ENRON
Oil Canada Ltd.

(403) 298-2600

17 November 1987

File: Appl #87-1
Waskada No. 16 Unit

Manitoba Energy and Mines
Petroleum Department
#555, 330 Graham Avenue
Winnipeg, Manitoba
R3C4E3

Attention: Mr. L.R. Dubreuill,
Chief Petroleum Engineer

Dear Sir:

Re: Waskada Unit No. 16 - MPR Exemption

In response to your letter dated October 7, 1987, Enron Oil Canada Ltd. hereby submits the following information to clarify the pool pressure data and Enron plans for future pressure data.

Although the pressures in two wells surveyed in June 1987 were below 5 000 kPa, this is not indicative of the pool itself. Because the Lower Amaranth is very heterogeneous, that is there are thin layers of high permeability and low permeability in all directions, shut in times become very important.

As an example, in March 1986 Enron voluntarily shut in the Waskada field amid our own concerns of going below the bubble point pressure. At the end of May 1986 an extensive pressure survey was completed. The results showed significant pressure differences from well to well after two months of shut in time. Therefore, another survey was then completed at the end of July 1986, which proved that the wells had not stabilized at an average reservoir pressure. In fact, one well notably (5-4) had a decrease of 172 kPa (25 psi), which was probably due to offset production (see Maps 1 and 2).

With this in mind, the surveys completed in June 1987 only two wells were below 5 000 kPa, one was 5-4 the other 16-5. The well 5-4 was shut in April 29, 1987 and a static gradient was performed on the well thirty-two days later (June 1, 1987), similarly 16-5 was shut in May 5th and the gradient was also performed June 1, 1987. Therefore these wells did not have a sufficient shut in time to reach a stabilized reservoir pressure indicative of the actual pressure in that area.

ENRON
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For your convenience, enclosed herewith please find the latest voidage report showing substantial gains in replacing voidage. As well, there has been a significant increase in productivity in the following wells; 4-4, 6-4, 12-4 and 14-4. This also demonstrates favourable waterflood performance and therefore pressure maintenance.

Also included are the results of a static gradient completed on 16-4 before the well was placed on production and acoustical pressure survey results from 9-5. The acoustical survey completed on 9-5 showed that the well had not reached a stablized reservoir pressure and in fact, was still building at 17 kPa (2.5 psi) per day (see Table 1).

As a part of our committment to the pressure maintenance scheme Enron will be conducting fall-off tests on all four injectors as per the Manitoba Schedule (Section 3) Pressure Maintenance Rules 3(2) commencing November 23, 1987. Details of the survey program are enclosed herewith.

Should you have any questions or require further information, please contact the undersigned at your convenience.

Yours very truly,

ENRON OIL CANADA LTD.

T. McKay,
Production Engineer

TM:pdc
attach

ENRON
Oil Canada Ltd.

MANITOBA SUMMARY

	August m³/d(STB/d)	September m³/d(STB/d)
Unit No. 16		
Average production	37.5(235.9)	43.42(273.1)
Total production	832.4(523.6)	990.6(623.1)

Waterflood Response

4-4-2-25	from	4.1 m^3/d to 6.5 m^3/d
12-4-2-25		2.9 m^3/d to 4.0 m^3/d
14-4-2-25		2.6 m^3/d to 4.0 m^3/d

NOVEMB/tm006a
16 November 1987

WASKADA FALL-OFF TEST PROGRAM

1. Shut in all four injectors (5-4, 11-4, 15-4, 16-5) on the morning of November 23, 1987.

2. Record initial shut in pressures with a dead weight guage. Continue to monitor wells every one to two hours, recording dead weight pressures.

3. Continue to monitor wells for five days, recording pressures four times daily.

4. For the next six to fourteen days continue to record pressures two times daily until the well goes on vacuum or 336 hours (14 days).

5. Restart water injection upon notification from the Calgary office which will include new target injection rates.

NOVEMB/tm006b
16 November 1987

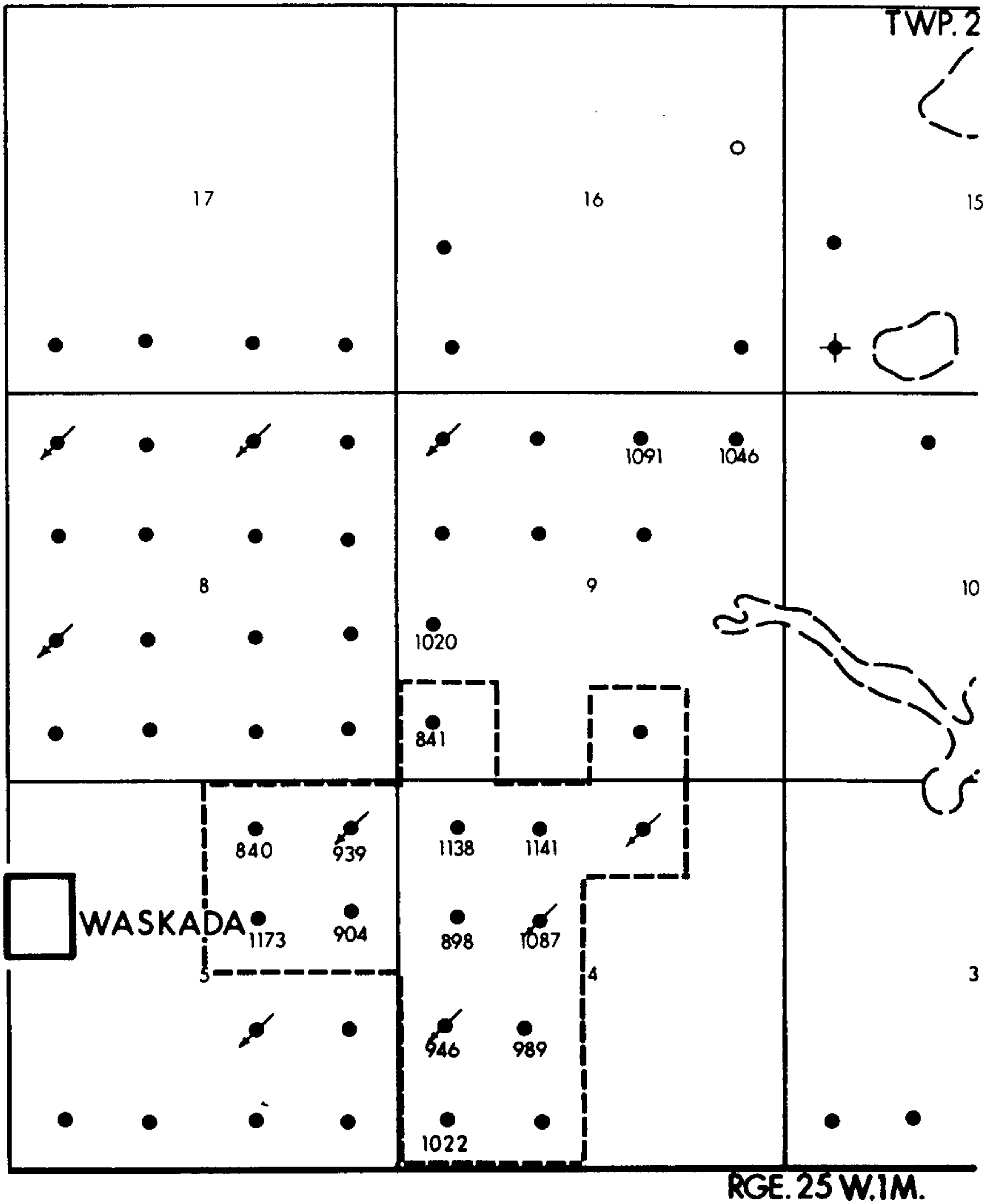
WAS[illegible].PRS

WASKADA,MANITOBA
SPEARFISH FORMATION
ACOUSTIC PRESSURE DATA
SEPT 1 AND 18 1987
LOCATION 9-5-2-25 W1M

OIL GRADIENT (37 API) = 0.3630

	WELL LOCATION	MID.PT PERFS (mKB)	MID.PT PERFS (ft KB)	DEAD WT. PRESSURE (kPag)	NO. OF JOINTS	FLUID LEVEL (m)	GAS COLUMN (ft)	OIL COLUMN (ft)	ACOUSTIC GAS GRADIENT (PSI/ft)	OIL PRESSURE Pws (PSIA)	COLUMN PRESSURE (PSIA)
SEPT 1	9-5-2-25W1	890.0	2920	1	37	355.20	1165	1755	0.0003	652	1060
SEPT 18	9-5-2-25W1	890.0	2920	60	34	326.40	1071	1849	0.0003	695	1060

WELL WAS SHUT-IN AUGUST 8/87



LEGEND

- O LOCATION
- ● OIL WELL
- WATER INJECTOR
- - - - - PROPOSED UNIT BOUNDARY

ANDEX OIL CO. LTD.

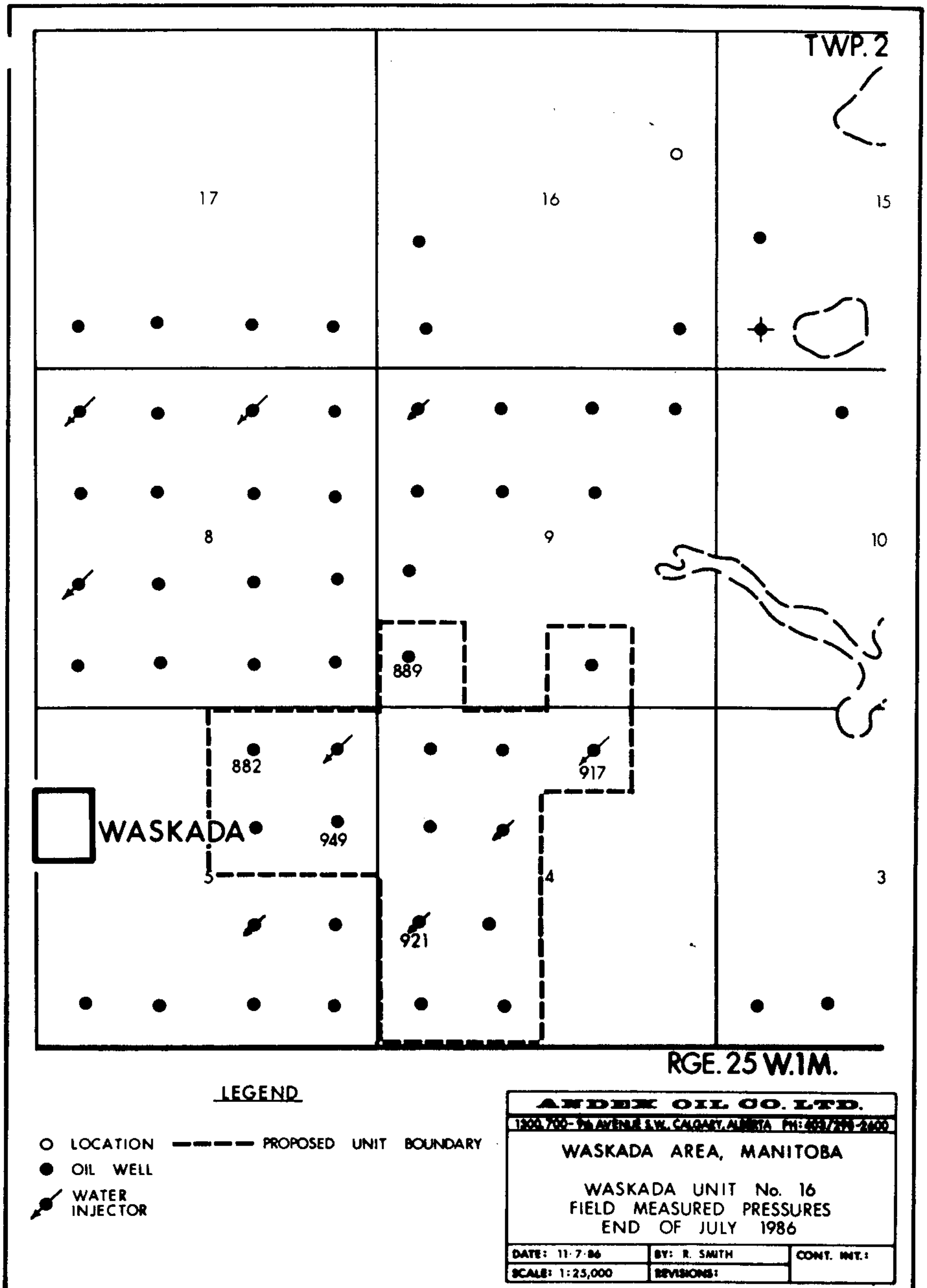
1300, 700 - 9th AVENUE S.W., CALGARY, ALBERTA PH: 403/298-2600

WASKADA AREA, MANITOBA

WASKADA UNIT No. 16
FIELD MEASURED PRESSURES
END OF MAY 1986

DATE: 11-7-86	BY: R. SMITH	CONT. INT.:
SCALE: 1:25,000	REVISIONS:	

MAP No. 1



TWP. 2
17
16
15
8
9
10
889
882
917
WASKADA
949
5
4
3
921
RGE. 25 W.1M.
LEGEND
LOCATION
PROPOSED UNIT BOUNDARY
OIL WELL
WATER INJECTOR
ANDEX OIL CO. LTD.
WASKADA AREA, MANITOBA
WASKADA UNIT No. 16
FIELD MEASURED PRESSURES
END OF JULY 1986
DATE: 11·7·86
BY: R. SMITH
CONT. INT.:
SCALE: 1:25,000
REVISIONS:

MAP No. 2

MOOSE MOUNTAIN
WELL SERVICES LTD.

COMPANY: ENRON OIL CANADA LTD.

WELL NAME: ENRON et al WASKADA

ADDRESS: CALGARY ALBERTA

LOCATION: 16-4-2-25-WPM

FIELD-POOL: SPEARFISH

WELL STATUS: OIL

TYPE OF TEST: STATIC GRADIENT

DATE OF TEST: 87SEP08

PERF/OH INTERVAL: 884-894

PRODUCING THROUGH: 60.3 TUBING

ELEVATIONS: (GL) 474.2 (KB) 478.4

MP PROD. INTER: 884.8 GL

POOL DATUM:

DATUM DEPTH: (CF)

SHUT IN: 1000 9/4/87

RUN DEPTH TEMP: (C) 43

DWG PRESS: (KPA) T=2040 C=1045

ON/OFF BTM: 0817 - 0832

	TOP RECORDER	BOTTOM RECORDER
ELEMENT SERIAL NO:	50700	50701
RUN DEPTH: (MCF)	888.2	890
RUN DEPTH PRESS: (KPA)	8060	8021
GRADIENT-RUN DEPTH: (KPA/M)	7.438	7.648
PRESSURE AT MMP: (KPA)	8035	7981
DATUM DEPTH PRESS: (KPA)		

REMARKS:

Company: ENRON OIL CANADA LTD. Location: 16-4-2-25-WPM

Element #: 50700 Range(kPa): 20685 IH#: 55495 3 hr Clock #: A10579

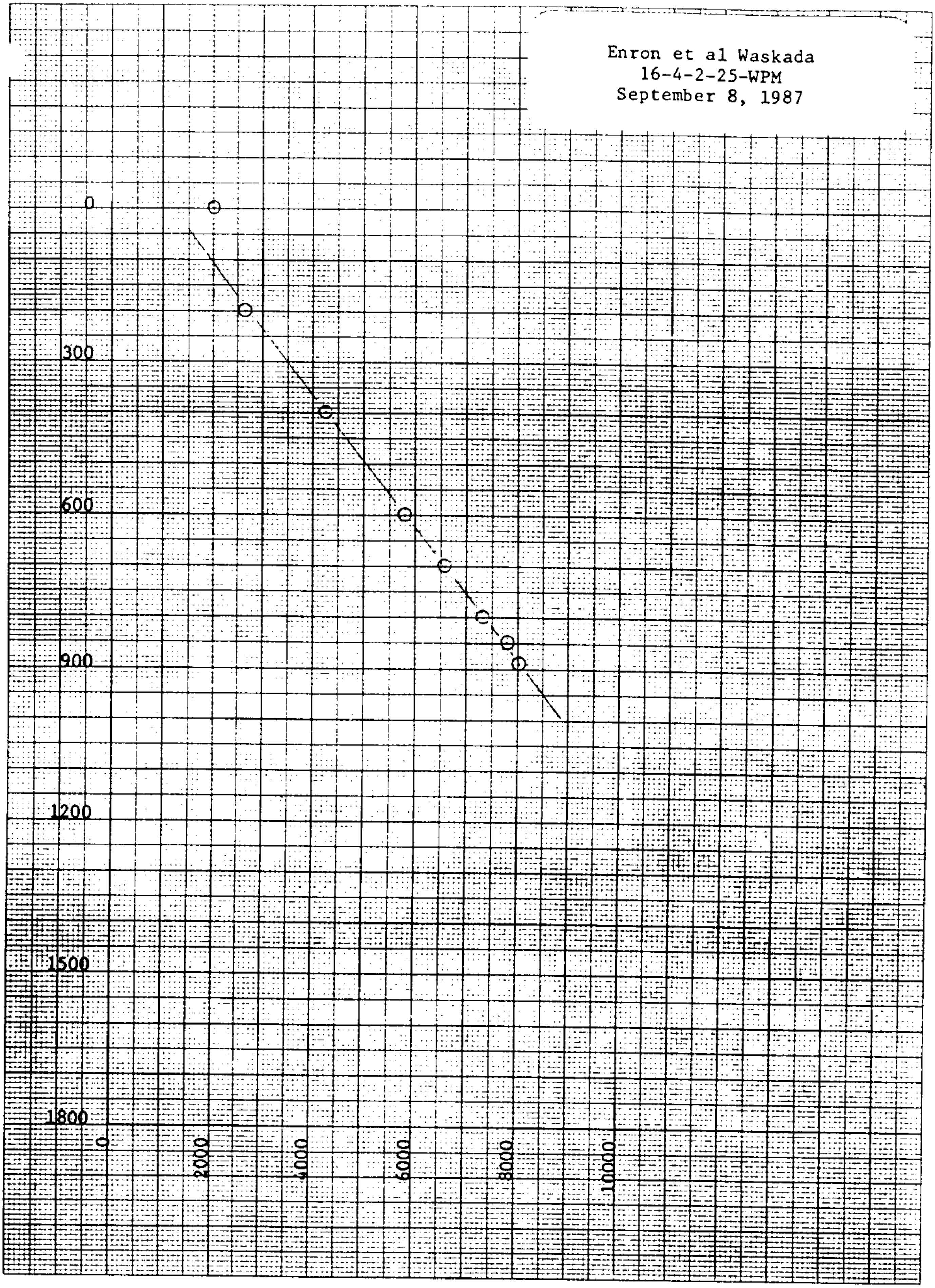
Run Date: 87SEP08 Calib. Equation: 412.54 7.36 Calib. Date: 87APR28

Depth Below cfm	Time	Deflection mm	P-PC kPa	Pressure kPa	Gradient kPa/m
-1.80	731- 736	4.935	-16	2027	0.000
198.20	740- 745	6.460	-19	2654	3.132
398.20	748- 753	10.300	-2	4254	8.003
598.20	754- 759	14.070	+37	5849	7.973
698.20	800- 805	15.935	+57	6638	7.888
798.20	806- 811	17.790	+50	7396	7.585
848.20	812- 817	18.700	+40	7762	7.317
888.20	817- 832	19.440	+33	8060	7.438

Element #: 50701 Range(kPa): 20685 IH#: 57284 3 hr Clock #: A14055

Run Date: 87SEP08 Calib. Equation: 411.43 25.71 Calib. Date: 87APR28

Depth Below cfm	Time	Deflection mm	P-PC kPa	Pressure kPa	Gradient kPa/m
0.00	731- 736	4.870	-6	2023	0.000
200.00	740- 745	6.420	+0	2667	3.220
400.00	748- 753	10.240	+10	4249	7.908
600.00	754- 759	13.990	+15	5796	7.738
700.00	800- 805	15.870	+17	6572	7.758
800.00	806- 811	17.725	+17	7336	7.633
850.00	812- 817	18.650	+17	7715	7.597
890.00	817- 832	19.395	+16	8021	7.648



Enron et al Waskada
16-4-2-25-WPM
September 8, 1987
0
300
600
900
1200
1500
1800
0
2000
4000
6000
8000
10000

0

ENRON WASKADA UNIT No.16 WATERFLOOD EVALUATION

FOR THE MONTH OF : SEPTEMBER 1987

UNIT No. 16

	MONTHLY	CUMULATIVE	CUMULATIVE SINCE INJECTION START-UP
OIL PRODUCTION (M3)	990.6	29198.1	3632.5
GOR (M3/M3)	29.4	26.0	
WATER CUT (%)	24.7	20.8	
WITHDRAWLS (RM3)	1519.6	42607.4	5568.7
REPLACEMENTS (RM3)	4013.1	13474.8	13474.8
VOIDAGE (RM3)	2493.5	-29132.7	7906.0
REPLACEMENT RATIO	2.6409	0.3163	2.4197
NO. OF PROD. WELLS	11		
OIL RATE (M3/CAL.DAY)	33.0		

PROJECT NO. 2

	MONTHLY	CUMMULATIVE
OIL PRODUCTION (M3)	853.6	1547.7
GOR (M3/M3)	2.7	2.0
WATER CUT (%)	28.4	57.2
WITHDRAWLS (RM3)	1368.7	3877.8
REPLACEMENTS (RM3)	0.0	0.0
VOIDAGE (RM3)	-1368.7	-3877.8
REPLACEMENT RATIO	0.0000	0.0000
NO. OF PROD. WELLS	6	
OIL RATE (M3/CAL.DAY)	28.5	

	MONTHLY	CUMULATIVE
OIL PRODUCTION (M3)	1844.2	30745.8
GOR (M3/M3)	17.0	24.8
WATER CUT (%)	26.5	24.0
WITHDRAWLS (RM3)	2888.3	46485.3
REPLACEMENTS (RM3)	4013.1	13474.8
VOIDAGE (RM3)	1124.8	-33010.5
REPLACEMENT RATIO	1.3894	0.2899
NO. OF PROD. WELLS	~~17~~	
OIL RATE (M3/CAL.DAY)	61.5	

ENRON WASKADA UNIT No.16 WATERFLOOD
WELL PRODUCTION AND INJECTION SUMMARY

SEPTEMBER 1987

PRODUCTION

WELL	HOURS ON	OIL MONTHLY (M3)	OIL PER OP. DAY(M3)	OIL CUM. (M3)	GAS MONTHLY (M3)	GAS GOR (M3/M3)	GAS CUM. (E03M3)	WATER MONTHLY (M3)	WATER W. CUT (%)	WATER CUM. (M3)	COMMENTS
UNIT No. 16											
3-4-2-25WPM	720	27.7	0.92	528.5	2.1	75.81	5.8	2.0	6.73	55.7	OK
4-4-2-25WPM	720	129.5	4.32	2484.8	2.6	20.08	33.5	2.7	2.04	69.4	OK
6-4-2-25WPM	720	265.6	8.85	3275.8	5.9	22.21	112.2	2.7	1.01	77.8	OK
12-4-2-25WPM	720	80.0	2.67	1855.5	1.5	18.75	9.3	2.7	3.26	123.2	OK
13-4-2-25WPM	720	59.0	1.97	2492.4	1.7	28.81	21.4	59.6	50.25	2063.3	OK
14-4-2-25WPM	720	79.2	2.64	1364.7	1.9	23.99	21.7	1.9	2.34	44.8	OK
9-5-2-25WPM	188	110.3	14.08	4864.4	2.4	21.76	126.0	* 0.7	0.63	213.5	OVER PROD.
10-5-2-25WPM	720	36.2	1.21	494.2	2.4	66.30	14.3	2.7	6.94	113.6	OK
15-5-2-25WPM	720	40.1	1.34	674.0	2.4	59.85	13.4	2.7	6.31	133.8	OK
2-9-2-25WPM	720	94.6	3.15	2105.6	4.0	42.28	64.9	5.8	5.78	171.9	OK
4-9-2-25WPM	720	68.4	2.28	2951.8	2.2	32.16	13.8	241.9	77.96	3769.6	OK
		990.6	43.42	29198.1	29.1	29.38	759.4	325.4	24.73	7648.6	
(OJECT NO 2											
9-4-2-25WPM	720	120.6	4.02	149.4	0.0	0.00	0.0	6.1	4.81	8.7	TO TANK
10-4-2-25WPM	720	210.2	7.01	261.0	0.0	0.00	0.0	6.0	2.78	10.0	TO TANK
16-4-2-25WPM	512	201.5	9.45	201.5	0.0	0.00	0.0	18.4	8.37	18.4	TO TANK
1-9-2-25WPM	720	44.9	1.50	93.3	0.0	0.00	0.0	239.1	84.19	326.1	TO TANK
3-9-2-25WPM	411	263.6	15.39	354.4	0.0	0.00	0.0	6.0	2.23	8.4	TO TANK
5-9-2-25WPM	528	12.8	0.58	488.1	2.3	179.69	3.1	62.5	83.00	1696.1	OK
		853.6	37.94	1547.7	2.3	2.69	3.1	338.1	28.37	2067.7	
TOTAL OF ALL WELLS		1844.2	81.37	30745.8	31.4	17.03	762.5	663.5	26.46	9716.3	

INJECTION

WELL	HOURS ON	MONTHLY INJECTION (M3)	INJECTION PER OPER. DAY (M3)	CUM. INJECTION (M3)	WELLHEAD INJECTION PRES (KPAG)	CALC B.H. INJ. PRES (KPAG)	INJECT INDEX (M3/D/KPA)	COMMENTS
5-4-2-25WPM	720	1277.4	42.58	4994.8	7300.0	16005.5	0.00337789	OK
11-4-2-25WPM	576	687.5	28.65	1644.6	220.0	8867.1	0.00760416	WELL FRACED
15-4-2-25WPM	720	879.9	29.33	2788.3	7600.0	16276.3	0.00330430	OK
16-5-2-25WPM	720	1154.6	38.49	4000.3	7200.0	15866.6	0.00341600	OK
'O INJECTOR	0	0.0	0.00	0.0	0.0	0.0	0.00000000	NO INJECTOR
		3999.4	139.04	13428.0				

ENRON WASKADA UNIT No.16 WATERFLOOD
INJECTION PATTERN SUMMARY

SEPTEMBER 1987

PATTERN NO. 1 5-4-2-25WPM

WELL	PERC. OF WELL IN PATTERN (%)	WITHDRAWLS MONTHLY (RM3)	CUM. (RM3)
3-4-2-25WPM	100.00	49.6	673.6
4-4-2-25WPM	100.00	154.1	2974.0
6-4-2-25WPM	50.00	156.6	1953.5
12-4-2-25WPM	37.50	36.1	859.7
9-5-2-25WPM	33.30	43.2	1964.7
5-4-2-25WPM	100.00	0.0	5553.6
		439.5	13979.2

TOTAL MONTH'S VOIDAGE = 439.5
TOTAL MONTH'S REPLACEMENT = 1282.6
MONTH'S REPLACEMENT RATIO = 2.91856

TOTAL CUMULATIVE VOIDAGE = 13979.2
TOTAL CUMULATIVE REPLACEMENT = 5015.1
CUMULATIVE REPLACEMENT RATIO = 0.35876

ENRON WASKADA UNIT No.16 WATERFLOOD
INJECTION PATTERN SUMMARY

SEPTEMBER 1987

PATTERN NO. 2   11-4-2-25WPM

WELL	PERC. OF WELL IN PATTERN (%)	WITHDRAWLS MONTHLY (RM3)	CUM. (RM3)
6-4-2-25WPM	50.00	156.6	1953.5
12-4-2-25WPM	37.50	36.1	859.7
13-4-2-25WPM	33.30	42.9	1659.5
14-4-2-25WPM	50.00	47.2	820.1
11-4-2-25WPM	100.00	0.0	889.6
		282.8	6182.4

TOTAL MONTH'S VOIDAGE = 282.8
TOTAL MONTH'S REPLACEMENT = 689.8
MONTH'S REPLACEMENT RATIO = 2.43936

TOTAL CUMULATIVE VOIDAGE = 6182.4
TOTAL CUMULATIVE REPLACEMENT = 1650.1
CUMULATIVE REPLACEMENT RATIO = 0.26691

ENRON WASKADA UNIT No.16 WATERFLOOD
INJECTION PATTERN SUMMARY

SEPTEMBER 1987

PATTERN NO. 3 15-4-2-25WPM

WELL	PERC. OF WELL IN PATTERN (%)	WITHDRAWLS MONTHLY (RM3)	CUM. (RM3)
14-4-2-25WPM	50.00	47.2	820.1
2-9-2-25WPM	100.00	116.4	2633.7
15-4-2-25WPM	100.00	0.0	505.0
		163.6	3958.8

TOTAL MONTH'S VOIDAGE = 163.6
TOTAL MONTH'S REPLACEMENT = 882.0
MONTH'S REPLACEMENT RATIO = 5.39005

TOTAL CUMULATIVE VOIDAGE = 3958.8
TOTAL CUMULATIVE REPLACEMENT = 2795.0
CUMULATIVE REPLACEMENT RATIO = 0.70601

ENRON WASKADA UNIT No.16 WATERFLOOD
INJECTION PATTERN SUMMARY

SEPTEMBER 1987

PATTERN NO. 4 16-5-2-25WPM

WELL	PERC. OF WELL IN PATTERN (%)	WITHDRAWLS MONTHLY (RM3)	CUM. (RM3)
12-4-2-25WPM	25.00	24.1	573.1
13-4-2-25WPM	66.70	85.9	3324.1
9-5-2-25WPM	66.70	86.5	3935.3
10-5-2-25WPM	100.00	57.2	691.6
15-5-2-25WPM	100.00	57.4	922.1
4-9-2-25WPM	100.00	322.7	7232.7
16-5-2-25WPM	100.00	0.0	1808.2
		633.7	18487.1

TOTAL MONTH'S VOIDAGE = 633.7
TOTAL MONTH'S REPLACEMENT = 1158.7
MONTH'S REPLACEMENT RATIO = 1.82848

TOTAL CUMULATIVE VOIDAGE = 18487.1
TOTAL CUMULATIVE REPLACEMENT = 4014.6
CUMULATIVE REPLACEMENT RATIO = 0.21716

ENRON WASKADA UNIT No.16 WATERFLOOD
INJECTION PATTERN SUMMARY

SEPTEMBER 1987

PATTERN NO. 5   NO INJECTOR

WELL	PERC. OF WELL IN PATTERN (%)	WITHDRAWLS MONTHLY (RM3)	CUM. (RM3)
9-4-2-25WPM	100.00	146.5	182.6
10-4-2-25WPM	100.00	250.6	313.8
16-4-2-25WPM	100.00	252.9	252.9
1-9-2-25WPM	100.00	291.8	435.3
3-9-2-25WPM	100.00	312.8	420.9
5-9-2-25WPM	100.00	114.1	2272.4
		1368.7	3877.8

TOTAL MONTH'S VOIDAGE = 1368.7
TOTAL MONTH'S REPLACEMENT = 0.0
MONTH'S REPLACEMENT RATIO = 0.00000

TOTAL CUMULATIVE VOIDAGE = 3877.8
TOTAL CUMULATIVE REPLACEMENT = 0.0
CUMULATIVE REPLACEMENT RATIO = 0.00000

Manitoba

Energy and Mines

Petroleum

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

(204) 945-6577

August 11, 1987

Enron Oil Canada Ltd.
1300, 700 - 9th Avenue S.W.
CALGARY, Alberta T2P 3V4

Attention: R.A. Smith

Re: Progress Reports
Waskada Unit No. 16 - Pressure Maintenance Project

It is noted that Enron has not yet submitted the required progress reports with respect to the subject pressure maintenance project.

Board Order No. PM 57 and attached Schedule authorize pressure maintenance operations for the subject Unit. Clause 6 of the Schedule requires monthly progress reports. Although much of the data to be incorporated in the required reports is otherwise submitted as part of the normal production report, the reports are intended to present this information in a manner to facilitate evaluation of the project's performance. Several acceptable formats of reports have been developed.

You are requested to submit the required reports for June and July as soon as possible, but not later than September 8, 1987. Reports for subsequent months are to be submitted prior to the end of the following month.

If you have any questions with regard to the foregoing, please contact me.

