Minimum		0.52	0.7	2.5
Maximum		0.75	10.0	27.0

Table 3 - Fracture Geometry

Well	Interval	Propped Geometry Length (ft)	Propped Geometry Height (ft)	Fracture Conductivity (md-ft)	Bed Concentration (lb/sqft)	Number of Fractures
Toroyaco No. 3	T Sand	45	87	3,780	0.71	3
	U Sand	66	98	3,200	0.60	4
Mary No. 3	T Sand	83	147	6,580	1.39	1
	U Sand	39	72	4,120	0.85	2
Toroyaco No. 1	T Sand	60	131	1,660	0.56	3
	U Sand	51	99	1,240	0.42	5
Linda No. 1	T Sand	27	42	9,920	1.45	3
	U Sand	45	91	10,920	0.45	1
Mary No. 2	U Sand	71	101	6,240	1.00	2
Mary No. 1	U Sand	51	106	5,040	1.05	2
Miraflor No. 1	T Sand	58	86	6,740	1.35	1
	U Sand	44	74	3,060	0.58	3
Mary No. 5	U Sand	98	107	2,340	0.47	1
Mary No. 3	U Sand	121	89	3,650	0.75	1
Toroyaco No. 4	U Sand	33	66	5,620	1.56	2
	T Sand	115	78	6,590	1.45	2
Linda No. 1	Upper U	32	80	2,700	1.79	2
	Lower U	12	73	2,420	1.58	2
Average (Mean)		59	91	4,826	1.02	2
Median		51	89	4,120	1.00	2
Minimum		12	42	1,240	0.42	1
Maximum		121	147	10,920	1.79	5

Table 4 - Pre-stimulation and post-stimulation production rates (bpd)

	Pre-Stimulation				Post-Stimulation			
	Total bbl	Oil bbl	Water bbl	Water %	Total bbl	Oil bbl	Water bbl	Water %
Toroyaco No. 3	662	438	224	33.8	2,382	1,908	474	19.9
Mary No. 3	479	532	47	8.0	1,638	1,361	277	16.9
Toroyaco No. 1	1,273	726	547	43.0	2,049	1,036	1,013	49.5
Linda No. 1	572	366	206	36.0	1,799	1,205	594	33.0
Mary No. 2	1,026	764	262	25.6	5,537	3,149	2,388	43.1
Mary No. 1	476	396	80	16.9	1,248	1,032	216	17.3
Miraflor No. 1	666	537	130	19.5	4,171	1,473	2,698	64.7
Mary No 5	1,931	1,061	870	45.1	2,136	931	1,206	56.4
Mary No. 3	1,103	707	396	35.9	1,935	1,057	879	45.4
Toroyaco No. 4	1,980	1,892	88	4.7	2,700	2,322	378	14.0
Linda No. 4	870	870	0	0.0	1,300	1,300	0	0.0
Average (Mean)	**1,003**	**754**	**259**	**24.4**	**2,445**	**1,525**	**920**	**32.7**
Median	**870**	**707**	**206**	**25.6**	**2,049**	**1,300**	**594**	**33.0**
Minimum	**476**	**366**	**0**	**0.0**	**1,248**	**931**	**0**	**0.0**
Maximum	**1,980**	**1,892**	**870**	**45.1**	**5,537**	**3,149**	**2,698**	**64.7**
Total	**11,038**	**8,289**	**2,850**	—	**26,895**	**16,774**	**10,123**	—

GAS PRODUCTION: Monitoring System Optimizes Fracture Treatments.

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Journal Title: GRID Gas Research Institute Digest
Publication Date: Summer 1990
Pagination: v13 n2, p22-23
Business Unit: Customer Relations & Communications

Summary

FRACPRO, developed for GRI by Resources Engineering Systems, Inc., is a three-dimensional computerized data acquisition and analysis system that monitors job parameters during the fracturing process. Using these measured values as inputs, the geometry model can be run in real time to match treating pressure and to interpret fracture geometry development. RESPRO uses data gathered by FRACPRO to create a production profile and reservoir stream projection to predict gas production over the life of the well.

Full Text:

"Five years ago when we'd do a hydraulic fracture treatment," recalls R. Wayne Pittman, a Senior Research Associate at Texaco USA's Exploration and Production Technology Division, "we had no way of visualizing what the actual fracture would look like. We would follow hydraulic fracture treatment designs based on assumptions of the reservoir containment conditions, but fracture performance was often inconsistent. Using FRACPRO(TM), and its counterpart RESPRO(TM), we now have the potential to custom design fracture treatments to optimize fracture performance."

A hydraulic fracture is a crack created in potentially productive rock by pumping thick fluids at high pressures into the formation until it cracks. The fracture during the process is filled with sand (proppant), which holds the fracture open after completion of the job. The created and propped fracture provides a conduit for gas to move out of the tight rock into the treated well where it is produced.

FRACPRO--developed for GRI by Resources Engineering Systems, Inc.--is a three-dimensional computerized data acquisition and analysis system that monitors job parameters (such as fracture fluid viscosity, pumping pressure, proppant concentration, etc.) during the fracturing process, and uses these measured values as real-time inputs into the same geometry model used in the original design. With these measured data, the geometry model can then be run in real time to match treating pressure and to interpret fracture geometry development.

RESPRO uses the data gathered by FRACPRO to create a production profile and reservoir stream projection to predict gas production over the life of the well. Both FRACPRO and RESPRO are now commercially available.

"If used diligently, FRACPRO and RESPRO can save the producer money on hydraulic treatments," says Pittman. "First, FRACPRO serves as a quality control tool because it allows the operator to see the effects of slight variations in job parameters, such as fluid viscosity. Then the operator can do a 'post mortem' evaluation by experimenting with a few different procedures to determine the best job parameters for other wells in the same field."

Independent producers are also finding FRACPRO useful.

"Our historical design models for hydraulic fracture treatments used to specify small prepads and relatively large pads. But, since we began examining and using FRACPRO, we've changed the way we do frac jobs," says Nathan Meehan, Senior Engineering Advisor for Union Pacific Resources. (A "prepad" is the initial pumping of fracture fluid into a gas well to fracture and prepare the reservoir for further treatment. After the prepad, operators inject thicker fluid to create a "pad" that opens the fracture wider so it can accept and hold the proppant, or sand, in the formation.)

"We used to pump 10,000 gallons of 10-lb gel during the prepad and 50,000 gallons of 50-lb crosslinked gel during the pad," continues Meehan. "But, the design model our service company used didn't account for the effect of the prepad on the reservoir. When we incorporated that effect, as simulated by FRACPRO, we found that the fracture caused during the prepad operation was actually pretty wide.

"So, now we've gotten more aggressive during the prepad phase and pump in 25,000 gallons of prepad and 10,000 gallons of pad. This saves us some money (because 10-lb gel is less expensive than 50-lb crosslinked gel) and leaves less residue in the well."

Union Pacific has also made other changes in the way it conducts hydraulic fracture treatments. FRACPRO demonstrated that, in some cases, Union Pacific could--

* Pump fewer but larger treatments in multiple zone wells with the same results;
* Economically justify using 5-1/2-in. casing instead of the less-expensive 4-1/2-in. casing;
* Adjust the size of the fracture treatment commensurate with the production potential of a given formation; and
* Make realistic production estimates based on more accurate fracture length calculations.

"Because it retains data on all frac treatments, FRACPRO will allow us to do frac job analyses on a consistent basis," explains Meehan. "So eventually we'll be able to design all our fracture treatments." "Using FRACPRO," says Pittman, "you don't have to recreate a mistake; you can learn from it."

Contacts:
* For sales information, contact Chris Wright, Resources Engineering Systems, Inc., 15 New England Executive Park, Burlington, MA 01803 (617/229-6349; fax 617/299-6839), or Phil Lewis, Resources Engineering Systems, Inc., 7136 S. Yale Ave., Suite 300, Tulsa, OK 74136 (918/481-3107; fax 918/496-7712).
* For R&D information, contact Kent Perry, GRI Manager, Tight Gas Sands.

Member Cost: $ 0.00
Non-Member Cost: $ 0.00

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FRACTURE MONITORING/Real-Time Fracture Monitoring System Helps Optimize Frac Jobs.

Document Type: Journal Article
Journal Title: FrontBurner
Publication Date: January-May 1990
Pagination: p11
GRI Contract Number: 5083-211-0861
Project Manager: Perry, Kent F.
Business Unit: Customer Relations & Communications

Summary

FRACPRO&T(TM), developed for Gas Research Institute by Resources Engineering Systems, Inc., is a computerized data acquisition and analysis system that provides information for hydraulic fracture treatment design and simulates the actual fracture as it grows. It helps to design optimal hydraulic fracturing treatments for low-permeability formations. The article describes the experience of Union Pacific Resources Company in using the system. Contacts for further information are listed.

Full Text:

"Our historical design models for hydraulic fracture treatments used to specify small prepads and relatively large pads," says Nathan Meehan, Senior Engineering Advisor for Union Pacific Resources. A "prepad" is the initial pumping of fracture fluid into a gas well to fracture and prepare the reservior for further treatment. After the prepad, operators inject thicker fluid to create a "pad" that opens the fracture wider so it can accept and hold the proppant, or sand, into the formation. "Since we began examining and using FRACPRO(TM), we've changed the way we do frac jobs." FRACPRO--developed for GRI by Resources Engineering Systems, Inc.--is a computerized data acquisition and analysis system that provides information for hydraulic fracture treatment design and simulates the actual fracture as it grows. "We used to pump 10,000 gallons of 10-lb gel during the prepad and 50,000 gallons of 50-lb crosslinked gel during the pad," continues Meehan. "But, the design model our service company used didn't account for the effect of the prepad on the reservoir. When we incorporated that effect, as simulated by FRACPRO, we found that the fracture caused during the prepad operation was actually pretty wide." "So, now we've gotten more aggressive during the prepad phase and pump in 25,000 gallons of prepad and 10,000 gallons of pad. This saves us some money (because 10-lb gel is less expensive than 50-lb crosslinked gel) and leaves less residue in the well." Union Pacific has also made other changes in the way it conducts hydraulic fracture treatments. FRACPRO demonstrated that, in some cases, Union Pacific could --pump fewer but larger treatments in multiple zone wells with the same results; economically justify using 5 1/2" casing instead of the less-expensive 4 1/2" casing; adjust the size of the fracture treatment commensurate with the production potential of a given formation; and make more realistic production estimates based on conservative fracture length calculations. "Because it retains data on all frac treatments, FRACPRO will allow us to do frac job analyses on a consistent basis," explains Meehan. "So eventually we'll be able to design all our fracture treatments."

For SALES INFORMATION, contact Chris Wright, Resources Engineering Systems, Inc., 15 New England Executive Park, Burlington, MA 01803 (617/229-6349; FAX 617/299-6839) or Phil Lewis, Resources Engineering Systems, Inc., 7136 S. Yale Ave., Suite 300, Tulsa, OK 74136 (918/481-3107; FAX 918/496-7712).

For R&D INFORMATION, contact Kent Perry, GRI's Manager of Tight Gas Sands (312/399-8292).

Member Cost: $ 0.00
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FRACPRO(TM) Software.

GRI Document Number: GRI-94/0126
Series Title: Pacesetters(TM): Leading the Way with New Gas Technologies.
Document Type: Brochure
Corporate Source: Gas Research Institute, Chicago, IL
Publication Date: March 1994
Pagination: 2p
GRI Contract Number: 5091-221-2134
Project Manager: Wolhart, Stephen L.
Business Unit: Customer Relations & Communications

Summary

The FRACPRO(TM) computer program is the gas industry's only three-dimensional fracture modeling system capable of real-time measurements. By using FRACPRO to design, monitor, and evaluate hydraulic fractures, well operators can dramatically reduce treatment costs. The model can also be used to obtain a match between predictions of a specific treatment's effect and the actual observations made during the fracture. The brochure describes the industry's need for the system, its applications, and the use of FRACPRO by Union Pacific Resources Company, which successfully tested the system's applications and obtained savings by switching to a less expensive proppant, reducing the pad volume, and increasing the amount of gas recovered from infill wells. For information contact: Tim Wright, Resources Engineering Systems, Inc., Cambridge, MA, 617-621-8555.

Member Cost: $ 0.00
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GRI Completes FRACPRO(R) Licensing Courses--279 Trained on System.

GRI Document Number: GRI-95/0137-0015
Document Type: Journal Article
Journal Title: GRID Gas Research Institute Digest
Publication Date: Spring 1995
Pagination: v18 n1, p25
Business Unit: Customer Relations & Communications

Summary

Initially developed for Gas Research Institute's Natural Gas Supply Project Advisor Group, the FRACPRO licensing course proved to be so successful as a technology transfer medium that from 1992 to 1994 ten two-day workshops were offered. FRACPRO((TM), a real-time three-dimensional hydraulic fracture modeling system developed for GRI by Resources Engineering Systems, Inc., proved to be able to reduce fracturing costs, optimize fracturing treatments, and improve production efficiency. A total of 279 attendees from 134 gas industry companies participated in the training. The article includes evaluations of the program by several participants.

Member Cost: $ 0.00
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Date: 8/5/98

Subject: Author=Wright

AUTHOR: **Wright, T.B.; Cipolla, C.; Perry, K.F.; Cleary, M.P.**
ORG: Integrated Petroleum Technologies; Union Pacific Resources; Gas Research Institute; Massachusetts
TITLE: **Identification and Comparison of True Net Fracturing Pressures Generated by Pumping Fluids with Different Rheology into the Same Formations**
SPE 26153
SOURCE: SPE Gas Technology Symposium held in Calgary, Alberta, Canada, 28-30 June
YEAR: 1993

AUTHOR: **Johnson, D.E.; Wright, T.B.; Tambini, Mauro; Maroli, Renato; Cleary, M.P.**
ORG: Resources Engineering Systems Inc.; AGIP SpA; Massachusetts Inst. of Technology
TITLE: **Real-Data On-Site Analysis of Hydraulic Fracturing Generates Optimum Procedures for Job Design and Execution**
SPE 25920
SOURCE: SPE Rocky Mountain Regional/Low Permeability Reservoirs Symposium held in Denver, CO, U.S.A., April 12-14
YEAR: 1993

AUTHOR: **Martinez, A.D.; Wright, C.A.; Wright, T.B.**
ORG: Texaco EPTD; Pinnacle Technologies Inc.; Resources Engineering Systems Inc.
TITLE: **Field Application of Real-Time Hydraulic Fracturing Analysis**
SPE 25916
SOURCE: SPE Rocky Mountain Regional/Low Permeability Reservoirs Symposium held in Denver, CO, U.S.A., April 12-14
YEAR: 1993

AUTHOR: **1Johnson, D.E.; Wright, C.A.; Stachel, Alfred; Schmidt, Holger; Cleary, M.P.**
ORG: Resources Engineering Systems Inc.;; RWE-DEA Aktiengesellschaft fur Mineraloel and Chemie;; Mas
TITLE: **On-Site Real-Time Analysis Allows Optimal Propped Fracture Stimulation of a Complex Gas Reservoir**
SPE 25414
SOURCE: Production Operations Symposium held in Oklahoma City, OK, U.S.A., March 21-23
YEAR: 1993

AUTHOR: **Cleary, M.P.; Wright, C.A.; Wright, T.B.**
ORG: Massachusetts Inst. of Technology; Resources Engineering Systems Inc.
TITLE: **Experimental and Modeling Evidence for Major Changes in Hydraulic Fracturing Design and Field Procedures**
SPE 21494
SOURCE: SPE Gas Technology Symposium held in Houston, Texas, January 23-25
YEAR: 1991

AUTHOR: **Svendson, A.P.; Wright, M.S.; Clifford, P.J.; Berry, P.J.**
ORG: BP Norway Ltd.; BP Research Centre
TITLE: **Thermally Induced Fracturing of Ula Water Injectors**
SPE 20898
SOURCE: Europec 90, The Hague, Netherlands, 22-24 October
YEAR: 1991

AUTHOR: **Leraand, Frode; Wright, J.W.; Zachary, M.B.; Thompson, B.G.**
ORG: Saga Petroleum A/S; John Wright Co.; Eastman Christensen Inc.; Vector Magnetics Inc.
TITLE: **Relief-Well Planning and Drilling for a North Sea Underground Blowout**
SPE 20420
SOURCE: JPT
YEAR: 1992

Date: 8/5/98

Subject: Author=Wright

AUTHOR: Wright, C.A.; Conant, R.A.
ORG: Pinnacle Technologies, Inc.
TITLE: Hydraulic Fracture Reorientation in Primary and Secondary Recovery from Low-Permeability Reservoirs
SPE 30484
SOURCE: SPE Annual Technical Conference & Exhibition held in Dallas, TX, U.S.A., 22-25 October
YEAR: 1995

AUTHOR: Wright, C.A.; Weijers, L.; Minner, W.A.; Snow, D.M.
ORG: Pinnacle Technologies, Inc.; Texaco Exploration & Producing, Inc.
TITLE: Robust Technique for Real-Time Closure Stress Determination
SPE 30503
SOURCE: SPE Annual Technical Conference & Exhibition held in Dallas, TX, U.S.A., 22-25 October
YEAR: 1995

AUTHOR: Wright, C.A.; Conant, R.A.; Stewart, D.W.; Byerly, P.M.
ORG: Pinnacle Technologies Inc.; Chevron USA; Unocal Corporation
TITLE: Reorientation of propped refracture treatments
SPE 28078
SOURCE: SPE/ISRM Rock Mechanics in Petroleum Engineering Conference held in Delft, The Netherlands, 29-31 August
YEAR: 1994

AUTHOR: Schemeta, J. E.; Minner, W. B.; Hickman, R.G.; Johnston, P.A.; Wright, C. A.; Watchi, N.
ORG: UNOCAL Corporation, Anaheim, USA; Pinnacle Technologies Inc.; Japan National Oil Corporation, Ja
TITLE: Geophysical monitoring during a hydraulic fracture in a fractured reservoir: Tiltmeter and passive seismic results
SPE 28145
SOURCE: SPE/ISRM Rock Mechanics in Petroleum Engineering Conference held in Delft, The Netherlands, 29-31 August
YEAR: 1994

AUTHOR: Cleary, M.P.; Doyle, R.S.; Meehan, D.N.; Massaras, L.V.; Wright, T.B.
ORG: Bass Enterprises Production Co.
TITLE: Major New Developments in Hydraulic Fracturing, with Documented Reductions in Job Costs and Increases in Normalized Production
SPE 28565
SOURCE: SPE 69th Annual Technical Conference and Exhibition held in New Orleans, LA, U.S.A., 25-28 September
YEAR: 1994

AUTHOR: Aud, W.W.; Wright, T.B.; Cipolla, C.L.; Harkrider, J.D.
ORG: Integrated Petroleum Technologies Inc.; Gas Research Inst.
TITLE: The Effect of Viscosity on Near-Wellbore Tortuosity and Premature Screenouts
SPE 28492
SOURCE: SPE 69th Annual Technical Conference and Exhibition held in New Orleans, LA, U.S.A., 25-28 September
YEAR: 1994

AUTHOR: Wright, C.A.; Stewart, D.W.; Emanuele, M.A.; Wright, W.W.
ORG: Pinnacle Technologies Inc.
TITLE: Reorientation of Propped Refracture Treatments in the Lost Hills Field
SPE 27896
SOURCE: Western Regional Meeting held in Long Beach, California, U.S.A., 23-25 March
YEAR: 1994

Date: 8/5/98

Subject: Author=Wright

AUTHOR: **Peterson, R.E.; Wolhart, S.L.; Frohne, K.H.; Branagan, P.T.; Warpinski, N.R.; Wright, T.B.**
ORG: *Branagan & Associates; Gas Research Institute; U.S. Department of Energy; Branagan & Associates;*
TITLE: **Fracture Diagnostics Research at the GRI/DOE Multi-Site Project: Overview of the Concept and Results**
SPE 36449
SOURCE: SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October
YEAR: 1996

AUTHOR: **Warpinski, N.R.; Wright, T.B.; Uhl, J.E.; Engler, B.P; Drozda, P.M.; Peterson, R.E.; Branagan, P.T.**
ORG: Sandia Natl. Labs; Resources Engineering Systems; Sandia Natl. Labs; Branagan & Assoc.
TITLE: **Microseismic Monitoring of the B-Sand Hydraulic Fracture Experiment at the DOE/GRI Multi-Site Project**
SPE 36450
SOURCE: SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October
YEAR: 1996

AUTHOR: **Branagan, P.T.; Peterson, R.E.; Warpinski, N.R.; Wright, T.B.**
ORG: Branagan & Associates; Sandia National Laboratories; Resources Engineering Systems
TITLE: **Characterization of a Remotely Intersected Set of Hydraulic Fractures: Results of Intersection Well No. 1-B, GRI/DOE Multi-Site Project**
SPE 36452
SOURCE: SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October
YEAR: 1996

AUTHOR: **Wright, C.A.; Weijers, L.; Germani, G.A.; MacIvor, K.H.; Wilson, M.K.; Whitman, B.A.**
ORG: Pinnacle Technologies; Chevron USA; BJ Services
TITLE: **Fracture Treatment Design and Evaluation in the Pakenham Field: A Real-Data Approach**
SPE 36471
SOURCE: SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October
YEAR: 1996

AUTHOR: **Arihara, N.; Abbaszadeh, M.; Wright, C.A.; Hyodo, M.**
ORG: *Waseda University; Japan National Oil Corporation; Pinnacle Technologies; Geothermal Energy Rese*
TITLE: **Integration of Fracturing Dynamics and Pressure Transient Analysis for Hydraulic Fracture Evaluation**
SPE 36551
SOURCE: SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October
YEAR: 1996

AUTHOR: **Wright, C.A.; Tanigawa, J.J.; Shixin, Mei; Li, Zhigang**
ORG: Pinnacle Technologies, Inc.; North China Bureau of Petroleum Geology (NCBPG)
TITLE: **Enhanced Hydraulic Fracture Technology for a Coal Seam Reservoir in Central China**
SPE 29989
SOURCE: International Meeting on Petroleum Engineering held in Beijing, PR China, 14-17 November
YEAR: 1995

AUTHOR: **Wright, C.A.; Conant, R.A.; Golich, G.M.; Bondor, P.L.; Murer, A.S.; Dobie, C.A.**
ORG: Pinnacle Technologies Inc.; CalResources; Mobil E&P U.S.; Crutcher-Tuffs Production Co.
TITLE: **Hydraulic Fracture Orientation and Production/Injection Induced Reservoir Stress Changes in Diatomite Waterfloods**
SPE 29625
SOURCE: Western Regional Meeting held in Bakersfield, CA, U.S.A., 8-10 March
YEAR: 1995

Date: 8/5/98

Subject: Author=Wright

AUTHOR: **Wright, C.A.; Minner, W.A.; Weijers, L.; Davis, E.J.; Golich, G.M.; Kikuchi, H.**
ORG: Pinnacle Technologies Inc.; Aera Energy LLC; Japan National Oil Corporation
TITLE: **Wellbore-to-Fracture Communication Problems Pose Challenges in California Diatomite Horizontal Wells**
SPE 38632
SOURCE: SPE Annual Technical Conference and Exhibition held in San Antonio, Texas, U.S.A., 5-8 October
YEAR: 1997

AUTHOR: **Strong, A.J.; Wright, R.J.; Skelly, G.J.**
ORG: Dyno Oil Field Chemicals UK Ltd.; Chemotechnics Ltd.; Amoco (UK) Exploration Company
TITLE: **Well Stimulation: A Mature Asset Case Study**
SPE 38769
SOURCE: SPE Annual Technical Conference and Exhibition held in San Antonio, Texas, U.S.A., 5-8 October
YEAR: 1997

AUTHOR: **Wright, John D.**
ORG: Questa Engineering Corporation
TITLE: **Actual Performance Compared to a 20 Year Old Probabilistic Reserve Estimate**
SPE 38802
SOURCE: SPE Annual Technical Conference and Exhibition held in San Antonio, Texas, U.S.A., 5-8 October
YEAR: 1997

AUTHOR: **Minner, W.A.; Molesworth, G.R.; Wright, C.A.; Wood, W.D.**
ORG: Pinnacle Technologies, Inc.; Chevron USA; Pinnacle Technologies, Inc.; BJ Services
TITLE: **Real-Data Fracture Analysis Enables Successful Hydraulic Fracturing in the Point of Rocks Formation, Kern County, California**
SPE 38326
SOURCE: SPE Western Regional Meeting held in Long Beach, California, U.S.A., 25-27 June
YEAR: 1997

AUTHOR: **Minner, W.A.; Wright, C.A.; Dobie, C.A.**
ORG: Pinnacle Technologies, Inc.; Crutcher-Tufts Production Co.
TITLE: **Treatment Diagnostics and Net Pressure Analysis Assist with Fracture Strategy Evaluation in the Belridge Diatomite**
SPE 35696
SOURCE: Western Regional Meeting held in Anchorage, Alaska, U.S.A., 22-24 May
YEAR: 1996

AUTHOR: **Wright, C.A.; Weijers, Leen; Minner, W.A.; Snow, D.M.**
ORG: Pinnacle Technologies Inc.; Texaco E&P
TITLE: **Robust Technique for Real-Time Closure Stress Determination**
SPE 30503-P
SOURCE: SPEPF
YEAR: 1996

AUTHOR: **de Pater, C.J. (Hans); Zoback, Mark D.; Wright, Chris A.; Engeser, Bernard**
ORG: Delft University of Technology; Stanford University; Pinnacle Technologies; Niedersachsisches Lande
TITLE: **Complications with Stress Tests - Insights from a fracture experiment in the ultra-deep KTB borehole**
SPE 36437
SOURCE: SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October
YEAR: 1996

Date: 8/5/98

Subject: Author=Wright

AUTHOR:	GROENEMAN, A.R.; WRIGHT, F.F.
ORG:	SINCLAIR OIL and GAS CO.
TITLE:	ANALYSIS of FLUID INPUT WELLS by SHUT-IN PRESSURES
SPE	620-G
SOURCE:	JPT
YEAR:	1956

AUTHOR: **Wright, B.K.; Hawkes, R.V.**
ORG: *Texaco Canada Resources; Fekete Assocs. Inc.*
TITLE: **Case Study Production Optimization Shunda Rundle B Pool**
SPE 18965
SOURCE: Joint Rocky Mountain Regional/Low Permeability Reservoirs Symposium and Exhibition held in Denver, Colorado, March 6-8
YEAR: 1989

AUTHOR: **Loeppke, Gelan E.; Glowka, David A.; Wright, Elton K.**
ORG: Sandia Natl. Laboratories
TITLE: **Design and Evaluation of Lost-Circulation Materials for Severe Environments**
SPE 18022
SOURCE: JPT
YEAR: 1990

AUTHOR: **Buharali, A.M.; Wright, T.B.; Willis Jr., R.M.**
ORG: *Resources Engineering Systems Inc.*
TITLE: **Real-Time Hydraulic Fracturing Simulation Using a Portable Microcomputer**
SPE 16486
SOURCE: Petroleum Industry Applications of Microcomputers held in Del Lago on Lake Conroe, Montgomery, Texas, June 23-26
YEAR: 1987

AUTHOR: **Wright, J.D.; Fields Jr., R.A.**
ORG: Colorado School of Mines; Colorado Interstate Gas Co.
TITLE: **Production Characteristics and Economics of the Denver Julesburg Basin Codell/Niobrara Play**
SPE 15554
SOURCE: JPT
YEAR: 1988

AUTHOR: **Wright, R.J.; Wheat, M.R.; Dawe, R.A.**
ORG: *Imperial C.; Imperial C.; Imperial C.*
TITLE: **Slug Size and Mobility Requirements for Chemically Enhanced Oil Recovery Within Heterogeneous Reservoirs**
SPE 13704
SOURCE: SPERE
YEAR: 1987

AUTHOR: **Gottschling, J.C.; Cecil, K.L.; Wright, J.N.**
ORG: BJ-Hughes Services; Petroleum Industries/Omega Oil Corp.
TITLE: **A Unified Approach to Devonian Shale Oilwell Development**
SPE 13357
SOURCE: SPE Eastern Regional Meeting held in Charleston, West Virginia, October 31-November 2
YEAR: 1984

AUTHOR: **WRIGHT, F.F.**
ORG: SINCLAIR OIL AND GAS CO.
TITLE: **Field Results Indicate Significant Advances In Water Flooding Effect of Rates on Performance In Browning Unit Water Flood**
SPE 1068-G
SOURCE: JPT
YEAR: 1958

SPE 36551

Integration of Fracturing Dynamics and Pressure Transient Analysis for Hydraulic Fracture Evaluation

N. Arihara, SPE, Waseda University, M. Abbaszadeh, SPE, Japan National Oil Corporation, C.A. Wright, SPE, Pinnacle Technologies, and M. Hyodo, Geothermal Energy Research and Development Co., Ltd.

This paper was prepared for presentation at the 1996 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October 1996.

Abstract

This paper presents pre- and post-fracture pressure transient analysis, combined with net fracture pressure interpretation, for a well in a naturally fractured geothermal reservoir. Integrated analysis was performed to achieve a consistent interpretation of the created fracture geometry, propagation, conductivity, shrinkage, reservoir flow behavior, and formation permeability characteristics. The interpreted data includes two-rate pre-frac injection tests, step-rate injection tests, a series of pressure falloff tests, and the net fracturing pressure from a massive fracture treatment. Pressure transient analyses were performed utilizing advanced well test interpretation techniques and a thermal reservoir simulator with fracture propagation option. Hydraulic fracture propagation analysis was also performed with a generalized 3-D dynamic fracture growth model simulator.

Three major conclusions resulted from the combined analysis: 1) that an increasing number of hydraulic fractures were being simultaneously propagated during the fracture treatment, 2) that the reservoir behaved as a composite reservoir with the outer region permeability being greater than the permeability of the region immediately surrounding the wellbore and 3) that the created fractures extended into the outer region during the fracture treatment but retreated to the inner region several days after stimulation had ceased. These conclusions were apparent from independent pressure transient analysis and from independent hydraulic fracture propagation analysis.

Integrated interpretation, however, increased the confidence in these conclusions and greatly aided the quantification of the created hydraulic fracture geometry and characterization of the reservoir permeability.

Introduction

Hydraulic fracturing is an effective way of well stimulation in tight oil and gas reservoirs. Development of geothermal systems including hot dry rock reservoirs also employs this technology. Hydrothermal energy extraction is typically controlled by the conductivity of the natural fracture system intersected by a wellbore. Hydraulic fracture stimulation is often applied to less prolific producers to enhance productivity by establishing the communication with nearby natural fracture systems.

Effective hydraulic fracture stimulation primarily depends on the modeling and diagnostic capability required to optimally design field operations and to reliably estimate the created geometry and dimensions of the induced hydraulic fracture systems. Realistic three-dimensional fracture models are necessary tools for these purposes. The required functions to be possessed by models are such that formation is characterised by rock and fluid parameters including stress, modulus, permeability, pressure, fluid saturation, etc., that physical mechanisms of fracture initiation, fluid leakoff fracture propagation and closing are modeled, and that observed well pressures can be reproduced by simulating a single fracture or multiple fractures.

Well testing is another indispensable tool which is normally conducted before and after hydraulic fracturing in order to obtain data for fracture evaluation. Analysis of injection and falloff tests in a fractured well can possibly be complicated by several effects including the multiphase effect and temperature effect. Another complexity in injection and falloff tests is caused by dynamic behaviors of the fractured well. Dynamic opening and closing of fractures are amplified in the case of an unpropped fracturing treatment. Because injection rate is usually very high in geothermal well testing, dynamic fractures can be easily initiated from natural fractures.

The following were used in this phase of the project:

- Comparison of long-term production response on new wells to previous wells.

P. 357

SPE 38374

Multi-Stage Fracture Stimulations are Making Better Wells Along the Cedar Creek Anticline

T.W. Green, S.A. Holditch & Assoc., Inc., M.R. Besler, Halliburton Energy Services, D.M. Zander, Williston Basin Interstate Pipeline Co.

This paper was prepared for presentation at the Rocky Mountain Regional Meeting held in Casper, Wyoming, U.S.A., 18-21 May 1997.

Abstract

In 1996, Williston Basin Interstate Pipeline Company (WBI), a wholly owned subsidiary of MDU Resources Group, Inc., implemented a pilot program to improve production from the Eagle Gas Sands in Southeastern Montana. The program included running Formation Micro-ScannerTM Logs (FMS) logs to identify natural fractures and permeable pay intervals and using three-dimensional fracture modeling to determine the optimum fracture treatment size. By applying technologies and multi-stage fracture treatments, WBI has more than tripled gas production rates. While the optimal completion program has yet to be determined, especially in the deeper (1700+ft) horizons, all wells drilled and completed in 1996 are producing gas. This 100 percent success ratio is a significant improvement over previous years when less than 60% of the wells responded to stimulation. A savings of $420,000 was realized in 1996 by eliminating the need to restimulate 50% of the wells. First year incremental NPV increased by 20% or $ 11,600 per well for the 24-well program in 1996. This equates to an incremental 10-year NPV of over $335,000 per well and over $8.8 million for the drilling program.

Introduction

WBI produces natural gas from the Cretaceous Eagle Gas Sands along the Cedar Creek Anticline in southeastern Montana, at an average depth of 1200 ft to 1700 ft (Fig. 1).

Previous completion designs included perforation of the entire 400+ft gross interval and stimulating with a single-stage hydraulic fracture treatment. In 1996, WBI implemented a 5-well pilot program with the objective to investigate the cost, execution, and benefits of completing wells in the Eagle Gas Sand formation utilizing advanced stimulation technologies promoted by the Gas Research Institute (GRI) and others. These technologies included: three-dimensional fracture modeling, strategic placement of perforations, enhanced fracture fluid systems, advanced logging techniques, and comprehensive flow testing.

S.A. Holditch & Associates, Inc. (SAH) became involved in the project via the GRI Advanced Stimulation Technology (AST) Deployment Program. Halliburton Energy Services of Williston North Dakota, provided the hydraulic fracturing services for WBI. Sunburst Consulting of Billings, Montana, provided WBI with logging and geologic interpretation. This paper discusses the historical Eagle Gas Sand completion practices, changes made as a result of AST, and the realized benefits of the project. We first provide a background discussion on the field history and geology.

Background

The first producing natural gas well on the Cedar Creek Anticline was drilled in 1914. By 1926, sufficient quantities of gas were being produced to provide natural gas to the Montana Dakota Utilities (MDL) electric power plant in Glendive, Montana. In 1936, oil was found in the lower horizons of the Cedar Creek Anticline and in 1950 MDU entered into a production agreement with Shell Oil Company limiting the company to a depth of 2000 ft when completing natural gas wells. WBI is a subsidiary of MDU Resources and now operates t1he gas production and storage operations along the anticline.

From the anticline's northern-most traceable point in Dawson County, Montana, to its southeastern end in South Dakota, the Cedar Creek Anticline extends more than 150 miles. Oil and gas are produced almost everywhere along the axis of the fold.

There are two groupings of hydrocarbon reservoirs to be considered when discussing the Cedar Creek Anticline: the shallow Cretaceous Gas Sands (including the Judith River and Eagle Gas Sands), and the deep oil reservoirs (including the Mississippian, Silurian, and Ordovician age formations).

SPE 38458-P

THE IMPORTANCE OF IN-SITU-STRESS PROFILES IN HYDRAULIC-FRACTURING APPLICATIONS

C.W. Hopkins, SPE, S.A. Holditch & Assocs. Inc.

Journal of Petroleum Technology, September 1997.

This paper is SPE 38458. Technology Today Series articles provide useful summary information on both classic and emerging concepts in petroleum engineering. Purpose: To provide the general reader with a basic understanding of a significant concept, technique, or development within a specific area of technology.

SUMMARY

In-situ stresses define the local forces acting on lithologic layers in the subsurface. Knowledge of these stresses is important in drilling, wellbore-stability, and, especially, hydraulic-fracturing applications. The measurement of in-situ stress is not straightforward and, therefore, often goes unmeasured. As such, we often assume values of in-situ stress or estimate in-situ stresses from logging parameters. This article illustrates the importance of in-situ-stress estimates as they relate to hydraulic fracturing and outlines several techniques for estimating in-situ-stress magnitudes.

IN-SITU STRESS

The in-situ stresses acting on a formation can be decomposed into three principal compressive stresses, one vertical and two horizontal. The two horizontal compressive stresses are usually not equal. The vertical stress is caused by the overburden weight acting on the top of a formation. The horizontal stresses are the result of the poroelastic deformation of the rocks plus externally applied tectonic forces. The parameters that affect the magnitude of the in-situ stresses include overburden weight, fluid pore pressure, porosity, anomalies in the rock fabric (i.e., natural fractures), rock mechanical properties (such as Poisson's ratio), and tectonic activity.

Knowledge of the in-situ-stress magnitude and direction can impact decisions and designs throughout the drilling and completion of a well. During drilling, in-situ stress may affect the mud and cement densities required to prevent unwanted fracturing of openhole strata in the wellbore. For wells that will be stimulated at high pressures, casing design must account for the maximum anticipated stresses. Wellbore-stability calculations, particularly for horizontal wells, require knowledge of in-situ-stress magnitude and direction.

For hydraulic-fracture treatment applications, the in-situ stresses control fracture azimuth and orientation (vertical and horizontal), fracture-height growth, fracture width, treatment pressures, and fracture conductivity. As Fig. 1 illustrates, fractures grow perpendicular to the minimum in-situ-stress direction; thus, stress direction can affect well-placement and -spacing decisions.

Many techniques are available for estimating stress orientation, including tiltmeters, microseismic surveys, fracture image logs, and core-based measurements. Because fracture-height growth and fracture width affect propped-fracture half-length for a given treatment size, stress is a critical parameter in fracture treatment modeling, design, and optimization. Finally, the conductivity of the proppant pack is greatly influenced by the in-situ stress. Under high-stress conditions (typically 4,000 psi or greater), 20/40-mesh Ottawa sand will be crushed and begin losing conductivity; thus, higher-cost resin-coated or manmade proppants often are needed to provide suitable conductivity for well-stimulation purposes (see Point A on Fig. 1). The final choice of proppant should be based on treatment optimization studies that use coupled reservoir and fracture models.

IMPORTANCE OF STRESS FOR FRACTURE MODELING

Early fracture modeling was performed with two-dimensional (2D) fracture models. Equations for viscous-fluid flow, rock deformation, and proppant transport were combined to describe the growth of hydraulic fractures in two dimensions. Given an estimate for fracture height, estimates for fracture half-length and width were calculated with the 2D fracture-growth equations. Unfortunately, fracture height was rarely known with certainty and often underestimated, resulting in fracture-half-length estimates that were too long and production-increase expectations that were overly optimistic. There was an obvious need to develop more rigorous three-dimensional (3D) fracture propagation models.

Three-dimensional fracture models can be used to predict fracture half-length, width, and height from vertical profiles of reservoir and rock mechanical properties. Unlike simulating fluid flow with reservoir simulators, simulating fracture growth requires knowledge of reservoir and rock properties for all layers of rock that will influence fracture growth, even if the particular rock layer is nonproductive. The stresses of adjacent bounding formations are the primary mechanism controlling vertical fracture-height growth and, consequently, fracture half-length.

As with all models, input-data requirements increase as the complexity of the model increases, and 3D fracture models are no exception. Development of a data set for a 3D fracture model can seem a daunting task even to the most experienced engineer. Many design engineers believe that measuring stresses in multiple nonpay intervals is not cost-effective and that the results from a 3D fracture model are useless without an accurate stress profile. Studies have shown the benefits of 3D fracture models compared with 2D models even if incremental data-collection costs are incurred.6 In fact, it is usually better to use a 3D model even if some of the data must be estimated.

With measured treatment parameters, such as injection rate, proppant concentration, and surface pressure, 3D models can be used to match the observed net pressure in the fracture with the model-predicted net pressure by varying model parameters. This process is similar to history matching production or well-test data with reservoir simulators and serves to calibrate the fracture model to the measured treatment data.

SPE 36674

Using 3D Fracture Simulation Alone May Result in Incorrect Fracture-Geometry Determination and Unreliable Real-Time Fracture Analysis

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This paper was prepared for presentation at the 1996 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October 1996.

Abstract

A sophisticated, commercially available, pseudo three-dimensional fracture simulator is used to demonstrate that during hydraulic fracturing a single net-treating pressure plot and fracture-fluid leak-off curve can be achieved by radically different fracture geometries and a large range of reservoir properties. The simulated fracture geometry for each reservoir description and combination are used to predict estimated future production performance using reservoir simulation. Production performance is shown to be a combination of reservoir quality and fracture geometry. However, essentially identical long-term production performance can be expected from different combinations of reservoir quality and fracture geometry. Consequently, decisions made from fracture simulations using only real-time fracture treatment data may yield unreliable correlations between hydraulic fracture design and reservoir performance.

Introduction

Modern pseudo three-dimensional and full three-dimensional fracture simulators have evolved sufficiently that when used carefully and in conjunction with pressure transient testing, radioactive tracer logging, production monitoring and reservoir engineering can provide an engineer with a reasonable understanding of the fracturing process, a reliable estimate of fracture geometry, an estimate of proppant placement and sufficient fracture description to augment reservoir engineering studies. A simulation study can provide methods to modify and optimize the fracture treatments of future wells and can be used to maximize the exploitation of hydraulically fractured reservoirs if a single unique fracture geometry can be determined. However, the interactions between the fracture fluid, the rock mechanical properties, the proppant and the reservoir properties are sufficiently complex that multiple fracture geometries may be created from a single set of data collected during the fracture treatment. Multiple fracture geometries are most likely when performing fracture simulations using only real-time pressure data. Decisions made based upon such real-time analysis need to be treated as informed estimates only.

Early-time fracture geometry estimates may be improved using fracture-fluid leak-off monitoring, pressure transient testing and radioactive tracer logging immediately after fracturing. These technologies permit an early determination of closure pressure, average reservoir transmissivity, skin damage, created fracture height and proppant distribution, each of which can be correlated with the calculated fracture simulation and the reservoir description used in the model. However, estimated future production performance based upon this data will not be reliable unless consideration is given to sufficient historical production data of offset wells which were stimulated with essentially the identical fracture treatment.

Using initial production data to prove the validity of the fracture geometry and reservoir description may decrease the number of simulated fracture geometries which satisfy both the fracture simulator and the reservoir response to the simulated fracture geometry. Yet, a single, unique fracture geometry is typically not determined and validated with only the early-time reservoir performance.

Further, data obtained during the fracture treatment may be significantly in error. Measured pressure fluctuations may have several causes, fracture fluid properties may vary from design specifications, reservoir properties may be different than those used in the original design and field measuring equipment may be improperly calibrated. Despite these potential data and analysis problems, several simulated fracture geometries can be obtained which apparently match the treating data.

SPE 37429

Completion Optimization Through Advanced Stimulation Technology and Reservoir Analysis: A Case Study in the Red Fork Formation, Okeene Field, Major County, Oklahoma

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This paper was prepared for presentation at the SPE Production Operations Symposium, held in Oklahoma City, Oklahoma, 9-11 March 1997.

