Daly unit No. 5
PM Application.

November ~~26~~ 30, 1992

Mr. Don R. Burns
Rideau Petroleums Ltd.
P. O. Box 520, Station A
Kelowna, BC V1Y 7P1

Dear Mr. Burns:

Re: Board Order No. PM 63
<u>Modification of Daly Unit No. 5 Pilot Waterflood</u>

Your application dated August 14, 1992 for conversion of the well, Rideau Butler Prov. 9-28-9-29(WPM), to water injection in Daly Unit No. 5 is approved under subsection 1(1) of Board Order No. PM 63. The conversion of the well, Rideau Daly Prov. WIW 9D-28-9-29(WPM), back to production is also approved conditional on a pressure survey being run prior to the well being placed back on production. The maximum wellhead injection pressure established under Section 5 of Board Order No. PM 63 has been reduced from 10,300 kPa to 9,000 kPa in order to reduce the possibility of out of zone injection.

Injection into 9-28 is not to commence until the Board has approved unit enlargement in accordance with Section 74 of The Mines Act. Please note that Rideau is required to obtain the consent of the Minister of Energy and Mines to enlarge the unit.

The Board requests that the 1994 progress report to be submitted in accordance with Section 7 of Board Order No. PM 63 include a discussion on the feasibility of unit enlargement and the potential for waterflood expansion.

If you have any questions in respect of this approval please contact L.R. Dubreuil, Director of Petroleum or John N. Fox, Chief Petroleum Engineer at (204) 945-6573 or 945-6574, respectively.

Yours respectfully,

ORIGINAL SIGNED BY
H. CLARE MOSTER

H. Clare Moster
Deputy Chairman

RIDEAU PETROLEUMS lTD.
Box 1078
Virden, Manitoba
R0M 2C0

February 16, 1994

Manitoba Energy and Mines
Petroleum Branch
555 - 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Attention: Mr. John Fox
Chief Petroleum Engineer

Dear Sir:

RE: Board Order No. PM 63 - Daly Unit No. 5
Daly Lodgepole D Pool - Pressure Maintenance
Maximum Allowable Wellhead Pressure

Rideau Petroleums Ltd. hereby requests approval to increase the maximum allowable wellhead pressure from 9000 kPa to 10000 kPa.

Water injection at our 9-28-9-29 WIW commenced on February 13, 1993. By August of that year the injection rate had declined to an average of 6.9 m3/d at 8900 kPa. It was decided that to have any positive effect on voidage replacement and pressure maintenance, the volume of water injected would have to be increased significantly. Therefore the pressure was increased to 10000 kPa resulting in an average injection rate of 17 m3/d. This increased rate should be sufficient to replace voidage over the long term and provide pressure maintenance within the Unit.

In consideration of the information above, we are requesting that the maximum allowable injection pressure be increased to 10000 kPa. If there are any questions or concerns, please contact me at 748-2158.

Yours truly,

W. G. Roberts

W.G. Roberts, P. Eng.,
Supervisor, Operations

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

June 21, 1991

Mr. W. G. Roberts, P. Eng.
Supervisor, Operations
Rideau Petroleums Limited
Box 1078
Virden, Manitoba
ROM 2CO

Dear Mr. Roberts:

Re: Board Order No. PM 63
Maximum Wellhead Injection Pressure
Rideau Daly Prov. WIW 9D-28-9-29 (WPM)

Your application dated June 11, 1991 for an increase in the maximum wellhead injection pressure for the subject well is approved.

The maximum wellhead injection pressure under Section 5 of Board Order No. PM 63 is increased to 10 300 kPa.

Yours respectfully,

H. Clare Moster
Deputy Chairman

VOIDAGE CALCULATIONS - DALY UNIT NO. 5

$B_{oi} = 1.05\ rm^3/m^3$

$B_w = 1.0\ m^3/rm^3$

- SINGLE 5-SPOT INJ. PATTERN USE TOTAL PRODUCTION IN VOIDAGE CALCULATION

	oil	water	voidage
monthly production 1st Qu. /91 excluding 9D-28	3.5 m³/d	2.2	5.9 rm³/d
cumulative production	15497.5	5217.8	21490 rm³

- one of the reasons previous waterfloods in the Lodgepole in Twp 9-29 failed was insufficient injection volumes

- target injection rate was 60-65 m³ during fill-up

TARGET FILL-UP — 1 year

	PRESSURE	RATE	DAILY VRR	TIME TO FILL-UP
INJECTIVITY RATES	8500 kPa	7.7 m³/d	1.3	32 YRS
	9600	15 m³/d	2.5	6.5 YRS.
	10000	25 m³/d	4.2	3.1 YRS
	10200	30 m³/d	5.1	2.4 YRS

FORMATION BREAKDOWN PRESSURE - 15500 kPa
AVER. DEPTH 820 m

est FRAC GRADIENT $\frac{15500}{820}$ = 18.9 kPa/m (0.84 psi/ft

WELLHEAD INJ. PRESSURE 9D-28-9-29

(0.84 psi/ft − 0.43 psi/ft) * 806 m (3.281 ft/m) (6.895 kPa/psi)

= 7475 kPa. conservative

use FRAC GRADIENT = 1.0 psi/ft

WELLHEAD INJ. PRESS = 10393 kPa

(NOTE: INJECTION PRESSURE FOR PILOT WATERFLOOD CONDUCTED IN SEC. 35-9-29 - 10340 kPa, SEC 26-9-29 - 9650 kPa)

AT 10300 kPa injection pressure there should be limited extension of any fractures that may occur @ the wellbore.

CLAUSE 5 max. wellhead inj. press. - 8500 kPa.
DALY UNIT No. 1 - MWHIP - 8000 kPa.
DALY UNIT No. 3 - MWHIP - 10000 kPa.

M nitoba

Memorandum

Date June 19, 1991

To The Oil and Natural Gas Conservation Board
- Ian Haugh, Chairman
- H. Clare Moster, Deputy Chairman
- Wm. McDonald, Member

From John N. Fox
Chief Petroleum Engineer
Petroleum Branch

Telephone

Subject

First | Fold

Re: Daly Unit No. 5
Maximum Wellhead Injection Pressure

Rideau Petroleums has made application to increase the maximum wellhead injection pressure at the well, Rideau Daly Prov. WIW 9D-28-9-29 (WPM) in Daly Unit No. 5 from 8 500 kPa to 10 300 kPa.

Recommendations:

It is recommended that the Board approve Rideau's application. The proposed Board letter of approval is attached.

Discussion:

Rideau commenced water injection into 9D-28-9-29 in March, 1991. The average injection rate at the approved maximum wellhead injection pressure of 8 500 kPa (Board Order No. PM 63) was 6.0 m^3/d, slightly greater than reservoir voidage. Rideau gradually increased the injection pressure during April and May, 1991 to 10 200 kPa resulting in an increase in injectivity to 30 m^3/d (Figure 1).

One of the reasons previous waterfloods in the Lodgepole Formation in Twp. 9-29 (WPM) failed, was insufficient injection volumes. At an injection rate of 6.0 m^3/d it would take in excess of 30 years to achieve reservoir fill-up. Increasing the maximum wellhead injection pressure to 10 300 kPa will allow reservoir fill-up to be achieved in less than 3 years.

There is a risk that injection near the fracture pressure, estimated at 9 600 to 10 400 kPa, will result in the formation being fracture causing out of zone injection. However, to properly evaluate the feasibility of waterflooding the Daly Lodgepole D Pool, it is necessary to achieve reasonable injection rates, even at the expense of out of zone injection. Therefore, it is recommended that the application be approved.

John N. Fox
Chief Petroleum Engineer

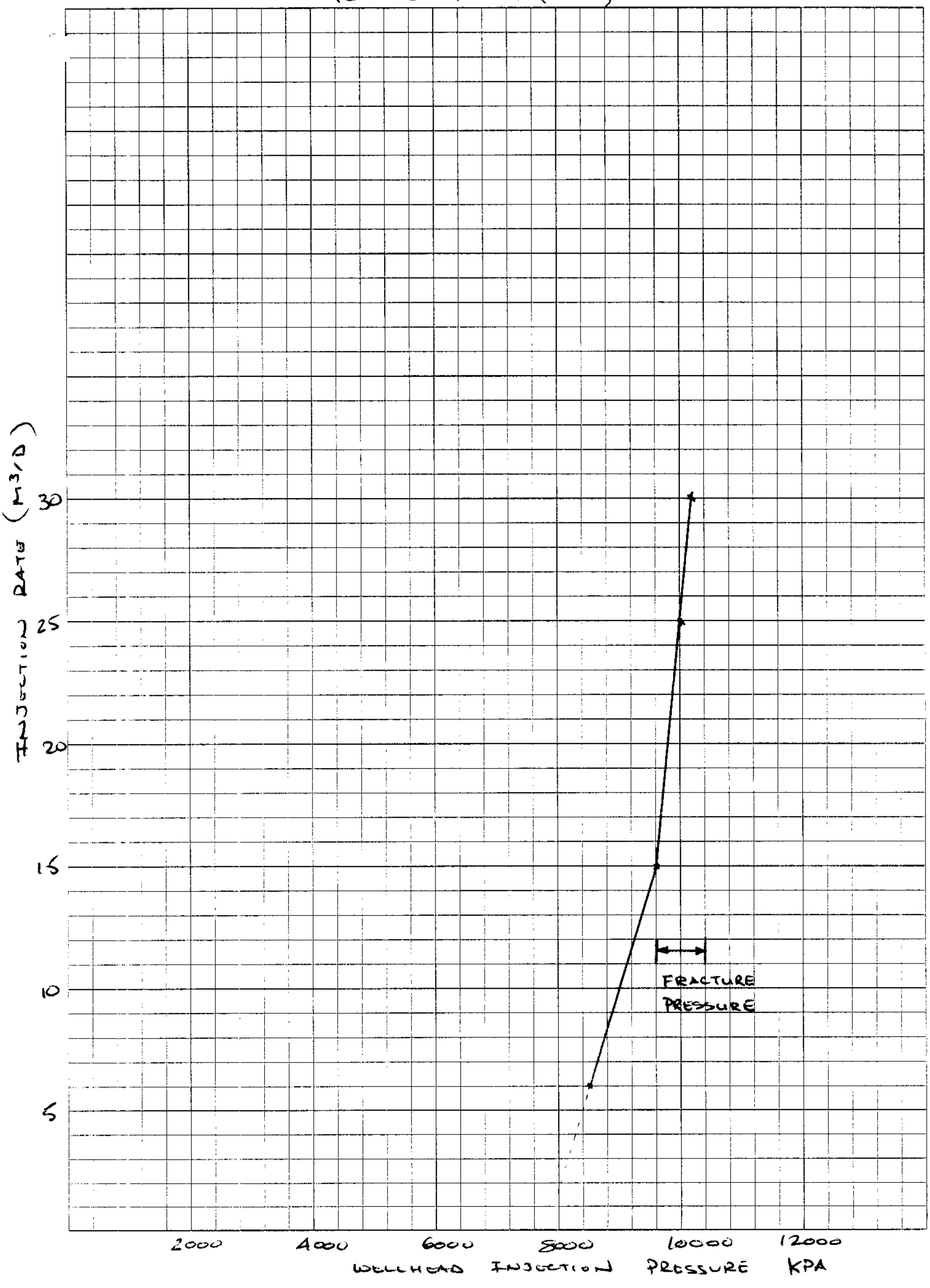
JNF/sml

Attachment

Recommended for Approval: ______________________
L. R. Dubreuil, Director

DALT UNIT No. 5
9D-28-9-29 (W4M)

FIGURE 1



Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

Mr. W. G. Roberts, P. Eng.
Supervisor, Operations
Rideau Petroleums Limited
Box 1078
Virden, Manitoba
ROM 2CO

Dear Mr. Roberts:

Re: Board Order No. PM 63
Maximum Wellhead Injection Pressure
Rideau Daly Prov. WIW 9D-28-9-29 (WPM)

Your application dated June 11, 1991 for an increase in the maximum wellhead injection pressure for the subject well is approved.

The maximum wellhead injection pressure under Section 5 of Board Order No. PM 63 is increased to 10 300 kPa.

Yours respectfully,

ORIGINAL SIGNED BY
H. CLARE MOSTER

H. Clare Moster
Deputy Chairman

Rideau Petroleums Limited
Box 1078
Virden, Manitoba
R0M 2C0

DEPARTMENT OF ENERGY AND MINES
JUN 18 1991
PETROLEUM BRANCH

June 11, 1991

Manitoba Department of Energy and Mines
Petroleum Branch
555 - 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Attention: Mr. John Fox
Chief Petroleum Engineer

Dear Sir:

Re: Board Order No. PM63 - Daly Unit No. 5
Daly Lodgepole D Pool - Pressure Maintenance
Maximum Allowable Wellhead Pressure

In response to our recent phone conversation on May 14, 1991 regarding injection pressures at Rideau Daly Prov. WIW 9D-28-9-29 and the information provided below, Rideau Petroleums Ltd. hereby requests the Board's approval to revise section 5 of the Order No. PM 63 to read that the maximum wellhead pressure shall not exceed 10300 kPa.

Water injection commenced on March 22, 1991 with pressures being monitored on an ongoing basis to stay within the maximum allowable pressure of 8500 kPa, as stated in Board Order No. PM 63. A pressure recorder was installed at the injection well to monitor wellhead pressures on a continuous basis. This maximum pressure was adhered to until mid way through April with water injection rates averaging 6 m3 per day. It was evident that the pressure would have to be increased to have any positive effect on the reservoir. Therefore the maximum pressure was gradually increased to 9600 kPa through the latter part of April to realize an average injection rate of 15 m3 per day. The injection pressure was again increased throughout the month of May to obtain an average injection rate of 25 m3 per day at 10000 kPa and 30 m3 per day at 10200 kPa. We are currently trying to maintain our injection pressure at 10000 kPa.

In consideration of the data obtained and outlined briefly above we are requesting that the maximum allowable injection pressure be increased to 10300 kPa from 8500 kPa.

If there are questions regarding this request please contact me at 748-2158.

Yours truly,

W. G. Roberts

W.G. Roberts, P. Eng.,
Supervisor, Operations

DALY UNIT # 5

Date: June 6, '91

Progress Report For: MAY 1991

1. Production:

Month	Oil Production (m^3)	Water Production (m^3)	Wells Producing	Cum. Oil (m^3)	Cum. Water (m^3)
MAY	101.3	52.1	4	15 706.2	5 333.2

2. Injection:

Max. Injection Pressure 10 200 kPa

Type of Water	Volume Injected (m^3)	Cumulative Injected (m^3)
Lodgepole Production	588.6	891.7

DALY UNIT # 5

Date: MAY 1 /91

Progress Report For: APRIL /91

1. Production:

Month	Oil Production (m^3)	Water Production (m^3)	Wells Producing	Cum. Oil (m^3)	Cum. Water (m^3)
APRIL	107.4	63.3	4	15 604.9	5281.1

2. Injection:

Max. Injection Pressure 9600 kPa

Type of Water	Volume Injected (m^3)	Cumulative Injected (m^3)
Lodgepole Production	302.9	372.8

DALY UNIT # 5

Date: April 3, /91

Progress Report For: March 1991

1. Production:

Month	Oil Production (m^3)	Water Production (m^3)	Wells Producing	Cum. Oil (m^3)	Cum. Water (m^3)
March	121.7	65.8	5	15497.5	5217.8

2. Injection:

Max. Injection Pressure 8500 kPa

Type of Water	Volume Injected (m^3)	Cumulative Injected (m^3)
Lodgepole Production	69.9	69.9

* 9D-28-9-29 WIW ON INJECTION MAR. 22, /90.

DALY UNIT # 5

Date: April 3, /91

Progress Report For: February 1991

1. Production:

Month	Oil Production (m^3)	Water Production (m^3)	Wells Producing	Cum. Oil (m^3)	Cum. Water (m^3)
Feb.	116.3	61.7	5	15 375.8	5152.0

2. Injection:

Type of Water	Volume Injected (m^3)	Cumulative Injected (m^3)
Lodgepole Production	0	0

DALY UNIT # 5

Date: April 3, /91

Progress Report For: January 1991

1. Production:

Month	Oil Production (m^3)	Water Production (m^3)	Wells Producing	Cum. Oil (m^3)	Cum. Water (m^3)
Jan.	119.2	72.0	5	15 259.5	5 090.3

2. Injection:

Type of Water	Volume Injected (m^3)	Cumulative Injected (m^3)
Lodgepole Production	0	0

NOTE: Cumulative Production for Wells in Daly Unit #5 to Dec. 31, /90 is as follows:

Well Location	Cum. Oil (m^3)	Cum. Water (m^3)
12-27-9-29	4 373.8	615.3
13-27-9-29	2 393.4	575.8
9-28-9-29	3 742.0	282.5
16-28-9-29	4 538.4	3 435.9
9D-28-9-29	92.7	108.8
Unit Area Total	15 140.3	5 018.3

May 3, 1990

The Oil and Natural Gas
Conservation Board
I. Haugh, Chairman
H.C. Moster, Deputy Chairman
Wm. McDonald, Member

John N. Fox
Chief Petroleum Engineer
Petroleum Branch

RE: Pilot Pressure Maintenance Project - Daly Lodgepole D Pool

Rideau Petroleums Ltd. has made application to conduct a pilot waterflood project in a portion of the subject pool. The project area is outlined in Figure No. 1 attached.

It is recommended that notice of the application be published in the Manitoba Gazette and the Virden Empire Advance. A copy of the proposed notice is attached.

It is also recommended that the working interest owners within and adjoining the project area be notified of the application directly by the Board. A copy of the proposed letters of notification is attached.

A technical review of the application is also underway and recommendations will be forwarded to the Board when the review is completed.

ORIGINAL SIGNED BY
JOHN N. FOX

John N. Fox

Att'd.

Approved by: L R Dubreuil

L.R. Dubreuil, Director

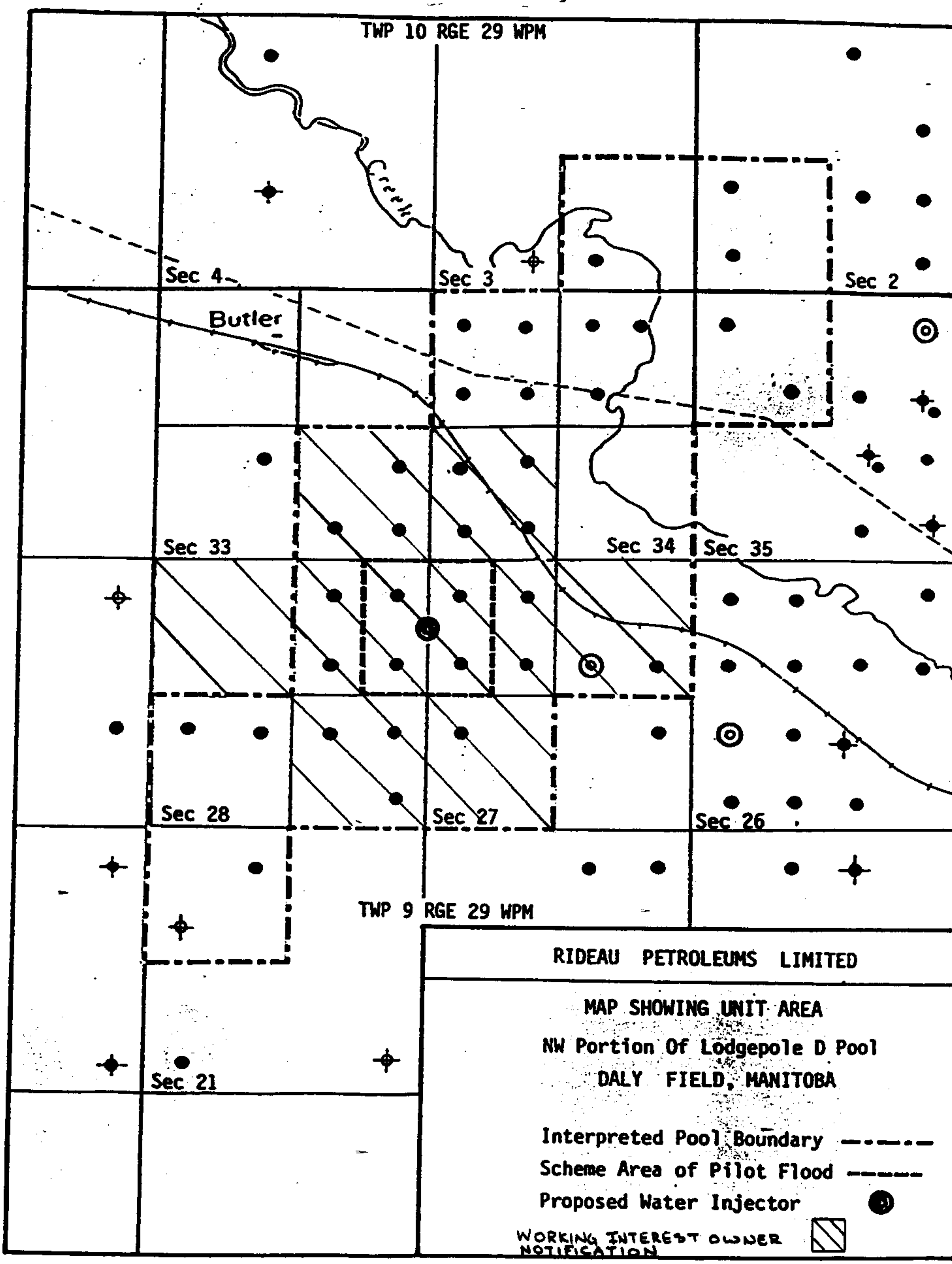

TWP 10 RGE 29 WPM
Creek
Sec 4
Sec 3
Sec 2
Butler
Sec 33
Sec 34
Sec 35
Sec 28
Sec 27
Sec 26
TWP 9 RGE 29 WPM
Sec 21
RIDEAU PETROLEUMS LIMITED
MAP SHOWING UNIT AREA
NW Portion Of Lodgepole D Pool
DALY FIELD, MANITOBA
Interpreted Pool Boundary
Scheme Area of Pilot Flood
Proposed Water Injector
WORKING INTEREST OWNER NOTIFICATION

FIG. 1

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

NOTICE

Under The Mines Act
Daly Oil Field

Rideau Petroleums Ltd. has made application under The Mines Act to conduct a pilot waterflood project in the Lodgepole Formation in that portion of the Daly Field described as follows: Lsd's 12 and 13 of Section 27-9-29 (WPM) and Lsd's 9 and 16 of Section 28-9-29 (WPM).

It is proposed to drill a water injection well in the northeast corner of Lsd 9 of Section 28-9-29 (WPM).

If no valid objection or intervention in writing is received by The Oil and Natural Gas Conservation Board at 555-330 Graham Avenue, Winnipeg, Manitoba, R3C 4E3 within 14 days of the publication of this notice, the Board may approve the application.

Copies of the application may be obtained from Rideau Petroleums Ltd., 201-215 Lawrence Avenue, Kelowna, British Columbia, V1Y 6L2.

Dated at Winnipeg, this day of , 1990.

H. C. Moster
Deputy Chairman.

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Dome Petroleum Ltd. (AMOCO)
Box 200, Station M
Calgary, Alberta
T2P 2H8

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Pipestone Petroleums Ltd.
201, 215 Lawrence Avenue
Kelowna, B.C.
V1Y 6L2

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
<u>Maintenance Project Daly Lodgepole D Pool</u>

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Prospect Hill Management Ltd.
c/o HRH Life Insurance Co.
102, 215 Lawrence Avenue
Kelowna, B.C.
V1Y 6L2

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Centennial Oilfield Sales Ltd.
Box 269
Virden, Manitoba
R0M 2C0

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Daniel Canart and Mildred Canart
Box 154
Elkhorn, Manitoba
ROM ONO

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Wydmar Resource Enterprises Ltd.
400, 255 - 17 Avenue S.W.
Calgary, Alberta
T2S 2T8

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

HCMoster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Laurel Explorations Ltd.
101-1861 Welch Street
North Vancouver, B.C.
V7P 1B7

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
<u>Maintenance Project Daly Lodgepole D Pool</u>

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Troy Oils Ltd.
705, 805 - 8 Avenue S.W.
Calgary, Alberta
T2P 1H7

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Zero Petroleums Ltd.
201, 215 Lawrence Avenue
Kelowna, B.C.
V1Y 6L2

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Maier Resources Ltd.
Site 2, Box 262
RR 7, East Chestmere Drive
Calgary, Alberta
T2P 2G7

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Interwest Construction Ltd.
500, 455 Granville Street
Vancouver, B.C.
V6C 1V2

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Corsair Petroleum Inc.
1200, 407 - 2nd Street S.W.
Calgary, Alberta
T2P 2Y3

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
<u>Maintenance Project Daly Lodgepole D Pool</u>

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Anna Resources Ltd.
500B, 805 - 8 Avenue S.W.
Calgary, Alberta
T2P 1H7

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

Yours truly,

H.C. Moster

H.C. Moster
Deputy Chairman

Att'd.

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

May 3, 1990

Tribros Enterprises
500, 455 Granville Street
Vancouver, B.C.
V6C 1V2

Dear Sir/Madam:

RE: Notice of Application - Pilot Pressure
Maintenance Project Daly Lodgepole D Pool

Attached please find a copy of the notice advertising an application filed with The Oil and Natural Gas Conservation Board ("the Board") by Rideau Petroleums Ltd. for approval of a pilot pressure maintenance project in the Daly Lodgepole D Pool.

As a working interest owner within or adjoining the proposed project area, this letter is to notify you of the subject application. If you have any questions or require further information in respect of the application, you may contact the Board or the company at the address shown in the notice.

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Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

NOTICE

Under The Mines Act
Daly Oil Field

Rideau Petroleums Ltd. has made application under The Mines Act to conduct a pilot waterflood project in the Lodgepole Formation in that portion of the Daly Field described as follows: Lsd's 12 and 13 of Section 27-9-29 (WPM) and Lsd's 9 and 16 of Section 28-9-29 (WPM).

It is proposed to drill a water injection well in the northeast corner of Lsd 9 of Section 28-9-29 (WPM).

If no valid objection or intervention in writing is received by The Oil and Natural Gas Conservation Board at 555-330 Graham Avenue, Winnipeg, Manitoba, R3C 4E3 within 14 days of the publication of this notice, the Board may approve the application.

Copies of the application may be obtained from Rideau Petroleums Ltd., 201-215 Lawrence Avenue, Kelowna, British Columbia, V1Y 6L2.

Dated at Winnipeg, this 3rd day of May, 1990.