Yours sincerely,

L.R. Dubreuil
Chief Petroleum Engineer
Petroleum Division

LRD:dah

File "Enron P.M. - 0329A

Manitoba

Energy and Mines

Petroleum

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

(204) 945-6577

February 12, 1987

Enron Oil Canada Limited
1300, 700 - 9th Avenue S.W.
CALGARY, Alberta
T2P 3V4

Attention: R.A.W. Smith, P. Eng.
Senior Reservoir Engineer

Re: Waskada Lower Amaranth A Pool - Pressure Maintenance
Proposed Waskada Unit No. 16

Dear Rick:

Enclosed is Oil and Natural Gas Conservation Board Order No. PM 57 authorizing pressure maintenance operations in the subject proposed Unit.

Please note that you are not authorized to commence water injection until the Unit agreement has been approved by the Board.

Yours sincerely,

L.R. Dubreuil
Chief Petroleum Engineer
Petroleum Division

LRD:dah

encl

Manitoba

Action / Route Slip

Date: January 29, 1987

To: (1) Bill McDonald
(2) Charles S. Kang

From: H. Clare Moster
(prepared by L. R. Dubreuil)

Telephone:

☐ 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 ☐ Please File

Comments: Board Order No. PM 57

1. Bill's signature required on six copies of the Order.
2. Charle's signature required on six copies of the Order.
3. Minister's signature required on six copies of the Order.
4. Date six copies of the Order.
5. Certificates for Order to be completed and signed by Charles.
6. File Order with Registrar and return extra signed copies to Petroleum.

MG-1298 PS-f-182

Manitoba

Memorandum

Date January 29, 1987

To The Oil and Natural Gas Conservation Board

Charles S. Kang - Chairman
Wm. McDonald - Deputy Chairman
B. Ball - Member

From H. Clare Moster
Executive Director
Petroleum Division

Telephone

Subject

Proposed Waskada Unit No. 16 - Pressure Maintenance

Enron Oil Canada Ltd. (formerly Andex Oil Co. Ltd.) has made application to conduct pressure maintenance by waterflooding in the proposed Waskada Unit No. 16. Notice of the application was published in the Manitoba Gazette (September 27, 1986) and The Deloraine Times and Star (September 24, 1986). Copies of the notice were also sent to offsetting working interest owners.

As a result of concerns expressed by the Board and by Omega Hydrocarbons Ltd. (an offsetting operator), Enron has modified its application with respect to the injection pattern to be used. As a result of these adjustments, the expressed concerns have largely been allayed.

Recommendation:

It is recommended that the application be approved and that Board Order No. PM 57 (attached) be issued.

Discussion:

The Waskada Lower Amaranth A Pool has been extensively and successfully developed as an inverted nine spot water injection project. It is a generally accepted premise that all other things being equal, recovery can be maximized by use of a uniform or regular injection pattern.

Enron's original injection proposal (Fig. No. 1) was a significant departure from the standard nine spot pattern (Fig. No. 2) utilized elsewhere in the Pool. In choosing its original injectors, Enron applied a complex set of criteria (net pay, possible communication with the Mississippian, productivity, etc.). The analysis did not include, however, the effect of the non-standard pattern on areal sweep efficiency. Also, the effect of the proposal on offset operators was not considered. The Board in its letter of September 10, 1986 requested that Enron quantify the potential loss of recovery due to poorer areal sweep of the irregular pattern. In addition, Omega Hydrocarbons Ltd. objected to the proposal on the grounds that Enron's proposals would not maximize ultimate recovery.

As a result of the Board's comments and Omega's intervention, Enron, after extensive discussions with both Omega and the Petroleum Division, has modified the proposed injection pattern (Fig. No. 3). In addition, Enron conducted model studies which indicated that the proposed pattern achieved a higher ultimate recovery (i.e. - at 35 years) than either the standard pattern or the original proposal (see Fig. No. 4).

As a result of Enron's proposed modification, Omega withdrew its intervention subject to approval of the project by the Board.

Upon review of the model study submitted by Enron, it was noted that while recovery after 35 years of operation was maximized by Enron's proposal, recovery after 10 years was substantially greater if the standard inverted nine spot pattern was used. It was further noted that the reliability of model predictions of a 10 year time frame is much higher than 35 year prediction, particularly in view of the limited production history available to calibrate the model.

In choosing injection locations, one of Enron's prime considerations was avoidance of wells where the likelihood of communication between the Lower Amaranth and the underlying Mississippian was great. Enron felt that at such locations, a substantial portion of the injected water would enter the Mississippian and would therefore be ineffective in maintaining pressure in the Lower Amaranth.

During completion of Lower Amaranth wells in Waskada, a fracture treatment is required to enable the wells to produce at economic rates. In a conventional fracture treatment, fluid (usually a mixture of oil and water) and sand are pumped into a well in sufficicnt pressures to fracture the formation. The sand grains are used to hold the fractures open after the pressure has been released. One hazard of this procedure is that it is sometimes very difficult to confine the fracture to the zone being completed (i.e. - the Lower Amaranth). If the fracture is not confined, communication between two zones is then set up. In Waskada, porous zones in the Lower Amaranth and Mississippian are separated by an impermeable interval or cap rock which varies in thickness from 2 to over 10 m. Where this zone is thin as it is in much of the project area, the chance of a fracture treatment causing communication between the two zones is greater. In an attempt to avoid the problem of establishing communication between the zones, an alternate technique called "Stressfraccing" has been utilized. This technique employs an explosive charge to shatter the formation near the wellbore. Its effect diminishes rapidly in areas removed from the wellbore, thereby eliminating or minimizing the chance of communication occurring.

In the project area, the Mississippian below the cap rock is generally water bearing, whereas the Lower Amaranth appears to be producible at very low water cuts. Based on this, Enron has postulated that any well with a producing water cut of more than 10% is likely in communication with the Mississippian. In further support of this, Enron notes that all wells which have been Stressfracced have water cuts below 10% whereas a number of the wells which were subjected to a conventional fracture have higher watercuts (see Fig. No. 5).

In the project area, five wells (12-4, 13-4, 9-5, 15-5 and 16-5) have water cuts in excess of 10% with 13-4 having the highest water cut (52%).

Because of the high water-cut at 13-4 and the likelihood of Mississippian communication at this point, Enron contends that continuation of the already established 9 spot pattern into the project area is impractical and thus have proposed alternates.

As noted above, the model study predictions indicated a significant loss of recovery over the mid term of the proposed pattern were adopted. Enron noted, however, that loss of water to the Mississippian would make the standard pattern less efficient. In a second deficiency letter (undated) the Board requested Enron, through suggested adjustments to its model study, attempt to quantify the potential loss in recovery due to loss of injected fluid to the Mississippian. The resultant runs (Fig. No. 6) show that, assuming the amount of injected water entering the Mississippian is proportional to the wells producing water cut above 10%, recovery at 10 years will be higher with the proposed pattern than with the standard pattern.

Although it is not possible to declare with certainty that the proposed pattern will result in higher recovery, a careful review of all the evidence available suggests this is so. In further support of this, the proposed injection locations result in a partial staggered line drive (5-4, 11-4 and 15-4) which provides more efficient areal sweep, (compared to an invered nine spot) although complete production response may be delayed somewhat.

In view of the foregoing analysis, it is recommended that Enron's proposal be approved. Board Order No. PM 57 which includes the normal provisions for an Order of this type is attached and recommended for approval.

for H. Clare Moster

LRD/lk

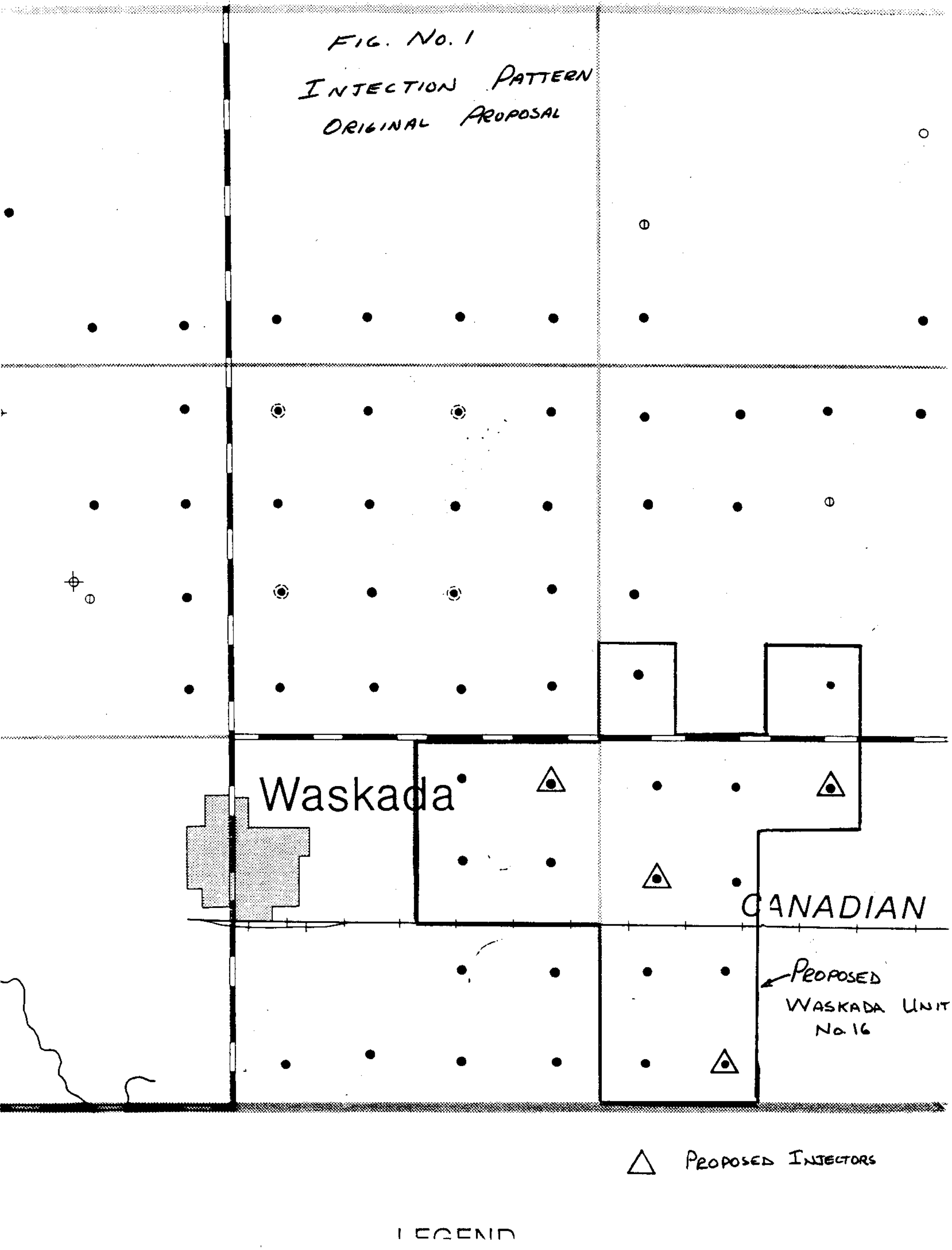
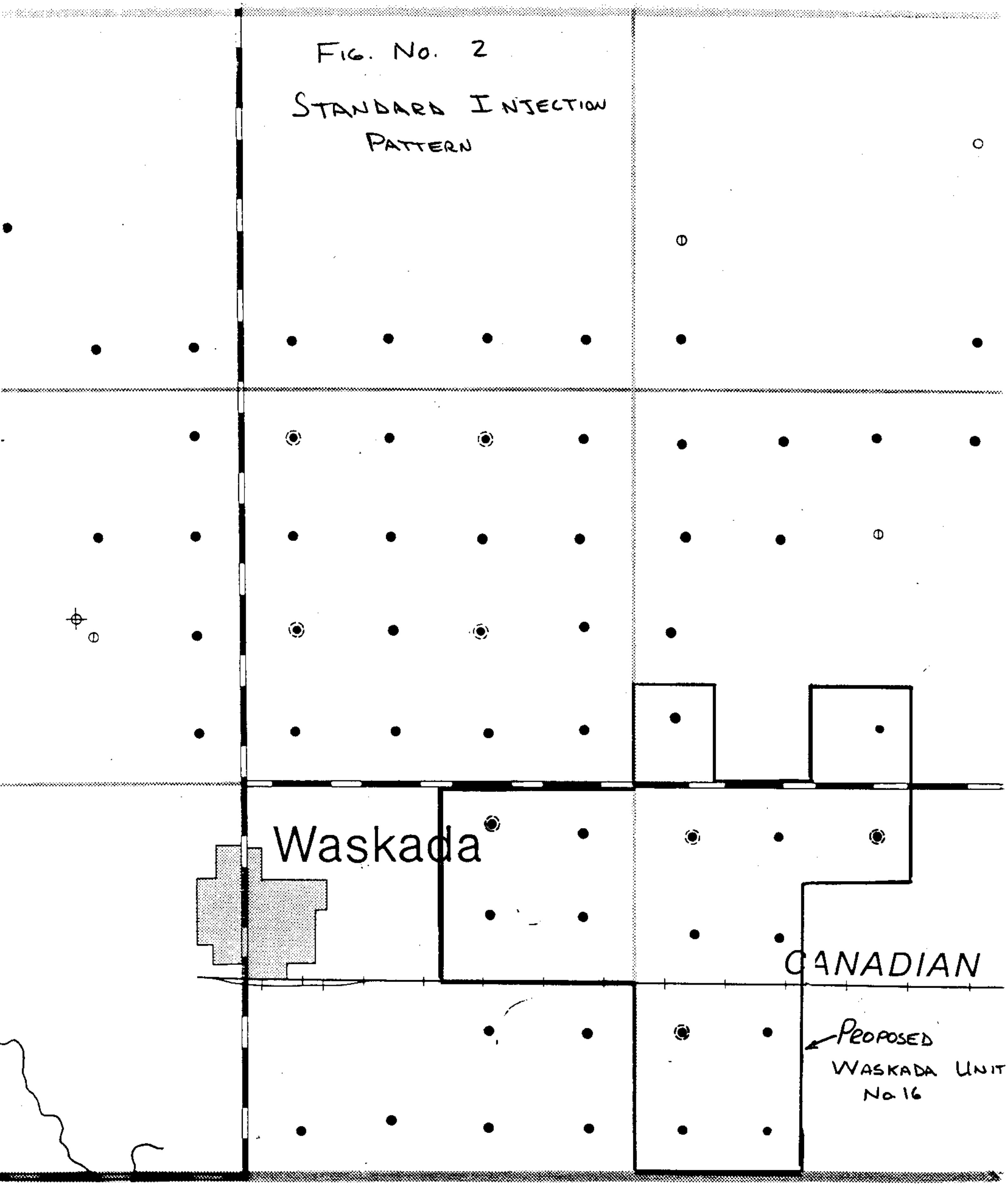


FIG. No. 1
INJECTION PATTERN
ORIGINAL PROPOSAL
Waskada
CANADIAN
PROPOSED
WASKADA UNIT
No. 16
PROPOSED INJECTORS
LEGEND

Fig. No. 2

Standard Injection Pattern



LEGEND

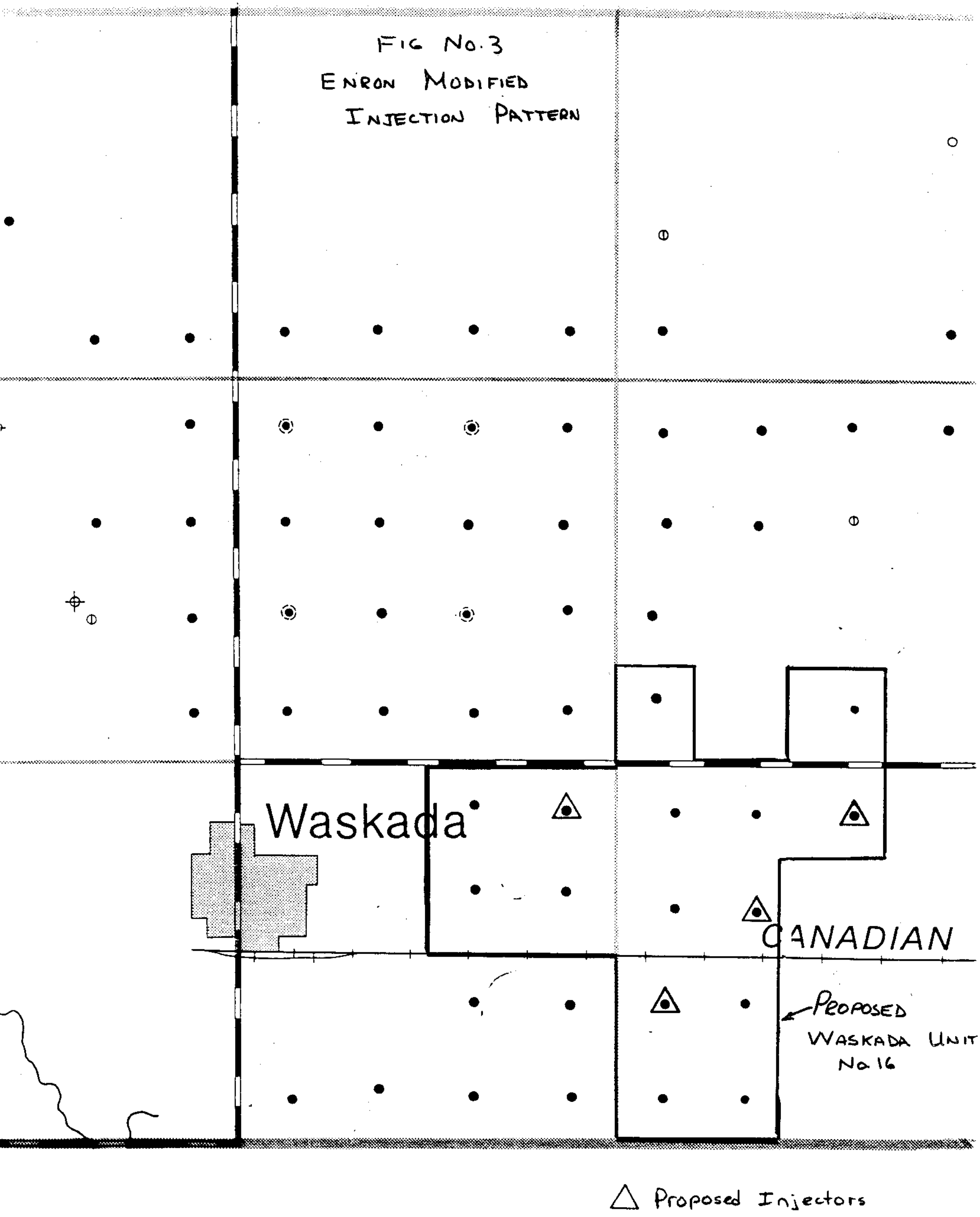


FIG No. 3
ENRON MODIFIED
INJECTION PATTERN
Waskada
CANADIAN
PROPOSED
WASKADA UNIT
No. 16
△ Proposed Injectors

LEGEND

WFLDCUMC.GPH

FIGURE No. 4

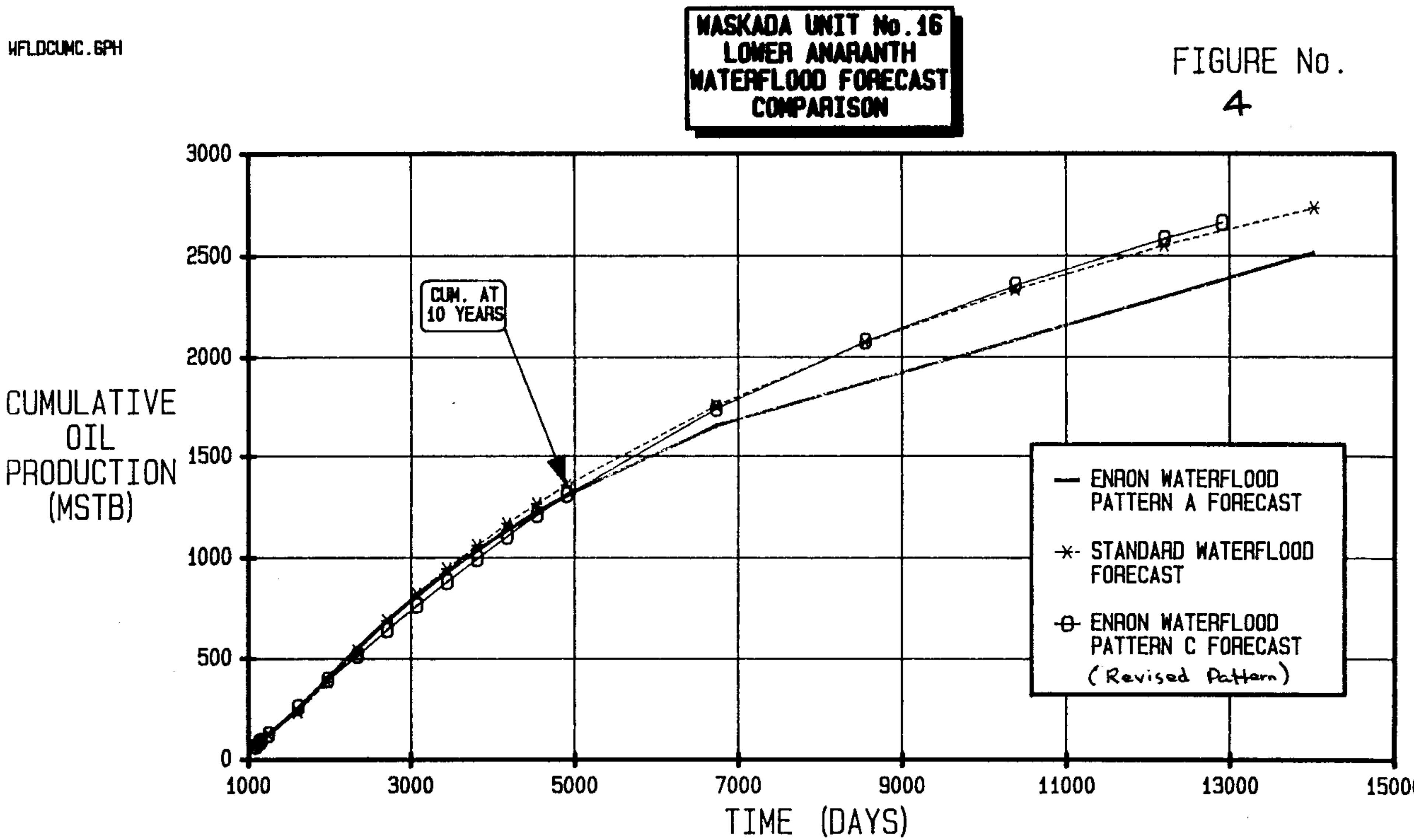
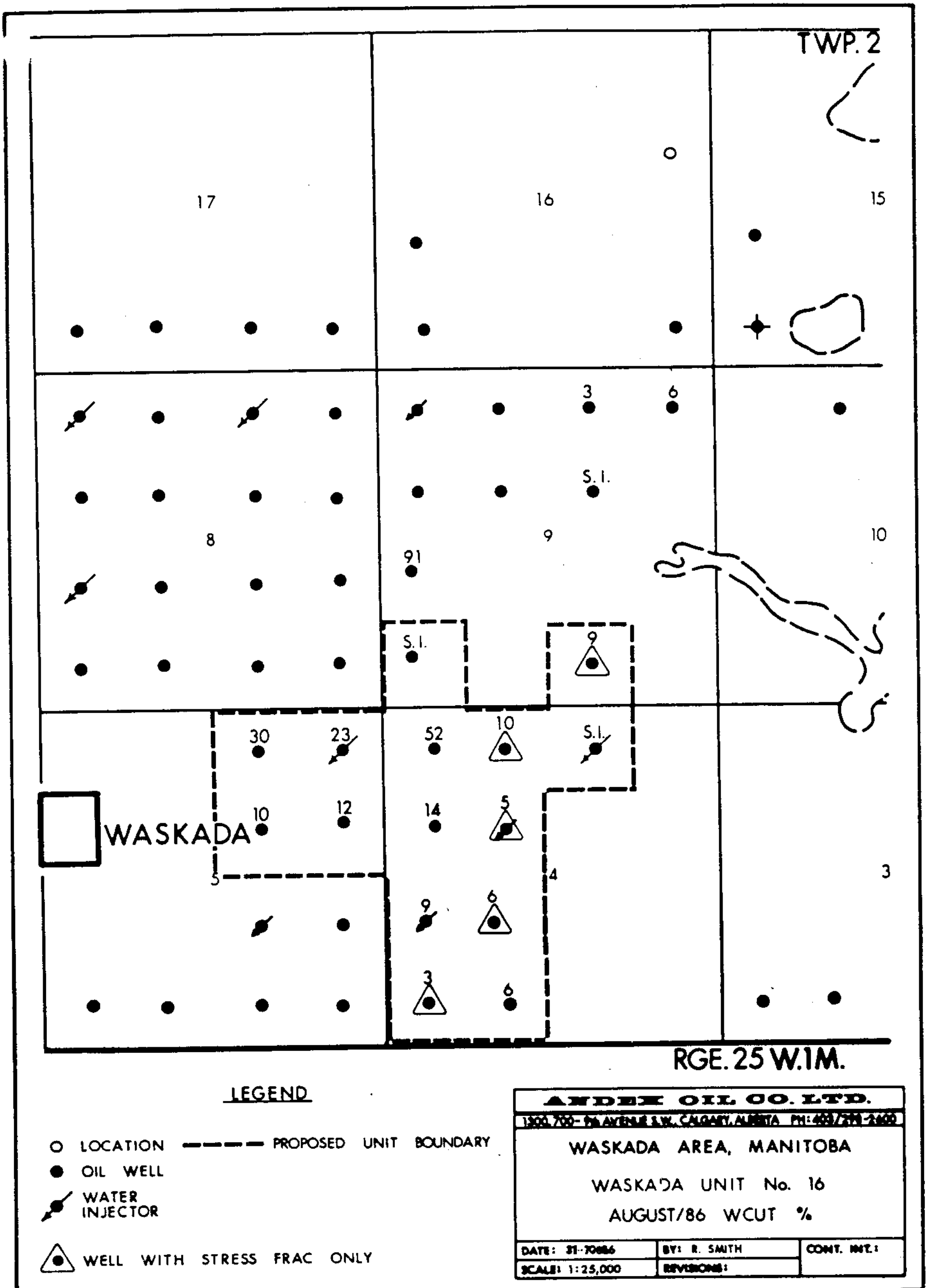
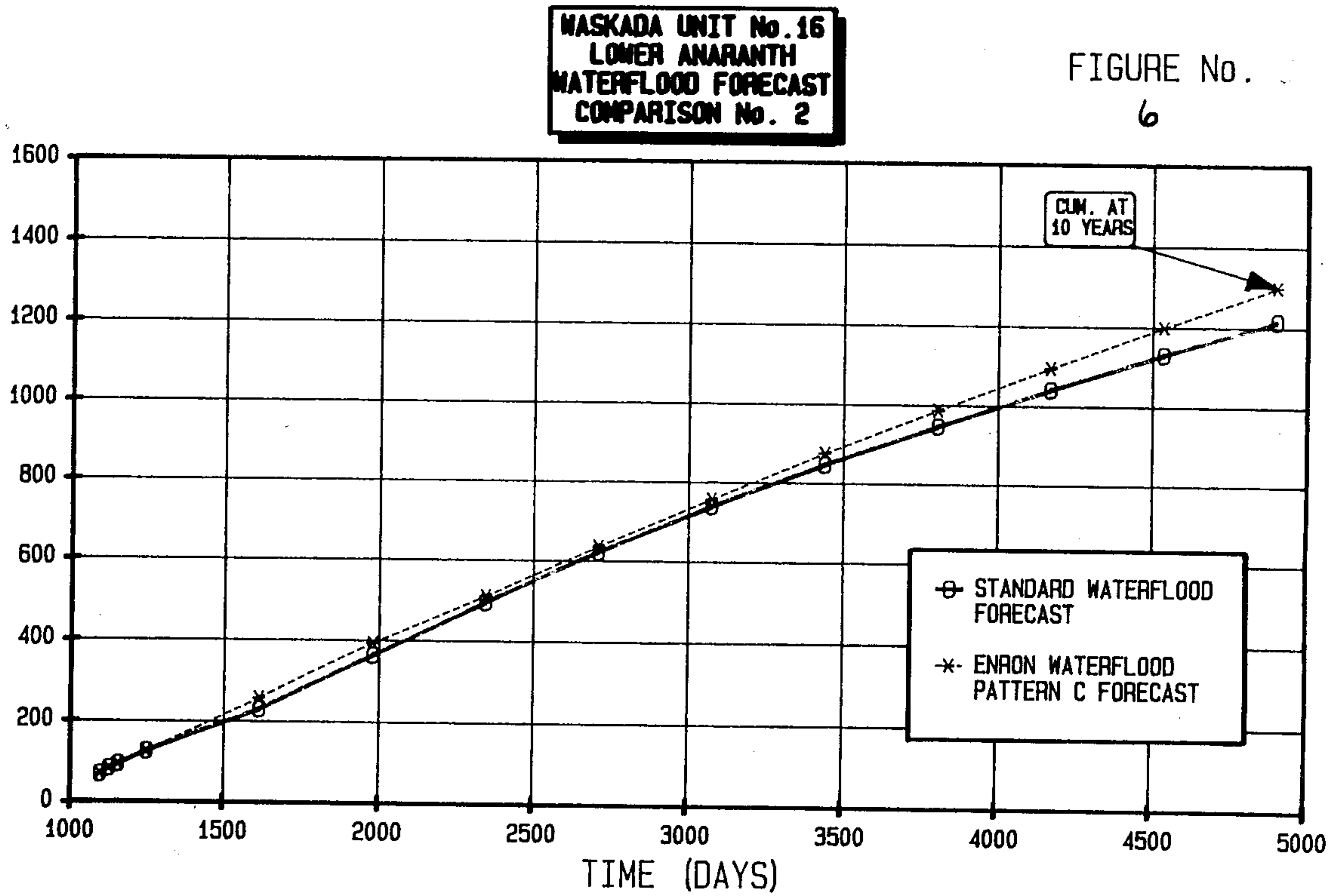


FIG. No. 5


TWP. 2
17
16
15
8
9
10
5
4
3
WASKADA
S.I.
RGE. 25 W.1M.
LEGEND
LOCATION
OIL WELL
WATER INJECTOR
WELL WITH STRESS FRAC ONLY
PROPOSED UNIT BOUNDARY
ANDEX OIL CO. LTD.
WASKADA AREA, MANITOBA
WASKADA UNIT No. 16
AUGUST/86 WCUT %
BY: R. SMITH
SCALE: 1:25,000
REVISIONS:
CONT. INT.:

WFLDCUM2.GPH

FIGURE No. 6



1. All things being equal, a ~~pa~~ regular pattern will give better areal sweep and therefore recovery than an irregular pattern.

2. The proposed pattern sets up a partial line drive (injectors 5-4, 11-4 + 15-4.
As the areal sweep for a line drive is ~~generally m~~ better than for a 9 spot, this tends to result in a better recovery in that part of the Unit.

3. A pattern flood will result in quicker response (i.e. no wells not offset by injector but a line drive will give better over all performance
This is illustrated by the model runs which ~~1~~ indicate higher earlier recovery for the 9 spot ~~and~~ but higher ultimate recovery for the modified.

4. Comparison of the saturation maps show ~~the~~ water bank developing in the modified case.

- The original model results are likely correct and if the flood is carried on long enough, ~~the~~ recovery will be increased of line drive However early recoveries would be higher for a 9 spot

- Enron contends that in some wells communication has been established with the Miss through a frac.

- Correlate WC with wells stress fracced. Ave WC = 6.6
normal frac " " 19.5

- There are definitely cases elsewhere in the field where communication exists between C. Am & Miss. and this has prob. been caused by fracs.

- In the study area, the cap rock - between top of Miss and top of MC porosity tends to be thinner than elsewhere in the field. Therefore it is prob. more likely that comm would occur in this area than elsewhere.

- Considering all of this Exxons contention that wells with higher WC are prob in comm with Miss is reasonable

- Omega has had good success in shutting off communication in producing wells. This has never been attempted in an injector

One would think that in an injector where the res is subject to much greater P than a producer, it might be difficult to shut off such communication.

- In summary Exxon's assumption of suspecting comm. where WC > 10% is prob. reasonable.

- Decreasing inject volumes to account for this (as per our method) results in higher recovery in proposed scheme

ENRON Oil Canada Ltd.