Abstract

This paper illustrates the use of advanced stimulation technologies coupled with reservoir analysis to improve gas production from a low permeability formation. Modern stimulation techniques used include real-time treatment data analysis, stress profiling, three dimensional fracture modeling and fluid quality control procedures. Implementation of these technologies was based on an evaluation of previous and current completion and stimulation approaches in the study area. A statistical review was performed to characterize the reservoir and establish a baseline from which to compare results and quantify benefits of the completion optimization process.

Part of the project was performed under the Gas Research Institute Advanced Stimulation Technology Deployment Program. Through the use of modern completion and stimulation practices, the operator was able to nearly double the average initial production rate in the Red Fork formation from 300 Mscf/d to over 600 Mscf/d. Ten year reserve estimates have increased about 38% from 390 MMscf to over 540 MMscf. Acceleration of reserves has allowed the operator to produce in less than 5 years the same amount of gas that was previously recovered in 13 years. The combination of improved reserve recovery and accelerated

production has increased the discounted cashflow about 43%.

Introduction

This project, from the beginning to the end, attempted to integrate the complete package of engineering practices to optimize costs and results. A multi-phase program was outlined and included an initial phase of evaluating previous completion and stimulation approaches in the area. The following technologies and techniques were implemented in baselining previous results:

- Integration of practical and theoretical considerations to evaluate prior completions.

- Advanced 3-D fracture modeling of breakdown and fracture treatment pressure responses.

- Reservoir simulation of production and pressure responses.

- Iteration between fracture treatment and production response on all wells to achieve consistency of overall interpretation.

- Establishment of a production response baseline from offset well history.

Once the baseline analysis was completed, field deployment was implemented and included a continued evaluation and evolution of approaches. This phase employed the following technologies and techniques:

- Intense surface and in-situ fluid and equipment quality control before and during each fracture treatment.

- Advanced real-time evaluation of the treating pressure response on all treatments.

- On-site, real-time integration of fluid and equipment quality control with pre-treatment diagnostics and main fracture treatment execution.

- Pre-treatment diagnostics to identify closure pressure of the Red Fork and adjacent layers, observe the leakoff response of various fluids and determine the quality and complexity of the near-wellbore and far-field fracture geometry.

- Real-time execution of fracture treatments to optimize near-wellbore and far-field proppant placement/conductivity.

- A coupled approach to acquire both post-treatment pressure decline data, which yields a better understanding of the fracture treatment, and rapid flowback to enhance fracture conductivity and minimize formation damage.

The final phase of the project was a cost benefit analysis. This comparative analysis of wells using modern completion practices to the offset production baseline quantified the benefits of optimization.

SPE 29600

Engineering Criteria for Fracture Flowback Procedures

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*SPE Members

This paper was prepared for presentation at the SPE Rocky Mountain Regional/Low-Permeability Reservoirs Symposium held in Denver, CO, U.S.A., 20-22 March 1995.

Abstract

Post treatment fracture flowback procedures during closure are often critical to the retention of fracture conductivity near the wellbore. Postfrac production performance largely depends on this conductivity. The importance of proper flowback procedure has been documented in the fracture industry, but definitive guidelines for flowback design have never been established. As a result, many misconceptions exist regarding the physics of proppant flowback and its effects on the final proppant distribution in the fracture.

This paper presents a rigorous study of fracture flowback and proppant migration during closure using a fully three-dimensional fracture geometry simulator (GOHFER). The effects of rate of flowback, location of the perforation interval, final proppant concentration, and the fracture geometry prior to flowback on the retained post closure proppant concentration are discussed. Consideration is given to the fluid velocity field in the created fracture resulting from the flowback, and its effects on proppant movement and localized fracture closure. These studies illustrate the difference between "forced closure" and "reverse screenout" concepts in flowback design. Other effects such as crossflow between multiple perforated layers are also studied. Simulation studies indicate that selection of a desirable flowback rate is very sensitive to crossflow effects resulting from induced fractures in multiple stress layers. This crossflow can result in significant overflushing of proppant in the lower stress zones, if not countered by properly applied flowback procedures. Very high

flowback rates, exceeding the total leakoff rate, may be needed to avoid such overflushing.

The results of this study are assimilated into a set of recommendations for optimum flowback design leading to the maximization of the near-wellbore fracture conductivity and maximum attainable conductive length in communication with the perforations. Ideally, any properly applied controlled flowback procedure should induce a reverse screenout at the wellbore - forcing closure on the proppant by packing the near-wellbore area, not by depleting fluid pressure and "pinching" the fracture closed.

Introduction

Postfracture flowback procedure is known to be very critical to the production performance of a fractured well. It is particularly so in tight formations. Experience shows that improper flowback procedures often lead to poor retained conductivity near the wellbore due to proppant movement into the wellbore or proppant crushing at or near the wellbore. Robinson et al. discussed the merits of flowing back wells on a small choke to minimize the closure stress on the proppant resulting in crushing. These authors also recommended initiation of low rate early flowback of the fracture fluid, in case of excessive closure time common in low permeability formations. Longer closure time allows proppant to settle in the open fracture due to breaking of the cross-linked polymer gel or rheological deterioration of foamed fluids. This may severely reduce proppant pack conductivity at or near the wellbore. An early induced closure, suggested by Robinson et al., should lock the proppant pack between the fracture walls before much settling can occur Subsequent studies by Ely, et al. showed that such a forced closure technique, coupled with high proppant concentrations and appropriate fluid quality control, significantly improves the productivity of low permeability oil and gas wells. Ely, et al. also recommend a forced closure implementation procedure within thirty seconds of completing flush. They suggest less than 10-15 gallons per minute flowback rate up to 30 minutes after near wellbore fracture closure is detected from surface pressure measurements.

SPE 25917

Successful Control of Fracture Height Growth by Placement of Artificial Barrier

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Abstract

This paper presents a method to control fracture height growth through the selective placement of artificial barriers above and below the pay zone. These barriers are created prior to the actual treatment by pumping a mix of different size and density proppants with low viscosity carrying fluid, that allows fast settling of these proppants or, if desired, floatation to the top of the fracture channel or both. Typically a viscous pad is pumped to create a fracture channel. This pad is followed with 5-10 cp fluid slurry carrying a mix of heavier proppant that settles to the bottom of the fracture channel and a light proppant that rises to the top of the fracture channel. The proppant slurry is allowed to bridge at the top or the bottom tip of the fracture, inhibiting further growth of these tips. The actual treatment following this barrier placement is thus focused through these barriers confining itself within the barriers and resulting in a longer extension within the pay zone. Such controlled fracture height allows further optimization of fracture length by reducing or increasing the amount of proppant as called for in the design. Two case studies are presented in this paper from two formations known to suffer from fracture height growth.

Introduction

For optimized well performance, adequate fracture half length and fracture conductivity are the two most important parameters. Generally, the importance of fracture half-lengths prevails over that of fracture conductivity in low permeability formations. It is quite well established that the lower the permeability, the longer the fracture half length requirement. Although for low permeability formations, if the reservoir pressure is high, the fracture conductivity may also need to be improved. This paper discusses the problems related to the fracture extension due to height growth, and a very effective method of mitigation of this problem within some practical limitations.

Warpinski, et al. (1980) showed the predominant influence of barrier in-situ stresses in the containment of height growth of induced hydraulic fractures. Recently with the emergence of three-dimensional fracture models, other authors also confirmed Warpinski, et al.'s conclusions. It can be said that in the absence of adequate stress barriers, hydraulic fractures grow uncontained into the barriers at the cost of extension. Two-dimensional fracture geometry models often undermine the effects of height growth resulting in an erroneous prediction of fracture length. Production performance or post fracture build-up tests often indicate this severe curtailment of fracture half lengths from designed. The problem is quite prevalent in some of the prolific hydrocarbon-producing formations in the Rocky Mountain area such as the Codell, Frontier, Dakota, Mancos, etc. to name a few. Thus, an effective method of mitigation of unwanted height growth problem can be very useful in the optimization of fracture half length for maximum return on the stimulation investment.

Fracture height containment has been studied for more than two decades by different authors. Specific height containment procedures by placing artificial barriers was first suggested by Prater and Braunlich. Prater suggested injection of a matched density proppant fluid slurry system for the control of fracture height growth. Braunlich patented a method of controlling the downward growth of fracture by bridging the lower fracture tip with heavy proppants. Hodges and Paoli used this method successfully to control down-ward fracture growth using 100-mesh sand to bridge the lower tip of the fracture. In 1983, Nguyen and Larson proposed the use of a buoyant proppant to bridge the upper tip of the fracture containing the upward height growth. All these authors presented their treatment schedules and validated the control of height growth by positive net pressure slope with time during treatment and post fracture temperature logs. In general, these authors failed to present any convincing post fracture production results validating the success in height containment. Theoretical justification for the height containment and systematic guidelines for the design of such procedures were completely ignored.

Placement of Artificial Barrier

Numerous mechanisms to arrest fracture growth have been suggested in the literature. However, the most dominant mechanism in the retardation of fracture growth is by fluid flow impedance at or near the tip as suggested by Cleary (1980). The method can be very effectively used in actual fracture treatment to contain fracture growth in any preferential directions such as upward, downward, or the front. Smith, et al. first presented the successful application of arresting the growth of the fracture area by accurate placement of dehydrated proppant slurry at the fracture tip along the perimeter of the fracture. They used this method in soft formations to get increased fracture width/conductivity by ballooning the fracture with continued pumping of high density slurry. Such a procedure is presently regularly followed for higher permeability and soft rocks where a short, wide fracture is required. Note that the softer rocks are more amenable to the creation of wider fractures. The procedure suggested by Smith, et al. is commonly known as the Tip Screen-out Design. A similar procedure is recommended in this paper to solely contain the fracture height growth.

The objective is to arrest the growth of either the upper or the lower tip or both these tips of the fracture, while keeping the fracture front tip open for extension. It is important to note that unlike the Tip Screen Out (TSO) design, where the growth of the whole perimeter of the fracture is contained, this method provides selective containment of the upper and the lower fracture tips only. Adequate caution is exercised to keep the front tip of the fracture open to extension. The growth of the upper tip is arrested by pumping buoyant 100+ mesh proppant (0.637 sp. gravity) in a low viscosity (5-10 cp) water-based fluid following the creation of a pre-designed fracture length with viscous pad fluid such as crosslinked gels. Low viscosity slurry is used to allow fast proppant rise to the upper fracture tip. This slurry stage is designed to make sure that the pad is not depleted during this stage. Otherwise, there is a risk of inducing Tip Screen Out, undesirable for future extension of the fracture. The slurry stage is over-flushed with a clean, low viscosity fluid to clear the fracture face in the perforated pay zone. The pump rate is maintained throughout the procedure at low fracture rate determined from an appropriate 3-D model study.

A similar procedure is followed to bridge the lower tip using 20/40 mesh sand or a mix of 100 mesh sand with 20/40 mesh sand. If, due to the lack of stress barrier above and below the pay zone, the fracture grows both upward and downward, a mixture of light and heavy proppant slurry can be pumped to bridge both the upper and the lower tips. During the slurry stages, the proppant concentration is generally ramped from 1/4 ppg to 1.5 ppg.

P. 89

SPE 29501

Design Guidelines for Artificial Barrier Placement and Their Impact on Fracture Geometry

Robert D. Barree,* Marathon Oil Company, and Hemanta Mukherjee,* Schlumberger Dowell

SPE Members

often inhibits fracture height growth through these tips. However, beyond these barriers the fracture loses the artificial containment and "mushrooms" in the natural rock stress regime. Mukherjee, et al. present case studies with field examples where such barriers were effectively placed with substantial production improvements due to increased effective fracture half-length. However, a general study of the process of artificial barrier placement and an appropriate set of guidelines for such placement is not reported in the available literature. This paper is intended to fill this gap.

In the placement of artificial barriers, understanding the process of proppant movement in the fracture is very important. Proppant movement is controlled by both individual particle settling or floatation, depending on the particle density, and also the convective movement of the particle slurry. The upper and the lower barrier experience different settlement, or segregation rates during placement of the diverting materials in the fracture channel. A brief discussion of the factors affecting these rates is presented. Also, with proper sensitivity studies of pump rates, proppant densities, slurry concentration, etc., a set of guidelines for the placement of artificial barriers is presented.

Particle Movement During Placement of Artificial Barriers

The development of artificial barriers to fracture height growth relies on placement of banks of sand or other particulates. These banks exhibit a high resistance to movement, and also restrict the transmission of fluid pressure to the fracture tips. Placement of the barriers relies on both single particle settling and convective slurry settling in the fracture. Equations to predict slurry and particle settling have already been presented.

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Record 22 of 22

Petroleum Abstracts No.: 473384
Title: FRACTURE CONTROL IS ENHANCED BY REAL-TIME MONITORING
Author: WOOTEN C T
Corporate Source: GAS RESEARCH INST
Source: AMER OIL GAS REPORTER V 32, NO 8, PP 17-18,22, AUG 1989 (ISSN 01459198)
Publication Year: 1989
ISSN: 0145-9198
Language: ENGLISH
Document Type: JOURNAL ARTICLE; J
Primary Descriptor: *HYDRAULIC FRACTURING
Major Descriptors: *FRACTURE GEOMETRY; *MOBILE LABORATORY; *MONITORING; *PROCESS CONTROL; *REAL TIME
Minor Descriptors: COMPUTER GRAPHICS; DATA ACQUISITION; MATHEMATICAL MODEL; SOFTWARE; THREE DIMENSIONAL MODEL; WELL STIMULATION
Subject Heading: WELL COMPLETION SERVICING & WORKOVER
Abstract: When successful, hydraulic fracturing increases gas deliverability from low permeability reservoirs. Higher production rates also accelerate revenue flow, which in turn lowers the unit production cost at the wellhead while enhancing the overall economics of production from lower permeability formations. Ultimately, this process translates into lower cost for the consumer and greater incentives for the producer to seek additional gas reserves. The economic benefits that can be achieved through advanced fracturing technology have led the Gas Research Inst. to fund development of a Real-Time Monitoring, Analysis, and Control System (RT-MACS). This system has the built-in capability of using existing engineering tools, but it is also structured to accept the latest developments in fracturing technology, i.e., fracture models, reservoir performance models, etc. This system allows the engineer to actually understand the relationships among the parameters that control the fracturing process. The system was called RT-MACS in its developmental stage. A licensed version is called FRACPRO, which is available for commercial use.
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Record 21 of 22

Petroleum Abstracts No.: 526526
Title: ANALYSIS OF TREATMENT DATA YIELDS COST-EFFECTIVE FRACTURE
Author: LEWIS P E
Corporate Source: RESOURCES ENG SYST INC
Source: AMER OIL GAS REPORTER V 35, NO 1, PP 32-34,36-38, JAN 1992 (ISSN 01459198)
Publication Year: 1992
ISSN: 0145-9198
Language: ENGLISH
Document Type: JOURNAL ARTICLE; J
Primary Descriptor: *HYDRAULIC FRACTURING
Major Descriptors: *FRACTURE GEOMETRY; *INDUCED FRACTURE; *PROPPANT TRANSPORT; *WELL COMPLETION EFFICIENCY; *WELL TESTING
Minor Descriptors: CONVECTION; FLOW CAPACITY; HISTORY MATCHING; LIQUID VISCOSITY; RESERVOIR PRESSURE; SIMULATION
Subject Heading: WELL COMPLETION SERVICING & WORKOVER
Abstract: There has been increasing use of actual well treatment data to interpret hydraulic fracture treatments. The most important issue is the degree of fracture height growth and, therefore, fracture length. The main element of treatment data analysis is determining and interpreting the pressure inside the open fracture. The Nolte plot commonly used for this purpose is problematic. An improved analysis tool has been developed called FRACPRO, which integrates a fracture model with well-bore and near well-bore hydraulics and proppant transport models. Once the user has extracted the true net pressure from the data, the model-predicted net pressure is history-matched to the true net pressure. A complete treatment record provides a large quantity of information for matching. Use of FRACPRO has demonstrated that conventional treatment of fracturing fluid viscosity is not consistent with the observed pressure response of actual wells, and fractures are generally wider, taller, and shorter than commonly thought. The fractured model can pass its proppant profile to an integrated reservoir simulator to forecast resulting production.
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Record 15 of 22

Petroleum Abstracts No.: 561328
Title: RESERVOIR ENGINEERING EVALUATION OF A HYDRAULIC FRACTURE TREATMENT FOR MAXUS EXPLORATION COMPANY AND THE GAS RESEARCH INSTITUTE, ELLIS RANCH FIELD, OCHILTREE COUNTY, TEXAS, H.T. GLASGOW NO. 2/CLEVELAND SAND : TOPICAL REPORT (SEPTEMBER 1992)
Source: GAS RES INST REP NO GRI-92/0369 (NTIS PB93-202562) (1992) (55 PP; 4 REFS)
Publication Year: 1992
Language: ENGLISH
Primary Descriptor: *HYDRAULIC FRACTURING
Major Descriptors: *ECONOMIC EVALUATION; *GAS RESERVOIR; *INDUCED FRACTURE; *PRESSURE BUILDUP ANALYSIS; *RESERVOIR ENGINEERING
Minor Descriptors: FRACTURE GEOMETRY; HISTORY MATCHING; MULTIPLE LAYER MODEL; OCHILTREE CO, TEX; OPTIMIZATION; SAND FLUID RATIO
Subject Heading: RESERVOIR ENGINEERING & RECOVERY METHOD
Abstract: The Maxus-H.T. Glasgow No.2 was fracture treated in the Cleveland Sand on Oct. 25, 1991, as part of an ongoing GRI-industry cooperative project. The reservoir engineering evaluation of the hydraulic fracture treatment is shown and the results and interpretations of Hydraulic Fracture Treatment Analysis are used in a discussion of the fracture treatment pressure matches using FRACPRO, and the associated predicted propped fracture geometry. The predicted propped fracture length is 359 ft with an average proppant concentration of 2.43 psi. The predicted dimensions have been corroborated by history matching the production and bottom-hole pressure responses with the FraPS (2-dimensional, single-phase) reservoir simulator. The results indicate that the predicted dimensions are consistent and that significant improvement in the treatment design is possible. Recommendations relating to the design of a pressure transient test on this well are also included.
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Record 2 of 22

Petroleum Abstracts No.: 657477
Title: DEVELOPMENT OF STIMULATION DIAGNOSTIC TECHNOLOGY: ANNUAL REPORT (JANUARY 1995-DECEMBER 1995)
Author: WARPINSKI N R; LORENZ J C; UHL J E; ENGLER B P; DROZDA P M; YOUNG C J; ELBRING G J; HOLCOMB D J; FREDRICH J T
Corporate Source: SANDIA NATIONAL LABS
Source: GAS RES INST REP NO GRI-96/0306 (NTIS PB97-133243) OCT 1996 (183 PP; 10 REFS)
Publication Year: 1996
Language: ENGLISH
Primary Descriptor: *WELL STIMULATION
Major Descriptors: *FRACTURED RESERVOIR; *INDUCED FRACTURE; *MINI FRACTURING; *ROCK MECHANICS; *ROCK STRESS
Minor Descriptors: FRACTURE EXTENSION; GAS RESERVOIR; GREEN RIVER BASIN; OBSERVATION WELL; RECEIVER (ELECTRONIC); TIGHT FORMATION
Subject Heading: WELL COMPLETION SERVICING & WORKOVER
Abstract: The approach to stimulation diagnostics is to integrate in situ stress measurements (including microfracs, anelastic strain recovery, circumferential velocity analysis, and coring-induced fractures) with natural fracture characterization, stimulation analyses (including FRACPRO(R), finite-element analyses, and pressure analyses), and fracture diagnostics in order to validate hydraulic fracture concepts, models and diagnostic capabilities. The M-site B-sand experiment has provided the time evolution of a series of hydraulic fracture injections conducted in a layered sedimentary sequence. Using a 30-level cemented-in receiver array and a 5-level wireline array in the 2 monitoring wells, detailed measurements of fracture growth have been obtained for 6 fracture injections. These results show limited fracture height growth for initial water and linear gel injections, but considerable asymmetric height growth for a larger-volume, cross-linked gel, propped-fracture treatment. Comparison with models shows areas of disagreement. Studies of location schemes for microseisms show strategies for using single-well, multiple-receiver arrays.
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Record 9 of 22

Petroleum Abstracts No.: 598877
Title: EFFECTIVE DESIGN, REAL-DATA ANALYSIS AND POST-JOB EVALUATION: FINAL REPORT (JUNE 16, 1989-DECEMBER 31, 1991)
Author: BARR D T; CLEARY M P; WRIGHT T B
Corporate Source: RESOURCES ENG SYSTEMS INC
Source: GAS RES INST REP NO GRI-93/0362 (NTIS PB94-206703) OCT 1993 (299 PP; OVER 40 REFS)
Publication Year: 1993
Language: ENGLISH
Primary Descriptor: *HYDRAULIC FRACTURING
Major Descriptors: *DATA ANALYSIS; *DESIGN; *EVALUATION; *OPTIMIZATION; *SOFTWARE
Minor Descriptors: COALBED METHANE; FRACTURING PRESSURE; FRONTIER FM; HISTORY MATCHING; MULTIPLE FRACTURE; REVIEW
Subject Heading: WELL COMPLETION SERVICING & WORKOVER
Abstract: Resources Engineering Systems, Inc. proceeded to implement the results of a previous GRI contract for GRI field operations on a variety of co-op wells, especially in coalbed methane wells and in the Frontier Formation around Moxa Arch, Wyoming (the site of Staged Field Experiment No. 4). Improvements were made to the RT-MACS capabilities, based on feedback from various users of the associated FRACPRO PC-based system: in particular, the automation of the fracture design optimization schemes with an integrated RESPRO capability and incorporation of multi-barrier features into a user-friendly menu, and incorporation of numerous alternative physical models (including most conventional models used by industry) to allow contrast with the physical data and also for contrast with realistic matching models. A definitive axisymmetric 3-D model (A3DH) was also developed as a physical basis for determining effects of rock dilatancy on fracture propagation; this model is now being employed to attempt understanding of the associated lab experiments and field data, the first apparent consistent explanation of observed pressures in many formations.
End of record 9
Records from set of 22 for FRACPRO
Edit Format | Format: Full | Style: Norma | Redisplay
Sort By | Ascendin | Title:
Prev | Next | Title List

Record 16 of 22

Petroleum Abstracts No.: 545217
Title: COOPERATIVE WELL REPORT : MAXUS EXPLORATION COMPANY H.T.GLASGOW NO.2, OCHILTREE COUNTY, TEXAS : TOPICAL REPORT (FEBRUARY 1992)
Author: HOLDITCH S A; WHITEHEAD W S; DAVIDSON B M
Corporate Source: HOLDITCH (S A) & ASSOCS
Source: GAS RES INST REP NO GRI-92/0087 (NTIS PB92-204387) FEB 1992 (213 PP; 4 REFS)
Publication Year: 1992
Language: ENGLISH
Primary Descriptor: *HYDRAULIC FRACTURING
Major Descriptors: *CLEVELAND SAND; *FRACTURE GEOMETRY; *PRESSURE BUILDUP ANALYSIS; *ROCK STRESS; *TIGHT FORMATION
Minor Descriptors: GAS RESERVOIR; OCHILTREE CO, TEX; PROCESS DESIGN; PRODUCTIVITY; SANDSTONE RESERVOIR; SKIN EFFECT (WELL)
Subject Heading: WELL COMPLETION SERVICING & WORKOVER
Abstract: Maxus Exploration drilled the H.T.Glasgow No.2 in the Ellis Ranch field, Ochiltree County, Texas, in June 1991. The GRI cooperative research program on this well included coring, logging, stress testing, pre-fracture well testing, and a fracture treatment. The well was completed in the Cleveland Formation at 7,194 to 7,228 ft. The pre-fracture flow rate was 80 Mscfd. The pre-fracture pressure buildup test resulted in a permeability-thickness product of 2.73 md-ft, a skin factor of +4.4, and a reservoir pressure of 2,050 psi. The well was fracture treated with 148,000 gal of a 40#/1,000-gal delayed-crosslink borate gel and 595,000 lb of 20/40 sand. Initial post-fracture flow rates were 700 to 800 Mscfd. Post-fracture analysis with FRACPRO indicated that the propped fracture height was 320 ft and the propped fracture length was 380 ft.
End of record 16

Record 13 of 22

Petroleum Abstracts No.: 579808
Title: RESEARCH AND DEVELOPMENT WELLS FOR TECHNOLOGY TRANSFER
Author: HANSEN J T; PERRY K F
Corporate Source: GAS RESEARCH INST
Source: SPE MID-CONTINENT GAS SYMP (AMARILLO, TX, 5/22-24/94) PROC PP 179-183, 1994 (SPE-27935; 8 REFS)
Publication Year: 1994 SPE Number: 27935
Language: ENGLISH
Document Type: MEETING PAPER TEXT; AT
Primary Descriptor: *HYDRAULIC FRACTURING
Major Descriptors: *DEVELOPMENT WELL; *FRACTURE MAPPING; *RESEARCH; *TECHNOLOGY; *UNCONVENTIONAL GAS RECOVRY
Minor Descriptors: CORE ANALYSIS; GAS WELL; SOFTWARE; STRESS ANALYSIS; THREE DIMENSIONAL MODEL
Subject Heading: WELL COMPLETION SERVICING & WORKOVER

Abstract: The Gas Research Inst. (GRI) has developed a project that is aimed at accelerating the transfer of several hydraulic fracturing-related technologies to the marketplace. The project, known as the Research and Development (R&D) Wells for Technology Transfer, was initiated in the spring of 1992 and to date has been applied with 9 producers on a total of 18 wells. The primary technology transfer vehicle used in the project is the cooperative research well, which is jointly sponsored by GRI and the participating producer. Emphasis is placed on hands-on technology training and application by the producer, rather than on conventional GRI contractor involvement. The new technologies that are being promoted in this project include special core tests and analysis; formation stress testing; expanded logging programs; 3-dimensional fracture modeling using FRACPRO; fracture diagnostics; fracture fluid quality control; and special well cleanup techniques.

End of record 13

Records from set of 22 for FRACPRO
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Petroleum Abstracts 1988 - April, 1998

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Records from set of 22 for FRACPRO

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Record 12 of 22

Petroleum Abstracts No.: 592208
Title: A SYSTEMATIC APPROACH TO IMPROVED HYDRAULIC FRACTURE PERFORMANCE
Author: FAIRCHILD N R; ASHCOM R L; MILLER M A
Corporate Source: EASTERN RESERVOIR SERV IN
Source: 32ND ANNU ONTARIO PETROL INST CONF (LONDON, ONTARIO, CAN, 11/3-5/93) PROC PAP NO 4, 1993 (7 PP)
Publication Year: 1993
Language: ENGLISH
Document Type: MEETING PAPER TEXT; AT
Primary Descriptor: *HYDRAULIC FRACTURING
Major Descriptors: *FRACTURED RESERVOIR; *LOW PERMEABILITY RESERVOIR; *PROCESS DESIGN; *SOFTWARE; *THREE DIMENSIONAL MODEL
Minor Descriptors: CORE ANALYSIS DATA; FRACTURE RADIUS; OPTIMIZATION; ROCK STRESS; WELL LOGGING DATA; WELL PERFORMANCE
Subject Heading: WELL COMPLETION SERVICING & WORKOVER
Abstract: For years, hydraulic fracturing has been used to increase recoverable reserves and production on low permeability formations that might otherwise be uneconomical to complete. For this reason, hydraulic fractures are designed not only to recover gas at an economic rate, but to keep stimulation costs within economic limits. One problem that has always accompanied frac design is the inability to consistently and accurately predict fracture geometry. This inability to predict fracture geometry makes it very difficult to optimize fracture treatment design and use well performance predictions to set economic limits. Over the past decade, the Gas Research Institute (GRI) has been studying these problems. One program that has been successful is the development and use of a reliable 3-D frac simulator called FracPro. This paper discusses the use of several new technologies and how to apply them in a systematic approach so that an optimal fracture can be designed and pumped.
End of record 12
Records from set of 22 for FRACPRO

Edit Format | Format: Full | Style: Normal | Redisplay
Sort By | Ascendin | Title:
Prev | Next | Title List

Record 10 of 22

Petroleum Abstracts No.: 595881
Title: FRAC SYSTEM IMPROVES WELL TREATMENT
Author: RAINBOLT M F
Corporate Source: MAXUS EXPLORATION CO
Source: AMER OIL GAS REPORTER V 37, NO 12, PP 63-64,66-67, DEC 1994 (ISSN 01459198)
Publication Year: 1994
ISSN: 0145-9198
Language: ENGLISH
Document Type: JOURNAL ARTICLE; J
Primary Descriptor: *HYDRAULIC FRACTURING
Major Descriptors: *GAS RESERVOIR; *GAS WELL; *PERMEABILITY (ROCK); *TIGHT FORMATION; *WELL STIMULATION
Minor Descriptors: FRACTURE GEOMETRY; FRACTURE RADIUS; FRACTURING PRESSURE; MONITORING; ROCK STRESS; STRESS ANALYSIS
Subject Heading: WELL COMPLETION SERVICING & WORKOVER
Abstract: Maxus Exploration Co. operates nearly 1,100 gas wells and 300 oil wells in the Texas Panhandle and W. Oklahoma. In this predominately gas-producing area, nearly all formations are low-permeability reservoirs. In order to obtain commercial production and reasonable drainage areas, the reservoirs must be hydraulically-fracture stimulated. Most reservoirs have permeabilities between 0.01 and 1.0 md, while fracture gradients range from 0.4 to 0.85 psi/ft. To fully exploit the reserve potential of these low-permeability reservoirs, the latest technology must be applied to design and monitor fracture stimulation treatments. Maxus utilizes FRACPRO, a state-of-the-art fracture stimulation system to enhance the productivity of its wells in the Panhandle. FRACPRO is capable of consistently and accurately predicting realistic created fracture half-lengths for various treatment sizes, given that correct stress profiles and leak-off information is input. Normally, predicted lengths assume that there are no adverse fracturing conditions such as multiple fractures and/or some other near well-bore problem. If a particular formation has a history of such problems, the risks can be accounted for and modeled before selecting a treatment. The fracture stimulation system is helping Maxus achieve optimum benefit from new wells and workovers, which improves cash flow and ultimately leads to increased drilling activity.
End of record 10
Records from set of 22 for FRACPRO

Edit Format | Format: Full | Style: Norma | Redisplay
Sort By | Ascendin | Title:
Prev | Next | Title List

Boone, D.

Hydraulic fracturing simulators. Product comparison.

Petro Systems World (September/October 1994) 30-32. Based on article by Warpinski et al., Comparison study of hydraulic fracturing models-- test case: GRI Staged Field Experiemnt no. 3. SPE Production & Facilities (Feb. 1994)

Location: Project Code Papers

Branagan, P./Lee, S.J./Prouty, J.L. (Branagan & Associates)

Evaluation of the ABC stress derivations methodology : final report (Nov. 1, 1994-June 30, 1995)
GRI-95/0353

Prepared for the Gas Research Institute (GRI) contract no. GRI 5094-220-3086, June 1995.

Location: LS-R-GRIC BRANAGAN EV Project Code Reports

Miller, M.A./Ashcom, R.L./FairchildJr., N.R./Eastern Reservoir Services

R&D wells for technology transfer : annual report (December 1993-December 1994).
GRI-95/0062

Prepared for Gas Research Institute (GRI) contract no. 5092-221-2420, January 1995.

Location: LS-R-GRIC EAS R&D-95 Project Code report

Miller, M.A./FairchildJr., N.R./Eastern Reservoir Services

R&D wells for technology transfer : final report (September 1996)

Prepared for Gas Research Institute (GRI) contract no. 5092-221-2420, October 1996.

Location: LS-R-GRIC EAS R&D-96 Project Code report

Resource Engineering Systems, Inc. (RES)

FRACPRO user's manual : version 5.1 : hydraulic fracture treatment stimulation and analysis.

With SAH cover dated 1992/03. Includes attachments bound in as appendises in the form of letters describing problems and suggestions from SAH staff to RES dated 4/7/92.

Location: LS-R-GRIC RES FRACPRO Project Code manual

Resources Engineering Systems, Inc. (RES)

Development of a real-time diagnostic and control system for GRI Mobile Test and Control Facility : annual report.
GRI-85/0001; GRI-87/0057

Prepared for Gas Research Institute (GRI). Contract No. 5083-211-0861.

Location: LS-R-GRIC RES D Project Code Reports

Rsources Engineering Systems, Inc. (RES)

Better fractures with FRACPRO from RES. [brochure]

Location: TX-FI-TG VI- 6- 5 RES Project Code misc. ref.

Warpinski, N.R./Abou-Sayed, I.S./Moschovidis, Z./Parker, C./Sandia National Laboratories/Mobil Explor. & Prod./AMOCO Prod./CONOCO

Hydraulic fracture model comparison study: complete results : topical report (February 1993).
GRI-93/0109; SAND93-7042

Prepared at Sandia National Laboratories for Gas Research Institute (GRI) contract no. 5089-211-2059, February 1993. Topical report on the results of the Fracture Propagation Modeling Forum.

Location: LS-R-GRIC SANDIA TG-HY Project Code Reports

Date: 8/5/98

Subject: Author=Fracpro

AUTHOR: Branagan, P.T.; Peterson, R.E.; Wilmer, R.
ORG: Branagan & Associates, Inc.
TITLE: Measurements of Well-to-Well Conductivity Through a Propped Hydraulic Fracture
SPE 38375
SOURCE: Rocky Mountain Regional Meeting held in Casper, Wyoming, U.S.A., 18-21 May
YEAR: 1997

AUTHOR: Branagan, P.T.; Warpinski, N.R.; Engler, B.; Wilmer, R.
ORG: Branagan & Associates; Sandia National Laboratories; Branagan & Associates
TITLE: Measuring the Hydraulic Fracture-Induced Deformation of Reservoirs and Adjacent Rocks Employing a Deeply Buried Inclinometer Array: GRI/DOE Multi-Site Project
SPE 36451
SOURCE: SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October
YEAR: 1996

AUTHOR: Branagan, P.T.; Peterson, R.E.; Warpinski, N.R.; Wright, T.B.
ORG: Branagan & Associates; Sandia National Laboratories; Resources Engineering Systems
TITLE: Characterization of a Remotely Intersected Set of Hydraulic Fractures: Results of Intersection Well No. 1-B, GRI/DOE Multi-Site Project
SPE 36452
SOURCE: SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 6-9 October
YEAR: 1996

AUTHOR: Voneiff, G.W.
ORG: S.A. Holditch & Assocs. Inc.
TITLE: Economic Assessment of Applying Advances in Fracturing Technology
SPE 24888
SOURCE: Journal of Petroleum Technology, January
YEAR: 1994

AUTHOR: Hansen, J.T.; Perry, K.F.
ORG: Gas Research Inst.
TITLE: Research and Development Wells for Technology Transfer
SPE 27935
SOURCE: SPE Mid-Continent Gas Symposium held in Amarillo, Texas, 22-24 May
YEAR: 1994

AUTHOR: Warpinski, N.R.; Moschovidis, Z.A.; Parker, C.D.; Abou-Sayed, I.S.
ORG: Sandia Natl. Labs; Conoco Inc.
TITLE: Comparison Study of Hydraulic Fracturing Models Test Case: GRI Staged Field Experiment No. 3
SPE 25890
SOURCE:
YEAR: 1993; 1994

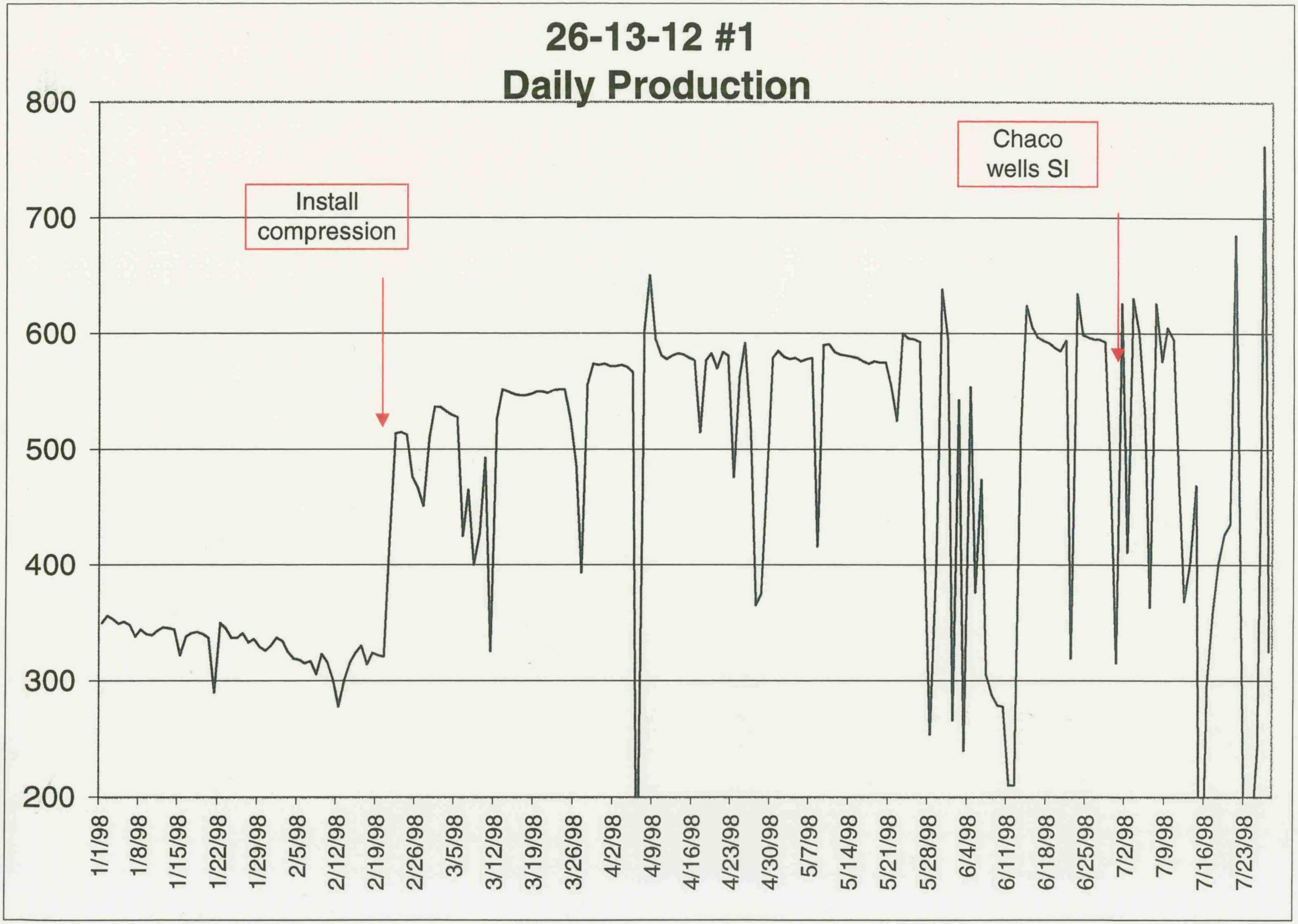
AUTHOR: Cleary, Michael P.
ORG:
TITLE: Discussion of Comparison Study of Hydraulic Fracturing ModelsTest Case: GRI Staged Field Experiment No. 3
SPE 28158
SOURCE: SPE Production & Facilities, February
YEAR: 1994

Date: 8/5/98

Subject: Author=Fracpro

AUTHOR: **Voneiff, G.W.; Holditch, S.A.**
ORG: S.A. Holditch and Assocs. Inc.
TITLE: **An Economic Assessment of Applying Recent Advances in Fracturing Technology to Six Tight Gas Formations**
SPE 24888
SOURCE: 67th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers held in Washington, DC, October 4-7
YEAR: 1992

AUTHOR: **Robinson, B.M.; Holditch, S.A.; Whitehead, W.S.; Peterson, R.E.**
ORG: S.A. Holditch and Assocs. Inc.; Texas A and M U.; S.A. Holditch and Assocs. Inc.; CER Corp.
TITLE: **Hydraulic Fracturing Research in East Texas: Third GRI Staged Field Experiment**
SPE 22878
SOURCE: 66th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers held in Dallas, TX, October 6-9
YEAR: 1992


26-13-12 #1
Daily Production
800
700
600
500
400
300
200
Install compression
Chaco wells SI
1/1/98
1/8/98
1/15/98
1/22/98
1/29/98
2/5/98
2/12/98
2/19/98
2/26/98
3/5/98
3/12/98
3/19/98
3/26/98
4/2/98
4/9/98
4/16/98
4/23/98
4/30/98
5/7/98
5/14/98
5/21/98
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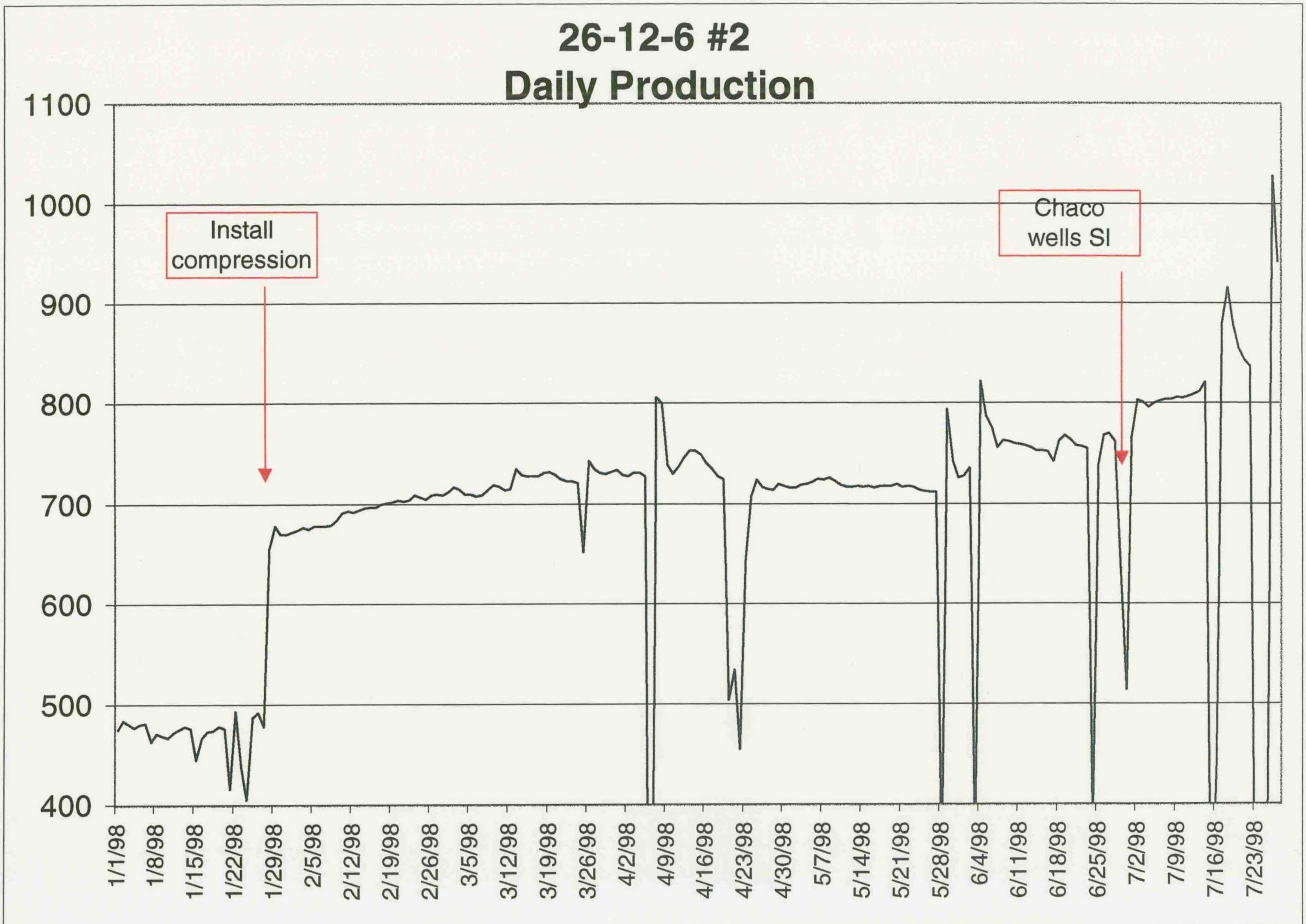
7/16/98
7/23/98