H C Moster

H. C. Moster
Deputy Chairman.

Manitoba

Action / Route Slip

Date: February 8, 1990

To: L.R. DUBREUIL

CC: Ian Haugh (no att.)

Wm. McDonald (no att.)

From: H. CLARE MOSTER

Telephone: 1111

DEPARTMENT OF ENERGY AND MINES
FEB 9 1990
PETROLEUM BRANCH

- [x] Take Action
- [ ] Per Your Request
- [ ] Circulate, Initial and Return
- [ ] For Approval and Signature
- [ ] Make ____ Copies
- [ ] May We Discuss
- [ ] For Your Information
- [ ] Return With Comments or Revisions
- [ ] Draft Reply for Signature
- [ ] Release

Comments: RE: RIDEAU PETROLEUM - APPLICATION FOR PILOT PRESSURE MAINTENANCE PROJECT:

Please initiate processing of this application to determine any technical deficiencies.

Draft appropriate Board reply to Rideau (i.e. acknowledging receipt and/or advising of deficiencies).

Attachment

/p

MG-1298 PS-f-182 8940100671

JOHN

Manitoba

Energy and Mines

Petroleum

555 — 330 Graham Avenue
Winnipeg, Manitoba, CANADA
R3C 4E3

(204) 945-6577

November 16, 1989

Rideau Petroleums Ltd.
201 - 215 Lawrance Ave
Kelowna, B.C.
V1Y 6L2

Dear Don:

Re: Proposed Pilot Pressure Maintenance Project Daly Lodgepole D Pool

Further to our recent conversation, enclosed is a copy of The Mines Act. Sections 76 through 86 deal with Unitization Orders.

As I mentioned, two parallel processes would be required prior to implementation of the project:

1. Technical Consideration and Approval of Pressure Maintenance

A pressure maintenance project must be approved by The Oil and Natural Gas Conservation Board prior to implementation. Please refer to sections 64 and 126 of the Petroleum Drilling and Production Regulation for details regarding an appropriate application. In the case of a pilot project, such as you are proposing, some of the technical data may not be required. On the other hand, a pilot project should include comprehensive monitoring provisions.

Upon receipt of a complete application (i.e. after any deficiencies had been supplied) the project would be advertised for objections. The Board would send notices to all potentially affected working interest, royalty interest and surface rights owners. Additionally the notice would be published in the local newspapers and the Manitoba Gazette. If valid objections were raised, the Board would either attempt to arbitrate the concerns or proceed to a hearing. Subsequent resolution of the interventions the Board would complete disposition of the application. If approved, a Pressure Maintenance Order would be issued providing terms and conditions of approval.

2. Unitization

If varying working or royalty interests are involved in the project area unitization of the area is necessary. If all working and royalty interests agree, this can be done by a unit agreement approved by the Board.

If unanamous agreement cannot be achieved, the forced unitization provisions of The Mines Act can be invoked. On application, the Board is bound to hold a hearing to consider unitization. The application should be accompanied by a plan of unitization which has been agreed to in writing by owners representing more than 75% of the proposed unit area (see Section 77 of The Mines Act for more details).

If a Unitization Order is necessary, it must be preceded by a Board hearing. If after notice of the technical application, there remain unresolved issues, the Petroleum Branch would recommend the Board consider such issues at the same hearing.

If the project area includes Crown owned mineral rights, Rideau would have to request the Minister to consent, as a royalty owner, to the unitization. This request should be made separately and should precede any application for a unitization order. In support of such a request, the proposed unit document and rationalization of any tract participation factor determinations should be included.

If you have any further questions with respect to the foregoing, please call (204) 945-6573.

Yours sinerely,

LRDubreuil

L. R. Dubreuil
Director of Petroleum

LRD/sl

cc: H. Clare Moster
Deputy Chairman
O & NGCB

Manitoba

'he Oil and Natural Gas
-onservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

JUL 19 1990

Mr. D.R. Burns, President
Rideau Petroleums Ltd.
2101 - 215 Lawrence Avenue
Kelowna, B.C.
V1Y 6L2

Dear Mr. Burns:

RE: Board Order No. PM 63
Daly Lodgepole D Pool - Pressure Maintenance

Attached please find a copy of Board Order No. PM 63 granting approval to conduct a waterflood in the proposed Daly Unit No. 5. Water injection is not authorized to commence until the Board has approved the proposed Daly Unit No. 5 Unit Agreement.

The Board, pursuant to subsection 51(8) of the Petroleum Drilling and Production Regulation, approves production from the proposed injection well, Rideau Daly Prov. WIW 9D-28-9-29 (WPM), for a period not to exceed six (6) months from the finished drilling date of the well. Production from the well will be classified as old oil in accordance with the provisions of the Petroleum Crown Royalty and Incentive Regulation.

Yours respectfully

ORIGINAL SIGNED BY
IAN HAUGH

Ian Haugh
Chairman

cc: H. Clare Moster, Deputy Chairman

File
Daly Lodgepole D Pool
Daly Unit #5
Pressure
Maintenance

JUL 19 1990

Mr. D.R. Burns, President
Rideau Petroleums Ltd.
2101 - 215 Lawrence Avenue
Kelowna, B.C.
V1Y 6L2

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Yours respectfully

ORIGINAL SIGNED BY
IAN HAUGH

Ian Haugh
Chairman

cc: H. Clare Moster, Deputy Chairman

bcc: Brad Thiessen, Petroleum Branch

JNF/ibj
Date typed: July 12, 1990

Manitoba

Action / Route Slip

Date: July 12, 1990

To: Ian Haugh
Deputy Minister
Manitoba Energy and Mines

From: Bob Dubreuil
Director
Petroleum Branch

Telephone: 6573

- [ ] Take Action
- [ ] May We Discuss
- [ ] Per Your Request
- [ ] For Your Information
- [ ] Circulate, Initial and Return
- [ ] Return With Comments or Revisions
- [ ] For Approval and Signature
- [ ] Draft Reply for Signature
- [ ] Make ____ Copies
- [ ] Please File

Comments: Attached is Board Order No. 63 and a proposed letter of transmittal. The operator of the pilot project, Rideau Petroleums Ltd., has requested approval to produce the proposed injector for a short period of time before converting the well to injection. Under the Crown royalty regulations, such production is classified as old oil.

Please return the letter and signed order to Petroleum for distribution and filing.

MG-1298 PS-f-182 8940100671

Manitoba

The Oil and Natural Gas
Conservation Board

Room 309
Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

(204) 945-3130

Mr. D.R. Burns, President
Rideau Petroleums Ltd.
2101 - 215 Lawrence Avenue
Kelowna, B.C.
V1Y 6L2

Dear Mr. Burns:

RE: Board Order No. PM 63
Daly Lodgepole D Pool - Pressure Maintenance

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Yours respectfully

Ian Haugh
Chairman

cc: H. Clare Moster, Deputy Chairman

bcc: Brad Thiessen, Petroleum Branch

JNF/ibj
Date typed: July 12, 1990

July 6, 1990

Ian Haugh

H. Clare Moster

cc: L.R. Dubreuil

FOR APPROVAL AND SIGNATURE

RE: BOARD ORDER No. PM 63 (Rideau - Daly Field)

- Attached and recommended for signature and Ministerial approval are two (2) copies of the subject Order.
- Also attached is a covering letter from the Board that pre-authorizes temporary production from the proposed new injection well and advises the operator that production from the well will be classified as "old oil" for royalty/tax purposes.
- Please return signed letter and Order to Petroleum for distribution.

Pat for H. Clare Moster

Attachments

1527T

July 5, 1990

The Oil and Natural Gas Conservation Board
Ian Haugh, Chairman
H. Clare Moster, Deputy Chairman
Wm. McDonald, Member

John N. Fox
Chief Petroleum Engineer
Petroleum Branch

RE: Application for Pressure Maintenance
Daly Lodgepole D Pool

Rideau Petroleums Ltd. has made application for a pilot pressure maintenance project in a portion of Sections 27 and 28-9-29 (WPM) in the Daly Lodgepole D Pool. The application was advertised in the Manitoba Gazette (May 12, 1990) and the Virden Empire Advance (May 9, 1990). No objections were received.

Recommendations:

It is recommended that Rideau's application for pressure maintenance be approved and Board Order No. PM 63 be issued. A copy of the proposed Board Order is attached.

It is also recommended that the proposed injection well 9D-28-9-29 (WPM), which will be the second well in the spacing unit, be pre-authorized by the Board to produce for a period not to exceed six (6) months.

Discussion:

Rideau proposes to conduct a pilot waterflood project in the Daly Lodgepole D Pool on an inverted 5-spot pattern in Lsd's 12 and 13 of Section 27-9-29 (WPM) and Lsd's 9 and 16 of Section 28-9-29 (WPM). Rideau is proposing to unitize the lands. Figure 1 shows an outline of the waterflood project area and the proposed Daly Unit No. 5.

The Upper Lodgepole Formation in this area consists of dolomite with poor intergranular to pin-point vuggy porosity with numerous anhydrite and shale interbeds. The average reservoir parameters for Daly Unit No. 5 are shown in Table 1.

The four wells in the proposed unit produce at a total rate of 4.8 m^3 OPD and as of May 1, 1990 cumulative production from the proposed unit totalled 14,044 m^3 or 3.8% of the OOIP. The estimated primary recovery is only 37,000 m^3 or 10% of the OOIP over a period of 30 years. A plot of the production performance of the four (4) wells is shown in Figure 2.

Three previous attempts have been made to try and waterflood the Lodgepole Formation in Twp. 9-29 (WPM). Figure 3 shows the North Ebor pilot waterflood project, Ebor Unit No. 1 and West Butler Unit No. 1 where pilot and pattern waterfloods were attempted without success between 1962 and 1980.

In all three cases, little or no waterflood production response was observed. The reasons given for the waterflood project failures were:

1. lack of reservoir continuity
2. insufficient injection volumes
3. poor injector completions and out of zone injection, and
4. lack of source water for injection.

Rideau's proposal addresses all these concerns. To reduce the concerns regarding a lack of reservoir continuity, Rideau plans to drill an injection well at 9D-28-9-29 (WPM) to create a 16 ha inverted 5-spot injection pattern. Previous floods have all had either irregular injection patterns or 32 ha 5-spot and inverted 5-spot injection patterns.

The other problems with the previous waterfloods centre around water injection. Due to source water supply problems, low injectivity and out of zone injection, the effective volume of water injected over the life of the projects was insufficient. Rideau proposes to use produced water from its 9-28-9-29 battery and inject at a rate of 60-65 m^3 WPD during the fill-up phase of the waterflood. Water production at the battery is currently 60 m^3 /day.

To reduce the possibility of out of zone injection into the underlying aquifer, Rideau proposed to complete and produce the 9D-28-9-29 injection well for a period of 4-6 months and monitor the production for any indication of communication with the underlying aquifer. If the well is in communication with the underlying aquifer, remedial work will be carried out before the well is converted to injection. Additionally, injection pressures will be limited to 8 500 kPa or 85% of the estimated fracture gradient of 22.6 kPa/m.

The 9D-28-9-29 well, when drilled, will be the second well in the spacing unit and will require Board approval to produce pursuant to subsection 51(8) of the Regulation.

There is a great deal of uncertainty regarding the success of waterflooding the Upper Lodgepole Formation in this area and it is difficult to predict waterflood response. Rideau estimates that waterflood response will be observed in 1-2 years and production will peak at 6.5 to 11 m^3 OPD (1.5 to 2.5 times current rates). Rideau predicts that waterflooding will result in an incremental recovery of between 36 to 55 x 10^3 m^3 oil. Table 1 shows a comparison between the estimated primary and secondary recoveries.

It is recommended that the application be approved. A copy of the proposed Board Order No. PM 63 containing the usual pressure maintenance terms and conditions is attached. It is also recommended that the Board pre-approve production from the 9D-28-9-29 (WPM).

ORIGINAL SIGNED BY
JOHN N. FOX

John N. Fox

Att'd.

Approved by: ______________________________
L.R. Dubreuil, Director

Order No. PM 63

An Order Pertaining to Pressure Maintenance by Water Flooding
Daly Lodgepole D Pool

WHEREAS, subsection(9)(d) of Section 62 of "The Mines Act", Cap. M160, of the Revised Statutes of Manitoba, provides as follows:

> "62(9) Without restricting the generality of subsection (8) the board, with the approval of the minister, may make orders
>
> (d) requiring the repressuring, recycling, or pressure maintenance, of any pool or portion thereof where it is econonomical so to do, and for that purpose where necessary requiring the introduction or injection into any pool or portion thereof of gas, air, water, or other substance;"

AND WHEREAS, the Board received an application dated February 2, 1990 from Rideau Petroleums Ltd. ("Rideau") for approval of a pilot project to inject water into the Daly Lodgepole D Pool in the proposed Daly Unit No. 5.

AND WHEREAS, notice of the application was published in the Manitoba Gazette on May 12, 1990 and the Virden Empire Advance on May 9, 1990.

AND WHEREAS, the Board has received no objections or interventions with respect to the application by Rideau.

AND WHEREAS, Rideau is the proposed unit operator of the proposed Daly Unit No. 5 ("the unit area").

AND WHEREAS, upon due consideration of the said application, the Board has found it is reasonable and desirable to inject water in the unit area.

NOW THEREFORE, the Board orders that:

1. The unit operator shall conduct pressure maintenance operations by the injection of water into the pool underlying the unit area.

2. The pressure maintenance operation shall be in accordance with, and subject to, the following rules:

PRESSURE MAINTENANCE RULES

1(1) Water shall be injected into the Lodgepole Formation through the well

Rideau Daly Prov. WIW 9D-28-9-29 (WPM)

and such other wells in the unit area as the Board may approve.

1(2) After the commencement of injection, the unit operator shall, subject to any remedial work required to be performed on the wells referred to in subsection (1), endeavour to maintain continuous injection.

1(3) Notwithstanding the provisions of subsection (2), the Board may, upon application by the unit operator, approve the suspension of water injection into any well or wells, provided that the Board is satisfied that pressure maintenance operations in the unit area will not be adversely affected.

1(4) The completion of the wells referred to in subsection (1) will be as prescribed by the Director of Petroleum.

2 The unit operator, upon the request of the Board, shall satisfy the Board as to the source, suitability and method of treatment of the water to be injected.

3(1) Before injection of water is commenced, the unit operator shall submit, to the Board, results of a survey conducted to determine the static reservoir pressure in not less than one well in the unit area.

3(2) The unit operator shall, not less than six months nor more than 12 months after the commencement of injection, and at yearly intervals thereafter, conduct a survey to determine the static reservoir pressure in not less than one well in the unit area.

3(3) The Board may, at any time, require the unit operator to carry out such additional reservoir pressure surveys as it deems necessary.

3(4) Within 30 days of the completion of the surveys described in subsections (1), (2) and (3) the unit operator shall submit the details of the surveys including:

(a) a list of wells surveyed,
(b) the measurement technique used,
(c) the shut in period for each well,
(d) the static reservoir pressure data obtained from the survey corrected to the pool datum depth, and;
(e) a discussion of the survey results and pressure distribution within the unit area.

4 The unit operator shall immediately report to the Board any indication of channelling or break-through of injected water to producing wells or any indication of other detrimental effects that may be attributable to the pressure maintenance operations.

5 The maximum wellhead pressure at which water is injected into the wells referred to in subsection 1(1) shall not exceed 8 500 kPa or such other maximum pressure as the Board may prescribe and the Board may, from time to time, prescribe a maximum or minimum rate at which water shall be injected into any well in the unit area.

6(1) The unit operator shall, not later than the last day of each month, file with the Petroleum Branch, a report of the quantity, source and pressure of water injected during the preceding month into each well referred to in subsection 1(1).

6(2) The unit operator shall, not later than the last day of each month, file with Petroleum Branch a summary report of production and injection operations during the preceding month, which report shall include:

(a) a tabulation of total oil, total water and total gas produced;
(b) a tabulation of the number of producing wells and injection wells which were active;
(c) the results of at least one twenty-four hour production test on each producing well in the unit area including volumes of oil, gas and water produced during the test; and
(d) a summary of any remedial operations carried out on any well in the unit area.

7 The unit operator, shall, within 60 days of the end of each calendar year, file with the Petroleum Branch a report of the pressure maintenance program, setting out graphically such interpretive information necessary to evalutate the efficacy of the waterflood.

H.C. Moster
Deputy Chairman

Ian Haugh
Chairman

OIL AND NATURAL GAS CONSERVATION
BOARD ORDER NO. PM 63 APPROVED THIS
DAY OF A.D.,
AT THE CITY OF WINNIPEG.

APPROVED:

Harold Neufeld
Minister of Energy and Mines

TABLE NO. 1

RESERVOIR PARAMETERS

DALY UNIT NO. 5

Area	64 ha
Net Pay	7.1 m
Porosity	13%
Permeability	3 - 10 md
Water Saturation	35%
Original Oil in Place	369,000 m^3
Cumulative Production as of May 1, 1990	14,044 m^3
Recovery Factor - Primary	10%
Recoverable Reserves - Primary	37,000 m^3
Recovery Factor - Secondary	20 - 25%
Recoverable Reserves - Secondary	73,800 - 92,250 m^3

TABLE NO. 1

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DALY UNIT NO. 5

Area	64 ha
Net Pay	7.1 m
Porosity	13%
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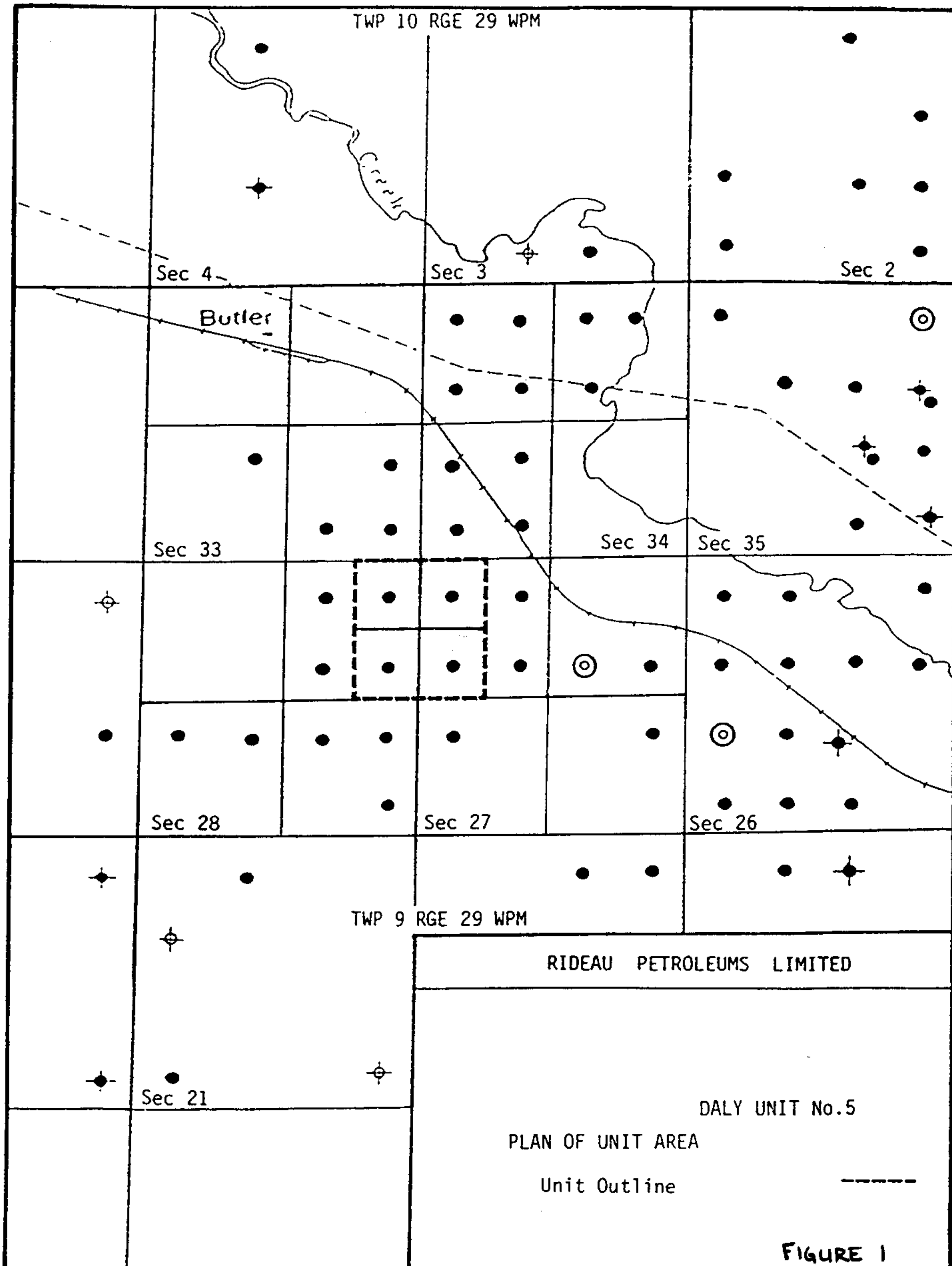
Recovery Factor - Secondary	20 - 25%
Recoverable Reserves - Secondary	73,800 - 92,250 m^3

383 968 1.091

369 000



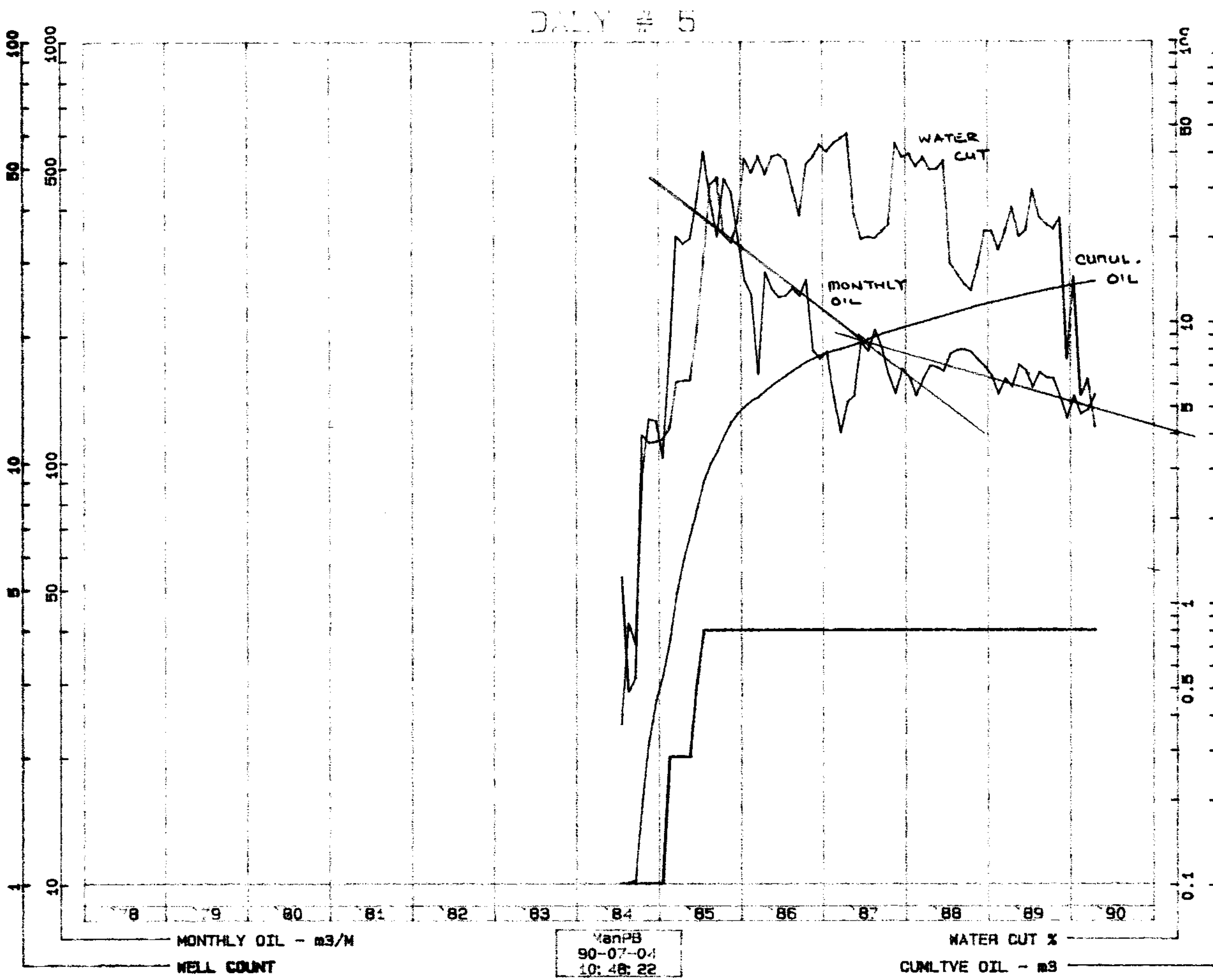
RIDEAU PETROLEUMS LIMITED

DALY UNIT No.5

PLAN OF UNIT AREA

Unit Outline ------

FIGURE 1



DALY # 5
WATER CUT
CUMUL. OIL
MONTHLY OIL
MONTHLY OIL - m3/M
WELL COUNT
WATER CUT %
CUMLTVE OIL - m3
VanPB
90-07-04
10:48:22

FIG. 2

PREVIOUS PRESSURE MAINTENANCE PROJECTS

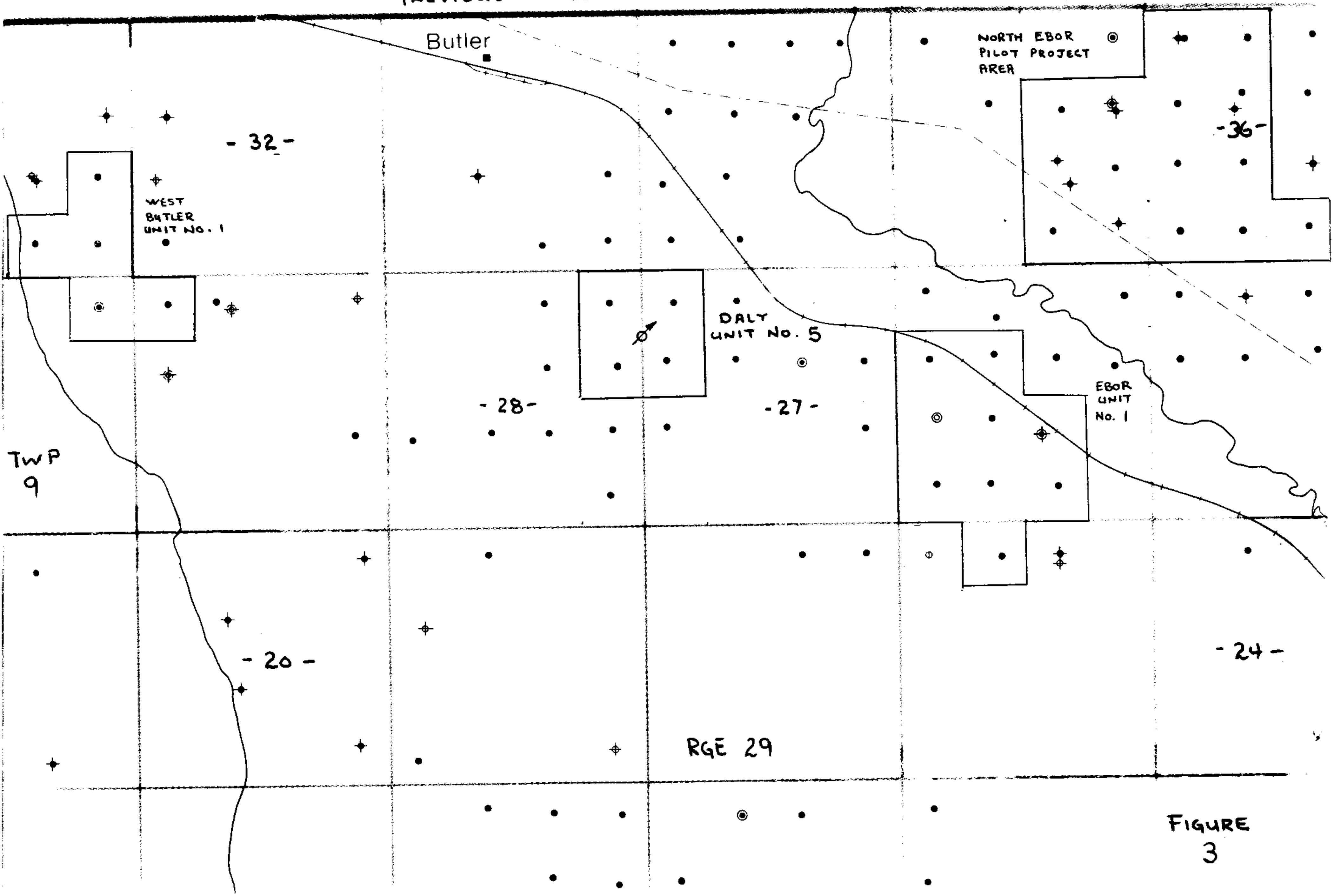


FIGURE 3

Mrs. Margaret Hayhurst, Reporter

family, all of

raldine Isaac had
/ith Connie Thies-
. G. Thiessen were
ith Mr. and Mrs.
inclair.
Mark Toews and
day dinner guests
:rs. Clifford Isaac
nclair.
cook and girls of
l with Verna and
ɔk last Sunday.

wed
ɔom

: 2, and the Legion
ry will serve lunch
lowing the service.