(403) 298-2600

13 January 1987

The Oil and Natural Gas Conservation Board
#555, 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Attention: Mr. Charles S. Kang,
Chairman

Dear Sir:

Re: Additional Information to
Waskada Lower Amaranth "A" Pool
Pressure Maintenance Application
Dated: August 13, 1986 (File 86-2)

In response to your letter (attached for reference) outlining the recovery concerns of Enron Oil Canada Ltd.'s pattern "C" compared to the standard, we have rerun both the standard and "C" runs (for ten years only) to incorporate an injection loss. The methodology used was as per your Attachment #3. The results of the new runs are summarized as follows:

Injection Data (10 years)

	Changed Wells	Previous Run Cum Injection	Current Run Cum Injection	Percent Change
Standard Pattern:				
	3-4	1100 MSTB	549 MSTB	49.9
	15-5	45.7 MSTB	39.2 MSTB	85.8
Enron "C":				
	16-5	351.5 MSTB	326.6 MSTB	92.9

Production Data (10 years)

	Standard Pattern Cum Oil Recovered		Enron Pattern "C" Cum Oil Recovered	
Gathering Centre	Previous	Current	Previous	Current
Enron Unit wells	1356 MSTB	1216 MSTB	1309 MSTB	1299 MSTB
Enron non-Unit wells	167 MSTB	149 MSTB	157 MSTB	155 MSTB
Omega wells	775 MSTB	732 MSTB	761 MSTB	757 MSTB
Total	2298 MSTB	2097 MSTB	2227 MSTB	2211 MSTB

1300, 700 - 9th Avenue S.W., Calgary, Alberta T2P 3V4

As shown in Figure 1, the percent recovery of the Enron pattern "C" is 12.47% at ten years using the current run compared to 11.67% for the standard pattern case.

The ten year results of the model substantiates that, 1) without the potential water injection loss to the Mississippian, the standard pattern does indeed yield the best ultimate recovery; and 2) a modified pattern that reduces injection losses can actually recover more oil within the ten year window. Using the recommended Enron "C" pattern yields an incremental increase of 114 MSTB over the standard pattern during the ten year period.

Detailed recoveries are exhibited on Tables 1 and 2 and Figures 1 through 3 as attached. Also included are the saturation and pressure maps (Tables 3 and 4) at the end of the ten year runs.

Yours very truly,

ENRON OIL CANADA LTD.

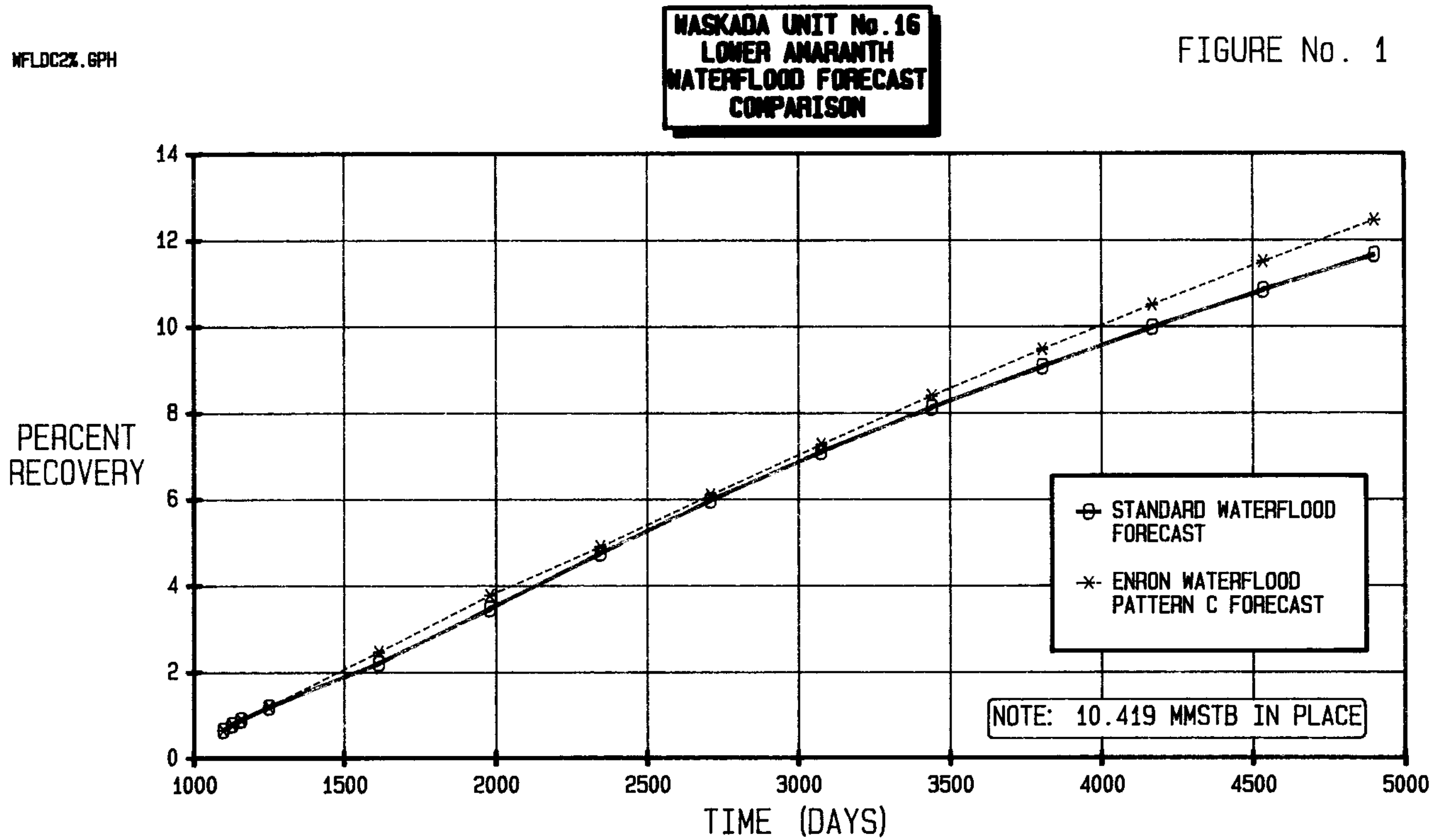
R.A.W. Smith, P.Eng.
Senior Reservoir Engineer

RAWS:pdc
attach

cc: Audax Gas & Oil Ltd., Attention: Mr. P.E. McComb
Chauvco Resources Ltd., Attention: Mr. E.A. Beaman
Consolidated Pipe Lines Company, Attention: Mr. P. Sidey
Highridge Exploration Ltd., Attention: Mr. R.T. Vanderham

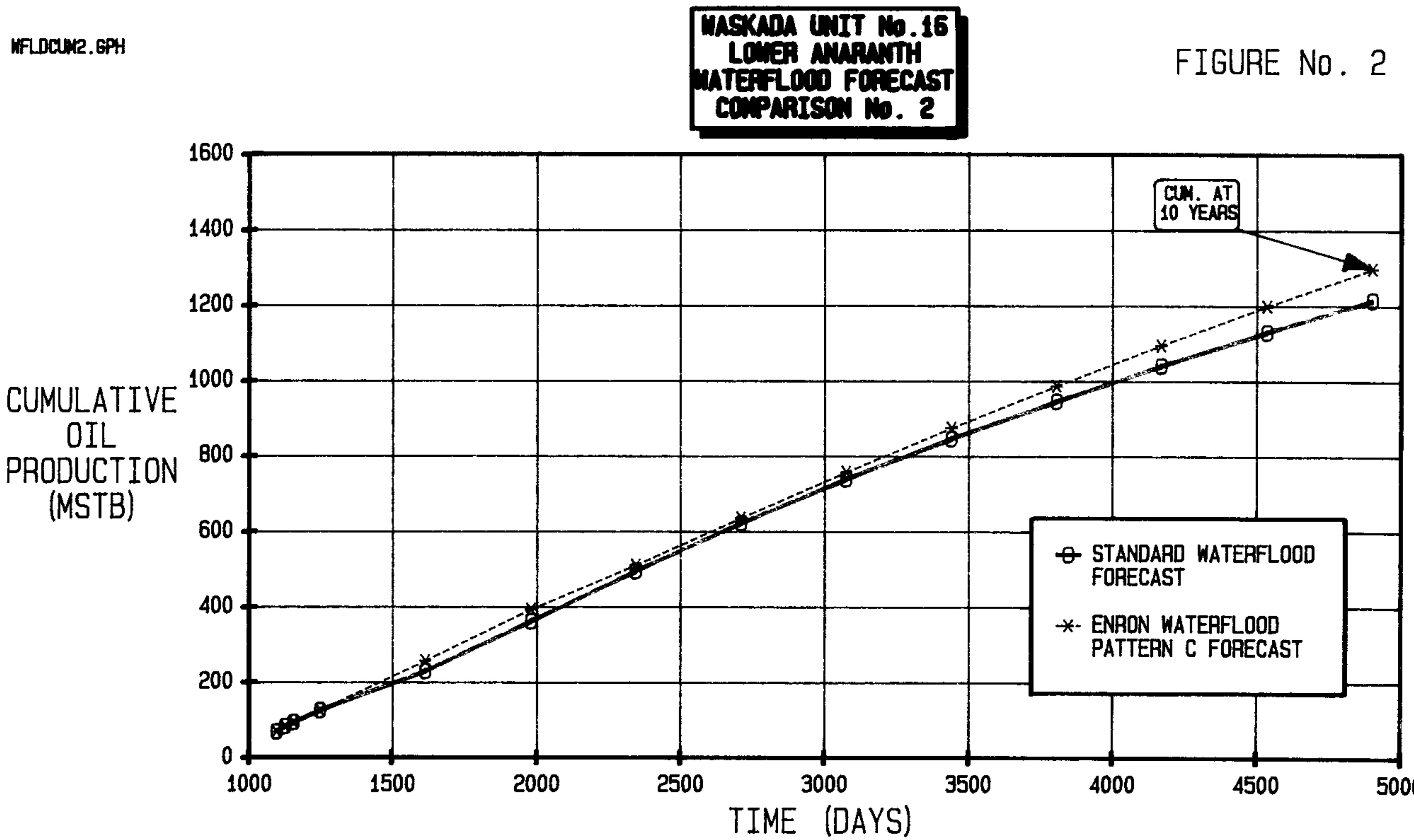
WFLDC2%.GPH

FIGURE No. 1



WFLDCUM2.GPH

FIGURE No. 2



WRATEC2.GPH

FIGURE No. 3

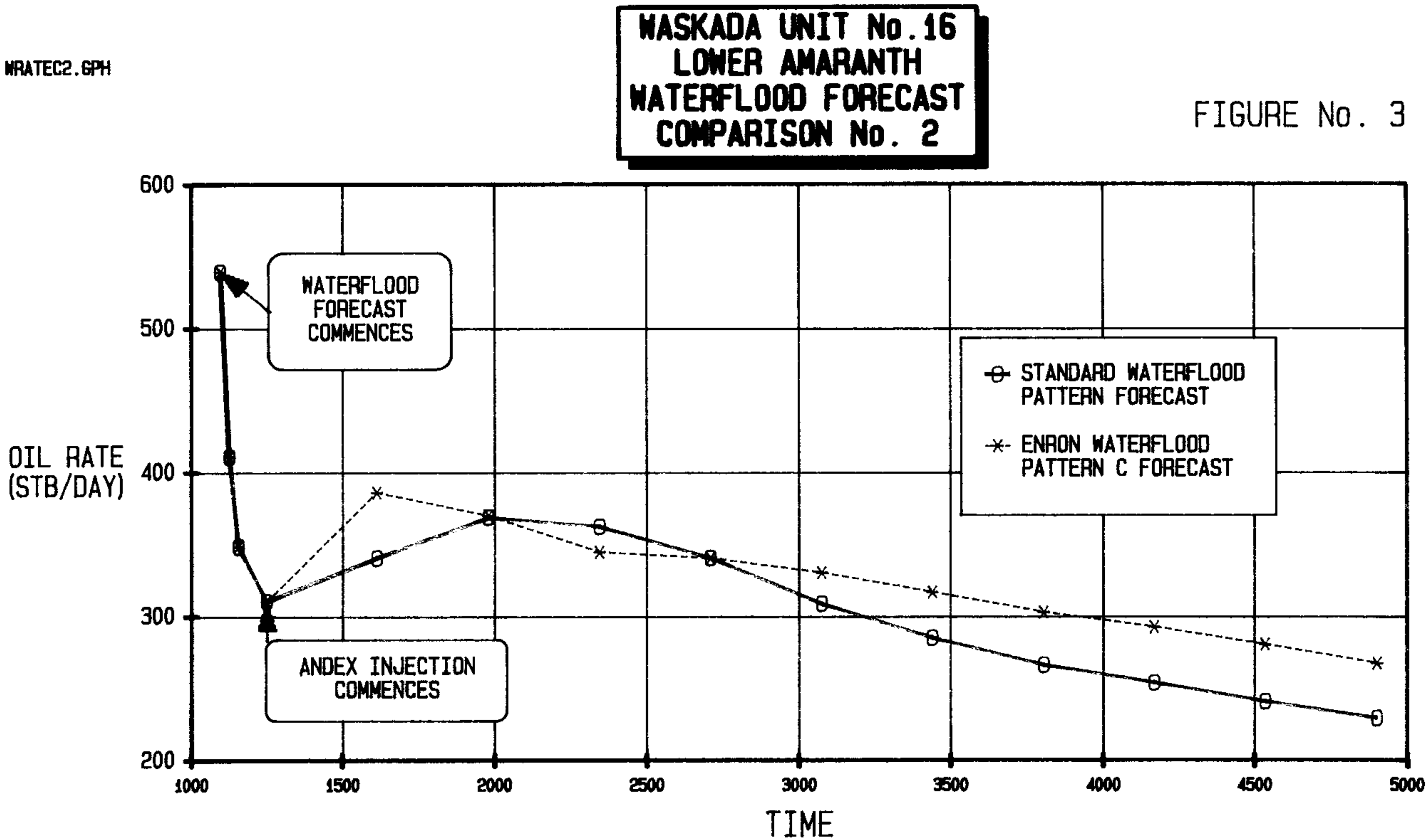


TABLE # 1

LEGEND
1 OMEGA WELLS
2 ANDEX UNIT WELLS
3 ANDEX NON-UNIT WELLS

Waskada Spearfish Standard Waterflood Pattern Forecast

TIME = 1096. DAYS (JULY, 1986)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	1096.	236.8	161.19	0.07	46.47	37.4	14.24	0.	0.	-550.0	-99.05
2	1096.	539.6	69.19	0.15	26.22	72.0	7.75	0.	0.	0.	0.
3	1096.	54.2	12.26	0.02	3.53	4.6	0.82	0.	0.	0.	0.

TIME = 1126. DAYS (AUG , 1986)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	1126.	224.1	168.02	0.06	48.44	36.5	15.34	0.	0.	-550.0	-115.55
2	1126.	411.1	82.81	0.18	31.54	73.3	10.00	0.	0.	0.	0.
3	1126.	47.3	13.74	0.01	3.95	4.2	0.94	0.	0.	0.	0.

TIME = 1156. DAYS (SEP , 1986)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	1156.	220.1	174.65	0.06	50.35	36.7	16.44	0.	0.	-550.0	-132.05
2	1156.	348.8	93.67	0.16	36.55	69.2	12.11	0.	0.	0.	0.
3	1156.	57.8	15.50	0.02	4.46	5.1	1.10	0.	0.	0.	0.

TIME = 1249. DAYS (DEC , 1986)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	1249.	224.6	195.29	0.06	56.30	39.3	19.10	0.	0.	-775.0	-203.25
2	1249.	310.5	125.25	0.14	50.72	57.2	18.72	0.	0.	0.	0.
3	1249.	50.5	20.45	0.02	5.99	4.7	1.55	0.	0.	0.	0.

TABLE # 1 cont'd

LEGEND
1 OMEGA WELLS
2 ANDEX UNIT WELLS
3 ANDEX NON-UNIT WELLS

Waskada Spearfish Standard Waterflood Pattern Forecast

TIME = 1614. DAYS (DEC , 1987)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION						INJECTION			
		OIL		GAS		WATER		GAS		WATER	
		RATE (STB/DAY)	CUMULATIVE (MSTB)	RATE (MMCF/DAY)	CUMULATIVE (MMCF)	RATE (STB/DAY)	CUMULATIVE (MSTB)	RATE (MMCF/DAY)	CUMULATIVE (MMCF)	RATE (STB/DAY)	CUMULATIVE (MSTB)
1	1614.	237.8	273.71	0.07	78.88	67.6	35.83	0.	0.	-1000.0	-566.22
2	1614.	340.8	229.73	0.10	86.55	33.2	24.41	0.	0.	-633.3	-189.10
3	1614.	41.6	36.26	0.01	11.42	3.9	3.08	0.	0.	0.	0.

TIME = 1979. DAYS (DEC , 1988)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION						INJECTION			
		OIL		GAS		WATER		GAS		WATER	
		RATE (STB/DAY)	CUMULATIVE (MSTB)	RATE (MMCF/DAY)	CUMULATIVE (MMCF)	RATE (STB/DAY)	CUMULATIVE (MSTB)	RATE (MMCF/DAY)	CUMULATIVE (MMCF)	RATE (STB/DAY)	CUMULATIVE (MSTB)
1	1979.	195.6	350.63	0.06	100.99	82.5	63.68	0.	0.	-307.1	-684.24
2	1979.	369.0	361.96	0.10	123.85	55.3	40.96	0.	0.	-620.4	-415.55
3	1979.	37.8	50.19	0.01	15.93	3.1	4.27	0.	0.	0.	0.

TIME = 2344. DAYS (DEC , 1989)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION						INJECTION			
		OIL		GAS		WATER		GAS		WATER	
		RATE (STB/DAY)	CUMULATIVE (MSTB)	RATE (MMCF/DAY)	CUMULATIVE (MMCF)	RATE (STB/DAY)	CUMULATIVE (MSTB)	RATE (MMCF/DAY)	CUMULATIVE (MMCF)	RATE (STB/DAY)	CUMULATIVE (MSTB)
1	2344.	172.0	416.23	0.05	119.85	95.0	96.81	0.	0.	-293.4	-793.53
2	2344.	362.6	495.38	0.10	161.06	83.2	67.53	0.	0.	-620.4	-641.99
3	2344.	36.7	63.72	0.01	20.38	2.9	5.36	0.	0.	0.	0.

TIME = 2709. DAYS (DEC , 1990)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION						INJECTION			
		OIL		GAS		WATER		GAS		WATER	
		RATE (STB/DAY)	CUMULATIVE (MSTB)	RATE (MMCF/DAY)	CUMULATIVE (MMCF)	RATE (STB/DAY)	CUMULATIVE (MSTB)	RATE (MMCF/DAY)	CUMULATIVE (MMCF)	RATE (STB/DAY)	CUMULATIVE (MSTB)
1	2709.	155.7	475.13	0.04	136.79	103.1	133.43	0.	0.	-282.9	-898.46
2	2709.	340.8	622.59	0.10	196.85	103.1	102.41	0.	0.	-561.1	-846.79
3	2709.	36.0	76.97	0.01	24.66	2.7	6.37	0.	0.	0.	0.

TABLE # 1 cont'd

LEGEND
1 OMEGA WELLS
2 ANDEX UNIT WELLS
3 ANDEX NON-UNIT WELLS

Waskada Spearfish Standard Waterflood Pattern Forecast

TIME = 3074. DAYS (DEC , 1991)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	3074.	142.3	528.84	0.04	152.24	109.6	172.59	0.	0.	-274.1	-999.95
2	3074.	308.9	739.42	0.09	229.98	118.7	143.61	0.	0.	-471.1	-1018.75
3	3074.	35.1	89.92	0.01	28.79	2.6	7.33	0.	0.	0.	0.

TIME = 3439. DAYS (DEC , 1992)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	3439.	130.6	578.02	0.04	166.39	115.1	213.91	0.	0.	-266.1	-1098.38
2	3439.	285.4	846.62	0.08	260.34	134.4	190.56	0.	0.	-471.1	-1190.70
3	3439.	33.9	102.47	0.01	32.82	2.4	8.24	0.	0.	0.	0.

TIME = 3804. DAYS (DEC , 1993)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	3804.	117.6	622.14	0.03	179.08	117.8	256.32	0.	0.	-253.2	-1191.93
2	3804.	266.5	946.36	0.08	288.62	149.3	243.11	0.	0.	-471.1	-1362.65
3	3804.	32.8	114.60	0.01	36.79	2.3	9.11	0.	0.	0.	0.

TIME = 4169. DAYS (DEC , 1994)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	4169.	104.0	661.79	0.03	190.49	70.6	286.95	0.	0.	-192.1	-1269.01
2	4169.	254.2	1040.69	0.07	315.26	169.5	302.03	0.	0.	-471.1	-1534.60
3	4169.	31.8	126.35	0.01	40.70	2.3	9.95	0.	0.	0.	0.

TABLE # 1 cont'd

LEGEND
1 OMEGA WELLS
2 ANDEX UNIT WELLS
3 ANDEX NON-UNIT WELLS

Waskada Spearfish Standard Waterflood Pattern Forecast

TIME = 4534. DAYS (DEC , 1995)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	4534.	96.3	697.94	0.03	200.90	70.4	312.65	0.	0.	-182.7	-1337.17
2	4534.	241.2	1130.40	0.07	340.71	186.1	367.84	0.	0.	-471.1	-1706.55
3	4534.	30.8	137.72	0.01	44.56	2.2	10.76	0.	0.	0.	0.

TIME = 4899. DAYS (DEC , 1996)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	4899.	90.0	731.58	0.03	210.58	70.5	338.35	0.	0.	-175.3	-1402.31
2	4899.	229.6	1215.67	0.07	364.95	199.7	438.96	0.	0.	-471.1	-1878.50
3	4899.	29.8	148.73	0.01	48.38	2.1	11.54	0.	0.	0.	0.

TABLE # 2

LEGEND
1 OMEGA WELLS
2 ANDEX UNIT WELLS
3 ANDEX NON-UNIT WELLS

Waskada Spearfish ANDEX Waterflood Pattern Forecast 'C'

TIME = 1096. DAYS (JULY, 1986)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	1096.	236.8	161.19	0.07	46.47	37.4	14.24	0.	0.	-550.0	-99.05
2	1096.	539.6	69.19	0.15	26.22	72.0	7.75	0.	0.	0.	0.
3	1096.	54.2	12.26	0.02	3.53	4.6	0.82	0.	0.	0.	0.

TIME = 1126. DAYS (AUG , 1986)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	1126.	224.1	168.02	0.06	48.44	36.5	15.34	0.	0.	-550.0	-115.55
2	1126.	411.1	82.81	0.18	31.54	73.3	10.00	0.	0.	0.	0.
3	1126.	47.3	13.74	0.01	3.95	4.2	0.94	0.	0.	0.	0.

TIME = 1156. DAYS (SEP , 1986)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	1156.	220.1	174.65	0.06	50.35	36.7	16.44	0.	0.	-550.0	-132.05
2	1156.	348.8	93.67	0.16	36.55	69.2	12.11	0.	0.	0.	0.
3	1156.	57.8	15.50	0.02	4.46	5.1	1.10	0.	0.	0.	0.

TIME = 1249. DAYS (DEC , 1986)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	OIL CUMULATIVE (MSTB)	GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	GAS CUMULATIVE (MMCF)	WATER RATE (STB/DAY)	WATER CUMULATIVE (MSTB)
1	1249.	224.6	195.29	0.06	56.30	39.3	19.10	0.	0.	-775.0	-203.25
2	1249.	310.5	125.25	0.14	50.72	57.2	18.72	0.	0.	0.	0.
3	1249.	50.5	20.45	0.02	5.99	4.7	1.55	0.	0.	0.	0.

TABLE #2 cont'd

LEGEND
1 OMEGA WELLS
2 ANDEX UNIT WELLS
3 ANDEX NON-UNIT WELLS

Waskada Spearfish ANDEX Waterflood Pattern Forecast 'C'

TIME = 1614. DAYS (DEC , 1987) — MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	1614.	240.4	274.59	0.07	79.13	69.5	36.10	0.	0.	-1000.0	-566.22
2	1614.	386.3	256.95	0.11	92.87	209.4	53.09	0.	0.	-914.5	-281.80
3	1614.	41.6	36.27	0.01	11.42	3.9	3.08	0.	0.	0.	0.

TIME = 1979. DAYS (DEC , 1988) — MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	1979.	198.4	352.53	0.06	101.53	89.1	65.78	0.	0.	-318.0	-686.39
2	1979.	370.0	393.43	0.10	131.14	300.8	151.44	0.	0.	-877.3	-602.02
3	1979.	37.5	50.12	0.01	15.93	3.1	4.27	0.	0.	0.	0.

TIME = 2344. DAYS (DEC , 1989) — MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	2344.	178.7	420.14	0.05	120.97	106.1	102.34	0.	0.	-310.5	-800.35
2	2344.	344.8	510.81	0.10	163.80	275.8	212.83	0.	0.	-858.7	-907.66
3	2344.	36.4	63.54	0.01	20.36	2.9	5.36	0.	0.	0.	0.

TIME = 2709. DAYS (DEC , 1990) — MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	2709.	163.7	481.84	0.05	138.72	116.7	143.56	0.	0.	-304.4	-912.47
2	2709.	340.6	635.96	0.10	198.90	329.4	326.48	0.	0.	-858.7	-1221.09
3	2709.	36.0	76.73	0.01	24.65	2.7	6.37	0.	0.	0.	0.

TABLE # 2 cont'd

LEGEND
1 OMEGA WELLS
2 ANDEX UNIT WELLS
3 ANDEX NON-UNIT WELLS

Waskada Spearfish ANDEX Waterflood Pattern Forecast 'C'

TIME = 3074. DAYS (DEC , 1991)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	3074.	150.8	538.55	0.04	155.03	125.7	188.25	0.	0.	-298.6	-1022.36
2	3074.	330.3	757.77	0.09	233.32	366.7	455.29	0.	0.	-858.7	-1534.51
3	3074.	36.0	89.88	0.01	28.79	2.6	7.33	0.	0.	0.	0.

TIME = 3439. DAYS (DEC , 1992)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	3439.	140.4	591.13	0.04	170.16	133.9	236.03	0.	0.	-294.6	-1130.48
2	3439.	316.9	875.34	0.09	266.67	396.1	596.08	0.	0.	-858.7	-1847.94
3	3439.	36.1	103.04	0.01	32.85	2.5	8.24	0.	0.	0.	0.

TIME = 3804. DAYS (DEC , 1993)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	3804.	125.5	639.31	0.04	184.03	85.1	277.31	0.	0.	-230.2	-1227.28
2	3804.	303.0	987.35	0.09	298.50	426.6	747.42	0.	0.	-858.7	-2161.36
3	3804.	36.0	116.20	0.01	36.86	2.4	9.13	0.	0.	0.	0.

TIME = 4169. DAYS (DEC , 1994)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	4169.	109.3	681.84	0.03	196.27	79.9	307.36	0.	0.	-206.3	-1306.72
2	4169.	292.7	1095.47	0.08	329.29	448.8	908.49	0.	0.	-848.7	-2471.14
3	4169.	35.8	129.29	0.01	40.82	2.3	10.00	0.	0.	0.	0.

TABLE # 2 cont'd

LEGEND
1 OMEGA WELLS
2 ANDEX UNIT WELLS
3 ANDEX NON-UNIT WELLS

Waskada Spearfish ANDEX Waterflood Pattern Forecast 'C'

TIME = 4534. DAYS (DEC , 1995)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	4534.	102.8	720.21	0.03	207.31	81.5	336.86	0.	0.	-200.2	-1380.73
2	4534.	280.6	1199.45	0.08	358.96	469.0	1077.07	0.	0.	-848.7	-2780.92
3	4534.	35.4	142.27	0.01	44.76	2.3	10.84	0.	0.	0.	0.

TIME = 4899. DAYS (DEC , 1996)

MATERIAL BALANCES

GATHERING CENTER NUMBER		PRODUCTION OIL RATE (STB/DAY)	PRODUCTION OIL CUMULATIVE (MSTB)	PRODUCTION GAS RATE (MMCF/DAY)	PRODUCTION GAS CUMULATIVE (MMCF)	PRODUCTION WATER RATE (STB/DAY)	PRODUCTION WATER CUMULATIVE (MSTB)	INJECTION GAS RATE (MMCF/DAY)	INJECTION GAS CUMULATIVE (MMCF)	INJECTION WATER RATE (STB/DAY)	INJECTION WATER CUMULATIVE (MSTB)
1	4899.	97.7	756.54	0.03	217.77	83.5	367.06	0.	0.	-196.1	-1452.93
2	4899.	267.6	1298.87	0.08	387.35	488.4	1252.78	0.	0.	-848.7	-3090.69
3	4899.	35.1	155.13	0.01	48.68	2.3	11.67	0.	0.	0.	0.