26-12-6 #2
Daily Production
1100
1000
900
800
700
600
500
400
Install compression
Chaco wells SI
1/1/98
1/8/98
1/15/98
1/22/98
1/29/98
2/5/98
2/12/98
2/19/98
2/26/98
3/5/98
3/12/98
3/19/98
3/26/98
4/2/98
4/9/98
4/16/98
4/23/98
4/30/98
5/7/98
5/14/98
5/21/98
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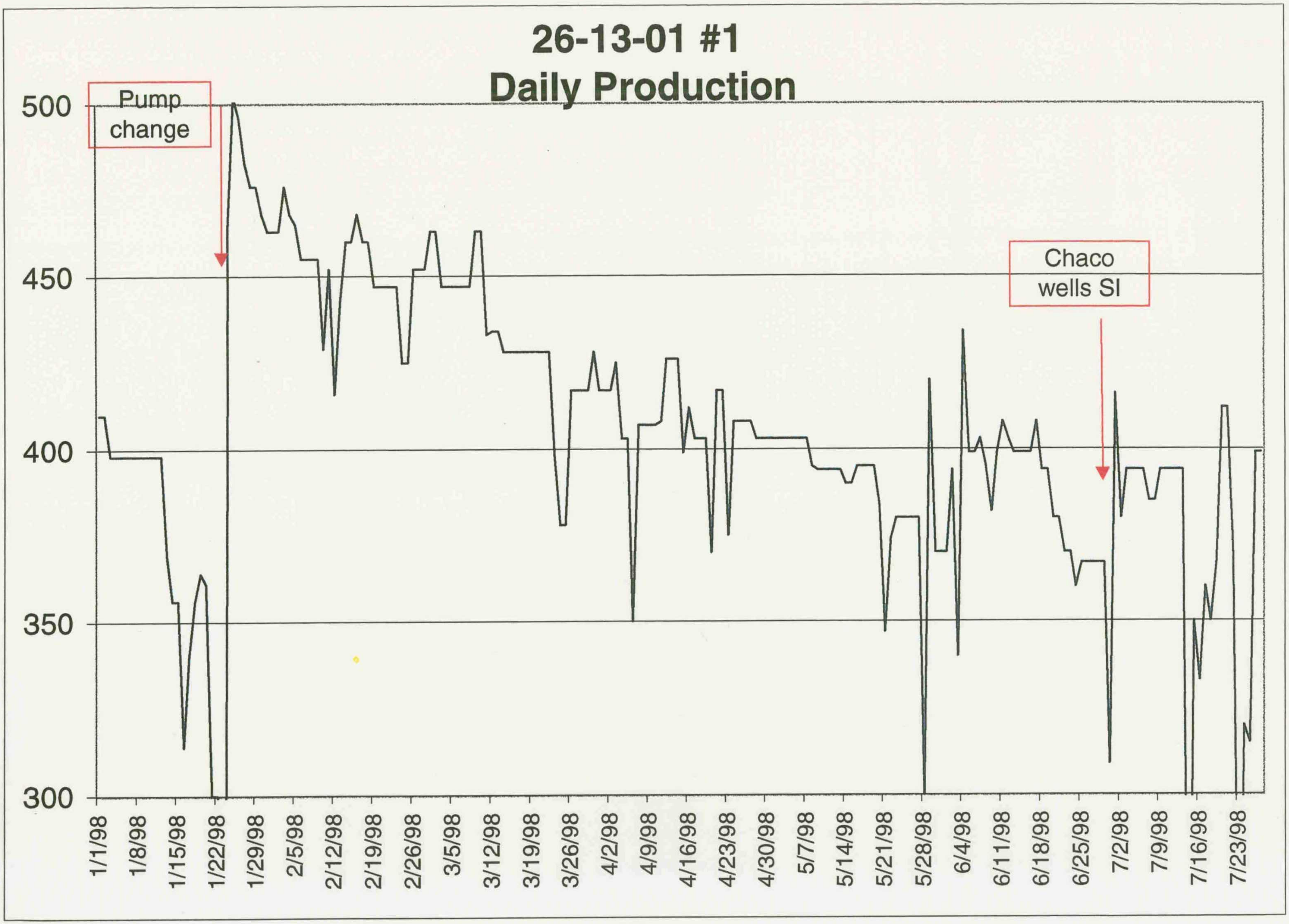
7/16/98
7/23/98



26-13-01 #1
Daily Production
Pump change
Chaco wells SI
500
450
400
350
300
1/1/98
1/8/98
1/15/98
1/22/98
1/29/98
2/5/98
2/12/98
2/19/98
2/26/98
3/5/98
3/12/98
3/19/98
3/26/98
4/2/98
4/9/98
4/16/98
4/23/98
4/30/98
5/7/98
5/14/98
5/21/98
5/28/98
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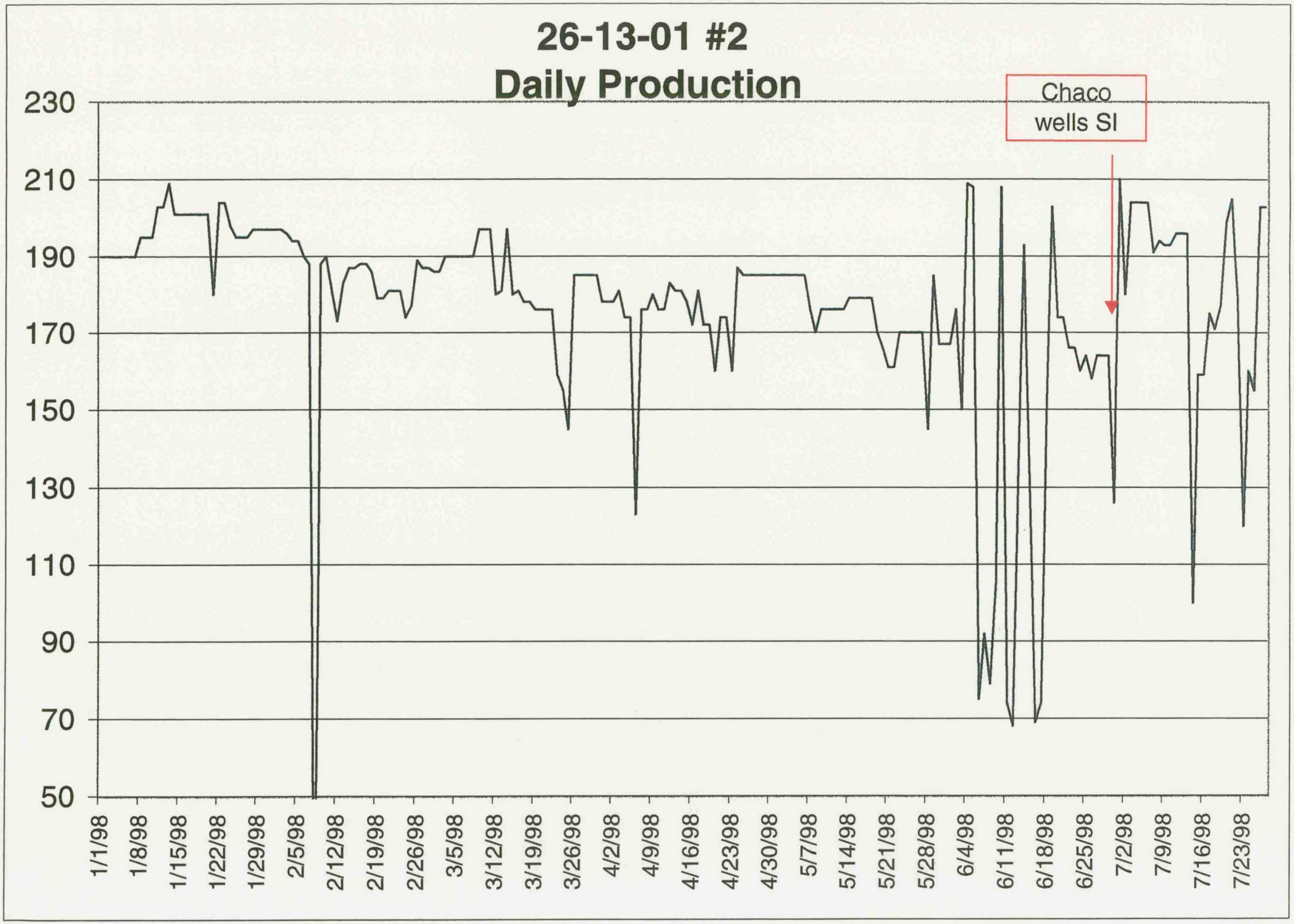
7/16/98
7/23/98


26-13-01 #2
Daily Production
Chaco
wells SI
230
210
190
170
150
130
110
90
70
50
1/1/98
1/8/98
1/15/98
1/22/98
1/29/98
2/5/98
2/12/98
2/19/98
2/26/98
3/5/98
3/12/98
3/19/98
3/26/98
4/2/98
4/9/98
4/16/98
4/23/98
4/30/98
5/7/98
5/14/98
5/21/98
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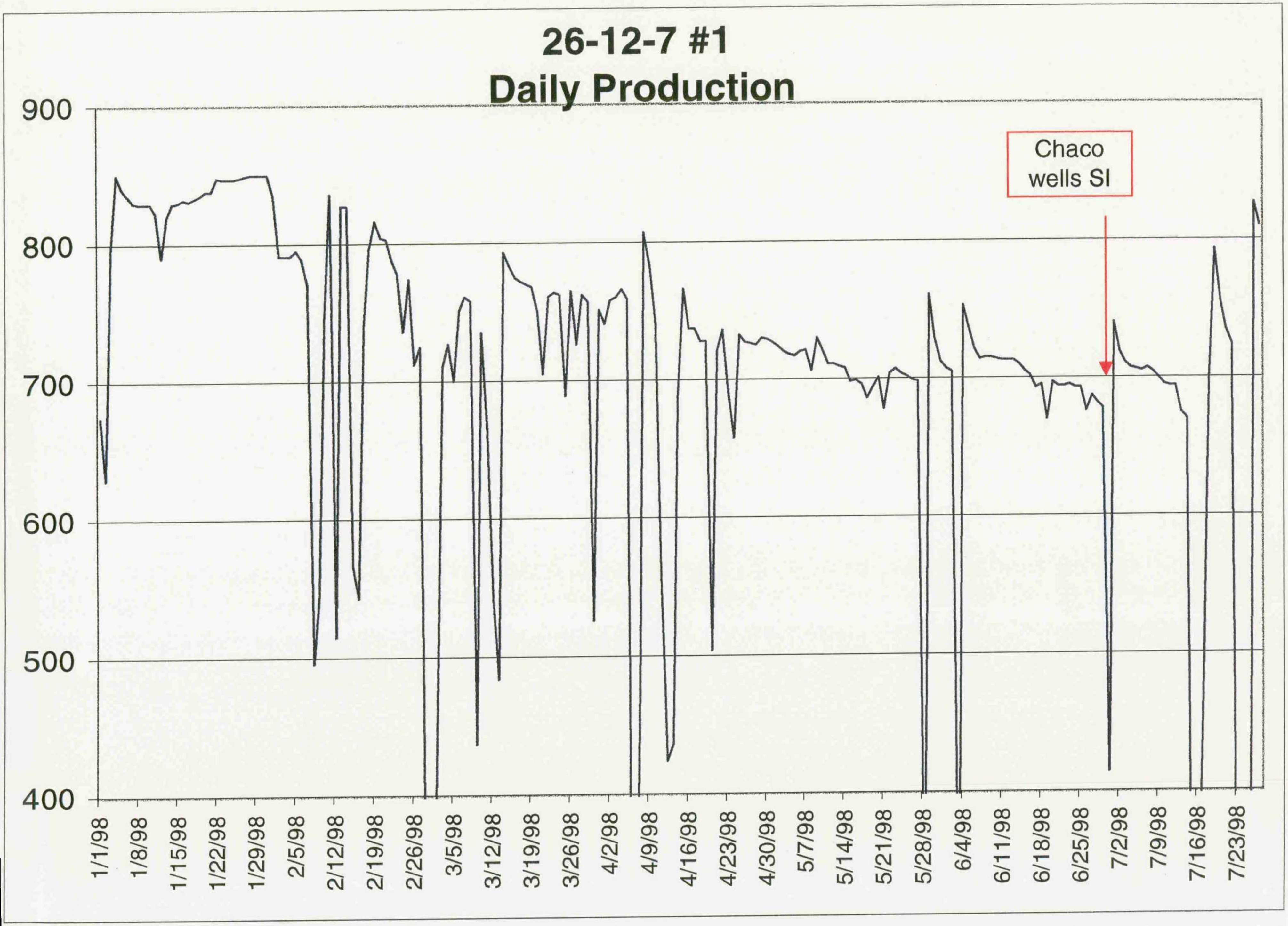
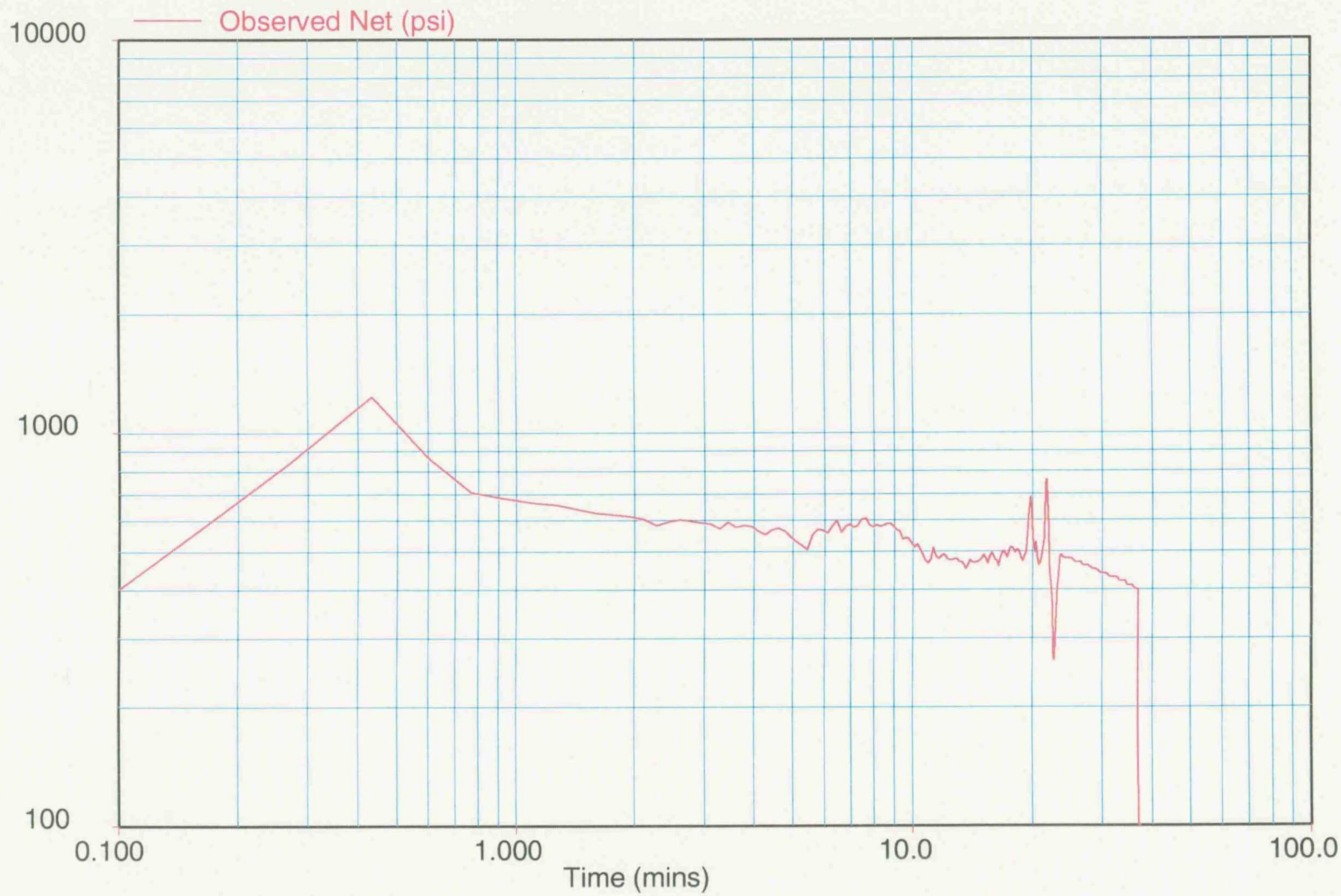
7/16/98
7/23/98


26-12-7 #1
Daily Production
Chaco
wells SI
900
800
700
600
500
400
1/1/98
1/8/98
1/15/98
1/22/98
1/29/98
2/5/98
2/12/98
2/19/98
2/26/98
3/5/98
3/12/98
3/19/98
3/26/98
4/2/98
4/9/98
4/16/98
4/23/98
4/30/98
5/7/98
5/14/98
5/21/98
5/28/98
6/4/98
6/11/98
6/18/98
6/25/98
7/2/98
7/9/98
7/16/98
7/23/98

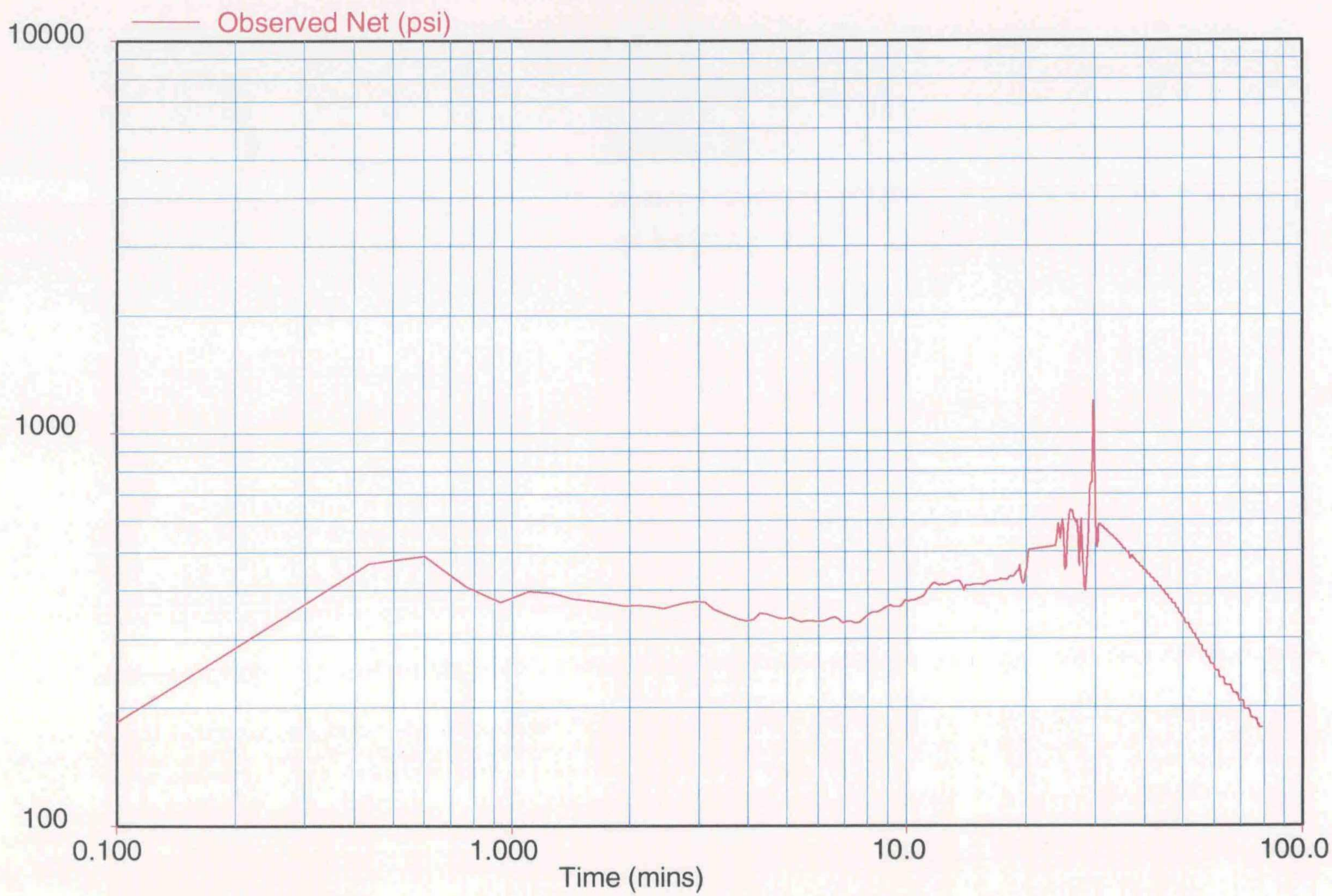
Well	Depth	Rho b	Porosity	Rt	FR	Sw	h	(1-Sw)*Phi*h	GIP/160A@240psig
Chaco 1	1113-19	2.22	26.1%	16	11.17	43.4%	5	0.737	89,121
	1126-28	2.25	24.2%	15	13.05	48.5%	2	0.250	30,202
	1134-39	2.24	24.8%	11	12.37	55.1%	6	0.669	80,894
									200,217
Chaco 4	1166-68	2.27	23.0%	10	14.57	62.7%	3	0.258	31,133
	1173-89	2.23	25.5%	17	11.75	43.2%	14	2.024	244,670
									275,803
Chaco 5	1165-69	2.3	21.2%	15	17.39	55.9%	3	0.280	33,887
	1174-92	Est	24.0%	13	13.33	52.6%	18	2.047	247,381
									281,267
Calculations done by Bruce Williams 3/98									

Chaco 1
Perfs: 1,113-1,139 ft



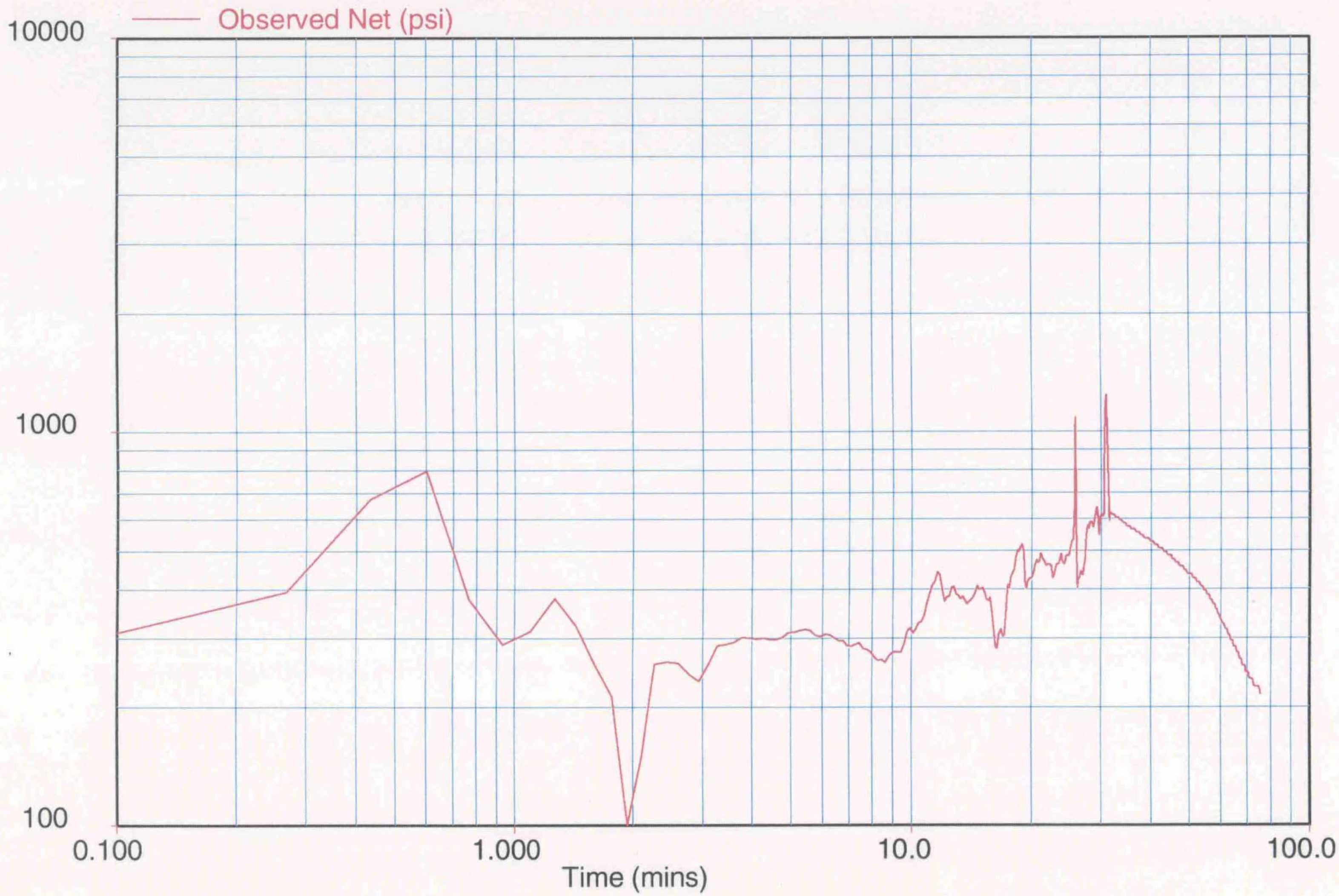
Pictured Cliffs

Chaco 4
Perf. Interval 1,163-1,189 ft

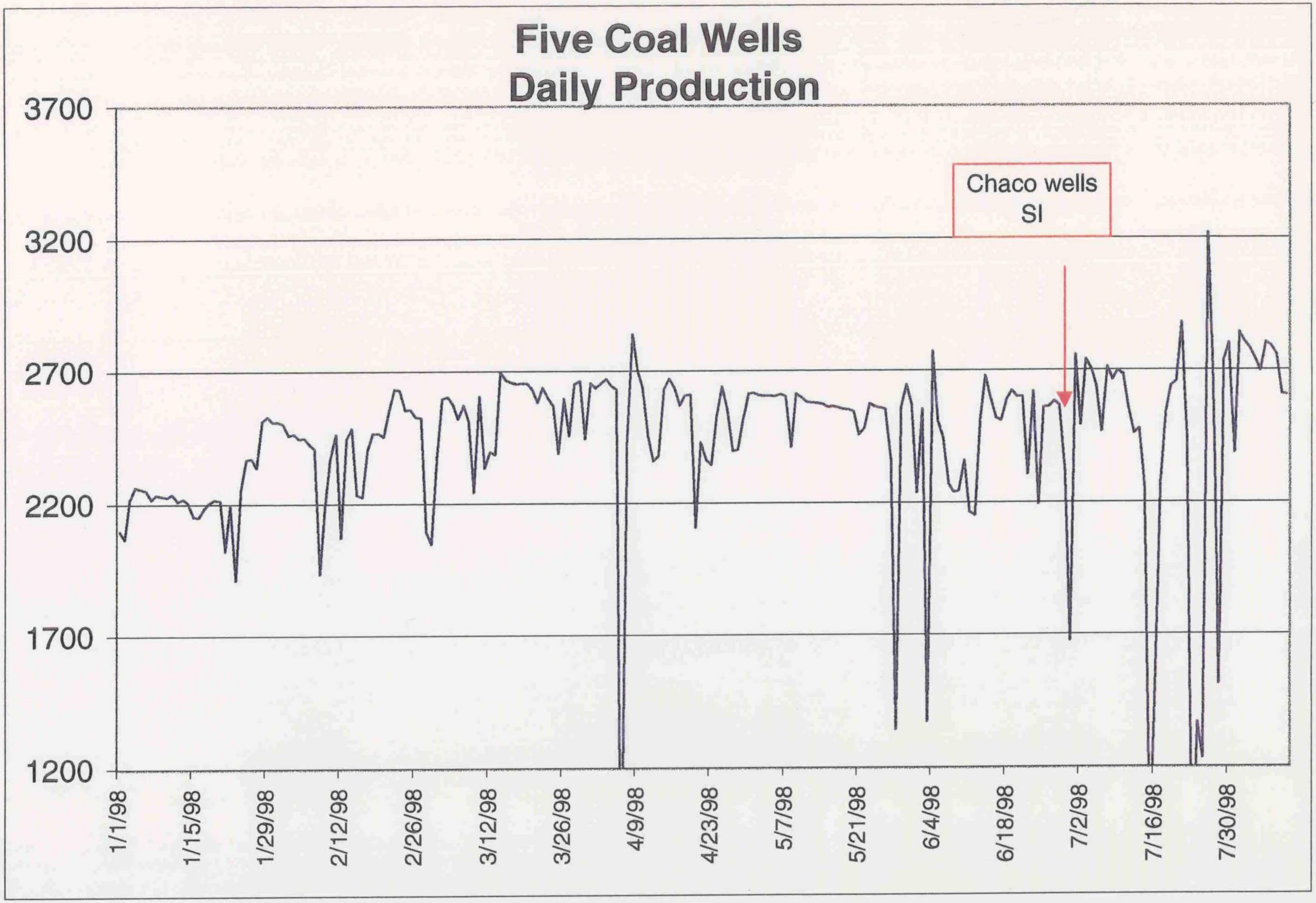


Pictured Cliffs

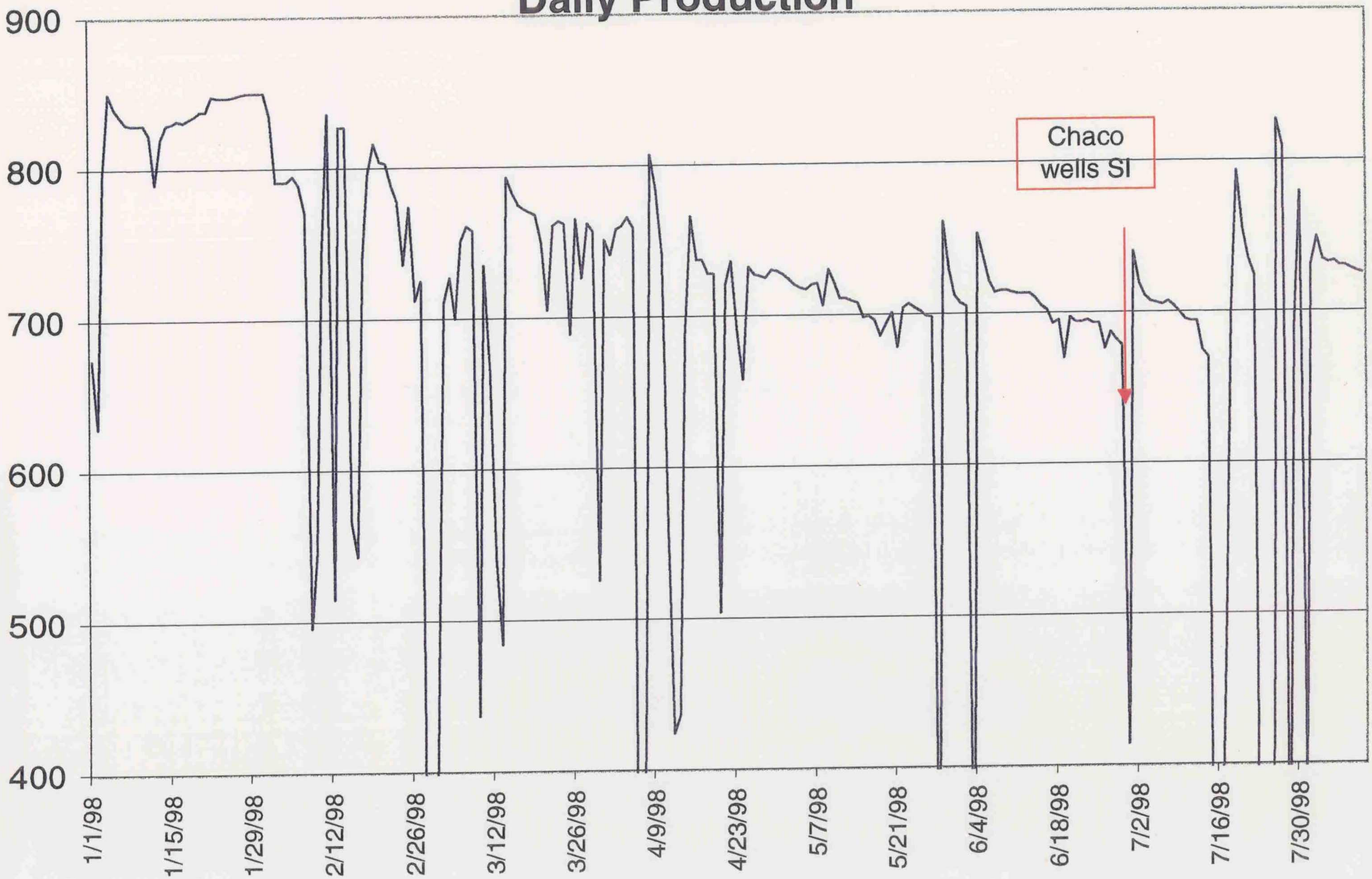
Chaco 5 (Perfs. 1165-1192)



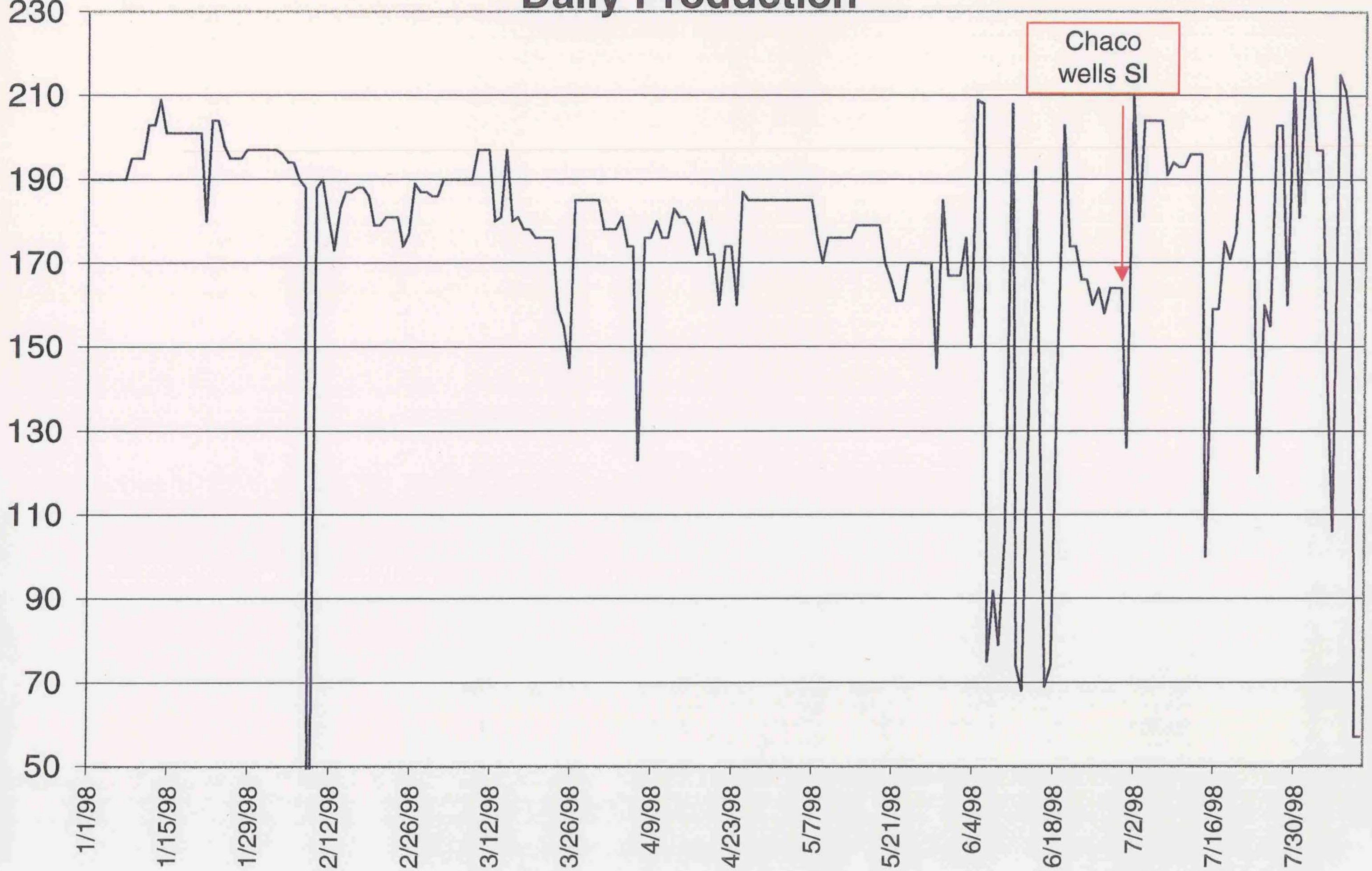
Pictured Cliffs

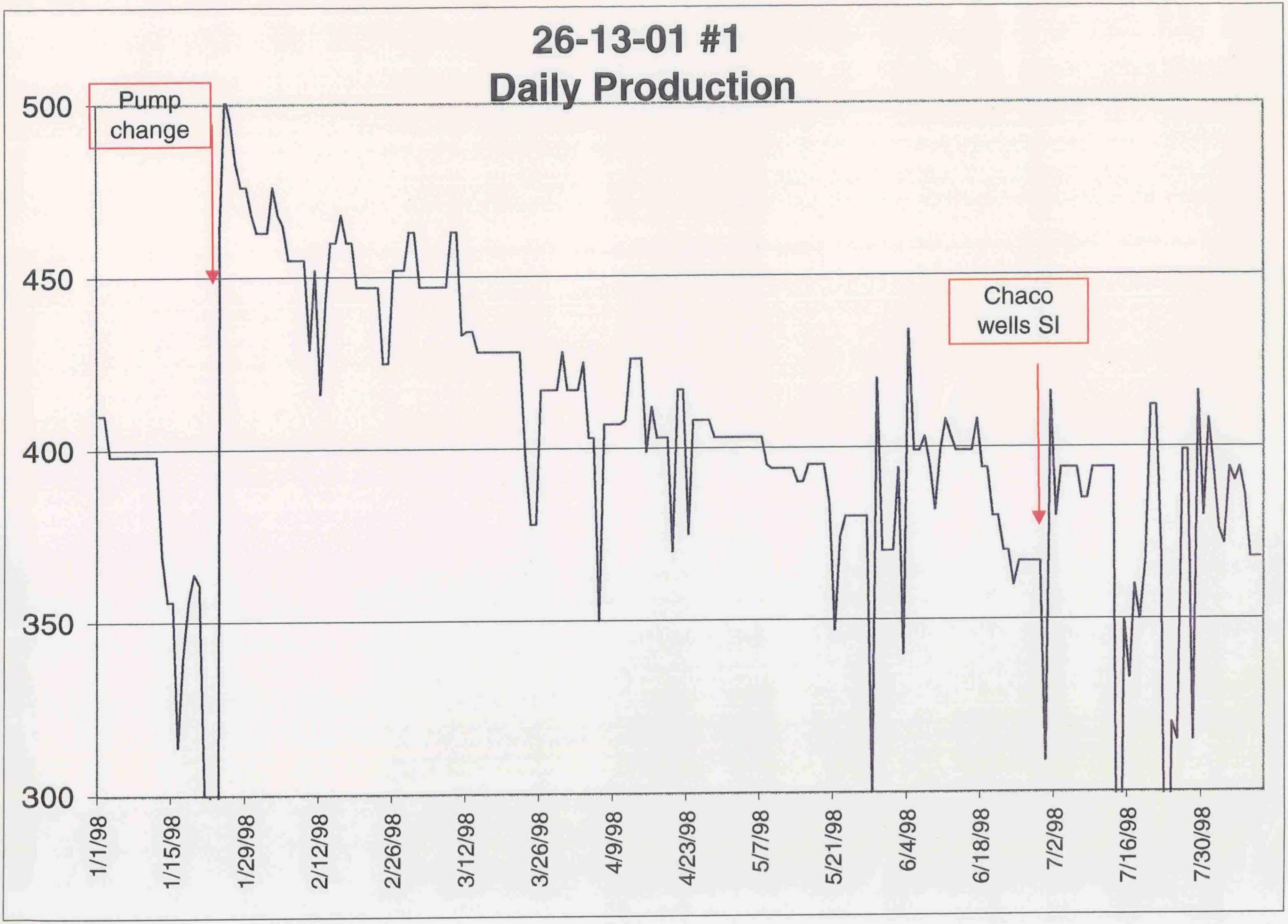

Five Coal Wells
Daily Production
3700
3200
2700
2200
1700
1200
1/1/98
1/15/98
1/29/98
2/12/98
2/26/98
3/12/98
3/26/98
4/9/98
4/23/98
5/7/98
5/21/98
6/4/98
6/18/98
7/2/98
7/16/98
7/30/98
Chaco wells
SI