The Ebor W.I. held their regular monthly meeting at the home of Dot Thornhill on Monday.

Kent Lewarne of Flin Flon and Kim Lewarne of Brandon were home for the weekend to visit their parents.

Carly and Allan Hayward spent the week with their grandparents, Allan and Barbara Cruickshank.

Visitors with Bob and Roberta Berry on the weekend were Michael Berry of Reston, Marlene and Sean Glover, and Jane Berry, all of Winnipeg, and Warren Kay of Yorkton.

Mr. and Mrs. Win McArthur of Melita visited with Addie and Earl Schlemmer on Sunday.

Morris Senkiw attended the funeral of Walter Enstrom of Riverhurst, Sask., on Saturday.

All the plans have been finalized for the Cromer Mother's Day Tea on Thursday, May 10.

NOTICE
Under The Mines Act
Daly Oil Field

Rideau Petroleums Ltd. has made application under The Mines Act to conduct a pilot waterflood project in the Lodgepole Formation in that portion of the Daly Field described as follows: Lsd's 12 and 13 of Section 27-9-29 (WPM) and Lsd's 9 and 16 of Section 28-9-29 (WPM).

It is proposed to drill a water injection well in the northeast corner of Lsd 9 of Section 28-9-29 (WPM).

If no valid objection or intervention in writing is received by The Oil and Natural Gas Conservation Board at 555-330 Graham Avenue, Winnipeg, Manitoba, R3C 4E3 within 14 days of the publication of this notice, the Board may approve the application.

Copies of the application may be obtained from Rideau Petroleums Ltd., 201-215 Lawrence Avenue, Kelowna, British Columbia, V1Y 6L2.

Dated at Winnipeg, this 3rd day of May, 1990.

H.C. Moster Deputy Chairman

THE HIGHWAY TRAFFIC BOARD

.ce is hereby given that a hearing of the Highway Traffic Board will be held on Tuesday, May 29, 1990 at 13:00 hours in Morden Recreation Centre Auditorium, 111 Gilmour Street, Morden, Manitoba.

Weight Restrictions — Section 68(7) H.T.A.

36-B — R.M. of Stanley

Consideration to be given to reclassify all roads within the jurisdiction of the R.M. of Stanley from class "C" to class "A1", as set out in By-Law 5-90 in the R.M. of Stanley.

Speed Zones — Sections 97 and 98 H.T.A.

19000-S — R.M. of Stanley

Consideration to be given to modified speed zones of 75 km/h for all trucks weighing in excess of 10,000 kilograms on all roads within the R.M. of Stanley excluding Provincial Trunk Highways, Provincial Roads and all other highways and roads that are otherwise regulated, R.M. of Stanley.

19000-S — R.M. of Stanley

Consideration to be given to restricted speed areas of 50 km/h in the Communities of Birkenhead, Blumenfield, Chortitz, Friedensfeld, Friedensruh, Haskett, Hochfield, Osterwick, Reinfeld, Reinland, Schanzenfeld and Thornhill, R.M. of Stanley.

The Highway Traffic Board will be prepared to consider all submissions written or oral on the above applications by contacting the Secretary prior to or at the hearing.

Room 206-301 Weston Street
Winnipeg, Manitoba
R3E 3H4
Phone: 945-8912

A. POLTARUK, MMM CD
Secretary,
THE HIGHWAY TRAFFIC BOARD.

7036—19

THE HIGHWAY TRAFFIC BOARD

Notice is hereby given that a hearing of the Highway Traffic Board will be held on Tuesday, May 22, 1990 at 10:00 hours in Room 204-301 Weston Street, Entrance "D", Winnipeg, Manitoba R3E 3H4 Phone: 945-8912.

Pedestrian Corridors — Section 78 H.T.A.

Consideration to be given for the relocation of a Pedestrian Corridor from the south side of Rathgar Avenue across Osborne Street to the south side of Walker Avenue across Osborne Street, City of Winnipeg.

The Highway Traffic Board will be prepared to consider all submissions written or oral on the above applications by contacting the Secretary prior to or at the hearing.

A. POLTARUK, MMM CD,
Secretary,
The Highway Traffic Board.

7062—19

UNDER THE MINES ACT

NOTICE
DALY OIL FIELD

Rideau Petroleums Ltd. has made application under The Mines Act to conduct a pilot waterflood project in the Lodgepole Formation in that portion of the Daly Field described as follows: Lsd's 12 and 13 of Section 27-9-29 (WPM) and Lsd's 9 and 16 of Section 28-9-29 (WPM).

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Copies of the application may be obtained from Rideau Petroleums Ltd., 201-215 Lawrence Avenue, Kelowna, British Columbia, V1Y 6L2.

Dated at Winnipeg, this 3rd day of May, 1990.

H. C. MOSTER,
Deputy Chairman.

7070—19

RIDEAU PETROLEUMS LTD.

PHONE (604) 861-4661

201 - 215 LAWRENCE AVE.
KELOWNA, B.C. V1Y 6L2

MAILING ADDRESS:
BOX 520, STN. A
KELOWNA, B.C. V1Y 7P1

2 February 1990

The Oil and Natural Gas Conservation Board
Room 309, Legislative Building
450 Broadway Avenue
Winnipeg, MB RC3 OV8

ASSISTANT DEPUTY MINISTER
ENERGY
FEB 7 1990
DEPARTMENT OF
ENERGY and MINES

Sent to I. Haugh's office Feb 6)

Attention: Mr. H. Clare Moster, Deputy Chairman

Dear Sir:

Re: Application for a Pilot Pressure Maintenance Project
Daly Lodgepole D Pool

Schedule of Attachments

The following Attachments are included in support of the project:

Attachment I	Map of Unit Area and Interpreted Pool Boundaries.
Attachment II	Log Section of Daly 09-28-09-29
Attachment III	Pore Volume Map
Attachment IV	Permeability Capacity Map
Attachment V	List of Mineral Owners
Attachment VI	List of Lessees
Attachment VII	List of Surface Owners
Attachment VIII	Registered Letter to Surface Owners in the Scheme Area
Attachment IX	Schematic Cross Section of Injection Well
Attachment X	Diagram of Configuration of Surface Facilities
Attachment XI	Paper entitled "The Stress Regime of the Western Canadian Basin and Implications for Hydrocarbon Production"
Attachment XII	Article entitled "Fine Tuning a Waterflood"

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Description of Proposal

The pilot pressure maintenance project involves the unitization of the following lands:

Lsds 12 and 13 Section 27-9-29 WPM
Lsds 09 and 16 Section 28-9-29 WPM

In this Application the above area is variously referred to as the Pilot Project Area, the Scheme Area and the Proposed Unit Area. Attachment I is a map that outlines this Area.

The Zone to be unitized occurs from 801 to 828 metres at Rideau Prov. Daly 09-28-09-29 which interval is shown on Attachment II, a log section of Daly 09-28-09-29. This Zone is referred to as the "Upper Undivided Lodgepole" in the literature. It would be helpful if the Zone were more specifically named. In this Application, the Zone will be referred to as the Ebor Zone or the Ebor Dolomite. The Zone consists of a series of carbonate beds interbedded with thin irregular bands of anhydrite and some chert. Within the Scheme Area the carbonates are dolomitized throughout the Zone. However, in some other parts of the Daly D Pool, carbonates in the lower portion of the Ebor Zone remain as limestone with little or no dolomitization.

Following unitization, our proposal calls for the drilling of an off-pattern well, Rideau Daly Prov. A9-28-09-29, in the extreme NE corner of Lsd 09-28-09-29 (the approximate centre of the unitized area). Following a short period of production to determine producing characteristics, produced water would be injected into Daly A9-28 and production from the four existing wells in the Unit area closely monitored.

It is expected reservoir voidage in the proposed Unit area could be replaced in about 12 months at an injection rate of approximately 65 m3 per day. Some response in the pilot area should be observed within 12 to 24 months. Of particular interest would be evidence of early response in a preferred direction as being indicative of a fracture pattern.

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Well Status and Zone of Completion

Listed below are wells within and adjoining the Scheme Area including status and zone of completion:

Well	Status	Zone of Completion	Formation
Daly 05-27-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 10-27-09-29	Saltwater Disposal	Ebor and Daly Zones	Lodgepole
Daly 11-27-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 12-27-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 13-27-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 14-27-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 07-28-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 08-28-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 09-28-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 10-28-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 15-28-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 16-28-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 01-33-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 02-33-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 03-34-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole
Daly 04-34-09-29	Producing Oilwell	Ebor Dolomite	Lodgepole

Discussion of Maps

The Pore Volume Map (Attachment III) was isopached from values determined as follows:

1. Selection of gross oil pay within the Ebor Zone was made from well logs. Generally intervals calculating greater than 50% water saturation were rejected.

2. Where core analysis was available, net pay within the gross interval was determined using cut-offs of 0.5md permeability and 6% porosity.

3. Where core analysis was not available or where not all pay was cored, net pore volume was determined from logs using relationships developed from core log comparisons.

The Permeability Capacity Map (Attachment IV) was constructed from core analysis permeability of 0.5 md or greater. Some weight was given to log characteristics in non-cored areas.

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Reservoir Fluid Properties

Fluid Property	Factor	Source
Formation volume factor	1.05	Chevron Daly 06-32-09-28
Solution gas SCF/barrel	104	Chevron Daly 06-32-09-28
Solution gas m3/m3 oil	18	Chevron Daly 06-32-09-29
Ave. formation water saturation	0.35	Log calculations

Pilot Project Area Original Oil and Gas in Place

Original oil in place per Lsd = 161,900 (porosity metres) (1-SW) (1/FVF)

Lsd 12-27-09-29 Pore volume = 0.87 porosity metres
OOIP = 161,900 (0.87) (0.65) (0.95) = 87,000 m3

Lsd 13-27-09-29 Pore volume = 0.91 porosity metres
OOIP = 161,900 (0.91) (0.65) (0.95) = 91,000 m3

Lsd 09-28-09-29 Pore volume = 0.97 porosity metres
OOIP = 161,900 (0.97) (0.65) (0.95) = 97,000 m3

Lsd 16-28-09-29 Pore volume = 0.94 porosity metres
OOIP = 161,900 (0.94) (0.65) (0.95) = 94,000 m3

Total calculated original oil in place within Pilot Project Area
is 369,000 m3

Total calculated original gas in place within Pilot Project Area
368,000 x 18 = 6,642,000 m3 gas

Predicted Primary Recovery

To January 1, 1990 the four wells in the Pilot Project Area have produced 13,500 m3 of oil or 3.7% of original oil in place (OOIP). Based on a projection of production for another 20 years, it is estimated that total primary production will be in the order of 37,000 m3 of oil or a 10% recovery of original oil in place. By comparison the Ebor Unit #1, one mile to the east, appears to have recovered between 9.0 and 9.5% of 001P. Total recovery from the Ebor Unit will probably be in the order of 11% to 12% of OOIP, but this has probably been helped somewhat by past and current water injection and disposal.

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Discussion of Waterflood Recovery and Future Production Rates

There have been two previous attempts to waterflood the Ebor Dolomite. These are briefly discussed below:

Ebor Unit No. 1 was formed in July 1964 with Sun Oil Company as operator. Approximately 19,700 m3 of water was injected into the pool to December 1965 including 8,900 m3 injected prior to unitization. This compares with total withdrawals of about 42,900 m3 (reservoir equivalent) to the end of 1965 when injection was suspended.

Injected water to December 1965 then amounted to only 46% of reservoir withdrawals. Sun reported that there was some doubt about the volume of water that actually entered the reservoir because of a suspected casing leak. Therefore, the 46% replacement of reservoir withdrawals may be high.

No improvement in oil production or recovery was noted. It is apparent the flood failed because of inadequate water injection. Sun indicated that the limiting factor to injection rates was the availability (or lack of) source water.

West Butler Unit No. 1 was formed in September 1972 by Chevron Canada. From September 1978 to October 1980, Chevron injected approximately 71,000 m3 of water into 4 wells offsetting Daly 13-29-09-29. There was no effect on the Daly 13-29 producer either in oil production or water cut. A review of completions combined with production results strongly suggests that the bulk of the injected water bypassed the Ebor Dolomite and went into the Daly Zone aquifer.

To determine the feasibility of waterflooding the Ebor Dolomite, it is essential that the proposed injector be completed in that Zone only, with no communication to the more permeable underlying Daly.

Successful Ebor Dolomite completions will generally come on production with less than a 35% water cut. Both fluid production and water cut will decrease with time. In contrast, completions in contact with the Daly Zone will produce with an increasing water cut and a stable to increasing total fluid volume over time. Due to factors discussed above we propose putting the injection well on production for 4 to 6 months and closely monitoring production. Any indication of communication with the Daly Zone would call for a remedial program.

The nature of the Ebor reservoir, which consists of about 65% dolomite interbedded with numerous thin, irregular, anhydrite bands and some chert, has an adverse effect on vertical permeability. The unknown here is the

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frequency and extent of vertical fractures. Vertical fractures probably exist in most if not all carbonate reservoirs. Submitted with this Application is a paper entitled "The Stress Regime of the Western Canadian Basin and Implications for Hydrocarbon Production" (Attachment XI) which makes a convincing case that vertical fractures, both natural and hydraulically induced, will be oriented normal to basin strike. In the Daly area, this would be NE-SW. Waterflooding in the Midale Zone of SE Saskatchewan demonstrates a NE-SW fracture lineation. Vertical fractures, regardless of orientation, could, to a considerable extent, compensate for the lack of vertical permeability in the reservoir rock allowing water to migrate vertically and flood additional reservoir.

The last attachment to this Application is an article entitled "Fine Tuning a Waterflood" (Attachment XII). This article describes the waterflooding of 2 Units in the Garza Field, Garza County, Texas. The waterflooded Garza reservoir is called the San Andres, and it appears to bear a number of similarities to the Daly Field Ebor Dolomite as demonstrated by the comparisons below:

Reservoir Factors	Daly Lodgepole D Pool	Garza Field SE & SW Units
Lithology	Dolomite w/interbedded anhydrite stringers	Dolomite with "interlacing barriers"
Ave. Depth	820 metres	915 metres
Ave. Porosity	10% to 15%	12% to 15%
Ave. Permeability	3 md to 10 md	1.2 md (SE Unit) 4.0 md (SW Unit)
Ave. Formation Breakdown Pressure	15,500 kPa	17,900 kPa

Injection-production response plots in the article indicate a production increase after water injection of 3 to 1 in the SE Unit and 5 to 1 in the SW Unit.

Predicting waterflood response in the Ebor Dolomite is particularly difficult in view of two previous apparent failures.

The following estimates are put forward for the proposed Pilot Flood Project assuming that water injection can be maintained and confined to the Ebor Zone. If that condition can be met it would seem reasonable to expect a favorable production response and corresponding increase in recoverable oil.

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Peak future production rate is estimated to be 1.5 to 2.5 times current production (January 1990) in the Scheme Area with a resulting increase in economic well life.

Recovery of original oil in place is estimated to increase from 10% by primary pressure depletion to 20-25% under pressure maintenance by water flooding.

An injection rate of 60 to 65 m3 per day is planned at an expected wellhead pressure in the range of 7000 kPa to 8500 kPa.

Reservoir Pressure Data

Original reservoir pressure is approximately 6700 kPa. Most of the bottom hole pressure data was obtained from extrapolation of drill stem test shut in pressures. Existing reservoir pressure probably varies from about 300 kPa near producing well bores to something near original pressure 200 metres back.

Source and Conditioning of Injection Water

Injection water for this pilot flood will consist of produced salt water from our existing wells. This will nullify any problems related to incompatibility, thereby eliminating the need for conditioning or treating of the water prior to injection. A hay filter may be installed upstream of the injection pump to reduce the possibility of solids such as wax or asphaltenes from entering the well bore. The injected water would be pumped out of a fiberglass storage tank, through a hay filter to a triplex pump and then through a high-pressure fiberglass flowline to the injection well.

Measurement of Injection Water

The quantity of water injected would be measured by a flow meter installed at the injection well as indicated on Attachment X. Another flow meter would be installed on the centrifugal pump which feeds the triplex pump thereby allowing a comparison and check of the accuracy of the quantity of water injected.

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Corrosion Control

Corrosion in the wellbore will be controlled by installing a plastic lined packer on the bottom of the tubing string. Tubing will be fiberglass, plastic lined, or cement lined. The annulus above the packer would be filled with inhibited fresh water. Corrosion within the surface facilities will be controlled by using either plastic lined or stainless steel fittings and valves wherever feasibly possible.

Summary

Rideau requests approval of this Application for a Pilot Pressure Maintenance Project in the Daly Field D Pool. In support of the application, we list the following factors for consideration:

1. Previous attempts at pressure maintenance by waterflood have probably failed because of insufficient voidage replacement or loss of water to the Daly Zone aquifer. Very restricted permeability in some injectors was also a factor.

2. The selected scheme area contains better than average porosity and permeability within the Ebor Zone, which should enhance the chances of success.

3. Ebor Zone carbonates within the scheme area are almost uniformly dolomites. Not having the added complication of a dolomite-limestone facies change should help keep injected water within the zone.

4. The proposed injection well will create an 8 hectare spacing pattern which should shorten response time. The NE-SW and NW-SE alignment of producers to injector may be advantageous, or at least will differ from previous N-S and E-W alignments.

5. Adequate produced water exists for at least the pilot stage of the proposed pressure maintenance project. Produced water will be compatible with the reservoir.

6. If the pilot flood attains sufficient response to generate an economic return, the pressure maintenance project could be expanded to include as many as 30 additional wells in the northwestern portion of the Daly Field D Pool. This in turn would lead to additional development drilling in the D Pool.

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We do not, as yet, have a proposed Unit Agreement or proposed Unit Operating Agreement available for submission to the Board. The documents will be forwarded when ready, hopefully with the support of all working interest and royalty interest holders in the proposed unit area.

This Application is submitted now to enable the Board to appraise and review its technical merits.

Yours sincerely,

RIDEAU PETROLEUMS LTD.

D R Burns

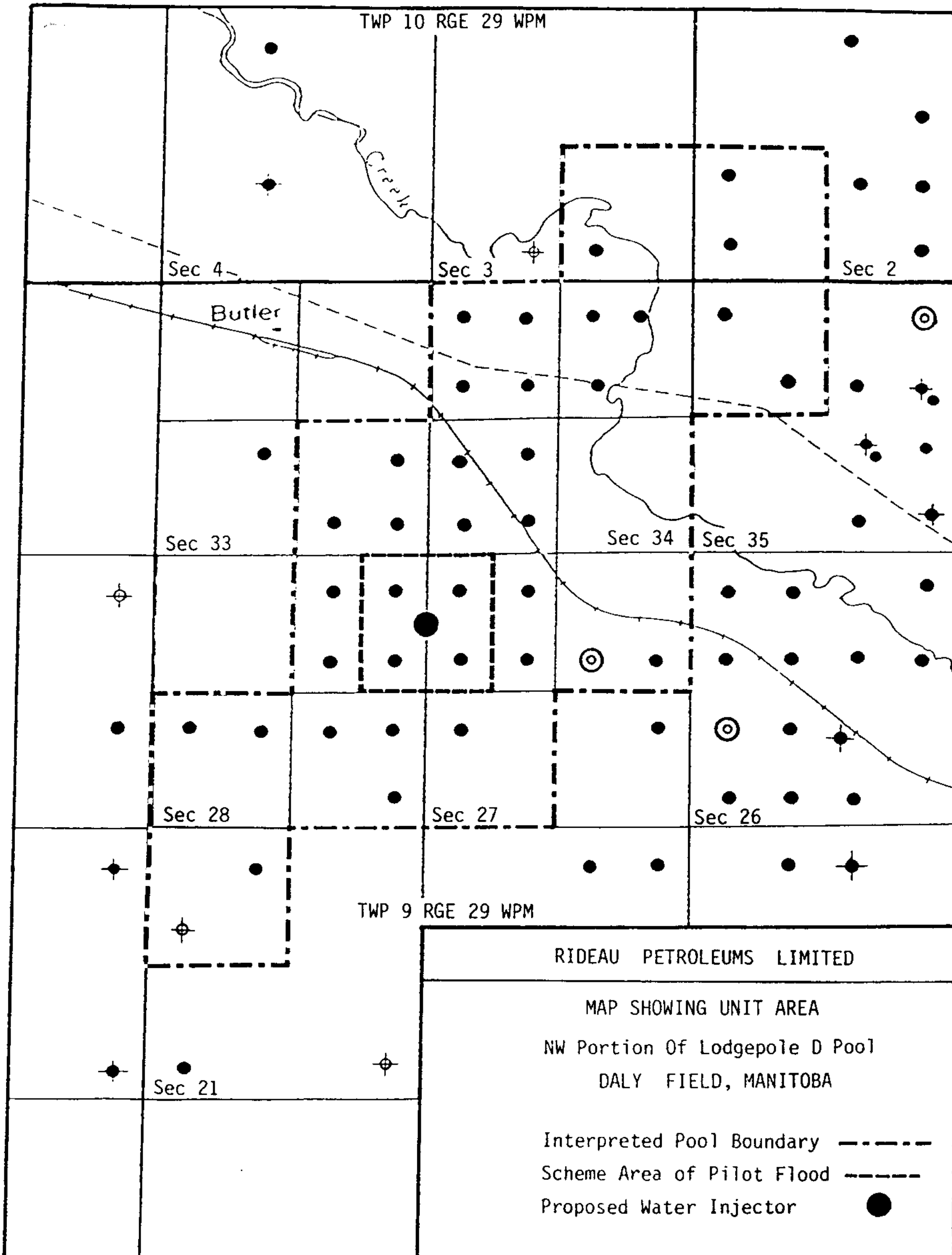
D.R. Burns, President

DRB:LB

Attachments 12

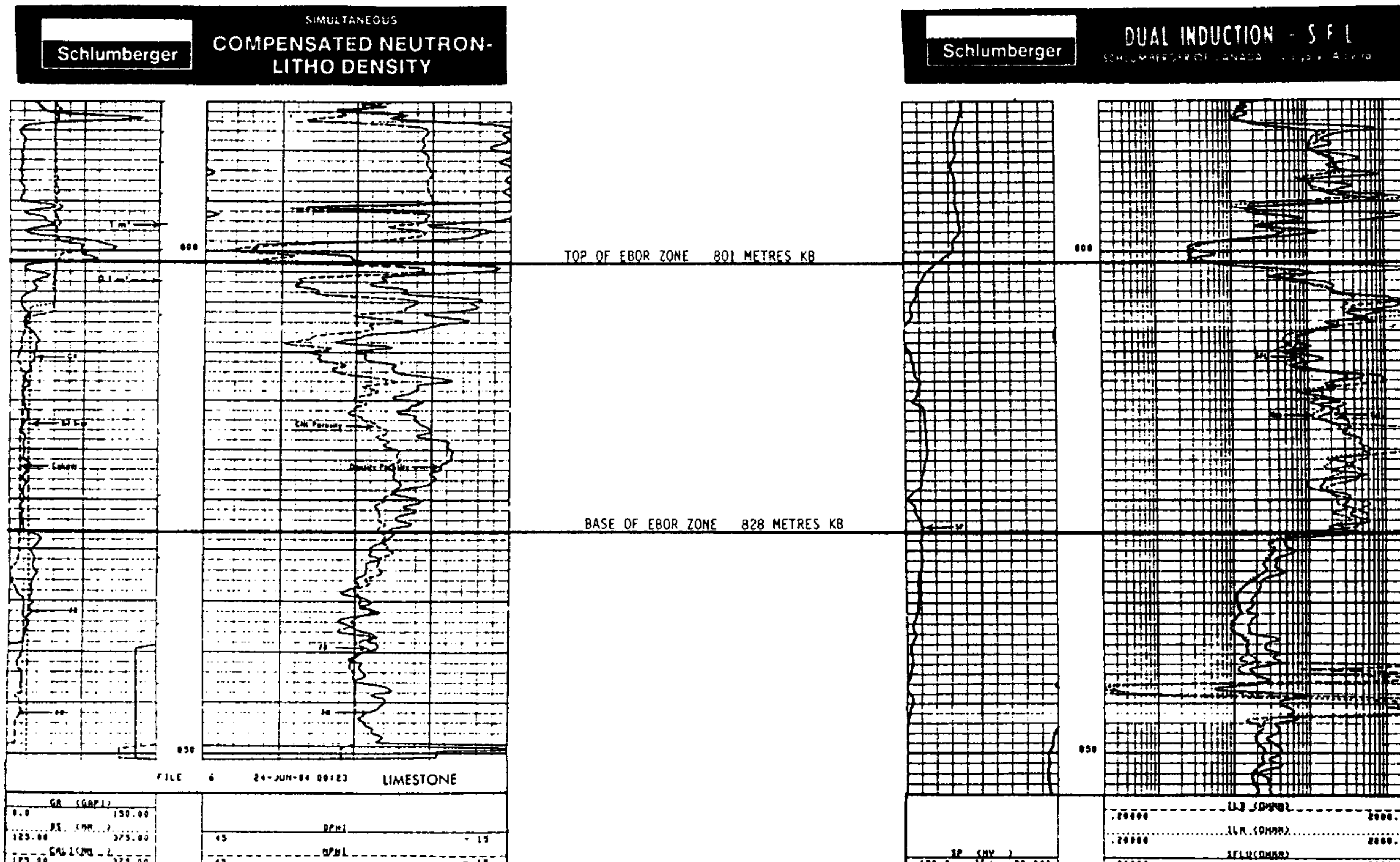
Copy to L.R. Dubreuil, Director, Petroleum