TABLE #3

Waskada Spearfish Standard Waterflood Forecast Pattern

Waskada Spearfish Standard Waterflood Forecast 4899.00 DAYS PRESSURES (PSIA) LAYER # 1 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	1290.1	1282.3	1263.0	1241.3	1211.1	1189.0	1169.5	1143.7	1094.3	1007.2	899.8	724.0	641.6	549.9	515.0	499.8	471.8
(2)	1290.3	1288.7	1274.8	1265.0	1194.3	1177.4	1176.3	1173.2	1160.8	1019.9	850.7	726.8	612.8	517.5	495.3	480.4	437.9
(3)	1290.9	1302.7	1274.0	1255.0	1075.5	1140.6	1183.5	1191.5	1172.8	968.5	645.8	[illegible]	564.6	418.5	475.4	460.8	355.5
(4)	1278.4	1262.4	1255.2	1244.3	1163.0	1153.7	1172.0	1166.9	1058.0	903.0	739.6	[illegible]	606.6	537.0	517.6	502.5	454.2
(5)	1277.6	1207.4	1247.6	1205.6	1117.8	1120.9	1108.9	1074.1	948.8	801.9	640.6	662.8	683.0	562.0	572.5	575.6	564.3
(6)	1332.9	1331.3	1327.2	1280.4	1174.3	1124.1	1085.4	1026.3	913.2	843.9	287.7	749.3	700.5	667.2	642.8	623.9	611.6
(7)	1337.1	1338.3	1331.7	1290.0	1149.6	1094.9	1050.6	1003.7	928.8	901.0	863.8	813.7	754.0	696.7	671.0	656.7	649.5
(8)	1338.0	1336.1	1300.7	1255.5	1126.2	1061.5	1045.2	939.8	787.1	981.4	955.6	895.0	787.6	645.8	647.8	664.2	667.4
(9)	1337.7	1297.8	1256.0	1143.8	1027.3	1009.2	968.8	[illegible]	861.9	1148.2	1132.0	1080.4	926.9	347.5	611.1	697.1	686.1
(10)	1684.9	2422.3	1490.0	1070.7	894.5	1039.6	1392.3	1417.2	1360.8	1301.6	1277.4	1271.4	1273.7	1533.1	1071.1	775.4	
(11)	2452.7	2462.9	2435.3	967.8	[illegible]	979.2	1443.0	1449.7	1443.3	1426.3	1376.6	1389.6	1531.8	1584.4	1570.8	839.6	
(12)	1865.9	2434.9	1669.6	1230.3	1062.1	1120.5	1436.7	1443.5	1437.1	1427.1	1396.4	1389.9	1393.3	1572.8	1233.7	863.7	
(13)	1674.8	1671.7	1669.9	1665.5	1030.8	1128.3	1401.2	1430.0	1428.1	1414.1	1383.8	1353.5	1249.7	1222.1	1219.2		
(14)	1677.8	1673.8	1671.8	1665.7	[illegible]	912.8	924.5	240.1	893.4	1008.9	764.9	962.6	1059.3	1083.7			
(15)	1687.3	1688.2	1685.0	1683.6	1366.3	1450.7	1544.1	1607.4	1645.1	1511.5	1250.7	1111.9	1072.5	1073.3			
(16)	1697.2	1702.8	1700.2	1702.5	1855.2	2027.1	2237.3	2416.7	2292.6	2138.4	1373.1	1131.9	1024.6				
(17)	1704.7	1708.9	1709.4	1745.8	1973.1	2202.8	2428.2	2434.9	2414.2	2130.1	122.4	763.6	982.5				
(18)	1679.7	1687.6	1707.5	1790.2	1928.1	2081.3	2235.7	2380.1	2215.8	2075.2	1334.3	1116.3	1033.1				
(19)	1416.4	1431.7	1519.1	1618.2	1718.3	1819.3	1936.2	1942.0	1842.0	1339.6	1223.6	1138.3	1080.8				
(20)	1173.5	1043.4	1221.2	1306.1	1267.7	1358.2	1133.2	1344.7	869.0	1087.2	1033.6	1056.2	1058.2				
(21)	1140.5	1117.4	1162.6	1194.8	1193.0	1171.8	1041.9	748.4	864.7	1005.1	1017.9	1032.9	1040.5				

PRESSURES (PSIA) LAYER # 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	1464.0	1453.3	1429.6	1400.9	1356.8	1317.3	1278.5	1232.2	1161.7	1052.0	941.1	851.2	769.4	687.9	646.0	624.9	588.5
(2)	1452.0	1448.7	1432.5	1420.8	1332.2	1299.2	1277.0	1269.2	1247.9	1055.9	880.5	806.5	733.5	648.6	622.3	603.5	553.4
(3)	1451.1	1461.1	1430.4	1407.9	1191.3	1251.9	1287.6	1292.5	1268.3	1016.4	677.7	724.9	674.0	515.6	599.5	587.6	452.7
(4)	1437.2	1418.0	1411.2	1399.5	1301.8	1286.8	1283.4	1272.7	1168.9	1014.2	862.9	810.7	762.6	691.1	679.4	667.8	616.2
(5)	1437.8	1355.5	1404.6	1366.1	1277.4	1283.9	1268.6	1234.8	1150.5	1028.0	845.3	881.1	850.0	754.6	777.8	794.2	788.1
(6)	1496.6	1494.0	1489.1	1444.3	1355.9	1316.6	1285.9	1249.2	1199.4	1145.7	1084.8	1041.0	986.3	921.7	885.1	862.7	850.0
(7)	1501.3	1502.1	1495.5	1451.3	1330.9	1315.3	1295.8	1278.2	1268.8	1272.7	1244.9	1191.4	1109.8	1012.9	959.8	930.6	915.2
(8)	1502.7	1499.2	1467.9	1434.0	1351.4	1316.7	1299.8	1231.2	1300.7	1447.5	1427.2	1357.7	1220.3	989.4	970.1	984.8	971.1
(9)	1504.1	1452.3	1444.1	1376.5	1284.0	1295.1	1232.8	636.8	1249.9	1686.6	1681.2	1620.0	1444.3	[illegible]	914.9	1072.7	1018.9
(10)	1875.9	2390.9	1740.3	1322.5	1292.3	1416.7	1944.0	1969.2	1924.4	1883.5	1861.2	1856.2	1861.7	2188.2	1562.2	1236.1	
(11)	2423.4	2435.1	2409.6	1163.0	931.7	1375.9	1992.8	1998.3	1992.5	1982.4	1947.1	1980.8	2163.1	2229.6	2221.5	1393.9	
(12)	1850.8	2396.8	1750.5	1378.6	1321.4	1495.3	1985.8	1992.8	1987.0	1982.4	1959.0	1954.7	1958.9	2205.7	1816.3	1451.0	
(13)	1623.7	1622.5	1622.6	1619.8	1266.6	1466.1	1958.7	1981.2	1979.7	1962.0	1931.3	1881.8	1694.8	1660.5	1670.2		
(14)	1624.7	1622.4	1622.4	1618.9	487.7	963.5	997.4	373.5	1107.7	1044.6	830.8	1169.7	1348.9	1396.6			
(15)	1627.4	1626.0	1626.9	1626.3	1260.8	1361.4	1460.7	1508.3	1495.4	1319.1	1134.7	1159.8	1207.5	1261.2			
(16)	1631.5	1634.9	1633.9	1633.7	1742.2	1933.9	2175.7	2343.8	2125.2	1820.0	1148.2	1034.0	1012.8				
(17)	1635.6	1638.6	1635.7	1651.3	1841.0	2102.2	2355.0	2361.3	2339.5	1832.5	[illegible]	761.6	926.2				
(18)	1609.5	1616.3	1610.3	1599.7	1692.3	1871.2	2099.9	2322.0	2081.1	1754.8	1022.0	912.0	913.0				
(19)	1319.5	1290.7	1316.9	1336.7	1373.3	1474.6	1641.3	1813.1	1658.8	1093.2	965.5	916.8	904.4				
(20)	1091.7	930.8	1044.0	1040.2	930.8	1004.3	894.6	127.7	723.3	872.3	828.8	863.7	873.5				
(21)	1039.7	993.0	999.4	988.9	956.5	940.8	893.7	695.8	759.8	840.6	845.6	855.6	860.8				

Waskada Spearfish Standard Waterflood Forecast 4899.00 DAYS PRESSURES (PSIA) LAYER # 3 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	1544.1	1537.5	1523.3	1507.2	1482.1	1463.5	1444.6	1414.5	1362.0	1270.4	1172.7	1099.5	1040.5	985.9	962.3	958.9	937.2
(2)	1513.4	1511.1	1498.5	1492.5	1433.4	1427.4	1429.2	1425.5	1409.2	1243.7	1087.5	1020.0	965.8	905.5	901.1	898.3	846.4
(3)	1508.1	1518.3	1485.6	1462.3	1247.0	1344.8	1432.9	1445.8	1430.3	1159.9	794.9	881.1	839.3	676.8	811.2	819.3	640.1
(4)	1488.1	1470.8	1463.7	1452.6	1365.1	1375.9	1415.7	1416.6	1313.0	1143.9	980.6	929.0	888.4	840.2	849.5	855.6	807.7
(5)	1480.8	1398.9	1446.5	1394.8	1299.5	1316.5	1310.8	1282.1	1222.6	1098.3	901.3	943.8	918.0	838.6	883.6	920.2	933.1
(6)	1468.9	1466.3	1463.8	1424.7	1335.2	1293.1	1263.6	1233.7	1190.4	1140.7	1083.3	1041.0	999.2	961.8	957.3	968.1	981.3
(7)	1470.7	1471.6	1462.3	1409.9	1273.2	1247.8	1226.1	1208.4	1192.4	1184.7	1157.9	1114.7	1058.6	1003.3	992.6	1008.8	1026.6
(8)	1470.2	1462.2	1411.8	1364.0	1251.0	1211.9	1206.8	1159.0	1188.4	1261.9	1243.4	1192.2	1094.3	935.3	967.1	1042.9	1068.3
(9)	1453.5	1391.4	1356.0	1255.3	1131.7	1137.3	1092.8	552.8	1050.2	1392.1	1385.0	1336.9	1200.1	405.2	893.2	1131.2	1109.7
(10)	1429.7	1691.4	1347.3	1187.9	1108.7	1169.3	1522.1	1550.6	1515.3	1495.0	1493.0	1497.4	1506.8	1898.2	1469.1	1284.4	
(11)	1712.7	1732.6	1706.0	939.8	687.5	1102.1	1580.0	1585.3	1579.5	1568.5	1564.6	1607.5	1855.1	1937.5	1929.7	1393.2	
(12)	1473.4	1705.7	1423.5	1205.1	1086.3	1208.5	1570.1	1579.6	1574.3	1571.1	1568.9	1577.9	1588.2	1916.6	1633.5	1423.8	
(13)	1575.8	1574.5	1574.8	1572.5	1060.1	1183.7	1527.6	1558.8	1563.6	1560.2	1554.0	1544.3	1438.2	1441.7	1456.0		
(14)	1577.6	1575.7	1575.5	1572.4	438.4	798.9	826.2	330.3	914.4	926.8	759.3	1045.1	1184.6	1227.9			
(15)	1581.0	1581.6	1581.3	1580.7	1165.3	1226.9	1310.9	1375.5	1395.4	1292.8	1117.8	1113.1	1139.5	1170.0			
(16)	1584.7	1588.8	1587.4	1586.9	1660.2	1821.9	2058.9	2272.8	2107.1	1914.0	1206.8	1072.9	1047.4				
(17)	1589.6	1592.8	1590.0	1603.1	1764.9	2009.7	2282.6	2291.1	2269.9	1979.1	120.6	777.0	999.3				
(18)	1566.7	1572.9	1567.1	1556.3	1635.2	1787.9	1996.6	2227.4	2016.6	1831.8	1108.7	1012.2	1010.5				
(19)	1334.9	1298.3	1319.1	1329.7	1356.2	1438.2	1563.5	1675.2	1561.3	1112.0	1033.2	1010.4	1006.6				
(20)	1130.1	965.2	1070.9	1058.1	939.0	1010.3	894.9	124.4	751.4	930.8	898.1	956.9	977.5				
(21)	1073.2	1019.8	1020.2	1003.3	964.7	946.4	898.3	717.8	816.3	920.2	933.4	958.2	972.1				

LEGEND

- P < 700 psia
- 700 ≤ P < 1000

TABLE # 3 cont'd

Waskada Spearfish Standard Waterflood Forecast Pattern

Waskada Spearfish Standard Waterflood Forecast 4899.00 DAYS OIL SATURATIONS LAYER # 1 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.628	0.593	0.602	0.610	0.627	0.630	0.627	0.588	0.585	0.618	0.627	0.629	0.629	0.623	0.619	0.613	0.606
(2)	0.580	0.342	0.387	0.453	0.547	0.622	0.530	0.372	0.419	0.492	0.577	0.622	0.628	0.622	0.616	0.609	0.604
(3)	0.337	0.205	0.243	0.303	0.432	0.499	0.312	[illegible]	[illegible]	0.351	0.437	0.622	0.625	0.619	0.617	0.612	0.606
(4)	0.418	0.294	0.308	0.375	0.468	0.593	0.454	0.311	0.370	0.448	0.544	0.616	0.627	0.624	0.622	0.619	0.618
(5)	0.577	0.370	0.432	0.499	0.558	0.627	0.591	0.505	0.527	0.577	0.609	0.628	0.629	0.628	0.628	0.628	0.625
(6)	0.572	0.379	0.426	0.490	0.574	0.623	0.628	0.623	0.625	0.629	0.629	0.628	0.629	0.629	0.629	0.628	0.628
(7)	0.443	[illegible]	0.291	0.360	0.450	0.586	0.625	0.629	0.629	0.629	0.628	0.622	0.625	0.628	0.629	0.629	0.628
(8)	0.612	0.361	0.404	0.477	0.569	0.620	0.629	0.629	0.629	0.617	0.620	0.577	0.576	0.602	0.628	0.628	0.629
(9)	0.629	0.504	0.539	0.590	0.619	0.628	0.626	0.565	0.606	0.574	0.595	0.498	0.508	0.505	0.553	0.621	0.628
(10)	0.625	0.501	0.612	0.627	0.629	0.624	0.582	0.347	0.489	0.526	0.569	0.441	0.327	[illegible]	0.332	0.579	
(11)	0.552	0.282	0.421	0.581	0.609	0.563	0.450	[illegible]	0.316	0.415	0.481	0.317	[illegible]	[illegible]	0.333	0.575	
(12)	0.619	0.438	0.591	0.629	0.627	0.579	0.454	0.306	0.457	0.586	0.627	0.613	0.519	0.400	0.555	0.627	
(13)	0.631	0.627	0.630	0.631	0.610	0.531	0.470	0.374	0.556	0.527	0.630	0.624	0.626	0.615	0.630		
(14)	0.631	0.616	0.617	0.625	0.498	0.414	0.414	0.402	0.456	0.486	0.555	0.627	0.629	0.629			
(15)	0.627	0.531	0.565	0.606	0.387	0.294	0.274	0.253	0.307	0.341	0.425	0.574	0.628	0.630			
(16)	0.572	0.363	0.466	0.340	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.310	0.442	0.608				
(17)	0.290	0.224	0.335	0.308	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.380	0.577	0.627				
(18)	0.407	0.341	0.427	0.389	[illegible]	[illegible]	[illegible]	[illegible]	0.219	[illegible]	0.312	0.476	0.619				
(19)	0.511	0.450	0.500	0.466	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.301	[illegible]	0.518	0.614				
(20)	0.595	0.553	0.580	0.579	0.439	0.354	0.358	0.404	0.353	0.395	0.497	0.619	0.629				
(21)	0.629	0.630	0.628	[illegible]	0.621	0.316	0.574	0.618	0.618	0.584	0.628	0.629	0.629				

OIL SATURATIONS LAYER # 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.523	0.519	0.528	0.539	0.550	0.558	0.565	0.559	0.561	0.574	0.579	0.582	0.585	0.588	0.590	0.591	0.591
(2)	0.508	0.389	0.436	0.489	0.530	0.556	0.532	0.422	0.476	0.533	0.567	0.581	0.585	0.587	0.590	0.591	0.586
(3)	0.385	[illegible]	[illegible]	0.338	0.440	0.504	0.402	[illegible]	0.335	0.418	0.499	0.554	0.558	0.565	0.571	0.570	0.573
(4)	0.443	0.324	0.361	0.433	0.503	0.557	0.528	0.400	0.467	0.536	0.568	0.577	0.578	0.582	0.586	0.587	0.587
(5)	0.508	0.398	0.470	0.508	0.522	0.559	0.565	0.521	0.534	0.546	0.546	0.532	0.538	0.553	0.582	0.582	0.582
(6)	0.538	0.466	0.510	0.524	0.536	0.555	0.568	0.572	0.573	0.574	0.573	0.572	0.573	0.575	0.576	0.577	0.577
(7)	0.501	[illegible]	0.411	0.474	0.509	0.549	0.566	0.552	0.570	0.569	0.565	0.562	0.563	0.567	0.570	0.569	0.569
(8)	0.526	0.444	0.504	0.522	0.522	0.542	0.560	0.535	0.567	0.562	0.551	0.542	0.539	0.546	0.552	0.551	0.553
(9)	0.509	0.501	0.509	0.511	0.511	0.541	0.551	0.521	0.558	0.562	0.546	0.524	0.520	0.516	0.527	0.535	0.533
(10)	0.494	0.474	0.471	0.488	0.496	0.547	0.533	0.380	0.500	0.555	0.545	0.504	0.476	0.350	0.498	0.551	
(11)	0.490	0.350	0.453	0.487	0.503	0.536	0.492	[illegible]	0.433	0.522	0.483	0.373	[illegible]	[illegible]	0.407	0.533	
(12)	0.470	0.449	0.517	0.512	0.526	0.555	0.545	0.443	0.537	0.569	0.556	0.528	0.482	0.377	0.499	0.541	
(13)	0.521	0.522	0.460	0.475	0.526	0.556	0.559	0.515	0.560	0.573	0.561	0.543	0.545	0.530	0.545		
(14)	0.521	0.518	0.517	0.519	0.525	0.533	0.547	0.530	0.551	0.544	0.530	0.514	0.512	0.493			
(15)	0.518	0.501	0.500	0.492	0.491	0.480	0.468	0.430	0.483	0.498	0.524	0.524	0.514	0.505			
(16)	0.500	0.423	0.469	0.526	0.503	0.448	0.392	0.301	0.386	0.429	0.473	0.518	0.520				
(17)	0.360	[illegible]	0.368	0.473	0.427	0.355	0.284	0.209	[illegible]	0.346	0.475	0.515	0.509				
(18)	0.489	0.435	0.464	0.514	0.487	0.425	0.378	0.296	0.392	0.448	0.512	0.557	0.564				
(19)	0.539	0.518	0.517	0.499	0.492	0.450	0.409	[illegible]	0.423	0.474	0.521	0.552	0.564				
(20)	0.550	0.520	0.527	0.485	0.496	0.478	0.464	0.458	0.447	0.483	0.505	0.542	0.557				
(21)	0.547	0.482	0.521	0.464	0.502	0.474	0.454	0.419	0.414	0.441	0.456	0.528	0.550				

Waskada Spearfish Standard Waterflood Forecast 4899.00 DAYS OIL SATURATIONS LAYER # 3 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.428	0.432	0.441	0.452	0.467	0.490	0.511	0.527	0.542	0.555	0.567	0.574	0.579	0.582	0.584	0.585	0.586
(2)	0.422	0.400	0.426	0.448	0.469	0.498	0.502	0.472	0.531	0.554	0.567	0.574	0.579	0.582	0.584	0.585	0.585
(3)	0.385	[illegible]	[illegible]	[illegible]	0.316	0.331	0.337	[illegible]	0.399	0.479	0.448	0.456	0.514	0.513	0.546	0.546	0.551
(4)	0.388	0.350	0.385	0.432	0.472	0.510	0.496	0.456	0.530	0.557	0.568	0.574	0.578	0.581	0.582	0.582	0.582
(5)	0.439	0.453	0.469	0.433	0.376	0.513	0.531	0.374	0.390	0.421	0.395	0.415	0.470	0.524	0.579	0.579	0.579
(6)	0.519	0.521	0.458	0.406	0.449	0.508	0.535	0.542	0.550	0.556	0.559	0.564	0.569	0.572	0.572	0.572	0.572
(7)	0.488	0.407	0.506	0.386	0.391	0.499	0.534	0.433	0.550	0.550	0.548	0.547	0.551	0.553	0.555	0.554	0.554
(8)	0.440	0.450	0.500	0.414	0.388	0.475	0.531	0.412	0.547	0.537	0.518	0.500	0.495	0.505	0.506	0.503	0.509
(9)	0.396	0.413	0.380	0.376	0.370	0.463	0.525	0.482	0.543	0.532	0.473	0.419	0.374	0.404	0.367	0.372	0.378
(10)	0.379	0.382	0.338	0.339	0.332	0.466	0.546	0.522	0.552	0.559	0.522	0.459	0.408	0.356	0.400	0.424	
(11)	0.405	0.377	0.349	0.339	0.243	0.479	0.535	[illegible]	0.526	0.554	0.466	0.377	[illegible]	[illegible]	0.318	0.355	
(12)	0.378	0.371	0.423	0.400	0.381	0.505	0.552	0.515	0.554	0.558	0.511	0.416	0.350	0.310	0.324	0.342	
(13)	0.464	0.460	0.357	0.358	0.416	0.514	0.549	0.539	0.550	0.558	0.528	0.461	0.408	0.373	0.368		
(14)	0.487	0.484	0.449	0.435	0.457	0.477	0.523	0.518	0.528	0.492	0.414	0.348	0.304	[illegible]			
(15)	0.498	0.478	0.443	0.411	0.403	0.399	0.413	0.428	0.450	0.444	0.434	0.401	0.365	0.337			
(16)	0.487	0.431	0.428	0.506	0.472	0.420	0.386	0.347	0.436	0.398	0.434	0.432	0.405				
(17)	0.399	0.243	0.412	0.484	0.415	0.352	0.290	0.230	0.341	0.445	0.492	0.417	0.398				
(18)	0.531	0.499	0.510	0.501	0.479	0.393	0.370	0.320	0.401	0.430	0.514	0.540	0.548				
(19)	0.549	0.539	0.523	0.461	0.450	0.408	0.339	0.299	0.327	0.378	0.453	0.523	0.546				
(20)	0.550	0.501	0.522	0.451	0.469	0.427	0.394	0.352	0.331	0.351	0.365	0.465	0.527				
(21)	0.546	0.471	0.513	0.433	0.465	0.412	0.372	0.314	0.287	0.296	0.302	0.407	0.503				

TABLE # 3 cont'd

Waskada Spearfish Standard Waterflood Forecast Pattern

Waskada Spearfish Standard Waterflood Forecast 4899.00 DAYS WATER SATURATION LAYER # 1 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.372	0.407	0.398	0.390	0.373	0.370	0.373	0.412	0.415	0.382	0.373	0.371	0.371	0.372	0.372	0.372	0.372
(2)	0.420	0.658	0.613	0.547	0.453	0.378	0.470	0.628	0.581	0.508	0.423	0.378	0.372	0.372	0.372	0.372	0.372
(3)	0.663	0.795	0.757	0.697	0.568	0.501	0.688	0.791	0.726	0.649	0.563	0.378	0.372	0.372	0.372	0.372	0.372
(4)	0.582	0.706	0.692	0.625	0.532	0.407	0.546	0.689	0.630	0.552	0.456	0.384	0.373	0.372	0.372	0.372	0.372
(5)	0.423	0.630	0.568	0.501	0.442	0.373	0.409	0.495	0.473	0.423	0.391	0.372	0.371	0.372	0.372	0.372	0.372
(6)	0.428	0.621	0.574	0.510	0.426	0.377	0.372	0.377	0.375	0.371	0.371	0.372	0.371	0.371	0.371	0.372	0.372
(7)	0.557	0.777	0.709	0.640	0.550	0.414	0.375	0.371	0.371	0.371	0.372	0.378	0.375	0.372	0.371	0.371	0.372
(8)	0.388	0.639	0.596	0.523	0.431	0.380	0.371	0.371	0.371	0.383	0.380	0.423	0.424	0.398	0.372	0.372	0.371
(9)	0.371	0.496	0.461	0.410	0.381	0.372	0.374	0.435	0.394	0.426	0.405	0.502	0.492	0.492	0.447	0.379	0.372
(10)	0.375	0.499	0.388	0.373	0.371	0.376	0.418	0.653	0.511	0.474	0.431	0.559	0.673	0.788	0.668	0.421	
(11)	0.448	0.718	0.579	0.419	0.391	0.437	0.550	0.800	0.684	0.585	0.519	0.683	0.797	0.800	0.667	0.425	
(12)	0.381	0.562	0.409	0.371	0.373	0.421	0.546	0.694	0.543	0.414	0.373	0.387	0.481	0.600	0.445	0.373	
(13)	0.369	0.373	0.370	0.369	0.390	0.469	0.530	0.626	0.444	0.373	0.370	0.376	0.374	0.385	0.370		
(14)	0.369	0.384	0.383	0.375	0.501	0.586	0.586	0.597	0.544	0.514	0.445	0.373	0.371	0.371			
(15)	0.373	0.469	0.435	0.394	0.613	0.706	0.726	0.747	0.693	0.659	0.575	0.426	0.372	0.370			
(16)	0.428	0.637	0.534	0.660	0.737	0.773	0.789	0.798	0.768	0.736	0.690	0.558	0.392				
(17)	0.710	0.776	0.665	0.692	0.773	0.797	0.800	0.801	0.797	0.788	0.615	0.423	0.373				
(18)	0.593	0.659	0.573	0.611	0.704	0.756	0.785	0.799	0.781	0.746	0.688	0.524	0.381				
(19)	0.489	0.550	0.500	0.534	0.640	0.703	0.738	0.778	0.745	0.699	0.618	0.482	0.386				
(20)	0.405	0.447	0.420	0.421	0.561	0.646	0.642	0.590	0.647	0.605	0.503	0.381	0.371				
(21)	0.371	0.370	0.372	0.372	0.379	0.484	0.426	0.382	0.382	0.416	0.372	0.371	0.371				

WATER SATURATION LAYER # 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.477	0.481	0.472	0.461	0.450	0.442	0.435	0.441	0.439	0.426	0.421	0.418	0.415	0.412	0.410	0.409	0.409
(2)	0.492	0.611	0.564	0.511	0.470	0.444	0.468	0.573	0.524	0.467	0.433	0.419	0.415	0.413	0.410	0.409	0.409
(3)	0.615	0.781	0.717	0.662	0.560	0.496	0.598	0.760	0.665	0.582	0.501	0.446	0.442	0.433	0.429	0.430	0.422
(4)	0.557	0.676	0.639	0.567	0.497	0.443	0.472	0.600	0.533	0.464	0.432	0.423	0.422	0.418	0.414	0.413	0.413
(5)	0.492	0.602	0.530	0.492	0.478	0.441	0.435	0.479	0.466	0.454	0.454	0.468	0.462	0.447	0.418	0.418	0.418
(6)	0.462	0.534	0.490	0.476	0.464	0.445	0.432	0.428	0.427	0.426	0.427	0.428	0.427	0.425	0.424	0.423	0.423
(7)	0.499	0.701	0.589	0.526	0.491	0.451	0.434	0.448	0.430	0.431	0.435	0.438	0.437	0.433	0.430	0.431	0.431
(8)	0.474	0.556	0.496	0.478	0.478	0.458	0.440	0.465	0.433	0.438	0.449	0.458	0.461	0.454	0.448	0.449	0.447
(9)	0.491	0.499	0.491	0.489	0.489	0.459	0.449	0.479	0.442	0.438	0.454	0.476	0.480	0.482	0.473	0.465	0.467
(10)	0.506	0.526	0.529	0.512	0.504	0.453	0.467	0.620	0.500	0.445	0.455	0.496	0.524	0.650	0.502	0.449	
(11)	0.510	0.650	0.547	0.513	0.497	0.464	0.508	0.767	0.567	0.478	0.517	0.627	0.775	0.794	0.593	0.467	
(12)	0.530	0.551	0.483	0.488	0.474	0.445	0.455	0.557	0.463	0.431	0.444	0.472	0.518	0.623	0.501	0.459	
(13)	0.479	0.478	0.540	0.525	0.474	0.444	0.441	0.485	0.440	0.427	0.439	0.457	0.455	0.470	0.455		
(14)	0.479	0.482	0.483	0.481	0.475	0.467	0.453	0.468	0.449	0.456	0.470	0.486	0.488	0.507			
(15)	0.482	0.499	0.500	0.508	0.509	0.520	0.532	0.570	0.517	0.502	0.476	0.476	0.486	0.495			
(16)	0.500	0.577	0.531	0.474	0.497	0.552	0.608	0.699	0.614	0.571	0.527	0.482	0.480				
(17)	0.640	0.784	0.632	0.527	0.573	0.645	0.716	0.791	0.710	0.654	0.514	0.485	0.491				
(18)	0.511	0.565	0.536	0.486	0.513	0.575	0.622	0.704	0.608	0.552	0.488	0.443	0.436				
(19)	0.461	0.482	0.483	0.501	0.508	0.550	0.591	0.635	0.577	0.526	0.479	0.448	0.436				
(20)	0.450	0.480	0.473	0.515	0.504	0.522	0.536	0.533	0.553	0.517	0.495	0.458	0.443				
(21)	0.453	0.518	0.479	0.536	0.498	0.526	0.546	0.581	0.586	0.559	0.544	0.472	0.450				

Waskada Spearfish Standard Waterflood Forecast 4899.00 DAYS WATER SATURATION LAYER # 3 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.572	0.568	0.559	0.548	0.533	0.510	0.489	0.473	0.458	0.445	0.433	0.426	0.421	0.418	0.416	0.415	0.414
(2)	0.578	0.600	0.574	0.552	0.531	0.502	0.498	0.528	0.469	0.446	0.433	0.426	0.421	0.418	0.416	0.415	0.415
(3)	0.615	0.779	0.753	0.737	0.684	0.669	0.663	0.737	0.601	0.521	0.552	0.544	0.486	0.487	0.454	0.454	0.449
(4)	0.612	0.650	0.615	0.568	0.528	0.490	0.504	0.544	0.470	0.443	0.432	0.426	0.422	0.419	0.418	0.418	0.418
(5)	0.561	0.547	0.531	0.567	0.624	0.487	0.469	0.626	0.610	0.579	0.605	0.585	0.530	0.476	0.421	0.421	0.421
(6)	0.481	0.479	0.542	0.594	0.551	0.492	0.465	0.458	0.450	0.444	0.441	0.436	0.431	0.428	0.428	0.428	0.428
(7)	0.512	0.593	0.494	0.614	0.609	0.501	0.466	0.567	0.450	0.450	0.452	0.453	0.449	0.447	0.445	0.446	0.446
(8)	0.560	0.550	0.500	0.586	0.612	0.525	0.469	0.588	0.453	0.463	0.482	0.500	0.505	0.495	0.494	0.497	0.491
(9)	0.604	0.587	0.620	0.624	0.630	0.537	0.475	0.518	0.457	0.468	0.527	0.581	0.626	0.596	0.633	0.628	0.622
(10)	0.621	0.618	0.662	0.661	0.668	0.534	0.454	0.478	0.448	0.441	0.478	0.541	0.592	0.644	0.600	0.576	
(11)	0.595	0.625	0.651	0.661	0.757	0.521	0.465	0.708	0.474	0.446	0.534	0.623	0.725	0.768	0.682	0.645	
(12)	0.622	0.629	0.577	0.600	0.619	0.495	0.448	0.485	0.446	0.442	0.489	0.584	0.650	0.690	0.676	0.658	
(13)	0.536	0.540	0.643	0.642	0.584	0.486	0.451	0.461	0.450	0.442	0.472	0.539	0.592	0.627	0.632		
(14)	0.513	0.516	0.551	0.565	0.543	0.523	0.477	0.480	0.472	0.508	0.586	0.652	0.696	0.728			
(15)	0.502	0.522	0.557	0.589	0.597	0.601	0.587	0.572	0.550	0.556	0.566	0.599	0.635	0.663			
(16)	0.513	0.569	0.572	0.494	0.528	0.580	0.614	0.653	0.564	0.602	0.566	0.568	0.595				
(17)	0.601	0.757	0.588	0.516	0.585	0.648	0.710	0.770	0.659	0.555	0.495	0.583	0.602				
(18)	0.469	0.501	0.490	0.499	0.521	0.607	0.630	0.680	0.599	0.570	0.486	0.460	0.452				
(19)	0.451	0.461	0.477	0.539	0.550	0.592	0.661	0.701	0.673	0.622	0.547	0.477	0.454				
(20)	0.450	0.499	0.478	0.549	0.531	0.573	0.606	0.648	0.669	0.649	0.635	0.535	0.473				
(21)	0.454	0.529	0.487	0.567	0.535	0.588	0.628	0.686	0.713	0.704	0.698	0.593	0.497				

TABLE # 3 cont'd

Waskada Spearfish Standard Waterflood Forecast Pattern

Waskada Spearfish Standard Waterflood Forecast 4899.00 DAYS GAS SATURATIONS LAYER # 1 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.005	0.009	0.016	0.022
(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.006	0.013	0.019	0.024
(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.003	0.009	0.012	0.016	0.022
(4)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.004	0.006	0.009	0.010
(5)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.001	0.001	0.	0.003
(6)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(7)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(8)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(9)	0.	0.	0.	0.	0.	0.	0.	0.001	0.	0.	0.	0.	0.	0.002	0.	0.	0.
(10)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(11)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(12)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(14)	0.	0.	0.	0.	0.000	0.	0.	0.001	0.	0.	0.	0.	0.	0.			
(15)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(16)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(17)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.005	0.	0.				
(18)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(19)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(20)	0.	0.	0.	0.	0.	0.	0.	0.006	0.	0.	0.	0.	0.				
(21)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				

GAS SATURATIONS LAYER # 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.006
(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.002	0.	0.	0.004
(4)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(5)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(6)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(7)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(8)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(9)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.001	0.	0.	0.
(10)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(11)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(12)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(14)	0.	0.	0.	0.	0.	0.	0.	0.002	0.	0.	0.	0.	0.	0.			
(15)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(16)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(17)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.011	0.	0.				
(18)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(19)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(20)	0.	0.	0.	0.	0.	0.	0.	0.009	0.	0.	0.	0.	0.				
(21)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				

Waskada Spearfish Standard Waterflood Forecast 4899.00 DAYS GAS SATURATIONS LAYER # 3 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(4)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(5)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(6)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(7)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(8)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(9)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(10)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(11)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(12)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(14)	0.	0.	0.	0.	0.	0.	0.	0.002	0.	0.	0.	0.	0.	0.			
(15)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(16)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(17)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.013	0.	0.				
(18)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(19)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(20)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(21)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				

- TABLE # 4

Waskada Spearfish Waterflood Forecast Pattern 'C'