26-12-7 #1
Daily Production



26-13-01 #2 Daily Production




26-13-01 #1
Daily Production
Pump change
Chaco wells SI
500
450
400
350
300
1/1/98
1/15/98
1/29/98
2/12/98
2/26/98
3/12/98
3/26/98
4/9/98
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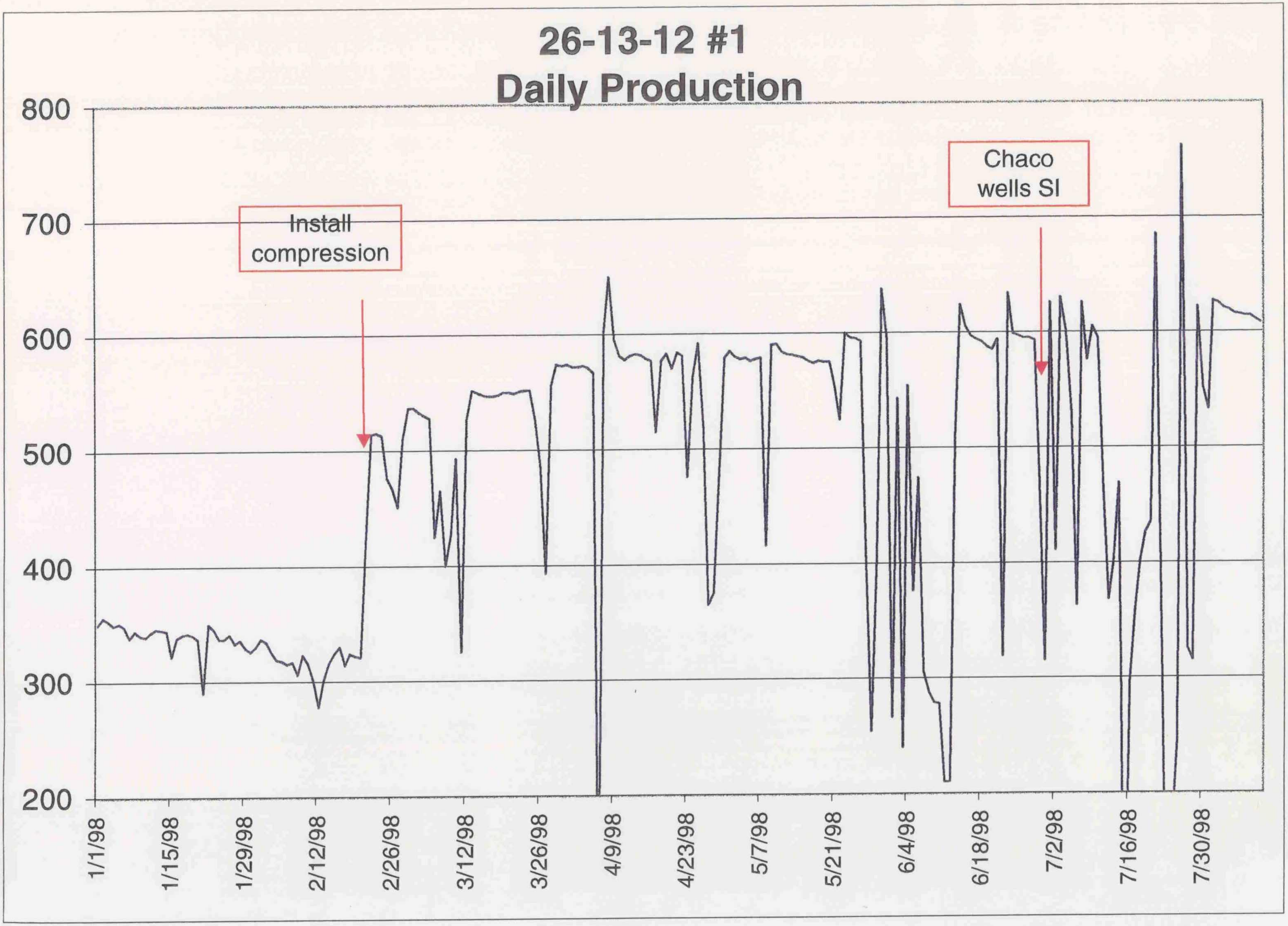
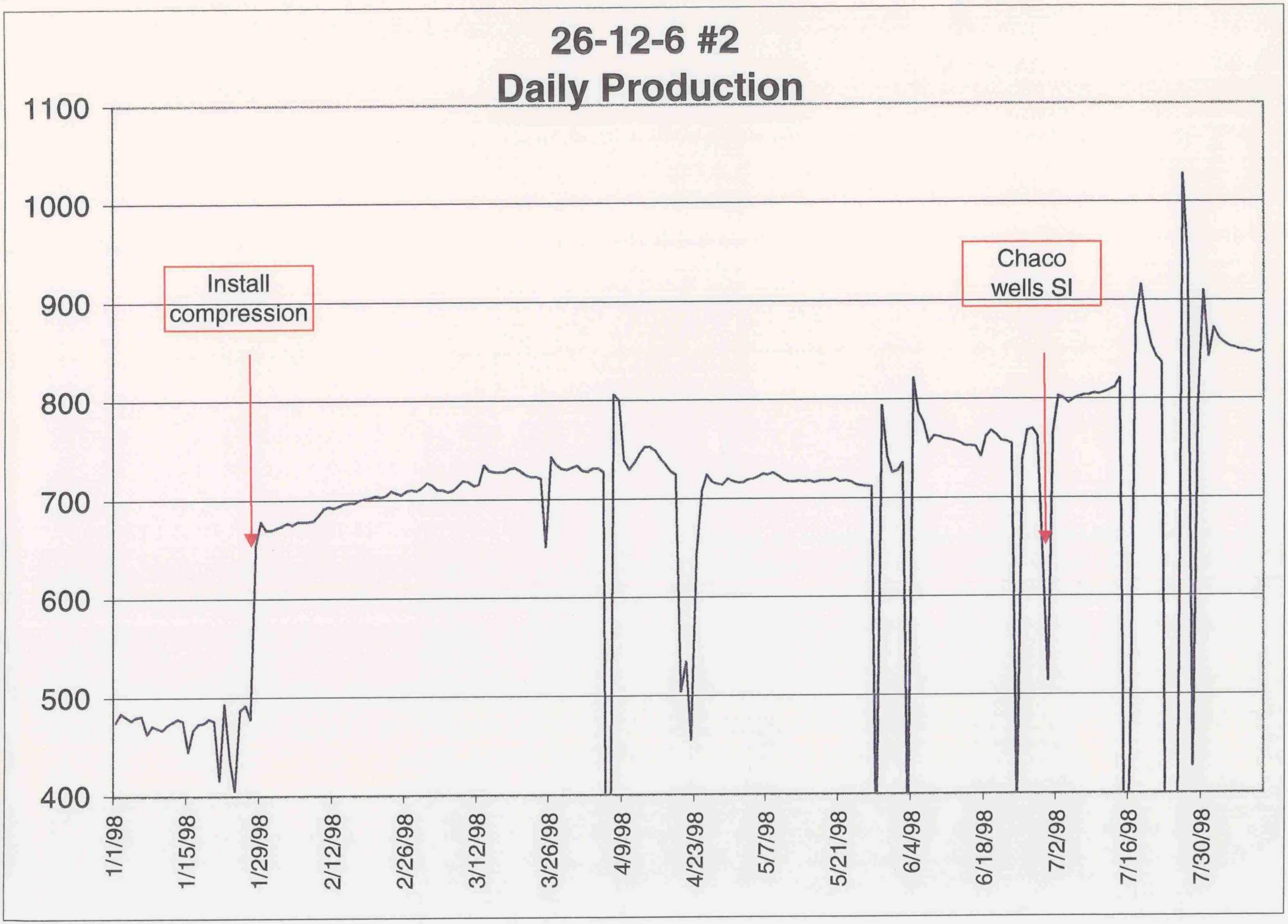
7/16/98
7/30/98



26-13-12 #1
Daily Production
800
700
600
500
400
300
200
1/1/98
1/15/98
1/29/98
2/12/98
2/26/98
3/12/98
3/26/98
4/9/98
4/23/98
5/7/98
5/21/98
6/4/98
6/18/98
7/2/98
7/16/98
7/30/98
Install compression
Chaco wells SI


26-12-6 #2
Daily Production
1100
1000
900
800
700
600
500
400
1/1/98
1/15/98
1/29/98
2/12/98
2/26/98
3/12/98
3/26/98
4/9/98
4/23/98
5/7/98
5/21/98
6/4/98
6/18/98
7/2/98
7/16/98
7/30/98
Install compression
Chaco wells SI

Examiner Catanach asked a question of Bruce Williams regarding Exhibit # __ (Daily production plots on the W/M coal wells). He asked why the production was down on the wells on June 3. Williams indicated that he would check and provide an answer. The El Paso Bisti #8 compressor was down on that day, resulting in high line pressure that reduced well production.

GALLEGOS LAW FIRM

A Professional Corporation

460 St. Michael's Drive
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August 13, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA HAND DELIVERY
Rand Carroll, Esq.
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

VIA HAND DELIVERY
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

Gentlemen:

Enclosed please find two (2) proposed forms of Order presented on behalf of Whiting Petroleum Corporation and Maralex Resources, Inc. in the above-captioned matter.

If you have any questions or need any additional information, please feel free to contact me.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
Enclosures
cc: J. Scott Hall
fxc: John Hazlett
Mickey O'Hare
ioc: J.E. Gallegos

STATE OF NEW MEXICO
ENERGY MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC., PENDRAGON RESOURCES, L.P., AND J.K EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

CASE NO. 11996

ORDER OF THE DIVISION

(Proposed by Whiting Petroleum Corporation and Maralex Resources, Inc.)

BY THE DIVISION:

This cause came on for hearing at 8:15 a.m. on July 28, 1998 at Santa Fe, New Mexico, before Examiner David R. Catanach, and continued through July 30, 1998.

NOW, on this ____ day of August, 1998, the Division Director, having considered the testimony, the record, and the recommendations of the Examiner, and being fully advised in the premises,

FINDS THAT:

(1) Due public notice having been given as required by law, the Division has jurisdiction of this cause and the subject matter thereof.

PARTIES AND NATURE OF DISPUTE

(2) The applicants, Pendragon Energy Partners, Inc., J.K. Edwards Associates, Inc., and Pendragon Resources LP (collectively "Pendragon"), seek an order finding that Pendragon is producing from the appropriate common source of supply, i.e., the Pictured Cliffs Formation, from the following wells in San Juan County, New Mexico:

Well Name	Location
Chaco No. 1	NW ¼, Section 18, T26N, R12W, N.M.P.M.
Chaco No. 2R	SW ¼, Section 7, T26N, R12W, N.M.P.M.
Chaco No. 4	NW ¼, Section 7, T26N, R12W, N.M.P.M.

Chaco No. 5	SE ¼, Section 1, T26N, R13W, N.M.P.M.
Chaco Ltd. No. 1J	SW ¼, Section 1, T26N, R13W, N.M.P.M.
Chaco Ltd. No. 2J	NE ¼, Section 1, T26N, R13W, N.M.P.M.

These wells are referred to as the "Chaco wells."

(3) Pendragon Resources LP and J.K. Edwards Associates, Inc. are interest owners in the referenced Chaco wells. Pendragon Energy Partners, Inc. operates the wells.

(4) Whiting Petroleum Corporation and Maralex Resources, Inc. (collectively "Whiting") own working interests in the following wells completed within the Basin-Fruitland Coal Gas Pool in San Juan County, New Mexico:

Well Name	Location
Gallegos Federal 26-12-6 No. 2	W ½, Section 6, T12N, R12W, N.M.P.M.
Gallegos Federal 26-12-7 No. 1	W ½, Section 7, T26N, R12W, N.M.P.M.
Gallegos Federal 26-13-1 No. 1	E ½, Section 1, T26N, R13W, N.M.P.M.
Gallegos Federal 26-13-1 No. 2	W ½, Section 1, T26N, R13W, N.M.P.M.
Gallegos Federal 26-13-12 No. 1	N ½, Section 12, T26N, R13W, N.M.P.M.

These wells are referred to herein as the "Whiting Coal wells."

(5) Pendragon and Whiting received assignments of oil and gas leases in the acreage identified in paragraphs (2) and (4) above, San Juan County, from common grantors, Robert Bayless, Merrion Oil and Gas, et al. ("Merrion"), during the period 1992-94. The assignments of rights to Whiting are as follows:

> Operating rights **from the surface of the earth to the base of the Fruitland (Coal-Gas) Formation,** subject to the terms and provisions of that certain Farmout Agreement, dated December 7, 1992 by and between Merrion Oil & Gas et al., Robert L. Bayless, Pitco Production Company, and Maralex Resources, Inc.

(6) The assignments of rights to Pendragon are as follows:

> **Limited from the base of the Fruitland Coal Formation to the base of the Pictured Cliffs Formation.**

(7) Whiting contends that Pendragon produces its Pictured Cliffs wells from casing perforations in formations that are within the vertical limits owned solely by Whiting. Whiting also contends that in 1995 acidization and fracture stimulations performed by Pendragon on its Chaco wells Nos. 1, 1J, 2J, 2R, 4 and 5 have caused communication into the Fruitland formation, and that those wells are producing gas from the Fruitland formation.

REGULATORY HISTORY

(8) On October 17, 1988, the Division entered Order No. R-8768 in Case No. 9420. That proceeding was initiated to consider the creation of a new pool for the production of gas from coal seams within the Fruitland formation underlying various Northwest New Mexico counties, the geographic area of which encompassed the properties at issue in this application. In companion Case No. 9421, the Division sought to contract the vertical limits of twenty-six existing Fruitland and/or Fruitland-Pictured Cliffs Gas Pools to include only the Pictured Cliffs Sandstone and/or Fruitland Sandstone intervals and to exclude the coal formations.

(9) Geologic evidence was presented at the hearing in Case No. 9420 by the Fruitland Coalbed Methane Committee, including evidence that the Fruitland formation is composed of alternating layers of shales, sandstones, and coal seams. Evidence was also presented at the hearing that the intent of the Committee was to include all of the coals beds as part of the Basin Fruitland Coal Gas Pool.

(10) Evidence was presented to the Division by the Committee in Case No. 9420 that there may be intertonguing between the sandstones and the Fruitland coal formation in some parts of the San Juan Basin. This could make picking the boundary between the two formations difficult unless a specific marker is located. The Committee relied on the accepted definition of formation boundaries and the work of established experts, such as James E. Fassett and Jim S. Hinds, in a study titled "Geology and Fuel Resources of the Fruitland Formation and the Kirtland Shale of the San Juan Basin, New Mexico and Colorado, Geological Survey Professional Paper 676 (1971)." In that work, Fassett and Hinds placed the contact between the Pictured Cliffs formation and the overlying Fruitland formation "at the top of the massive sandstone below the lowermost coal of the Fruitland except in those areas where the Fruitland and the Pictured Cliffs intertongue." The Committee relied on industry-recognized boundaries in making their recommendations to the Division in Case No. 9420.

(11) The vertical boundary between the Fruitland formation and the Pictured Cliffs formation in the area in question is and has historically been the top of the massive marine sandstone below the lowermost coal of the Fruitland.

(12) Evidence was also presented to the Division in those proceedings that due to their close proximity, fracture stimulations of the Pictured Cliffs sandstone in the Basin frequently caused communication with the coal formations.

(13) In Order R-8768, the Division created the Basin-Fruitland Coal Gas Pool, with vertical limits comprising all coal seams within the equivalent of the stratigraphic interval from a the depth of approximately 2,450 feet to 2,880 feet as shown on the Gama Ray/Bulk Density Log from the Amoco Production Company's Schneider Gas Com "B" Well No. 1. Spacing for coal gas wells was established on 320-acre proration units.

(14) In Order No. R-8768, the Division adopted Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool. Rule 3 authorizes the Director to require an operator of a proposed or existing Pictured Cliffs Sandstone well to submit certain data in order to demonstrate to the satisfaction of the Division that the well will be or is currently producing from the appropriate common source of supply. Rule 2 of the Special Rules identifies the following data to be used in such a determination:

a. Electric Log Data
b. Drilling Time
c. Drill Cuttings or Log Cores
d. Mud Logs
e. Completion Data
f. Gas Analysis
g. Water Analysis
h. Reservoir Performance
i. Other evidence which may be utilized in making such determination

(15) On July 16, 1991, the Division entered Order No. R-8768-A in reopened Case No. 9420. The Division considered in the course of that proceeding whether the Special Rules and Regulations promulgated by Order No. R-8768 afforded owners of properties in the Basin-Fruitland Coal Gas Pool the opportunity to produce their just and equitable share of gas in that pool, and concluded that the Special Rules and Regulations of Order R-8768 did satisfactorily provide owners with that opportunity.

(16) Order No. R-8768-A confirmed 320-acre spacing for coal gas wells in the Basin-Fruitland Coal Gas Pool, and amended Rule No. 3 which provided that confirmation that a well is producing exclusively from the Basin-Fruitland Coal Gas Pool would consist of approval of Division Form C-104, but that that approval would be for Division purposes only, and should not preclude any other governmental jurisdictional agency from making its own determination of production origination utilizing its own criteria.

(17) In Case No. 9421, the Division entered Orders R-8769 and R-8769-A on October 17, 1988 and April 11, 1989 respectively. Those Orders established the vertical limits of the WAW Fruitland-Pictured Cliffs Pool in San Juan County, New Mexico as follows:

(z) The vertical limits of the WAW Fruitland-Pictured Cliffs Pool in San Juan County, New Mexico, are hereby contracted to include only the Pictured Cliffs formation and the sandstone interval of the Fruitland formation and said pool is hereby redesignated as the WAW Fruitland Sand-Pictured Cliffs Pool.

PRODUCTION AND PRESSURE HISTORY

(18) The Chaco wells were originally drilled by Merrion in the late 1970s. At that time, Merrion owned unified interests from the surface of the earth to the base of the Pictured Cliffs formation in the Chaco wells. The well casings were perforated at various sandstone layers, and were classified as Pictured Cliffs formation wells producing from the WAW Fruitland PC or NIIP PC Pool in notices filed with the Division. The Chaco wells were drilled and completed prior to the establishment of the Basin-Fruitland Coal Gas Pool.

(19) By the mid-1980s, the Chaco wells exhibited signs consistent with production from a depleting Pictured Cliffs sandstone reservoir. Pressures were steadily declining, and production levels had dropped to between 2 and 5 mcf per day. No evidence of skin damage or other mechanical problems with the wells that would account for the low production figures and low pressures is found in any of the Chaco well files which were made exhibits in this proceeding. The decline in both volume of gas and pressure is consistent with a depleted sandstone reservoir.

(20) Whiting drilled its Gallegos Canyon Coal wells in 1992. After completion the wells exhibited performance typical of coal seam wells. They produced high volumes of water initially and virtually no (or little) gas production in the initial months of production. Gas production inclined as the wells dewatered and by 1995 gas production was at economic levels except for the 26-13-1 No. 1 and No. 2 wells.

(21) Pendragon began its activities in this area in December 1994 by reworking the Lansdale Federal No. 1 well on 160-acres in the SE/4 of Section 7, T-26-N, R-12-W. Pendragon owns rights in the Lansdale from a depth of 536 feet to a depth of 1340 feet, including the Fruitland formation and Pictured Cliffs sandstone.

(22) When the Lansdale Federal No. 1 well was originally completed in March, 1980, the operator recovered black water and noted rising casing pressures. Water from the well showed a heavy coal content, and coal fines were recovered, indicating that the well was in communication with coal seams when it was originally completed.

(23) A Walsh Engineering Production Workover and Completion Report for the Lansdale Federal No. 1 well, dated December 19, 1994, shows that Pendragon expressly planned to perforate the Fruitland Coal and treat the well with acid. Pendragon in fact did perforate the Fruitland coal formation on December 20, 1994 in the Lansdale Federal No. 1 well from 1042' to 1056'.

(24) Pendragon failed to report the perforations in the Fruitland coal in sundry notices filed with the Division. Pendragon's regulatory filings misrepresented the well as a Pictured Cliffs well. The Lansdale Federal No. 1 well was on 160-acre spacing, at a nonstandard location. One Hundred Sixty-acre spacing is appropriate for a Pictured Cliffs well, but is illegal for a Fruitland coal seam gas well.

(25) Pendragon illegally produced the Lansdale Federal No. 1 well from December, 1994 until the week prior to the hearing in this case from the Fruitland coal. For 3 and 1/2 years, Pendragon operated the Lansdale Federal No. 1 well under false regulatory filings which failed to disclose that the well was producing from the Fruitland Coal. No water production was reported on the well until March, 1998. Pendragon represented that it squeezed off the perfs in the Fruitland formation less than one (1) week before the hearing in this case on July 28-30, 1998.

(26) Pendragon began its rework program on the Chaco wells in January, 1995. Pendragon acidized and/or fracture stimulated the Chaco 1, 1J, 2J 2R, 4 and 5 wells during the period January, 1995 through May, 1995. These wells are direct offsets to the Whiting Coal wells which, by early 1995, had shown declines in water production and were on an incline for coal seam gas production.

(27) In each case of reworking the Chaco wells Nos. 1, 2R, 4 and 5, Pendragon achieved significant pressure increases in the wells following the acidization or fracture stimulation. A chart demonstrating the pressure increases resulting from the rework of these wells is as follows:

Well Name	Pre-Treatment Wellhead Shut-in Pressure	Treatment Date and Type	Post-Treatment Wellhead Shut-in Pressure
Chaco 1	137 (07/05/83)	Frac (01/27/95)	170 (03/14/95)
Chaco 4	119(01/30/95)	Acid (01/30/95)	170 (02/14/95)
Chaco 5	121 (06/21/80)	Frac (05/10/95)	151 (05/19/95)

(28) Pendragon introduced evidence at the hearing that pressures in the Chaco No. 5 well had risen prior to any acidization or fracture stimulation on that well. However, the well file indicates that a casing leak occurred in that well prior to May, 1995. In February, 1995, black water was discovered flowing from the bradenhead. Given the evidence of the casing leak, and water behind the column, it is clear that communication in the Chaco No. 5 well had already been established between the PC sandstone and the coal prior to January, 1995.

(29) The significant pressure increase achieved in these wells was markedly higher than the natural pressure increase experienced in the wells prior to acidization and fracture treatment from the early 1980s, and demonstrates that the Chaco wells became in communication with the coal formations following the acidizations or fracture stimulations.

(30) Following the acidization and fracture treatment on the Chaco wells, Pendragon experienced very large increases in gas production from the Chaco wells which was not characteristic of Pictured Cliff restimulations. In each case, production levels exceeded production levels experienced when the wells were originally drilled under virgin reservoir conditions. The increases in production from about 3 to 5 MCFD to sustained rates of 400 MCFD are far above any results that could be expected had Pendragon simply been overcoming skin damage by the stimulations.

(31) From 1995 until the Chaco wells were shut-in by order of the Santa Fe County District Court on June 30, 1998, each of the Chaco wells produced volumes of gas which exceeded the total of original gas in place per well for the Pictured Cliffs reservoir in this area. The Chaco wells have produced significantly more gas from 1995 to the present than they produced in the entire first 15-17 years of production.

(32) The evidence of production volumes and pressure data on the Chaco wells since the acidization and fracture stimulations in 1995 is consistent with the conclusion that these wells have been producing significant volumes of coal seam gas.

(33) Since the Chaco wells were shut-in by Order of the Santa Fe County District Court, pressure readings in the Chaco wells have confirmed communication with the coal formations. As Whiting Exhibit 31 demonstrates, the shut-in pressure readings on the shut-in Chaco wells have fluctuated. The fluctuations in the Chaco wells wellhead shut in pressures have coincided with periods when the Whiting Coal wells were shut-in due to pipeline and plant restrictions and when the Whiting wells went back on. If there were no communication between the Pictured Cliffs and the Fruitland coal formations in the Chaco wells, the Chaco wells should exhibit a basically flat line of pressure once they achieved their static pressure following shut-in.

FRACTURE STIMULATIONS

(34) There is little or no stress barrier between the massive Pictured Cliffs sandstone and overlying coal seams. Perforations in the Chaco wells though which hydraulic fractures were administered lay in the Fruitland sandstone between coal seam layers.

(35) The acidizations performed on Chaco wells Nos. 1J, 2J, 2R, and 4 resulted in communication between the Fruitland formation coal seams and the Pictured Cliffs sandstone in these wells. The result of this communication is that since the acid stimulations were performed in 1995, these Chaco wells have been producing coal seam gas from the Fruitland formation which is owned by Whiting.

(36) The evidence presented to the Division established that Pendragon's fracture stimulations on Chaco wells No. 1, 2R, 4 and 5 extended into and through the lower and upper coal seams in the Fruitland formation (B Coal and Basal coal) which is owned by Whiting. These fracture stimulations caused communication between the

Fruitland coal seams and the Pictured Cliffs sandstone and thence to the Chaco well bores, and have, since performed in 1995, resulted in the production of coal seam gas from these Chaco wells by Pendragon.

WATER PRODUCTION

(37) Water production from wells is one indicator of whether a well is producing strictly Pictured Cliffs sandstone gas or coal seam gas. Wells producing coal seam gas would tend to show high volumes of water production in the early stages of production, with water production declining as gas production increases. No significant water production would be expected from a well producing only from the Pictured Cliffs sandstone.

(38) The Chaco wells have produced significant volumes of water since the acidizations and fracture stimulations performed in 1995 on the Chaco wells Nos. 1, 2R, 4 and 5. The produced water volumes in these wells since 1995 are inconsistent with production of solely Pictured Cliffs sandstone gas, and are consistent with the conclusion that these wells are producing coal seam gas from the Fruitland formation.

(39) The problem with accurately quantifying volumes of produced water from the Chaco wells since 1995 exists because Pendragon failed to report volumes of water production as required by NMOCD Form C-115. The evidence in this case established that Pendragon did not begin reporting water volumes from its Chaco wells until, and only for February, 1998, which coincided with a site visit to the Chaco wells by Ernie Busch of the Division's Aztec office.

(40) Pendragon disposed of the produced water from its Chaco wells in unlined earthen pits in an area of sandy soils. The result of such disposal is that significant amounts of produced water were disposed of through evaporation and absorption into the soil, thus making it impossible to precisely quantify the volumes of water produced from the Chaco wells because the water production was not recorded by the pumpers or contract operator.

(41) Pendragon has not, to date, produced all documents related to water production from the Chaco wells. Evidence presented by Whiting at the hearing, based on documents first produced by Pendragon the day before the start of the hearing, indicated that Pendragon continued to produce water from the Chaco wells into at least June, 1998. Pendragon's C-115 reports for that period of time do not reflect water production, even though their internal files demonstrated water production and water hauling from the Chaco wells.

(42) While water production evidence on the Chaco wells is sparse owing to Pendragon's non-preservation of the information and ongoing violations of Division rules and regulations and its failure to report water production from these wells, the water production records and generally evidence in this case are consistent with a finding that the Pendragon Chaco wells have, since their acidizations and fracture stimulations in

1995, been producing coal seam gas in significant quantities from these Chaco wells. The water/gas ratio on the Chaco wells generally shows a higher water/gas ratio than the Whiting coal wells for the same period.

(43) Presumptions on the issue of water from the Chaco wells will be made adverse to Pendragon in this proceeding in light of Pendragon's failure to report water production from its Chaco wells.

GAS ANALYSIS

(44) The Division has recognized that gas analysis is one method of differentiating coal seam gas from Pictured Cliffs sandstone gas. Pictured Cliffs sandstone gas typically has a BTU content in this area of between 1050 and 1100, whereas Fruitland coal seam gas in this area typically has a BTU content of approximately 1000.

(45) Historical data submitted in this case demonstrated that the Pendragon Chaco wells prior to the acidization and fracture stimulations in 1995 produced gas with a BTU content consistent with Pictured Cliffs sandstone gas.

(46) Following the acidizations and fracture stimulations in 1995, the Pendragon Chaco wells began producing gas with a BTU content consistent with Fruitland coal seam gas. The documentary evidence presented to the Division demonstrated that the BTU readings on Whiting's coal seam gas and Pendragon's gas produced from the Chaco wells has become increasingly similar and consistent overtime, thus indicating that the Chaco wells are producing significant volumes of coal seam gas.

GEOLOGIC EVIDENCE

(47) As demonstrated in Whiting Exhibit 16, a cross-section of logs for the Chaco wells at issue in this proceeding, there are two continuous lower Fruitland coal seams in the area. The upper coal seam, characterized on Whiting Exhibit 16 as the B Coal, is approximately 20 feet thick throughout the subject area. The lower continuous coal seam in the area, characterized by Whiting at the hearing as the Basal coal, varies from 2 feet to 4 feet in thickness and overlies the massive marine sandstone formation designated on the Whiting Exhibit 16 as the Pictured Cliffs Sandstone formation.

(48) There is in this area a small, 2 to 7 feet in thickness sandstone stringer which runs between the B Coal and the Basal coal. Whiting presented geologic evidence that demonstrated that this sandstone layer is a Fruitland sandstone. The sandstone stringer is not a marine sandstone, but rather is a coastal plain sandstone.

(49) The vertical boundary between the Fruitland formation and the Pictured Cliffs Sandstone formation in this area is set below what is characterized as the Basal Coal stringer on the Whiting Exhibit 16, at the top of the massive Picture Cliffs

sandstone. This boundary is consistent with industry-accepted standards, the work of the U.S. Geological Survey, and the Coalbed Methane Committee. The Division rejects the attempt by Pendragon to characterize this Fruitland sandstone stringer as an "Upper Pictured Cliffs Sand," a phrase coined by Pendragon's president for this hearing, and which finds no support in the literature or prior geologic testimony taken before the Division, or in prior Orders of the Division.

(50) Pendragon produces from perforations in the Fruitland Sandstone in its Chaco wells Nos. 1, 2J, 4 and 5. These perfs are located in the Fruitland formation owned by Whiting.

BASED ON THE FOREGOING, THE DIVISION FINDS THAT:

(1) Pendragon, as the Applicant, has the burden to establish that its Chaco wells are producing from the appropriate common source of supply which would be the Pictured Cliffs formation below the base of the Fruitland formation.

(2) Pendragon has failed to meet its burden in this proceeding.

(3) Pendragon's Chaco wells Nos. 1, 2J, 4 and 5 include perforations open in the Fruitland sandstone above the base of the Fruitland formation owned by Whiting. These wells have been producing gas to which Whiting is solely entitled since 1995.

(4) Pendragon's acidizations and/or fracture stimulations on its Chaco wells Nos. 1, 1J, 2J, 2R, 4 and 5 caused communication with the coal seams in the Fruitland formation. Whiting is solely entitled to produce coal seam gas from this formation. The Chaco wells 1, 2R, 4 and 5 since 1995 have been producing predominantly coal seam gas. Chaco wells 1J and 2J have also produced coal seam gas since 1995.

(5) A fair and equitable allocation based upon the engineering evidence presented at the hearing demonstrates that following the 1995 stimulations, 90% of gas production from the Chaco wells should be allocated to Whiting's Coal wells, and 10% should be allocated to Pendragon's Chaco wells.

(6) Given the volumes produced by the Chaco wells beginning in 1995 and on the basis of the 90% source in Fruitland formation gas and 10% source in Pictured Cliffs sandstone gas, well before June 30, 1998 the Pendragon wells had produced more than all of the gas which they were capable of producing from the Pictured Cliffs sandstone.

(7) Pendragon's Application seeking an order that Pendragon's Chaco wells are producing from the appropriate common source of supply is not supported by the evidence and should be denied.

(8) It would be violative of correlative rights, inequitable, and injurious to Whiting to allow the Pendragon Chaco wells to continue to produce coal seam gas.

(9) Pendragon has already produced in excess of its allocable Pictured Cliffs share of gas from the Chaco wells. Whiting will produce all coal seam gas, which might otherwise be produced from the Chaco wells, from Whiting's own wells if the Chaco wells are shut-in.

(10) Pendragon has engaged in an ongoing and consistent practice of violating Division rules and regulations by (a) operating the Lansdale Federal No. 1 well as a Pictured Cliffs well, fully knowing that the well was producing coal seam gas, (b) operating the Lansdale Federal No. 1 well on a 160-acre proration unit at a nonstandard location in violation of Order R-8768 and R-8768-A, and (c) failing to document and report volumes of water production from the Chaco wells since the stimulation treatments in 1995.

(11) Plugging and abandoning Pendragon's Chaco wells will prevent waste and protect the correlative rights of the parties.

IT IS THEREFORE ORDERED THAT:

(1) Pendragon is to plug and abandon Chaco wells Nos. 1, 1J, 2J, 2R, 4 and 5 within thirty (30) days and duly report such procedures by Sundry Notice, Form C-103, in accordance with the Rules and Regulations of the Division.

(2) Pendragon is ordered to appear before the Division and show cause why the Division should not prohibit Pendragon from further serving as the record operator of wells in New Mexico a result of the ongoing, knowing and persistent violations of the Division's rules and regulations which were established at the hearing in this matter.

(3) Pendragon's Application is denied in its entirety.

(4) The rights and remedies and defenses between and among the parties that may exist under common law remain to be decided by the district court in which litigation between the parties is pending and are not within the jurisdiction of the Division.

(5) Jurisdiction of this cause is retained for the entry of such further orders as the Division may deem necessary within the scope of its regulatory authority.

DONE at Santa Fe, New Mexico, on the day and year hereinabove designated.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION

Lori Wrotenbery
Director

STATE OF NEW MEXICO
ENERGY MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC., PENDRAGON RESOURCES, L.P., AND J.K EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

CASE NO. 11996

ORDER OF THE DIVISION

(Proposed by Whiting Petroleum Corporation and Maralex Resources, Inc.)

BY THE DIVISION:

This cause came on for hearing at 8:15 a.m. on July 28, 1998 at Santa Fe, New Mexico, before Examiner David R. Catanach, and continued through July 30, 1998.

NOW, on this ____ day of August, 1998, the Division Director, having considered the testimony, the record, and the recommendations of the Examiner, and being fully advised in the premises,

FINDS THAT:

(1) Due public notice having been given as required by law, the Division has jurisdiction of this cause and the subject matter thereof.

(2) The applicants, Pendragon Energy Partners, Inc., J.K. Edwards Associates, Inc., and Pendragon Resources LP (collectively "Pendragon"), seek an order finding that Pendragon is producing from the appropriate common source of supply, i.e., the Pictured Cliffs Formation, from the following wells in San Juan County, New Mexico:

Well Name	Location
Chaco No. 1	NW ¼, Section 18, T26N, R12W, N.M.P.M.
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Chaco No. 4	NW ¼, Section 7, T26N, R12W, N.M.P.M.
Chaco No. 5	SE ¼, Section 1, T26N, R13W, N.M.P.M.

Chaco Ltd. No. 1J	SW ¼, Section 1, T26N, R13W, N.M.P.M.
Chaco Ltd. No. 2J	NE ¼, Section 1, T26N, R13W, N.M.P.M.

(3) Pendragon, as the Applicant, has the burden to establish that its Chaco wells are producing from the appropriate common source of supply which would be the Pictured Cliffs formation below the base of the Fruitland formation.

(4) Pendragon has failed to meet its burden in this proceeding.

IT IS THEREFORE ORDERED THAT:

(1) Pendragon's Application is denied in its entirety.

(2) The rights and remedies and defenses between and among the parties that may exist under common law remain to be decided by the district court in which litigation between the parties is pending and are not within the jurisdiction of the Division.

DONE at Santa Fe, New Mexico, on the day and year hereinabove designated.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION

Lori Wrotenbery
Director

MILLER, STRATVERT & TORGERSON, P. A.

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FACSIMILE TRANSMISSION COVER SHEET

DATE: July 27, 1998

TO: Rand Carroll — FAX NO.: 827-8177

FROM: J. Scott Hall — OPERATOR: Michelle

MESSAGE: Here are your copies of the letters we are hand-delivering to Mr. Condon today.

NUMBER OF PAGES INCLUDING COVER SHEET: FOUR (4)

IF YOU DO NOT RECEIVE THE ENTIRE DOCUMENT, PLEASE CALL OUR SANTA FE OFFICE AS SOON AS POSSIBLE AT (505) 989-9614.

* * * * * * * *

MILLER, STRATVERT & TORGERSON, P. A.
LAW OFFICES

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PLEASE REPLY TO SANTA FE

July 27, 1998

HAND-DELIVERED

Michael Condon, Esq.
Gallegos Law Firm
460 St. Michaels Drive, Building 300
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Michael:

Enclosed are copies of materials requested for the following wells:

Chaco 5: 5/17/77 Completion Report; 4/30/77 Induction Log; 4/30/77 Density Log.

Chaco Ltd. 2-J: 12/31/79 Completion Report; 9/10/79 Density/Neutron Log; 9/10/97 Induction Log.

Chaco 4: 5/17/77 Completion Report; 9/10/79 Density/Neutron Log; 9/10/97 Induction Log.

Chaco 1: 3/29/77 Completion Report; 2/22/77 Induction Log; 2/22/77 Density Log.

Chaco Ltd. 1-J: 8/18/82 Completion Report.

Chaco 2-R: 1/23/80 Completion Report; 10/3/79 Induction Log.

Very truly yours,

MILLER, STRATVERT & TORGERSON, P. A.

J. Scott Hall, Esq.

JSH/mg
Enclosures
cc: Rand Carroll, Esq., NMOCD (w/o encls.)
Al Nicol, Pendragon Energy Partners, Inc. (w/o encls.)
Keith Edwards, J. K. Edwards Associates, Inc. (w/o encls.)

MILLER, STRATVERT & TORGERSON, P. A.
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PLEASE REPLY TO SANTA FE

July 27, 1998

HAND-DELIVERED

Michael Condon, Esq.
Gallegos Law Firm
460 St. Michaels Drive, Building 300
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Michael:

Enclosed herein are copies of pumper's reports and hauler's invoices reflective of water production for the following wells:

Chaco #1; Chaco #1J; Chaco #2J; Chaco #2R; Chaco #4; Chaco #5; and Lansdale Federal #1.

Also enclosed are the Sundry Notices and Reports on the subject wells.

Very truly yours,
MILLER, STRATVERT & TORGERSON, P. A.

J. Scott Hall

J. Scott Hall, Esq.

JSH/mg
Enclosures
cc: Rand Carroll, Esq., NMOCD (w/o encls.)
Al Nicol, Pendragon Energy Partners, Inc. (w/o encls.)
Keith Edwards, J. K. Edwards Associates, Inc. (w/o encls.)

MERRION

OIL & GAS

JUL 27 1998

OIL CONS. DIV.

July 24, 1998

Mr. David Catanach
New Mexico Oil Conservation Division
2040 S. Pacheco
Santa Fe, New Mexico 87505

Fax (505) 827-1389

Re: Request To Be An Interested Party
Case 11996
Application of Pendragon Energy Partners and JK Edwards Assoc.
to Confirm Production from Common Source of Supply
San Juan County, New Mexico

Dear Mr. Catanach:

Merrion Oil & Gas Corporation and RL Bayless Companies have an economic interest in the outcome of the subject hearing. In that regard, we request to be included as Interested Parties in the case. While we may make a statement at the end of the hearing, we do not plan to actively participate with any sworn testimony at this time. However, we would like to preserve our right to participate at a later date should the case be continued or appealed.

Tommy Roberts of the Roberts & Strother law firm will be our council. Please direct any questions to either him (505-325-6810) or myself at 505-327-9801, ext. 114.

Sincerely,

George Sharpe

George F. Sharpe
Manager - Oil & Gas Investments

xc: Frank Chavez - Aztec OCD
Tommy Roberts
RL Bayless

MERRION

OIL & GAS

July 24, 1998

Mr. David Catanach
New Mexico Oil Conservation Division
2040 S. Pacheco
Santa Fe, New Mexico 87505

Fax (505) 827-1389

Re: **Request To Be An Interested Party**
Case 11996
Application of Pendragon Energy Partners and JK Edwards Assoc. to Confirm Production from Common Source of Supply
San Juan County, New Mexico

Dear Mr. Catanach:

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Tommy Roberts of the Roberts & Strother law firm will be our council. Please direct any questions to either him (505-325-6810) or myself at 505-327-9801, ext. 114.

Sincerely,

George Sharpe

George F. Sharpe
Manager - Oil & Gas Investments

xc: Frank Chavez - Aztec OCD
Tommy Roberts
RL Bayless

610 Reilly Avenue • Farmington, New Mexico 87401 • 505-327-9801 / 505-326-5900 (Fax)

Correspondence

June 25, 1998	Copy of Letter from Pendragon to Judge Encinias
June 25, 1998	Copy of Letter from Pendragon to Judge Encinias
June 30, 1998	Letter from Pendragon to Whiting/Maralex requesting Pre-Hearing Statement
July 1, 1998	Letter from Whiting/Maralex to Rand confirming cancellation of July 9th hearing and scheduling for June 28, 29, 1998.
July 8, 1998	Letter from Whiting/Maralex to Rand with copy of Preliminary Injunction against Pendragon issued by Judge Encinias
July 9, 1998	Letter from Pendragon to Rand with copy of Order Regarding Motion to Dismiss for Lack of Jurisdiction
July 10, 1998	Letter from Pendragon to Whiting/Maralex making sure they have all the data on the Chaco 2R. Also Pendragon advises it will be unable to participate in pre-hearing depositions before OCD Hearing.
July 13, 1998	Letter from Whiting/Maralex to Rand advising that Pendragon objects to short depositions before OCD Hearing. Requests short hearing on this issue.
July 13, 1998	Letter from Pendragon to Rand citing reasons Pendragon objects to depositions and advising Rand dates Scott will be available for short hearing.
July 13, 1998	Letter from Whiting/Maralex requesting more information on the Chaco wells.
July 15, 1998	Letter from Whiting/Maralex to Rand with copy of July 13th letter.
July 16, 1998	Letter from Pendragon to Whiting/Maralex withdrawing request for materials to be used by Bradley Robinson.
July 21, 1998	Letter from Whiting/Maralex to Pendragon again requesting information on the Chaco wells. Well files, Water production, disposal, land files, production data.
July 22, 1998	Letter from Pendragon to Whiting/Maralex stating all documents had been produced to Jim Bruce.
July 24, 1998	Letter from Whiting/Maralex to Pendragon stating it has not received all data requested and asking OCD to require that Pendragon provide this data prior to the July 29th hearing.
July 24, 1998	Letter from Whiting/Maralex to Rand concerning Ernie's possible testimony. Also requests copy of Type Log.

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Telephone No. 505-983-6686
Telefax No. 505-986-1367
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July 24, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA HAND DELIVERY
Rand Carroll, Esq.
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

VIA HAND DELIVERY
David Catanach
Hearing Examiner
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application; NMOCD Cause No. 11996

Dear Messrs. Carroll and Catanach:

Ernie Busch of the Aztec office called me yesterday, and indicated that both he and Frank Chavez intend to appear and apparently testify at the hearing in this proceeding. I do not know if they are being called by the Division, or if they are being called by Pendragon. Pendragon has not listed them on the Pre-Hearing Statement which Pendragon has provided to us. If the Division plans on calling witnesses, we would like notice.

Mr. Busch's comments raise a question as to whether the NMOCD or the Aztec office specifically have a Type Log for the Fruitland Formation-Pictured Cliffs boundary in the area of concern for this case, T-26-N, R-12 and 13-W, San Juan County, New Mexico. If such a Type Log exists, we would appreciate it if we could be provided with copies prior to Tuesday's hearing. Thank you for your cooperation.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:rjl
fxc:

Ernie Busch
Frank Chavez
Scott Hall
Walter Ayers
John Hazlett
Mickey O'Hare

// GALLEGOS LAW FIRM
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MICHAEL J. CONDON

July 24, 1998
(Our File No. 98-266.00)

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

Dear Scott:

I just received your letter of July 22, 1998 which was mailed, not faxed, even though we have a deadline to deal with on production.

Unfortunately, your letter misstates our conversations. In addition, it demonstrates an ongoing refusal by Pendragon to produce complete copies of its well files on the Chaco wells and all documents in Pendragon's possession related to the Chaco wells. For instance, in the well files that you produced to Jim Bruce in NMOCD case 11921, there are no copies of Sundry notices, no lease file information, and no documents that reference any water production or disposal of water related to the Chaco well restimulations in 1995. That is precisely why I have been requesting for some time that Pendragon produce their entire wells files for the Chaco wells that are subject to your Application in sufficient time prior to next week's hearing in order to allow us to review the complete well files and all documents in Pendragon's possession that relate to these wells.

Moreover, as I have informed you repeatedly, we have never received the well file for the Chaco 2R well. I am at a lost to explain why you have stonewalled production of these materials, and why Pendragon simply does not produce these documents prior to next week's hearing.