ATTACHMENT 1

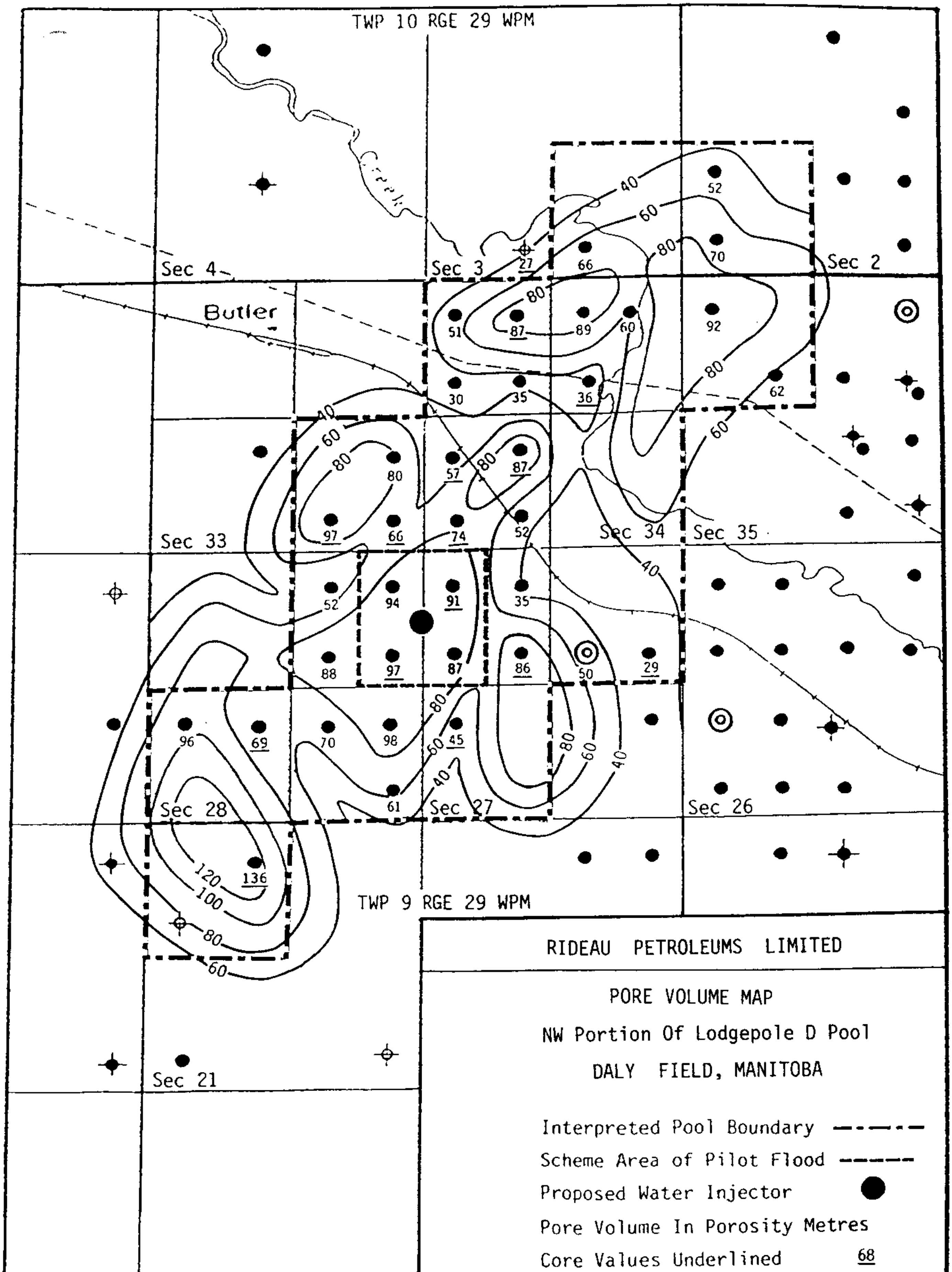


ATTACHMENT II

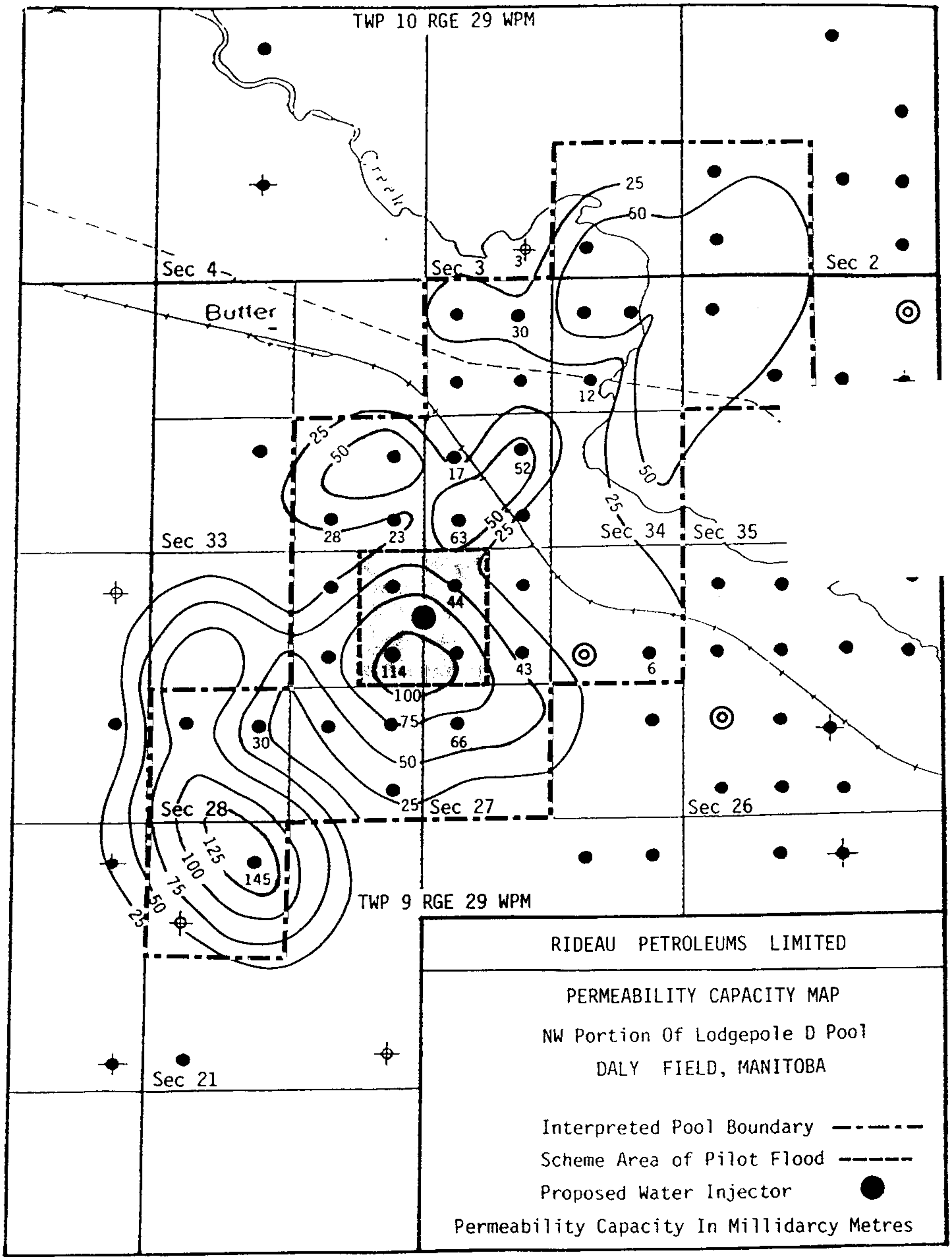
LOG SECTION OF RIDEAU PROV DALY 9-28-9-29



ATTACHMENT III



ATTACHMENT IV



Attachment V

LIST OF MINERAL OWNERS WITHIN AND ADJOINING SCHEME AREA

SW 27-09-29 WPM

Ethel McLean	Box 851 Virden, MB ROM 2CO
Delwyn D. Smith	Box 218 Strathmore, AB TOJ 3HO
Dome Petroleums (AMOCO)	Box 200 Station M Calgary, AB T2P 2H8

N/2 27-09-29 WPM

Garnet Ross McDougall	RR No. 1 Cromer, MB ROM OJO
Gordon Kenneth McDougall	832 Mount Royal Drive Kelowna, BC V1Y 8G3
Phyllis Baker	8604 - 44 Avenue Edmonton, AB T6K OZ8
CN Exploration	1300, 530 - 8 Avenue SW Calgary, AB T2P 3S8

Section 28-09-29 WPM

Crown (Manitoba)	Petroleum Branch 555 - 330 Graham Avenue Winnipeg, MB R3C 4E3

SE 33-09-29 WPM

Omro Resources Ltd.	c/o Orrin E. Sharratt Box 1473 Virden, MB ROM 2CO
Canada Trust Company	c/o Montreal Trust Company 411 - 8 Avenue SW Calgary, AB T2P 1E7

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SW 34-09-29 WPM

Omro Resources Ltd.	c/o Orrin E. Sharrat Box 1473 Virden, MB ROM 2CO
Canada Trust Company	c/o Montreal Trust Company 411 - 8 Avenue SW Calgary, AB T2P 1E7
Russell J. Caskey and Doris Pfefferle	Box 399 Eston, SK SOL 1AO

Attachment VI

LIST OF LESSEES WITHIN AND ADJOINING SCHEME AREA

SW 27-09-29 WPM

Rideau Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Dome Petroleums (AMOCO)	Box 200 Station M Calgary, AB T2P 2H8
Pipestone Petroleums Inc.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Tribros Enterprises	500, 455 Granville Street Vancouver, BC V6C 1V2

N/2 27-09-29 WPM

Rideau Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Anna Resources Ltd.	500 B, 805 - 8 Avenue SW Calgary, AB T2P 1H7
Corsair Petroleum Inc.	1200, 407 - 2nd Street SW Calgary, AB T2P 2Y3
Interwest Construction Ltd.	500, 455 Granville St. Vancouver, BC V6C 1V2
Maier Resources Ltd.	Site 2 - Box 262 RR 7, East Chestmere Drive Calgary, AB T2P 2G7
Zero Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Pipestone Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Troy Oils Ltd.	705, 805 - 8 Avenue SW Calgary, AB T2P 1H7

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SE 28-09-29 WPM

Rideau Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 7P1
Laurel Explorations Ltd.	101 - 1861 Welch Street North Vancouver, BC V7P 1B7
Pipestone Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Tribros Enterprises Ltd.	500, 455 Granville Street Vancouver, BC V6C 1V2
Wydmar Resource Enterprises Ltd.	400, 255 - 17 Avenue SW Calgary, AB T2S 2T8
Zero Petroleums Ltd.	201 - 215 Lawrence Avenue Kelowna, BC V1Y 6L2

NE 28-09029 WPM

Rideau Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Interwest Construction Ltd.	500, 455 Granville St. Vancouver, BC V6C 1V2
Pipestone Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2

SE 33-09-29 WPM

Rideau Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Anna Resources Ltd.	500 B, 805 - 8 Avenue SW Calgary, AB T2P 1H7
Daniel Canart and Mildred Canart	Box 154 Elkhorn, MB ROM ONO
Centenniel Oilfield Sales Ltd.	Box 269 Virden, MB ROM 2CO
Prospect Hill Management Ltd.	c/o HRH Life Insurance Co. 102, 215 Lawrence Avenue Kelowna, BC V1Y 6L2

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<u>SW 34-09-29 WPM</u>

Rideau Petroleums Ltd.	201, 215 Lawrence Avenue Kelowna, BC V1Y 6L2
Anna Resources Ltd.	500 B, 805 - 8 Avenue SW Calgary, AB T2P 1H7
Daniel Canart and Mildred Canart	Box 154 Elkhorn, MB ROM ONO
Centenniel Oilfield Sales Ltd.	Box 269 Virden, MB ROM 2CO
Prospect Hill Management Ltd.	c/o HRH Life Insurance Co. 102, 215 Lawrence Avenue Kelowna, BC V1Y 6L2

Attachment VII

LIST OF SURFACE OWNERS WITHIN AND ADJOINING SCHEME AREA

	SW 27-09-29 WPM NW 27-09-29 WPM NE 27-09-29 WPM SE 28-09-29 WPM	
Edgar Penner	Box 42 Kola, MB ROM 1BO	
	NE 28-09-29 WPM	
Ross McDougall	Box 1300 Virden, MB ROM 2CO	
	SE 33-09-29 WPM	
Elwin Penner	RR No. 1 Cromer, MB ROM OJO	
	SW 34-09-29 WPM	
Thomas Naylen	Box 336 Maryfield, SK SOG 3KO	

RIDEAU PETROLEUMS LTD.

PHONE (604) 861-4661

201 - 215 LAWRENCE AVE.
KELOWNA, B.C. V1Y 6L2

MAILING ADDRESS:
BOX 520, STN. A
KELOWNA, B.C. V1Y 7P1

17 January 1990

Mr. Edgar Penner
Box 42
Kola, MB ROM 1BO

Mr. Ross McDougall
Box 1300
Virden, MB ROM 2CO

Dear Sir:

Re: Proposed Pilot Waterflood Project
Daly Lodgepole D Pool

Rideau Petroleums is currently preparing an application to the Manitoba Oil and Natural Gas Conservation Board to initiate a pilot waterflood project. The pilot project will include the following lands:

Lsds 12 and 13 Section 27-9-29 WPM
Lsds 9 and 16 Section 28-9-29 WPM

Following approval of the project by the Conservation Board, Rideau would drill an off-pattern water injection well in the extreme NE corner of Lsd 9-28-9-29. This injection well would be in the approximate centre of the scheme area as shown on the attached map. Injection water would be supplied from water currently being produced in association with oil from the Daly D pool.

The purpose of this letter is to notify you, as a surface owner in the project area, of our intentions.

Yours sincerely,

RIDEAU PETROLEUMS LTD.

D.R. Burns

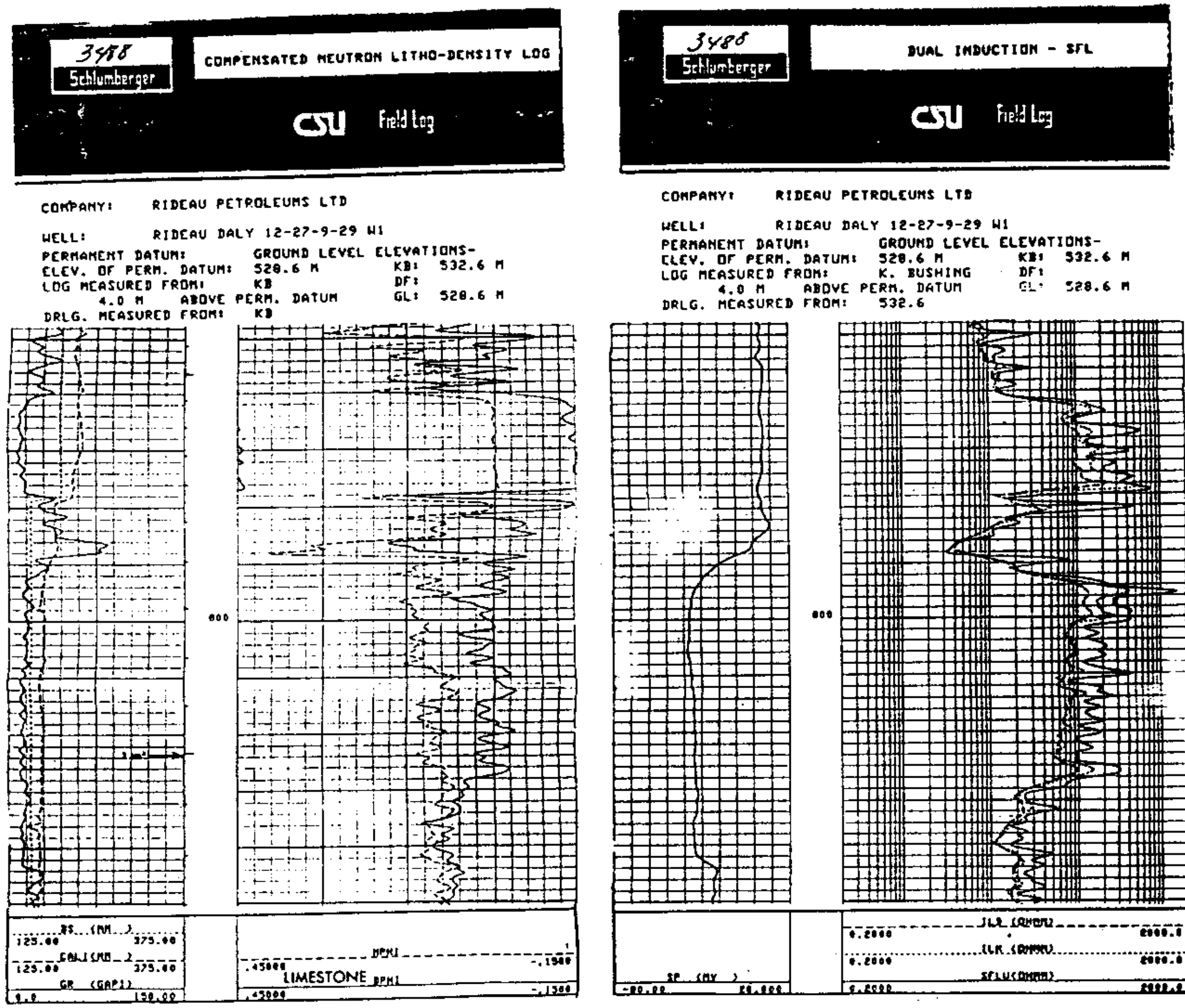
DRB:LB

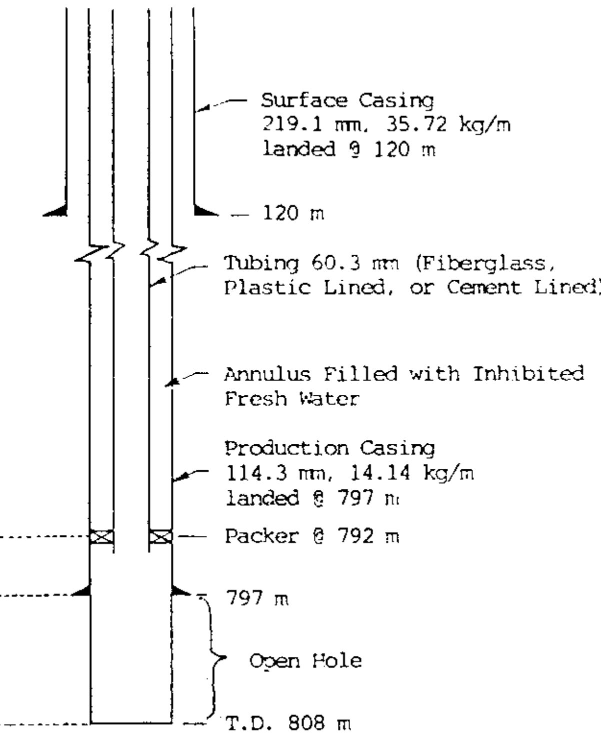
Attachment

DOUBLE REGISTERED

ATTACHMENT IX

Wellbore Cross Section and Method of Completion for Proposed W.I.W.
at Daly 9 A 28-9-29 WPM

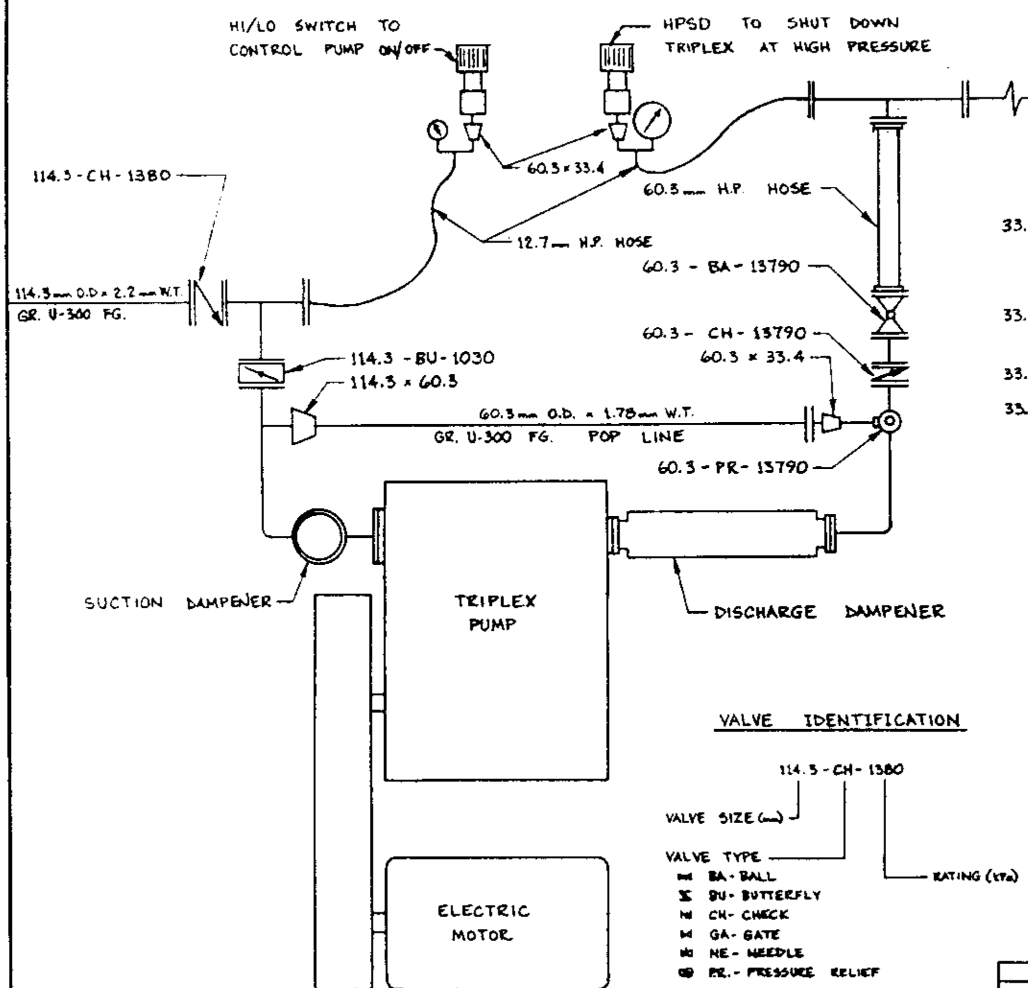


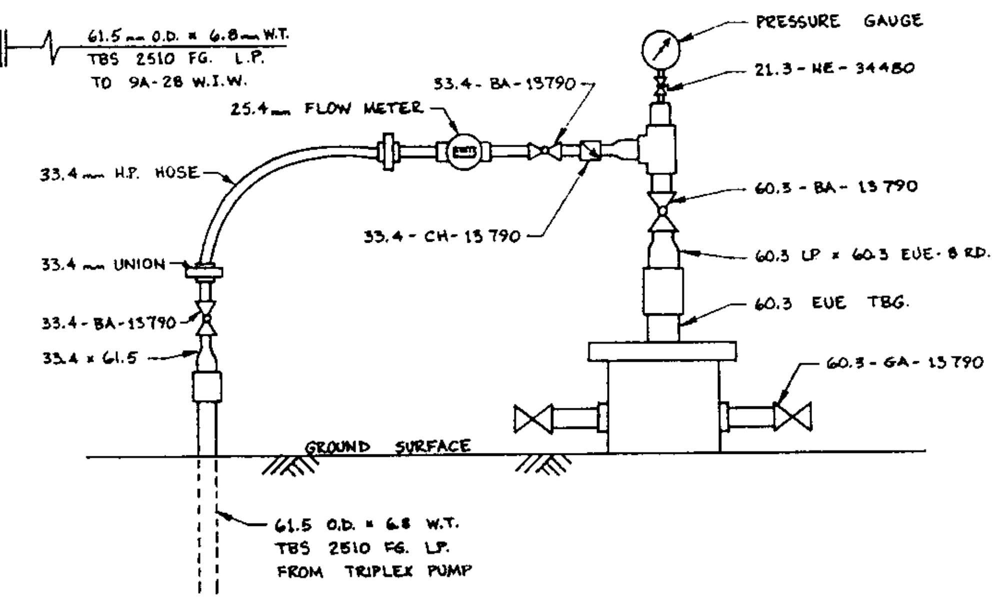


Note: The depths shown above are based on a geological cross section similar to Daly 12-27-9-29 WPM.

The open hole interval would be sand fraced with 10 tonnes 20/40 sand in gelled water.