Waskada Spearfish Waterflood Forecast Pattern 'C' 4899.00 DAYS PRESSURES (PSIA) LAYER # 1 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	1543.1	1532.8	1506.8	1477.1	1435.1	1404.0	1376.7	1342.9	1279.9	1168.4	1032.4	873.9	706.7	588.5	545.9	526.4	492.3
(2)	1551.0	1540.2	1530.3	1517.2	1422.0	1392.6	1386.1	1381.4	1365.7	1192.0	984.8	822.7	677.1	558.1	529.3	510.1	459.9
(3)	1554.2	1565.7	1531.7	1508.1	1282.3	1353.0	1395.0	1402.4	1380.2	1134.7	745.6	724.9	628.3	455.8	517.5	499.4	379.2
(4)	1545.2	1525.1	1517.0	1503.9	1401.9	1382.9	1387.0	1377.1	1251.8	1070.1	874.7	775.8	702.5	613.1	584.2	564.1	504.2
(5)	1550.3	1466.5	1518.7	1479.4	1373.3	1375.3	1353.8	1300.7	1145.1	965.8	768.5	788.1	748.6	658.6	668.2	671.5	653.9
(6)	1689.0	1687.1	1681.1	1623.0	1492.9	1423.1	1367.0	1280.5	1122.7	1028.1	953.1	902.1	849.9	797.9	766.5	741.8	724.9
(7)	1695.4	1698.3	1693.2	1655.7	1512.8	1455.0	1385.4	1293.7	1155.3	1104.8	1050.1	986.5	911.1	840.4	810.2	793.6	784.8
(8)	1696.1	1697.7	1696.6	1684.4	1612.1	1533.4	1469.6	1220.9	1168.9	1196.9	1163.3	1096.4	963.5	783.2	790.2	813.4	817.5
(9)	1689.9	1654.8	1720.7	1800.9	1842.6	1681.1	1553.8	602.8	1046.1	1370.6	1366.7	1314.6	1133.7	402.7	759.5	870.8	849.8
(10)	1753.4	1790.8	1932.4	2217.2	2480.3	1933.0	1512.0	1494.0	1498.3	1509.1	1529.1	1545.3	1560.2	2123.4	1429.2	1006.9	
(11)	1787.9	1933.1	2155.4	2504.6	2507.6	2496.4	1626.1	1623.6	1620.8	1619.3	1655.9	1712.4	2070.8	2204.4	2183.3	1115.5	
(12)	1694.2	1738.2	1885.6	2285.0	2487.9	2187.1	1632.5	1630.4	1634.3	1644.4	1701.2	1716.1	1736.0	2184.2	1753.1	1150.0	
(13)	1659.0	1659.0	1660.7	1662.2	1779.6	1739.7	1644.0	1636.2	1643.7	1693.3	1903.5	1774.2	1789.5	1801.7	1794.1		
(14)	1659.1	1658.7	1658.5	1658.0	1598.3	1626.3	1659.7	1763.9	1863.5	1958.0	2053.3	1931.8	1834.7	1802.6			
(15)	1680.4	1686.1	1683.8	1684.6	1885.7	1970.6	2077.8	2232.3	2249.7	2183.0	2050.0	1833.5	1722.6	1739.4			
(16)	1699.6	1708.3	1707.2	1713.8	2047.2	2293.1	2521.3	2683.7	2577.6	2451.2	1751.9	1522.6	1372.0				
(17)	1711.3	1716.5	1720.3	1773.1	2119.9	2435.8	2730.2	2816.3	2614.7	2308.8	126.0	960.9	1241.3				
(18)	1688.0	1696.8	1729.1	1856.9	2044.2	2222.1	2365.4	2431.5	2314.8	2178.9	1440.6	1275.3	1240.5				
(19)	1440.1	1457.3	1564.0	1694.0	1814.2	1926.0	2041.8	2009.9	1930.3	1441.1	1333.5	1264.9	1235.3				
(20)	1203.9	1072.0	1263.3	1368.9	1336.5	1436.6	1196.4	136.5	925.5	1178.6	1130.5	1169.9	1184.1				
(21)	1174.9	1154.1	1207.2	1248.3	1260.0	1246.1	1110.9	800.1	931.7	1097.4	1116.3	1140.4	1155.2				

PRESSURES (PSIA) LAYER # 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	1642.3	1628.8	1598.8	1562.7	1507.6	1458.6	1411.7	1357.2	1275.1	1147.7	1020.0	916.7	822.7	729.2	680.5	654.9	610.4
(2)	1642.2	1637.9	1617.6	1601.8	1489.1	1444.9	1417.9	1408.7	1383.6	1160.6	966.8	871.2	786.6	688.9	656.9	633.3	570.8
(3)	1644.7	1654.8	1619.3	1592.7	1336.8	1398.5	1432.1	1436.5	1409.0	1123.2	740.6	787.9	727.7	548.9	637.2	621.8	471.1
(4)	1635.1	1612.2	1604.5	1590.6	1473.1	1448.6	1432.7	1417.2	1303.2	1128.0	954.3	892.3	835.6	751.9	735.0	719.5	660.1
(5)	1644.6	1548.6	1607.1	1573.9	1471.7	1475.5	1450.7	1404.6	1302.8	1158.4	946.5	983.7	945.2	833.4	855.4	871.2	862.3
(6)	1789.6	1787.2	1779.2	1719.1	1611.5	1560.4	1512.8	1454.1	1381.7	1311.4	1235.6	1180.0	1112.0	1032.5	984.9	954.0	936.3
(7)	1797.6	1801.7	1798.1	1764.0	1650.9	1634.2	1589.3	1532.2	1485.7	1476.5	1436.7	1368.3	1267.1	1147.4	1079.0	1038.4	1015.7
(8)	1798.5	1802.8	1827.6	1844.7	1836.6	1780.8	1703.6	1497.2	1532.0	1690.2	1664.3	1581.4	1412.9	1132.7	1101.1	1109.7	1085.5
(9)	1790.0	1755.2	1886.7	2065.0	2154.9	2009.6	1826.5	756.8	1470.9	1983.7	1992.3	1933.7	1706.9	513.0	1048.5	1226.5	1146.3
(10)	1679.6	1681.0	2067.3	2649.1	2980.6	2465.5	2189.1	2181.0	2190.9	2203.6	2240.7	2272.6	2291.2	2970.6	2022.7	1460.8	
(11)	1340.1	1285.4	2124.5	3006.1	3009.2	2998.1	2354.9	2354.7	2357.3	2357.7	2434.7	2513.4	2893.7	3039.3	3025.2	1700.3	
(12)	1937.8	1932.1	2235.0	2783.8	2997.7	2777.9	2362.0	2363.7	2374.1	2389.1	2499.1	2523.2	2544.4	3007.4	2471.5	1783.9	
(13)	2206.2	2206.7	2209.4	2212.6	2525.9	2480.3	2367.6	2368.5	2383.0	2487.1	2830.5	2600.1	2599.4	2600.3	2572.1		
(14)	2207.3	2207.2	2207.4	2207.3	2241.3	2325.9	2424.8	2667.0	2838.6	2968.3	3053.5	2811.3	2649.1	2599.4			
(15)	2209.3	2209.4	2210.6	2211.2	2373.7	2466.3	2589.1	2794.7	2865.5	2939.4	3041.1	2637.3	2462.2	2493.3			
(16)	2212.7	2216.6	2216.5	2217.8	2437.7	2670.7	2903.4	3041.7	2883.4	2671.8	2132.1	1969.9	1867.5				
(17)	2216.3	2220.1	2216.5	2233.3	2461.3	2766.2	3063.0	3141.5	2927.7	2330.2	127.9	1286.7	1582.2				
(18)	2179.4	2187.3	2172.3	2118.4	2204.8	2390.2	2612.0	2779.5	2544.0	2185.1	1356.3	1349.0	1416.1				
(19)	1748.1	1709.2	1725.9	1730.1	1757.4	1866.5	2051.2	2192.3	2038.3	1402.8	1274.1	1255.1	1280.7				
(20)	1406.9	1191.2	1332.8	1320.5	1170.7	1257.0	1112.7	134.1	895.9	1118.9	1078.5	1146.2	1175.1				
(21)	1323.1	1257.8	1260.7	1241.6	1194.2	1168.9	1105.0	850.0	941.2	1073.0	1090.0	1114.5	1129.1				

Waskada Spearfish Waterflood Forecast Pattern 'C' 4899.00 DAYS PRESSURES (PSIA) LAYER # 3 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	1578.9	1571.6	1555.5	1537.0	1508.2	1486.9	1466.3	1434.5	1379.3	1283.6	1182.2	1106.3	1045.2	988.6	963.9	959.9	937.6
(2)	1556.4	1554.2	1539.4	1531.5	1463.1	1453.8	1456.8	1453.0	1435.1	1259.5	1097.2	1026.5	970.1	908.0	902.5	899.2	846.7
(3)	1552.9	1564.6	1528.6	1503.6	1275.4	1372.5	1462.4	1476.7	1460.1	1176.5	801.9	886.1	842.7	678.4	812.3	820.0	640.3
(4)	1533.4	1515.4	1506.7	1494.1	1397.0	1404.1	1443.9	1445.3	1333.6	1155.8	987.5	933.6	891.7	842.5	851.1	856.5	808.0
(5)	1528.2	1443.3	1491.3	1437.4	1335.1	1347.7	1337.1	1304.1	1239.3	1109.2	908.0	949.4	922.7	842.0	886.5	922.4	934.5
(6)	1544.6	1542.2	1538.1	1491.3	1391.5	1341.4	1302.4	1262.1	1210.8	1155.7	1095.0	1050.5	1007.2	968.5	963.1	972.6	984.7
(7)	1548.0	1551.4	1543.3	1495.1	1363.9	1333.0	1293.9	1253.9	1221.3	1206.9	1176.8	1131.2	1072.8	1015.4	1003.4	1018.3	1034.4
(8)	1547.0	1544.4	1521.8	1500.0	1432.9	1375.3	1333.9	1209.6	1216.4	1288.6	1271.5	1220.8	1119.3	954.1	985.6	1062.4	1083.6
(9)	1526.4	1476.2	1509.4	1527.8	1532.6	1432.6	1335.7	588.6	1068.5	1426.4	1431.9	1392.5	1244.3	423.1	924.8	1170.7	1133.7
(10)	1383.2	1294.0	1393.8	1626.8	1862.0	1525.8	1423.4	1433.0	1472.6	1523.8	1562.0	1596.5	1620.9	2407.8	1725.4	1372.2	
(11)	1163.7	481.0	1291.0	1891.5	1895.4	1887.6	1575.7	1581.3	1588.3	1597.4	1698.3	1794.3	2296.9	2466.4	2453.3	1520.5	
(12)	1388.1	1318.2	1453.7	1747.1	1884.9	1715.6	1579.5	1584.6	1597.2	1612.9	1705.0	1740.3	1766.1	2430.1	1931.8	1553.4	
(13)	1578.7	1578.7	1580.3	1580.2	1582.3	1577.5	1579.1	1587.4	1603.2	1650.7	1960.5	1755.7	1702.8	1712.0	1676.2		
(14)	1579.8	1579.8	1580.2	1580.4	1546.2	1592.7	1649.9	1805.9	1928.5	2035.2	2132.6	1881.4	1708.2	1658.9			
(15)	1585.6	1587.2	1587.7	1588.4	1695.7	1767.7	1871.8	2052.1	2094.6	2105.9	2124.6	1759.0	1594.2	1583.8			
(16)	1590.6	1596.1	1595.4	1597.1	1815.6	2051.8	2310.3	2512.4	2377.9	2235.3	1623.1	1396.4	1268.1				
(17)	1597.1	1600.8	1598.9	1620.8	1874.4	2199.3	2541.0	2645.4	2436.1	2129.5	122.9	880.3	1131.4				
(18)	1573.8	1580.8	1578.3	1586.6	1696.3	1867.8	2059.5	2191.1	2042.2	1859.8	1127.9	1056.7	1078.7				
(19)	1338.5	1304.4	1331.5	1351.2	1388.0	1476.0	1598.6	1664.8	1568.3	1118.7	1042.3	1025.9	1032.4				
(20)	1131.3	968.1	1078.0	1068.7	951.7	1025.7	907.6	124.5	751.8	933.7	902.2	963.8	986.9				
(21)	1073.0	1021.1	1023.9	1008.8	971.3	953.3	903.3	718.0	815.7	921.4	935.4	961.1	975.7				

TABLE # 4 cont'd

Waskada Spearfish Waterflood Forecast Pattern 'C'

Waskada Spearfish Waterflood Forecast Pattern 'C' 4899.00 DAYS OIL SATURATIONS LAYER # 1 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.628	0.585	0.592	0.600	0.626	0.630	0.627	0.585	0.578	0.613	0.627	0.629	0.629	0.629	0.625	0.620	0.615
(2)	0.562	0.336	0.377	0.435	0.527	0.617	0.522	0.376	0.412	0.479	0.564	0.619	0.628	0.626	0.623	0.619	0.613
(3)	0.332	0.204	0.233	0.290	0.420	0.507	0.314	[illegible]	0.267	0.339	0.425	0.617	0.627	0.624	0.625	0.624	0.618
(4)	0.439	0.302	0.309	0.368	0.452	0.596	0.467	[illegible]	0.362	0.435	0.528	0.611	0.627	0.628	0.628	0.627	0.626
(5)	0.583	0.372	0.441	0.496	0.553	0.628	0.600	0.512	0.524	0.571	0.605	0.629	0.629	0.629	0.629	0.629	0.629
(6)	0.528	0.341	0.390	0.448	0.543	0.616	0.629	0.628	0.627	0.629	0.629	0.628	0.628	0.629	0.629	0.629	0.629
(7)	0.399	0.220	0.299	0.373	0.465	0.588	0.624	0.629	0.630	0.630	0.626	0.612	0.618	0.627	0.629	0.629	0.629
(8)	0.599	0.375	0.479	0.561	0.572	0.590	0.626	0.630	0.630	0.626	0.595	0.529	0.528	0.572	0.629	0.628	0.629
(9)	0.629	0.312	0.616	0.580	0.404	0.425	0.501	0.587	0.627	0.609	0.521	0.425	0.443	0.468	0.517	0.611	0.629
(10)	0.631	0.630	0.624	[illegible]	[illegible]	[illegible]	0.588	0.628	0.629	0.583	0.465	[illegible]	0.275	0.204	0.298	0.550	
(11)	0.631	0.631	0.587	0.397	[illegible]	0.256	0.503	0.590	0.623	0.528	0.357	[illegible]	[illegible]	[illegible]	0.300	0.549	
(12)	0.631	0.631	0.596	0.389	0.240	0.326	0.558	0.614	0.572	0.505	0.417	0.587	0.361	0.364	0.528	0.625	
(13)	0.631	0.631	0.623	0.501	0.370	0.458	0.511	0.461	0.395	0.331	[illegible]	0.413	0.627	0.614	0.631		
(14)	0.630	0.600	0.593	0.603	0.381	0.290	0.219	0.210	0.208	[illegible]	[illegible]	0.339	0.537	0.627			
(15)	0.620	0.497	0.528	0.572	0.410	0.335	0.307	[illegible]	0.378	0.440	0.354	0.403	0.563	0.631			
(16)	0.547	0.350	0.428	0.291	0.258	0.231	0.215	[illegible]	0.253	0.288	0.335	0.431	0.583				
(17)	0.285	0.243	0.310	0.266	0.215	[illegible]	0.200	0.199	[illegible]	[illegible]	0.387	0.565	0.620				
(18)	0.404	0.355	0.433	0.354	0.280	0.235	0.216	0.203	0.221	[illegible]	0.312	0.496	0.627				
(19)	0.507	0.437	0.502	0.436	0.344	0.289	0.260	0.229	0.257	0.302	0.387	0.536	0.623				
(20)	0.593	0.556	0.582	0.561	0.418	0.343	0.348	0.404	0.354	0.392	0.500	0.620	0.630				
(21)	0.629	0.630	0.628	0.627	0.618	0.501	0.564	0.615	0.620	0.583	0.628	0.630	0.630				

OIL SATURATIONS LAYER # 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.522	0.517	0.526	0.537	0.549	0.557	0.565	0.557	0.559	0.573	0.579	0.582	0.585	0.588	0.590	0.591	0.591
(2)	0.505	0.381	0.428	0.481	0.526	0.555	0.527	0.423	0.469	0.527	0.565	0.580	0.585	0.587	0.590	0.591	0.590
(3)	0.380	0.216	[illegible]	0.330	0.434	0.506	0.404	[illegible]	0.328	0.411	0.493	0.554	0.558	0.566	0.571	0.570	0.576
(4)	0.448	0.326	0.361	0.428	0.498	0.555	0.531	0.397	0.461	0.531	0.566	0.576	0.578	0.582	0.585	0.587	0.587
(5)	0.513	0.401	0.480	0.510	0.522	0.558	0.565	0.524	0.535	0.546	0.547	0.532	0.539	0.553	0.582	0.582	0.582
(6)	0.531	0.434	0.492	0.517	0.533	0.553	0.567	0.571	0.573	0.574	0.573	0.572	0.573	0.575	0.576	0.576	0.577
(7)	0.476	0.294	0.427	0.481	0.507	0.546	0.563	0.554	0.568	0.569	0.564	0.561	0.562	0.567	0.569	0.568	0.569
(8)	0.524	0.463	0.529	0.520	0.496	0.523	0.553	0.536	0.567	0.561	0.547	0.535	0.536	0.545	0.552	0.550	0.553
(9)	0.509	0.503	0.500	0.478	0.397	0.449	0.509	0.547	0.563	0.560	0.528	0.499	0.510	0.507	0.524	0.535	0.532
(10)	0.495	0.503	0.467	0.415	[illegible]	0.374	0.551	0.568	0.568	0.554	0.502	0.458	0.429	0.313	0.470	0.548	
(11)	0.510	0.506	0.469	0.390	[illegible]	0.319	0.537	0.523	0.565	0.519	0.401	0.319	0.205	[illegible]	0.371	0.523	
(12)	0.473	0.480	0.517	0.456	0.339	0.452	0.564	0.566	0.536	0.482	0.396	0.321	0.455	0.353	0.482	0.539	
(13)	0.519	0.519	0.455	0.481	0.480	0.534	0.540	0.496	0.435	0.348	0.213	0.382	0.535	0.528	0.544		
(14)	0.513	0.498	0.475	0.418	0.250	0.226	0.206	0.202	0.201	0.200	[illegible]	0.329	0.447	0.473			
(15)	0.517	0.503	0.498	0.487	0.477	0.475	0.475	0.474	0.493	0.437	0.274	0.375	0.481	0.500			
(16)	0.497	0.422	0.468	0.522	0.500	0.452	0.398	0.325	0.432	0.460	0.407	0.455	0.505				
(17)	0.344	0.212	0.354	0.460	0.410	0.337	0.269	0.207	0.285	0.345	0.460	0.500	0.508				
(18)	0.463	0.404	0.433	0.502	0.475	0.410	0.366	0.297	0.382	0.437	0.505	0.559	0.550				
(19)	0.527	0.498	0.502	0.499	0.488	0.441	0.402	0.361	0.418	0.469	0.520	0.554	0.563				
(20)	0.547	0.517	0.524	0.486	0.494	0.473	0.461	0.457	0.445	0.481	0.507	0.543	0.557				
(21)	0.546	0.481	0.521	0.463	0.500	0.473	0.453	0.418	0.413	0.440	0.456	0.527	0.550				

Waskada Spearfish Waterflood Forecast Pattern 'C' 4899.00 DAYS OIL SATURATIONS LAYER # 3 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.428	0.432	0.440	0.452	0.467	0.490	0.511	0.527	0.542	0.555	0.567	0.574	0.579	0.582	0.584	0.585	0.586
(2)	0.421	0.398	0.426	0.448	0.469	0.498	0.501	0.470	0.530	0.554	0.567	0.574	0.579	0.582	0.584	0.585	0.585
(3)	0.383	0.221	0.246	0.268	0.316	0.331	0.336	0.262	0.398	0.478	0.449	0.456	0.514	0.513	0.546	0.546	0.551
(4)	0.388	0.349	0.384	0.431	0.472	0.510	0.495	0.453	0.529	0.556	0.568	0.574	0.578	0.581	0.582	0.582	0.582
(5)	0.439	0.453	0.469	0.433	0.375	0.513	0.531	0.377	0.390	0.422	0.396	0.415	0.470	0.524	0.579	0.579	0.579
(6)	0.519	0.518	0.459	0.406	0.448	0.508	0.534	0.543	0.550	0.556	0.559	0.564	0.569	0.572	0.572	0.572	0.572
(7)	0.486	0.403	0.506	0.384	0.389	0.498	0.533	0.434	0.547	0.550	0.548	0.547	0.550	0.553	0.555	0.554	0.554
(8)	0.439	0.450	0.501	0.410	0.385	0.472	0.528	0.413	0.547	0.532	0.518	0.500	0.495	0.505	0.506	0.502	0.509
(9)	0.395	0.412	0.373	0.371	0.356	0.450	0.517	0.484	0.543	0.528	0.471	0.418	0.373	0.402	0.366	0.372	0.377
(10)	0.379	0.386	0.338	0.332	0.302	0.449	0.546	0.560	0.553	0.555	0.514	0.452	0.399	0.340	0.395	0.422	
(11)	0.411	0.408	0.352	0.323	0.207	0.442	0.552	0.353	0.557	0.539	0.445	0.359	0.247	[illegible]	0.309	0.353	
(12)	0.379	0.376	0.423	0.394	0.358	0.494	0.554	0.555	0.555	0.550	0.497	0.413	0.345	0.300	0.320	0.341	
(13)	0.464	0.460	0.355	0.358	0.406	0.505	0.545	0.535	0.535	0.534	0.372	0.461	0.405	0.370	0.365		
(14)	0.487	0.483	0.453	0.440	0.425	0.391	0.340	0.314	0.289	0.252	[illegible]	0.332	0.297	0.267			
(15)	0.497	0.477	0.443	0.408	0.389	0.392	0.410	0.429	0.444	0.438	0.388	0.396	0.362	0.333			
(16)	0.486	0.429	0.429	0.506	0.467	0.418	0.384	0.350	0.441	0.391	0.428	0.428	0.402				
(17)	0.395	0.242	0.429	0.482	0.406	0.345	0.283	0.228	0.338	0.441	0.490	0.416	0.395				
(18)	0.531	0.500	0.513	0.500	0.476	0.390	0.368	0.328	0.402	0.431	0.514	0.540	0.547				
(19)	0.549	0.539	0.523	0.461	0.450	0.407	0.339	0.299	0.327	0.378	0.453	0.523	0.546				
(20)	0.550	0.501	0.522	0.451	0.469	0.426	0.394	0.352	0.331	0.351	0.365	0.465	0.527				
(21)	0.546	0.471	0.513	0.433	0.465	0.412	0.371	0.314	0.287	0.296	0.302	0.407	0.503				

TABLE #4 cont'd

Waskada Spearfish Waterflood Forecast Pattern 'C'

Waskada Spearfish Waterflood Forecast Pattern 'C' 4899.00 DAYS WATER SATURATION LAYER # 1 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.372	0.415	0.408	0.400	0.374	0.370	0.373	0.415	0.422	0.387	0.373	0.371	0.371	0.371	0.372	0.372	0.372
(2)	0.438	0.664	0.623	0.565	0.473	0.383	0.478	0.624	0.588	0.521	0.436	0.381	0.372	0.372	0.372	0.372	0.372
(3)	0.668	0.796	0.767	0.710	0.580	0.493	0.686	0.792	0.733	0.661	0.575	0.383	0.373	0.372	0.372	0.373	0.372
(4)	0.561	0.698	0.691	0.632	0.548	0.404	0.533	0.690	0.638	0.565	0.472	0.389	0.373	0.372	0.372	0.372	0.372
(5)	0.417	0.628	0.559	0.504	0.447	0.372	0.400	0.488	0.476	0.429	0.395	0.371	0.371	0.371	0.371	0.371	0.371
(6)	0.472	0.659	0.610	0.552	0.457	0.384	0.371	0.372	0.373	0.371	0.371	0.372	0.372	0.371	0.371	0.371	0.371
(7)	0.601	0.780	0.701	0.627	0.535	0.412	0.376	0.371	0.370	0.370	0.374	0.388	0.382	0.373	0.371	0.371	0.371
(8)	0.401	0.625	0.521	0.439	0.428	0.410	0.375	0.370	0.370	0.374	0.405	0.471	0.472	0.428	0.371	0.372	0.371
(9)	0.371	0.488	0.384	0.420	0.596	0.575	0.499	0.413	0.373	0.391	0.479	0.575	0.557	0.531	0.483	0.389	0.371
(10)	0.369	0.370	0.376	0.550	0.746	0.674	0.412	0.372	0.371	0.417	0.535	0.629	0.725	0.796	0.702	0.450	
(11)	0.369	0.369	0.413	0.603	0.798	0.744	0.497	0.410	0.377	0.472	0.643	0.736	0.800	0.800	0.700	0.451	
(12)	0.369	0.369	0.404	0.611	0.760	0.674	0.442	0.386	0.428	0.495	0.583	0.413	0.539	0.636	0.472	0.375	
(13)	0.369	0.369	0.377	0.499	0.630	0.542	0.489	0.539	0.605	0.669	0.791	0.587	0.373	0.386	0.369		
(14)	0.370	0.400	0.407	0.397	0.619	0.770	0.787	0.790	0.792	0.797	0.801	0.661	0.463	0.373			
(15)	0.380	0.503	0.472	0.428	0.590	0.665	0.693	0.704	0.622	0.560	0.646	0.597	0.437	0.369			
(16)	0.453	0.650	0.572	0.709	0.742	0.769	0.785	0.796	0.747	0.711	0.665	0.569	0.417				
(17)	0.715	0.757	0.690	0.734	0.785	0.799	0.800	0.801	0.798	0.789	0.608	0.435	0.380				
(18)	0.596	0.648	0.567	0.646	0.720	0.765	0.784	0.797	0.779	0.745	0.688	0.504	0.373				
(19)	0.493	0.543	0.498	0.564	0.656	0.711	0.740	0.771	0.743	0.698	0.613	0.464	0.377				
(20)	0.407	0.444	0.418	0.439	0.582	0.657	0.652	0.591	0.646	0.608	0.500	0.380	0.370				
(21)	0.371	0.370	0.372	0.373	0.382	0.499	0.436	0.385	0.380	0.417	0.372	0.370	0.370				

WATER SATURATION LAYER # 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.478	0.483	0.474	0.463	0.451	0.443	0.435	0.443	0.441	0.427	0.421	0.418	0.415	0.412	0.410	0.409	0.409
(2)	0.495	0.619	0.572	0.519	0.474	0.445	0.473	0.577	0.531	0.473	0.435	0.420	0.415	0.413	0.410	0.409	0.409
(3)	0.620	0.784	0.726	0.670	0.566	0.494	0.596	0.763	0.672	0.589	0.507	0.446	0.442	0.434	0.429	0.430	0.423
(4)	0.552	0.674	0.639	0.572	0.502	0.445	0.469	0.603	0.539	0.469	0.434	0.424	0.422	0.418	0.415	0.413	0.413
(5)	0.487	0.599	0.520	0.490	0.478	0.442	0.435	0.476	0.465	0.454	0.453	0.468	0.461	0.447	0.418	0.418	0.418
(6)	0.469	0.566	0.508	0.483	0.467	0.447	0.433	0.429	0.427	0.426	0.427	0.428	0.427	0.425	0.424	0.424	0.423
(7)	0.524	0.706	0.573	0.519	0.493	0.454	0.437	0.446	0.432	0.431	0.436	0.439	0.438	0.433	0.431	0.432	0.431
(8)	0.476	0.537	0.471	0.480	0.504	0.477	0.447	0.464	0.433	0.439	0.453	0.465	0.464	0.455	0.448	0.450	0.447
(9)	0.491	0.497	0.500	0.522	0.603	0.551	0.491	0.453	0.437	0.440	0.472	0.501	0.490	0.493	0.476	0.465	0.468
(10)	0.505	0.497	0.533	0.585	0.718	0.626	0.449	0.432	0.432	0.446	0.498	0.542	0.571	0.687	0.530	0.452	
(11)	0.490	0.494	0.531	0.610	0.784	0.681	0.463	0.477	0.435	0.481	0.599	0.681	0.795	0.800	0.629	0.477	
(12)	0.527	0.520	0.483	0.544	0.661	0.548	0.436	0.434	0.464	0.518	0.604	0.479	0.545	0.645	0.518	0.461	
(13)	0.481	0.481	0.545	0.519	0.520	0.466	0.460	0.504	0.565	0.652	0.787	0.618	0.465	0.472	0.456		
(14)	0.487	0.502	0.525	0.582	0.750	0.774	0.794	0.798	0.799	0.800	0.801	0.671	0.553	0.527			
(15)	0.483	0.497	0.502	0.513	0.523	0.525	0.525	0.526	0.507	0.563	0.726	0.625	0.519	0.500			
(16)	0.503	0.578	0.532	0.478	0.500	0.548	0.602	0.675	0.568	0.540	0.593	0.545	0.495				
(17)	0.656	0.788	0.646	0.540	0.590	0.663	0.731	0.793	0.715	0.655	0.531	0.500	0.492				
(18)	0.537	0.596	0.567	0.498	0.525	0.590	0.634	0.703	0.618	0.563	0.495	0.441	0.450				
(19)	0.473	0.502	0.498	0.501	0.512	0.559	0.598	0.639	0.582	0.531	0.480	0.446	0.437				
(20)	0.453	0.483	0.476	0.514	0.506	0.527	0.539	0.535	0.555	0.519	0.493	0.457	0.443				
(21)	0.454	0.519	0.479	0.537	0.500	0.527	0.547	0.582	0.587	0.560	0.544	0.473	0.450				

Waskada Spearfish Waterflood Forecast Pattern 'C' 4899.00 DAYS WATER SATURATION LAYER # 3 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.572	0.568	0.560	0.548	0.533	0.510	0.489	0.473	0.458	0.445	0.433	0.426	0.421	0.418	0.416	0.415	0.414
(2)	0.579	0.602	0.574	0.552	0.531	0.502	0.499	0.530	0.470	0.446	0.433	0.426	0.421	0.418	0.416	0.415	0.415
(3)	0.617	0.779	0.754	0.737	0.684	0.669	0.664	0.738	0.602	0.522	0.551	0.544	0.486	0.487	0.454	0.454	0.449
(4)	0.612	0.651	0.616	0.569	0.528	0.490	0.505	0.547	0.471	0.444	0.432	0.426	0.422	0.419	0.418	0.418	0.418
(5)	0.561	0.547	0.531	0.567	0.625	0.487	0.469	0.623	0.610	0.578	0.604	0.585	0.530	0.476	0.421	0.421	0.421
(6)	0.481	0.482	0.541	0.594	0.552	0.492	0.466	0.457	0.450	0.444	0.441	0.436	0.431	0.428	0.428	0.428	0.428
(7)	0.514	0.597	0.494	0.616	0.611	0.502	0.467	0.566	0.453	0.450	0.452	0.453	0.450	0.447	0.445	0.446	0.446
(8)	0.561	0.550	0.499	0.590	0.615	0.528	0.472	0.587	0.453	0.463	0.482	0.500	0.505	0.495	0.494	0.498	0.491
(9)	0.605	0.588	0.627	0.629	0.644	0.550	0.483	0.516	0.457	0.472	0.529	0.582	0.627	0.598	0.634	0.628	0.623
(10)	0.621	0.614	0.662	0.668	0.698	0.551	0.454	0.440	0.447	0.445	0.486	0.548	0.601	0.660	0.605	0.578	
(11)	0.589	0.584	0.648	0.677	0.793	0.558	0.448	0.647	0.443	0.461	0.555	0.641	0.753	0.784	0.691	0.647	
(12)	0.621	0.624	0.577	0.606	0.642	0.506	0.446	0.445	0.445	0.450	0.503	0.587	0.655	0.700	0.680	0.659	
(13)	0.536	0.540	0.645	0.642	0.594	0.495	0.455	0.465	0.465	0.466	0.623	0.539	0.595	0.630	0.635		
(14)	0.513	0.517	0.547	0.560	0.575	0.609	0.660	0.686	0.711	0.748	0.781	0.668	0.703	0.733			
(15)	0.503	0.523	0.557	0.592	0.611	0.608	0.590	0.571	0.556	0.562	0.612	0.604	0.638	0.667			
(16)	0.514	0.571	0.571	0.494	0.533	0.582	0.616	0.650	0.559	0.609	0.572	0.572	0.598				
(17)	0.605	0.758	0.571	0.518	0.594	0.655	0.717	0.772	0.662	0.559	0.498	0.584	0.605				
(18)	0.469	0.500	0.487	0.500	0.524	0.610	0.632	0.672	0.598	0.569	0.486	0.460	0.453				
(19)	0.451	0.461	0.477	0.539	0.550	0.593	0.661	0.701	0.673	0.622	0.547	0.477	0.454				
(20)	0.450	0.499	0.478	0.549	0.531	0.574	0.606	0.648	0.669	0.649	0.635	0.535	0.473				
(21)	0.454	0.529	0.487	0.567	0.535	0.588	0.629	0.686	0.713	0.704	0.698	0.593	0.497				

TABLE # 4 cont'd

Waskada Spearfish Waterflood Forecast Pattern 'C'

Waskada Spearfish Waterflood Forecast Pattern 'C' 4899.00 DAYS GAS SATURATIONS LAYER # 1 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.003	0.008	0.014
(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.003	0.006	0.009	0.015
(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.004	0.003	0.004	0.010
(4)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.001	0.002
(5)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(6)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(7)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(8)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(9)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.001	0.	0.	0.
(10)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(11)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(12)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(13)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(14)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(15)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(16)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(17)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.006	0.	0.				
(18)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(19)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(20)	0.	0.	0.	0.	0.	0.	0.	0.005	0.	0.	0.	0.	0.				
(21)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				

GAS SATURATIONS LAYER # 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.001
(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.001	0.	0.	0.001
(4)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(5)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(6)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(7)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(8)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(9)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(10)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(11)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(12)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(13)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(14)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(15)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(16)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(17)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.009	0.	0.				
(18)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(19)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(20)	0.	0.	0.	0.	0.	0.	0.	0.008	0.	0.	0.	0.	0.				
(21)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				

Waskada Spearfish Waterflood Forecast Pattern 'C' 4899.00 DAYS GAS SATURATIONS LAYER # 3 RUNTIME

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(3)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(4)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(5)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(6)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(7)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(8)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(9)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(10)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(11)	0.	0.009	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(12)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(13)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(14)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(15)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(16)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(17)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.011	0.	0.				
(18)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(19)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(20)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(21)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				

Manitoba

The Oil and Natural Gas Conservation Board

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

(204) 945-3130

Enron Oil Canada Ltd.
1300, 700 - 9th Avenue S.W.
Calgary, Alberta
T2P 3V4

Attention: R.A. Smith, P. Eng.
Senior Reservoir Engineer

Dear Sirs:

Re: Waskada Unit No. 16
Pressure Maintenance Project

Your letter of December 1, 1986 regarding the subject proposed pressure maintenance scheme has been reviewed in detail.