By copy of this letter, I would request that the NMOCD require that Pendragon produce complete well files for all of the Chaco wells at issue in Pendragon's application review complete well files prior to next Tuesday's hearing. Copies of my prior correspondence on these issues are enclosed with the letter to Rand Carroll for his review and convenience.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By
MICHAEL J. CONDON

MJC:rjl
attachments
hd: Rand Carroll (w/encl.)
fxc: Mickey O'Hare
John Hazlett
Jim Bruce
ioc: J.E. Gallegos

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OIL CONSERVATION DIV.

98 JUL 24 PM 3:43

July 8, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Attachments

Re: NMOCD Case No. 11996; Whiting Petroleum, et al. v. Pendragon, et al.
Santa Fe County Cause No. SF-CV-98-01295

Dear Scott:

I have your letter of July 7, 1998 and have sent that along to my clients for review and response. Thank you for the casing collar logs from the recently completed surveys. Regarding tracer survey results and core samples, I am relatively certain that we have neither, since that would require access to the wells which we don't have. However, I will check to verify this.

My understanding is that we do not have digitized data for the frac jobs on the Whiting/Maralex wells. We have checked with Haliburton and they do not have it either. If such data does exist, I will let you know. With respect to the underlying materials and raw data utilized by Bradley Robinson, I believe that the only raw data he had available to him is the data produced by Pendragon in the original NMOCD proceeding, as well as publicly available production data on the Pendragon Chaco wells. Again, I will verify this and get back to you if there is any additional raw data that you do not already have.

My clients inform me that we have never received any materials from your clients on the Chaco 2R well. Would you please provide us with a copy of the well file on the Chaco 2R well? In addition, we would like to get up to date production reports on the Chaco wells, as well as daily production data from the Thompson daily reports that Pendragon receives.

There is one final discovery matter. Obviously, in light of the Preliminary Injunction hearing, you had an opportunity to see the exhibits which our witnesses will use in the NMOCD hearing, and to get testimony from those witnesses on the opinions they intend to offer. We would like to have a level playing field and an equal opportunity to depose your witnesses Al Nicol, Ken Ancell, Roland Blauer, and Jack McCartney

prior to the NMOCD proceeding, and to receive copies of the exhibits they intend to utilize in connection with their testimony. I would suggest July 17 and spilling over to July 18 if necessary. We would prefer to schedule the depositions in Santa Fe, where the court proceeding is filed and where the NMOCD proceeding will take place, but would travel to Denver to take the depositions if that is more convenient.

I will look forward to hearing from you at your earliest convenience.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By MICHAEL J. CONDON

MJC:sa
fxc: Mickey O'Hare
John Hazlett
ioc: J.E. Gallegos

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July 13, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

Dear Scott:

In addition to the documents we have received and have already requested, we would also like to request copies of the complete well files, including but not limited to any documents pertaining to water production, for the Chaco wells. A copy of our subpoena defining the Chaco wells is attached for your review. If water was hauled from any of those wells, we would like the water hauling tickets and any other related documents. If any pits were constructed at the site for water disposal, we would like all documents related to that process. Thank you for your cooperation.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: Mickey O'Hare
John Hazlett
ioc: J.E. Gallegos

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A Professional Corporation

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Telefax No. 505-986-1367
Telefax No. 505-986-0741

MICHAEL J. CONDON

July 15, 1998
(Our File No. 98-266.00)

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

Dear Scott:

I have your letters of July 14, 1998. I have forwarded the requests to my clients and will have a response for you shortly.

On the issue of your clients' production, I think you did not understand my request on the Chaco 2-R. We do not have a copy of the well file that your clients maintain, similar to that produced for the other Chaco wells. I do not know if this was not actually produced, or if it was produced and simply did not make it into our well files here. In any event, we need another copy of Pendragon's Chaco 2-R well file.

With respect to all of the Chaco wells, while we have certain documents that one would expect to be in a well file, the files you produced did not include any C-101, C-102, C-103, C-104 or C-105 forms. We would like to look at Pendragon's copies of those documents, in addition to reviewing the documents which are part of the public record file. We already have those, so we do not need copies of the separate NMOCD well files. In addition, as I stated in my latest correspondence, we need any and all documents related to water production from the Chaco wells. There are no such documents in the files you have produced, even though numerous witnesses, including Ernie Busch, witnessed water production at the Chaco wells.

The fact that water production documents and sundry notices were not produced as part of the well files is troubling. If those documents were not produced, what other documents related to the Chaco wells have not been produced? It is for that reason that we have requested the production of complete well files for all the Chaco wells. I would appreciate being provided with the requested documents sufficiently in advance of the July 28 hearing to allow for their meaningful review. Thank you for your cooperation.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By
MICHAEL J. CONDON

MJC:sa
fxc: Mickey O'Hare
John Hazlett
ioc: J.E. Gallegos

GALLEGOS LAW FIRM

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MICHAEL J. CONDON

July 17, 1998
(Our File No. 98-266.00)

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

Dear Scott:

I am writing in response to your letter of July 14, 1998 requesting "raw underlying data" utilized by Brad Robinson in connection with his testimony at the preliminary injunction hearing. Many of your categories are not really requesting raw data, but rather assumptions and figures utilized in forming his opinions. Specifically, your requests 5, 6 and 7 are not truly requests for raw data.

What I would propose is that we agree to simultaneously exchange documents and information prior to the hearing, in time to allow for meaningful review, including the opinions of your witnesses, the various assumptions, cut-off figures, clay content figures, and water saturation figures utilized by both of our witnesses and experts in connection with this proceeding. We will not agree to any procedure where we provide you not only our opinions, which you already have, and all underlying assumptions for our witnesses' opinions, but you refuse to provide us with the opinions your witnesses intend to offer or the underlying data and assumptions for those opinions.

With respect to your requests 1 and 2, the production data that was utilized was production data obtained at considerable expense from either Petroleum Information or Dwights on the Chaco wells operated by Pendragon, and on 139 other Pictured Cliff wells in the area, and 59 additional coal wells in the area. We will agree to provide you with a list of the wells for which we obtained publicly available production data, and you can then obtain the production data yourself.

Requests 3, 4 and 8 involve data exchanged by and between Whiting and Pendragon in the original NMOCD case. That is, you already have the data underlying the testimony Mr. Robinson intends to give on these issues. Again, we are not willing to provide additional information to you prior to the hearing unless you are willing to agree to a fair and full exchange of information, where you would provide us with the opinions, assumptions and bases for your witnesses' testimony.

This brings us to our requests for information. Specifically, my prior letters to you have requested copies of the complete well files on the Pendragon Chaco wells, all documents related in any way to water production from the wells, all notices filed with any regulatory body related to the Chaco wells since 1995, and the complete file on the Chaco 2-R well. In addition, we would request the following documents:

1. Any data or documents that allegedly support a claim of "skin damage," justification for restimulations, and projections of results of the restimulation procedure performed on the Chaco Nos. 1, 2-R, 4 and 5 wells.

2. All files which would contain or include title documents, assignments, evidence of purchase payment title opinions, and correspondence related to the manner and terms by which Edwards and Pendragon came to acquire their interests in the Chaco wells and the Pictured Cliffs formation.

3. Any documents, texts, treatises, articles, industry standards or things your witnesses will rely on for their testimony at the hearing, including but not limited to:

    a. Articles, logs, exhibits from prior NMOCD proceedings, or other documents which concern locating the base of the Fruitland Coal formation and the top of the Pictured Cliffs formation;

    b. Reserve calculations and evaluations for the Chaco wells;

    c. Documents which establish or justify any assumptions used to calculate drainage areas for the Chaco wells;

    d. Pressure data for the Chaco wells;

    e. All documents upon which Mr. Blauer or any other witness intends to rely to characterize the effect and result of the fracture simulation jobs performed on the Chaco wells;

    f. Porosity cut-off figures your witnesses intend to utilize for their reserve analysis;

g. Water saturation data, assumptions or figures for the Pictured Cliffs formation which your witnesses intend to use in support of their testimony;

h. Formation clay content figures or assumptions your witnesses intend to use in support of their testimony; and

i. Any other documents, assumptions, or figures your witnesses intend to use in support of any opinion testimony you intend to offer at the NMOCD proceeding in this case.

I look forward to hearing from you at your earliest convenience. We need production and any exchange of information to occur no later than July 22, 1998 for meaningful preparation.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: Mickey O'Hare
John Hazlett
ioc: J.E. Gallegos

GALLEGOS LAW FIRM
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MICHAEL J. CONDON

July 21, 1998
(Our File No. 98-266.00)

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

Dear Scott:

I have your letter of July 16, 1998. There remains the outstanding issue of the production of the Pendragon well files on the Chaco wells, including the Chaco 2R, documents related to water production and disposal from the Chaco wells, land files for the Pendragon Chaco wells, as well as the most current production data for the Chaco wells. Please let me know when we will be in a position to exchange information prior to the hearing.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: Mickey O'Hare
John Hazlett
Bruce Williams
Rand Carroll, Esq.
David Catanach
ioc: J.E. Gallegos

GALLEGOS LAW FIRM
A Professional Corporation

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Telefax No. 505-986-0741

MICHAEL J. CONDON

July 23, 1998
(Our File No. 98-266.00)

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

Dear Scott:

Bruce Williams of Whiting received a call from Jack McCartney this afternoon, asking for updated production information. We are prepared to exchange production data, and have been, but have not heard from you on when the most recent Pendragon production data will be provided, when we can expect copies of the Chaco well files and other documents pertaining to gas and water production from the Chaco wells, a complete copy of the Chaco 2R well file, as well as copies of the various sundry notices and APDs in Pendragon's and Edwards' files. Rather than have the witnesses trying to exchange information, I would rather do this through our offices. Please advise when you will be prepared to exchange the requested information.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:rjl
fxc: Mickey O'Hare
John Hazlett
ioc: J.E. Gallegos

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PLEASE REPLY TO SANTA FE

July 22, 1998

Michael J. Condon, Esq.
Gallegos Law Firm, P. C.
460 St. Michaels Dr., #300
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K .Edwards Associates, Inc., San Juan County, New Mexico

Dear Michael:

As we discussed today, I believe our earlier production of documents with respect to well files for the Chaco wells was complete. I understand you may not have received all the file materials that were produced to Jim Bruce last winter in NMOCD Case No. 11921 and that you and he will soon undertake a review of those documents. Please let me know the results of that review and if anything appears to be missing, I will make every effort to make sure you have all responsive documents to the extent the same are contained in our clients' files.

I am still unclear whether you had located the post-frac summary report on the Chaco 2-R well. We confirmed that this particular document was produced earlier. However, another copy is enclosed in any event.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

Elizabeth A. McGee for J. Scott Hall

J. Scott Hall

JSH/eam
Enclosure
cc: Rand Carroll, Esq. NMOCD w/o enclos.

GALLEGOS LAW FIRM
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Telefax No. (505) 986-0741 or (505) 986-1367

CLIENT: **WHITING**
CLIENT NO.: 98-266.00

DATE: **July 21, 1998**

TO: **Rand Carroll**

COMPANY: **New Mexico Oil Conservation Division**

TELEFAX NO.: **(505) 827-8177**

FROM: **Michael J. Condon**

MESSAGE:

NUMBER OF PAGES INCLUDING COVER SHEET: **2**

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MICHAEL J. CONDON

July 21, 1998
(Our File No. 98-266.00)

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

Dear Scott:

I have your letter of July 16, 1998. There remains the outstanding issue of the production of the Pendragon well files on the Chaco wells, including the Chaco 2R, documents related to water production and disposal from the Chaco wells, land files for the Pendragon Chaco wells, as well as the most current production data for the Chaco wells. Please let me know when we will be in a position to exchange information prior to the hearing.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: Mickey O'Hare
John Hazlett
Bruce Williams
Rand Carroll, Esq.
David Catanach
ioc: J.E. Gallegos

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PLEASE REPLY TO SANTA FE

July 16, 1998

Michael J. Condon, Esq.
Gallegos Law Firm, P. C.
460 St. Michaels Dr., #300
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Michael:

In the interests of efficiency, I am hereby withdrawing my earlier requests for the information and materials utilized by your expert, Bradley Robinson, in order to avoid any disputes over the discovery of expert witness "underlying data" in this case.

Thank you for your cooperation.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall

JSH/eam
cc: Rand Carroll, Esq. NMOCD

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Telefax No. 505-986-0741

JUL 16 1998

CONFIRMATION COPY OF FACSIMILE

MICHAEL J. CONDON

July 15, 1998
(Our File No. 98-266.00)

VIA TELECOPY
Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application Cause No. 11996

Dear Rand:

Attached is a copy of the latest letter I sent to Scott Hall on the document discovery matters in anticipation of the hearing in this case. If you need anything else, please let me know.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
Attachment
fxc: Scott Hall
John Hazlett
Mickey O'Hare
ioc: J.E. Gallegos

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Telefax No. 505-986-0741

July 13, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

Dear Scott:

In addition to the documents we have received and have already requested, we would also like to request copies of the complete well files, including but not limited to any documents pertaining to water production, for the Chaco wells. A copy of our subpoena defining the Chaco wells is attached for your review. If water was hauled from any of those wells, we would like the water hauling tickets and any other related documents. If any pits were constructed at the site for water disposal, we would like all documents related to that process. Thank you for your cooperation.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: Mickey O'Hare
John Hazlett
ioc: J.E. Gallegos

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CLIENT: WHITING
CLIENT NO.: 98-266.00

DATE: **July 15, 1998**

TO: **Rand Carroll**

COMPANY: **New Mexico Oil Conservation Division**

TELEFAX NO.: **(505) 827-8177**

FROM: **Michael J. Condon**

MESSAGE:

NUMBER OF PAGES INCLUDING COVER SHEET: 3

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MICHAEL J. CONDON

July 15, 1998
(Our File No. 98-266.00)

VIA TELECOPY
Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application Cause No. 11996

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July 13, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: Pendragon Application NMOCD Case No. 11996

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CONFIRMATION COPY OF FACSIMILE

MICHAEL J. CONDON

July 13, 1998
(Our File No. 98-266.00)

RECEIVED
JUL 14 1998

VIA TELECOPY
Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application Cause No. 11996

Dear Rand:

On Wednesday, July 8, 1998, I wrote Scott Hall requesting that we have an opportunity to level the playing field for the upcoming hearing by taking short depositions of the witnesses they have identified in their initial Pre-Hearing Statement. A copy is attached. Pendragon is the applicant in this proceeding, and has had an opportunity to hear the testimony of our witnesses in the district court proceeding on the hearing for preliminary injunction. They have also been provided with many documents we intend to utilize as exhibits at the upcoming hearing in this matter. Due to the nature of the application, and given that Pendragon has already in essence been provided with discovery from our witnesses, we would request the same courtesy. Since Scott has not responded to my letter, I assume Pendragon objects to this request.

We would request a short hearing on this matter at your earliest convenience.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
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July 8, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
& Schlenker, P.A.
150 Washington, Suite 300
Santa Fe, New Mexico 87501

Re: NMOCD Case No. 11996; Whiting Petroleum, et al. v. Pendragon, et al.
Santa Fe County Cause No. SF-CV-98-01295

Dear Scott:

I have your letter of July 7, 1998 and have sent that along to my clients for review and response. Thank you for the casing collar logs from the recently completed surveys. Regarding tracer survey results and core samples, I am relatively certain that we have neither, since that would require access to the wells which we don't have. However, I will check to verify this.

My understanding is that we do not have digitized data for the frac jobs on the Whiting/Maralex wells. We have checked with Haliburton and they do not have it either. If such data does exist, I will let you know. With respect to the underlying materials and raw data utilized by Bradley Robinson, I believe that the only raw data he had available to him is the data produced by Pendragon in the original NMOCD proceeding, as well as publicly available production data on the Pendragon Chaco wells. Again, I will verify this and get back to you if there is any additional raw data that you do not already have.

My clients inform me that we have never received any materials from your clients on the Chaco 2R well. Would you please provide us with a copy of the well file on the Chaco 2R well? In addition, we would like to get up to date production reports on the Chaco wells, as well as daily production data from the Thompson daily reports that Pendragon receives.

There is one final discovery matter. Obviously, in light of the Preliminary Injunction hearing, you had an opportunity to see the exhibits which our witnesses will use in the NMOCD hearing, and to get testimony from those witnesses on the opinions they intend to offer. We would like to have a level playing field and an equal opportunity to depose your witnesses Al Nicol, Ken Ancell, Roland Blauer, and Jack McCartney

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Telefax No. (505) 986-0741 or (505) 986-1367

CLIENT: WHITING
CLIENT NO.: 98-266.00

DATE: **July 13, 1998**

TO: **Rand Carroll**

COMPANY: **New Mexico Oil Conservation Division**

TELEFAX NO.: **(505) 827-8177**

FROM: **Michael J. Condon**

MESSAGE:

NUMBER OF PAGES INCLUDING COVER SHEET: 4

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MICHAEL J. CONDON

July 13, 1998
(Our File No. 98-266.00)

VIA TELECOPY
Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application Cause No. 11996

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GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

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ioc: J.E. Gallegos

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July 8, 1998
(Our File No. 98-266.00)

MICHAEL J. CONDON

VIA TELECOPY
J. Scott Hall
Miller, Stratvert, Torgerson
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150 Washington, Suite 300
Santa Fe, New Mexico 87501

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WILLIAM K. STRATVERT, COUNSEL
PAUL W. ROBINSON, COUNSEL
RALPH WM. RICHARDS, COUNSEL
ROSS B. PERKAL, COUNSEL

PLEASE REPLY TO SANTA FE

RECEIVED
JUL 14 1998
OIL CONSERVATION DIVISION

July 13, 1998

Bayless & Merrion & Tommy Roberts w/ Whiting Maralex

BY: FACSIMILE 827-8177
Mr. Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco Street
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Rand:

Attached is a copy of my July 10th reply to Michael Condon's July 8, 1998 correspondence suggesting we engage in depositions before the July 28th examiner hearing in the above matter. I believe you were copied with the July 10th letter, but I am taking the precaution of sending you another. It appears Mr. Condon's July 13, 1998 fax letter to you was sent before Michael received my July 10th reply. In any event, we do object to the "request" and do not wish to see this issue result in a further delay of the hearing now set for July 28th and 29th.

It should be borne in mind that Whiting and Maralex have been pursuing their claim before the Division for over two years. Indeed, Pendragon and Edwards willingly participated in the meetings with Whiting and Maralex at the Division's Aztec District Office where the issues and proof were the subject of free and open discussion. Accordingly, Whiting and Maralex are fully aware of the issues involved in this case and have had adequate opportunity to prepare. At the same time, we did not have the opportunity to depose the Whiting and Maralex witnesses before the preliminary injunction hearing and note further that those witnesses were not listed on the Whiting and Maralex Pre-Hearing Statement filed with the Division in this case.

I don't believe a hearing on this matter should be necessary. However, should you wish to consider the matter further, the only times I have available to attend a hearing this week are on Thursday (all day) or Friday (morning only). I will be out of town the week of July 20th.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall

JSH/eam
Enclosure
cc: Michael Condon, Esq.
Al Nicol
Keith Edwards

C

MILLER, STRATVERT & TORGERSON, P. A.
LAW OFFICES

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PLEASE REPLY TO SANTA FE

July 10, 1998

Michael Condon, Esq.
Gallegos Law Firm
460 St. Michaels Drive, Building 300
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Michael:

I am attempting to verify the production of documents on the Chaco 2-R. Our records reflect a substantial number of documents were produced to Jim Bruce last winter pursuant to the subpoena duces tecum issued by the NMOCD in Case No. 11921. If there are documents of a particular nature that appear to be missing or incomplete, please let me know. We will make sure we have completely complied with the subpoena in any event and will produce the well file again, if needed. In the interim, we have obtained a copy of the complete NMOCD well file on the Chaco 2-R and will be pleased to send you a copy of the same. Please advise. We will also endeavor to supply you with up to date production data and understand your clients will do the same.

Separately, we will be unable to accommodate the untimely request to conduct depositions in advance of the NMOCD hearing for the reasons that (1) my schedule simply won't allow it and (2) the rules and practice of the New Mexico Oil Conservation Division do not provide for pre-hearing depositions. Moreover, the fact that only the Plaintiffs were afforded an opportunity to present witness testimony at the June 29, 1998 injunction hearing was a result of their insistence on having an expedited hearing with only a half-day setting, even though you were advised that a full hearing would require one and one-half days, at least. If anything, I think the fact that an injunction

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Very truly yours,

MILLER, STRATVERT & TORGERSON, P. A.

J. Scott Hall

J. Scott Hall, Esq.

JSH:MBC
cc: Rand Carroll, Esq., NMOCD
Al Nicol, Pendragon Energy Partners, Inc.
Keith Edwards, J. K. Edwards Associates, Inc.

:condonltr.dot

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PLEASE REPLY TO SANTA FE

FACSIMILE TRANSMISSION COVER SHEET

DATE: July 13, 1998

TO: Rand Carroll — FAX NO.: 827-8177

FROM: J. Scott Hall — OPERATOR: Betty

MESSAGE: For your information

NUMBER OF PAGES INCLUDING COVER SHEET: 5

IF YOU DO NOT RECEIVE THE ENTIRE DOCUMENT, PLEASE CALL OUR SANTA FE OFFICE AS SOON AS POSSIBLE AT (505) 989-9614.

* * * * * * * * *

MILLER, STRATVERT & TORGERSON, P. A.

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PLEASE REPLY TO SANTA FE

July 13, 1998

<u>BY: FACSIMILE 827-8177</u>
Mr. Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco Street
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Rand:

Attached is a copy of my July 10th reply to Michael Condon's July 8, 1998 correspondence suggesting we engage in depositions before the July 28th examiner hearing in the above matter. I believe you were copied with the July 10th letter, but I am taking the precaution of sending you another. It appears Mr. Condon's July 13, 1998 fax letter to you was sent before Michael received my July 10th reply. In any event, we do object to the "request" and do not wish to see this issue result in a further delay of the hearing now set for July 28th and 29th.

It should be borne in mind that Whiting and Maralex have been pursuing their claim before the Division for over two years. Indeed, Pendragon and Edwards willingly participated in the meetings with Whiting and Maralex at the Division's Aztec District Office where the issues and proof were the subject of free and open discussion. Accordingly, Whiting and Maralex are fully aware of the issues involved in this case and have had adequate opportunity to prepare. At the same time, we did not have the opportunity to depose the Whiting and Maralex witnesses before the preliminary injunction hearing and note further that those witnesses were not listed on the Whiting and Maralex Pre-Hearing Statement filed with the Division in this case.

I don't believe a hearing on this matter should be necessary. However, should you wish to consider the matter further, the only times I have available to attend a hearing this week are on Thursday (all day) or Friday (morning only). I will be out of town the week of July 20th.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall

JSH/eam
Enclosure
cc: Michael Condon, Esq.
Al Nicol
Keith Edwards

C

MILLER, STRATVERT & TORGERSON, P. A.

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PLEASE REPLY TO SANTA FE

July 10, 1998

Michael Condon, Esq.
Gallegos Law Firm
460 St. Michaels Drive, Building 300
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Michael:

I am attempting to verify the production of documents on the Chaco 2-R. Our records reflect a substantial number of documents were produced to Jim Bruce last winter pursuant to the subpoena duces tecum issued by the NMOCD in Case No. 11921. If there are documents of a particular nature that appear to be missing or incomplete, please let me know. We will make sure we have completely complied with the subpoena in any event and will produce the well file again, if needed. In the interim, we have obtained a copy of the complete NMOCD well file on the Chaco 2-R and will be pleased to send you a copy of the same. Please advise. We will also endeavor to supply you with up to date production data and understand your clients will do the same.

Separately, we will be unable to accommodate the untimely request to conduct depositions in advance of the NMOCD hearing for the reasons that (1) my schedule simply won't allow it and (2) the rules and practice of the New Mexico Oil Conservation Division do not provide for pre-hearing depositions. Moreover, the fact that only the Plaintiffs were afforded an opportunity to present witness testimony at the June 29, 1998 injunction hearing was a result of their insistence on having an expedited hearing with only a half-day setting, even though you were advised that a full hearing would require one and one-half days, at least. If anything, I think the fact that an injunction

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Very truly yours,

MILLER, STRATVERT & TORGERSON, P. A.

J. Scott Hall

J. Scott Hall, Esq.

JSH:MBC
cc: Rand Carroll, Esq., NMOCD
Al Nicol, Pendragon Energy Partners, Inc.
Keith Edwards, J. K. Edwards Associates, Inc.

:condonltr.dot

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PLEASE REPLY TO SANTA FE

July 10, 1998

Michael Condon, Esq.
Gallegos Law Firm
460 St. Michaels Drive, Building 300
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc., San Juan County, New Mexico

Dear Michael:

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MILLER, STRATVERT & TORGERSON, P. A.

J. Scott Hall

J. Scott Hall, Esq.

JSH:MBC
cc: Rand Carroll, Esq., NMOCD
Al Nicol, Pendragon Energy Partners, Inc.
Keith Edwards, J. K. Edwards Associates, Inc.

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PLEASE REPLY TO SANTA FE

July 9, 1998

Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Whiting Petroleum, et al. v. Pendragon, et al. Santa Fe County
Cause No SF-CV-98-01295

Dear Rand:

For your information, enclosed please find a copy of Order Regarding Motion To Dismiss For Lack Of Jurisdiction filed on July 6, 1998.

Very Truly Yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall

JSH/eam
Enclosure
cc: J.E. Gallegos
Al Nichols
Keith Edwards
w/o enclosures

ENDORSED

JUL 0 6 1998

FIRST JUDICIAL DISTRICT COURT
SANTA FE, RIO ARRIBA & LOS ALAMOS COUNTIES
P. O. Box 2268
Santa Fe, New Mexico 87504-2268
JoAnn Vigil Quintana
Court Administrator/District Court Clerk

FIRST JUDICIAL DISTRICT COURT
COUNTY OF SANTA FE
STATE OF NEW MEXICO

WHITING PETROLEUM CORPORTION, a corporation, and MARALEX RESOURCES, INC., a corporation,

Plaintiffs,

vs. No. D-0101-CV-98-01295

PENDRAGON ENERGY PARTNERS, INC., a corporation, and J.K. EDWARDS ASSOCIATES, INC., a corporation,

Defendants.

ORDER REGARDING MOTION TO DISMISS FOR LACK OF JURISDICTION

THIS MATTER having come before the court on June 29, 1998 on Defendants' Motion to Dismiss For Lack of Subject Matter Jurisdiction Or, In the Alternative, For Failure to State A Claim Upon Which Relief Can Be Granted, the parties having appeared by counsel and the Court having reviewed the pleadings and having heard argument of counsel for the parties, concludes as follows:

1. This Court has jurisdiction over the subject matter of this case and the claims alleged by Plaintiffs, and the Defendants' motion to dismiss for lack of subject matter jurisdiction is denied in part and granted in part.

2. Defendants have requested that the Court refer this matter to the New Mexico Oil Conservation Division under the doctrine of primary jurisdiction. This Court has determined to defer to the jurisdiction of the New Mexico oil Conservation Division in view of the greater expertise of the New Mexico Oil Conservation Division in this particular field and to promote more uniform decision making.

3. Those issues raised by the lawsuit which relate to the parties' relative rights in the land and are subject to meaningful relief through the New Mexico Oil Conservation Division should be recognized as within the jurisdiction of the New Mexico Oil Conservation Division. What the Court retains are those claims, regardless of how they are denominated that are not susceptible of relief through the New Mexico Conservation Division.

IT IS THEREFORE ORDERED that Defendants' Motion to Dismiss For Lack Of Subject Matter Jurisdiction Or, In The Alternative, For Failure To State A Claim Upon Which Relief Can Be Granted be and hereby is denied in part and granted in part and as a matter of comity, the Court defers to the New Mexico Oil Conservation Division as above stated.

[signature]

The Honorable Art Encinias
District Judge 7/6/98

GALLEGOS LAW FIRM

A Professional Corporation

460 St. Michael's Drive
Building 300
Santa Fe, New Mexico 87505
Telephone No. 505-983-6686
Telefax No. 505-986-1367
Telefax No. 505-986-0741

CONFIRMATION COPY OF FACSIMILE

MICHAEL J. CONDON

July 8, 1998
(Our File No. 98-266.00)

RECEIVED
JUL - 9 1998

VIA TELECOPY
Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application Cause No. 11996

Dear Rand:

Attached please find a copy of the Preliminary Injunction which was entered in the court proceeding on July 7, 1998. If you have any questions, please contact me.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: Scott Hall
John Hazlett
Mickey O'Hare
ioc: J.E. Gallegos

ENDORSED

JUL 07 1998

FIRST JUDICIAL DISTRICT COURT
SANTA FE, RIO ARRIBA & LOS ALAMOS COUNTIES
P. O. Box 2268
Santa Fe, New Mexico 87504-2268
JoAnn Vigil Quintana
Court Administrator/District Court Clerk

FIRST JUDICIAL DISTRICT COURT
COUNTY OF SANTA FE
STATE OF NEW MEXICO

WHITING PETROLEUM CORPORATION, a corporation, and MARALEX RESOURCES, INC., a corporation,

Plaintiffs,

vs. **No. SF-CV-98-01295**

PENDRAGON ENERGY PARTNERS, INC., a corporation, and J.K. EDWARDS ASSOCIATES, INC., a corporation

Defendants.

PRELIMINARY INJUNCTION

THIS MATTER came before the Court on June 29, 1998 on Plaintiffs' Verified Application for Preliminary Injunction with the parties appearing by their corporate representatives and counsel. The Court having received evidence and arguments of counsel for all parties, FINDS that good grounds have been established in behalf of the plaintiffs' Application and it should be granted.

Upon the evidence presented and application of the law concerning issuance of preliminary injunctions the Court CONCLUDES AS FOLLOWS:

1. The Court has jurisdiction of the parties and of the subject matter.

2. Plaintiffs have established a substantial likelihood that they will prevail on the merits of their claim that defendants have trespassed into plaintiffs' Fruitland formation and that defendants are converting the plaintiffs' gas.

3. Issuance of an injunction may cause harm to defendants but the continuing harm to plaintiffs should the injunction not issue greatly outweighs the harm

to the defendants.

4. Issuance of an injunction against defendants' continued taking of plaintiffs' gas will not be adverse to the public interest.

5. The Court has weighed the factors to be considered under New Mexico law in determining whether to issue a preliminary injunction and having done so concludes that the Application for Preliminary Injunction in behalf of plaintiffs is well taken and should be granted.

IT IS THEREFORE ORDERED AS FOLLOWS:

1. The defendants upon entry of this Preliminary Injunction shall immediately shut-in Chaco wells 1, 2R, 4 and 5 and cease and desist all gas production therefrom.

2. This Preliminary Injunction is to remain in force for a period of ninety (90) days from entry, or until further order of the Court, to permit review by the Court and consideration by the New Mexico Oil Conservation Division or New Mexico Oil Conservation Commission on certain issues within their administrative jurisdiction.

3. The Court will review this matter prior to the expiration of ninety (90) days from entry to consider the disposition of an administrative proceeding, if any, and to make any further orders as may be deemed appropriate or necessary.

4. No bond shall be required of plaintiffs, however, defendants are encouraged to track production loss in the event they become entitled to claim they have been wronged by the issuance of this Preliminary Injunction.

____
The Honorable Art Encinias
District Judge

ORIGINAL SIGNED BY
ART ENCINIAS

GALLEGOS LAW FIRM

A Professional Corporation

460 St. Michael's Drive
Building 300
Santa Fe, New Mexico 87505
Telephone No. (505) 983-6686
Telefax No. (505) 986-0741 or (505) 986-1367

CLIENT: WHITING
CLIENT NO.: 98-266.00

DATE:	**July 8, 1998**
TO:	**Rand Carroll**
COMPANY:	**New Mexico Oil Conservation Division**
TELEFAX NO.:	**(505) 827-7177** 8177
FROM:	**Michael J. Condon**

MESSAGE:

NUMBER OF PAGES INCLUDING COVER SHEET: 5

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OF FACSIMILE

MICHAEL J. CONDON

July 8, 1998
(Our File No. 98-266.00)

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Santa Fe, New Mexico 87505

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By [signature]
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ENDORSED

JUL 0 7 1998

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4. Issuance of an injunction against defendants' continued taking of plaintiffs' gas will not be adverse to the public interest.

5. The Court has weighed the factors to be considered under New Mexico law in determining whether to issue a preliminary injunction and having done so concludes that the Application for Preliminary Injunction in behalf of plaintiffs is well taken and should be granted.

IT IS THEREFORE ORDERED AS FOLLOWS:

1. The defendants upon entry of this Preliminary Injunction shall immediately shut-in Chaco wells 1, 2R, 4 and 5 and cease and desist all gas production therefrom.

2. This Preliminary Injunction is to remain in force for a period of ninety (90) days from entry, or until further order of the Court, to permit review by the Court and consideration by the New Mexico Oil Conservation Division or New Mexico Oil Conservation Commission on certain issues within their administrative jurisdiction.

3. The Court will review this matter prior to the expiration of ninety (90) days from entry to consider the disposition of an administrative proceeding, if any, and to make any further orders as may be deemed appropriate or necessary.

4. No bond shall be required of plaintiffs, however, defendants are encouraged to track production loss in the event they become entitled to claim they have been wronged by the issuance of this Preliminary Injunction.

ORIGINAL SIGNED BY ART ENCINIAS

The Honorable Art Encinias
District Judge

ORIGINAL SIGNED BY
ART ENCINIAS

Submitted on Notice of Presentment:

GALLEGOS LAW FIRM, P.C.

By______________________________
J.E. Gallegos
Michael J. Condon
460 St. Michael's Drive, Bldg. 300
Santa Fe, New Mexico 87505

Attorneys for Plaintiffs

GALLEGOS LAW FIRM
A Professional Corporation

460 St. Michael's Drive
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Santa Fe, New Mexico 87505
Telephone No. 505-983-6686
Telefax No. 505-986-1367
Telefax No. 505-986-0741

JUL - 2 1998

CONFIRMATION COPY
OF FACSIMILE

MICHAEL J. CONDON

July 1, 1998
(Our File No. 98-266.00)

VIA TELECOPY
Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application Cause No. 11996

Dear Rand:

I just wanted to write to confirm our conversation of yesterday and our understanding that there will be no hearing on Thursday, July 9, 1998 on Pendragon's Application in this matter. I assume we do not need to appear next Thursday. If that assumption is incorrect, please let me know.

You indicated that you would tentatively schedule the matter for hearing on July 28 and 29, 1998, but would need to confirm that date when David Catanach returns to the office next week. You will send us a formal notice setting the hearing at that time.

Thank you for your time and consideration.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By [signature]
MICHAEL J. CONDON

MJC:sa
fxc: John Hazlett
Mickey O'Hare
ioc: Michael J. Condon

GALLEGOS LAW FIRM

A Professional Corporation

460 St. Michael's Drive
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Santa Fe, New Mexico 87505
Telephone No. (505) 983-6686
Telefax No. (505) 986-0741 or (505) 986-1367

CLIENT: WHITING
CLIENT NO.: 98-266.00

DATE: **July 1, 1998**

TO: **Rand Carroll**

COMPANY: **New Mexico Oil Conservation Division**

TELEFAX NO.: **(505) 827-7177**

FROM: **Michael J. Condon**

MESSAGE:

NUMBER OF PAGES INCLUDING COVER SHEET: 2

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MICHAEL J. CONDON

July 1, 1998
(Our File No. 98-266.00)

VIA TELECOPY
Rand Carroll
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87505

Re: Pendragon Application Cause No. 11996

Dear Rand:

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Thank you for your time and consideration.

Very truly yours,

GALLEGOS LAW FIRM, P.C.

By Michael J. Condon
MICHAEL J. CONDON

MJC:sa
fxc: John Hazlett
Mickey O'Hare
ioc: Michael J. Condon

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June 30, 1998

Case File 11996

J. E. Gallegos, Esq.
Michael Condon, Esq.
Gallegos Law Firm, P.C.
460 St. Michaels Drive
Building 300
Santa Fe, New Mexico 87505

Re: NMOCD Case No. 11996; Application of Pendragon Energy, Inc., and J. K. Edwards Associates, Inc.

Dear Counsel:

Please provide me with a copy of the Pre-hearing Statement filed earlier by you in the above matter.

This is the second request for a copy.

Very truly yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall, Esq.

JSH:MBC
cc: David Catanach, NMOCD
Rand Carroll, NMOCD

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PLEASE REPLY TO SANTA FE

June 25, 1998

BY HAND DELIVERY
Honorable Art Encinias
District Judge
1st Judicial District Court
P. O. Box 2268
Santa Fe County Judicial Complex Bldg.
Santa Fe, New Mexico 87504-2268

Re: Whiting Petroleum Corporation and Maralex Resources, Inc. v. Pendragon Energy Partners, Inc. and J. K. Edwards Associates, Inc.; No. D-0101-CV-9801295

Dear Judge Encinias:

This morning, I was advised that Plaintiffs' counsel had obtained a June 29th setting on their Application for Preliminary Injunction Requiring Defendants To Shut-In Gas Wells. In this regard, it appears counsel may not have informed the Court that this same subject matter is presently scheduled for a hearing on the merits before the New Mexico Oil Conservation Division on July 9, 1998.

We are this day filing the following motions: (1) Defendants' Motion To Dismiss For Improper Venue and (2) Motion To Dismiss For Lack of Subject Matter Jurisdiction. We are also filing the Defendants Response To Application For Preliminary Injunction.

In our view, the venue and subject matter jurisdiction issues call into question the Court's authority to issue a preliminary injunction order in the first place. Consequently, we ask that these two motions be addressed, on an expedited basis, before the Court takes up the Application for Preliminary Injunction. To facilitate the Court's consideration of this request, we are providing you with courtesy copies of the following:

1. Defendants' Motion To Dismiss For Improper Venue;
2. Defendants' Motion To Dismiss For Lack Of Subject Matter Jurisdiction Or, In The Alternative, For Failure To State A Claim Upon Which Relief Can Be Granted;
3. Defendants' Memorandum In Response To Plaintiffs' Application For A Preliminary Injunction;
4. Defendants' Response To Plaintiffs' Motion For An Order Enjoining Defendants From Prosecuting an Administrative Proceeding along with a copy of Plaintiffs' motion therefore; and
5. LR 1-306.I(4) Request For Expedited Hearing

We request that these matters be considered as the first order of business at the hearing on Monday, June 29, 1998.

Thank you for your consideration of this request.

Very truly yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall, Esq.

JSH:MBC
cc: Michael Condon, Esq. and
J. E. Gallegos, Gallegos Law Firm
Alan Konrad, Esq. and
Marte Lightstone, Esq. of
Miller, Stratvert & Torgerson
Rand Carroll, Esq., New Mexico Oil
Conservation Division

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PLEASE REPLY TO SANTA FE

June 25, 1998

BY HAND DELIVERY
Honorable Art Encinias
District Judge
1st Judicial District Court
P. O. Box 2268
Santa Fe County Judicial Complex Bldg.
Santa Fe, New Mexico 87504-2268

Re: Whiting Petroleum Corporation and Maralex Resources, Inc. v. Pendragon Energy Partners, Inc. and J. K. Edwards Associates, Inc.; No. D-0101-CV-9801295

Dear Judge Encinias:

After I was made aware this morning of the June 29th hearing setting in the above matter, I immediately began to contact my witnesses to arrange for their appearance here next Monday. It turns out that two of my witnesses, Ken Ancell, and Roland Blauer, cannot be present in Santa Fe on Monday. Mr. Ancell has a previous commitment before a regulatory body in Texas and Mr. Blauer is leaving tomorrow for a job in Australia. See attached fax copies of a letter and affidavit from Mr. Ancell and Mr. Blauer.) Both Mr. Ancell and Mr. Blauer are petroleum engineers and their expert testimony will be essential in the context of any hearing on a preliminary injunction application. In fact, Mr. Blauer designed the reservoir fracture stimulation treatment jobs that are directly at issue in this proceeding.

Additionally, I conferred with Mr. Condon today, and we are in agreement that it will take at least one and one-half days to present the necessary witness testimony in a preliminary injunction hearing. Mr. Condon also indicated he is experiencing problems arranging for the attendance of some of his witnesses on Monday.

In view of the above, and in view of the fact that the Defendants have filed motions to dismiss for improper venue and lack of subject matter jurisdiction, I would suggest that the resources of the Court and the parties would be better utilized by vacating Monday's hearing on the preliminary injunction application and devoting that same setting to hear the Defendants' motions instead. I should advise you, however, that Mr. Condon does not agree to vacating the preliminary injunction hearing at this time.

Thank you for your consideration of this request. Please have your office inform us of your wishes in this regard by tomorrow so we can advise our witnesses accordingly.

Very truly yours,

MILLER, STRATVERT & TORGERSON, P.A.

J. Scott Hall

J. Scott Hall, Esq.

JSH:MBC
Enclosure
cc: Michael Condon, Esq. and
J. E. Gallegos, Gallegos Law Firm (w/encl.)
Alan Konrad, Esq. and
Marte Lightstone, Esq. of
Miller, Stratvert & Torgerson (w/encl.)
Rand Carroll, Esq., New Mexico Oil
Conservation Division (w/encl.)

:encinias1ltr.dot

STATE OF COLORADO)
) ss.
COUNTY OF DENVER)

AFFIDAVIT OF ROLAND E. BLAUER

Roland E. Blauer, being duly sworn, states:

1. I am the age of majority and am otherwise competent to testify to the matters set forth herein. I also have personal knowledge of the facts set forth in this affidavit.

2. I am a petroleum engineer and am employed by Resource Services International, Inc. located in Denver, Colorado.

3. I am sole owner of a subchapter "S" corporation that is a partner in Pendragon Resources, L.P., the owner of leasehold working interests in the lands in San Juan County, New Mexico that are the subject of New Mexico Oil Conservation Division (NMOCD) Case No. 11996; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc. To Confirm Production From The Appropriate Common Source Of Supply, and in Whiting Petroleum Corporation and Maralex Resources, Inc. vs Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc; Sante Fe County District Court Case No. D-0101-CV-980129S. Pendragon Energy Partners, Inc. is the operator of the wells that are also the subject of both the NMOCD case and the District Court case.

4. I am a consultant to Pendragon Energy Partners, Inc. and designed all of the fracture restimulation treatment jobs on the wells that are at issue in both proceedings. Consequently, I expect to be called on to testify at any hearing in these matters.

5. I am consulting with another oil and gas operator on an unrelated matter in Australia. I have previously scheduled meetings in Australia and will be out of the country from June 26, 1998 until July 9, 1998.

FURTHER AFFIANT SAYETH NOT.

[signature]
Roland E. Blauer

State of Colorado)
)ss.
County of Denver)

Subscribed and sworn to before me this 25th day of June, 1998, by Roland E. Blauer.

[signature]
Notary Public

CYNTHIA BAMBAUER NOTARY PUBLIC STATE OF COLORADO

My Commission expires:

6-17-2001

Fairchild, Ancell & Wells, Inc.
PETROLEUM AND ENVIRONMENTAL CONSULTANTS

June 25, 1998

Mr. J. Scott Hall
Miller, Stratvert & Torgerson
150 Washington Ave., Suite 300
Santa Fe, NM 87504

VIA FAX 505 989-9614

Subject: Pendragon Energy Partners

Dear Scott:

Mr. Al Nicol of Pendragon Energy Partners has asked me to inform you that I am not available for hearing testimony on Monday June 29, 1998. Unfortunately, I am already committed for that day.