ATTACHMENT X





NOTES

1. TRIPLEX PUMP WILL BE LOCATED AT 9-28-9-29 BATTERY SITE.
2. PIPING ON SUCTION SIDE OF TRIPLEX WILL BE 114.3 mm FIBERGLASS. PIPING ON DISCHARGE SIDE OF TRIPLEX WILL BE 60.3 mm O.D SCH.40 GR. 290 L.P., EITHER CEMENT OR PLASTIC LINED. ALL FLANGES ON DISCHARGE LINE WILL BE 900# ANSI.
3. ALL VALVES AND FITTINGS USED TO TIE IN THE W.I.W. WILL BE EITHER S.S. OR PLASTIC COATED TO REDUCE CORROSION PROBLEMS.
4. TRANSFER PUMP AT SW TANK AT 9-28 BTY WILL CHARGE SUCTION LINE TO TRIPLEX.

REVISION	BY	DATE	CHECKED
REVISIONS			

DRAWN W.G.R.	DATE 90-01-16	RIDEAU PETROLEUMS LTD.
CHECKED	DATE	PROPOSED CONFIGURATION OF PIPING FOR INJECTION BOTH AT THE PUMPING FACILITY AND AT THE WELL
ENG. W.G.R.	DATE 90-01-16	
APPROVED	DATE	SCALE: NTS / DWG. Nº DWI-51 / REV.

ATTACHMENT XI

BULLETIN OF CANADIAN PETROLEUM GEOLOGY
VOL. 34, NO. 3 (SEPT. 1986), P. 364-378

THE STRESS REGIME OF THE WESTERN CANADIAN BASIN AND IMPLICATIONS FOR HYDROCARBON PRODUCTION

J.S. BELL[1] AND E.A. BABCOCK[2]

ABSTRACT

In the Western Canadian Basin, overcoring measurements, hydraulic fractures, bed-slip movements and wellbore breakouts suggest a contemporary stress regime where from surface to about 350 m depth $S_{Hmax}>S_{Hmin}>S_v$, from about 350 m to about 2500 m depth $S_{Hmax}>S_v>S_{Hmin}$, and below about 2500 m $S_v>S_{Hmax}>S_{Hmin}$. S_{Hmax} appears to be oriented NE-SW, approximately perpendicular to the strike of Rocky Mountain thrust faults, except over the Peace River Arch and other basement uplifts that appear to refract the stress trajectories.

Hydraulic fractures will propagate along planes normal to the least principal stress. Thus, above about 350 m such fractures will be horizontal, and below that depth they will be vertical and oriented parallel to S_{Hmax}. Knowledge of the stress configuration will assist directional drilling and planning of waterflood well configurations. This knowledge is also essential for planning multifractured inclined wells, such as might economically drain Deep Basin tight gas sands. Anisotropic horizontal principal stresses may have affected the Western Canadian Basin since the onset of the Laramide orogeny and induced non-uniform horizontal permeability fabrics in Mesozoic sandstones.

The Western Canadian Basin is part of a widespread North American midcontinent stress province that exhibits a common orientation of compressive stresses. It is speculated that this stress regime is largely caused by NE-directed drag exerted on the base of the lithosphere by a mantle convection cell which upwells beneath western North America.

RÉGIME DE TENSION DU BASSIN SÉDIMENTAIRE DE L'OUEST CANADIEN, APPLICATION À LA PRODUCTION D'HYDROCARBURES

RÉSUMÉ

Dans le bassin sédimentaire de l'ouest canadien, des mesures de surcarottages de forages, des fractures hydrauliques, des plans de glissement et des fracturations/écroulements de puits suggèrent un régime de tension où $S_{Hmax}>S_{Hmin}>S_v$ de la surface à 350 m de profondeur, $S_{Hmax}>S_v>S_{Hmin}$ de 350 m à 2500 m de profondeur et $S_v>S_{Hmax}>S_{Hmin}$ en-dessous de 2500 m de profondeur. S_{Hmax} aurait une orientation nord-est/sud-ouest, à peu près perpendiculaire à la trace des chevauchements des Montagnes Rocheuses, sauf au-dessus du Peace River Arch et d'autres soulèvements de socle qui semblent réfracter les trajectoires de tension.

Les fractures hydrauliques se propagent le long des plans perpendiculaires à la composante minimale de tension. De telles fractures seront ainsi horizontales au-dessus de 350 m de profondeur, et verticales parallèles à S_{Hmax} en-dessous. La connaissance des configurations de régimes de tension faciliterait les forages orientés ainsi que la planification des forages d'injection. Ces données sont aussi essentielles pour planifier les puits inclinés avec fractures à orientations multiples tels qu'ils puissent drainer économiquement les grès peu perméables du Deep Basin. Le bassin sédimentaire de l'ouest canadien aurait été soumis à des tensions à composante principale horizontale et anisotropique depuis le début de l'orogénèse laramienne; ceci aurait produit un régime à perméabilité horizontale très peu uniforme au sein des grès mésozoïques.

Le bassin sédimentaire de l'ouest canadien fait partie d'une province au centre du continent nord-américain ayant une composante de compression commune. Le régime de tension serait causé, en majeure partie, par une cellule de convection du manteau remontant en-dessous de l'Amérique du Nord et traînant la base de la lithosphère vers le nord-est.

Traduction: André Zolnai et Jean Pelletier

INTRODUCTION

The purpose of this paper is to summarize and interpret all available information on the present-day state of stress in the Western Canadian Basin, and to interpret the implications of the stress regime for hydrocarbon production.

Stress magnitudes have been measured by overcoring and hydraulic fracturing. Principal stress directions have been determined from overcoring, induced-fracture orientations, wellbore breakouts, stress and strain gauge grids and bed slips in recent excavations. Horizontal stress anisotropy is inferred from the presence of breakouts.

By far the largest body of data is provided by wellbore breakouts, and this paper reports analyses from 154 wells. Mean breakout azimuths from 94 of these wells have been

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During the some eight years of their research, the authors have received prints of uncomputed dipmeter logs from many oil companies and had invaluable discussions with J.W. Cox, M.B. Dusseault, C.K. Fordjor, D.I. Gough, J.M. Gronseth, K.Y. Lo, and R.E. Wyman. A.J. Deal, C. Lambert, S. Leung and A. Podrouzek assisted in data collection and reduction. J.S. Bell is grateful for encouragement and support from B.P. Canada Resources Ltd. and the Geological Survey of Canada. E.A. Babcock's research has been supported by the Natural Science and Engineering Research Council of Canada. The manuscript was typed by Nelly Koziel; G.L. Cook drafted the figures; and the text has benefited considerably from the suggestions of J.M. Dixon, D.I. Gough, A.C. Grant, J. Kramers and G. Stockmal.

published previously (Babcock, 1978; Gough and Bell, 1981; Fordjor and others, 1983), but logs for each of these wells have been reviewed for this study and, in some cases, the results have been revised (see Appendix).

Analyses of 60 additional wells are also included, extending coverage into the Rocky Mountain Foothills, southeastern Alberta, and Saskatchewan.

Stress Magnitude

The stress field at a point can be represented by three principal stresses (Jaeger and Cook, 1976), which are identified in this paper as σ_1, σ_2, and σ_3 for the maximum, intermediate, and minimum principal compressive stresses, respectively. One of the principal stresses is approximately vertical and is designated here S_v. The greater and lesser horizontal principal stresses are labelled S_{Hmax} and S_{Hmin}.

At the present time, there is not a large amount of published information on *in situ* stress magnitudes in western Canada. Most of the measurements have been made either at shallow depths in tar-sand units or at depths of 2 km to 3 km in Mesozoic sandstones and shales of the Deep Basin. No measurements in carbonate sequences have been reported.

Table 1 lists published stress magnitude measurements; their locations are shown in Figure 1. In Figure 2, the inferred principal stress magnitudes are plotted against depth. This is a somewhat arbitrary approach because it groups data from several widely separated areas where the stress profiles may differ. However, it does argue for an anistropic stress regime in the Western Canadian Basin.

The ratio of the greater horizontal principal stress to the lesser appears to be of the order of 1.3 to 1.6 (Table 1). Except at shallow depths, as at Wabasca in north central Alberta (Fig. 1), S_{Hmin} appears to be the least principal stress, provided the vertical stress is lithostatic.

The stress magnitudes reported by Kaiser and others (1982) for the Kipp Mine in southern Alberta are based on direct measurements by means of multipoint extensometers and borehole stress-change gauges, so that S_{Hmax} and S_{Hmin} were measured independently. The principal stress values reported by Holzhausen and others (1980), Imperial Oil (1978), Settari and Raisbeck (1978), Wyman and others (1980), Kry and Gronseth (1982) and McLennan and others (1982) are derived from hydraulic-fracturing results. With appropriate interpretation, the instantaneous shut-in pressure will be equal to the lesser horizontal principal stress (Gronseth and Kry, 1983). The greater horizontal principal stress can be estimated from the relationship:

$$S_{Hmax} = 3S_{Hmin} - P_r - P_o \quad (1)$$

where P_r is the reopening pressure and P_o is the pore pressure in the rock (Bredehoeft and others, 1976). Wyman and others (1980) described massive hydraulic fracturing of the Cretaceous Fahler sandstone between depths of 2021 m and 2066 m in the Canhunter Texcan 11-12-71-13W6 well. They stated that the mean gradient for fracture propagation was 19.7 KPa/m, which is equivalent to between 39.7 and 40.7 MPa over the fractured interval. Reopening of fractures occurred at pressures exceeding 42.1 MPa, and the pore pressure in the sandstone was 15.2 MPa. If the fracture propagation pressure is equated to the lesser horizontal principal stress S_{Hmin}, equation (1) yields S_{Hmax} values in the 61.8 to 64.8 MPa range. These values are listed in Table 1, together with a vertical stress estimate based on the lithostatic stress (the load exerted by a column of rock plus pore fluids of mean density 2500 kg/m^3).

As can be seen, the picture of stress magnitudes in the Western Canadian Basin is far from complete at the present time. The capability of different rocks to transmit stress laterally is known to vary, and this is vividly illustrated by Kry and Gronseth's (1982) S_{Hmin} measurements of 30 MPa and 36 MPa in, respectively, shale and sandstone sequences that were separated vertically by only 28 m at locality 8 (Table 1, Fig. 2). True stress profiles are not likely to exhibit uniform increases with depth (Rosepiler, 1979), although the widespread reference to "fracture gradients" by petroleum engineers might suggest otherwise. In practice, fracture gradients give a useful indication of the average change of S_{Hmin} with depth in a basin, and information of this type for many oil and gas fields in the Western Canadian Basin is known to company production engineers. Figures ranging between 0.7 psi/ft (15.8 KPa/m) and 0.9 psi/ft (20.4 KPa/m) are used; Wyman and others (1980) report a fracture gradient of 0.87 psi/ft (19.7 KPa/m) for the Deep Basin area.

Indications of relative principal stress magnitudes at shallow depths in central and eastern Alberta are given by induced-fracture orientations at heavy oil and pilot plants (Table 2). Above approximately 350 m, induced fractures are horizontal, which implies that σ_3, the least principal stress, is vertical. Below that depth, the vertical induced fractures imply that σ_3 is horizontal.

This information suggests the following stress magnitude model. From the surface to depths of the order of 350 m, σ_1 and σ_2 are probably horizontal and σ_3 vertical. Below this, to depths of approximately 2500 m, σ_1 and σ_3 are horizontal and σ_2 vertical. At greater depths, σ_1 may become vertical; but it should be noted that this interpretation is based on S_{Hmax} values which are inferred, not measured, and on the assumption that the vertical stress, S_v, is equivalent to the lithostatic load. Hence, the stress field appears to be that associated with strike-slip faulting in the top 2500 m, but may be of normal faulting type at greater depths.

Principal Stress Directions

In this paper it is assumed that one principal stress is vertical, or nearly vertical, and oriented normal to the

Loc. No.	Depth	Location	Rock Type	S_{Hmax}	S_{Hmin} (In MPa)	S_v	S_{Hmax}/S_{Hmin}	Method	Source
1	152 m	Kipp Mine	Shale/siltstone	4.25±0.6	~3.0	3.6	1.4	Overcoring	Kaiser and others, 1982
	180 m	Kipp Mine	Shale/siltstone	5.0	3.3	4.2	1.5	Overcoring	Kaiser and others, 1982
2	240 m	Wabasca	Poorly consolidated sandstone		6.4-7.7	5.8-6.1		Hydraulic fracture	Settari and Raisbeck, 1978
3	317 m	Gregoire Lake	Poorly consolidated sandstone		5.6	7.0		Hydraulic fracture	Holzhausen and others, 1980
4	417 m	Cold Lake	Poorly consolidated sandstone		9.8	10.4		Hydraulic fracture	Settari and Raisbeck, 1978
	420 m	Cold Lake	Poorly consolidated sandstone		7.9-9.1	11.1-12.1			
5	457 m	Cold Lake	Poorly consolidated sandstone		9.0	11.25		Hydraulic fracture	Imperial Oil, 1978
6	2021-2066 m	11-12-71-13W6 well	Deep Basin sandstone	61.8-64.8	39.7-40.7	50.4-51.7	1.6	Hydraulic fracture	Inferred from Wyman, Holditch and Randolph, 1980
7	2073 m	c-16-I 93-P-1 well	Sandstone	63-71	40.7	50.2	1.6	Hydraulic fracture	Kry and Gronseth, 1982
	2095 m	c-16-I 93-P-1 well	Sandstone	51-57	34.5	52.7	1.6		
	2128 m	c-16-I 93-P-1 well	Sandstone	61-63	38.6	53.3	1.6		
	2149 m	c-16-I 93-P-1 well	Sandstone	65-72	42.3	53.8	1.6		
	2165 m	c-16-I 93-P-1 well	Sandstone/shale	62-65	39.0	54.3	1.6		
8	2213 m	10-16-69-11W6 well	Shale	40	30		1.3	Hydraulic fracture	Kry and Gronseth, 1982
	2241 m	10-16-69-11W6 well	Sandstone	51	36		1.4		
7	2269 m	c-16-I 93-P-1 well	Sandstone/shale	62-63	45.1	66.7	1.4	Hydraulic fracture	Kry and Gronseth, 1982
	2679 m	c-16-I 93-P-1 well	Sandstone/shale	60-77	44.3	67.0	1.5		
	2699 m	c-16-I 93-P-1 well	Sandstone		45.2	67.5			
	2717 m	c-16-I 93-P-1 well	Shale	59-71	44.0	68.0	1.5		
	2740 m	c-16-I 93-P-1 well	Shale		46.2	68.5			
	2750 m	c-16-I 93-P-1 well	Shale		45.1	68.8			
	2765 m	c-16-I 93-P-1 well	Sandstone/shale		46.6	69.1			
9	2992 m	1-12-35-7W5 well	Calcareous siltstone		60.0	74.8		Hydraulic fracture	McLennan and others, 1982
	2996-3009 m	1-12-35-7W5 well	Sandstone/siltstone		61.0	75.1			

Table 1. Stress-magnitude measurements in the Western Canadian Basin.

mean topographic surface. Stress measurements from various parts of the world support this assumption (McGarr and Gay, 1978).

In contrast to the limited availability of stress magnitude measurements, there are numerous indications of the orientations of the principal horizontal stresses in the Western Canadian Basin. Table 3 lists S_{Hmax} asimuths derived from overcoring measurements, induced fractures and surficial stress-relief phenomena. The locations of these stress-oriented indications and their azimuths are shown in Figure 1.

Overcoring, Induced Fractures and Stress-Relief Features

Around Exshaw and in the Kananaskis Valley, Bell (1985) reported updip bed slip in recently excavated road cuts and concluded that this movement represented surficial stress relief in the S_{Hmax} direction. Nearby, in the Wilson Mine at Canmore, Grant (1970) reported S_{Hmax} determinations from two overcovered boreholes drilled in the mine roof. The more reliable readings suggest an approximately ENE orientation for S_{Hmax}. Overcoring measurements at the Kipp Mine gave similar S_{Hmax} azimuths (Kaiser and others, 1982).

McLeod (1977) reported fluid communication between NE-SW-aligned wells during water flooding of "J" lease in the Pembina oil field (Location 13, Figs. 1 and 7). Gough and Bell (1981) interpreted this behaviour as resulting from induced vertical hydraulic fracturing of the Cardium sandstone normal to S_{Hmin} and they therefore inferred that S_{Hmax} was oriented NE-SW.

Hassan (1982) analyzed the results of fracture stimulation in Amoco's "F" lease in the same field and noted that where injection and production wells lay on a NE-SW trend, fracturing caused a 135 percent increase in the water-to-oil ratio (Location 14, Figs. 1 and 7). In the

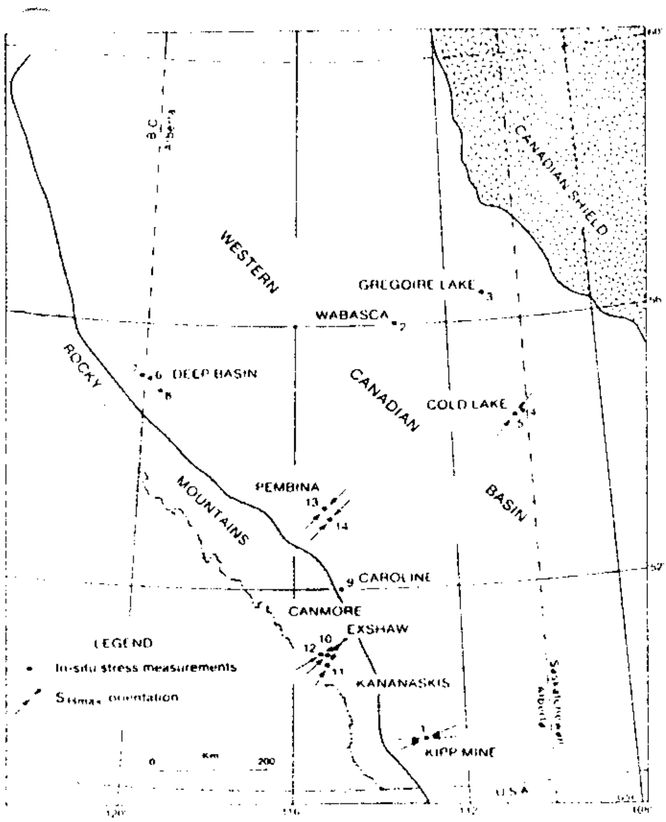

Fig. 1. Locations of *in situ* stress magnitude measurements and orientations in the Western Canadian Basin and Rocky Mountains. Depths, rock types and stress-magnitude values for numbered locations are listed in Table 1.

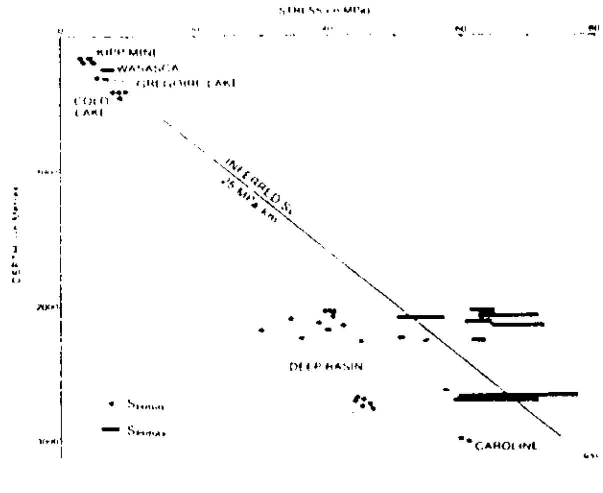

Fig. 2. Stress-magnitude measurements made in the Western Canadian Basin plotted against burial depth. The values are listed in Table 1.

nearby Violet Grove "AB" lease, where injection and production wells are offset along a N-S axis, post-fracture increases in the water-to-oil ratio averaged only 19 percent. Again, this flow pattern is consistent with NE-SW-oriented vertical hydraulic fractures being induced along the S_{Hmax} azimuth (Hubbert and Willis, 1957).

A similar stress configuration appears to exist at Cold Lake, where Imperial Oil (1978) report propagating fractures between wells at depths of approximately 450 m. Imperial Oil noted that the observed fluid movement at Cold Lake during steam injection was mainly in a preferred NE-SW direction, and their planned well configurations in several proposed pilot plants suggest that the induced fractures were expected to be oriented between 030° and 045°. This implies that, in the Cold Lake area, S_{Hmax} is also oriented approximately NE-SW.

These measurements and observations favour a generally NE-SW orientation for S_{Hmax} over much of the Western Canadian Basin, but they do not provide a focussed picture of the principal stress configuration. Fortunately, some details can be filled in by breakout azimuths.

Breakouts

The walls of boreholes spall so as to produce intervals with noncircular cross sections which have long axes that share a common mean orientation (Cox, 1970; Babcock, 1978). Such spalled intervals are defined as breakouts in cases where the shorter diameter of the borehole corresponds to the drill-bit diameter. Breakouts exhibiting well-grouped azimuths have been reported in the Yukon and Northwest Territories, the Canadian Arctic, Western Canada, Quebec and the Maritimes, various areas in the United States, Europe, Africa, Asia, Australia and the East Pacific Ocean (Cox, 1983; Bell and Gough, 1983; Newmark and others, 1984). In all areas where reliable *in situ* stress measurements are available, the mean breakout axes can be shown to be parallel to S_{Hmin} and therefore perpendicular to S_{Hmax}. This relationship is well established empirically and strongly supported by theory (Bell and Gough, 1979; Gough and Bell, 1982; Zoback and

Company — Location	Depth	Fracture Type	Fracture Pressure	Data Source
Shell Canada — Athabasca	45.7 m	Horizontal	Not reported	Nicholls and Luhning, 1977
Mobil Canada — Athabasca	115.8 m	Horizontal	Not reported	Nicholls and Luhning, 1977
AOSTRA/Numac — Athabasca	above 152.4 m	Horizontal	Not reported	Nicholls and Luhning, 1977
Amoco Canada — Athabasca	183-274 m	Horizontal	Not reported	Nicholls and Luhning, 1977
Gulf Canada — Wabasca	243.8 m	Horizontal	6.4 - 7.7 MPa	Nicholls and Luhning, 1977 Settari and Raisbeck, 1978
Gulf Canada — Gregoire Lake	317 m	Vertical/ horizontal	5.6 - 9.3 MPa	Holzhausen and others, 1980
Shell Canada — Athabasca	330 m	Horizontal	Not reported	Doscher and others, 1963
Atlantic Richfield — Athabasca	365.8 m	Vertical	Not reported	Nicholls and Luhning, 1977
Esso Resources — Cold Lake	457.2 m	Vertical NE/SW	9.0 MPa	Imperial Oil Ltd., 1978
AOSTRA/Shell — Peace River	548.6 m	Not reported	above 7.6 MPa	Nicholls and Luhning, 1977

Table 2. Reported fractures in heavy oil sand *in situ* pilot plants.

Loc. No.	Depth	Location	S_{Hmax}	Indicator	Data Source
10	Surface	Exshaw	049°	Updip bed slip	Bell (in press)
11	Surface	Kananaskis Valley	032°	Updip bed slip	Bell (in press)
1	152 m	Kipp Mine	≈ 090°	Overcoring	Kaiser and others, 1982
1	180 m	Kipp Mine	070° ± 20°	Overcoring	Kaiser and others, 1982
12	240 m	Canmore	055° – 066°	Overcoring	Grant, 1970
5	457 m	Cold Lake	030° – 045°	Induced fracture	Grant, 1970
13	1615 m	Pembina Oil Field "J" lease	≈ 045°	Inferred induced fractures	McLeod, 1977
14	1675 m	Pembina Oil Field "F" lease	≈ 045°	Inferred induced fractures	Hassan, 1982

Table 3. Principal horizontal stress orientations indicated by overcoring, induced fractures, and surficial stress-relief phenomena.

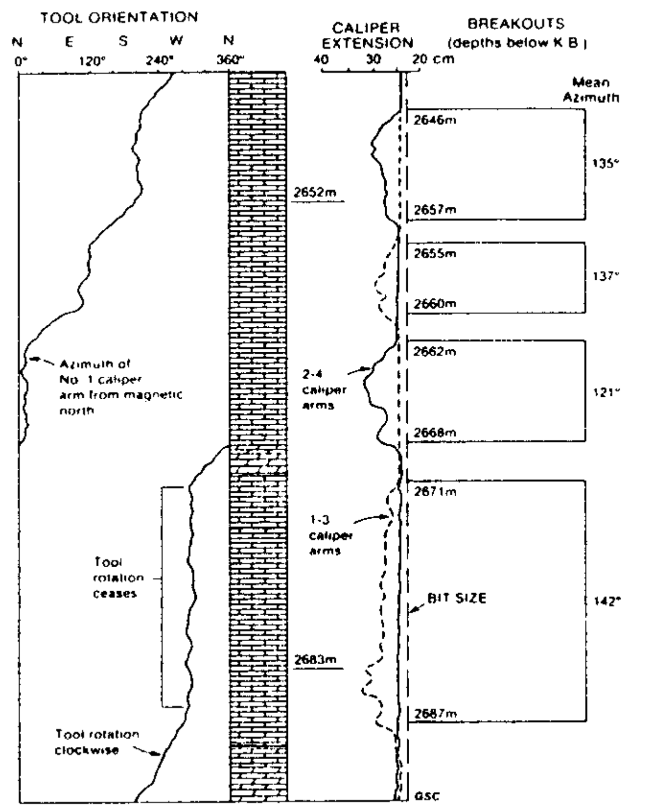

Fig. 3. Dipmeter record of four breakouts in the Nairb Petroleums Pembina 1-9-50-12W5 well as documented on the unprocessed log. The breakouts are characterized by differential extension of the two pairs of caliper arms and concurrent nonrotation of the dipmeter tool while two caliper arms are locked into the elongated, pseudo-elliptical breakout zone. The azimuths of the long axes of breakouts are calculated from the tool-orientation record after correcting for the magnetic declination at the well site.

others, 1985). It is now clear that breakouts will reliably indicate the orientations of the principal horizontal stresses affecting the borehole in which they have been measured.

Breakouts in the Western Canadian Basin

Because of the width of the spalled sections of borehole walls that have broken out, breakouts can be felt by the hydraulically extendible pads of four-arm dipmeter tools. These tools are generally raised up wells at approximately 10 m/minute, and the cable is torqued so as to cause the tool to rotate clockwise. This rotation ceases if one or both pads of a pair are trapped in a breakout. Breakouts are recognized on the uncomputed dipmeter log from the records of the azimuth of the No. 1 caliper and the extensions of calipers 1-3 and 2-4, as described below and, in more detail, by Babcock (1978), Bell and Gough (1981, 1983), and Cox (1983).