In general, the Board's position on approval of off pattern injectors is that such off pattern injection should clearly result in an improvement in ultimate recovery while not jeopardizing the rights of offsetting operators and mineral rights owners. The reason for this is that all other things being equal, a regular pattern will result in the optimum areal sweep and hence recovery.

Upon detailed review of your submission, we are not convinced that it has been clearly demonstrated that the proposed pattern will result in an increase in ultimate recovery in the area.

It is generally accepted that the accuracy of a reservoir model prediction decreases as the length of predition increases. Thus it follows that a prediction of say 10 years will be more valid than a prediction of 35 years. This is particularly true when the history match period is limited.

In view of this, we refer you to Attachments 1 and 2. These figures depict the predicted change in cumulative production (for your proposed pattern compared with the standard pattern) for the Unit Area and the study area as a whole. Note that in both cases, the proposed pattern results in a considerable loss of recovery over the standard pattern at 10 years. While this differential decreases over the next 25 years, it never becomes significantly positive. Also, further to our above comments regarding predictions, it would appear that the loss of cumulative recovery over the first 10 years of the project is more likely to occur than the subsequent convergence of cumulative production at 35 years.

As a result of the foregoing, we contend that the potential cost in lost reserves of the proposed pattern may total as much as 75,000 STB (12 000 m^3).

We do recognize that due to communication with the Mississippian that use of the standard pattern may result in some loss of reserves as compared with theoretical results. However, no attempt has been made to quantify this in your predictions. We suggest that a model study using the standard injection pattern locations and assuming that only a portion of the water injected will enter the Lower Amaranth would be useful in providing an indication of the potential for recovery loss. Further to this, a method of estimating the portion of fluid lost to the Mississippian is suggested on Attachment No. 3.

Yours sincerely,

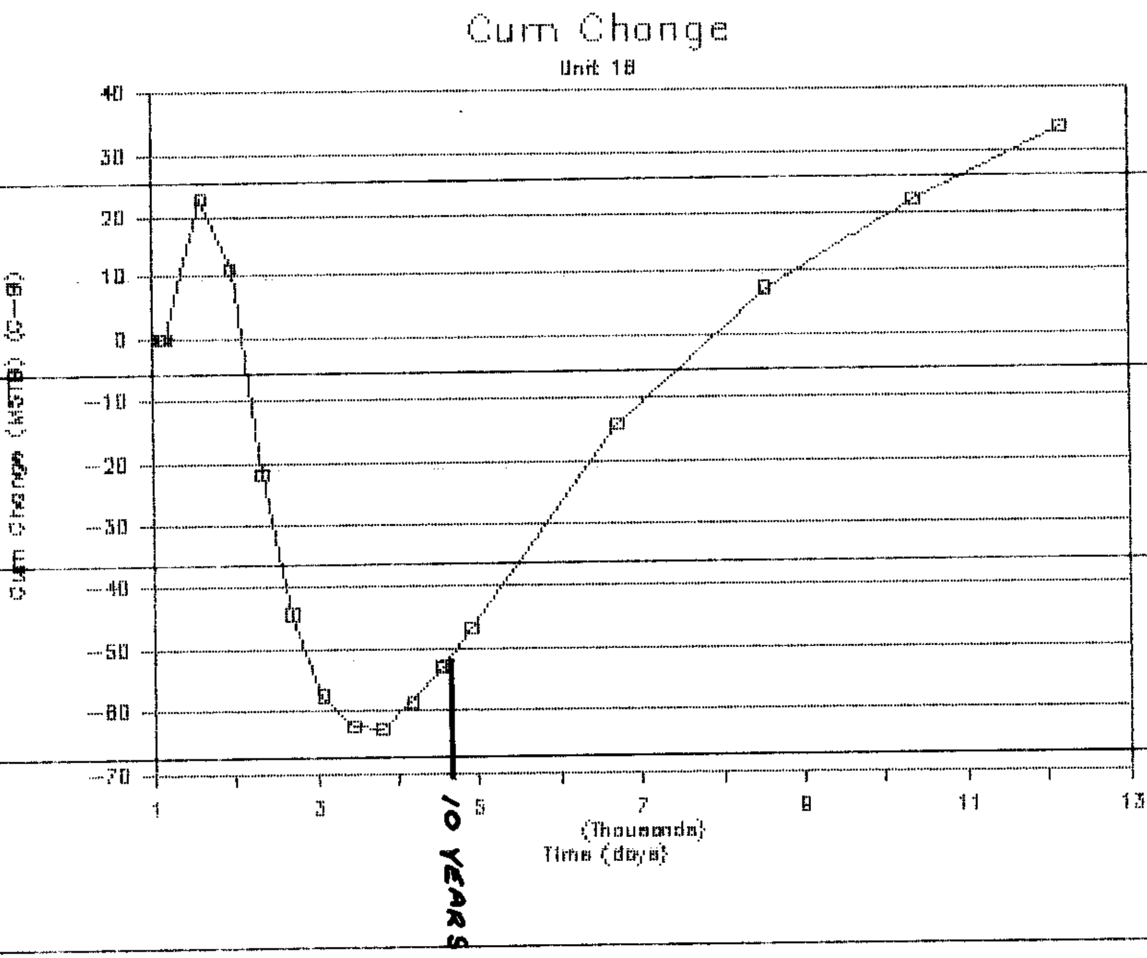
Wm. McDonald
Deputy Chairman

LRD/HCM/lk

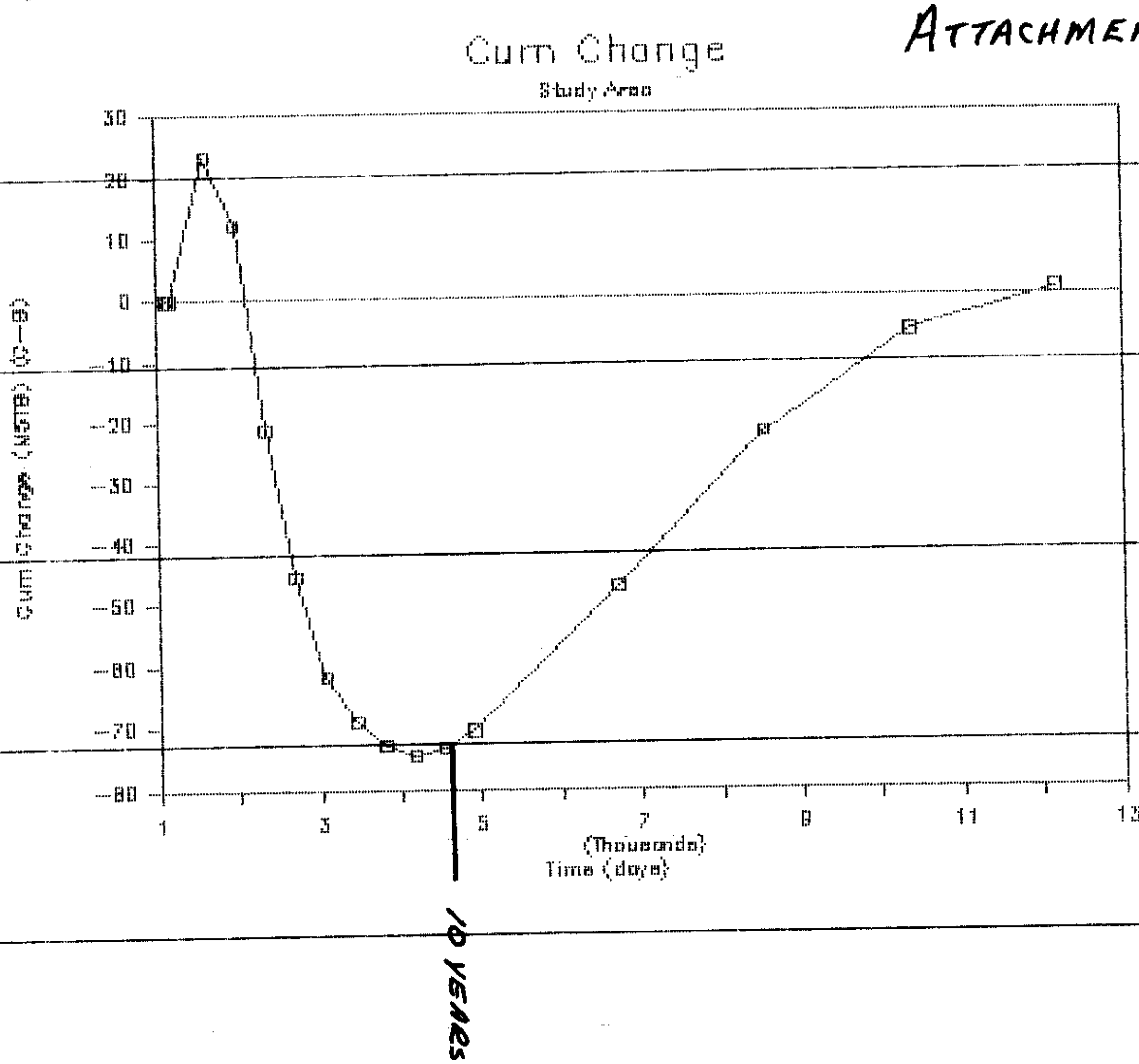
b.c. Charles S. Kang
B. Ball
Petroleum

0857P

ATTACHMENT #1



ATTACHMENT #2



ATTACHMENT NO. 3

Estimate of Injection
Loss to Mississippian

Assumptions

1. All oil and up to a 10 percent water cut originates in the Lower Amaranth.

2. A water shut off treatment is conducted that allows maintenance of a constant percentage split between the Mississippian and the Lower Amaranth.

Calculations:

Three wells exhibit water cuts substantially in excess of 10% suggesting possible water encroachment from the Mississippian.

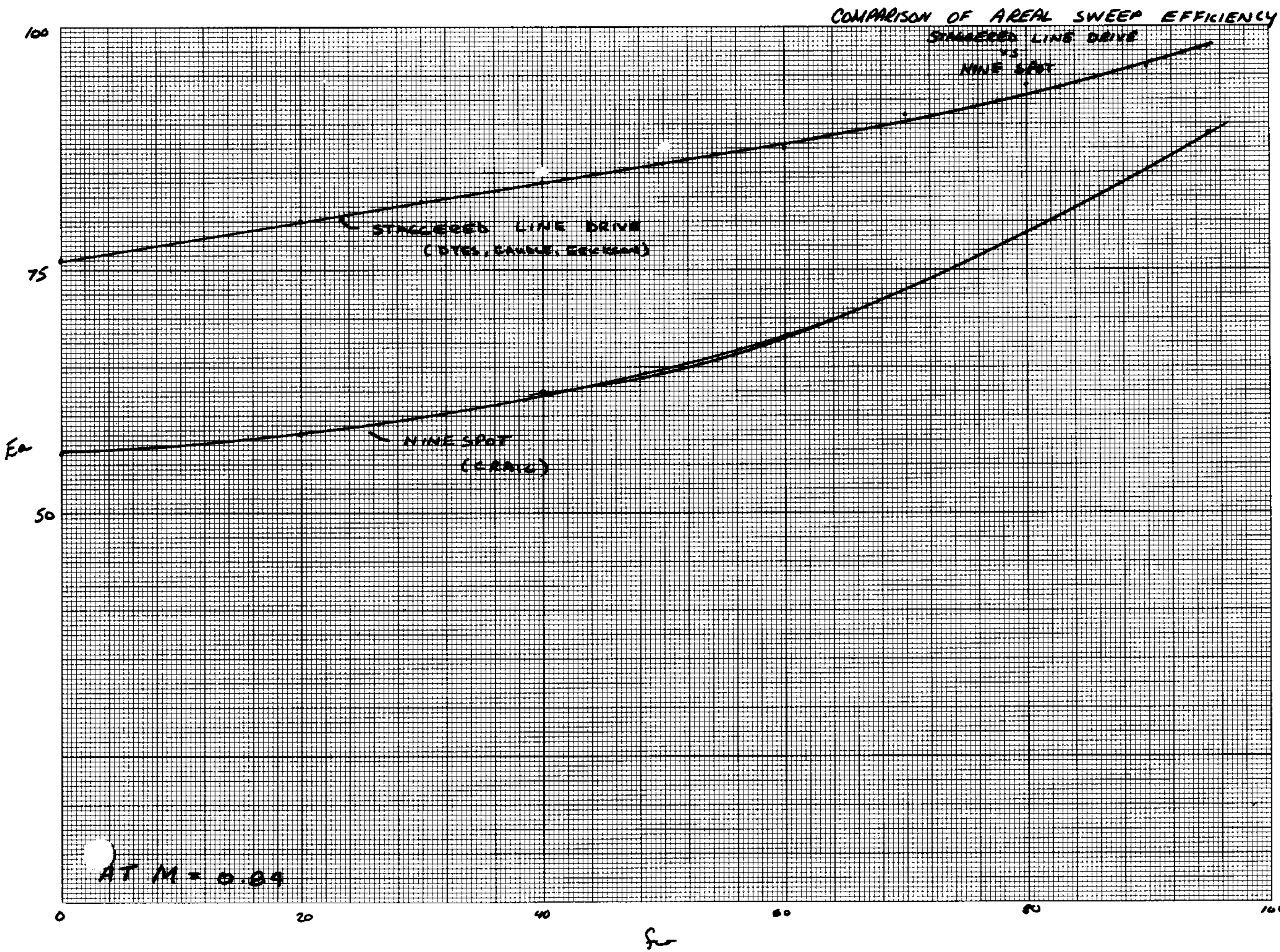
A) 13-4-2-25
Oil = 2.8 m^3/d
Water cut = 55.2%
Water = 3.45 m^3/d
Fluid from L.Am = 2.8 m^3/d oil and 0.31 m^3/d water
= 3.11 m^3
Total Fluids = 2.8 + 3.45 = 6.25 m^3/d
Percent from L.Am = 3.11 ÷ 6.25 = 50%

B) 15-5-2-25
Oil = 1.7 m^3/d
Water Cut = 22.3%
Water = 0.49 m^3/d
Fluid from L.Am = 1.7 m^3/d oil + 0.19 m^3/d water = 1.89 m^3/d
Total Fluids = 1.7 + 0.49 = 2.19 m^3/d
Percent from L.Am = 1.89 ÷ 2.19 = 86%

C) 16-5-2-25
Oil = 1.9 m^3/d
Water Cut = 165%
Water = 0.38 m^3/d
Fluid from L.Am = 1.9 m^3/d oil + 0.21 m^3/d water = 2.11 m^3/d
Total Fluids = 1.9 + 0.38 = 2.28
Percent from L.Am = 2.11 ÷ 2.28 = 93%

NO. 341-M DIETZGEN GRAPH PAPER
MILLIMETER

DIETZGEN CORPORATION
MADE IN U.S.A.



Comparison of Forecasts B & C for Recovery outside Unit 16 area

Time	Case B OIL	Case B CUM	Case C OIL	Case C CUM	
1096	291.0	173.45	291.0	173.45	
1126	271.4	181.76	271.4	181.76	
1156	277.9	190.15	277.9	190.15	
1249	275.1	215.74	275.2	198.41	
1614	281.6	210.18	280.5	310.53	
1979	239.9	402.81	239.4	403.83	
2344	220.2	485.47	217.3	486.08	
2709	208.0	562.97	201.4	561.64	
3074	196.0	636.14	188.4	632.08	
3439	184.5	704.98	177.8	698.32	
3804	175.3	770.20	162.8	760.13	
4169	167.4	832.33	150.2	816.45	
4534	150.3	888.65	139.2	868.55	
4899	143.7	941.96	133.8	918.09	
6724	113.7	1176.08	115.3	1143.02	
8549	100.6	1370.59	103.0	1341.2	
10374	85.4	1536.25	85.4	1508.7	
12199	76.5	1683.37	74.6	1650.89	
14024	65.6	1811.28	72.4	1702.49	-6.39

@ 6724 (Dec 2001)	C - 1740.32 B - 1754.48	Δ = 14.16 MSTB − ve
@ 12199	C 2585.72 B 2551.96	Δ = 33.76 MSTB + ve

∴ AT Dec 2016 Overall Cum P is about equal

However at Dec 2001 the proposed pattern results in ≈ 47 MSTB less recovery than the standard one.

Given that the longer one carries out a prediction, the more suspect the results are, it is suggested there is a reasonable chance that the proposed scheme will result in an overall loss of some 45-50 MSTB.

In your model run with 13-4 as an injector, I assume that you did not model loss of some water to the Mississippian - Can this be done?

In other words, we know the potential loss of recovery by switching patterns. ~~Can this~~ ~~To evaluate the effect of possible Mississippian communication~~. We should now have some indication of the effect of injection losses on recovery.

See Study

File in

Engineering Room

For

"Waterflood Study"

"Waskada Lower Amaranth Zone

Proposed Unit No. 16"

ENRON
OIL CANADA LTD.

1300, 700 - 9th Avenue S.W., Calgary, Alberta T2P 3V4 (403) 298-2600

DEPARTMENT OF ENERGY AND MINES
DEC 3 1986
PETROLEUM BRANCH

1 December 1986

The Oil and Natural Gas Conservation Board
#555, 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Attention: Mr. Charles S. Kang,
Chairman

Dear Sir:

Re: Additional Information and Amendments to
Waskada Lower Amaranth "A" Pool
Pressure Maintenance Application
Dated: August 13, 1986

Within the following application we will first address the deficiencies as noted in your letter of September 10, 1986 and following this we will discuss the results of the simulation study as contained in the attached report, as well as Enron's proposed amendment.

Deficiencies

1. In regards to the injector 15-4, the original text should have read:

   "Enron Oil Canada Ltd. requests permission to inject water into wells' Andex Waskada 12-4-2-25, Andex Waskada 15-4-2-25, Andex Waskada 16-5-2-25 and Andex Waskada 3-4-2-25 coincident with the effective date of the new Unit."

2. The letter from Omega regarding the water supply agreement is attached as complete.

3. The reservoir pressures discussed in the Preliminary Engineering Report (dated July 1986) were not corrected to the pool datum. They are now corrected and included as such in Table 3 in the attached report. The impact was insignificant due to the flat topography of the study area.

4. In regards to the Claridge analytical model; the results were intended as a preliminary look. With any analytical model it lacks some of the discreteness of a 3D simulator which study we have now completed. For additional information please refer to paper number SPE 2930 for the original paper by E.L. Claridge. Also included is a paper by B.A. Slevinsky et al which compare the performance of the Claridge model to simulator results. The program was purchased from D & S Consultants in Calgary; please contact Bruce Slevinsky for further discussion (403-268-6617).

5. With regards to the final deficiency of insufficient information regarding off-patter injection we wish to state the following in support of our position:

   There is no doubt that the advantage of a regular pattern allows for optimum sweep when all things considered are equal. Strict adherence however does not allow for heterogeneities and other producing/injecting considerations which can affect the flood performance. For example:

   i) Although the Lower Amaranth A zone is "blanket" in nature, it does not equate that it is necessarily continuous in all lenses. This fact is demonstrated by various papers discussing infill drilling. One such (attached for your perusal) "Infill Drilling to Increase Reserves - Actual Experience in Nine Fields in Texas, Oklahoma and Illinois; JPT August 1983" shows that pools with 40 acre spacing which were initially thought to have 85% lens continuity actually only had 30% continuity between 40 acre locations and 60% between 10 acre locations after infill drilling down to 10 acre spacing. Thus, injecting into a well that evidenced more stringers increases the probability that all lenses will be swept to some degree. This is a more important consideration in a nine spot with a 3 to 1 producer/injector ratio rather than a 5 spot pattern that has a 1 to 1 ratio. At least with a 5 spot a "partial pattern" would probably exist for any given lens.

   ii) Due to the variance in well productivity, some attention should be devoted to this criteria. The gain in water injection capacity from oil production capacity after converting an oil well to a water injector is far greater than the oil rate gains experienced by an oil well subsequent to pressure maintenance. This point was discussed in the original application but the data which exemplifies the injection capacity gains is repeated below for convenience.

Location	Initial Oil Rate (m^3/day)	Maximum Injection Rate (m^3/day)	Average Injection Rate (m^3/day)
15-8-1-26	2.8	89	53

As can be seen from the Omega well within the study area, the ratio of injectivity rate to oil rate is very large. Looking at injectors further removed from our project is as follows:

Location	Initial Oil Rate (m^3/day)	Injection Rate (m^3/day)
15-23-1-26	6.5	62
13A-24-1-26	1.3	72
15-24-1-26	2.1	82
5-25-1-26	6.7	126
7-25-1-26	9.7	106
13-25-1-26	2.0	28
15-25-1-26	2.5	28
7-26-1-26	2.8	57

The high capacity gains upon converting to an injector not only substantiates the viability of an inverted nine spot but also allows flexibility in keeping the better producers as oil producers. All other things being equal the preference should be to convert one of two wells having the lower productivity, thus shortening the waterflood life. Depending on the economic limit, the recoverable reserves could be noticeably higher if most of the high rate wells were maintained as producers.

iii) A final consideration in examining injection location possibilities is the potential of injection losses to the Mississippian. Commmunication with the Mississippian is a common problem in the Lower Amaranth A and where it exists it always results in high water cuts in producers and injection losses for the injectors. This loss in injection is more of a concern than one would at first anticipate. We currently operate two waterfloods in Alberta (Highvale Field) that are under injected (due to injection loss) as confirmed by pressure analysis. The complications are as follows:

a) Pressure surveys must be on producers with low water cuts to eliminate the effect of Mississippian pressure communication. Our experience indicates that getting reliable pressure surveys from seven day buildups in a rock that is layered and often tight could be difficult. However, assuming success in obtaining the necessary reservoir pressures it would take a few years (time to fillup) to identify the disparity between actual reservoir pressure and the presumed reservoir pressure. Unfortunately the initial reservoir pressure in the project area is unknown but assumed, which introduces some uncertainty as to further preclude early idenfification of injection losses. Once the loss is identified there remains the task of determining which injectors are transmitting losses and how much. Potential anisotropy and uneven continuity will make the above mentioned task difficult.

b) If over injection is the preferred path, thus ensuring that replacement will be acheived, the risk of channelling is increased (if in fact the injector is over injecting) and again the magnitude of over or under injection will be uncertain until approximately fillup as discussed in a) above.

c) Workovers to shut off the Mississippian water have not been completely successful. Within the project area, location 4-9 is an example of reducing water cuts from 95% to its current 50% value. The question of successfully shutting off the Mississippian in an injector is even more uncertain considering that for producers where low wellbore pressures tend to keep the frac closed, the water production is often only reduced not shut off completely as in location 4-9. Add to this the high bottom hole pressures of an injector and the successful cement squeezes on a producer will not necessarily retain its integrity. The success of the cement squeeze on an injector would be difficult to assess via pressure analysis since the pressure response of the Mississippian would behave most like a high permeability layer within the Lower Amaranth Unit. Also, the production response of the offset producers would not be a reliable indicator as point d) below demonstrates.

d) Another element of concern associated with injection losses is the potential flood losses in the medium and low permeability sands. With restricted vertical communication, the amount of water received by any lens is proportionate to its permeability. Hence with fracture communication to the Mississippian, the lion's share of injection volumes will no doubt go to the high permeability lens and the Mississippian. Since the high permeability layers yield the majority of the production in the early years of a flood this phenomenon as discussed above will not be recognizable, and all will seem to be going well, at least during the initial phase. However as water breakthrough becomes evident, the high capacity layer will yield mostly water and the medium and low capacity layers will not perform as predicted due to lack of water supply and the later stages of the flood will perform very poorly.

e) Finally, the results of further model study as the flood progresses becomes tenuous due to the uncertainty of injection volumes into the Lower Amaranth A zone.

Following the above reasoning, the specific injector locations as preferred by Enron of Canada Ltd., can be addressed in conjunction with a review of the 1986 production data and calculated net pay as displayed below.

INJECTION LOCATION COMPARISON

Oil Rate (m^3/d)	Jan	Feb	Mar	April	May	June	July	Aug	Sept
3-4	-	-	-	-	-	-	3.0	1.8	1.4
4-4	-	8.2	7.8	-	-	10.3	8.4	6.9	5.9
5-4	13.4	10.4	9.6	-	-	-	-	10.8	8.6
6-4	-	9.9	7.3	-	-	10.9	10.2	8.7	7.8
11-4	-	3.8	2.6	-	-	4.1	2.6	2.2	2.0
12-4	-	8.4	6.0	-	-	10.3	8.1	4.8	4.1
13-4	7.7	6.0	6.3	-	-	6.6	3.7	3.2	2.8
14-4	-	4.8	3.6	-	-	4.9	3.6	3.0	2.9
15-4	1.4	1.4	1.4	-	-	-	-	-	-
9-5	16.0	14.6	10.9	-	-	-	-	11.8	10.4
10-5	2.1	1.3	1.4	-	-	2.3	1.1	1.3	2.5
15-5	2.1	1.7	1.4	-	-	-	-	2.9	1.7
16-5	2.3	2.3	2.0	-	-	4.1	2.5	2.0	1.9
Water Cut (%)									
3-4	-	-	-	-	-	-	16.8	6.2	9.5
4-4	-	2.8	5.7	-	-	8.0	3.6	2.5	4.8
5-4	8.5	7.4	10.7	-	-	-	-	8.8	10.8
6-4	-	3.1	7.8	-	-	8.4	4.2	5.7	2.3
11-4	-	2.4	3.9	-	-	5.9	4.4	4.6	4.5
12-4	-	7.0	4.6	-	-	9.9	9.6	13.7	5.0
13-4	40.3	41.2	35.5	-	-	49.7	51.7	52.3	55.2
14-4	-	2.4	2.6	-	-	6.6	2.7	9.5	3.4
15-4	11.1	5.9	8.5	-	-	-	-	-	-
9-5	8.3	5.8	5.5	-	-	-	-	11.8	6.1
10-5	N/A	11.2	N/A	-	-	11.2	12.6	10.0	9.6
15-5	22.6	17.1	24.0	-	-	-	-	30.3	22.3
16-5	17.9	10.6	20.0	-	-	17.1	19.6	22.6	16.5

Calculated net pay taken from Table 1 (attached report) is repeated below.

Well Location	Total Calculated Net Pay (ft)
3-4-2-25*	23.8
4-4-2-25	14.8
5-4-2-25	18.7
6-4-2-25	11.9
11-4-2-25*	38.1
12-4-2-25	8.6
13-4-2-25*	26.6
14-4-2-25	21.4
15-4-2-25*	44.8
9-5-2-25	13.2
10-5-2-25*	9.0
15-5-2-25*	14.9
16-5-2-25*	23.5

*Wells with core data.

Choosing Injector Locations

The various quarter sections can be examined with reference to the three criteria discussed above.

	Net Pay	Potential Productivity Loss	Barrier to Mississippian Communication
NE¼ Section 4			
15-4	High	Low	Good
NW¼ Section 4			
11-4	High	Low	Excellent
12-4	Low	Medium	Excellent
13-4	Medium	Low	Very Poor
14-4	Medium	Low	Excellent
SW¼ Section 4			
3-4	High	Low	Good
4-4	Medium	Medium	Excellent
5-4	Medium	High	Good
6-4	Low	High	Excellent
NE¼ Section 5			
9-5	Medium	High	Excellent
10-5	Low	Low	Good
15-5	Medium	Low	Poor
16-5	High	Low	Medium

Although there is only one candidate for NE¼ Section 4, the qualifications are excellent for an injector location; high net pay increases the probability that all lenses will be at least partially swept, the barrier to Mississippian communication is obvious with water cuts less than 10%, and finally the overall oil production capacity of the project is affected very little by converting 15-4 to an injector.

All wells of the SW¼ of Section 4 exhibit good communication barrier status. To avoid high productivity loss would eliminate 5-4 and 6-4 as choice. Considering net pay figures also rules out 6-4 and identifies 3-4 as the best choice. Location 3-4 is also the best choice as identified by the low loss to oil productivity upon converting it to an injector.

The NW¼ of Section 4 immediately looses 13-4 as a potential candidate due to its very poor barrier status; water cuts in excess of 50% are the highest of any potential injector location. To avoid placing an injector next to another injector, ie always having one producer separating two injectors as in an inverted nine spot, requires elimination of 14-4 and possibly 11-4 leaving 12-4. Location 11-4 certainly stacks up as the best injector location of this quarter and could be considered as a viable alternative to 12-4.

The NE¼ of Section 5 is more of a mixed bag. Location 15-5 has the highest water cuts of this quarter which again, being our major concern, disallows this choice. Location 10-5 is next to the 7-5 Omega injector, and also has very low net pay which suggests inadequate flooding of some lenses. Neither of the remaining choices, being 9-5 and 16-5, are excellent choices. The concern of 16-5 is the water cut which although not high averages 18% for 1986. Location 9-5 has excellent "barrier to communication" status but would be next to injector 12-4 and as the best producer within the whole project area would suffer high oil productivity losses. Location 16-5 on the other hand has excellent net pay and would suffer very little in the way of productivity loss. Everything considered, our choice is location 16-5.

Proposed Amendment to Injector Locations

Because the above injector pattern choice has met with objection from Omega Hydrocarbons Ltd. we have met with Omega and discussed the elements of the pattern and in consideration of the concerns of both parties we have proposed to Omega that amendments (see attached letter dated November 21, 1986) be made as follows:

- Move injector location from 3-4 to 5-4; and
- Move injector location from 12-4 to 11-4

Appropriate schematic changes (injection well diagrams and flowline maps) are included. The model results show that this final injector pattern gives the best recovery of all three waterflood cases. Omega has agreed to waive their objection based on the above (see attached letter dated November 18, 1986).

Simulation Model Results

The attached 3D black oil simulation study presents details of five thirty-five year forecast cases.

- Project under primary with outside Omega injectors injecting (Case A).
- Project under primary with outside Omega injectors as oil producers (Case B).
- Project under waterflood with Enron initial preferred injector locations (Case A).
- Project under waterflood with standard pattern (Case B).
- Project under waterflood with Enron final injector locations (Case C).

Results are summarized below:

	Prim A	Prim B	Wtrfld A	Wtrfld B	Wtrfld C
Percent recovery @ 10 years	7.2	5.6	12.5	13.0	12.6
Produced oil @ 10 years (MSTB)	747	586	1 305	1 356	1 313
Water injected @ 10 years (MSTB)	0	0	2 666	2 436	3 116
Percent recovery @ 35 years	11.8	8.8	24.2	26.3	26.5
Produced oil @ 35 years (MSTB)	1 232	913	2 516	2 736	2 761
Water injected @ 35 years (MSTB)	0	0	8 527	7 618	9 702

Due to the assumptions and restrictions of the model, the above figures do not consider the following items nor their impact on recovery and performance.

- The Mississippian zone is not modelled and thus communication with the wet Mississippian on either producers or injectors is unaccounted for. Case B, the standard pattern, uses two injections wells (15-5 and 13-4) that are obviously in communication with the Mississippian. The negative effect of water injection loss is unaccounted for and the total impact on Case B is unknown.
- The actual injectivity of the injectors is unknown and the assumption of multiplying the injector cell transmissibility by 100X has limited reliability. A higher number would change the performance as all cases are injector restricted due to the pressure constraint thus affecting withdrawal replacement.
- The data available for history match is somewhat scanty due to the newness of the wells and uncertainty over GOR and WOR data. Also, the pressure survey includes mostly AWS results which are not as reliable as the static gradients taken at the same time.

All simulations were run using D&S Consultants "FAST", fully implicit three dimensional black oil simulator.

Yours very truly,

ENRON OIL CANADA LTD.

R.A.W. Smith, P.Eng.
Senior Reservoir Engineer

RAWS:pdc
attach

cc/w: Audax Gas & Oil Ltd., Attention: Mr. P.E. McComb
Chauvco Resources Ltd., Attention: Mr. E.A. Beaman
Consolidated Pipe Lines Company, Attention: Mr. P. Sidey
Highridge Exploration Ltd., Attention: Mr. R.T. Vanderham

OMEGA
HYDROCARBONS LTD.