Please advise us of any future needs so that we can arrange schedules and can be of service. I apologize for not being able to be more flexible in this instance.

Very truly yours,

Kenneth L. Ancell

1155 DAIRY ASHFORD SUITE 206 HOUSTON TEXAS 77079 TEL (281) 497-8990 FAX (281) 497-8368 Email: faw@fawinc.com

NEW MEXICO ENERGY, MINERALS
& NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION
2040 South Pacheco Street
Santa Fe, New Mexico 87505
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July 8, 1998

J. Scott Hall
Miller, Stratvert & Torgerson, P.A.
P. O. Box 1986
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Attorneys for Pendragon Energy Partners, Inc. et. al

J.E. Gallegos
Michael J. Condon
Gallegos Law Firm
460 St. Michael's Drive
Santa Fe, NM 87505

Attorneys for Whiting Petroleum Corporation et. al

RE: OCD Case No. 11996--Application of Pendragon Energy Partners, Inc.

Gentlemen:

This will confirm that this case is set for a special hearing date of Tuesday, July 28 and, if needed, Wednesday, July 29. If the discovery issues between the parties have not yet been resolved, please notify the Division.

If you have any questions, please feel free to call me at 827-8156.

Sincerely,

Rand Carroll
Legal Counsel

c: David Catanach, OCD Hearing Examiner

NEW MEXICO ENERGY, MINERALS
& NATURAL RESOURCES DEPARTMENT

OIL CONSERVATION DIVISION
2040 South Pacheco Street
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June 25, 1998

Case File 11996

J. Scott Hall
Miller, Stratvert & Torgerson, P.A.
P. O. Box 1986
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Attorneys for Pendragon Energy Partners, Inc. et. al

J.E. Gallegos
Michael J. Condon
Gallegos Law Firm
460 St. Michael's Drive
Santa Fe, NM 87505

Attorneys for Whiting Petroleum Corporation et. al

RE: OCD Case No. 11996--Application of Pendragon Energy Partners, Inc.
- Motions to (i) dismiss and (ii) quash subpoenas

Gentlemen:

At the hearing on the above motions on June 23, 1998, held before Examiner Catanach and myself, the OCD decided to retain jurisdiction but continue the hearing of this case until the District Court decides whether to enjoin Pendragon et. al from pursuing this case before the OCD.

The parties were instructed to keep the OCD informed as to when the judge would hear the motions as well as the judge's decision. Both parties have informed me that Judge Encinas will hear argument on the afternoon of Monday, June 29 on at least the motion for a preliminary injunction shutting in the wells in question. but may not have sufficient time to hear the motion to enjoin the defendants from pursuing the OCD case. The parties are instructed to continue to keep the OCD informed. Although the case has been continued to July 9, 1998, it will not be heard on that date. Once the Judge Encinas issues his ruling, a hearing date will be set before Examiner Catanach.

The parties indicated they would work out what information requested in the OCD-issued subpoenas had already been provided and Whiting et.al would determine whether they would voluntarily provide a copy of the study that was prepared and disclosed and/or referenced in its meeting(s) with the OCD Aztec District Office. If agreement is not reached on the information exchanged, the OCD will then issue a ruling on the disputed items.

If you have any questions, please feel free to call me at 827-8156.

Sincerely,

Rand Carroll
Legal Counsel

c: David Catanach, OCD Hearing Examiner

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES
DEPARTMENT
OIL CONSERVATION DIVISION

IN THE MATTER OF:

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC. and J.K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO. **CASE NO. 11996**

RESPONSE TO MOTION TO DISMISS APPLICATION FOR LACK OF JURISDICTION

Pendragon Energy Partners, Inc. ("Pendragon") and J. K. Edwards Associates, Inc. ("J. K. Edwards"), for their response to the motion submitted on behalf of Whiting Petroleum Corporation and Maralex Resources, Inc. to dismiss this matter for lack of jurisdiction state:

BACKGROUND FACTS

Wh. 'ng and Maralex first invoked the Division's jurisdiction well over two (2) years ago when it first sought the agency's expertise in resolving a perceived problem of communication between the Pictured Cliffs formation in the WAW Fruitland-Pictured Cliffs Pool and the Basin-Fruitland Coal formation. (See Whiting/Maralex Motion to Partially Quash Subpoena Duces Tecum; Case No. 11921.) Although their approach to the problem was suspect and their analytical methods flawed, Whiting and Maralex represented to the Aztec District Office of the NMOCD that drilling and fracture restimulation operations in the Pictured Cliffs interval by Pendragon caused that formation to become communicated with the Basin-Fruitland Coal formation and that Pendragon's Pictured Cliffs completions were producing coal bed methane.[1] If indeed the operations in the Pictured Cliffs formation are causing interference with production from the Fruitland formation as Whiting/Maralex say, then ostensible violations of a number of the statutes, rules and orders administered by the Division are implicated.

In addition to their multiple contacts and on-going consultation with the NMOCD Aztec District Office, Whiting and Maralex compiled what they have called a "detailed engineering study" which its styled "Fruitland/PC WAW Study-Gallegos Canyon Project" dated December 1, 1997. This study was prepared for and presented to the NMOCD. Soon thereafter, at the request of Whiting and Maralex, the NMOCD Aztec District Office convened a number of public meetings between January and April of 1998. These meetings were attended by, among others, representatives from Whiting, Maralex, Pendragon, J. K. Edwards and the BIA/BLM. At the initial meeting, the Division and the parties agreed that the scope and purpose of the meetings would be as follows:

1. To determine if the Pictured Cliffs completions were interfering with production from the Fruitland Coal.
2. To identify the affected wells.
3. To identify regulatory solutions to bring wells into compliance with NMOCD Rules and Regulations.

[1] The Pendragon wells are completed in and producing from the Pictured Cliffs formation below the base of the Fruitland formation. None of the Pendragon wells are completed in the sandstone interval of the Fruitland formation.

Contemporaneous with the first meeting before the Division, Whiting and Maralex filed their Application in NMOCD Case No. 11921. (Exhibit A, attached.) In their initial Application, Whiting and Maralex generally alleged, as before, that the drilling and fracture restimulation operations in the Pictured Cliffs formation had caused that formation to become communicated with the Basin-Fruitland Coal formation. Whiting and Maralex also claimed that Pendragon's Pictured Cliffs wells were draining reserves owned by Whiting and the other interest owners in its wells and that their correlative rights were being impaired. Whiting and Maralex specifically invoked the Division's jurisdiction under N. M. Stat. Ann. § 70-2-12. B. (2), (7) and 10, NMOCD Rule 104.D (3), and Order No. R-8768, Special Pool Rules 2 and 3, seeking regulatory relief, including the issuance of an order requiring Pendragon's Pictured Cliffs wells to be shut-in.

Subsequently, on February 10, 1998, Whiting and Maralex, at the request of the Division, filed their Amended Application seeking additional administrative relief, including down-hole commingling in accordance with Rule 12 of the Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool as promulgated by the Division in Order No. R-8768-A. (Exhibit B, attached.)

In the interim, the parties continued to participate in the public meetings before the Division and Whiting and Maralex persisted in seeking regulatory redress for the claimed numerous violations by Pendragon of the New Mexico Oil and Gas Act and the Division's Regulations. The parties expended significant time, effort and cost in preparing for the Division hearing on the Whiting/Maralex Application and the matter was set to proceed to hearing on June 11, 1998. Suddenly, at the eleventh hour, Whiting and Maralex lost faith in their case and the administrative process. On May 26, 1998 Whiting and Maralex attempted to withdraw from the administrative proceeding which they, themselves, initiated and instead began their forum-hopping adventure in avoidance of the Division's jurisdiction. That same day, Whiting and Maralex filed their District Court lawsuit. While their District Court actions seeks judicial relief under novel and unique common law theories, the underlying factual allegations are the same as those raised in their administrative applications and are based upon numerous claimed violations of the New Mexico Oil and Gas Act and the Division's Rules, Regulations and Orders. Indeed, both proceedings seek the drastic relief of an order requiring Pendragon to shut-in its Pictured Cliffs wells.

THE APPLICABILITY OF DIVISION JURISDICTION

Whiting and Maralex originally invoked the Division's jurisdiction and discretion under the New Mexico Oil and Gas Act, the Division's Rules, and Order No. R-8768-A in particular. Now, however, Whiting and Maralex improperly seek to circumvent this agency's legitimate exercise of its regulatory authority over oil and gas operations. To justify their forum-hopping, Whiting and Maralex set forth a lengthy discourse on the nature of their common law claims and property ownership issues. These matters are wholly inapposite to the issues brought before the Division by the Pendragon/J. K. Edwards Application and the original claims that Whiting and Maralex had pursued before the Division for well over two (2) years.

The Whiting and Maralex assertions, if true, involve serious violations of The Oil and Gas Act, the Division's Rules its and Orders. Among others, the claims implicate violations of the following statutes and regulations administered exclusively by the Division:

§ 70-2-12 B(2):	Segregation requirement.
§ 70-2-10:	Filing false reports; NMOCD filing forms implicated by the Whiting/Maralex allegations are Form C-101 Application For Permit To Drill, Deepen Or Plug Back; Form C-103 Sundry Notices And Reports On Wells; Form C-105 Well Completion Or Recompletion Report And Log; Form C-107 Application For Multiple Completion (Commingling).
§ 70-2-28:	Sets forth the obligation of the Division to bring suit for violations of any provision of the Oil and Gas Act or any rule, regulation or order of the Division.
§ 70-2-29:	Provides that it is the primary responsibility for the Division to bring an action for enjoining violations of the act.
§ 70-2-31:	Penalties for violations of the Oil and Gas Act.
Rule 303.A:	Segregation requirement.
Rule 104.D.3:	Simultaneous dedication.
Rule 112.A:	Unapproved multiple completions.
Rule 303.C.1.B:	Down-hole commingling.
Rule 304:	Segregation required for different common sources of supply.
§ 70-2-12.B(12):	The OCD has the power to "to determine limits of any pool producing.....natural gas....and from time to time redetermine the limits." (Both vertical and horizontal limits.)
§ 70-2.6 and 70-2-11:	General authority for the Division to enforce the provisions of the Oil and Gas Act (including the issuance of shut-in orders.)
Order R-8768:	Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool.

No other body, judicial, administrative or otherwise has been charged with the specific statutory mandate to exercise jurisdiction, authority and control over oil and gas operations in this state. See § 70-2-6-A NMSA 1978 (1935); See also Continental Oil Company v. Oil Conservation Commission, 70 N.M. 310, 323, 373 P.2d. 809, 817 (1962). The Division's powers broadly encompass the prevention of underground waste, defined as the "prevention of inefficient, excessive or improper, use or dissipation of reservoir energy" and "the locating, spacing, drilling, equipping, operating or producing, of any well or wells in a manner to reduce or tend to reduce the total quantity of ....natural gas ultimately recovered from any pool....". § 70-2-3-A NMSA 1978 (1935). Moreover, no other body in the State possesses the technical expertise in petroleum geology and petroleum engineering necessary to effect a solution to these particular issues should one be required. Only the Division can resolve the factual questions presented to it in both the Pendragon/J.K. Edwards Application in Case No. 11996 and the Whiting/Maralex application in Case No. 11921. See Far East Conference v. The United States, 342 U.S. 570 (1952). This view has been acknowledged by the New Mexico Supreme Court when it affirmed that NMOCD decisions are accorded special weight and credence in light of the Division's technical competence and specialized knowledge. See Grace v. Oil Conservation Commission, 87 N. M. 203, 531 P.2d 939 (1975).

The fact that Whiting and Maralex are attempting to bring a separate suit in district court does not mean that the Division is somehow required to abstain from or defer action on this Application. Indeed the opposite is true.

New Mexico courts, both federal and state, have long-recognized the doctrine of primary jurisdiction. The doctrine often comes into play where issues requiring a regulatory body's technical expertise are involved. In such cases, the doctrine recognizes that the administrative process should be allowed to proceed whenever dispute requires the resolution of issues which, under a regulatory scheme, have been placed within the special competence of an administrative body. See State ex rel. Norvell v. Arizona Public Service Co., 85 N.M. 165, 510 P.2d 98 (1973).

This case is a perfect example of the applicability of the primary jurisdiction doctrine. Contrary to the assertions of Whiting and Maralex, Pendragon and Edwards do not seek to have the Division declare the "entitlement" of one party to produce coalbed methane through their Pictured Cliffs completions, or vice versa. Neither does the Application ask the Division to declare the Fruitland coal formation and the Pictured Cliffs formation are a "common source of supply." More correctly, the application requests the Division (1) to determine the parties' wells are completed and producing in accordance with the Division's rules and orders. If not, then the Division is fully authorized to bring the wells into compliance with the regulations by a variety of means. The exercise of authority in such manner is fully in accord with the Division's mandate to prevent waste and maintain the segregation between different common sources of supply. (§70-2-2; §70-2-12 B[2].)

THE DIVISION EXPRESSLY RETAINED JURISDICTION OVER THE SUBJECT MATTER OF THIS APPLICATION BY VIRTUE OF ORDER NO. R-8768.

As the Division has consistently done, Order No. R-8768 establishing the Basin-Fruitland Coal Gas Pool provided that "Jurisdiction of this cause is retained for the entry of such further orders as the Division may deem necessary." (Decretal Paragraph 9, Order R-8768, as amended, Exhibit D, attached.) The argument that the Division has now somehow lost jurisdiction over matters arising under the terms of Order R-8768 is baseless. In this regard, a recent case raises interesting parallels:

In **Case No. 11792, Application of Doyle Hartman To Give Full Force And Effect To Commission Order R-6447,** Hartman, a non-operator in the Myers Langlie-Mattix Unit, filed his application with the Division at the same time he pursued separate common-law claims against the unit operator in district court.

In addition to invoking the Division's jurisdiction to address the matter of the claimed escape of water out-of-zone from unit operations, the applicant (Hartman) also sought the Division's declaration and enforcement of the terms of its prior order approving of the unit. There, Hartman cited the Division's expertise and the agency's statutory mandate giving rise to its "primary jurisdiction" over the dispute. Hartman also argued that the Division's retained jurisdiction over the matter under the express terms of the orders approving of the unit. (See excerpts from Hartman's Response To Oxy's Motion To Dismiss, Case No. 11792, Exhibit C, attached.) Hartman argued:

> "[C]hanges in circumstance and factual developments often occur after the date of entry of an Order which require subsequent action by an administrative agency after entry of an order. That is the very purpose for

including the retained jurisdiction provision in the orders." Id., at page 33.[2]

It is a point well taken and one that is particularly applicable here.

Just like Order No. R-6447 approving of the Myers Langlie-Mattix Unit, Order No. R-8768 for the Basin-Fruitland Coal Gas Pool also provides that the Division retains jurisdiction. (Order No. R-8768, decretal paragraph 9, Exhibit D.) It is also significant that Order No. R-6778, in both establishing operating rules and the designating the vertical limits for the Basin-Fruitland Coal Gas Pool, made special provisions for the Division to monitor operations in and production from the coal formation and the nearby sandstone formations. Although each formation is its own separate "common source of supply", the Division anticipated the possibility of problems, either real or perceived, with simultaneous operations in separate zones laying in close proximity to each other and with foresight, wisely provided a means for the Division to address the very matters that are raised by the Pendragon/J.K. Edwards Application. (See Rules 2 and 3, Special Rules and Regulations For The Basin-Fruitland Coal Gas Pool.)

The pool rules for the Basin-Fruitland Coal Gas Pool also provided various remedies for operational problems that might arise, including exceptions to the acreage dedication requirements (Special Rule 4) and commingling (Special Rule 12). Of course, if neither of these solutions is appropriate, Order No. R-8768 also provides for the entry of such further orders "...as the Division may deem necessary." (Order R-8768, decretal paragraph 9.) It is unquestionable, then, that the Division's jurisdiction here is both appropriate and ongoing.

[2] Significantly, the Division retained jurisdiction in Case No. 11792

CONCLUSION

The Division should not be misled by the Whiting/Maralex motion. This proceeding does not involve any dispute arising under a contract among the parties; neither is the Division being requested to determine the ownership of mineral rights under an assignment containing depth restrictions. Such arguments are merely in furtherance of Whiting's and Maralex's efforts to avoid the Division's legitimate exercise of its authority under the Oil and Gas Act and under the express provisions of Order R-8768, as amended. Whiting and Maralex have contended that fracture stimulation in and production from the Pictured Cliffs has resulted in interference with production and operations in the Fruitland coal. These are matters that are exclusively within the Division's province. Whiting and Maralex, having once invoked the jurisdiction of the Division on the very subject matter that is the subject of the Pendragon/J.K. Edwards application cannot now argue that the Division is without jurisdiction. The Whiting/Maralex motion should be denied accordingly.

Respectfully submitted,

MILLER, STRATVERT & TORGERSON, P.A.

By ______________________________

J. Scott Hall, Esq.
Attorneys for Pendragon Energy Partners
Post Office Box 1986
Santa Fe, New Mexico 87504-1986
(505) 989-9614

Certificate of Mailing

I hereby certify that a true and correct copy of the foregoing was mailed to counsel of record on the 22nd day of June, 1998, as follows:

James Bruce, Esq.
P.O. Box 1056
Santa Fe, New Mexico 87504

J. E. Gallegos, Esq.
Gallegos Law Firm, P. C.
460 St. Michaels Dr., #300
Santa Fe, New Mexico 87505-7602

By J. Scott Hall (signature)
J. Scott Hall, Esq.

:11996.2DISMISSAPP.DOC

Field File

BEFORE THE NEW MEXICO OIL CONSERVATION DIVISION

Oil Conservation RECEIVED
JAN 1 2 1998
WHITING PET. CORP. PRODUCTION DEPT.

APPLICATION OF WHITING PETROLEUM CORPORATION AND MARALEX RESOURCES, INC. FOR AN ORDER SHUTTING-IN CERTAIN WELLS, SAN JUAN COUNTY, NEW MEXICO.

Case

APPLICATION

Whiting Petroleum Corporation ("Whiting") and Maralex Resources, Inc. ("Maralex") hereby apply for an order requiring certain wells located in San Juan County, New Mexico to be shut-in, and in support thereof, state:

1. Whiting operates the following wells:

Well Name	Well Unit
(1) Gallegos Fed. 26-12-6 No. 2 ✓	W½ §6-26N-12W
(2) Gallegos Fed. 26-12-7 No. 1	W½ §7-26N-12W
(3) Gallegos Fed. 26-13-1 No. 1	E½ §1-26N-13W
(4) Gallegos Fed. 26-13-1 No. 2 ✓	W½ §1-26N-13W
(5) Gallegos Fed. 26-13-12 No. 1	N½ §12-26N-13W

The above wells were drilled before the end of 1992, and are completed in and producing from the Basin-Fruitland Coal Gas Pool, as defined in Division Order No. R-8768, as amended. Spacing for each well is 320 acres. Maralex is an interest owner in the wells.

2. Thompson Engineering & Production Corp. ("Thompson") operates the following wells:

Well Name	Well Unit
Stacey No. 1	SE¼ §6-26N-12W
Leslie No. 1	NE¼ §7-26N-12W[1]

[1]This well is at an orthodox location for a Fruitland Coal well, and thus Whiting and Maralex do not seek to have it shut-in. However, applicants believe that it is producing from the Basin-Fruitland Coal Gas Pool, should be recognized as such, and its well spacing unit adjusted accordingly.

EXHIBIT
A

Pendragon Energy Partners, Inc. ("Pendragon") operates the following wells:

Well Name	Well Unit
Chaco No. 1	NW¼ §18-26N-12W
Chaco No. 2R	SW¼ §7-26N-12W
Chaco No. 4	NW¼ §7-26N-12W
Chaco No. 5	SE¼ §1-26N-13W
Chaco Ltd. No. 1J	SW¼ §1-26N-13W
Chaco Ltd. No. 2J	NE¼ §1-26N-13W

The Edwards and Pendragon wells are designated as being completed in the WAW Fruitland Sand-Pictured Cliffs Pool, as defined in Division Order No. R-8769, as amended. Spacing for wells completed in the WAW Fruitland Sand-Pictured Cliffs Pool is 160 acres.

3. Ownership in the Basin-Fruitland Coal Pool, in the above sections, differs from ownership in the WAW Fruitland Sand-Pictured Cliffs Pool. Moreover, because of the difference in well spacing, 4 wells may be drilled per section in the WAW Fruitland-Pictured Cliffs Pool, as opposed to 2 wells per section in the Basin-Fruitland Coal Gas Pool.

4. As of 1995-96, each of the above-described Thompson and Pendragon wells was shut-in, was a marginal producer, or had not been drilled. In 1995 and 1996, Thompson and Pendragon drilled or "restimulated" their wells, resulting in the following:

(a) Production from their wells increased, in some cases substantially;

(b) Production from the offsetting Whiting wells has declined or decreased;

(c) The BTU content of the gas decreased so that it is similar or identical to the BTU content of the Whiting wells;

(d) Water production increased substantially; and

(e) The limited available pressure data shows that pressures increased to levels similar to those found in the Basin-Fruitland Coal Gas Pool in this area.

5. Based on the foregoing, the Thompson and Pendragon wells are communicated with and are producing from the Basin-Fruitland Coal Gas Pool. As a result, the Thompson and Pendragon wells are draining reserves owned by Whiting and its interest owners, and are impairing their correlative rights.

6. In addition, (a) the Stacey Well No. 1, Chaco Well No. 1, Chaco Well No. 4, and Chaco Well No. 5 are at unapproved unorthodox gas well locations in the Basin-Fruitland Coal Gas Pool, (b) all of the Thompson and Pendragon wells, except the Leslie Well No. 1, do not have Division approval for simultaneous dedication in the Basin-Fruitland Coal Gas Pool as required by Division Rule 104.D.(3), or Division Memoranda dated July 27, 1988 and August 3, 1990, and (c) none of the Thompson and Pendragon wells have 320 acres dedicated to them.

7. The Division has the authority and the duty to:

(a) Prevent natural gas from escaping from strata in which it is found into other strata;

(b) require wells to be drilled, operated, and produced in such manner as to prevent injury to neighboring leases or properties; and

(c) to fix the spacing of wells.

NMSA §70-2-12.B.(2), (7), (10) (1995 Repl. Pamp.). Moreover, the Division has the authority to require an operator to submit data to demonstrate that a well is producing from the appropriate common source of supply. **Order No. R-8768, Special Rules 2, 3.** Therefore, the relief requested herein is proper.

WHEREFORE, Whiting and Maralex request that, after notice and hearing, the Division enter its order:

A. Determining that the Thompson and Pendragon wells, described above, are producing from the Basin-Fruitland Coal Gas Pool;

B. Determining that the Stacey Well No. 1, Chaco Well No. 1, Chaco Well No. 4, Chaco Well No. 5 are at unapproved unorthodox gas well locations in the Basin-Fruitland Coal Gas Pool, and that all wells except the Leslie Well No. 1 do not have approval for simultaneous dedication in the Basin-Fruitland Coal Gas Pool;

C. Ordering the Thompson Stacey Well No. 1 and all of the Pendragon wells to be permanently shut-in; and

D. Granting such further relief as the Division deems proper.

Respectfully submitted,

James Bruce
P.O. Box 1056
Santa Fe, New Mexico 87504
(505) 982-2043

Attorney for Whiting Petroleum Corporation and Maralex Resources, Inc.

BEFORE THE NEW MEXICO OIL CONSERVATION DIVISION

APPLICATION OF WHITING PETROLEUM CORPORATION AND MARALEX RESOURCES, INC. FOR AN ORDER SHUTTING-IN, LIMITING PRODUCTION FROM, OR APPROVING DOWNHOLE COMMINGLING IN, CERTAIN WELLS, SAN JUAN COUNTY, NEW MEXICO.

Case No. 11,921

AMENDED APPLICATION

Whiting Petroleum Corporation ("Whiting") and Maralex Resources, Inc. ("Maralex") hereby apply for an order requiring that certain wells located in San Juan County, New Mexico be shut-in or have their producing rates limited, or in the alternative approving downhole commingling of production and fixing allocation percentages. In support of their application, Whiting and Maralex state:

1. Whiting operates the following wells:

Well Name	Well Unit
Gallegos Fed. 26-12-6 No. 2	W½ §6-26N-12W
Gallegos Fed. 26-12-7 No. 1	W½ §7-26N-12W
Gallegos Fed. 26-13-1 No. 1	E½ §1-26N-13W
Gallegos Fed. 26-13-1 No. 2	W½ §1-26N-13W
Gallegos Fed. 26-13-12 No. 1	N½ §12-26N-13W

The above wells were drilled before the end of 1992, and are completed in and producing from the Basin-Fruitland Coal Gas Pool, as defined in Division Order No. R-8768, as amended. Spacing for each well is 320 acres. Maralex is an interest owner in the Whiting-operated wells.

2. Thompson Engineering & Production Corp. ("Thompson") operates the following wells:

Well Name	Well Unit
Stacey No. 1	SE¼ §6-26N-12W

EXHIBIT

B

Leslie No. 1	NE¼ §7-26N-12W[1]

Pendragon Energy Partners, Inc. ("Pendragon") operates the following wells:

Well Name	Well Unit
Chaco No. 1	NW¼ §18-26N-12W
Chaco No. 2R	SW¼ §7-26N-12W
Chaco No. 4	NW¼ §7-26N-12W
Chaco No. 5	SE¼ §1-26N-13W
Chaco Ltd. No. 1J	SW¼ §1-26N-13W
Chaco Ltd. No. 2J	NE¼ §1-26N-13W

The Thompson and Pendragon wells are designated as being completed in the WAW Fruitland Sand-Pictured Cliffs Pool, as defined in Division Order No. R-8769, as amended. Spacing for wells completed in the WAW Fruitland Sand-Pictured Cliffs Pool is 160 acres.

3. Ownership in the Basin-Fruitland Coal Gas Pool, in the sections in which the Whiting wells are located, differs from ownership in the WAW Fruitland Sand-Pictured Cliffs Pool. Moreover, because of the difference in well spacing, 4 wells may be drilled per section in the WAW Fruitland-Pictured Cliffs Pool, as opposed to 2 wells per section in the Basin-Fruitland Coal Gas Pool.

4. As of 1995-96, each of the above-described Thompson and Pendragon wells was shut-in, was a marginal producer, or had not been drilled. In 1995 and 1996, Thompson and Pendragon drilled or "restimulated" their wells, resulting in the following:

[1]This well is at an orthodox location for a Fruitland Coal well, and thus Whiting and Maralex do not seek to have it shut-in, *etc.* However, applicants believe that the well is producing from the Basin-Fruitland Coal Gas Pool, should be recognized as such, and its spacing and proration unit adjusted accordingly.

(a) Production from the Thompson and Pendragon wells increased, in some cases substantially;

(b) Production from the Whiting-operated wells offsetting the Thompson and Pendragon wells has declined or decreased;

(c) The BTU content of the gas produced from the Thompson and Pendragon wells has decreased so that it is similar or identical to the BTU content of the Whiting wells;

(d) Water production from the Thompson and Pendragon wells has increased substantially; and

(e) The available pressure data shows that pressures in the Thompson and Pendragon wells has increased to levels similar to those found in wells completed in the Basin-Fruitland Coal Gas Pool in this area.

5. Based on the foregoing, the Thompson and Pendragon wells are communicated with and are producing from the Basin-Fruitland Coal Gas Pool. As a result, the Thompson and Pendragon wells are draining reserves owned by Whiting and the other interest owners in its wells, and are impairing their correlative rights.

6. In addition, (a) the Stacey Well No. 1, Chaco Well No. 1, Chaco Well No. 4, and Chaco Well No. 5 are at unapproved unorthodox gas well locations in the Basin-Fruitland Coal Gas Pool, (b) all of the Thompson and Pendragon wells, except the Leslie Well No. 1, do not have Division approval for simultaneous dedication in the Basin-Fruitland Coal Gas Pool as required by Division Rule 104.D.(3) or Division Memoranda dated July 27, 1988 and August 3, 1990, and (c) none of the Thompson and Pendragon wells have 320

acres dedicated to them.

7. The Division has the authority and the duty to:

(a) Prevent natural gas from escaping from strata in which it is found into other strata;

(b) require wells to be drilled, operated, and produced in such manner as to prevent injury to neighboring leases or properties; and

(c) to fix the spacing of wells.

NMSA 1978 §70-2-12.B.(2), (7), (10) (1995 Repl. Pamp.). Moreover, the Division has the authority to require an operator to submit data to demonstrate that a well is producing from the appropriate common source of supply, and to order the downhole commingling of Fruitland Coal and Pictured Cliffs production. **Order No. R-8768, Special Rules 2, 3, 12.** Therefore, the relief requested herein is proper.

WHEREFORE, Whiting and Maralex request that, after notice and hearing, the Division enter its order:

A. Determining that the Thompson and Pendragon wells, described above, are producing from the Basin-Fruitland Coal Gas Pool;

B. Determining that the Stacey Well No. 1, Chaco Well No. 1, Chaco Well No. 4, and Chaco Well No. 5 are at unapproved unorthodox gas well locations in the Basin-Fruitland Coal Gas Pool, and that all wells except the Leslie Well No. 1 do not have approval for simultaneous dedication in the Basin-Fruitland Coal Gas Pool;

C. Ordering the Thompson Stacey Well No. 1, and all of the Pendragon wells, to be permanently shut-in or have their production restricted, or in the alternative approve downhole commingling of Fruitland Coal and Pictured Cliffs/Fruitland Sand production from the Thompson and Pendragon wells and allocating production from each pool; and

D. Granting such further relief as the Division deems proper.

Respectfully submitted,

James Bruce
P.O. Box 1056
Santa Fe, New Mexico 87504
(505) 982-2043

Attorney for Whiting Petroleum Corporation and Maralex Resources, Inc.

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing Amended Application was mailed this 10th day of February, 1998 to J. Scott Hall, Miller, Stratvert & Torgerson, P.A., P.O. Box 1986, Santa Fe, New Mexico 87504.

James Bruce

STATE OF NEW MEXICO
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT
OIL CONSERVATION DIVISION

RECEIVED
JUN 9 1997
OIL CONSERVATION DIVISION

IN THE MATTER OF THE HEARING CALLED BY THE OIL CONSERVATION DIVISION FOR THE PURPOSE OF CONSIDERING:

CASE NO. 6987
CASE NO. 11792

AMENDED APPLICATION OF DOYLE HARTMAN TO GIVE FULL FORCE AND EFFECT TO COMMISSION ORDER R-6447, TO REVOKE OR MODIFY ORDER 4-4680-A, TO ALTERNATIVELY TERMINATE THE MYERS LANGLIE-MATTIX UNIT, LEA COUNTY, NEW MEXICO

HARTMAN'S RESPONSE IN OPPOSITION TO OXY'S MOTION TO DISMISS

Applicant Doyle Hartman, Oil Operator ("Hartman") hereby files this Response in Opposition to the Motion to Dismiss filed by Oxy USA, Inc. ("Oxy"). As Hartman will demonstrate, there is no factual or legal basis for Oxy's Motion.

I.

INTRODUCTION

Hartman filed an Application in this matter on April 28, 1997. An Amended Application was subsequently filed May 8, 1997. By this proceeding, Hartman seeks entry of an Order (a) enforcing the New Mexico Oil Conservation Commission ("NMOCC") Order R-6447,[1] (b) recognizing that the operation of the Myers

[1] The misrepresentations in Oxy's Motion to Dismiss begin with a gross mischaracterization of Hartman's position. Hartman does not "complain about Order R-6447." Motion to Dismiss, p. 1. Instead, Hartman seeks enforcement of the Order and all of its terms against Oxy.

EXHIBIT
C

whom would not. Aside from the fact that this theory circumvents mandatory statutory provisions, it makes absolutely no sense in the administrative practice of the unit.

POINT TWO

OXY'S LAWSUIT IS A COLLATERAL ATTACK ON ORDER R-6447

NMOCC Order No. R-6447 is entitled to preclusive effect. Amoco Production Company v. Heimann, 904 F.2d 1405 (10th Cir. 1990), cert. denied, 498 U.S. 942 (1990). Unitization orders made by the NMOCC must remain inviolate to collateral attack. Id. Oxy has filed suit against Hartman to recover joint interest billings associated with the 1994 Redevelopment Program to which Hartman timely objected and voiced his desire to go non-consent.

The NMOCC expressly retained jurisdiction in Order R-6447 for the entry of such further orders as the NMOCC may deem necessary. The New Mexico Legislature has expressly vested the NMOCD and NMOCC with jurisdiction, power and authority to make and enforce such orders and to do such things as may be necessary or proper to carry out and effectuate the purposes of the Statutory Unitization Act. NMSA 1978, § 70-7-3.

Questions about the operation of the MLMU subject to the Statutory Unitization Act are within the primary jurisdiction of the NMOCC and the NMOCD, who have not just the authority, but a statutory mandate to insure the legal operation of units subject to the Act. Here, the undisputed evidence demonstrates that Oxy has violated Order R-6447 by its ongoing refusal to recognize the right of MLMU working interest owners to go non-consent with respect to unit operations. This body has every right to view the facts presented by this Application and enter an order confirming for the benefit of Oxy and all working interest owners in the MLMU the nature, effect, and meaning of the express terms of its Order. Amarex v. Baker, 655 P.2d 1040 (Okla. 1973) (petition to Corporation Commission to interpret or construe its own order is not a collateral attack).

POINT THREE

THIS APPLICATION IS PROPER UNDER NMOCC'S AND NMOCD'S CONTINUING JURISDICTION

In Order R-6447 and Order R-4680-A, the NMOCC and NMOCD both retained jurisdiction for the entry of such further orders as may be necessary. As this case demonstrates, changes in circumstance and factual developments often occur after the date of entry of an Order which require subsequent action by an administrative agency after entry of an order. That is the very purpose for including the retained jurisdiction provision in the orders. Oxy's Motion to Dismiss seeks to deprive the NMOCC and the NMOCD of its continuing jurisdiction.

Under the jurisdiction vested by Section 70-7-3 and given the express retention of jurisdiction by Orders R-6447 and R-4680-A, the NMOCC and NMOCD are entitled to consider all matters presented by this Application. Those questions include whether Oxy's operation of the MLMU is inconsistent with the Statutory Unitization Act, whether Oxy has violated Order R-6447 and the Act in its operation of the MLMU, whether changed circumstances in the form of the failed 1994 Redevelopment Program justify termination or substantial modification of the operation of the MLMU, and whether Oxy's operation of the MLMU has caused a water out of zone problem. These ıes involve changed circumstances developed or discovered since the entry of the orders. Changed conditions are sufficient to justify review of a previously issued order, and such review does not constitute a collateral attack on the order. Wood Oil Company v. Corporation Commission, 205 Okla. 534, 239 P.2d 1021 (1950); Railroad Commission of Texas v. Aluminum Co. of America, 380 S.W.2d 599 (1964).

Oxy is the unilateral cause of the problems and conflicts at issue in this Application. In filing its Application in Case No. 11168, Oxy failed to apprise the NMOCD of the existence and effect of Order R-6447. Consequently, the NMOCD considered and granted Oxy's application as if the provisions of the Statutory Unitization Act did not apply, and on the assumption that Oxy did not need to make the necessary showing in support of the application which sought an amendment to the ın of unit operations. NMSA 1978 § 70-7-9. Having unilaterally caused the problem at issue by its failure to recognize the existence of Order R-6447, Oxy cannot be heard to complain that the NMOCC and the NMOCD are without jurisdiction to remedy the problem.

Oxy's complaint about the timing of Hartman's application and his objections to Oxy's conduct is particularly inappropriate. Hartman elected to go non-consent with respect to unit operations in August, 1994, but Oxy has denied that Hartman has that right. Hartman has not paid his share of joint interest billings since that time, and has maintained all revenues from his share of crude oil from the MLMU in a segregated account because Oxy has refused to recognize his right to go non-consent and has refused to take his share of proceeds as provided by Order R-6447. Oxy did not, however, institute its lawsuit against Hartman in violation of Order R-6447

'Aarch, 1997, almost three (3) years after Hartman elected to go non-consent and stopped paying MLMU invoices submitted by Oxy. Under the circumstances, there was no reason for Hartman to file this Application until Oxy demonstrated its intent to collaterally attack Order R-6447 by filing suit against Hartman. Once Oxy determined to undertake such a course of action, Hartman immediately and in a timely manner sought relief in the form of this Application regarding all issues arising from Oxy's failure to recognize and give full force and effect to the terms of Order R-6447, as well as issues relating to whether Oxy's operation of the MLMU has caused waste and failed to protect the correlative rights of working interest owners in the MLMU.

Obviously, Hartman did not have evidence supporting his contention that the 1994 Redevelopment Program was a financial failure until the program was given a ient opportunity to play out to demonstrate its ineffectiveness. The facts supporting Hartman's contention will be presented at hearing, at which time Oxy will have ample opportunity to present any evidence it can muster to support the financial integrity of the program. These matters involve changed circumstances since the entry of Order R-4680-A, and which could not have been presented in 1994.

The NMOCD and the NMOCC clearly have continuing jurisdiction to monitor surface injection pressure authorizations for the MLMU. Hartman did not discover evidence demonstrating water out of zone as a result of MLMU operations until November, 1996, when he attempted to rework the Myers "B" Federal No. 30 ("Myers") well in Section 5, T-24-S, R-37-E, which lies within the exterior surface boundaries of the MLMU. During the re-entry of the Myers well, Hartman encountered large quantities of water in the gas productive Yates Formation, where water is <u>not</u> naturally occurring in th area. This evidence strongly suggests that the operation of the MLMU, including excessive surface injection pressures, has caused a water out of zone problem, which the NMOCD and the NMOCC have the power and duty to investigate.

POINT FOUR

THE NMOCD AND NMOCC HAVE AUTHORITY TO REVIEW AN ORDER IMPROPERLY ENTERED

Hartman's Application and Amended Application have documented numerous procedural and due process problems which attended the entry of Order R-4680-A. Oxy largely ignores these problems, except to argue that Hartman had notice with respect to the 1,800 psi surface injection pressure authorization request that was buried in documents attached to a C-108 form. Oxy does not explain why the request was not set out in the application itself, why no evidence was introduced at the hearing to support the authorization, or how the 1,800 psi surface injection pressure authorization came to be embodied in Order R-4680-A.

Again, Oxy seeks to preclude review by the NMOCC and the NMOCD of the numerous procedural defects that attended the entry of Order R-4680-A. However, Oxy is the cause of the problem. Had Oxy notified the NMOCD and working interest owners in its Application in Case No. 11168 of the existence of Order R-6447, had it provided sufficient notice to the working interest owners of its request for an excessive surface injection pressure, and had it complied with the provisions of Section 70-7-9 in its request for amend unit operations by its 1994 Application, all affected parties would have had sufficient notice of the issues posed by Oxy's Application. Oxy failed to do so. Under the circumstances, Order R-4680-A should be vacated and held to be void idable. Uhden v. New Mexico Oil Conservation Commission, 112 N.M. 528, 817 P.2d 721 (1991).

IV.

CONCLUSION

Based upon the foregoing facts and authorities, Hartman respectfully requests that Oxy's Motion to Dismiss be denied in its entirety, and that Oxy's Application and Amended Application be scheduled for hearing before the full NMOCC at the presently scheduled special hearing set for June 30 - July 2, 1997. Because Oxy's Motion to Stay Discovery is based solely on its Motion to Dismiss, which has been shown to be meritless, that Motion should also be denied.

Respectfully submitted,

GALLEGOS LAW FIRM, P.C.

By [signature]
J.E. GALLEGOS
MICHAEL J. CONDON
460 St. Michael's Drive, Bldg. 300
Santa Fe, New Mexico 87505
(505) 983-6686

CERTIFICATE OF SERVICE

I hereby certify that I have caused a true and correct copy of Hartman's Response in Opposition to Oxy's Motion to Dismiss to be hand-delivered on this 9th day of June, 1997 to the following counsel of record:

William F. Carr
Campbell, Carr, Berge & Sheridan
110 N. Guadalupe, Suite 1
Santa Fe, New Mexico 87501

(CEDAR HILL-FRUITLAND BASAL COAL GAS (VERTICAL LIMITS EXTENSIONS) POOL - Cont'd.)

further defined and described as having vertical limits consistent within the vertical extension of the Cedar Hill-Fruitland Basal Coal Pool.

(3) Rule 1 of said Division Order No. R-7588, as amended is hereby suspended and shall be replaced with the following:

RULE 1. (A) Each well completed or recompleted in the Cedar Hill-Fruitland Basal Coal Pool shall be spaced, drilled, operated and prorated in accordance with the Special Rules and Regulations hereinafter set forth.

RULE 1. (B) A Cedar Hill-Fruitland Basal Coal Pool well will be defined as one which meets a preponderance of the generally characterized coalbed methane criteria as derived from:
(a) Wireline log data:
(b) Drilling time;
(c) Drill cutting;
(d) Mud logs;
(e) Completion data;
(f) Gas analysis;
(g) Water analysis;
(h) Reservoir performance;
(i) Any other evidence that indicates the production is predominantly coal methane.

No one characteristic of lithology, performance or sampling will either qualify or disqualify a well from being classified as a coal gas well. Absent any finding to the contrary, any well completed in accordance with these rules that has met a preponderance of the criteria for determining a coal well is therefrom presumed to be completed in and producing from the Cedar Hill-Fruitland Basal Coal Pool. The District Supervisor may, at his discretion, require that an operator document said determination of the appropriate pool or require an order under the provisions of General Rule 303(c) authorizing the commingling of pools in the event a coal well fails to meet the criteria for a coal well as set forth in this rule.

IT IS FURTHER ORDERED THAT:
(4) Any well drilling to or completed in a coal member of the Fruitland formation within this vertical extension of the Cedar Hill-Fruitland Basal Coal Pool on or before November 1, 1988 that will not comply with the well location requirements of Rule 4 is hereby granted an exception to the requirements of said rule. The operator of any such well shall notify the Aztec District Office of the Division, in writing, of the name and location of any such well on or before January 1, 1989.

(5) Applicant's request to authorize downhole commingling of Fruitland Sandstone Gas and Fruitland Coal Gas at the District Office level of the Division is hereby denied.

(6) This case shall be reopened at an examiner hearing in October, 1990, at which time the operators in the subject pool may appear and show cause why the vertical extension of the Cedar Hill-Fruitland Basal Coal Pool should not be rescinded and Division Order No. R-7588, as amended, should not be reinstituted as they existed prior to the issuance of this order.

(7) Jurisdiction of this cause is retained for the entry of such further orders as the Division may deem necessary.

DONE at Santa Fe, New Mexico, on the day and year hereinabove designated.

BASIN-FRUITLAND COAL GAS POOL
San Juan, Rio Arriba, McKinley and Sandoval Counties, New Mexico

Order No. 8768, Creating and Adopting Temporary Operating Rules for the Basin-Fruitland Coal Pool, San Juan, Rio Arriba, McKinley and Sandoval Counties, New Mexico, November 1, 1988, as Amended by Order No. R-8768-A, July 16, 1991.

In the Matter of the Hearing called by the Oil Conservation Division (OCD) on its own Motion for Pool Creation and Special Pool Rules, San Juan, Rio Arriba, McKinley and Sandoval Counties, New Mexico.