Figure 3 illustrates an uncomputed four-arm dipmeter record. The curves on the far right of the log record the diameters measured by the two pairs of opposed calipers, with diameter increasing to the left. Tool orientation is indicated on the left side of the log, where the solid curve records the azimuth of caliper 1 with respect to magnetic north. A typical breakout zone is present from 2687 m to 2671 m. Over this interval, opposed calipers 2 and 4 record a hole width of approximately 24 cm, equivalent to the diameter of the drill bit (22.7 cm). Calipers 1 and 2 record a varying borehole diameter which generally ranges between 28.5 cm and 31 cm. The curve recording the compass azimuth of caliper 1 near the base of the figure shows that the tool had been rotating clockwise as it was drawn up the well. At 2687 m, tool rotation ceased, calipers 1 and 3 became fixed within the elongated breakout, and the dipmeter was drawn up the borehole with caliper 1 oriented at an average azimuth of 299°. Adding the magnetic declination (23°) we obtain an azimuth of 322°, or 142°, for the breakout. Like other breakouts of any length, this one shows variations of azimuth of 10 to 20 degrees. Some of this is presumably a result of variation in the fit of the dipmeter pads into the fractured borehole wall, but some probably reflects true variation in the azimuth of the long diameter. Borehole televiewer records of breakouts document a similar vertical variation in azimuth over breakout zones (Plumb and Hickman, 1985).

All the breakouts referred to in this paper were identified and oriented in this manner using the following criteria:

1. The log must indicate tool rotation above and below the breakout.

2. Rotation must cease over the breakout interval (No. 1 Caliper arm must record a roughly constant azimuth).

3. One pair of calipers must record the original, or slightly enlarged, drilled diameter of the borehole, and the other a larger diameter. Within each breakout, the azimuth of the larger diameter of the hole was measured at depth intervals of 61 cm (2 ft) or 1 m. These azimuths were combined with equal weights to give a mean azimuth with standard deviation for each well by means of the statistical

methods described by Mardia (1972) for nonpolar directional data.

Many of the wells studied were logged only in their deeper parts by four-arm dipmeter tools, but a large number were logged over all but the shallowest sections. Breakouts were identified in all lithologies; however, they were least abundant in Mesozoic sandstones and particularly well-developed in Paleozoic carbonates. The total thickness of all the breakouts recognized in a single well ranged from 2 m to 2086.9 m (Appendix). The shallowest breakout measured extended upward to a level of 112.5 m KB, whereas the base of the deepest breakout was at a depth of 5485.2 m KB. (Appendix). Forty-four wells exhibited significantly consistent breakout orientations. In these wells, the total thickness of breakouts exceeded 100 m, and their mean azimuths exhibited standard deviations of less than 10°.

Fordjor and others (1983) found no evidence of any significant vertical variation of breakout azimuth in wells in which breakout azimuths were measured over depth ranges of 600 m or more. We have not observed this either, although, if basement topography influences stress trajectories (Lloyd and Bell, 1985), denser data grids may enable us ultimately to recognize subtle systematic azimuth changes with depth around areas of significant basement relief. At our resolution, it is reasonable to interpret the breakout azimuths as indicating essentially constant stress geometry at all depths of a well.

Mean breakout azimuths of 154 wells are plotted in Figure 4. Seventeen wells contain a minor population of breakouts with mean azimuths which vary significantly from their major population. In 13 wells this variation is between 70° and 90°, whereas in four wells the minor population azimuth differs from the major by only approximately 30°. As can be seen from Figure 4, the minor population azimuths do not conform to the regional trends established by the major azimuths. It is not obvious what these anomalous breakout orientations mean. They meet the three recognition criteria described above, yet they still may not represent true breakouts. There are hints in some wells that the discordant borehole ellipticity has resulted from mudcake adhering preferentially to an extended broken-out zone (Fig. 5C) and in some cases in intervals where the entire borehole circumference has caved (Fig. 5D). In other words, washouts (Cox, 1983) have been "padded" so as to reduce the borehole diameter along their larger

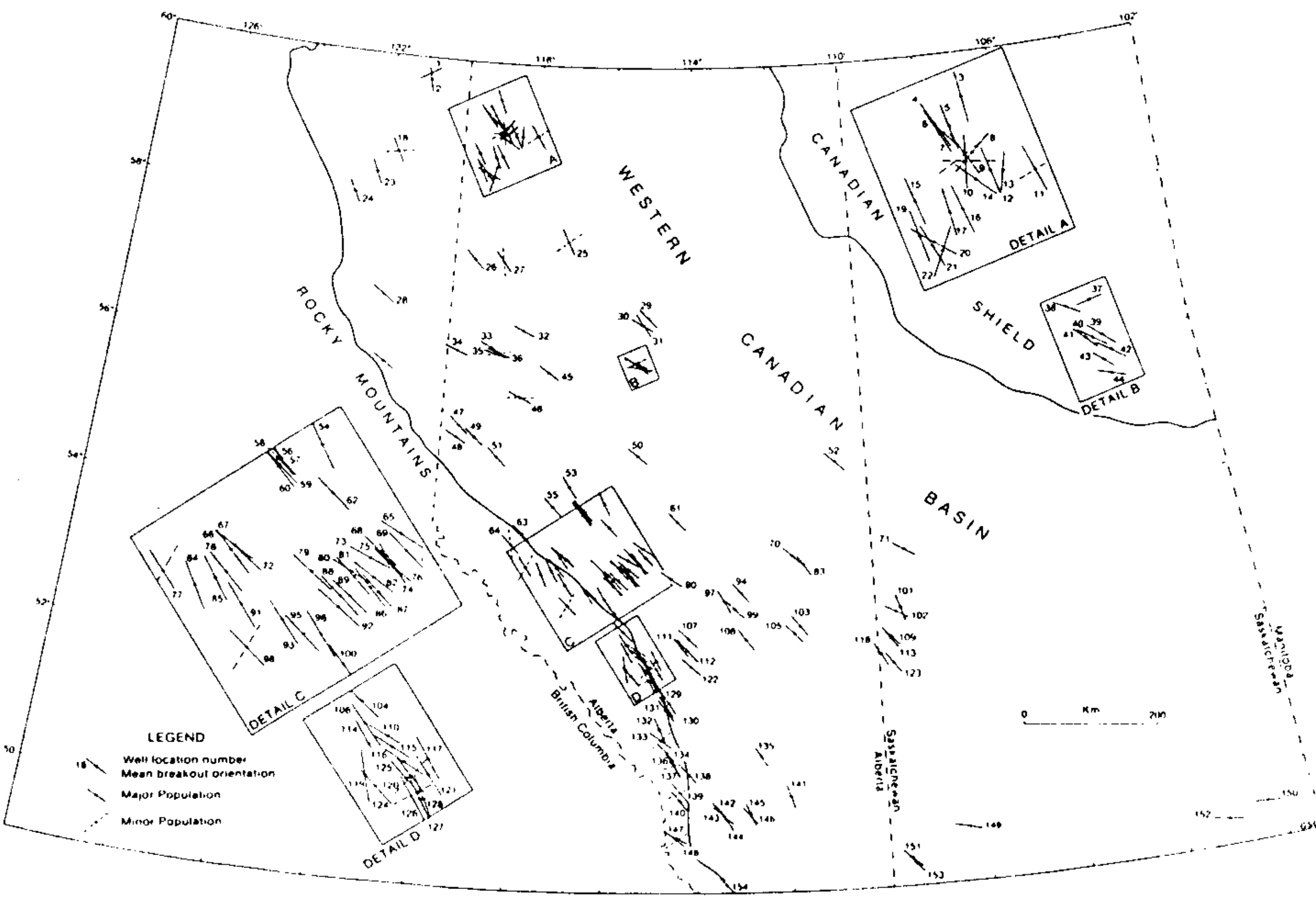

Fig. 4. Mean azimuths of major and minor breakout populations for 154 wells in the Western Canadian Basin and Rocky Mountains. The well-location numbers correspond with the listing in the Appendix containing location data and details of breakout abundance, depth and orientation statistics. Azimuths from wells 149, 150 and 152, which depart from the regional orientation, are based on limited data and may not be reliable.

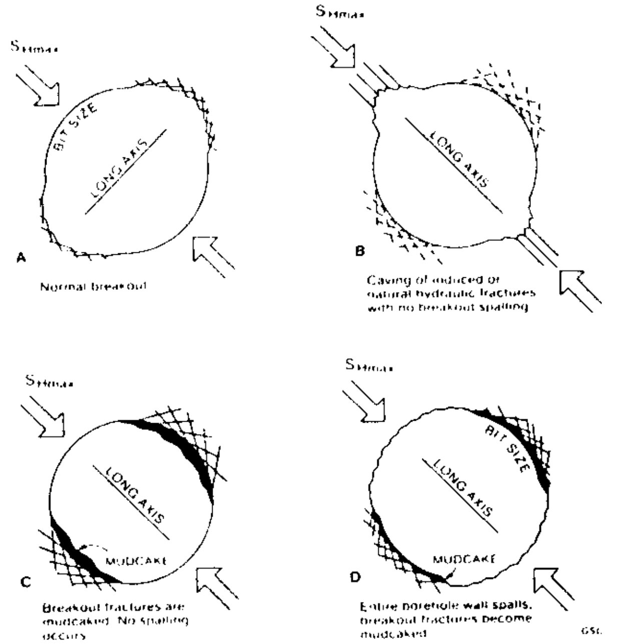

Fig. 5. Possible causes of anomalous breakout orientations discussed in the text.

axis, and so produce wellbore ellipticity normal to the natural breakout direction. An alternative possibility is that high mud pressures during drilling initiated hydraulic fractures locally, which have subsequently caved and extended the borehole because of contributory rock-fabric weaknesses (Fig. 5B).

The majority of the wells analyzed, however, contain only breakouts with common azimuths which delineate a coherent and consistent picture of principal stress axes across the Western Canada Basin in British Columbia, Alberta and Saskatchewan (Fig. 4). The picture that emerges is one in which S_{Hmin} is oriented more or less parallel to the Rocky Mountains, but there are also areas which exhibit departures from this trend. This is brought out more clearly in Figure 6 where the breakout azimuths have been used to construct a horizontal stress trajectory map of the basin. Between latitudes 55° and 57°N, the breakout azimuths, and inferred stress trajectories, show a significant clockwise rotation relative to those south and north of this region. Fordjor and others (1983) suggest that this rotation of the stress tensor could be related to the Peace River Arch. The area of rotated horizontal principal stresses coincides areally with this subsurface basement peninsula (Fig. 6), and the sense of stress rotation is consistent with the stress tensor refraction such a configuration would produce (Lloyd and Bell, 1985). A similar effect may be present in southern Alberta and Saskatchewan, over the Sweetgrass Arch (Fig. 6). There are also a number of local anomalies in the mean breakout azimuths in the cluster of northwestern Alberta wells (Fig. 4, detail A). These may also be related to an unnamed basement high (Porter and others, 1982) in that area, which is outlined in Figure 6. In regional terms, what the mean breakout azimuths appear to be documenting is a stress province in which S_{Hmax} is oriented approximately NE-SW except where this signature is modified by basement topography. This picture is fully compatible with the stress tensor geometry inferred from the overcoring measurements, induced-fracture orientations and stress-relief features discussed previously.

It is valid to ask how accurate the stress trajectory map of the Western Canadian Basis is likely to be. Control points are somewhat spottily distributed, but there is a consistency to the data which is noteworthy. For example, fifteen closely spaced wells in the West Pembina area exhibit very similar mean breakout azimuths in the Devonian carbonate section. They are all oriented approximately NW-SE (Fig. 7). This implies a similar direction for S_{Hmin}; and if this is also the orientation of the least principal stress in the Cardium Formation at depths of 1600 m to 1700 m, the induced-fracture orientations are well accounted for. Another approach to evaluating the reliability of directional data is to plot only the best. Figure 8 portrays only those wells where the breakout intervals total more than 100 m and the mean azimuths exhibit standard deviations of less than 10°. These forty-four wells constitute a coherent data set compatible with the stress trajectory map (Fig. 6) compiled from all the breakout azimuths.

Implications for Hydrocarbon Recovery

A valuable application of knowing the directions and relative magnitudes of the principal stresses at a point in the Earth's crust is that it permits one to predict the orientation of hydraulically induced fractures. These will open in the plane perpendicular to σ_3, the least principal stress (Hubbert and Willis, 1957). At depths below approximately 350 m in the Western Canadian Basin $\sigma_3 = S_{Hmin}$. Hydraulic fractures will, therefore, be vertical and oriented parallel to S_{Hmax}. The stress trajectory map (Fig. 6) is thus a tool for predicting induced-fracture orientations within the area it covers.

Predicting fracture propagation directions can be advantageous in a number of situations. If a well has missed a target such as a pinnacle reef, and the target's location is known, it may prove possible to connect the well to the reservoir by hydraulic fracturing (Fig. 9). This is likely to be a much cheaper option that additional directional drilling. Another possible application, suggested by Hassan (1982), is blowout-well control. Where blowout control involves pumping a heavy slurry down a relief well — if the relief well is so located that predicted hydraulic fractures would intersect the blowout well — there will be a higher chance of establishing communication between the two wellbores.

If the preferred hydraulic-fracture azimuths in an oil or gas field are known, this knowledge can be used to help design the optimum well configuration for development. Negative experience with waterflood-induced fractures within the Cardium Sandstone in the Pembina oil field has shown that oil recovery can be reduced by inappropriate

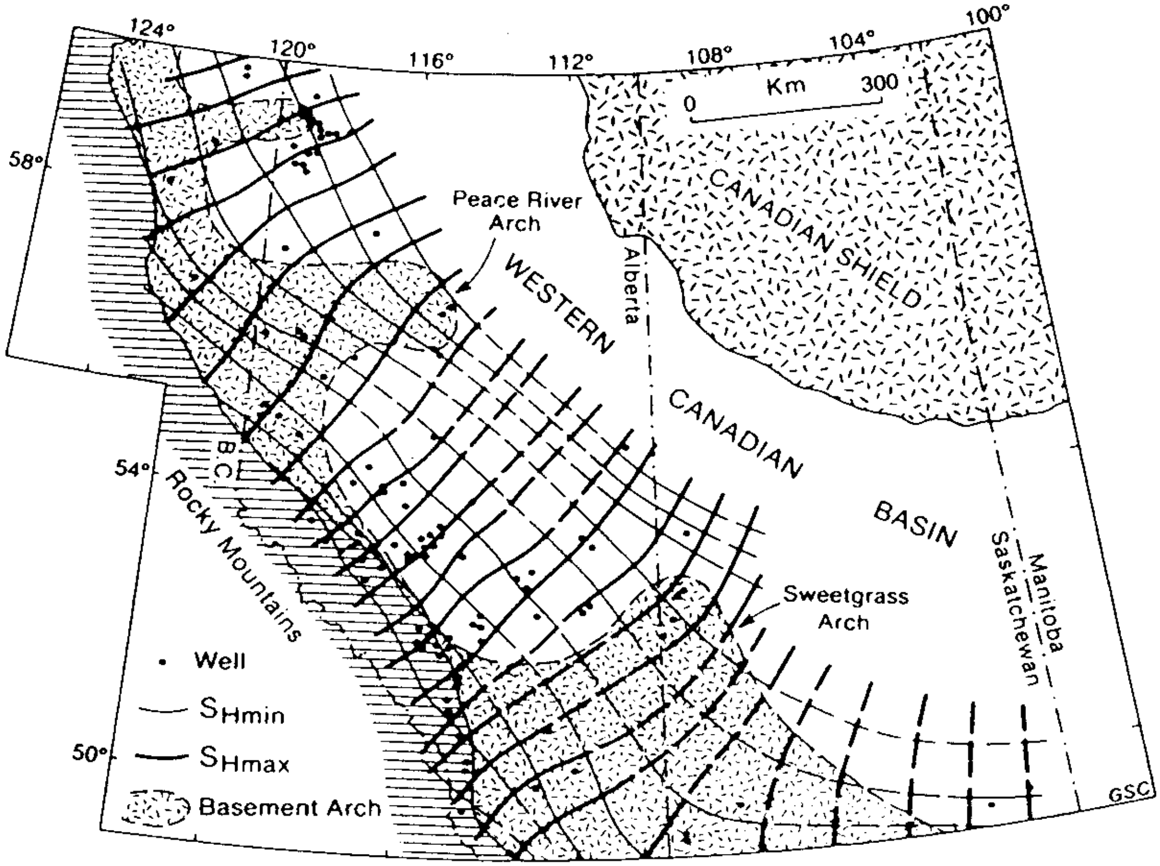

Fig. 6. Possible stress trajectories inferred from breakout orientations in the Western Canadian Basin. Note the deflections of principal horizontal stress directions around basement arches.

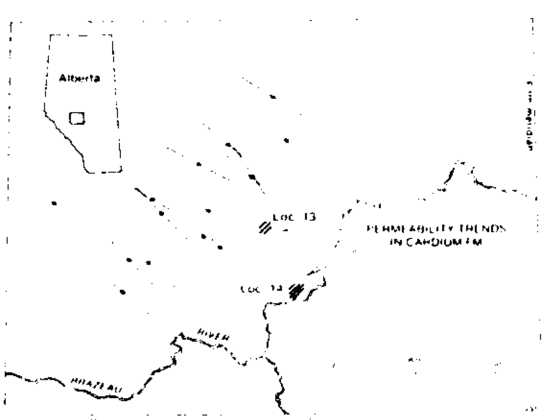

Fig. 7. Consistent NW-SE orientations of the mean breakout azimuths from 15 closely spaced wells in the West Pembina area implying that S_{Hmax} is oriented NE-SW in this area. Inferred hydraulic fractures, expressed as permeability trends in the Cardium Formation sandstone reservoirs, agree with these principal stress directions.

placement of injection and production wells (McLeod, 1977; Hassan, 1982). Figure 10 illustrates an idealized oil field in a reservoir stressed so that hydraulic fractures will be vertical and propagate northeastward and southwestward away from injection wells. Two well configurations are shown. In the "bad" array, injection and production wells along the fracture trend become linked by hydraulic fractures with the result that most of the water flows in one well and out another without sweeping much oil towards other production wells. In the "good" array, injection and production wells are spaced so that hydraulic fractures do not connect wells but distribute the injected water so that it can effectively sweep oil towards many production wells.

The Wattenberg field in the Denver Basin produces, from Muddy "J" Formation, tight gas sands requiring massive hydraulic fracturing. The fractures exhibit a preferred orientation of 340° (Smith and others, 1978), and simulation studies suggest that an optimum fracture length is approximately 1200 m (Roberts, 1981). Field monitoring documents gas drainage into the fractures from axially aligned ellipsoidal zones around them, and the most profitable gas wells are those which are spaced so as to exploit the optimum fracture length and preferred orientation (Smith, 1979).

In areas where induced fractures are consistently oriented and thick pay sections are present, drilling inclined wells and spacing a series of fractures along them (Fig. 11) may prove commercially advantageous. For good results, the inclined well should be directed at a high angle to the preferred fracture plane.

Strubhar and others (1975) describe an experimental well drilled through low-permeability chalk in the Caddo-Pine Island oil field of northwestern Louisiana. The well

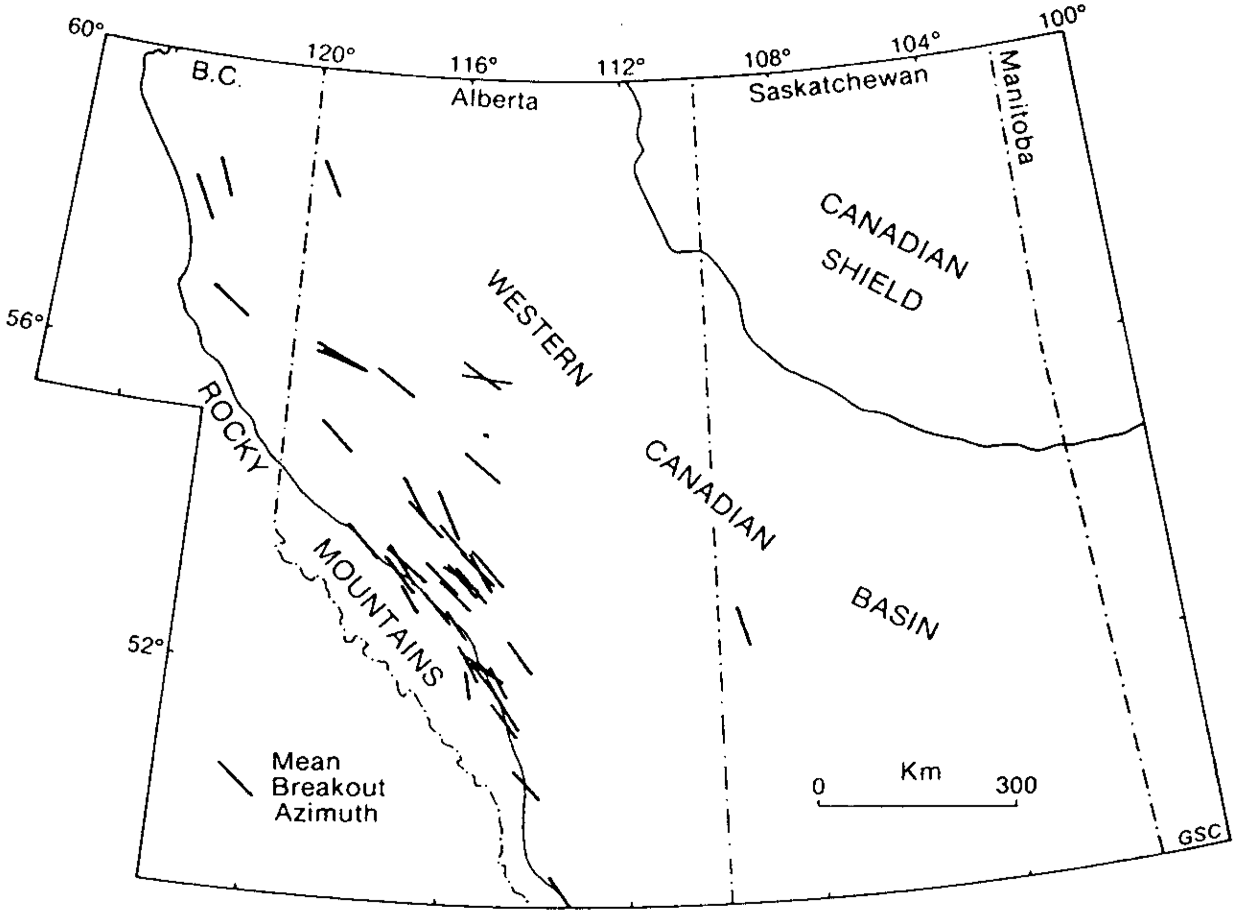

Fig. 8. Mean breakout azimuths of 44 wells containing a large number of consistently oriented breakouts. The total vertical thickness of all breakouts exceeds 100 m per well, and orientation standard deviations are less than 10°. The figure portrays the "best data."

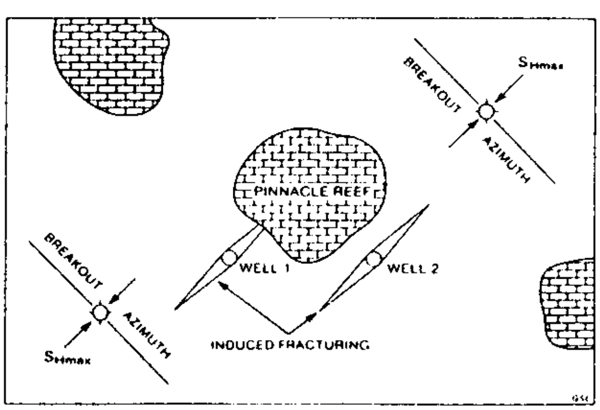

Fig. 9. Prediction of hydraulic-fracture orientation. Horizontal principal stress directions derived from breakouts in nearby wells show that hydraulic fractures propagated from Well 1 could intersect the pinnacle reef target, whereas fractures from Well 2 are likely to miss the reef.

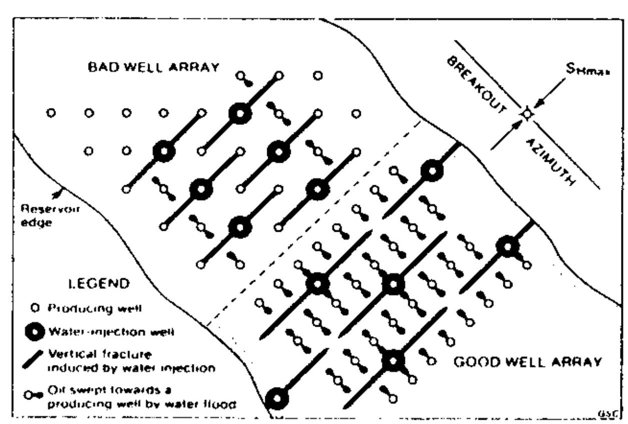

Fig. 10. Well arrays in an idealized oil field where waterflooding promotes hydraulic fracturing. In the "bad" array, little oil is recovered because induced fractures connect water injection wells with intended production wells. In the "good" array, the induced fractures do not connect wells but distribute the injected water so that it drives oil towards many production wells. Breakouts predict fracture orientations.

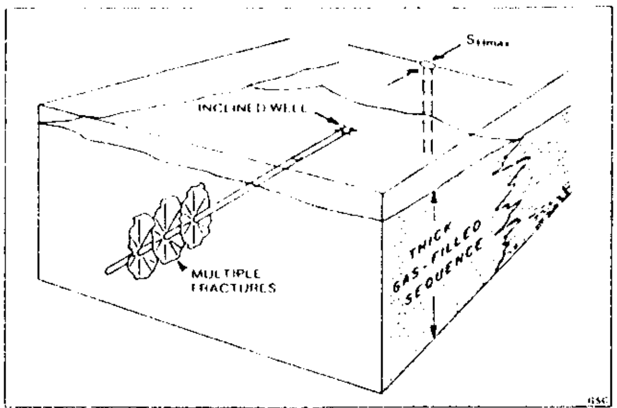

Fig. 11. Schematic diagram showing an inclined well drilled at approximately right angles to S_{Hmax}, from which several spaced fractures have been propagated. This configuration would provide greater reservoir drainage and higher flow rates than could be obtained from a vertical well with a single fracture feeding it. Knowledge of principal stress directions, provided by breakouts, is needed to align such a multifractured inclined well.

was drilled normal to the induced-fracture azimuth at an angle of 52° from the vertical. Four hydraulic fractures were propagated at measured depths of 1540 ft, 1595 ft, 1650 ft and 1700 ft (469 m to 518 m). This multifractured well produced between two and three times as much oil as a conventionally fractured well in the field. The experimental well cost approximately four times as much to drill and complete, but Strubhar and others (1975) believed cost reductions were feasible and that deeper wells could be very cost-effective. In western Canada, much of the 5000-m-thick Mesozoic section of tight, gas-bearing sandstones in the Deep Basin (Masters, 1979) may be profitably produced from multifractured inclined wells.