1300 SUN LIFE PLAZA III
112 - 4th AVENUE S.W.
CALGARY, ALBERTA, CANADA T2P 0H3
TELEPHONE (403) 261-0743

August 8, 1986

Andex Oil Co. Ltd.
1300, 700 - 9th Avenue S.W.
Calgary, Alberta
T2P 3V4

Attention: R.A. Schultz

Dear Sirs:

Re: Purchase of Formation Water

Omega Hydrocarbons Ltd. (Omega) has equipped the well Omega Waskada 2-18-2-25 as a water source well. Andex Oil Co. Ltd. (Andex) has offered to purchase water produced from the Blairmore Formation underlying the said well (the water) and Omega has agreed to sell the water to Andex under the following terms and conditions:

1. The water will be delivered to Andex via pipeline at a presure of at least 9,000 kilopascals (kPa) to a point located in Legal Subdivision Twelve (12) of Section Nine (9), Township Two (2), Range Twenty-five (25), West of the Principal Meridian (WPM) in the Province of Manitoba (point of delivery).

2. All costs and expenses required and necessary to tie-in Andex's pipeline to Omega's pipeline shall be borne by Andex.

3. Omega will endeavour to deliver to Andex its full requirement of water during each and every month of the term hereof (such amount estimated to be one hundred thirty (130) cubic metres per day); provided, however, it reserves the right to limit or discontinue the delivery of water at any time or from time to time immediately after notice of such intention has been given either verbally or in writing to Andex.

4. Andex will obtain any and all governmental permission and authorization required or necessary to accept water from Omega and use the water for its intended purposes.

5. Andex will be charged and will pay to Omega $1.60 per cubic metre for all water delivered to it by Omega at the point of delivery. Payment for the water delivered hereunder will be on the basis of measuring devises of a type appropriate for its intended use which shall be furnished and installed at the point of delivery by Andex. Invoices will be rendered each month and payment made on or before the 20th day of the month following the month in which the invoice was received.

6. Following the initial period of two (2) years as provided in paragraph 8 hereof, the charge per cubic metre for water delivered hereunder is subject to change from time to time by Omega on Thirty (30) days written notice to Andex of such change, after which period the new charge will be effective and the Agreement modified thereby shall continue to be valid and subsisting until terminated.

7. Control of and risk respecting the water shall pass to Andex at the point of delivery and Andex agrees to indemnify Omega from and against any actions, causes of action, suits, debts, claims and demands of any nature whatsoever arising out of or connected with the acceptance by Andex of the water and hereby release Omega from and against any suits, actions, causes of action, debts, claims and demands whatsoever that Andex might have now or in the future against it arising out of or connected with the acceptance by it of the water.

8. This Agreement shall be for an initial period of two (2) years from the date hereof and thereafter shall remain in force and effect until terminated by either party hereto on sixty (60) days written notice.

9. Omega's address for service hereunder is:

1300, 112 - 4th Avenue S.W.
Calgary, Alberta
T2P 0H2

Andex's address for service hereunder is:

1300, 700 - 9th Avenue S.W.
Calgary, Alberta
T2P 3V4

If the foregoing meets with your approval, kindly indicate your acceptance of this Agreement by having the attached copy of this letter executed by Andex in the space provided below and return the same to Omega.

Yours truly,

OMEGA HYDROCARBONS LTD.

G.E. Patey,
Vice President, Production

GEP/sk
Encl.

Accepted this 11 day of August, A.D., 1986.

Andex Oil Co. Ltd.

PETROLEUM SOCIETY OF CIM PAPER NO. 81-32-21

THIS IS A PREPRINT — SUBJECT TO CORRECTION

RECOVERY PREDICTIONS AN EXTENSION OF EXISTING CORRELATION TECHNIQUES

CLARIDGE

by
B.A. Slevinsky[1], B.G. Kergan[1], R.P. Delaney
Esso Resources Canada Ltd.
[1] Now with D&S Petroleum Consultants Ltd.

ABSTRACT

This paper deals with the development of an analytical tool to predict recovery under both waterflood and miscible flood environments. The recovery predictions are based on correlations in the literature derived as a function of mobility ratio. These correlations are applied on a pattern by pattern basis for the entire reservoir. Extensions were developed to handle the impacts on recovery resulting from the stratified multiple layer character of a reservoir in addition to the areal discontinuities.

INTRODUCTION

Recovery prediction methods for five spot patterns have been extensively analyzed in the literature. In general, they tend to be complex and tedious to apply. E.L. Claridge (1) has developed a correlation to model laboratory miscible flood data which simplifies these calculations. The enhancements proposed in this paper are extensions of the original formulation that deal with predictions of both miscible and waterflood performance while taking into account the geological complexities specific to each reservoir.

The sweepout correlation developed by Claridge is comprised of three components dealing with specific aspects of a flood. He found that breakthrough of the displacing phase is a function of mobility ratio and can be represented by the following:

$$N_{bt} = \frac{0.9}{1.1 + M} \quad \text{...............(1)}$$

The second component of the correlation was actually developed by Koval (2), who proposed that for miscible floods the effects of fluid mixing needs to be considered. He postulated that this mixing behaviour resulted in an effective viscosity ratio represented by:

$$K = \left[0.78 + 0.22 \left[\frac{\mu o}{\mu d}\right]^{0.25}\right]^{4} \quad H\text{......(3)}$$

replace by MR

Kov. .ncluded a term (H) to allow for the ability to account for reservoir hetrogeneities. In practise, it was found by the authors to be more practical to account for this factor by a different approach which will be discussed later in the paper.

Combining these two correlating equations with the laboratory data resulted in the following relationship between breakthrough recovery, effective viscosity ratio, poor volumes of injected fluid and oil recovery:

$$\left[\frac{N_p - N_{bt}}{1 - N_p}\right] = \left[\frac{1.6}{K^{0.61}}\right]\left[\frac{N_i - N_{bt}}{1 - N_{bt}}\right]^{\left[\frac{1.28}{K^{0.26}}\right]} \quad \ldots\ldots(4)$$

This equation can be rearranged to explicitly solve for cumulative recovery as follows:

$$A = \left[\frac{1.6}{K^{0.61}}\right]\left[\frac{N_i - N_{bt}}{1 - N_{bt}}\right]^{\left[\frac{1.28}{K^{0.26}}\right]} \quad \ldots\ldots\ldots\ldots(5)$$

$$N_p = N_i \qquad N_i \leqslant N_{bt}$$

$$N_p = \left[\frac{A + N_{bt}}{1 + A}\right] \qquad N_i > N_{bt} \quad \ldots\ldots\ldots\ldots(6)$$

These equations are capable of determining recovery as a function of both mobility ratio and injected hydrocarbon pore volumes, but apply only to a single layer homogeneous reservoir.

The need exists then to extend this approach to account for the geological complexities of the reservoir specifically in the areas of permeability distribution and reservoir continuity. Also, these equations were developed for a single fluid displacement from initial conditions to final depletion. However, in determining performance under a miscible flood environment, modifications were required to account for a pre-existent secondary waterflood. These modifications are discussed in the next section.

In a complex reservoir situation, two parameters can greatly influence the recovery estimates. These are the permeability distribution and reservoir continuity. The permeability distribution effects are applied by considering the reservoir as being comprised of a number of layers, each with a specific permeability, porosity and thickness characteristic. Each layer is then treated as a distinct reservoir and injections allocated in proportion to the permeability thickness of the layer with respect to that of the total zone open to injection.

The reservoir continuity effect needs to be included to account for the degree to which a zone is connected between the injector and producer. Application of a continuity term to the injected volume, allows its conversion to a hydrocarbon pore volume (HCPV) basis. The permeability thickness weighting technique can then be used to allocate injection on a zonal basis (i.e. a number of layers). Should the discontinuities be such that the layers are easily correlatable, then an approach allowing allocation of injection only to those layers which are continuous between both the injector and producer could be used, in lieu of the general zone calculation. This application of reservoir continuity effects is outlined schematically in Figure 1.

The second major extension is to account for the pre-existent secondary waterflood. The approach taken is to superimpose an incremental tertiary production forecast on a base of waterflood forecast as shown schematically in Figure 2.

The incremental tertiary forecast is calculated simply on the basis of the difference between the tertiary and waterflood forecasts starting from initial conditions, and added to the waterflood forecast beginning at the point where the pre-injection stops. This approach, by its nature mandates that there is no influence on the break-through, response time, or incremental recovery because of the waterflood pre-injection. If the waterflood injection volumes have been small (<.3 HCPV) the impact of this assumption is minor. However, if the pre-injection volumes are large, the tertiary response time will be shortened. The acceleration of the tertiary flood response can be explained using a Buckly-Leverett illustration (Figure 3). The waterflood pre-injection moves the average pattern water saturation up the water fractional flow curve (typically S shaped, as shown). Having moved up the curve, the tangent to the fractional flow curve shifts to the left (i.e. the saturation at the front is reduced) and the incremental saturation change behind the front is reduced. This translates to an increase in the speed of response to the tertiary injection. If the fractional flow curve is simply decreased by the pre-injection (for large water injection volumes greater than the break-through volumes), this assumption yields unrealistic acceleration.

APPLICATION

The basic Claridge method with the extensions developed in this paper have been extensively applied to the Judy Creek Beaverhill Lake "A" Pool in order to estimate both waterflood and CO_2 miscible flood recoveries.

For the purposes of analysis and to account for geological variations in the reservoir, the field was divided into fifty four areas which closely approximate existing waterflood patterns. The oil bearing part of the reservoir is comprised of six generally separable zones. Each pattern was analyzed geologically for continuity on a zone basis where each zone was composed of an average of 15 layers, each of which were about 0.6 m thick. Permeability and porosity data were developed for each layer based on an extensive analysis of core and log data. In addition, an analysis of the continuity for each well and for each zone was undertaken in order to ascertain the continuouspore volume to be used in the allocation of injection. The data obtained from the above analyses formed the basis of the reservoir description that was used in combination with the correlations to derive recovery estimates for each pattern. At the same time, an analysis of the productivity decline for each pattern was undertaken as well as a field wide displacement calculation. The general results of these analyses were in agreement to ± 1% of recovery.

In order to use this technique for production forecasting, it was deemed appropriate to compare the Claridge results to those obtained from a black oil simulator. The general method for conducting the simulation is described in a recent CIM paper (3) on "Judy Creek CO_2 Performance Predictions". The simulation and correlation calculations were performed using a seven layer one quarter five-spot pattern. The results generally compared favourably, but it was found that the Claridge method predicted a slightly longer time to displacing phase breakthrough equation in order to achieve a match for breakthrough time.

$$N_{bt} = \frac{0.9}{2.6 + M} \qquad \text{.............................(6)}$$

A comparison of the results obtained is shown in Figure (4).

Future plans are to attempt to develop further correlations between the constant term and the applicable relative permeability curves. Incorporation of material balance terms into the methodology is also an area for enhancements.

CONCLUSION

In conclusion then, some general extensions to a simple and effective analytical method for predicting recoveries have been formulated. Their prime advantages lie in the ease of their application as well as their computational efficiency. The normal simulator approach would have required twenty times as much computer time and would have made it impractical to model each of the fifty-four areas of the field. The reservoir simulation results of both rate and recovery are comparable to the analytical correlation technique. Limitations do exist and the information provided is not as complete as that obtained from a simulator. Also, the need exists to calibrate the analytical tool to the more rigorous reservoir simulation model. The method though shows promise as an effective tool for examination and comparison of individual pattern performance, and screening of enhanced recovery processes.

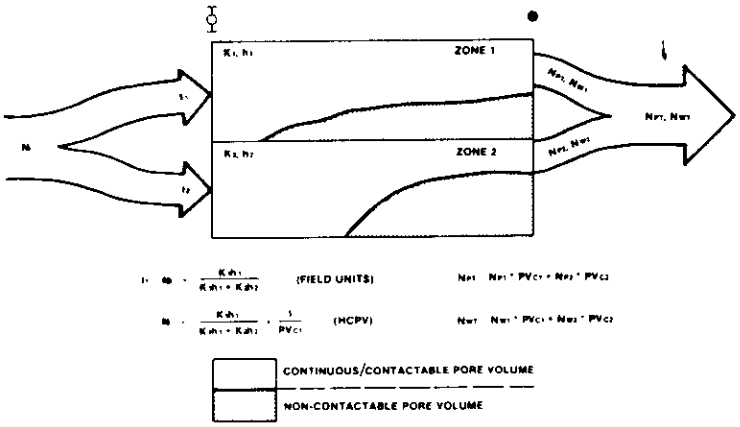
REFERENCES

(1) Claridge, E.L.: "Prediction of Recovery in Unstable Miscible Flooding", Soc. Pet. Eng. J. (April, 1972) 144.

(2) Kovel, E.J.: "A Method for Prediction the Performance of Unstable Miscible Displacement in Heterogeneous Media", Soc. Pet. Eng. J. (June, 1963) 145.

(3) Delaney, R.P. and Fish, R.M.: "Judy Creek CO_2 Flood Performance Predictions", CIM Preprint, May, 1980, Paper No. 80-31-23.

can use Buckley Leverett curve & get N_{bt} (ie Sw behind flood front @ breakthrough) & set this value = $\frac{0.9}{x+M}$ & solve for x.



INJECTION ALLOCATION

FIGURE 1

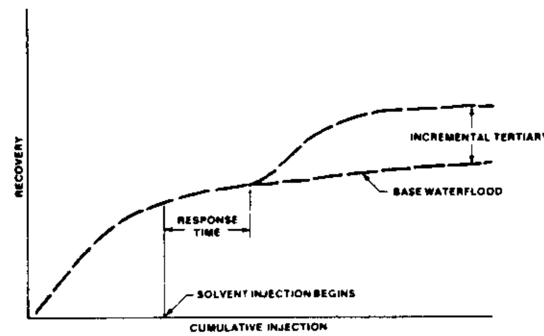


FIGURE 2

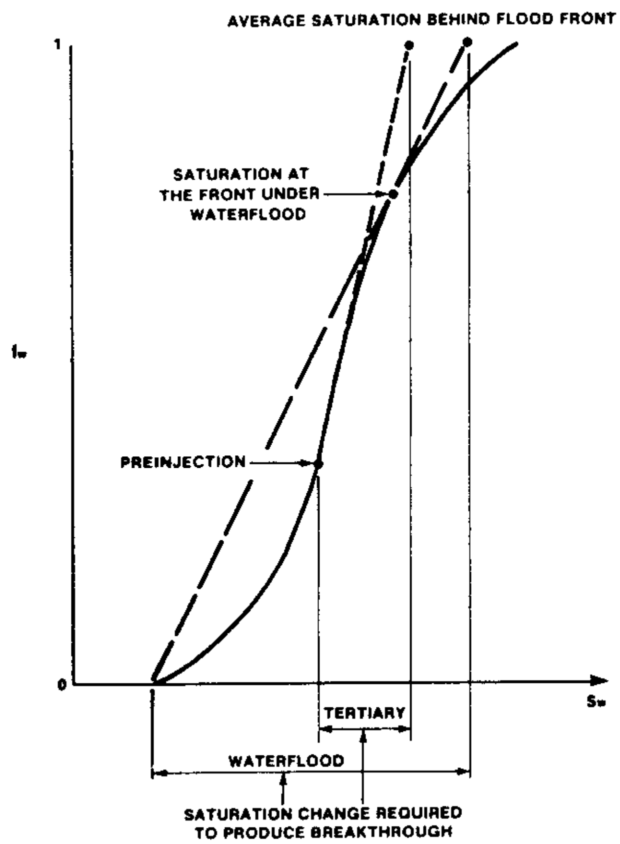


FIGURE 3

COMPARISON OF CLARIDGE AND SIMULATION 7 LAYER WATERFLOOD

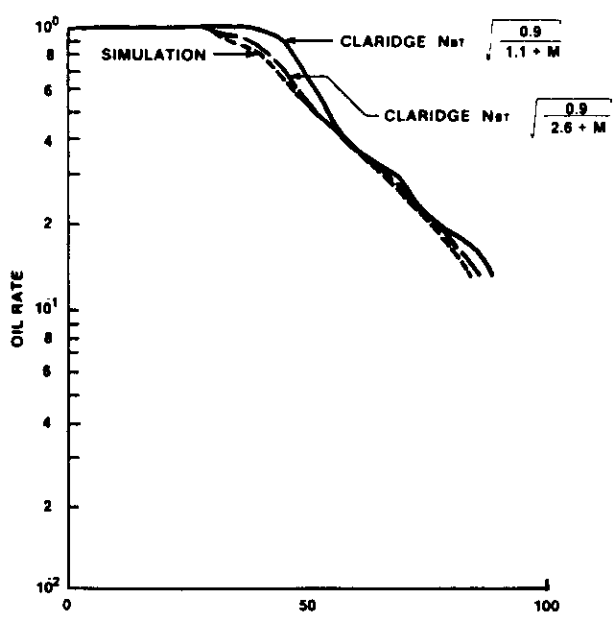


FIGURE 4

Infill Drilling To Increase Reserves—Actual Experience in Nine Fields in Texas, Oklahoma, and Illinois

A.H. Barber Jr., SPE, Exxon Co. U.S.A.
C.J. George, SPE, Exxon Co. U.S.A.
L.H. Stiles, SPE, Exxon Co. U.S.A.
B.B. Thompson, SPE, Exxon Co. U.S.A.

Summary

Evaluation of reservoir discontinuity has been used by industry to estimate potential oil recovery to be realized from infill drilling. That this method may underestimate the additional recovery potential is shown by continuity evaluation in a west Texas carbonate reservoir, as infill drilling progressed from 40-acre (162×10^3-m^2) wells to 20-acre (81×10^3-m^2) wells and eventually to 10-acre (40.5×10^3-m^2) wells.

Actual production history from infill drilling in nine fields, including carbonate and sandstone reservoirs, shows that additional oil recovery was realized by improving reservoir continuity with increased well density.

Introduction

One objective of an orderly field-development program is to determine the maximum well spacing that will effectively drain oil and gas reserves. While wide spacing has proved effective in many oilfield applications, there are a growing number of examples where infill drilling, combined with water-injection pattern modifications, has provided substantial additional oil reserves. This paper deals with such fields: Means, Fullerton, Robertson, IAB (Menielle Penn), Howard Glasscock, Dorward, and Sand Hills fields in west Texas, Hewitt field in southern Oklahoma, and Loudon field in Illinois. The paper will quantify the contribution to current production and the additional reserves attributable to this action, using data available through Oct. 1981. Infill drilling has continued in most of these fields. Also revealed by infill drilling is the fact that the west Texas carbonate reservoirs are more stratified, and porous stringers are more discontinuous than revealed by initial studies.

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Background

The theoretical concepts indicating that infill drilling will increase reservoir continuity and improve waterflood pattern conformance in heterogeneous west Texas carbonate reservoirs were researched and published in the early 1970's by Ghauri,[1] Ghauri *et al.*,[2] Stiles,[3] George,[4] and Driscoll.[5]

Detailed field studies recommending infill-drilling and waterflood-pattern modifications were made for the Means, Fullerton, and Robertson fields by Stiles and George.[3,4] Unpublished studies were made for the other reservoirs prior to infill drilling.

Borrowed from a previous work by George and Stiles,[4] Fig. 1 is a type cross section in the Fullerton Clearfork reservoir that illustrates the concept of "continuity," the percentage of pay in a well that is continuous to another well. The two original Wells A and B are 40-acre (162×10^3-m^2) locations, and the center well is an infill location 660 ft (201.2 m) from either original well. Note the discontinuous nature of the porosity stringers and that correlation before the infill well was drilled would have been considerably different than it is after the infill well was drilled. The increase in net pay in the infill well, especially in the upper part of the Clearfork formation, illustrates the fact that the more wells that are drilled, the more highly stratified, discontinuous, and complex a given west Texas carbonate reservoir is found to be. This fact leads to a conservative evaluation of the potential increased recovery from an infill well.

Considerations in Infill Drilling

A progression of continuity improvement was revealed by infill drilling in the Means San Andres field. Fig. 2 is a statistical plot of continuous pay vs. horizontal distance

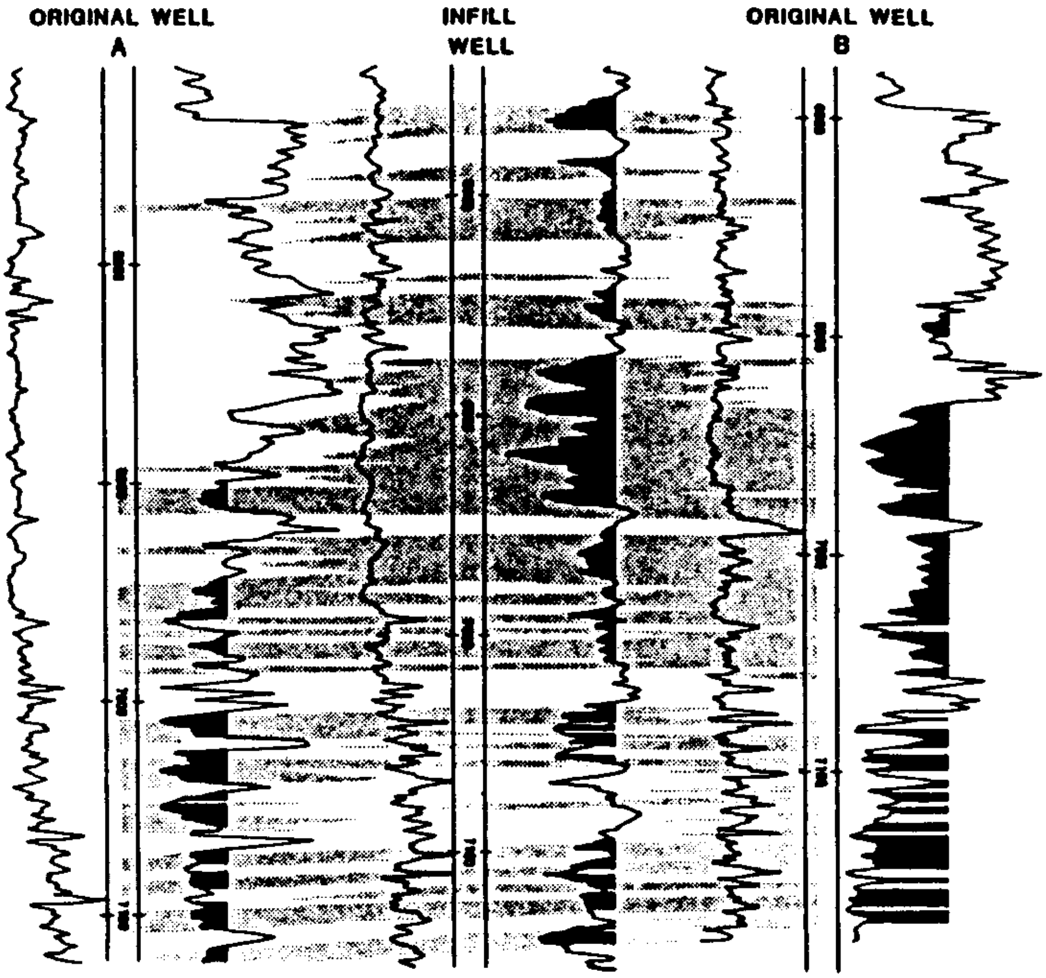


Fig. 1—Type cross section—Fullerton Clearfork reservoir (adapted from Ref. 4).

between wells for an area at Means that has been infill drilled to 10-acre (40.5×10^3-m^2) density. This technique was used by Shell Oil Co.[6] and was discussed by Stiles[3] in a previous paper. The top curve, made prior to infill drilling, shows the increase in apparent continuity between wells with increasing well density. Subsequent curves, made after infill drilling, show the pay development to be more discontinuous than would have been predicted. As shown by the upper curve, based on 40-acre (162×10^3-m^2) wells alone, an increase in continuity of 3% would be expected as spacing decreased from 20 acres ($81\times10^3 m^2$) to 10 acres (40.5×10^3 m^2). The second curve, after 20-acre (81×10^3-m^2) wells were drilled, shows that with only 40-acre (162×10^3-m^2) and 20-acre (81×10^3-m^2) wells, an increase in continuity of 4% would be anticipated as spacing decreased from 20 acres (81×10^3 m^2) to 10 acres (40.5×10^3 m^2). The analysis including the 10-acre (40.5×10^3-m^2) wells, shown by the lower line, indicates an apparent 14% improvement in continuity. The absolute values obtained for this particular area of the field are not necessarily typical of what would be expected throughout the field but do illustrate the concept of progressive increase in continuity with closer well spacing.

The complexity of stringerization is even more obvious after Fig. 3 is examined. This is a cross section

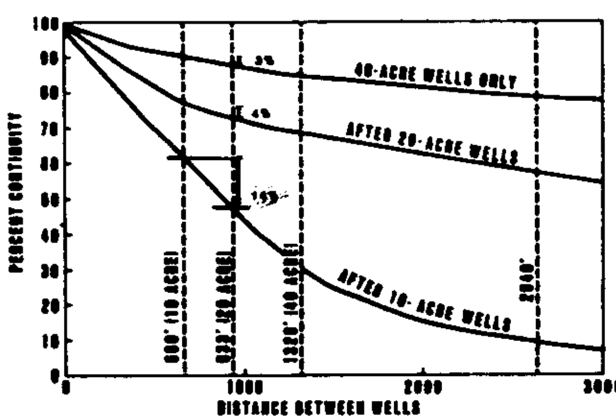


Fig. 2—Continuity progression—Means San Andres Unit.

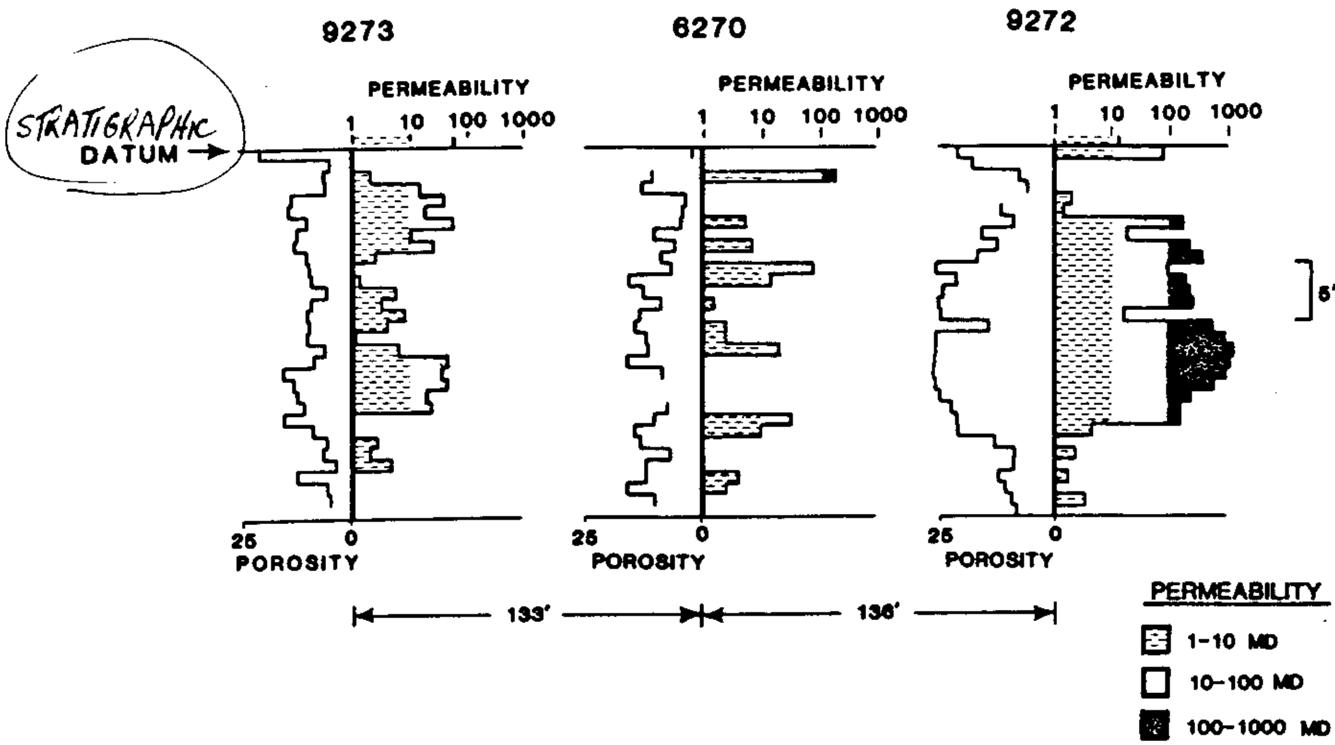


Fig. 3—Porosity and permeability variations—Means tertiary pilot.

through three wells in a tertiary pilot in the Means San Andres reservoir. The wells are located approximately 150 ft (45.7 m) apart, and core porosity and permeability have been correlated over the same stratigraphic interval. Porosity is plotted to the left and permeability is plotted on a log scale to the right. The pay intervals are relatively continuous between wells, but the porosity variations are significant in an individual stringer between wells. Permeability variations are even more severe. With injected fluids taking the path of least resistance, this plot serves to illustrate why, even in stringers that are continuous between wells, recovery may be lower than anticipated. ie WITHOUT INFILL WELLS.

In a previous paper,[3] it was stated that a pay interval must meet the following three requirements for waterflooding.

1. It must be continuous and reasonably homogeneous between an injection well and the offset producing wells.
2. It must be injection supported.
3. It must be effectively completed in the offset producing well.

In many west Texas Permian carbonate reservoirs there may be 50 or more individual pay stringers. Only rarely will all the stringers be effectively completed in a specific well. When a pay stringer is not effectively completed in a given well, a partial pattern exists for that stringer, and recovery will be less than for a complete pattern. These considerations were used to evaluate infill drilling and pattern modifications in several fields.

Infill Drilling Results

Major infill drilling programs were implemented in nine fields in west Texas, Oklahoma, and Illinois. These fields include dolomite, limestone, and sandstone reservoirs with porosities varying from 4 to 21% and with average permeabilities varying from 0.65 to about 184 md. Two of the fields are still on primary production, the other seven are waterflood fields. A detailed discussion of each of these fields follows.

Means San Andres Unit

One of the first fields studied was the Means San Andres reservoir in Andrews County, TX. Production is from a depth of 4,400 ft (1341 m). The San Andres is over 1,400 ft (427 m) thick, but only the upper 200 to 300 ft (61 to 91 m) is productive at Means. It is predominantly dolomite with minor shale and anhydrite. Average porosity and permeability are 9% and 20 md, respectively. Oil viscosity was 6 cp (6 mPa·s) at initial reservoir conditions. The reservoir was discovered in 1934 and drilled to 40-acre (162×10^3-m^2) spacing. Waterflooding began in 1963 with a peripheral pattern, which was expanded to a three-to-one line drive in 1970. Following a detailed reservoir study in 1975, a large-scale infill-drilling and pattern-modification program was begun. By the 1981 study cutoff date, 141 twenty-acre (81×10^3-m^2) and 16 ten-acre (40.5×10^3-m^2) infill wells had been drilled. During this period the pattern was gradually changed, generally to an 80-acre (324×10^3-m^2) inverted nine-spot. ie 3 Prod to 1 injector

Actual production from the 40-acre (162×10^3-m^2) wells is shown by the lower line in Fig. 4. Production from the total unit is shown by the upper line. The area between these lines is wellbore oil production from the infill wells. The area between the dashed line and actual 40-acre (162×10^3-m^2) well production is interference oil. Increased recovery resulting from infill drilling is that production represented by the area between the dashed line and the total unit production. The infill wells count for 68% of the unit daily production.

Increased recovery is calculated to be 15.4 million bbl (2.4×10^6 m^3) oil, or 66% of the total oil produced by the infill wells. The unit was divided into 40-acre (162×10^3-m^2) tracts and the original oil in place (OOIP) was calculated volumetrically for each of these tracts.[4] Additional recovery was calculated for each infill well, and as to be expected, the recoveries varied widely. In general, the additional recovery for the 20-acre (81×10^3-m^2) infill wells ranged from 5 to 8% OOIP in the 40-acre (162×10^3-m^2) tract in which the infill well was drilled.

In a smaller area in the Means field sixteen 10-acre (40.5×10^3-m^2) wells were drilled in two pilot areas in 1979 and 1980. Fig. 5 shows the impact of the 10-acre (40.5×10^3-m^2) infills on the production in the pilot areas. Decline-curve analysis indicates that additional recovery from the 10-acre (40.5×10^3-m^2) infills will be 1.2 million bbl (1.9×10^5 m^3) oil, or 67% of the wellbore recovery. Additional recovery from the 10-acre (40.5×10^3-m^2) infill wells is estimated to vary from 2 to 5% OOIP in the 40-acre (162×10^3-m^2) tract in which the infill well was drilled.