CASE NO. 9420
Order No. R-8768

ORDER OF THE DIVISION

BY THE DIVISION: This Cause came on for hearing at 8:30 a.m. on July 6, 1988, at Farmington, New Mexico, before Examiner David R. Catanach.

NOW, on this 17th day of October, 1988, the Division Director, having considered the testimony, the record, and the recommendations of the Examiner, and being fully advised in the premises,

FINDS THAT:
(1) Due public notice having been given as required by law, the Division has jurisdiction of this cause and the subject matter thereof.

(2) Division Case Nos. 9420 and 9421 were consolidated at the time of the hearing for the purpose of testimony.

(3) The Oil Conservation Division, hereinafter referred to as the "Division", on the recommendations of the Fruitland Coalbed Methane Committee, hereinafter referred to as the "Committee", seeks the creation of a new pool for the production of gas from coal seams within the Fruitland formation underlying the following described area in San Juan, Rio Arriba, McKinley, and Sandoval Counties, New Mexico:

Township	19	North,	Ranges	1	West	through	6	West;
Township	20	North,	Ranges	1	West	through	8	West;
Township	21	North,	Ranges	1	West	through	9	West;
Township	22	North,	Ranges	1	West	through	11	West;
Township	23	North,	Ranges	1	West	through	14	West;
Township	24	North,	Ranges	1	East	through	16	West;
Township	25	North,	Ranges	1	East	through	16	West;
Township	26	North,	Ranges	1	East	through	16	West;
Township	27	North,	Ranges	1	West	through	16	West;
Township	28	North,	Ranges	1	West	through	16	West;
Township	29	North,	Ranges	1	West	through	15	West;
Township	30	North,	Ranges	1	West	through	15	West;
Township	31	North,	Ranges	1	West	through	15	West;
Township	32	North,	Ranges	1	West	through	13	West;

(4) The Division further seeks, also upon the recommendations of the Committee, the promulgation of special pool rules, regulations, and operating procedures for said pool including, but not limited to, provisions for 320-acre spacing and proration units, designated well locations, well density, horizontal wellbore and deviated drilling procedures, venting and flaring rules, downhole commingling, and gas well testing requirements.

EXHIBIT
D

(BASIN-FRUITLAND COAL GAS POOL - Cont'd.)

(5) In companion Case No. 9421, the Division seeks to contract the vertical limits of twenty-six existing Fruitland and/or Fruitland-Pictured Cliffs Gas Pools to include only the Pictured Cliffs sandstone and/or Fruitland sandstone intervals.

(6) The Committee, which included representatives of the oil and gas industry, New Mexico Oil Conservation Division, Colorado Oil and Gas Conservation Commission, Bureau of Land Management, and Southern Ute Indian Tribe, was originally formed in 1986 for the purpose of studying and making recommendations to the Division as to the most orderly and efficient methods of developing coal seam gas within the Fruitland formation.

(7) Geologic evidence presented by the Committee indicates that the Fruitland formation, which is found within the geographic area described above, is composed of alternating layers of shales, sandstones, and coal seams.

(8) The evidence at this time further indicates that the coal seams within the Fruitland formation are potentially productive of natural gas in substantial quantities.

(9) The gas originating from the coal seams within the Fruitland formation is composed predominantly of methane and carbon dioxide and varies significantly from the composition of the gas currently being produced from the sandstone intervals, and as such, represents a separate common source of supply.

(10) A new pool for gas production from coal seams within the Fruitland formation should be created and designated the Basin-Fruitland Coal Gas Pool with vertical limits comprising all coal seams within the equivalent of the stratigraphic interval from a depth of approximately 2450 feet to 2880 feet as shown on the Gamma Ray/Bulk Density log from Amoco Production Company's Schneider Gas Com "B" Well No. 1 located 1110 feet from the South line and 1185 feet from the West line of Section 28, Township 32 North, Range 10 West, NMPM, San Juan County, New Mexico.

(11) The proposed horizontal pool boundary, which represents the geographic area encompassed by the Fruitland formation, contains within it, an area previously defined as the Cedar Hill-Fruitland Basal Coal Gas Pool (created by Division Order No. R-7588 effective February 1, 1984); said area currently comprises Sections 3 through 6 of Township 31 North, Range 10 West, and Sections 19 through 22 and 27 through 34 of Township 32 North, Range 10 West, NMPM, San Juan County, New Mexico.

(12) The proposed horizontal boundary of the Basin-Fruitland Coal Gas Pool should be amended to exclude that acreage currently defined as the Cedar Hill-Fruitland Coal Gas Pool described in Finding No. (11) above.

(13) The Committee has recommended the promulgation of special rules and regulations for the Basin-Fruitland Coal Gas Pool including a provision for 320-acre spacing and proration units, and in support thereof presented pressure interference data obtained from producing and pressure observation wells located within the Cedar Hill-Fruitland Coal Gas Pool, which indicates definite pressure communication between wells located 2,180 feet apart (radius of drainage of a 320-acre proration unit = 2,106 feet).

(14) Further testimony and evidence indicates that due to the unique producing characteristics of coal seams (i.e. initial inclining production rates), engineering methods such as decline curve analysis and volumetric calculations traditionally used to aid in the determination of proper well spacing, cannot be utilized.

(15) The Committee further recommended the adoption of a provision in the proposed pool rules allowing for the drilling of a second well on a standard 320-acre proration unit in order to give an operator flexibility when addressing regional geological trends.

(16) Dugan Production Corporation, Merrion Oil and Gas Corporation, Hixon Development Company, Robert L. Bayless, and Jerome P. McHugh and Associates, hereinafter referred to as the "Dugan Group", appeared at the hearing and presented geologic and engineering evidence and testimony in support of a proposal which includes the following:

1. Establishment of an area within the Southern portion of the Basin-Fruitland Coal Gas Pool to be developed on 160-acre spacing and proration units.

2. Creation of a demarcation line and buffer zone separating the 320-acre spacing portion of the pool and the proposed 160-acre spacing portion of the pool.

(17) The Dugan Group owns oil and gas leasehold operating rights in the Fruitland formation in various areas of the San Juan Basin, and currently operates numerous wells producing from coal seams and sandstone intervals within the Fruitland formation.

(18) The Dugan Group has defined the location of the proposed demarcation line and 160-acre spacing area by utilizing a preponderance of geologic factors such as coal rank, depth of burial, thermal maturation, thickness of coal, and amount of gas in place.

(19) In support of the proposed 160-acre spacing area for the subject pool, the Dugan Group presented production data obtained from four producing wells, the Nassau Well Nos. 5, 6, 7 and 8 located in Section 36, Township 27 North, Range 12 West, NMPM, San Juan County, New Mexico, which indicates that the production rate from said Nassau Well No. 5 was unaffected by initiation of 160-acre offset production in said Nassau Well Nos. 6, 7, and 8.

(20) The evidence presented by the Dugan Group further indicates however, that the Nassau Well Nos. 5, 6, 7, and 8 are producing from commingled coal seam and sandstone intervals within the Fruitland formation, and as such, do not conclusively demonstrate 160-acre non-interference exclusively within the coal seams.

(21) Insufficient evidence exists at the current time to justify the creation of a 160-acre spacing area and demarcation line within the Basin-Fruitland Coal Gas Pool.

(22) The best technical evidence available at this time indicates that 320-acre well spacing is the optimum spacing for the entire Basin-Fruitland Coal Gas Pool.

(23) In order to prevent the economic loss caused by the drilling of unnecessary wells, avoid the augmentation of risk arising from the drilling of an excessive number of wells, prevent reduced recovery which might result from the drilling of too few wells, and to otherwise protect correlative rights, special rules and regulations providing for 320-acre spacing units should be promulgated for the Basin-Fruitland Coal Gas Pool.

(24) The special rules and regulations should also provide for restrictive well locations in order to assure orderly development of the subject pool and protect correlative rights.

(25) Due to the relatively large area encompassed by the Basin-Fruitland Coal Gas Pool, and the relatively small amount of reservoir data currently available, the special rules and regulations should be promulgated for a temporary period of two years in order to allow the operators in the subject pool the opportunity to gather additional reservoir data relative to the determination of permanent spacing rules for the subject pool and/or specific areas within the pool.

(26) The evidence and testimony presented at the hearing is insufficient to approve at the present time, the proposed provision allowing for the drilling of a second well on a standard 320-acre proration unit.

(BASIN-FRUITLAND COAL GAS POOL - Cont'd.)

(27) The Committee further recommended the adoption of a provision in the Special Rules and Regulations allowing the venting or flaring of gas from a Basin-Fruitland Coal Gas well during initial testing in an amount not to exceed a cumulative volume of 50 MMCF or a period not to exceed 30 days.

(28) The evidence presented does not justify the establishment of a specific permissible volume of gas to be vented or flared from Basin-Fruitland Coal Gas Wells at this time, however, the supervisor of the Aztec district office of the Division should have the authority to allow such venting or flaring of gas from a well upon a demonstration such flaring or venting is justified and upon written application from the operator.

(29) Evidence and testimony presented at the hearing indicates that the gas well testing requirements as contained in Division Order No. R-333-I may cause damage to a Basin Fruitland Coal Gas Well, and that special testing procedures should be established.

(30) The special rules and regulations promulgated herein should include operating procedures for determination and classification of Basin-Fruitland Coal Gas Wells, horizontal wellbore and deviated drilling procedures, and procedures and guidelines for downhole commingling.

(31) This case should be reopened at an examiner hearing in October, 1990, at which time the operators in the subject pool should be prepared to appear and present evidence and testimony relative to the determination of permanent rules and regulations for the Basin-Fruitland Coal Gas Pool.

IT IS THEREFORE ORDERED THAT:

(1) Effective November 1, 1988, a new pool in all or parts of San Juan, Rio Arriba, McKinley and Sandoval Counties, New Mexico, classified as a gas pool for production from Fruitland coal seams, is hereby created and designated the Basin-Fruitland Coal Gas Pool, with vertical limits comprising all coal seams within the equivalent of the stratigraphic interval from a depth of approximately 2450 feet to 2880 feet as shown on the Gamma Ray/Bulk Density log from Amoco Production Company's Schneider Gas Com "B" Well No. 1 located 1110 feet from the South line and 1185 feet from the West line of Section 28, Township 32 North, Range 10 West, NMPM, San Juan County, New Mexico.

(2) The horizontal limits of the Basin-Fruitland Coal Gas Pool shall comprise the following described area in all or portions of San Juan, Rio Arriba, McKinley and Sandoval Counties, New Mexico, with the exception of Section 3 through 6 of Township 31 North, Range 10 West, and Section 19 through 22, and 27 through 34 of Township 32 North, Range 10 West, San Juan County, New Mexico, which said acreage currently comprises the Cedar Hill-Fruitland Basal Coal Gas Pool:

Township 19 North, Ranges 1 West through 6 West;
Township 20 North, Ranges 1 West through 8 West;
Township 21 North, Ranges 1 West through 9 West;
Township 22 North, Ranges 1 West through 11 West;
Township 23 North, Ranges 1 West through 14 West;
Township 24 North, Ranges 1 East through 16 West;
Township 25 North, Ranges 1 East through 16 West;
Township 26 North, Ranges 1 East through 16 West;
Township 27 North, Ranges 1 West through 16 West;
Township 28 North, Ranges 1 West through 16 West;
Township 29 North, Ranges 1 West through 15 West;
Township 30 North, Ranges 1 West through 15 West;
Township 31 North, Ranges 1 West through 15 West;
Township 32 North, Ranges 1 West through 13 West;

(3) Temporary Special Rules and Regulations for the Basin-Fruitland Coal Gas Pool are hereby promulgated as follows:

SPECIAL RULES AND REGULATIONS FOR THE BASIN-FRUITLAND COAL GAS POOL

RULE 1. Each well completed or recompleted in the Basin-Fruitland Coal Gas Pool shall be spaced, drilled, operated, and produced in accordance with the Special Rules and Regulations hereinafter set forth.

RULE 2. A gas well within the Basin-Fruitland Coal Gas Pool shall be defined by the Division Director as a well that is producing from the Fruitland coal seams as demonstrated by a preponderance of data which could include the following:

a. Electric Log Data
b. Drilling Time
c. Drill Cuttings of Log Cores
d. Mud Logs
e. Completion Data
f. Gas Analysis
g. Water Analysis
h. Reservoir Performance
i. Other evidence which may be utilized in making such determination.

RULE 3. (As Amended by Order No. R-8768-A, July 16, 1991) The Division Director may require the operator of a proposed or existing Basin-Fruitland Coal Gas well, Fruitland Sandstone well, or Pictured Cliffs Sandstone well, to submit certain data as described in Rule (2) above, which would not otherwise be required by Division Rules and Regulations, in order to demonstrate to the satisfaction of the Division that said well will be or is currently producing from the appropriate common source of supply. The confirmation that a well is producing exclusively from the Basin-Fruitland Coal Gas Pool shall consist of approval of Division Form C-104, provided however that such approval shall be for Division purposes only, and shall not preclude any other governmental jurisdictional agency from making its own determination of production origination utilizing its own criteria.

RULE 4. (As Amended by Order No. R-8768-A, July 16, 1991) Each well completed or recompleted in the Basin-Fruitland Coal Gas Pool shall be located on a standard unit containing 320 acres, more or less, comprising any two contiguous quarter sections of a single governmental section, being a legal subdivision of the United States Public Lands Survey.

Individual operators may apply to the Division for an exception to the requirements of Rule No. (4) to allow the drilling of a second well on standard 320-acre units or on approved non-standard units in specifically defined areas of the pool provided that:

(a) Any such application shall be set for hearing before a Division Examiner;

(b) Actual notice of such application shall be given to operators of Basin-Fruitland Coal Gas Pool wells, working interest owners of undrilled leases, and unleased mineral owners within the boundaries of the area for which the infill provision is requested, and to all operators of Basin-Fruitland Coal Gas Pool wells within one mile of such area, provided however any operator in the pool or other interested party may appear and participate in such hearing.

Such notice shall be sent certified or registered mail or by overnight express with certificate of delivery and shall be given at least 20 days prior to the date of the hearing.

RULE 5. (As Amended by Order No. R-8768-A, July 16, 1991) The Supervisor of the Aztec district office of the Division shall have the authority to approve a non-standard gas proration unit within the Basin-Fruitland Coal Gas Pool without notice and hearing when the unorthodox size or shape is necessitated by a variation in the legal subdivision of the United States Public Lands Survey and/or consists of an entire governmental section and the non-standard unit in not less than 70% nor more than 130% of a standard gas proration unit. Such approval shall consist of acceptance of Division Form C-102 showing the proposed non-standard unit and the acreage contained therein.

(BASIN-FRUITLAND COAL GAS POOL - Cont'd.)

RULE 6. (As Amended by Order No. R-8768-A, July 16, 1991) The Division Director may grant an exception to the requirements of Rule (4) when the unorthodox size or shape of the gas proration unit is necessitated by a variation in the legal subdivision of the United States Public Lands Survey and the non-standard gas proration unit is less than 70% or more than 130% of a standard gas proration unit, or where the following facts exist and the following provisions are complied with:

(a) the non-standard unit consists of quarter-quarter sections or lots that are contiguous by a common bordering side.

(b) The non-standard unit lies wholly within a governmental half section, except as provided in paragraph (c) following.

(c) The non-standard unit conforms to a previously approved Blanco-Mesaverde or Basin-Dakota Gas Pool non-standard unit as evidenced by applicant's reference to the Division's order number creating said unit.

(d) The applicant presents written consent in the form of waivers from all offset operators or owners of undrilled tracts and from all operators owning interests in the half section in which the non-standard unit is situated and which acreage is not included in said non-standard unit.

(e) In lieu of paragraph (d) of this rule, the applicant may furnish proof of the fact that all of the aforesaid parties were notified by certified or registered mail or overnight express mail with certificate of delivery of his intent to form such non-standard unit. The Division Director may approve the application if no such party has entered an objection to the formation of such non-standard unit within 30 days after the Division Director has received the application.

(f) The Division Director, at his discretion, may set any application under Rule (6) for public hearing.

RULE 7. The first well drilled or recompleted on every standard or non-standard unit in the Basin-Fruitland Coal Gas Pool shall be located in the NE/4 or SW/4 of a single governmental section and shall be located no closer than 790 feet to any outer boundary of the proration unit nor closer than 130 feet to any quarter section line nor closer than 10 feet to any quarter-quarter section line or subdivision inner boundary.

RULE 8. The Division Director may grant an exception to the requirements of Rule (7) without hearing when an application has been filed for an unorthodox location necessitated by topographical conditions, the recompletion of a well previously drilled to a deeper horizon,provided said well was drilled at an orthodox or approved unorthodox location for such original horizon, or the drilling of an intentionally deviated horizontal wellbore. All operators or owners of undrilled tracts offsetting the proposed location shall be notified of the application by registered or certified mail, and the applicant shall state that such notice has been furnished. The Director may approve the application upon receipt of written waivers from all parties described above or if no objections to the unorthodox location has been entered within 20 days after the Director has received the application.

RULE 9(A). The Division Director shall have the authority to administratively approve an intentionally deviated well in the Basin-Fruitland Coal Gas Pool for the purpose of penetrating the coalbed seams by means of a wellbore drilled horizontally, provided the following conditions are complied with:

(1) the surface location of the proposed well is a standard location or the applicant has obtained approval of an unorthodox surface location as provided for in Rule (8) above.

(2) The bore hole shall not enter or exit the coalbed seams outside of a drilling window which is in accordance with the setback requirements of Rule (7), provided however, that the 10 foot setback distance requirement from the quarter-quarter section line or subdivision inner boundary shall not apply to horizontally drilled wells.

(B) To obtain administrative approval to drill an intentionally deviated horizontal wellbore, the applicant shall file such application with the Santa Fe and Aztec offices of the Division and shall further provide a copy of such application to all operators or owners of undrilled tracts offsetting the proposed gas proration unit for said well by registered or certified mail, and the application shall state that such notice has been furnished. The application shall further include the following information:

(1) A copy of Division Form C-102 identifying the proposed proration unit to be dedicated to the well.

(2) Schematic drawings of the proposed well which fully describe the casing, tubing, perforated or open hole interval, kick-off point, and proposed trajectory of the drainhole section.

The Director may approve the application upon receipt of written waivers from all parties described above or if no objection to the intentionally deviated horizontal wellbore has been entered within 20 days after the Director has received the application. If any objection to the proposed intentionally deviated horizontal well is received within the prescribed time limit as described above, the Director shall, at the applicant's request, set said application for public hearing.

(C) During or upon completion of drilling operations the operator shall further be required to conduct a directional survey on the vertical and lateral portions of the wellbore and shall submit a copy of said survey to the Santa Fe and Aztec Offices of the Division.

(D) The Division Director, at his discretion, may set any application for intentionally deviated horizontal wellbores for public hearing.

RULE 10. Notwithstanding the provisions of Division Rule No. 404, the Supervisor of the Aztec district office of the Division shall have the authority to approve the venting or flaring of gas from a Basin-Fruitland Coal Gas Well upon a determination that said venting or flaring is necessary during completion operations, to obtain necessary well test information, or to maintain the producibility of said well. Application to flare or vent gas shall be made in writing to the Aztec district office of the Division.

RULE 11. Testing requirements for a Basin-Fruitland Coal Gas well hereinafter set forth may be used in lieu of the testing requirements contained in Division Order No. R-333-I. The test shall consist of a minimum twenty-four hour shut-in period, and a three hour production test. The Division Director shall have the authority to modify the testing requirements contained herein upon a showing of need for such modification. The following information from this initial production test must be reported:

1. The surface shut-in tubing and/or casing pressure and date these pressures were recorded.

2. The length of the shut-in period.

3. The final flowing casing and flowing tubing pressures and the duration and date of the flow period.

4. The individual fluid flow rate of gas, water, and oil which must be determined by the use of a separator and measurement facilities approved by the Supervisor of the Aztec district office of the Division; and

(BASIN-FRUITLAND COAL GAS POOL - Cont'd.)

5. The method of production, e.g. flowing, pumping, etc. and disposition of gas.

RULE 12. The Division Director shall have the authority to approve the commingling within the wellbore of gas produced from coal seams and sandstone intervals within the Fruitland and/or Pictured Cliffs formations where a finding has been made that a well is not producing entirely from either coal seams or sandstone intervals as determined by the Division. All such applications shall be submitted to the Santa Fe office of the Division and shall contain all the necessary information as described in General Rule 303 (C) of the Division Rules and Regulations, and shall meet the prerequisites described in 303 (C) (1) (b). In addition, the Division Director may require the submittal of additional well data as may be required to process such application.

RULE 13. The Division Director may approve the commingling within the wellbore of gas produced from coal seams and sandstone intervals within the Fruitland and/or Pictured Cliffs formations where a well does not meet the prerequisites as described in General Rule 303 (C) (1) (b) provided that such commingling had been accomplished prior to July 1, 1988, and provided further that the application is filed as described in Rule (12).

IT IS FURTHER ORDERED THAT:

(4) The locations of all wells presently drilling to, completed in, commingled in, or having an approved APD for the Basin-Fruitland Coal Gas Pool are hereby approved; the operator of any well having an unorthodox location shall notify the Aztec district office of the Division in writing of the name and location of the well within 30 days from the date of this order.

(5) Pursuant to Paragraph A. of Section 70-2-18, N.M.S.A. 1978, Comp., contained in Laws of 1969, Chapter 271, existing gas wells in the Basin-Fruitland Coal Gas Pool shall have dedicated thereto 320 acres in accordance with the foregoing pool rules; or pursuant to Paragraph C. of said Section 70-2-18, existing wells may have non-standard spacing and proration units established by the Division and dedicated thereto.

(6) In accordance with (5) above, the operator shall file a new Form C-102 dedicating 320 acres to the well or shall obtain a non-standard unit approved by the Division. The operator shall also file a new C-104 with the Aztec district office of the Division.

(7) Failure to comply with Paragraphs (5) and (6) above within 60 days of the date of this order shall subject the well to a shut-in order until such requirements have been met.

(8) This case shall be reopened at an examiner hearing in October, 1990 at which time the operators in the subject pool may appear and present evidence and testimony relative to the determination of permanent rules and regulations for the Basin-Fruitland Coal Gas Pool.

(9) Jurisdiction of this cause is retained for the entry of such further orders as the Division may deem necessary.

DONE at Santa Fe, New Mexico, on the day and year hereinabove designated.

VADA-DEVONIAN POOL
Lea County, New Mexico

Order No. R-8770, Adopting Temporary Operating Rules for the Vada-Devonian Pool, Lea County, New Mexico, October 26, 1988.

Order No. R-8770-A, May 30, 1990, rescinds the temporary operating rules adopted in Order No. R-8770, October 26, 1988.

Application of Union Pacific Resources Company for Pool Extension and Special Pool Rules, Lea County, New Mexico.

CASE NO. 9439
Order No. R-8770

ORDER OF THE DIVISION

BY THE DIVISION: This cause came on for hearing at 8:15 a.m. on August 17, 1988, at Santa Fe, New Mexico, before Examiner David R. Catanach.

NOW, on this 26th day of October, 1988, the Division Director, having considered the testimony, the record, and the recommendations of the Examiner, and being fully advised in the premises,

FINDS THAT:

(1) Due public notice having been given as required by law, the Division has jurisdiction of this cause and the subject matter thereof.

(2) Division Case Nos. 9439 and 9440 were consolidated at the time of the hearing for the purpose of testimony.

(3) By Order No. R-8667 dated June 10, 1988, the Division created and defined the Vada-Devonian Pool with horizontal limits consisting of the SW/4 of Section 26, Township 10 South, Range 33 East, NMPM, Lea County, New Mexico.

(4) The applicant, Union Pacific Resources Company, seeks to extend the horizontal limits of the Vada-Devonian Pool to include the NW/4 of Section 35, Township 10 South, Range 33 East, NMPM, Lea County, New Mexico, and further seeks the promulation of temporary special rules and regulations for said pool, including a provision for 80-acre spacing and proration units, designated well locations, and a poolwide exception to Division Rule No. 111 allowing for directional drilling or well deviations of more than five degrees in any 500-foot interval.

(5) The applicant is the owner and operator of the discovery well for said pool, the State "26" Well No. 1 located 330 feet from the South line and 2310 feet from the West line of said Section 26.

(6) The applicant is also the owner and operator of the State "26" Well No. 2 located 1910 feet from the South line and 1980 feet from the East line (Unit J) of said Section 26, which was spudded on April 21, 1988, was drilled to a depth of 12,953 feet and is currently being sidetracked to an unorthodox subsurface location within a 150-foot radius of a point 1910 feet from the South line and 2580 feet from the East line (Unit J) of said Section 26, (being the subject of companion Case No. 9440).

BEFORE THE NEW MEXICO OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC., and J.K. EDWARDS ASSOCIATES, INC. and J.K. EDWARDS ASSOICATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

Case No. 11996

MOTION TO QUASH SUBPOENAS DUCES TECUM

Whiting Petroleum Corporation and Maralex Resources, Inc. (collectively "Whiting"), by and through their counsel the Gallegos Law Firm, P.C. and James Bruce, Attorney at Law, hereby move the New Mexico Oil Conservation Division ("NMOCD") for its Order quashing subpoenas duces tecum served by applicant Pendragon Energy Partners, Inc. ("Pendragon"). As grounds for this Motion, Whiting states as follows:

1. On May 26, 1998, Whiting filed in the First Judicial District Court against Pendragon a Complaint for Tortious Conduct and for Damages and Equitable Relief arising out of Pendragon's operation of certain wells in San Juan County, New Mexico. After notice of the filing of the Complaint was provided to Pendragon and its counsel, J. Scott Hall, Pendragon filed this Application seeking an advisory opinion that the wells that are subject of the district court action "are producing from the appropriate common source of supply."

2. On June 9, 1998, without prior notice to Whiting, Pendragon sought and received from NMOCD subpoenas duces tecum which are the subject of this Motion. Those subpoenas, copies attached, order Whiting to produce documents at 9:00 a.m. on Tuesday, June 16, 1998.

3. Counsel for Pendragon did not have the subpoenas served when issued. Instead, the subpoenas were sent ordinary mail and received by undersigned counsel and Whiting on Friday, June 12, 1998.

4. Whiting is filing concurrently herewith a Motion to Dismiss Pendragon's Application in this cause for lack of jurisdiction. Based upon the points and authorities set forth in that Motion, the NMOCD should dismiss Pendragon's Application on legal grounds. There is no justification for the subpoenas and requests for production of documents given the lack of jurisdiction of NMOCD to entertain this Application.

5. Pendragon's subpoenas are oppressive and duplicative. A subpoena and request for production of documents received June 12, 1998, compelling production over a weekend on June 16, 1998, is harrasment and does not give Whiting an opportunity to respond to the discovery request in an orderly fashion.

6. Whiting has already produced many of the documents requested in Case No. 11921 subject to a Motion to Partially Quash Subpoenas Duces Tecum which Whiting filed in that case. Even if NMOCD had jurisdiction in this matter, there is no reason to respond to duplicate discovery requests where documents have previously been produced in another proceeding.

7. The requests for production are not limited to raw data, but include requests for interpretations, analysis and other materials comprising the work product of Whiting. Whiting objects to the requests to the extent that they seek such interpretations, analysis or other materials comprising the work product based upon Division policy which requires the turnover of raw data, but not interpretations thereof

made or prepared by the party subpoenaed. See Commission ruling dated February 15, 1991 in Case No. 10211 (Application of Santa Fe Energy Operating Partners, L.P. for compulsory pooling).

8. Without waiving its right to contest the NMOCD's jurisdiction in this matter, and the scope of the subpoena, Whiting requests that it have the full thirty (30) days from service of the subpoenas to produce documents. Rule 1-034, NMRA 1997.

WHEREFORE, Whiting respectfully requests that the NMOCD quash the subpoenas issued in this action or, alternatively, grant Whiting until July 13, 1998 to respond to the subpoenas.

Respectfully submitted,

GALLEGOS LAW FIRM, P.C.

By ______________________
J.E. GALLEGOS
MICHAEL J. CONDON
460 St. Michael's Drive, Bldg. 300
Santa Fe, New Mexico 87505
(505) 983-6686

James Bruce
Post Office Box 1056
Santa Fe, New Mexico 87504
(505) 982-2043

Attorneys for Movants

CERTIFICATE OF SERVICE

I hereby certify that I have caused a true and correct copy of a Motion to Quash Subpoenas Duces Tecum to be mailed on this 5th day of June, 1998 to the following counsel for defendants:

J. Scott Hall
Miller, Stratvert, Torgerson & Schlenker, P.A.
150 Washington Avenue
Santa Fe, New Mexico 87501

MICHAEL J. CONDON

BEFORE THE NEW MEXICO OIL CONSERVATION DIVISION

JUN 12 '98 PM 2:15

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC. and J. K. EDWARDS ASSOCIATES, INC. and J. K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

Case No. 11996

SUBPOENA DUCES TECUM

TO: Whiting Petroleum Corporation
c/o C. T. Corporation System
123 East Marcy
Santa Fe, New Mexico 87501

Pursuant to Section 70-2-8, NMSA (1978), and Rule 1211 of the New Mexico Oil Conservation Division's Rules of Procedure, you are hereby ORDERED to appear at 9:00 a.m., on Tuesday, June 16, 1998, at the offices of the Oil Conservation Division, 2040 South Pacheco, Santa Fe, New Mexico 87505 and to produce the documents and items specified in attached Exhibit A and to make available to Pendragon Energy Partners, Inc. and its attorney, J. Scott Hall, Esq., for copying, all of said documents.

This subpoena is issued on behalf of Pendragon Energy Partners, Inc. through its attorneys Miller, Stratvert & Torgerson , P.A., Post Office Box 1986, Santa Fe, New Mexico 87504.

Dated this 9th day of June, 1998.

NEW MEXICO OIL CONSERVATION DIVISION

By Lori Wrotenbery
Lori Wrotenbery, Director

JEG

EXHIBIT 'A'

TO SUBPOENA DUCES TECUM
TO WHITING PETROLEUM CORPORATION
IN NEW MEXICO OIL CONSERVATION DIVISION
CASE NO. 11996

DEFINITIONS AND INSTRUCTIONS

1. For purposes of this Exhibit "A", the "Subject Wells" are identified as follows:

Gallegos Fed. 26-12-6 No. 2	W½ §6-26N-12W
Gallegos Fed. 26-12-7 No. 1	W½ §7-26N-12W
Gallegos Fed. 26-13-1 No. 1	E½ §1-26N-13W
Gallegos Fed. 26-13-1 No. 2	W½ §1-26N-13W
Gallegos Fed. 26-13-12 No. 1	N½ §12-26N-13W

2. For each of the Subject Wells, all of the following materials, documents or data:

A. Electric Log Data

B. Drilling Time

C. Drill Cuttings of Log Cores

D. Mud Logs

E. Completion Data

F. Gas Analysis

G. Water Analysis

H. Reservoir Performance Data

3. The <u>Fruitland/PC/WAW Study-Gallegos Canyon Project</u> and all related data and materials provided or revealed to New Mexico Oil Conservation Division staff.

BEFORE THE NEW MEXICO OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC. and J. K. EDWARDS ASSOCIATES, INC. and J. K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

Case No. 11996

SUBPOENA DUCES TECUM

TO: Whiting Petroleum Corporation
c/o C. T. Corporation System
123 East Marcy
Santa Fe, New Mexico 87501

Pursuant to Section 70-2-8, NMSA (1978), and Rule 1211 of the New Mexico Oil Conservation Division's Rules of Procedure, you are hereby ORDERED to appear at 9:00 a.m., on Tuesday, June 16, 1998, at the offices of the Oil Conservation Division, 2040 South Pacheco, Santa Fe, New Mexico 87505 and to produce the documents and items specified in attached Exhibit A and to make available to Pendragon Energy Partners, Inc. and its attorney, J. Scott Hall, Esq., for copying, all of said documents.

This subpoena is issued on behalf of Pendragon Energy Partners, Inc. through its attorneys Miller, Stratvert & Torgerson , P.A., Post Office Box 1986, Santa Fe, New Mexico 87504.

Dated this 9th day of June, 1998.

NEW MEXICO OIL CONSERVATION DIVISION

By Lori Wrotenbery
Lori Wrotenbery, Director

JEG

EXHIBIT 'A'

TO SUBPOENA DUCES TECUM
TO MARALEX RESOURCES, INC.
IN NEW MEXICO OIL CONSERVATION DIVISION
CASE NO. 11996

DEFINITIONS AND INSTRUCTIONS

1. For purposes of this Exhibit "A", the "Subject Wells" are identified as follows:

Gallegos Fed. 26-12-6 No. 2	W½ §6-26N-12W
Gallegos Fed. 26-12-7 No. 1	W½ §7-26N-12W
Gallegos Fed. 26-13-1 No. 1	E½ §1-26N-13W
Gallegos Fed. 26-13-1 No. 2	W½ §1-26N-13W
Gallegos Fed. 26-13-12 No. 1	N½ §12-26N-13W

2. For each of the Subject Wells, all of the following materials, documents or data:

A. Electric Log Data

B. Drilling Time

C. Drill Cuttings of Log Cores

D. Mud Logs

E. Completion Data

F. Gas Analysis

G. Water Analysis

H. Reservoir Performance Data

3. The Fruitland/PC/WAW Study-Gallegos Canyon Project and all related data and materials provided or revealed to New Mexico Oil Conservation Division staff.

STATE OF NEW MEXICO
OIL CONSERVATION DIVISION
ENERGY, MINERALS AND NATURAL RESOURCES DEPARTMENT

IN THE MATTER OF THE HEARING CALLED BY THE OIL CONSERVATION DIVISION FOR THE PURPOSE OF CONSIDERING:

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC. and J.K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

CASE NO.

MOTION OF WHITING PETROLEUM CORPORATION AND MARALEX RESOURCES, INC. TO DISMISS APPLICATION FOR LACK OF JURISDICTION

Whiting Petroleum Corporation ("Whiting") and Maralex Resources, Inc. ("Maralex") hereby appear to contest the jurisdiction of this agency and hereby move the Oil Conservation Division ("OCD") for an order dismissing the Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates in this docket. In support of this Motion, respondents state as follows:

1. Pendragon Energy Partners, Inc. ("Pendragon") and J.K. Edwards Associates, Inc. ("Edwards") (collectively "applicants") own rights to produce gas from the Pictured Cliffs Pool. In contrast, respondents Whiting and Maralex own rights to produce gas from the Basin Fruitland Coal Gas Pool that overlies the Pictured Cliffs Pool in the area of applicants' wells; applicants Pendragon and Edwards own no rights in the Fruitland formation. Applicants apparently want the OCD to "confirm" or decide questions of the ownership of mineral rights and to thereby inferentially "rule" that

defendants are not converting Whiting's and Maralex's gas and not trespassing into Whiting and Maralex's Fruitland formation. That is beyond the limited jurisdiction of the NMOCD.

2. This dispute is the subject of litigation between respondents and applicants. On May 26, 1998, Whiting and Maralex filed their Complaint for Tortious Conduct and for Damages and Equitable Relief ("Complaint"), Case No. D-0101-CV-9801295, in the First Judicial District Court, County of Santa Fe, State of New Mexico. The Complaint contains five common-law claims against both Pendragon and Edwards arising out of applicants' well reworking operations that cause applicants' Pictured Cliffs wells to produce Fruitland formation gas through the wellbores of applicants' wells: conversion, negligence, trespass, quasi-contract/unjust enrichment, and for an accounting. The Complaint asks for actual, consequential and punitive damages, an accounting for revenues attributable to the tortfeasors' past sales of gas owned by Whiting and Maralex and an equitable ownership allocation of future production from the combined Pictured Cliffs/Fruitland gas stream, and injunctive relief to prevent future trespasses and continued conversion. On May 26, 1998, Whiting and Maralex contemporaneously filed in the First Judicial District Court a verified application for a preliminary injunction to stop the tortious activities of Pendragon and Edwards.

3. After the filing and service upon applicants' counsel of both (a) the Complaint, and (b) the verified application for a preliminary injunction, Pendragon and Edwards rushed to the NMOCD and filed this Application.

4. Neither Pendragon or Edwards are, by any stretch of the imagination, injured parties; they have no possible claims for damages or for any

affirmative or coercive relief, and do not seek any such relief from the NMOCD. Applicants are instead seeking cover or shelter in the form of a ruling from the NMOCD that might assist them to later defend the claims Whiting and Maralex have filed in court: the NMOCD is thus asked to declare that applicants have "no liability" by "confirming" applicants' putative ownership of the gas that is being produced from applicants' wells. If the applicants are innocent of the civil wrongs alleged in the Santa Fe County Court action, then they should hasten to defend themselves rather than expect a state agency to be their guardian.

5. The NMOCD "is a creature of statute expressly defined, limited and empowered by the laws creating it." Continental Oil Co. v. Oil Conservation Comm'n, 70 N.M. 310, 318, 373 P.2d 809, 814 (1962.) Nothing in the Oil and Gas Act gives NMOCD jurisdiction to render a declaratory judgment or to "confirm" a party's conduct as not violative of the property rights of others. Jurisdiction over declarations of rights rests solely with the judiciary. See NMSA 1978, § 44-6-2. Moreover, courts have expressly disapproved the tactic of preemptive filing by a non-aggrieved party for a declaration of non-liability. See, e.g., Abor v. Black, 695 S.W.2d 564 (Tex. 1985) (trial court should decline to exercise jurisdiction over a preemptive action for declaration of non-liability because it deprives the real plaintiff of the traditional right to choice the time and place of suit); UNC Resources, Inc. v. Benally, 514 F. Supp. 358, 363 (D.N.M. 1981) ("it is not one of the purposes of the declaratory judgment acts to enable a prospective negligence action defendant to obtain a declaration of non-liability"); K.M.S. Research Laboratories, Inc. v. Willingham, 629 S.W.2d 173, 174 (Tex. Civ. App. --

Dallas 1982.) The NMOCD surely has no jurisdiction over a request that would not be entertained even by a court with a colorable claim to jurisdiction.

6. The Application broadly asserts that the NMOCD has jurisdiction over anything "related to the conservation of oil and gas or oil and gas operations in this state." (Application, p. 4, ¶ 8.) Applicants are wrong.

7. An administrative agency does not have jurisdiction over common-law tort or contract claims, and has no jurisdiction when the agency is "without power to grant the relief" sought in court by the aggrieved party. O'Hare v. Valley Utilities, Inc., 89 N.M. 105, 111, 547 P.2d 1147, 1153 (Ct. App.), rev'd in part, 89 N.M. 262, 550 P.2d 274 (1976); McDowell v. Napolitano, 119 N.M. 696, 700, 895 P.2d 218, 222 (1995) (court has jurisdiction to exclusion of agency "where there is an applicable common-law or legal remedy apart from or in addition to an administrative remedy, or where there is no applicable statutory administrative remedy"); Eldridge, supra, ¶ 25, 934 P.2d at 1079-1080 (courts, and not agencies, have jurisdiction over common-law tort claims) (citing Nader v. Allegheny Airlines, Inc., 426 U.S. 290, 305-306, 96 S. Ct. 1978, 1987-1988 (1976).) The NMOCD has no authority under the Oil and Gas Act to, e.g., award damages to plaintiffs. Consequently, the NMOCD does not have, to the exclusion of the First Judicial District Court, jurisdiction over any part of this dispute. Napolitano, supra; see also Foree v. Crown Central Petroleum Corp., 431 S.W.2d 312, 316 (Tex. 1968) (Texas Railroad Commission lacked jurisdiction because Commission had no power to award damages.)

8. Administrative agencies do not have jurisdiction over disputes involving mineral trespass, negligence, or conversion of oil or natural gas. See, e.g.,

Wronski v. Sun Oil Company, 279 N.W.2d 564, 567, 568 (Mich. Ct. App. 1979) (claim of overproduction of oil in violation of proration order was claim for conversion within court's jurisdiction to the exclusion of administrative agency); Dorchester Gas Producing Co. v. Harlow Corp., 743 S.W.2d 243, 252 (Tex. Civ. App. -- Amarillo 1987 writ dismissed in part); Marshall v. El Paso Natural Gas Company, 874 F.2d 1373, 1377 (10th Cir. 1989) (claims for negligent plugging of gas well were "factual issues. . . of the sort that [a] court routinely considers" and therefore not within the jurisdiction of Oklahoma Corporation Commission.) Similarly, claims for subsurface trespass -- including trespass caused by an improper frac job, which is a topic central to the allegations of the Complaint -- are matters for judicial determination, and are not to be resolved by agencies. See Gregg v. Delhi-Taylor Oil Corp., 344 S.W.2d 411, 416 (Tex. 1961.) In Gregg, the Texas Supreme Court specifically rejected arguments that the Railroad Commission's staff made it more qualified to ascertain the extent of any subsurface trespass by well fraccing, 344 S.W.2d at 413, ruling instead that courts alone had authority to ascertain the existence of a trespass and to enjoin it, because "the issue is one inherently judicial in nature. . .". 344 S.W.2d at 415.

9. Notwithstanding the Application's confused and cavalier (but incorrect) reference to a "common source of supply," this is no situation of two producers trying to produce gas from any common pool such as might support NMOCD's jurisdiction to prevent waste or to ascertain or protect correlative rights. Pendragon/Edwards have rights to the Pictured Cliffs Pool and only the Pictured Cliffs Pool. Attached as Exhibits A1-A3 are copies of the Assignments which reflect the single formation ownership of applicants. Applicants own:

From the base of the Fruitland Coal Formation
to the base of the Pictured Cliffs Formation.

Whiting/Maralex neither have nor claim any right to produce from that pool. On the other hand, Whiting/Maralex own rights to the Basin-Fruitland Coal Gas Pool, and Pendragon/Edwards neither have nor claim any ownership rights to that pool. There is no common source of supply to be "just[ly] and equitabl[y] share[d]. . . " NMSA 1978, § 70-2-23H.

10. The "common source of supply" issue is not dispostive of the dispute between the parties. The district court will ultimately need to determine whether Pendragon and Edwards are producing gas from the sandstone and coal intervals of The Fruitland Formation, in which they own no interest, and on doing so award Whiting and Maralex damages for that civil trespass.

11. Pendragon's Application does not allege, nor could it, that Pendragon owns rights to the gas which it is producing from the wells at issue in its Application. Pendragon only denies " that the drilling or fracture stimulation of their Pictured Cliffs wells resulted in the communication of the two pools or that they are producing from the Basin-Fruitland Coal Gas Pool through their Pictured Cliffs completions." Application, ¶ 5, p.3. Thus, Pendragon has no standing to either invoke the jurisdiction of the NMOCD or to seek the requested relief.

12. Along with a case of trespass, Whiting's and Maralex's lawsuit claims conversion by Pendragon and Edwards taking gas, title to which belongs to Whiting and Maralex. See Dorchester, supra, 743 S.W.2d at 252 (action for conversion of natural gas is essentially allegation that defendant has divested plaintiff "of its title to the gas," and plaintiff thus "invokes the aid of the court to secure compensation for the

gas by an award of damages. . . ".) By claiming in their Application that such gas is produced from the Pictured Cliffs formation, applicants are claiming ownership of that gas. Resolution of that conflict requires an adjudication of the ownership of property. Nothing in the Oil and Gas Act pretends to grant the OCD any authority to determine or affect private property rights and through the years the OCD has consistently and correctly refused to address such disputes. See Dorchester, id. (Texas Railroad Commission "does not have authority to determine the ownership of oil or gas, or how the proceeds from the sale of oil or gas should be apportioned" between disputants in a conversion action) (quoting Railroad Commission of Texas v. City of Austin, 524 S.W.2d 262, 267-268 (Tex. 1975).) The NMOCD has no jurisdiction to adjudicate private ownership rights.