There are several other implications arising from the anisotropic stress regime in the Western Canadian Basin (Fig. 6). The principal horizontal stress configuration appears to be geometrically related to the overthrust faulting in the Foothills and Rocky Mountains. It is likely that similarly oriented lateral compression was imposed on the basin in early Mesozoic time as the Laramide orogeny evolved. In other words, S_{Hmax} probably has had a generally NE-SW orientation for at least the last 100 million years and maybe longer. Therefore, the sediments in the Western Canadian Basin (of Paleocene age and older) most likely have been subjected to anisotropic horizontal compression for a considerable period; in the case of the Upper Mesozoic sediments this could amount to nearly their entire burial life. One has to ask whether some of these rocks have developed a diagenetic fabric in consequence. To the authors' knowledge, this possibility has not been investigated systematically; however, directional permeability is widely recognized and documented in core analyses performed for company production departments. Uneven solution by pressure cementation of quartz grains could produce anisotropic permeability fabrics in sandstones subjected to unequal lateral compression. In addition, overpressuring in deeply buried sequences could cause natural hydraulic fracturing oriented parallel to S_{Hmax}, which would lead to preferred directions of fluid flow through the affected section. Stylolites, which exhibit preferred orientations in limestones, may also represent a response to anisotropic subsurface stress regimes (Nelson, 1981). From a diagenetic standpoint, mineral transformations that are strongly pressure-dependent may be promoted by S_{Hmax} levels rather than be depth-dependent as heretofore assumed. Clearly, there is much to investigate in documenting how sediments respond over time to high and unequal horizontal stresses.

It is well known that cores recovered from deeply buried rocks expand and fracture on being raised to the surface (Teufel, 1981; Montgomery and Ren, 1983). If these cores have been subjected to unequal horizontal *in situ* stresses, expansion fractures which form will tend to open along vertical planes normal to S_{Hmax}. This possibility should be borne in mind when examining cores, and assessing measurements which apparently diagnose permeability anisotropy in rocks tested under atmospheric conditions.

Implications for Crustal Kinematics

As Fordjor and others (1983) have demonstrated, the stress regime in the Western Canadian Basin is not a local phenomenon. The area lies on the northwestern edge of the Mid-Continent Stress Province (Zoback and Zoback, 1980) in which NE-SW S_{Hmax} azimuths occur in an area bounded by the plains of the United States Mid West, Arkansas, Tennessee, New York State (Zoback and Zoback, 1980), the Canadian Maritimes, the Arctic Islands (Cox, 1983) and the Northwest Territories (Gough and others, 1983). Consistent stress orientation over the whole mid-continent of North America is difficult to ascribe to any cause other than contemporary northeastward traction on the underside of the lithosphere. Other mechanisms are not likely to have imprinted so widespread a stress signature. For example, in the Western Canadian Basin, postglacial uplift might have produced a NE-SW orientation of S_{Hmax} but would have produced a very different orientation in New York State and Ontario. Similarly, pressure exerted on the western Canadian lithosphere by the subducting Juan de Fuca plate might produce the observed compression of the Western Canadian Basin but would not cause the same stress orientation in Arkansas and Missouri (Zoback and Zoback, 1980).

Northeastward traction would arise (1) if the lithospheric plate containing the mid-continent of North America is sliding SW and is experiencing viscous drag from a passive asthenosphere, as suggested by Zoback and Zoback (1980), or (2) if northeastward flow in the underlying mantle is pushing the plate, again by viscous drag (Fordjor and others, 1983). The stress orientations in the Mid-Continent Stress Province alone cannot be used to discriminate between these two possibilities.

To the west of the Mid-Continent Stress Province in the United States of America, Zoback and Zoback (1980) have identified a series of extensional stress provinces in the region between the east front of the United States Rocky Mountains and the Sierra Nevada (Fig. 12). These extensional stress provinces include the Basin and Range, Colorado Plateau and Rio Grande Rift, and are characterized by contemporary normal faulting in stress regimes where σ_1 is vertical. Dixon and Farrar (1980), Farrar and Dixon (1980), and Gough (1984) have pointed out that this region is one of current basaltic vulcanism and high heat flow. In addition, they noted that seismological studies indicate that elastic body-wave velocities are reduced and their amplitudes attenuated in the underlying upper mantle. In the same region, magnetometer arrays have recorded anomalous electrical conductivity so distributed that it correlates positively with heat flow and the seismic low-velocity high-attenuation layer (Gough, 1974). As Farrar and Dixon (1980) and Gough (1984) emphasized, this close association of vulcanism, high heat flow, low seismic velocity and electrical conductivity is most logically accounted for in terms of partial melting in the uppermost mantle and a concurrent upflow of mantle material. The area involved is undergoing extension, as would be expected above an upcurrent in the mantle. Now an extensional stress province of these dimensions (Fig. 12), between the Great Plains and the Sierra Nevada, could not exist in this location if the North American plate were sliding over a passive asthenosphere towards the southwest. Such kinematics would require NE-SW compression to continue westward as far as the Sierra Nevada or even to the San Andreas fault zone. The observed extensional stress regime, with σ_1 vertical, implies vertical pressure from below and points to a mantle upcurrent which bends over towards the northeast to push the North American plate northeastward by viscous drag (Fig. 13). As Houseman (1983) has shown, such viscous drag could be provided by a large aspect ratio convection cell driven by lateral, rather than vertical, temperature differences in the mantle.

In that the postulated region of mantle upflow is likely to have originally formed part of the East Pacific Rise (Dixon and Farrar, 1980; Gough, 1984), the proposed mechanism for plate dynamics is analagous to "ridge-push." Solomon and others (1980) found that much of the reliable intraplate stress orientation data obtained from earthquake mechanisms agreed well with predictions from a model that included ridge push as one of the driving forces of plate tectonics. Recently, Newmark and others (1984) have measured breakout azimuths in the Deep Sea Drilling Program holes drilled in the East Pacific Ocean and obtained principal stress orientations which are also consistent with ridge push by the East Pacific Rise and the Costa Rica Rift.

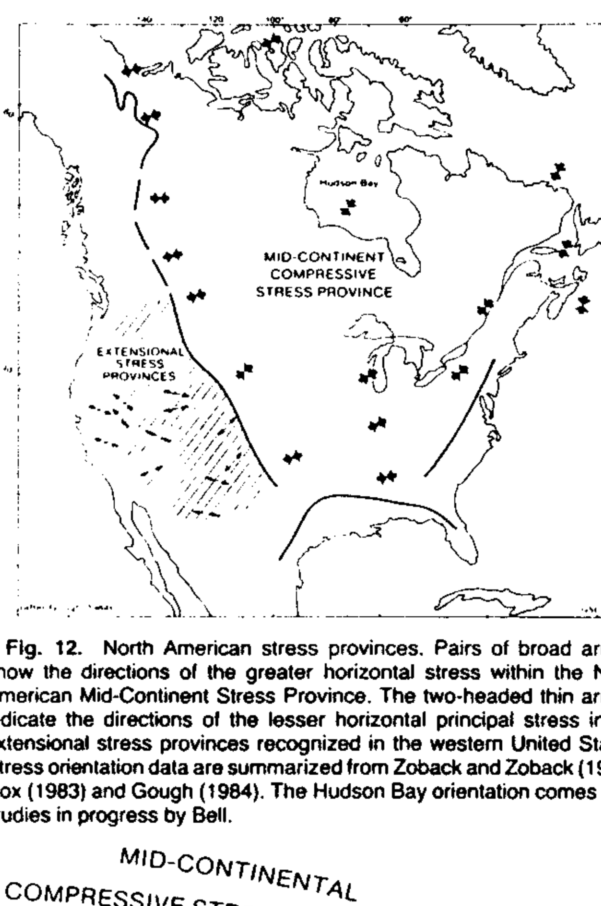

Fig. 12. North American stress provinces. Pairs of broad arrows show the directions of the greater horizontal stress within the North American Mid-Continent Stress Province. The two-headed thin arrows indicate the directions of the lesser horizontal principal stress in the extensional stress provinces recognized in the western United States. Stress orientation data are summarized from Zoback and Zoback (1980), Cox (1983) and Gough (1984). The Hudson Bay orientation comes from studies in progress by Bell.

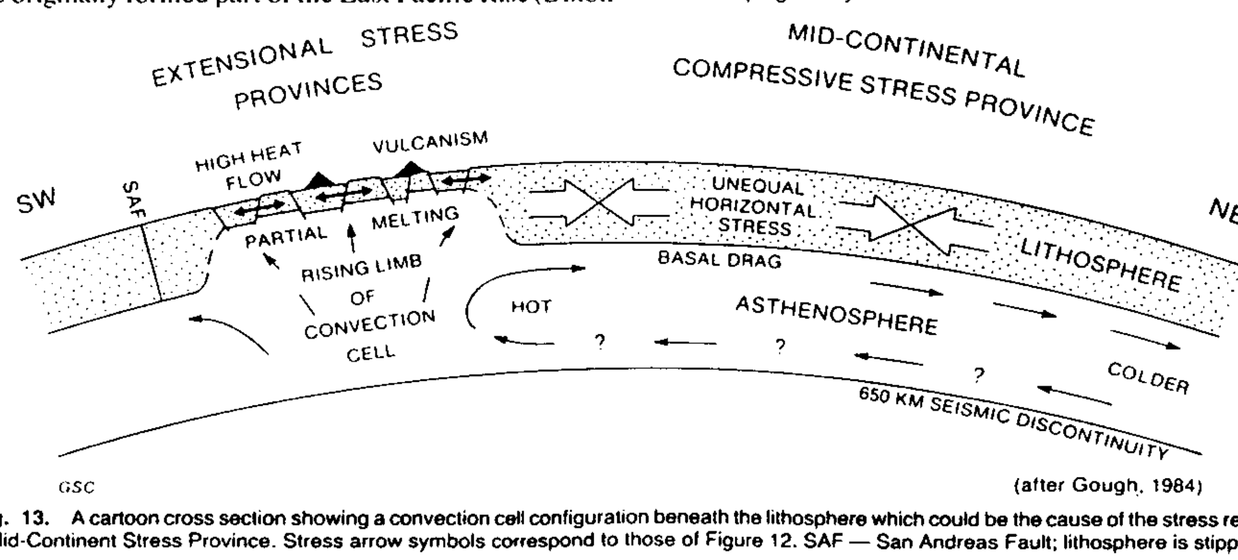

Fig. 13. A cartoon cross section showing a convection cell configuration beneath the lithosphere which could be the cause of the stress regime of the Mid-Continent Stress Province. Stress arrow symbols correspond to those of Figure 12. SAF — San Andreas Fault; lithosphere is stippled.

In summary, it appears probable that the anisotropy in the stress regime of the Western Canadian Basin is largely caused by the mid-American lithosphere's being pushed northeastward by a mantle convection cell which rises beneath western North America.

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ATTACHMENT XII

Fine Tuning A Waterflood

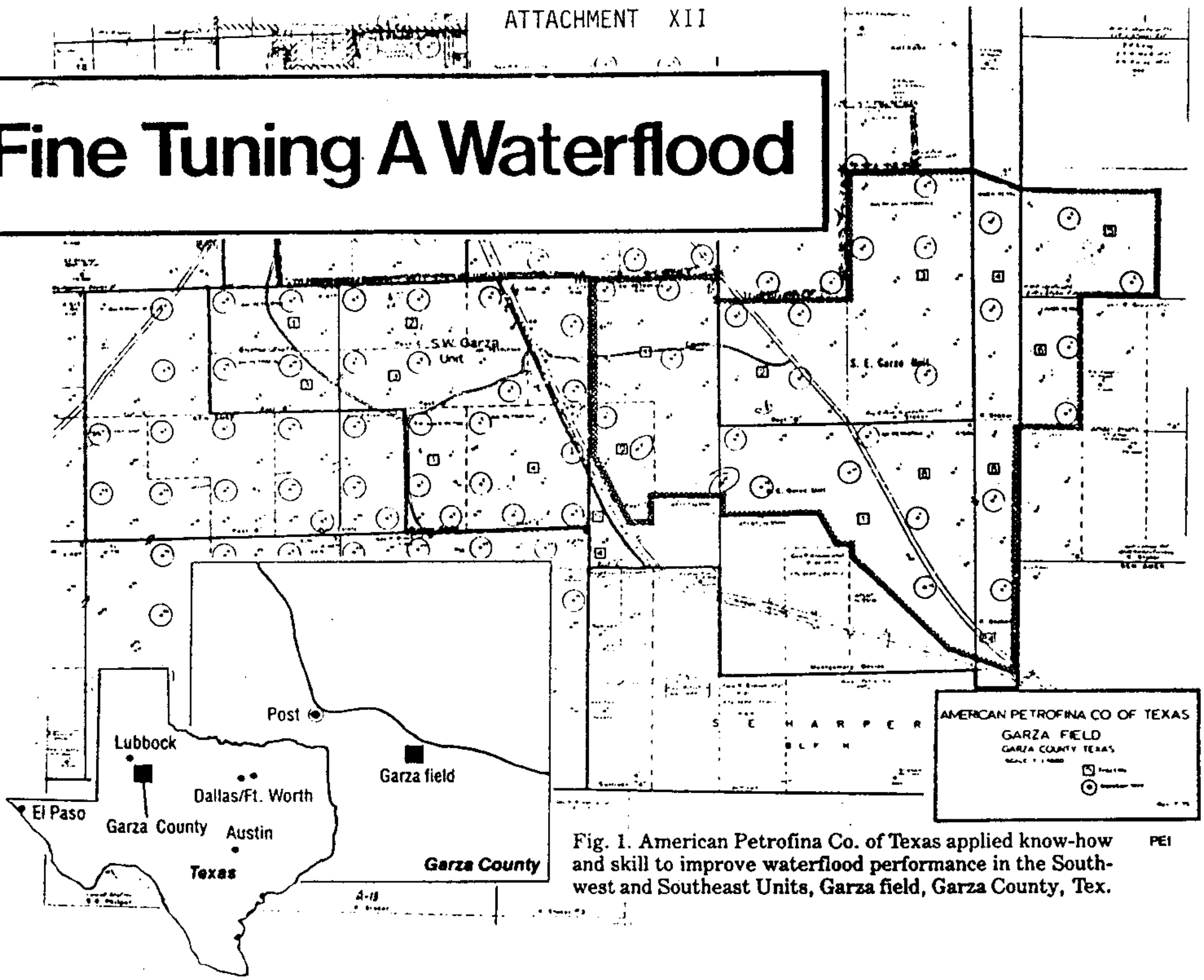


Fig. 1. American Petrofina Co. of Texas applied know-how and skill to improve waterflood performance in the Southwest and Southeast Units, Garza field, Garza County, Tex. PEI

A PETROLEUM ENGINEER INTERNATIONAL Staff Report

Redevelopment is frequently a matter of engineering present-day technical and economic standards to a field. This is what American Petrofina Co. of Texas (Fina) is doing in the Southeast and Southwest Units of the Garza field, Garza County, Texas (Fig. 1).

No single project at the field is particularly high technology. But the combination of projects – streamlining the waterflood system, elimination of produced water disposal problems, infill drilling, multistage stimulation, and scale control – will maintain the units as a successful waterflood well beyond the 1980's.

The 647-acre Southwest Unit is a combination of lower tier and upper tier oil, and exhibits the better pay quality. Erratic zone transitions result in a relatively poorer pay quality in the 1,535-acre Southeast Unit. The Southeast Unit is classified as stripper oil.

Early Field History

The Garza field, on the eastern shelf of the Permian Basin, was discovered with the M. L. Richards No. 1 Sullivan well in August 1935. Development of the mostly dolomite San Andres was slow, with only six producers in the entire field at the end of 1944.

Production is from about 3,000 ft. Porosity ranges from 2% to 30%, with most zones averaging 12% to 15%. Permeable stringers range from 0.1 md to 15 md, averaging about 1.2 md in the Southeast Unit and 4 md in the Southwest Unit with interlacing barriers. Producing interval ranges in thickness from 30 ft to 230 ft. Other portions of Garza field produce some from the Glorieta, but Fina units do not.

When Fina began acquiring the two units during the early 1960's, about 80 wells were producing.

As with many older fields, Garza was developed by a number of operators, mostly independents. The result is a variety of completion techniques and very few formation records.

A common field practice in the 1930's and 1940's was to rotary drill to the top of the San Andres, set casing, then use cable tools to drill through the producing zone. Most of these wells are open-hole completions. Some were acidized, and many were shot with nitroglycerin.

Initial Waterflood

Fina's waterflood operations in the two units began in the fall of 1967. The Southeast Unit was initially flooded using a peripheral pattern, until nine more wells were converted to injection in 1976. These conversions bisected the waterflood and began five-spot pattern development. Only token volumes of water

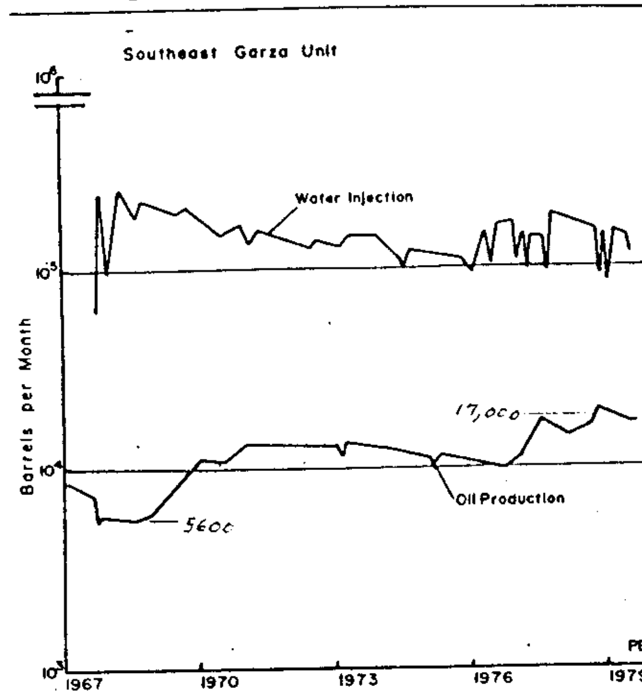


Fig. 2. Injection-production relationship for Southeast Garza field unit.

were injected into the Southwest Unit until the unit became effective in the late fall of 1973, when it was set up on a 40-acre five-spot pattern. Both units showed response to waterflooding in less than a year and a half. Since then, both units have been partially infill drilled on 20-acre five spots (Figs. 2 and 3).

Injection water is produced from the Santa Rosa formation. When this water is mixed with San Andres water it seriously precipitates, so produced water is separated and pumped into a disposal well in each unit.

Recent Data Development

The prospect for at least partial price decontrol prompted Fina to begin accumulating data for field improvement planning several years ago. Final planning and actual work started in mid-1978.

One of the first steps was an analysis of individual well crude and water production before and after the waterflood started. Widely varying water cuts were charted to provide basic insight to reservoir flow patterns. Density and neutron logs were run in one well in the Southeast Unit and four wells in the Southwest Unit. With this data, sites were selected for eight infill wells (four in each unit) drilled during 1979. Formation density, compensated neutron, and dual lateralog logs were run on new wells and generated computerized log calculations.

A 50-ft core was pulled on the tract 1 well and a 200-ft core was pulled on the tract 2 well in the Southeast Unit. In the Southwest Unit, 200-ft cores were pulled on four wells in tract 2. The core in the Southeast tract 2 well revealed poor production and flood characteristics.

Water Handling

Injection water is produced from six supply wells in the Southeast Unit and three supply wells in the

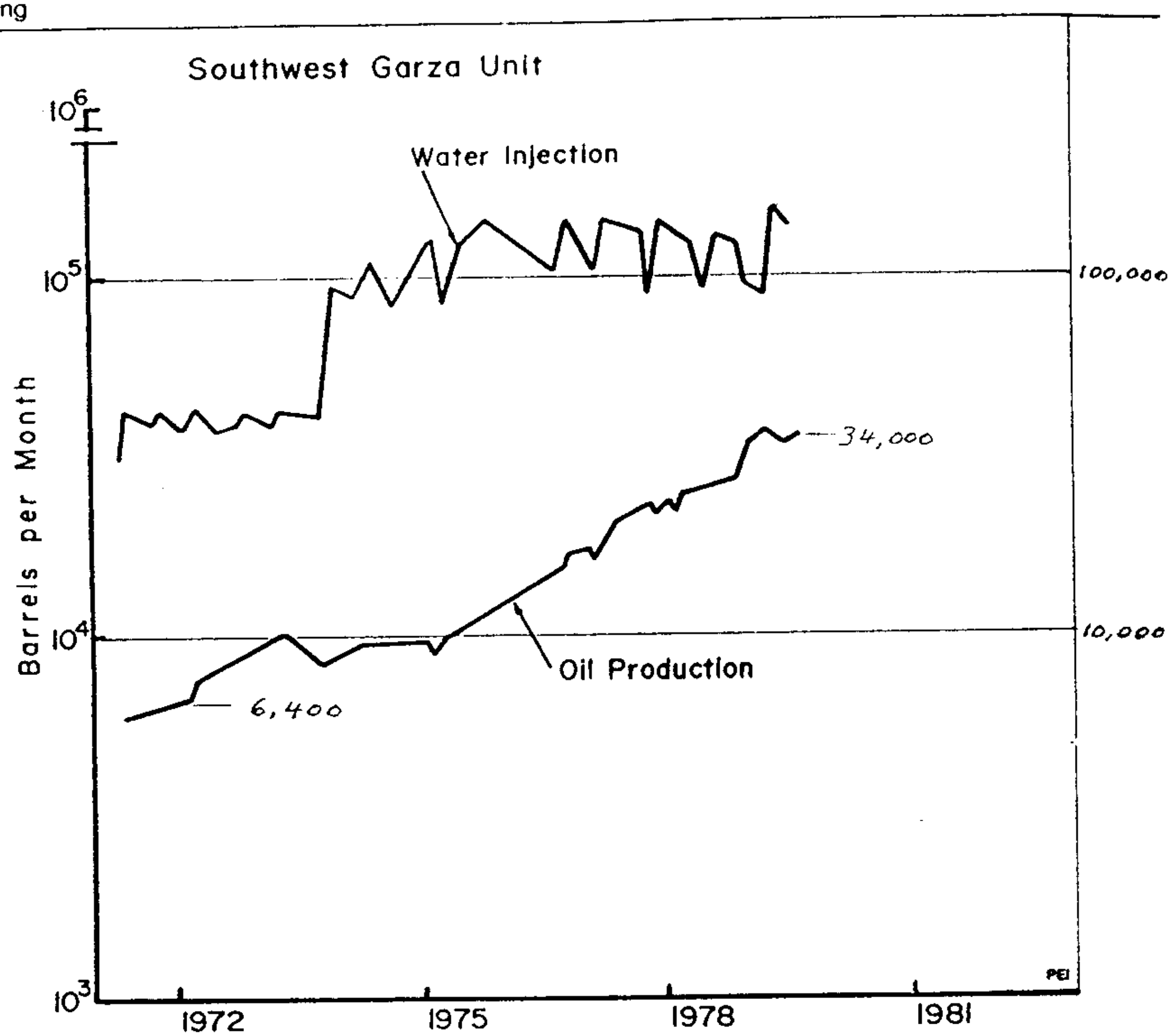


Fig. 3. Injection-production relationship for Southwest Garza field unit.

Southwest Unit. An injection pump station is centrally located in each unit.

Initially, produced water was separated and pumped into a disposal well in each unit. In mid-1979, for economics and for conservation of Santa Rosa water, disposal wells were discontinued and produced water was cycled as injection water. A consolidated injection pump system in the Southwest unit includes separate tanks for Santa Rosa and San Andres water, with appropriate manifolding to handle each water separately. About 45% of Southwest Unit injection is produced water.

Produced water moves from heater-treater to storage tanks then to injection pumps through low-pressure fiberglass pipe, and from pumps to injection wells through high-pressure fiberglass pipe. The water is naturally moderately corrosive, so significant attention is paid to minimizing its exposure to air. Corrosion inhibition treatment of injection water has been required down the casing of waterflood supply wells.

Because fiberglass is easier to handle and less affected by scaling, paraffin, and corrosion than metal pipe, fiberglass is expected to become the standard pipe on the two Garza field units. Conversion to fiberglass tanks is being considered as technology improves.

Infill Completion and Stimulation

On all recent wells, a 12¼-in. hole is drilled through occasionally troublesome red bed and water zones, and 8⅝-in. suface pipe set – normally to about 120 ft. San Andres wells have relatively few drilling problems except for a few waterflows that are encountered when the pay is drilled.

The 5½-in. production string joints through the producing zone are sandblasted to facilitate cement bonding. Centralizers and reciprocating scratchers are used through the pay to assure a competent cement sheath and to prevent channeling by existing or potential water.

Perforations are selectively shot, usually at 2-ft or longer spacing. This is followed by a ballout acid job designed to put at least a barrel of acid into each perforation.

In areas of relatively low cumulative water injection, producing wells are fractured with conventional gelled water techniques. In these wells, 100-mesh sand is an effective proppant.

Several variations of alternating stages of acid and

-led water treatments have been tried. Early re-s are positive enough to merit more work with them. Treatments involve about 2,000 gal of 15% HCl, 2,000 gal of 20% HCl, and 6,500 gal of 20-lb gelled water carrying 100-mesh sand.

In areas where large cumulative water injection had pressured the reservoir, some of the 100-mesh sand flowed back into the producing wells. Therefore, on one treatment, 20-40 mesh sand was tailed in with the final gelled water pad.

On the last well, the final pad was 10-lb brine carrying 100-mesh salt. Salt was added to push the sand proppant farther into fractures. Formation water eventually dissolved the salt, leaving clear fractures immediately around the well bore.

Formation breakdown pressure averages about 2,600 psi. After breakdown, treatment pressures have been in the 1,200-psi range. Various pumping rates have been tried, as high as 40 bbl/min for the gelled water phases. Early data indicate that high pumping rates result in better sustained crude production.

Calcium Sulfate

San Andres water often forms a crystalline calcium sulfate scale on well bores. Some believe this "gyp scale" does at least some good. The reasoning is that crystals form fastest and largest where the most water flows, eventually stopping the water flow and putting more restriction on oil flow.

Conversion of old producers to injection wells previously required cleaning gypsum deposits from bore walls. The injectors were then acidized and an injection packer run on plastic-lined tubing.