13. Pendragon and Edwards further invoke NMSA 1978, § 70-2-12B(2) for the asserted jurisdiction of the NMOCD. (Application, p. 4, ¶ 8.) That subsection only gives the OCD authority to permit a single wellbore to produce from multiple formations. This dispute has nothing to do with multiple completions. Moreover, at a minimum, application of § 70-2-12(B)(2) presupposes that the applicant owns gas in each of the multiple formations, and simply seeks guidance from OCD regarding technical aspects of multiple completions. But Pendragon and Edwards do not own gas in the Fruitland formation or pool, which they have involved, and the OCD could not therefore have any say in the manner of the "completion" of defendants' trespassing wells. Cf. Dorchester, supra. Technical expertise regarding completion techniques is irrelevant absent an adjudication of ownership -- a subject external to

OCD's jurisdiction and uniquely reserved to New Mexico courts -- as a predicate to any ability to complete a well into any producing formation.

14. The OCD has no jurisdiction over the matters set forth in this Application. Whiting and Maralex have accordingly filed with the First Judicial District Court a motion to enjoin Pendragon and Edwards from prosecuting their Application, and to require them to dismiss it. Hearing on that motion, originally scheduled for June 22, 1998, has been delayed due to applicants dodging a hearing on the merits by filing a Recusal of the presiding Judge on June 14, 1998.

WHEREFORE, respondents Whiting Petroleum Corporation and Maralex Resources, Inc. respectfully request that the OCD dismiss, for lack of jurisdiction, this Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc.

Respectfully submitted,

GALLEGOS LAW FIRM, P.C.

By [signature]
J.E. GALLEGOS
MICHAEL L. OJA
460 St. Michael's Drive, Bldg. 300
Santa Fe, New Mexico 87505
(505) 983-6686

James Bruce
Post Office Box 1056
Santa Fe, New Mexico 87504
(505) 982-2043

Attorneys for Movants

CERTIFICATE OF SERVICE

I hereby certify that I have caused a true and correct copy of the Special Appearance and Motion of Whiting Petroleum Corporation and Maralex Resources, Inc. to Dismiss Application For Lack of Jurisdiction to be hand-delivered on this 15th day of June, 1998 to the following counsel for defendants:

J. Scott Hall
Miller, Stratvert, Torgerson & Schlenker, P.A.
150 Washington Avenue
Santa Fe, New Mexico 87501

J.E. GALLEGOS

1194-803

Chaco Ltd. 1J, 2J

ASSIGNMENT, BILL OF SALE AND CONVEYANCE
Chaco Limited No. 1-J, 2-J

This Assignment, Bill of Sale and Conveyance is made and entered into this 14th day of December, 1994, by and between the J. Gregory Merrion and Rita V. Merrion Revocable Trust, Robert L. Bayless, et ux, Merle L. Elisaesser, et ux, Steven S. Dunn, et ux, and Merrion Oil & Gas Corporation, collectively referred to as "Assignor", and JK EDWARDS & ASSOCIATES, INC. hereinafter referred to as "Assignee".

WITNESSETH:

WHEREAS, Assignor owns certain right, title and interest in the properties described below in subparagraphs (a) through (f), hereinafter referred to as "the Subject Properties";

WHEREAS, Assignor desires to sell, and Assignee desires to acquire, all of Assignor's right, title and interest in, to, and under the Subject Properties.

NOW THEREFORE, in consideration of the mutual benefit to all parties and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged for all purposes, Assignor does hereby grant, bargain, sell, convey, assign, transfer, set over, and deliver unto Assignee all of Assignor's right, title and interest in, to and under the said properties, which properties are more specifically described as follows:

(a) All of those properties described in Exhibit "A";

(b) All right, title and interest in and to all presently existing and valid oil, gas and/or mineral unitization, pooling, and/or communitization agreements, declarations and/or orders and in and to the properties covered and the units created thereby (including, without limitation, units formed under orders, rules, regulations or other official acts of any federal, state or other authority having jurisdiction, voluntary unitization agreements, designations and/or declaration, and so called "working interest units" created under operating agreements or otherwise), which relate to any of the properties described in subparagraph (a);

(c) All right title and interest in and to all presently existing and valid production sales (and sales related) contracts, operating agreements, and other agreements and contracts which relate to any of the properties described in subparagraphs (a) and (b) above, or which relate to the exploration, development, operation or maintenance thereof or the treatment, storage, transportation or marketing of production therefrom (or allocated thereto);

Lot 99

Exhibit A-1

(d) All right, title and interest in and to the Chaco Limited No. 1-J and Chaco Limited No. 2-J wellbores, all the equipment associated with the wells, together with all rights, titles and interest in and to other materials, supplies, machinery, equipment, improvements, and any other personal property and fixtures associated with the wells in Exhibit "A". All easements, rights-of-way, surface leases and other surface rights, all permits and licenses, and all other appurtenances being used or held for use in connection with, or otherwise related to, the exploration, development, operation or maintenance of any of the properties described in subparagraphs (a), (b) and (c) above, or the treatment, storage, gathering, transportation or marketing or production therefrom or allocated thereto;

(e) All interest in lease records, and other data and records used or held for use in connection with the exploration, development or operation of the properties described in Exhibit "A"; and

(f) Except as specified below, all oil, gas, casinghead gas, condensate, distillate, liquid hydrocarbons, and gaseous hydrocarbons (collectively called "Hydrocarbons") in and under that may be produced and saved from the base of the Fruitland Coal formation to the base of the Pictured Cliffs formation on the Subject Properties from and after the effective date, and all proceeds attributable thereto. All Hydrocarbons in and under and produced and saved from the Subject Properties before the effective date, and all proceeds attributable thereto, are hereby retained and reserved in favor of Assignor.

TO HAVE AND TO HOLD, the Subject Properties unto Assignee, its successors and assigns, provided, however, this Assignment is made subject to the following terms and provisions:

I.

The Subject Properties are sold "AS IS" and "WHERE IS" without any warranty of merchantability, condition or fitness for a particular purpose, either express or implied; however, Assignor warrants and covenants that there are no liens, mortgages, security interests, financing statements, or other claims or encumbrances as to the Subject Properties.

II.

Assignor hereby assumes and agrees to pay and perform and discharge all obligations attributable to the interest conveyed by Assignor to Assignee in the Subject Properties prior to the effective date of this assignment. Assignee hereby assumes and agrees that it has rights to all revenues received on production, and to pay, perform and discharge all obligations attributable to the interests conveyed by Assignor to Assignee in the Subject Properties which are attributable after the effective date of this Agreement.

III.

Assignor hereby agrees to execute any and all other instruments and/or documents necessary to give effect to the transfer of Assignor's interests in the Subject Properties.

IV.

This agreement may be executed in any number of counterparts, no one of which needs to be executed by all parties, or may be ratified or consented to by separate instruments, in writing, specifically referring hereto, and shall be binding upon all parties who have executed such a counterpart, ratification or consent hereto with the same force and effect as if all parties had signed the same document.

V.

This agreement shall be binding upon the parties hereto and shall extend to and be binding upon their respective heirs, executors, administrators, and successors and assigns.

IN WITNESS WHEREOF, this Assignment, Bill of Sale, and Conveyance has been executed and delivered on the date and year first above written, but shall be effective for all purposes as of 7:00 o'clock a.m., Farmington, New Mexico time on December 31st, 1994.

ASSIGNOR:
J. GREGORY MERRION AND RITA V. MERRION REVOCABLE TRUST

By: [signature]
J. Gregory Merrion, Trustee

MERRION OIL & GAS CORPORATION

By: [signature]
T. Greg Merrion, President

[signature]
Robert L. Bayless

[signature]
Bernice M. Bayless, his wife

[signature]
Merle L. Ellsaesser

[signature]
Jo Anne Ellsaesser, his wife

Steven S. Dunn

Melinda A. Dunn, his wife

ASSIGNEE:
J.K. EDWARDS & ASSOCIATES, INC.

By: [signature]
DON POE, Attorney-In-Fact

ACKNOWLEDGMENTS

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

This instrument was acknowledged before me this 2nd day of December, 1994, by J. Gregory Merrion, Trustee of the J. Gregory Merrion and Rita V. Merrion Revocable Trust, on behalf of said Trust.

My commission expires: 6-27-98

Notary Public

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

This instrument was acknowledged before me this 2nd day of December, 1994, by T. Greg Merrion, President of Merrion Oil & Gas Corporation, a New Mexico corporation, on behalf of said corporation.

My commission expires: 6-27-98

Notary Public

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

Before me, a notary public, on this 5th day of December, 1994, personally appeared Robert L. Bayless and Bernice M. Bayless, husband and wife, to me known to be the identical persons who executed the within and foregoing instrument and acknowledged that they executed the same as their free and voluntary act and deed.

My commission expires: 9-20-96

Notary Public

9500455 B-1194 P-803 01/09/95 03:00P PG 4 OF 6

EXHIBIT "A"

Attached to and made a part of that certain Assignment, Bill of Sale and Conveyance effective December 31st, 1994, by and between Assignor and Assignee

LEASES AND LANDS FROM THE BASE OF THE FRUITLAND COAL FORMATION TO BASE OF THE PICTURED CLIFFS FORMATION

I. LEASES

Lease No.	SF-080238-A
Lessor:	United States of America
Lease Effective Date:	April 1, 1951
Original Lessee:	Beulah Morgan
Lease Description:	Township 26 North, Range 13 West, NMPM
	Section 1: Lots 1,2, S/2NE, SW
	Containing 320.08 acres, more or less
County:	San Juan
State:	New Mexico
Well:	Chaco Limited No. 1-J, 2-J
WI Being Conveyed:	100%

II. WELLS

NAME	LOCATION(SPACING)
Chaco Limited No. 1-J	T-26-N,R-13-W Sec. 1: NESW (SW)
Chaco Limited No. 2-J	T-26-N,R-13-W Sec. 1: NWNE (NE)

FILED OR RECORDED
BOOK 1194 PAGE 803
SAN JUAN COUNTY, NEW MEXICO
JAN 0 9 1995
at 3:00 o'clock P M
COUNTY CLERK
DEPUTY
REC 210123

SAN JUAN COUNTY CLERK, STATE OF NEW MEXICO

1194-799

Chaco 1,2R

9500451 B-1194 P-799 01/09/95 02:56P PG 1 OF 6 REC 22.00 DOC 2.00
CAROL BANDY, CLERK SAN JUAN COUNTY, NEW MEXICO

ASSIGNMENT, BILL OF SALE AND CONVEYANCE
Chaco No. 1, 2R

This Assignment, Bill of Sale and Conveyance is made and entered into this 14th day of December, 1994, by and between the J. Gregory Merrion and Rita V. Merrion Revocable Trust, Robert L. Bayless, et ux, Merle L. Ellsaesser, et ux, Steven S. Dunn, et ux, and Merrion Oil & Gas Corporation, collectively referred to as "Assignor", and J.K. Edwards + Associates, Inc. hereinafter referred to as "Assignee".

WITNESSETH:

WHEREAS, Assignor owns certain right, title and interest in the properties described below in subparagraphs (a) through (f), hereinafter referred to as "the Subject Properties";

WHEREAS, Assignor desires to sell, and Assignee desires to acquire, all of Assignor's right, title and interest in, to, and under the Subject Properties.

NOW THEREFORE, in consideration of the mutual benefit to all parties and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged for all purposes, Assignor does hereby grant, bargain, sell, convey, assign, transfer, set over, and deliver unto Assignee all of Assignor's right, title and interest in, to and under the said properties, which properties are more specifically described as follows:

(a) All of those properties described in Exhibit "A";

(b) All right, title and interest in and to all presently existing and valid oil, gas and/or mineral unitization, pooling, and/or communitization agreements, declarations and/or orders and in and to the properties covered and the units created thereby (including, without limitation, units formed under orders, rules, regulations or other official acts of any federal, state or other authority having jurisdiction, voluntary unitization agreements, designations and/or declaration, and so called "working interest units" created under operating agreements or otherwise), which relate to any of the properties described in subparagraph (a);

FILED OR RECORDED
BOOK 1194 PAGE 799
SAN JUAN COUNTY, NEW MEXICO
JAN 0 9 1995
2:56 o'clock P
County Clerk
Deputy

(c) All right title and interest in and to all presently existing and valid production sales (and sales related) contracts, operating agreements, and other agreements and contracts which relate to any of the properties described in subparagraphs (a) and (b) above, or which relate to the exploration, development, operation or maintenance thereof or the treatment, storage, transportation or marketing of production therefrom (or allocated thereto);

SAN JUAN COUNTY CLERK STATE OF NEW MEXICO

6+98

Exhibit A-2

(d) All right, title and interest in and to the Chaco No. 1 and Chaco No. 2R wellbores, all the equipment associated with the wells, together with all rights, titles and interest in and to other materials, supplies, machinery, equipment, improvements, and any other personal property and fixtures associated with the wells in Exhibit "A". All easements, rights-of-way, surface leases and other surface rights, all permits and licenses, and all other appurtenances being used or held for use in connection with, or otherwise related to, the exploration, development, operation or maintenance of any of the properties described in subparagraphs (a), (b) and (c) above, or the treatment, storage, gathering, transportation or marketing or production therefrom or allocated thereto;

(e) All interest in lease records, and other data and records used or held for use in connection with the exploration, development or operation of the properties described in Exhibit "A"; and

(f) Except as specified below all oil, gas, casinghead gas, condensate, distillate, liquid hydrocarbons, and gaseous hydrocarbons (collectively called "Hydrocarbons") in and under that may be produced and saved from the base of the Fruitland Coal formation to the base of the Pictured Cliffs formation on the Subject Properties from and after the effective date, and all proceeds attributable thereto. All Hydrocarbons in and under and produced and saved from the Subject Properties before the effective date, and all proceeds attributable thereto, are hereby retained and reserved in favor of Assignor.

TO HAVE AND TO HOLD, the Subject Properties unto Assignee, its successors and assigns, provided, however, this Assignment is made subject to the following terms and provisions:

I.

The Subject Properties are sold "AS IS" and "WHERE IS" without any warranty of merchantability, condition or fitness for a particular purpose, either express or implied; however, Assignor warrants and covenants that there are no liens, mortgages, security interests, financing statements, or other claims or encumbrances as to the Subject Properties.

II.

Assignor hereby assumes and agrees to pay and perform and discharge all obligations attributable to the interest conveyed by Assignor to Assignee in the Subject Properties prior to the effective date of this assignment. Assignee hereby assumes and agrees that it has rights to all revenues received on production, and to pay, perform and discharge all obligations attributable to the interests conveyed by Assignor to Assignee in the Subject Properties which are attributable after the effective date of this Agreement.

III.

Assignor hereby agrees to execute any and all other instruments and/or documents necessary to give effect to the transfer of Assignor's interests in the Subject Properties.

IV.

This agreement may be executed in any number of counterparts, no one of which needs to be executed by all parties, or may be ratified or consented to by separate instruments, in writing, specifically referring hereto, and shall be binding upon all parties who have executed such a counterpart, ratification or consent hereto with the same force and effect as if all parties had signed the same document.

V.

This agreement shall be binding upon the parties hereto and shall extend to and be binding upon their respective heirs, executors, administrators, and successors and assigns.

IN WITNESS WHEREOF, this Assignment, Bill of Sale, and Conveyance has been executed and delivered on the date and year first above written, but shall be effective for all purposes as of 7:00 o'clock a.m., Farmington, New Mexico time on December 31, 1994.

ASSIGNOR:
J. GREGORY MERRION AND RITA V. MERRION REVOCABLE TRUST

By: [signature]
J. Gregory Merrion, Trustee

MERRION OIL & GAS CORPORATION

By: [signature]
T. Greg Merrion, President

[signature]
Robert L. Bayless

[signature]
Bernice M. Bayless, his wife

[signature]
Merle L. Ellsaesser

[signature]
Jo Anne Ellsaesser, his wife

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

Before me, a notary public, on this 6th day of December, 1994, personally appeared Merle L. Ellsaesser and Jo Anne Ellsaesser, husband and wife, to me known to be the identical persons who executed the within and foregoing instrument and acknowledged that they executed the same as their free and voluntary act and deed.

My commission expires: Crystal Williams
Notary Public

6-27-98

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

Before me, a notary public, on this 5th day of December, 1994, personally appeared Steven S. Dunn and Melinda A. Dunn, husband and wife, to me known to be the identical persons who executed the within and foregoing instrument and acknowledged that they executed the same as their free and voluntary act and deed.

My commission expires: Crystal Williams
Notary Public

6-27-98

(Corporate)

STATE OF)
§
COUNTY OF)

This instrument was acknowledged before me this 14th day of December, 1994, by Don Poe, Attorney-In-Fact of J.K. Edwards & Associates, Inc. a Colorado corporation, on behalf of said corporation.

My commission expires: Sharon Kaye Jaynes
Notary Public

SHARON KAYE JAYNES
Notary Public, State of Texas
My Commission Expires April 5, 1998

EXHIBIT "A"

Attached to and made a part of that certain Assignment, Bill of Sale and Conveyance effective December 14th, 1994, by and between Assignor and Assignee

LEASES AND LANDS FROM THE BASE OF THE FRUITLAND COAL FORMATION TO BASE OF THE PICTURED CLIFFS FORMATION

I. LEASES

(1)

Lease No.	NM-23472
Lessor:	United States of America
Lease Effective Date:	February 1, 1975
Original Lessee:	Robert L. Bayless
Lease Description:	Township 26 North, Range 12 West, NMPM Section 7: Lots 3,4 (W/2SW) Section 18: Lots 1,2 (W/2NW) Containing 152.73 acres, more or less
County:	San Juan
State:	New Mexico
Well:	Chaco 1, 2R
WI Being Conveyed:	100%

(2)

Lease No.	NM-22046
Lessor:	United States of America
Lease Effective Date:	September 1, 1974
Original Lessee:	Judy Payne
Lease Description:	Township 26 North, Range 12 West, NMPM Section 7: E/2SW Section 18: E/2NW Containing 160.00 acres, more or less
County:	San Juan
State:	New Mexico
Well:	Chaco 1, 2R
WI Being Conveyed:	100%

II. WELLS

NAME	LOCATION(SPACING)
Chaco No. 1	T-26-N,R-12-W Sec. 18: SENW (NW)
Chaco No. 2R	T-26-N,R-12-W Sec. 7: NESW (SW)

Chaco 4,6

ASSIGNMENT, BILL OF SALE AND CONVEYANCE
Chaco No. 4,5

This Assignment, Bill of Sale and Conveyance is made and entered into this 14th day of December, 1994, by and between the J. Gregory Merrion and Rita V. Merrion Revocable Trust, Robert L. Bayless, et ux, Merle L. Ellsaesser, et ux, Steven S. Dunn, et ux, and Merrion Oil & Gas Corporation, collectively referred to as "Assignor", and J.K. Edwards + Associates, Inc. hereinafter referred to as "Assignee".

WITNESSETH:

WHEREAS, Assignor owns certain right, title and interest in the properties described below in subparagraphs (a) through (f), hereinafter referred to as "the Subject Properties";

WHEREAS, Assignor desires to sell, and Assignee desires to acquire, all of Assignor's right, title and interest in, to, and under the Subject Properties.

NOW THEREFORE, in consideration of the mutual benefit to all parties and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged for all purposes, Assignor does hereby grant, bargain, sell, convey, assign, transfer, set over, and deliver unto Assignee all of Assignor's right, title and interest in, to and under the said properties, which properties are more specifically described as follows:

(a) All of those properties described in Exhibit "A";

(b) All right, title and interest in and to all presently existing and valid oil, gas and/or mineral unitization, pooling, and/or communitization agreements, declarations and/or orders and in and to the properties covered and the units created thereby (including, without limitation, units formed under orders, rules, regulations or other official acts of any federal, state or other authority having jurisdiction, voluntary unitization agreements, designations and/or declaration, and so called "working interest units" created under operating agreements or otherwise), which relate to any of the properties described in subparagraph (a);

(c) All right title and interest in and to all presently existing and valid production sales (and sales related) contracts, operating agreements, and other agreements and contracts which relate to any of the properties described in subparagraphs (a) and (b) above, or which relate to the exploration, development, operation or maintenance thereof or the treatment, storage, transportation or marketing of production therefrom (or allocated thereto);

Lot 99

Exhibit A-3

(d) All right, title and interest in and to the Chaco No. 4 and Chaco No. 5 wellbores, all the equipment associated with the wells, together with all rights, titles and interest in and to other materials, supplies, machinery, equipment, improvements, and any other personal property and fixtures associated with the wells in Exhibit "A". All easements, rights-of-way, surface leases and other surface rights, all permits and licenses, and all other appurtenances being used or held for use in connection with, or otherwise related to, the exploration, development, operation or maintenance of any of the properties described in subparagraphs (a), (b) and (c) above, or the treatment, storage, gathering, transportation or marketing or production therefrom or allocated thereto;

(e) All interest in lease records, and other data and records used or held for use in connection with the exploration, development or operation of the properties described in Exhibit "A"; and

(f) Except as specified below, all oil, gas, casinghead gas, condensate, distillate, liquid hydrocarbons, and gaseous hydrocarbons (collectively called "Hydrocarbons") in and under that may be produced and saved from the base of the Fruitland Coal formation to the base of the Pictured Cliffs formation on the Subject Properties from and after the effective date, and all proceeds attributable thereto. All Hydrocarbons in and under and produced and saved from the Subject Properties before the effective date, and all proceeds attributable thereto, are hereby retained and reserved in favor of Assignor.

TO HAVE AND TO HOLD, the Subject Properties unto Assignee, its successors and assigns, provided, however, this Assignment is made subject to the following terms and provisions:

I.

The Subject Properties are sold "AS IS" and "WHERE IS" without any warranty of merchantability, condition or fitness for a particular purpose, either express or implied; however, Assignor warrants and covenants that there are no liens, mortgages, security interests, financing statements, or other claims or encumbrances as to the Subject Properties.

II.

Assignor hereby assumes and agrees to pay and perform and discharge all obligations attributable to the interest conveyed by Assignor to Assignee in the Subject Properties prior to the effective date of this assignment. Assignee hereby assumes and agrees that it has rights to all revenues received on production, and to pay, perform and discharge all obligations attributable to the interests conveyed by Assignor to Assignee in the Subject Properties which are attributable after the effective date of this Agreement.

III.

Assignor hereby agrees to execute any and all other instruments and/or documents necessary to give effect to the transfer of Assignor's interests in the Subject Properties.

IV.

This agreement may be executed in any number of counterparts, no one of which needs to be executed by all parties, or may be ratified or consented to by separate instruments, in writing, specifically referring hereto, and shall be binding upon all parties who have executed such a counterpart, ratification or consent hereto with the same force and effect as if all parties had signed the same document.

V.

This agreement shall be binding upon the parties hereto and shall extend to and be binding upon their respective heirs, executors, administrators, and successors and assigns.

IN WITNESS WHEREOF, this Assignment, Bill of Sale, and Conveyance has been executed and delivered on the date and year first above written, but shall be effective for all purposes as of 7:00 o'clock a.m., Farmington, New Mexico time on December 31st, 1994.

ASSIGNOR:
J. GREGORY MERRION AND RITA V. MERRION REVOCABLE TRUST

By: [signature]
J. Gregory Merrion, Trustee

MERRION OIL & GAS CORPORATION

By: [signature]
T. Greg Merrion, President

[signature]
Robert L. Bayless

[signature]
Bernice M. Bayless, his wife

[signature]
Merle L. Ellsaesser

[signature]
Jo Anne Ellsaesser, his wife

Steven S. Dunn

Melinda A. Dunn, his wife

ASSIGNEE:
JK EDWARDS & ASSOCIATES, INC

By: ______________________
Don Poe, Attorney-In-Fact

ACKNOWLEDGMENTS

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

This instrument was acknowledged before me this 2nd day of December, 1994, by J. Gregory Merrion, Trustee of the J. Gregory Merrion and Rita V. Merrion Revocable Trust, on behalf of said Trust.

My commission expires:
6-27-98

Notary Public

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

This instrument was acknowledged before me this 2nd day of December, 1994, by T. Greg Merrion, President of Merrion Oil & Gas Corporation, a New Mexico corporation, on behalf of said corporation.

My commission expires:
6-27-98

Notary Public

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

Before me, a notary public, on this 5th day of December, 1994, personally appeared Robert L. Bayless and Bernice M. Bayless, husband and wife, to me known to be the identical persons who executed the within and foregoing instrument and acknowledged that they executed the same as their free and voluntary act and deed.

My commission expires:
9-20-96

Notary Public

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

Before me, a notary public, on this 6th day of December, 1994, personally appeared Merle L. Ellsaesser and Jo Anne Ellsaesser, husband and wife, to me known to be the identical persons who executed the within and foregoing instrument and acknowledged that they executed the same as their free and voluntary act and deed.

My commission expires: 6-27-98

Crystal Williams
Notary Public

STATE OF NEW MEXICO)
§
COUNTY OF SAN JUAN)

Before me, a notary public, on this 5th day of December, 1994, personally appeared Steven S. Dunn and Melinda A. Dunn, husband and wife, to me known to be the identical persons who executed the within and foregoing instrument and acknowledged that they executed the same as their free and voluntary act and deed.

My commission expires: 6-27-98

Crystal Williams
Notary Public

(Corporate)

STATE OF TEXAS)
§
COUNTY OF HARRIS)

This instrument was acknowledged before me this 14th day of December, 1994, by Don Poe, Attorney-In-Fact of J.K. Edwards Associates, Inc a Colorado corporation, on behalf of said corporation.

My commission expires:

Sharon Kaye Jaynes
Notary Public

SHARON KAYE JAYNES
Notary Public, State of Texas
My Commission Expires April 9, 1998

EXHIBIT "A"

Attached to and made a part of that certain Assignment, Bill of Sale and Conveyance effective December 31st, 1994, by and between Assignor and Assignee

LEASES AND LANDS FROM THE BASE OF THE FRUITLAND COAL FORMATION TO BASE OF THE PICTURED CLIFFS FORMATION

I. LEASES

Lease No.:	SF-080238-A
Lessor:	United States of America
Lease Effective Date:	April 1, 1951
Original Lessee:	Beulah Morgan
Lease Description:	Township 26 North, Range 12 West, NMPM Section 7: Lots 1,2, E/2NW Township 26 North, Range 13 West, NMPM Section 1: SE Containing 316.10 acres, more or less
County:	San Juan
State:	New Mexico
Well:	Chaco 4, 5
WI Being Conveyed:	100%

II. WELLS

NAME	LOCATION(SPACING)
Chaco No. 4	T-26-N,R-12-W Sec. 7: NWNW (NW)
Chaco No. 5	T-26-N,R-13-W Sec. 1: SESE (SE)

BEFORE THE NEW MEXICO OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC. and J. K. EDWARDS ASSOCIATES, INC. and J. K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO

Case No. 11996

SUBPOENA DUCES TECUM

TO: Maralex Resources, Inc.
c/o James R. Graves, III
5001 Tarry Terrace
Farmington, New Mexico 87402

Pursuant to Section 70-2-8, NMSA (1978), and Rule 1211 of the New Mexico Oil Conservation Division's Rules of Procedure, you are hereby ORDERED to appear at 9:00 a.m., on Tuesday, June 16, 1998, at the offices of the Oil Conservation Division, 2040 South Pacheco, Santa Fe, New Mexico 87505 and to produce the documents and items specified in attached Exhibit A and to make available to Pendragon Energy Partners, Inc. and its attorney, J. Scott Hall, Esq., for copying, all of said documents.

This subpoena is issued on behalf of Pendragon Energy Partners, Inc. through its attorneys Miller, Stratvert & Torgerson , P.A., Post Office Box 1986, Santa Fe, New Mexico 87504.

Dated this 9th day of June, 1998.

NEW MEXICO OIL CONSERVATION DIVISION

By Lori Wrotenbery
Lori Wrotenbery, Director

EXHIBIT 1

DEFINITIONS AND INSTRUCTIONS

The following definitions and instructions apply to this Subpoena Duces Tecum:

A. "Pendragon" means Pendragon Energy Partners, Inc.

B. "You" or "yours" refers to the named defendant, Maralex Resources, Inc. and any of its agents, employees or representatives.

C. Hereinafter "the person" or "persons" shall mean each and every individual, corporation, partnership, joint venture, trust, estate, or associations.

D. Corporate affiliate - is any corporation with common officers, directors, employees, shareholders or accounts.

E. "Document" refers to any original, written, recorded or graphic matter whatsoever and all non-identical copies thereof whether or not privileged, classified or marked or treated as confidential including but not limited to, papers, books, records, letters, photographs, correspondence, communications, telegrams, cables, telex messages, memoranda, notations, workpapers, jottings, agendas, statistical records, desk calendars, appointment books, expenses account vouchers, blueprints, plans, diaries, lists, tabulations, transcripts, minutes, reports, affidavits, statements, summaries, opinions, studies, analyses, evaluations, contract, agreements, bulletins, notices, announcements, advertisements, instructions, charts, manuals, brochures, publications, schedules, price lists, client lists, journals, books of account, records, invoices, statements of account, credit memoranda, records reflecting business operations, sound recordings, recordings by any means of telephone or other conversations, or of interviews or of conferences, or of other meetings, computer printouts, data processing program library, data processing input and output, microfilm, all records kept by electronic, photographic or mechanical means, pleadings, motions, responses to discovery, any notes or drafts relating to any of the foregoing, all things similar to any of the foregoing, however denominated by the parties and any other documents within the scope of Rule 34 of the Federal Rules of Civil Procedure. In all cases where original or non-identical copies are available, "document" also means identical copies of an original document and non-identical copies thereof. In all cases where documents are in a language other than English, "document" shall also include all translations and materials related to particular translations.

F. Documents produced shall be identified according to each specific request to which they are responsive.

G. If you do not respond to any request or subpart thereof, on the basis of any privilege, or claim of privilege, state the privilege asserted, and the facts upon which you rely to support the claim of privilege.

H. If, in response to any request for production of documents, it is claimed that the documents requested are protected by the attorney/client privilege or attorney work-product doctrine, you are requested to identify such documents according to the criteria set forth in Rule 26(b)(5) of the Federal Rules of Civil Procedure. Specifically, you are requested to list and describe each document showing (a) the nature of the documents, communications, or things not produced or disclosed, (b) the identity and corporate position of the person or persons interviewed or supplying the information, (c) the place, approximate date, and manner of recording or otherwise preparing the documents, (d) the names of the person or persons (other than stenographical or clerical assistants) participating in the interview and preparation of the document, and (e) the name and corporate position, if any, of each person to whom the contents of the documents have heretofore been communicated by copy, exhibition, reading or substantial summarization. In addition, you should set forth the precise and certain reason for preserving the confidentiality of the documents.

This Subpoena Duces Tecum seek all information available to you or in your possession, custody or control from any source, wherever situated, including but not limited to information from any files, records, documents, employees, former employees, counsel and former counsel.

If any part of the information provided in these documents is within the personal knowledge of the person responding to this subpoena, identify each person to whom such information is a matter of personal knowledge and each person who communicated to the person answering these interrogatories any part of that information.

Reference to the singular shall include the plural and references to the plural shall include singular. References to the masculine gender include the feminine and neuter genders.

The use of a verb in any tense shall be construed as the use of the verb in the past or present tense, whenever necessary to bring within the scope of the subpoena all responses which might otherwise be construed to be outside its scope.

When used herein in reference to an individual person, "identify" shall mean to state the full name, present or last known address, telephone number, present or last known employment, job title, position or business affiliation of said individual. When used herein in reference to a firm, partnership, corporation, business entity or other organization, "identify" shall mean to state its full name, present or last known address and telephone number.

When used herein in reference to a document "identify" shall mean:

a. to state the date, author, addressee, file number, type of document (i.e. letter, memorandum, book, telegram, chart, etc.), or some other means of identifying it sufficient to support a request for production; and

b. to state its present location and custodian.

When used herein in reference to a communication, "identify" shall mean to state the date of communication, the type of communication (telephone conversation, meeting, discussion, etc.), the place where the communication took place, the identity of the person who made the communication, the identity of the person who received the communication, the identity of each person present when it was made, and the subject matter discussed.

When used herein in reference to a meeting, "identify" shall mean to state the date of the meeting, the place where the meeting took place, the identity of each person invited to attend, the identity of each person who attended, and the subject matter discussed.

When used herein "person" means an individual, firm, partnership, corporation, club, company, association, joint venture, syndicate, business entity or other organization.

When used herein, "you" or "your" refers to the person or entity to whom these interrogatories are addressed and includes all of his or its attorneys, officers, agents, employees, directions, representatives, officials, departments, divisions, subdivision, subsidiaries or predecessors.

When used herein "and" as well as "or" shall be construed either disjunctively or conjunctively, as necessary to bring within the scope of the subpoena all responses which might otherwise be construed to be outside its scope. "Each" shall be construed to include the word "every" and "every" shall be construed to include the word "each". "Any" shall be construed to include the word "all" and "all" shall be construed to include the word "any".

EXHIBIT 'A'

TO SUBPOENA DUCES TECUM
TO MARALEX RESOURCES, INC.
IN NEW MEXICO OIL CONSERVATION DIVISION
CASE NO. 11996

DEFINITIONS AND INSTRUCTIONS

1. For purposes of this Exhibit "A", the "Subject Wells" are identified as follows:

Gallegos Fed. 26-12-6 No. 2	W½ §6-26N-12W
Gallegos Fed. 26-12-7 No. 1	W½ §7-26N-12W
Gallegos Fed. 26-13-1 No. 1	E½ §1-26N-13W
Gallegos Fed. 26-13-1 No. 2	W½ §1-26N-13W
Gallegos Fed. 26-13-12 No. 1	N½ §12-26N-13W

2. For each of the Subject Wells, all of the following materials, documents or data:

A. Electric Log Data

B. Drilling Time

C. Drill Cuttings of Log Cores

D. Mud Logs

E. Completion Data

F. Gas Analysis

G. Water Analysis

H. Reservoir Performance Data

3. The <u>Fruitland/PC/WAW Study-Gallegos Canyon Project</u> and all related data and materials provided or revealed to New Mexico Oil Conservation Division staff.

MILLER, STRATVERT & TORGERSON, P.A.

By______________________________________

J. Scott Hall
Attorneys for Pendragon Energy Partners
and J. K. Edwards Associates, Inc.
Post Office Box 1986
Santa Fe, New Mexico 87504-1986
(505) 989-9614

Certificate of Mailing

I hereby certify that a true and correct copy of the foregoing was mailed to counsel of record on the ___ day of June, 1998, as follows:

James G. Bruce, Esq.
P.O. Box 1056
Santa Fe, New Mexico 87504

J. E. Gallegos, Esq.
Gallegos Law Firm, P. C.
460 St. Michaels Dr., #300
Santa Fe, New Mexico 87505

MILLER, STRATVERT & TORGERSON, P. A.

LAW OFFICES

RANNE B. MILLER
ALAN C. TORGERSON
ALICE TOMLINSON LORENZ
GREGORY W. CHASE
ALAN KONRAD
LYMAN G. SANDY
STEPHEN M. WILLIAMS
STEPHAN M. VIDMAR
ROBERT C. GUTIERREZ
SETH V. BINGHAM
JAMES B. COLLINS
TIMOTHY R. BRIGGS
RUDOLPH LUCERO
DEBORAH A. SOLOVE
GARY L. GORDON
LAWRENCE R. WHITE
SHARON P. GROSS
VIRGINIA ANDERMAN
MARTE D. LIGHTSTONE
J. SCOTT HALL
THOMAS R. MACK
TERRI L. SAUER

JOEL T. NEWTON
JUDITH K. NAKAMURA
THOMAS M. DOMME
C. BRIAN CHARLTON
RUTH O. PREGENZER
JEFFREY E. JONES
MANUEL I. ARRIETA
ROBIN A. GOBLE
JAMES R. WOOD
DANA M. KYLE
KIRK R. ALLEN
RUTH M. FUESS
JAMES B. GREEN
KYLE M. FINCH
H. BROOK LASKEY
KATHERINE W. HALL
FRED SCHILLER
MICHAEL I. GARCIA
LARA L. WHITE
PAULA G. MAYNES
DEAN B. CROSS

WILLIAM K. STRATVERT, COUNSEL
PAUL W. ROBINSON, COUNSEL
RALPH WM. RICHARDS, COUNSEL
ROSS B. PERKAL, COUNSEL

ALBUQUERQUE
500 MARQUETTE N.W. SUITE 1100
POST OFFICE BOX 25687
ALBUQUERQUE, NM 87125-0687
TELEPHONE: (505) 842-1950
FACSIMILE: (505) 243-4408

LAS CRUCES
500 S. MAIN ST., SUITE 600
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May 28, 1998

FACSIMILE TRANSMISSION COVER SHEET

DATE: May 28, 1998

TO: LORI WROTENBERY — FAX NO.: 827-8177

FROM: J. SCOTT HALL, ESQ. — OPERATOR: Bea

MESSAGE: Please see attached.

NUMBER OF PAGES INCLUDING COVER SHEET: 3

IF YOU DO NOT RECEIVE THE ENTIRE DOCUMENT, PLEASE CALL OUR SANTA FE OFFICE AS SOON AS POSSIBLE AT (505) 989-9614.

* * * * * * * *

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The attached pages were sent at: 2:55PM

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May 28, 1998

Ms. Lori Wrotenbery, Director
New Mexico Oil Conservation Division
2040 South Pacheco
Santa Fe, New Mexico 87504

BY FACSIMILE

Re: NMOCD Case No. 11921; Application of Whiting Petroleum Corporation and Maralex Resources, Inc. for Shut-in Order, San Juan County, New Mexico

NMOCD Case No. ___; Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc. To Confirm Production From Appropriate Common Source Of Supply, San Juan County, New Mexico

Dear Ms. Wrotenbery:

I was reluctant to subject you to a round-robin competition of faxed letters from counsel, however, one of Mr. Gallegos's assumptions needs correction: As soon as it became apparent on Tuesday morning that Whiting and Maralex were attempting to avoid the jurisdiction of the NMOCD, I telephoned Division counsel Rand Carroll and advised him of the complaint and later had a copy of the same hand-delivered to him. At that point in time, the complaint had not yet been filed with the Court.

Rather than see counsel attempt to make their cases by way of further letters to the Director, I believe it is more appropriate for Mr. Gallegos to enter his appearance in the above-pending cases. That way, Mr. Gallegos can explain directly why Whiting and Maralex, having invoked the jurisdiction of the NMOCD originally, are now attempting to change their position.

Very truly yours,

MILLER, STRATVERT, TORGERSON

J. Scott Hall, Esq.

JSH:MBC

cc: Mr. Al Nicol, Pendragon Energy
Mr. Keith Edwards, J.K. Edwards Associates
Rand Carroll, Esq.
Gene Gallegos, Esq.
James Bruce, Esq.

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Case 11996

May 27, 1998

Lori Wrotenbery, Director
New Mexico Oil Conservation Division
2040 South Pacheco Street
Santa Fe, New Mexico 87505

VIA FACSIMILE: (505) 827-8177

Re: Application of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc. to Confirm Production from the Appropriate Common Source of Supply, San Juan County, New Mexico

Dear Ms. Wrotenbery:

Attached is our Motion for Consolidation to be filed on behalf of Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc. An original and two copies will be forwarded tomorrow by hand-delivery. Thank you for your assistance in this matter.

Very truly yours,

MILLER, STRATVERT & TORGERSON P.A.

J. Scott Hall

J. Scott Hall, Esq.

JSH/mg
Enclosure
cc: Jim Bruce (w/enc.)

BEFORE THE NEW MEXICO OIL CONSERVATION DIVISION

APPLICATION OF PENDRAGON ENERGY PARTNERS, INC. and J.K. EDWARDS ASSOCIATES, INC. TO CONFIRM PRODUCTION FROM THE APPROPRIATE COMMON SOURCE OF SUPPLY, SAN JUAN COUNTY, NEW MEXICO.

CASE NO. 11996

MOTION FOR CONSOLIDATION

Pendragon Energy Partners, Inc. ("Pendragon") and J.K. Edwards Associates, Inc. ("J. K. Edwards") through their counsel, move for an Order consolidating the instant case with Case No. 11921[1] and setting the consolidated cases for hearing before the Division's Examiner on a special hearing date as soon as may be conveniently scheduled. In support, Pendragon and J.K. Edwards state:

1. By their Application in this case, Pendragon and J.K. Edwards seek to have the Division issue its order confirming that certain wells completed within the vertical limits of the WAW Fruitland-Pictured Cliffs Pool and that certain wells operated by Whiting Petroleum Corporation and Maralex Resources, Inc. completed in the Basin-Fruitland Coal Gas Pool are producing from the appropriate common source of supply. The Application of Pendragon and J.K. Edwards is based on Rule 3 of the Special Rules and Regulation for the Basin Fruitland Coal Gas pool promulgated by the Division by Order No. R-8768 and R-8768(A).

2. By their separate application, Whiting and Maralex have invoked the jurisdiction of the Division to obtain relief based on their allegations that the drilling or the fracture stimulation

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[1]Application of Whiting Petroleum Corporation and Maralex Resources, Inc. For An Order Shutting In, Limiting Production From, or Approving Downhole Commingling in Certain Wells, San Juan County, New Mexico; NMOCD Case No. 11921.

of the Pendragon operated wells in the WAW Fruitland Pictured Cliffs Sandstone have become communicated with and are producing from the Basin Fruitland Coal Gas Pool. Pendragon and J.K. Edwards generally deny the Whiting/Maralex allegations. Moreover, it is the specific position of Pendragon and J.K. Edwards that the drilling and fracture stimulation of their Pictured Cliffs Sandstone wells did not result in the communication between zones.

3. Both the Pendragon/J.K. Edwards Application and the Whiting/Maralex Application involve a common nexus of fact. Consolidation of these two matters will interject no new issues into the proceedings and will not result in prejudice to any party. Whiting, Maralex, Pendragon and J.K. Edwards are presently parties in the pending proceeding and are already represented by counsel of record.

4. The consolidation of these two matters into one proceeding will result in administrative efficiency and economy.

WHEREFORE, Pendragon Energy Partners, Inc. and J.K. Edwards Associates, Inc. request entry of an order consolidating this matter with Case No. 11921 and setting the same for hearing before the Division's Examiner on a special hearing date as soon as may be conveniently scheduled.

Respectfully submitted,

MILLER, STRATVERT & TORGERSON, P.A.

By ______________________

J. Scott Hall
P.O. Box 1986
Santa Fe, New Mexico 87501-1986
(505) 989-9614
Attorneys for Pendragon Energy Partners, Inc. and
J.K. Edwards Associates, Inc.

Certificate of Mailing

I hereby certify that a true and correct copy of the foregoing was mailed to counsel of record on the 27 day of May, 1998, as follows:

James Bruce, Esq.
P.O. Box 1056
Santa Fe, New Mexico 87504

____
J. Scott Hall