A program is underway to squeeze scale inhibitor into all wells. A packer is run in on tubing, the inhibitor injected through the tubing, and bottomhole pressure built to about 1,000 psi. The well is then shut in 24 hr.

A polymer chemical used in the squeezes has been successful in retarding deposition of calcium sulfate and calcium carbonate. Recently a polyacrylamide also has been used in squeeze treatments.

Treatments are expected to be effective longer than a year. Until wells get this treatment, each receives periodic injections of conventional scale inhibitor.

So far this year, Fina has added 15 infill wells to the two units, each located and stimulated in accordance with data from core and log analysis. Infill wells fractured with modern techniques, and scale inhibition of all wells, are expected to at least double production over the remaining life of the two units. Concurrently, economics will improve through elimination of disposal wells, reduction of pumping make up injection water, and adoption of corrosion, scale, and paraffin-resistant fiberglass piping. ■

Acknowledgement. Appreciation is expressed to the following for their assistance in the preparation of this article: Dick Bott, American Petrofina of Texas' district production manager in Big Spring, Tex.; Dick Rieman, production engineer; and Cliff Chapman and Lance Williamson who engineered the waterflood.

PROPOSED INJECTION RATES

60-65 m³WPD - proposed inj rate

9-28-9-29 battery BOD 01-170-02

estimated water production

VVR

MARCH/90

	OIL	WATER
12-27	0.96	~~0~~
13-27	0.57	0.12
9-28	1.22	~~0~~
16-28	1.56	0.14
	4.31 m³OPD	0.26 m³WPD

B_{oi} = 1.05 m³/m³

Reservoir withdrawal = 4.31 * 1.05 + 0.26 = 5 Rm³/d

VRR = 12-13 m³/m³

INJECTION PRESSURE

frac grad. 1 psi/ft = 22.6 kPa/m

aver. depth 820 m
hydraulic grad = 0.44 psi/ft ≡ 9.95 kPa/m

max surface inj. press = 820 × (22.6 − 9.95)

= 10370 kPa

using a safety factor SF = 0.8

Maximum wellhead inj. pressure: 8300 kPa.

BATTERY: RIDEAU DALY 9-28-9-29 (WPM)

PERMIT NO: B-01-170-02 DATE ISSUED: 02/06/86

WELL(S) TIED INTO BATTERY:

14-21-09-29 —	05-27-09-29 —	09-27-09-29 —
11-27-09-29 —	12-27-09-29 0.7	13-27-09-29 3.7
14-27-09-29 3.7	01-28-09-29 —	05-28-09-29 0.9
06-28-09-29 —	07-28-09-29 —	08-28-09-29 —
09-28-09-29 —	10-28-09-29 [illegible]	15-28-09-29 —
16-28-09-29 4.5	01-33-09-29 [illegible]	02-33-09-29 [illegible]
08-33-09-29 44.1	03-34-09-29 14.9	04-34-09-29 [illegible]
05-34-09-29 592.0		
641.9	[illegible]	52.1

[illegible] = 60 m³ WPD

PAGE NO. 1 *** S T O R E *** ManPS
DALY4 90-07-04
DALY # 5 10:48:22

MONTH	WELL COUNT PRDN	INJN	P/IN	S/AB	HOURS	OIL m3/M	WATER m3/M	OIL m3/D	WOR	CUM.OIL m3	I.WATER m3/M
'84-07	1	0	0	0	288	23.9	0.3	0.8	0.01	23.9	0.0
'84-08	1	0	0	0	744	41.5	0.2	1.3	0.00	65.4	0.0
'84-09	1	0	0	0	720	37.0	0.2	1.2	0.01	102.4	0.0
'84-10	1	0	0	0	504	94.5	3.9	3.0	0.04	196.9	0.0
'84-11	1	0	0	0	600	127.1	4.9	4.2	0.04	324.0	0.0
'84-12	1	0	0	0	744	125.7	4.9	4.1	0.04	449.7	0.0
'85-01	1	0	0	0	744	102.8	4.1	3.3	0.04	552.5	0.0
'85-02	2	0	0	0	864	181.0	8.0	6.5	0.04	733.5	0.0
'85-03	2	0	0	0	1488	346.1	22.6	11.2	0.07	1079.6	0.0
'85-04	2	0	0	0	1440	331.5	21.9	11.1	0.07	1411.1	0.0
'85-05	2	0	0	0	1488	341.0	22.6	11.0	0.07	1752.1	0.0
'85-06	2	0	0	0	1824	419.3	42.8	14.0	0.10	2171.4	0.0
'85-07	4	0	0	0	2328	550.2	107.7	17.7	0.20	2721.6	0.0
'85-08	4	0	0	0	2976	421.2	189.8	13.6	0.45	3142.9	0.0
'85-09	4	0	0	0	2568	345.3	168.8	11.5	0.49	3488.1	0.0
'85-10	4	0	0	0	2976	473.6	121.6	15.3	0.26	3961.7	0.0
'85-11	4	0	0	0	2688	440.8	104.8	14.7	0.24	4402.5	0.0
'85-12	4	0	0	0	2655	345.7	101.9	11.2	0.29	4748.2	0.0
'86-01	4	0	0	0	2976	270.8	168.0	8.7	0.62	5019.0	0.0
'86-02	4	0	0	0	2352	250.3	129.0	8.9	0.52	5269.3	0.0
'86-03	4	0	0	0	1536	162.4	104.8	5.2	0.65	5431.7	0.0
'86-04	4	0	0	0	2880	284.1	144.1	9.5	0.51	5715.8	0.0
'86-05	4	0	0	0	2976	258.3	164.6	8.3	0.64	5974.1	0.0
'86-06	4	0	0	0	2880	246.9	162.9	8.2	0.66	6221.0	0.0
'86-07	4	0	0	0	2976	249.6	151.4	8.1	0.61	6470.6	0.0
'86-08	4	0	0	0	2976	259.9	112.0	8.4	0.43	6730.5	0.0
'86-09	4	0	0	0	2880	249.1	78.4	8.3	0.31	6979.6	0.0
'86-10	4	0	0	0	2976	272.4	157.1	8.8	0.58	7252.0	0.0
'86-11	4	0	0	0	2880	184.6	118.1	6.2	0.64	7436.6	0.0
'86-12	4	0	0	0	2976	176.5	133.2	5.7	0.75	7613.1	0.0
'87-01	4	0	0	0	2976	183.6	125.3	5.9	0.68	7796.7	0.0
'87-02	4	0	0	0	2688	142.6	109.9	5.1	0.77	7939.3	0.0
'87-03	4	0	0	0	2976	117.9	97.7	3.8	0.83	8057.2	0.0
'87-04	4	0	0	0	2880	139.6	124.7	4.7	0.89	8196.8	0.0
'87-05	4	0	0	0	2928	144.6	46.3	4.7	0.32	8341.4	0.0
'87-06	4	0	0	0	2544	194.0	47.7	6.5	0.25	8535.4	0.0
'87-07	4	0	0	0	2808	184.0	46.4	5.9	0.25	8719.4	0.0
'87-08	4	0	0	0	2976	207.2	51.5	6.7	0.25	8926.6	0.0
'87-09	4	0	0	0	2880	187.6	50.1	6.3	0.27	9114.2	0.0
'87-10	4	0	0	0	2976	161.9	46.6	5.2	0.29	9276.1	0.0
'87-11	4	0	0	0	2856	145.9	112.4	4.9	0.77	9422.0	0.0
'87-12	4	0	0	0	2880	166.9	105.2	5.4	0.63	9588.9	0.0
'88-01	4	0	0	0	2928	159.8	105.8	5.2	0.66	9748.7	0.0
'88-02	4	0	0	0	2568	144.2	79.9	5.0	0.55	9892.9	0.0
'88-03	4	0	0	0	2976	158.0	100.5	5.1	0.64	10050.9	0.0
'88-04	4	0	0	0	2880	170.0	91.1	5.7	0.54	10220.9	0.0
'88-05	4	0	0	0	2976	168.5	90.9	5.4	0.54	10389.4	0.0
'88-06	4	0	0	0	2872	164.9	99.6	5.5	0.60	10554.3	0.0

4.9

4.9

PAGE NO. 2 *** S T O R E *** ManPB

DALY4 90-07-04

DALY # 5 10:48:22

MONTH	WELL COUNT PRDN	INJN	P/IN	S/AB	HOURS	OIL m3/M	WATER m3/M	OIL m3/D	WOR	CUM.OIL m3	I.WATER m3/M
88-07	4	0	0	0	2952	181.5	34.9	5.9	0.19	10735.8	0.0
88-08	4	0	0	0	2904	185.3	32.3	6.0	0.17	10921.1	0.0
88-09	4	0	0	0	2808	186.0	29.4	6.2	0.16	11107.1	0.0
88-10	4	0	0	0	2904	183.2	27.3	5.9	0.15	11290.3	0.0
88-11	4	0	0	0	2880	175.4	33.2	5.8	0.19	11465.7	0.0
88-12	4	0	0	0	2976	169.1	45.3	5.5	0.27	11634.8	0.0
89-01	4	0	0	0	2832	161.0	43.1	5.2	0.27	11795.8	0.0
89-02	4	0	0	0	2568	145.5	32.0	5.2	0.22	11941.3	0.0
89-03	4	0	0	0	2952	158.5	42.4	5.1	0.27	12099.8	0.0
89-04	4	0	0	0	2880	151.3	52.1	5.0	0.34	12251.1	0.0
89-05	4	0	0	0	2976	171.2	43.2	5.5	0.25	12422.3	0.0
89-06	4	0	0	0	2880	165.6	44.6	5.5	0.27	12587.9	0.0
89-07	4	0	0	0	2976	150.9	63.7	4.9	0.42	12738.8	0.0
89-08	4	0	0	0	2928	164.1	50.8	5.3	0.31	12902.9	0.0
89-09	4	0	0	0	2880	159.2	45.7	5.3	0.29	13062.1	0.0
89-10	4	0	0	0	2952	158.5	43.1	5.1	0.27	13220.6	0.0
89-11	4	0	0	0	2616	143.2	44.0	4.8	0.31	13363.8	0.0
89-12	4	0	0	0	2880	127.3	10.1	4.1	0.08	13491.1	0.0
90-01	4	0	0	0	2928	144.1	24.4	4.6	0.17	13635.2	0.0
90-02	4	0	0	0	2664	130.2	7.5	4.7	0.06	13765.4	0.0
90-03	4	0	0	0	2976	133.5	8.9	4.3	0.07	13898.9	0.0
90-04	4	0	0	0	2880	144.8	6.4	4.8	0.04	14043.7	0.0

EBOR UNIT No. 1 (eff JULY/64)

- pool discovered 1955

ϕ = 12.1 % cut-off ϕ = 9% k = 0.8 md
k: 8.6 md
h = 13.8'

- difficult to correlate pay zones between wells
- primary recovery ≈ 6.5% of OOIP

- WF recovery estimated @ 13%

Board order PM-2 Oct/62 pilot WF 11-26-9-29 injection well - injection Oct/62 to 1963 105-120 BWPD @ 1400 #
no response insufficient wtr injected

OOIP = 469000 m^3
ROIP = 31000 m^3 primary

WF project Jul/64 5-26, 11-26, 3-26, 7-26 -9-29
wtr source 4-26

- no production response by DEC/66 VRR 0.46
- cumul inj to Dec/65 - 19716 m^3

limited by source wtr availability

WEST BUTLER UNIT No. 1   Sec 30 & 31-9-29

APPLICATION

Upper Lodgepole Fm

OOIP = 397,500 m³

PRIMARY RECOVERY = 25437 m³

RECOVERY FACTOR = 6.4%

WF RECOVERY EST. = 32.4% → 128617 m³

- low injectivity (25 m³WPD/well) original plans to convert 16-30 & 8-31

- wells drilled 1955 & 56 - very rapid production decline no wtr drive

Reservoir Characteristics

h_{ave} = 7.6 m ϕ_{ave} = 10.6%   Sw = 35%

B_{oi} = 1.07 rb/stb k_{ave} = 8.2 md

- water source @ 7-31-9-29

- net pay k_{cutoff} = 1 md thin stringers < 0.46 m exclude as effective pay — reduce net pay estimates by 50%

- P_R = 1050 psig T_R = 82 °F

CUMULATIVE PROD to 90-03 · 32728 m³

- original pilot WF commenced Sept 1972 & suspended Oct 1974 insufficient inj. vol. due poor supply VRR = 0.33 70074 bbls inj

PILOT PERFORMANCE REPORT 1980-09

- lack of pressure communication / reservoir continuity

- 16-30 in communication with underlying reservoir
- 14-29 low injectivity
- 13-29 no production response
- 12-29 also injection well
4-32 also inj. well
- 80 ac pilot recommended
1-31-9-29 Devonian with source
- pressure fall-off injection wells - evidence restrictions within close proximity of inj wells

pn 35 - 2ND pilot need for pattern configuration & confined injection.
- pressure difference 16-30 @ 1080 psi
13-29 • 44 psi

- 80 acre inj. pattern 5-spot 13-29
OOIP = 45150 m^3

- no pressure support @ 13-29, response expected in 6 months
- low k reservoir - uncertainty in waterflooding

- high inj rates required @ high injection pressures

2ND pilot inj. commenced Sept/78 - Oct/80 ceased inj.
inj. press 7000-8000 KPa

- question of mission continuity

cumulative days 76856 –2

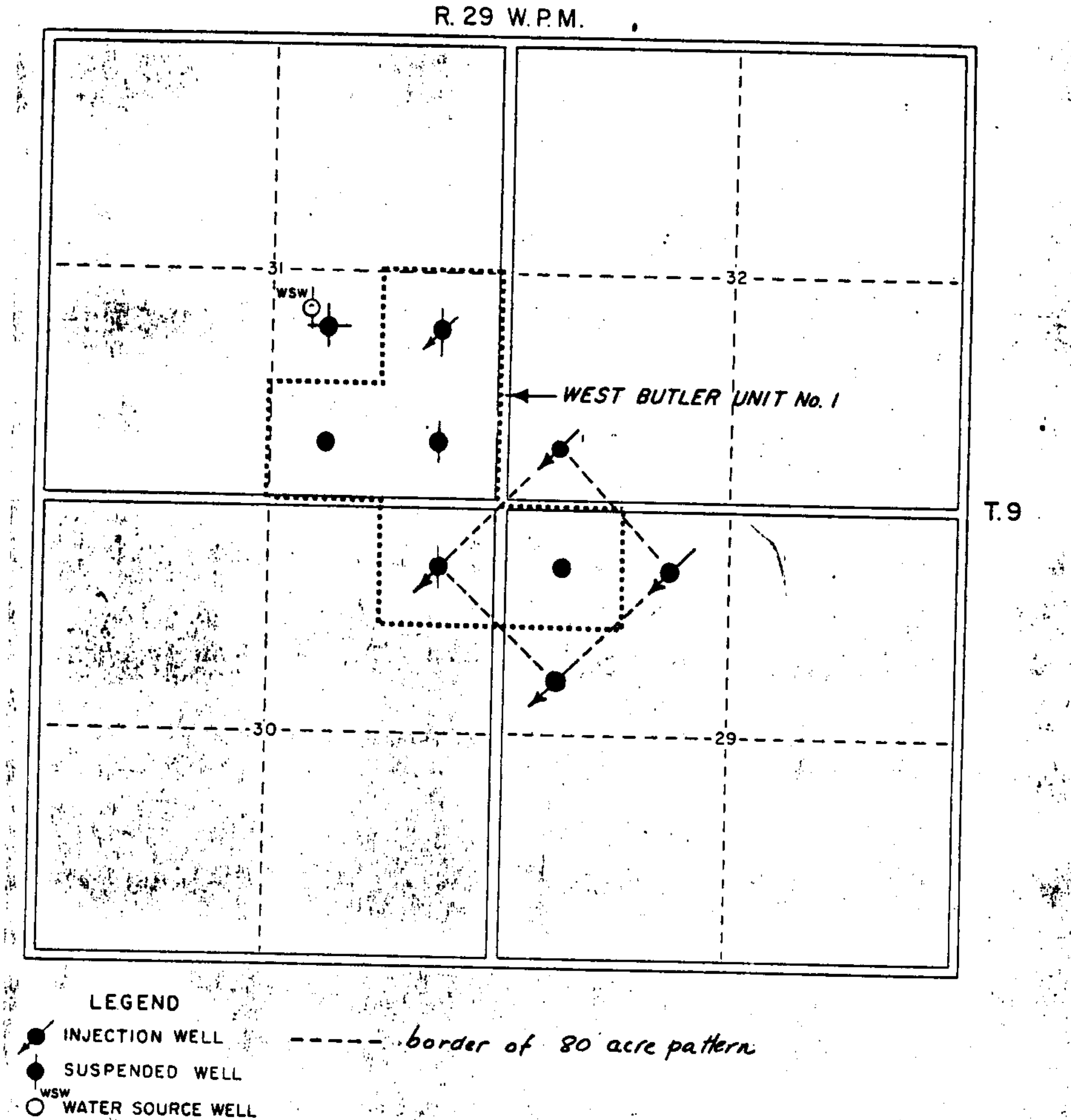


FIGURE 1
WEST BUTLER UNIT No. 1
AS OF 1977 - 12 - 31
SCALE: 3" = 1 MILE

PILOT WATERFLOOD SEC. 35 & 36 - 9 - 29 (WPM) (APR/66)

- production characterized by rapid decline typical of highly undersaturated reservoir, result low primary recovery

- no effective water-drive

- dolomite microcrystalline - microgranular, poor intergranular to pp vuggy ø, anhydrite + shale inter beds

- OOIP 1.336 MMBBl / 1/4 sec.
- primary recovery 98000 bbl for 8 well ≡ 2% of OOIP
- est WF recovery 21%
- Pilot WF convert 9-35-9-29 to injection
desired inj rate 500-1000 bbl/d concern that injection press. in excess of the fracture press. necessary to achieve target rates

Feb/90

wells ~ pilot - ɸ 1-35 3824 — 2-36 - 8469 m^3 — 11-36 - 892 SI
- ɸ A7-35 104.8 — ɸ 7-35 4702 — 5-36 - 8270 — 13-36 - 1570 SI
ɸ 9-35 1476 — 6-36 - 9582

cum prod. 244618 bbls
≈ 18% recovery

ø = 10-13%
K_{aver} 4-36 - ?

Board order No. PM 6 - JUN 14/66 - approval to Bralorne to conduct a pilot WF in Lodgepole injection into well 9-35-9-29 for 180 days progress report submitted after 6 mo pilot

9-35-9-29 injection performance

on inj. July, 1966 to Oct/66
inj. pressure 1500 #
inj. vol. 65,164 bbl
aver daily inj. rate 632 BWPD

- @ termination of pilot no indication of breakthrough of injection wtr

- small increase in production noted

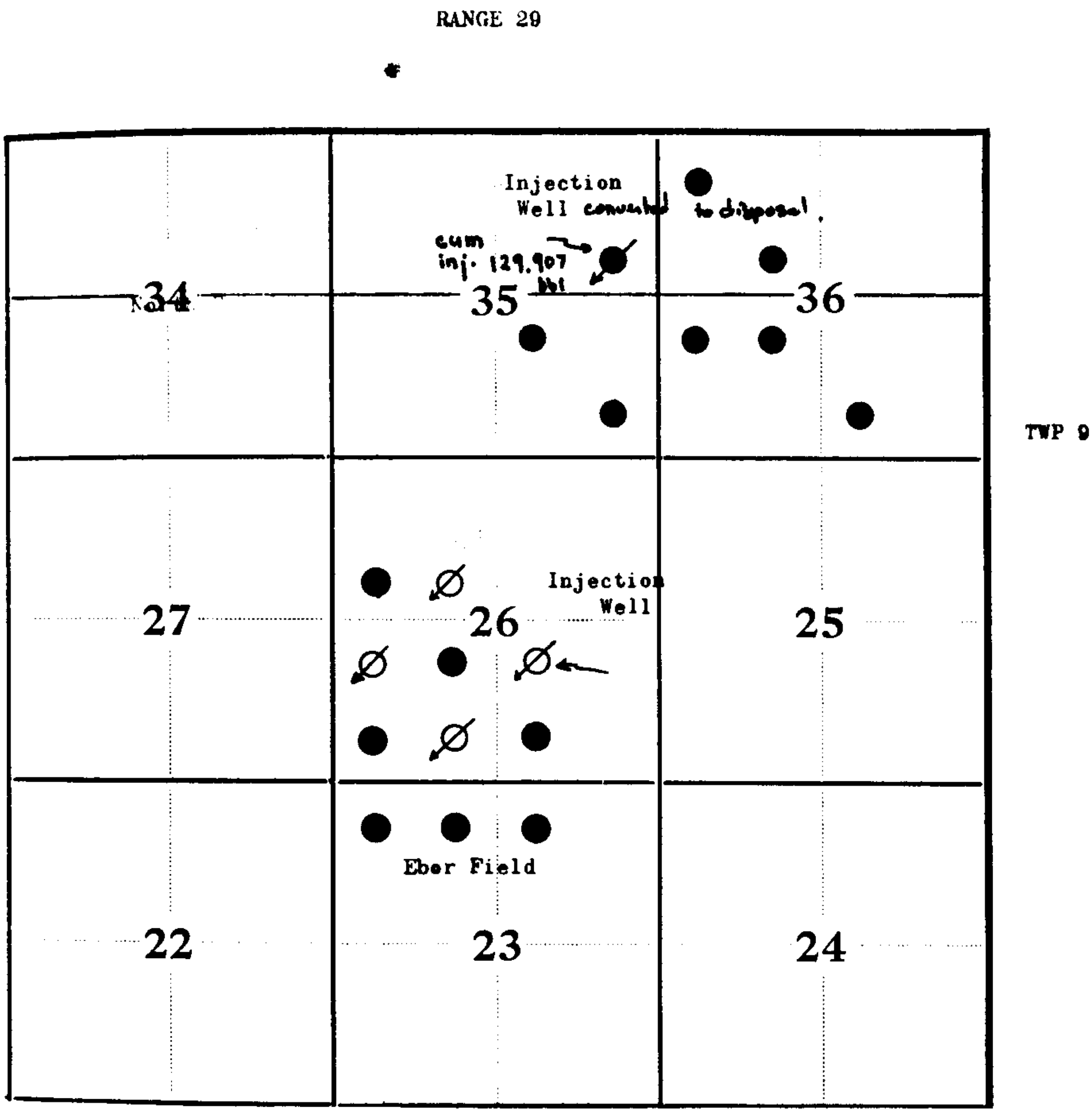
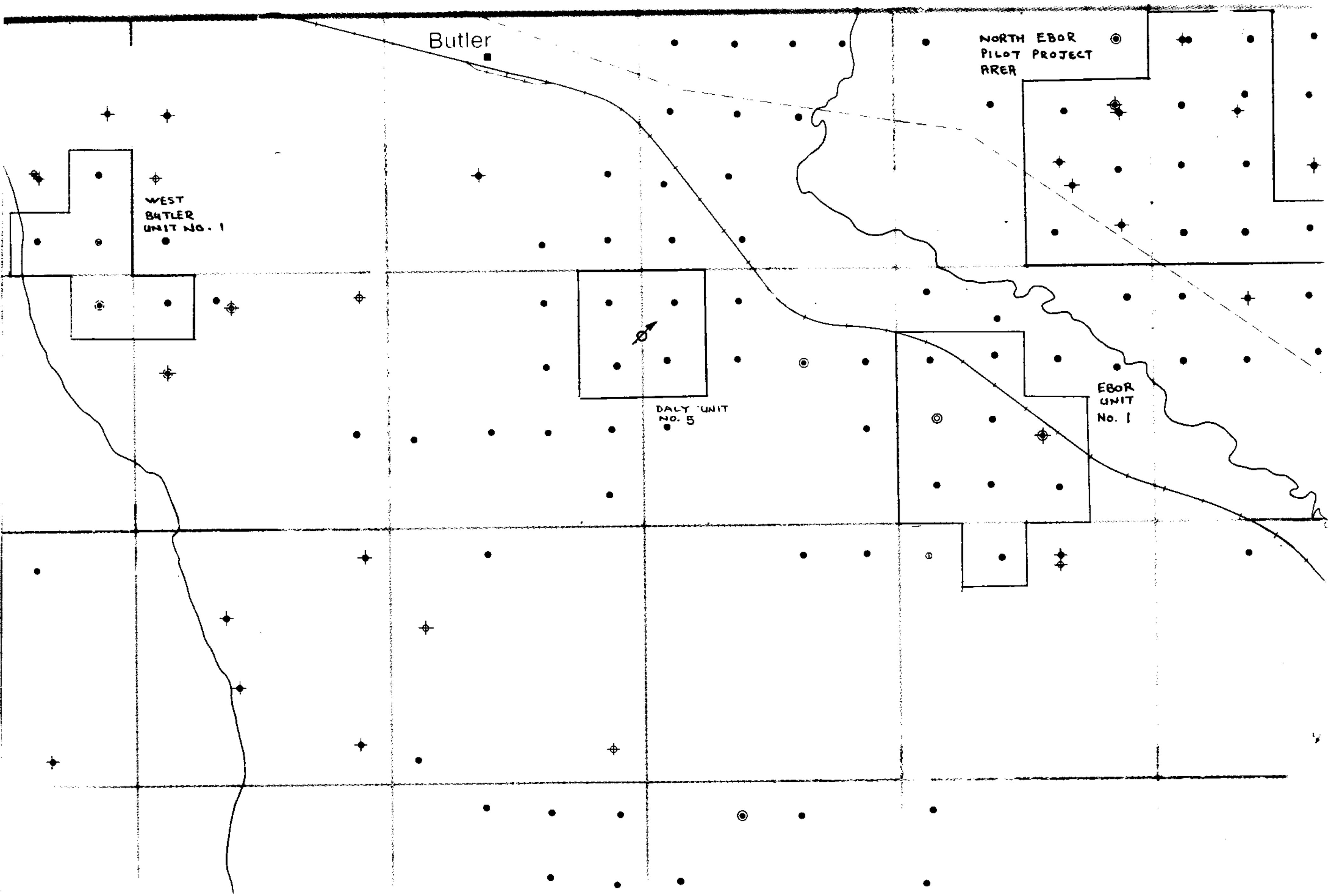


Figure 1. Section 35 & 36-9-29 WPM well location map.


Butler
NORTH EBOR
PILOT PROJECT
AREA
WEST
BUTLER
UNIT NO. 1
DALY UNIT
NO. 5
EBOR
UNIT
No. 1

Cab. Sub
ORIG + 33

30 copies

OIC 2 ORIG
+ 4 copies

dual

24 - 1 + 23 photocopies

1 copy for each OIC of schedule

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