Fullerton Field

The Fullerton Clearfork Unit, also located in Andrews County, TX, produces from the Permian Clearfork and Wichita formations, which are predominantly dolomite interbedded with limestone, anhydrite, and shale. Production is from an average depth of 7,000 ft (2134 m), and the reservoir averages 10% porosity and 3-md permeability. At initial reservoir conditions, the oil viscosity was 0.75 cp (0.75 mPa·s).

Fullerton was discovered in 1942 and was originally developed on 40-acre (162×10^3-m^2) spacing. The Fullerton Clearfork Unit has been under water injection since 1961. The original pattern used in the largest portion of the field, the North dome, was a three-to-one line drive, with the injectors oriented north-south. The original north-south injection rows are shown in Fig. 6. Note the 80 acres (324×10^3 m^2) outlined by the dashed line. An 80-acre (324×10^3-m^2) tract in this position will be discussed further.

Based on the recommendations of a 1973 study reported by Stiles,[3] a program later called the Phase I Infill Program was initiated. Under this program, the wells shown by the solid dots in Fig. 6 were drilled as infill producers, and half the adjacent row producers were converted to injection wells as shown by the solid triangles. Sixty-one Phase I wells were drilled. At the conclusion of the Phase I drilling in 1976, the average production of the Phase I wells was 88 B/D (14 m^3/d) oil with a 46% water cut. Average production for the offset wells was about half, or 46 B/D (7.3 m^3/d) oil, with a 68% water cut. The fact that these infill wells performed better than the offsets indicated that additional pay was being opened up, which in turn implied that less than all the pay was being flooded.

An 80-acre (324×10^3-m^2) tract, outlined in Fig. 6, has been enlarged and is shown in Fig. 7. The original north-south injection row is to the left and the black dot to the right fixes the location of the 61 Phase I wells. The

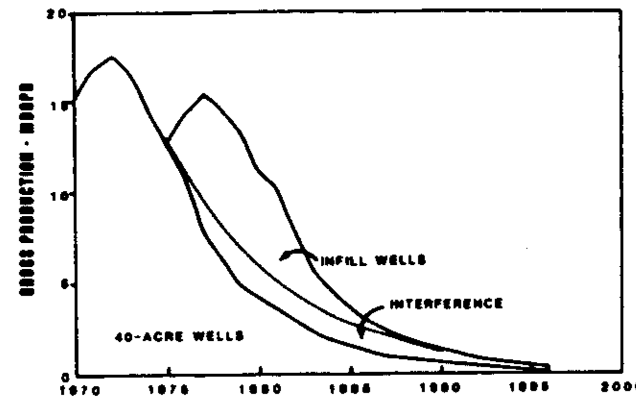


Fig. 4—Production datagraph—Means San Andres Unit.

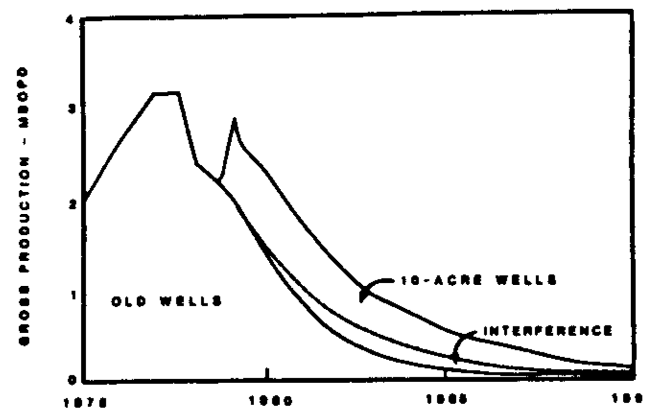


Fig. 5—Production datagraph—10-acre pilot, Means San Andres Unit.

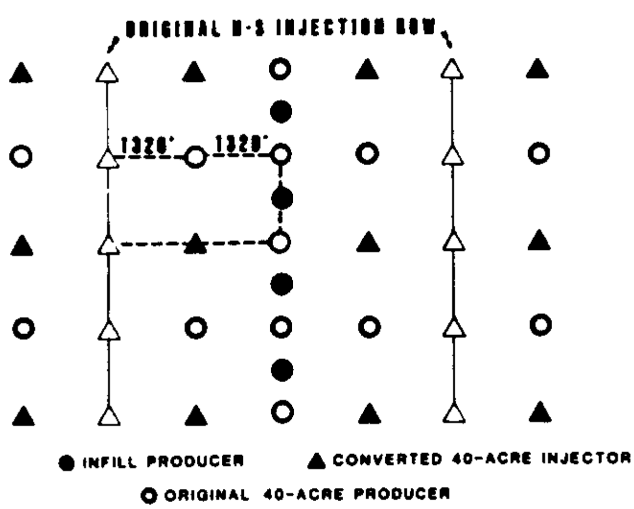


Fig. 6—Phase 1 infill drilling—Fullerton Clearfork Unit.

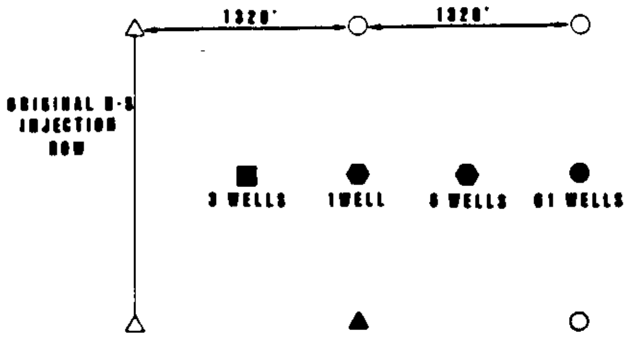


Fig. 7—Pilot infill drilling—Fullerton Clearfork Unit.

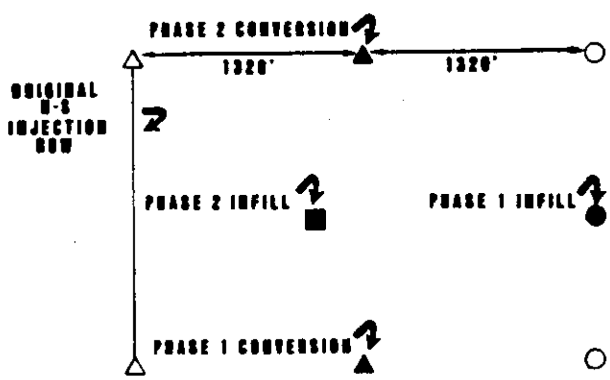


Fig. 8—Phase 2 infill drilling—Fullerton Clearfork Unit.

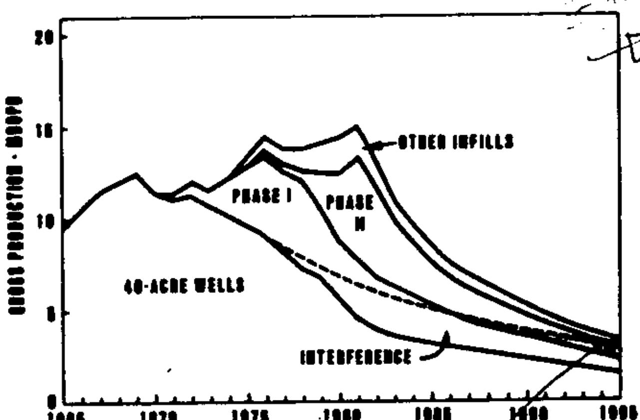


Fig. 9—Production datagraph—Fullerton Clearfork Unit.

solid triangle shows the location of the Phase I injection conversion. Prior to the Phase I program, seven wells had been drilled between 1970 and 1972 in the positions shown by the hexagons. These wells had average initial potentials of 221 B/D (35.1 m^3/d) oil, and in July 1976 they were producing an average of 92 B/D (14.6 m^3/d) oil and 70% water. Their offset wells were producing an average of 26 B/D (4.1 m^3/d) oil. The performance of the Phase I wells and the seven earlier wells suggested that additional recovery might be obtained if wells were drilled anywhere within the pattern. In 1976, three wells were drilled in the position shown by the square. They produced an average of 115 B/D (18.3 m^3/d) oil with a 74% water cut. Four of the six direct offsets to these wells had been shut in from 4 to 9 years earlier as uneconomical to produce. One was a producer testing 1 B/D (0.16 m^3/d) oil and 500 B/D (79.5 m^3/d) water. The sixth was an injector that had been converted in 1975 while producing 38 B/D (6 m^3/d) oil.

As a result of these 10 pilot wells, a 151-well Phase II infill drilling program at Fullerton was undertaken. Phase II wells have been drilled in the position shown by the square in Fig. 8. Wells in the position captioned "Phase II Conversion" are being converted to injection as part of the Phase II program. Of the 171 wells in this conversion location, 111 were watered out by 1976. Most others were producing at very low rates. It can be concluded that Phase II wells are mostly additional recovery. The production contribution from these infill drilling programs can be seen in Fig. 9. This datagraph shows the impact of the Phase I, Phase II, and other infill wells. These wells account for 71% of the unit's current production and will result in additional recovery of 24.6 million bbl (3.9×10^6 m^3) oil. Fifty-six percent of the wellbore reserves are increased recovery and will average about 97,000 bbl (15.4×10^3 m^3) per infill well.

Robertson Field

The Robertson Clearfork Unit in Gaines County, TX, produces from the Permian Glorieta, Upper Clearfork, and Lower Clearfork formations, at an average depth of 6,500 ft (1981 m). The reservoir is about 1,400 ft (427 m) thick with actual net pay of about 200 to 300 ft (61 to 91 m), broken vertically into as many as 50 to 60 separate porosity stringers in any given well: Fig. 10, a cross section between two 40-acre (162×10^3-m^2) wells, better illustrates the extreme stringerization. The reservoir rock is predominantly dolomite with anhydrite and shale. Porosity averages 6.3% and permeability averages 0.65 md. Oil viscosity at reservoir conditions is 1.2 cp (1.2 mPa·s). Beginning in 1942, the area was drilled on 40-acre (162×10^3-m^2) locations. In 1969, the unit was formed for waterflooding. From 1976 through 1980, 107 infill wells were drilled on 20-acre (81×10^3-m^2) spacing. A 10-acre (40.5×10^3-m^2) drilling program has begun with 31 wells completed through Oct. 1981.

The contribution of the 20-acre (81×10^3-m^2) and 10-acre (40.5×10^3-m^2) wells is shown in Fig. 11. The dashed line represents the expected production from the 40-acre (162×10^3-m^2) wells had there been no infills. Infill wells provide 73% of the current production. They are expected to add additional reserves of 10.7 million bbl (1.7×10^6 m^3). Increased recovery represents 79% of the wellbore reserves and is about 73,000 bbl (11.6×10^3 m^3) per well.

IAB Field

The IAB (Menielle Penn) field is located in Coke County, TX. The Menielle Penn reservoir produces from a depth of 5,800 ft (1768 m) and is a coarse skeletal limestone buildup with an average of 7% porosity and 27-md permeability. The oil viscosity at initial reservoir conditions was only 0.2 cp (0.2 mPa·s) at IAB. The reservoir was discovered in 1958 and was drilled initially on 80-acre (324×10^3-m^2) spacing. Waterflooding began in 1962 with an initial pattern which was essentially a three-to-one line drive. Fig. 12 is the production datagraph showing the impact from a 17-well 40-acre (162×10^3-m^2) infill drilling program that began in 1978. The dashed line is an extrapolation of what the 80-acre (324×10^3-m^2) wells would have done if the infill wells had not been drilled. The lower solid line shows the actual and forecasted performance of the old wells. This analysis shows that the infill wells will increase the field's reserves by 1.7 million bbl (2.7×10^6 m^3). This represents additional recovery of 100,000 bbl (1.59×10^4 m^3) per well, which is 58% of the wellbore reserves and 4% of OOIP in the affected area.

Howard-Glasscock Field

The Douthit Unit, located in Howard and Sterling Counties, TX, was formed for waterflooding the Permian Seven Rivers reservoir in the Howard-Glasscock field. The reservoir is approximately 1,400 ft (427 m) deep and is a sandstone with a porosity of 18% and a permeability of 44 md. In this reservoir, the oil viscosity of 9.4 cp (9.4 mPa·s) is relatively high for west Texas reservoirs. Development of the Seven Rivers reservoir in this area began in 1957, and it was originally drilled on 40-acre (162×10^3-m^2) locations. Waterflooding began in 1968 with a peripheral injection pattern. Ten-acre (40.5×10^3-m^2) development began in 1976, and, by the 1981 study cutoff date, 52 infill wells had been drilled. The production datagraph, Fig. 13, shows the additional production from the infills along with production from the older wells. The infill wells account for 75% of the current production, and wellbore production is 88% additional recovery. Total additional recovery of 1.0 million bbl (1.59×10^6 m^3) is expected.

Dorward Field

The Dorward field is located in Scurry and Garza Counties, TX. Production is commingled from the Permian San Angelo and San Andres formations at average depths of 2,350 and 2,100 ft (716 and 640 m), respectively. The San Angelo formation is mostly dolomite interbedded with shale and sandstone. The San Andres consists of dolomite, anhydrite, and shale. Apparent porosity for the San Angelo and San Andres are 15 and 13.5%, respectively. Actual porosities are probably less because of the presence of gypsum, which causes optimistic measurements of porosities in cores and logs. Average permeability is about 3 md in both reservoirs. In the San Angelo, the oil viscosity is 1.9 cp (1.9 mPa·s) while in the San Andres, it is 3.2 cp (3.2 mPa·s).

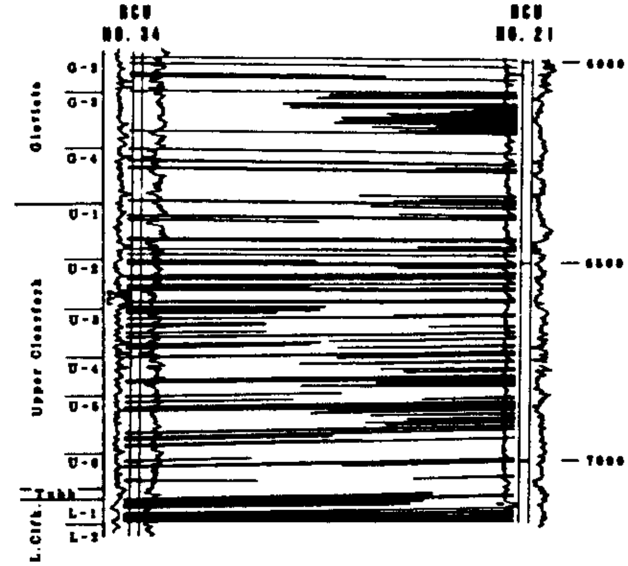


Fig. 10—Cross section—Robertson Clearfork Unit.

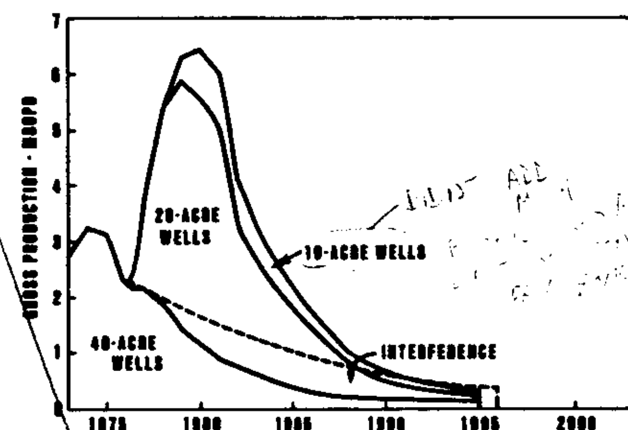


Fig. 11—Production datagraph—Robertson Clearfork Unit.

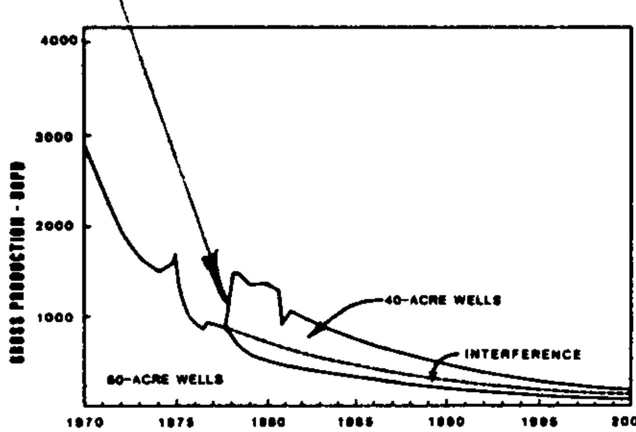


Fig. 12—Production datagraph—IAB (Menielle Penn) field.

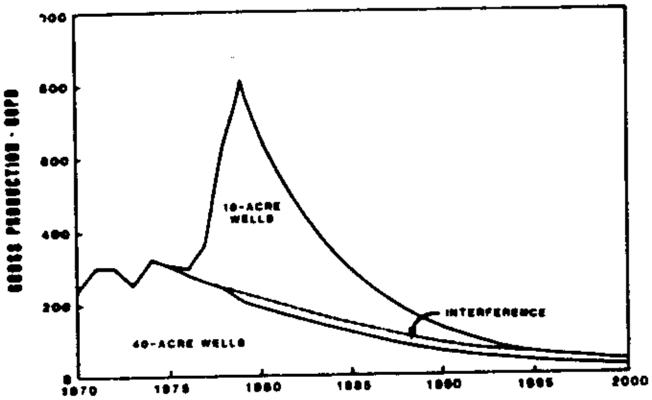


Fig. 13—Production datagraph—Douthit Unit, Howard-Glasscock field.

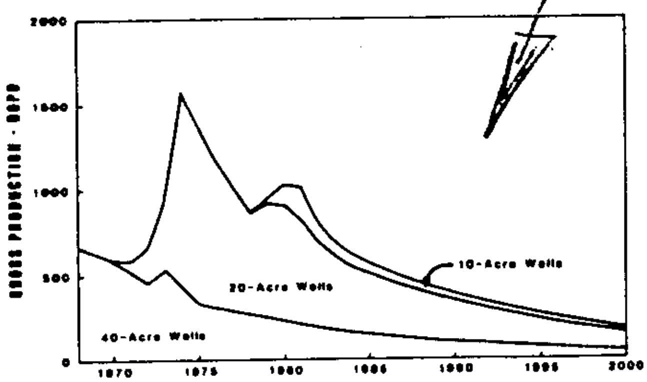


Fig. 14—Production datagraph—Dorward field.

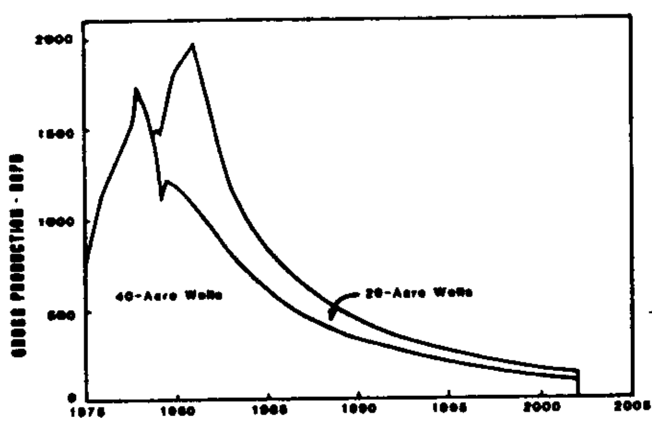


Fig. 15—Production datagraph—Sand Hills area.

The field was discovered in 1950 and drilled on 40-acre $(162\times10^3\text{-m}^2)$ spacing. Although waterflooding began in 1958 in a portion of the field, most of the field has been and is currently producing primary oil by dissolved-gas drive. Peripheral and 80-acre $(324\times10^3\text{-m}^2)$ five-spot patterns were tried. Early water breakthrough, caused by directional permeability and severe stratification, discouraged expansion of waterflooding to other areas.

Infill drilling began in 1971. At that time, 149 wells on 40-acre $(162\times10^3\text{-m}^2)$ spacing had been drilled. An average of 49,400 bbl (7850 m^3) oil per well had been accumulated, and production had declined to an average of 4.8 B/D (0.76 m^3/d) oil per well for the 107 wells still producing at that time. From 1971 through 1980, there were 123 twenty-acre $(81\times10^3\text{-m}^2)$ infill wells drilled. Ten-acre $(40.5\times10^3\text{-m}^2)$ drilling began in 1979, and 17 wells had been drilled by the end of 1980. Fig. 14 shows the results.

Because production was nearing the economic limit when infill drilling began, essentially all production from the infill wells is considered increased recovery. The infill wells will provide additional recovery of 4.6 million bbl (7.3×10^5 m^3) of oil or 33,000 bbl (5244 m^3) per well. The field is now being studied for further 10-acre $(40.5\times10^3\text{-m}^2)$ development and to determine if waterflooding is feasible with increased well density.

Sand Hills

Infill drilling in the Sand Hills area of Crane County, TX has been concentrated in the Sand Hills (Tubb and McKnight) fields. The Tubb reservoir produces from the Permian Lower Clearfork formation at a depth of 4,250 ft (1295 m) and is anhydritic dolomite with a minor amount of limestone. Average porosity and permeability are 4% and 12 md, respectively. Oil viscosity in the Tubb is 1.5 cp (1.5 mPa·s) at initial reservoir conditions. The McKnight reservoir produces from the Permian Lower San Andres at a depth of 3,200 ft (975 m) and is also mostly anhydritic dolomite. In this reservoir, average porosity and permeability are 5% and 1.3 md, respectively. In the McKnight reservoir, the oil viscosity is 1.0 cp (1.0 mPa·s). Gross productive interval is approximately 400 ft (122 m) in the Tubb and 350 ft (107 m) in the McKnight. Both reservoirs are highly stringerized with indications of poor reservoir continuity. They are both productive throughout the area of interest.

The Sand Hills (Tubb) field was discovered in 1931 and was generally developed on 40-acre $(162\times10^3\text{-m}^2)$ spacing. In the area of interest, most of the Tubb 40-acre $(162\times10^3\text{-m}^2)$ drilling was between 1936 and 1941. Development of the McKnight reservoir did not begin until 1955. McKnight development was erratic, depending largely on recompletions from the depleting Tubb reservoir; however, there was some drilling along with the workovers. Most of the 40-acre $(162\times10^3\text{-m}^2)$ McKnight activity was from 1955 to 1965 and later during the 1970's.

A 20-acre $(81\times10^3\text{-m}^2)$ infill program was begun in 1979. By the 1981 cutoff date, 56 infill wells had been drilled, with most of them being dually completed in both reservoirs. As expected, these wells found stringers that were pressure depleted but also found stringers that

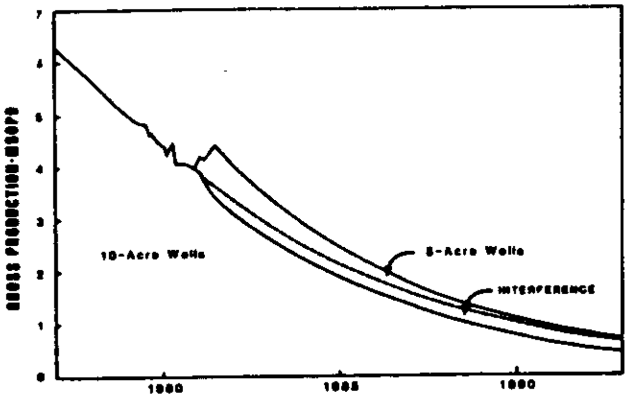


Fig. 16—Production datagraph—Hewitt Unit, Hewitt field (OK).

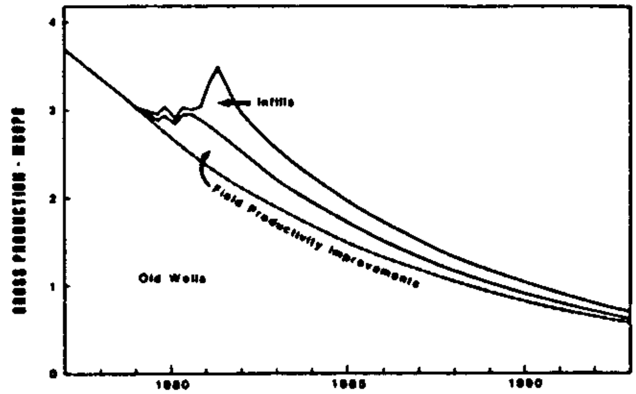


Fig. 17—Production datagraph—Loudon field (IL).

were only partially depleted or had not been penetrated by other wells. Forty-acre (162×10^3-m^2) development had continued until the time when the 20-acre (81×10^3-m^2) infill program began. Thus, a substantial amount of total production was flush production from recently drilled wells. Production from the older 40-acre (162×10^3-m^2) locations, those drilled before 1975, was 5.5 B/D (0.87 m^3/d) oil from the McKnight and 5.3 B/D (0.84 m^3/d) oil from the Tubb. Remaining reserves from these wells were about 9,000 bbl (1431 m^3) per well.

Fig. 15 shows both the performance of the 20-acre (81×10^3-m^2) infills and offset 40-acre (162×10^3-m^2) wells, including the recently drilled ones. During 1981, the infills produced 45% of the total production. Performance to date indicates they will ultimately produce 1.6 million bbl (2.5×10^5 m^3) of additional oil or 28,400 bbl (4516 m^3) per well. This recovery compares favorably with the estimated remaining 9,000 bbl (1430 m^3) per well from the older 40-acre (162×10^3-m^2) wells. Because of the extreme lenticularity of these reservoirs and difficulty in obtaining reliable porosity data, good values for OOIP are not available.

Hewitt Field

The Hewitt field, located in Carter County, OK, was discovered in 1919. Production is from 22 Pennsylvanian Hoxbar and Deese sand intervals, with a gross thickness of over 1,500 ft (457 m). The many sand intervals are separated by shale zones. Average depth to the top of the first pay interval is about 2,000 ft (610 m). The sands have an average porosity of 21% and an average permeability of 184 md. Oil viscosity in this reservoir is 8.7 cp (8.7 mPa·s). In the area of infill drilling, the original spacing was 2.5 acres (10×10^3-m^2). After the field was unitized for secondary recovery operations, many of the old wells were plugged and the field was redrilled on 10-acre (40.5×10^3-m^2) spacing. A fieldwide 20-acre (81×10^3-m^2) five-spot water injection project was begun.[7] Fifteen five-acre (20×10^3-m^2) infills have been drilled and their impact is shown in Fig. 16. The infills account for 23% of current unit production. Our analysis indicates about 60% of the wellbore reserves will be increased recovery and will total about 400,000 bbl (6.4×10^4 m^3) from the 15 wells.

The performance of the best well of these infills is a good example of the erratic nature of the porosity development and fluid-flow characteristics of this reservoir. This well potentialed for 414 B/D (65.8 m^3/d) oil with a 50% water cut, although one offset was producing 44 B/D (7.0 m^3/d) oil with a 96% water cut, and the other was producing only 7 B/D (1.1 m^3/d) oil with a 99% water cut. Overall project water cut is 97%. This type of result was obtained in a reservoir that was developed on 2.5-acre (10×10^3-m^2) spacing with a 20-acre (81×10^3-m^2) five-spot pattern.

Loudon Field

The Loudon field, discovered in 1937, is located in Fayette and Effingham Counties, IL, and produces from four Mississippian sandstones, the Weiler, Paint Creek, Bethel, and Aux Vases, at an average depth of 1,500 ft (457 m). Average porosity is 19%, and average permeability is about 100 md. The oil viscosity is 5 cp (5 mPa·s). The northern half of the field was drilled on 20-acre (81×10^3-m^2) spacing in a sunflower pattern. The southern half of the field was drilled on 10-acre (40.5×10^3-m^2) spacing. Waterflooding began in the early 1950;s, with the north half of the field on a 70-acre (283×10^3-m^2) nine-spot pattern and the south half on a 20-acre (81×10^3-m^2) five-spot pattern. Subsequently, injection wells were drilled in 10-acre (40.5×10^3-m^2) "dead" spots that are characteristic of the sunflower pattern, thus creating 10-acre (40.5×10^3-m^2) five-spot patterns. Producing water cut is now 98%.

Beginning in 1979, 50 infill wells have been drilled in the 20-acre (81×10^3-m^2) development area. These infills were drilled at the intersection of a line between 20-acre (81×10^3-m^2) producing wells and a line connecting offset injection wells. This is a dead area in the flood pattern, and it was thought that these areas had been inadequately flooded. Initial production ranged from 131 B/D (20.8 m^3/d) oil to 3.4 B/D (0.54 m^3/d) oil, with the average being 25 B/D (4.0 m^3/d) oil. Offsets were producing less than 4 B/D (0.6 m^3/d) oil average prior to the drilling of the infill wells. Fig. 17 shows the impact of drilling these 50 infills. At the time of analysis these wells were producing about 600 B/D (95.4 m^3/d) oil or 18% of total field production.

Because of their location and the stage of depletion of the d, essentially all production from these wells is considered increased recovery. These infills are expected to increase oil reserves by 970,000 bbl (1.5×10^5 m^3).

Conclusions

The conclusions formulated from this infill drilling study are as follows.

1. Infill drilling in nine fields has resulted in per-well-recovery improvements that are attractive under current economic conditions.
2. Increased oil recovery from the drilling of 870 infill wells in 9 fields ranges from 56% to 100% of their wellbore production.
3. Total additional reserves from these wells will be 60.8 million bbl (9.7×10^6 m^3) oil.
4. Continuity calculations made after infill drilling indicated the pay zones to be more discontinuous than when calculations were made before infill drilling.
5. The experience in these nine fields indicates that the ultimate well density in any given field can be determined only after several years of field performance provide sufficient information on reservoir continuity and recovery efficiencies.

Acknowledgments

We thank the many persons who made this paper possible by supplying data, preparing graphics, and typing the manuscript.

References

1. Ghauri, W.K.: "Production Technology Experience in a Large Carbonate Waterflood, Denver Unit, Wasson San Andres Field," *J. Pet. Tech.* (Sept. 1980) 1493-1502.
2. Ghauri, W.K., Osborne, A.F., and Magnuson, W.L.: "Changing Concepts in Carbonate Waterflooding—West Texas Denver Unit Project—An Illustrative Example," *J. Pet. Tech.* (June 1974) 595-606.
3. Stiles, L.H.: "Optimizing Waterflood Recovery in a Mature Waterflood—The Fullerton Clearfork Unit," paper SPE 6198 presented at the 1976 SPE Annual Fall Technical Conference and Exhibition, New Orleans, Oct. 3-6.
4. George, C.J. and Stiles, L.H.: "Improved Techniques for Evaluating Carbonate Waterfloods in West Texas," *J. Pet. Tech.* (Nov. 1978) 1547-54.
5. Driscoll, V.J.: "Recovery Optimization Through Infill Drilling—Concepts, Analysis, and Field Results," paper SPE 4977 presented at the 1974 SPE Annual Technical Conference and Exhibition, Houston, Oct. 6-9.
6. "Application for Waterflood Response Allowable for Wasson Denver Unit," hearing testimony before Texas Railroad Commission by Shell Oil Co., March 21, 1972, Docket 8-A-61677.
7. Ruble, David B.: "Case Study of a Multiple Sand Waterflood, Hewitt Unit, OK," *J. Pet. Tech.* (March 1982) 621-27.

SI Metric Conversion Factors

acre	× 4.046 873	E+03	=	m^2
bbl	× 1.589 873	E−01	=	m^3
ft	× 3.048*	E−01	=	m

*Conversion factor is exact.

JPT

Original manuscript received in Society of Petroleum Engineers office July 20, 1982. Paper accepted for publication Jan. 26, 1983. Revised manuscript received May 5, 1983. Paper (SPE 11023) first presented at the 1982 SPE Annual Technical Conference and Exhibition held in New Orleans, Sept. 26-29.

21 November 1986

Omega Hydrocarbons Ltd.
1300, 112 - 4 Ave. S.W.
CALGARY, Alta.

Attn: Mr. Richard Brekke

Dear Sir:

In regards to the meeting held with yourself on November 14, 1986 we wish to confirm our position relative to the injector locations. Enron Oil Canada, Ltd. proposes a change in the injection pattern locations from the initial application. The new locations would be; 5-4-2-25 WPM, 11-4-2-25 WPM, 15-4-2-25 WPM and 16-5-2-25 WPM. Considering the similar recoveries from our previous two forecasts i.e. the initial Enron Pattern (injectors 3-4, 12-4, 15-4 and 16-5) and the standard pattern, we feel that the new injector locations will not reduce the ultimate recoveries and to confirm this we will run the model for verification. We anticipate that these changes will significantly reduce the negative impact on the offset lands. If Omega is agreeable to this arrangement and therefore willing to waive the previous objection please indicate in writing.

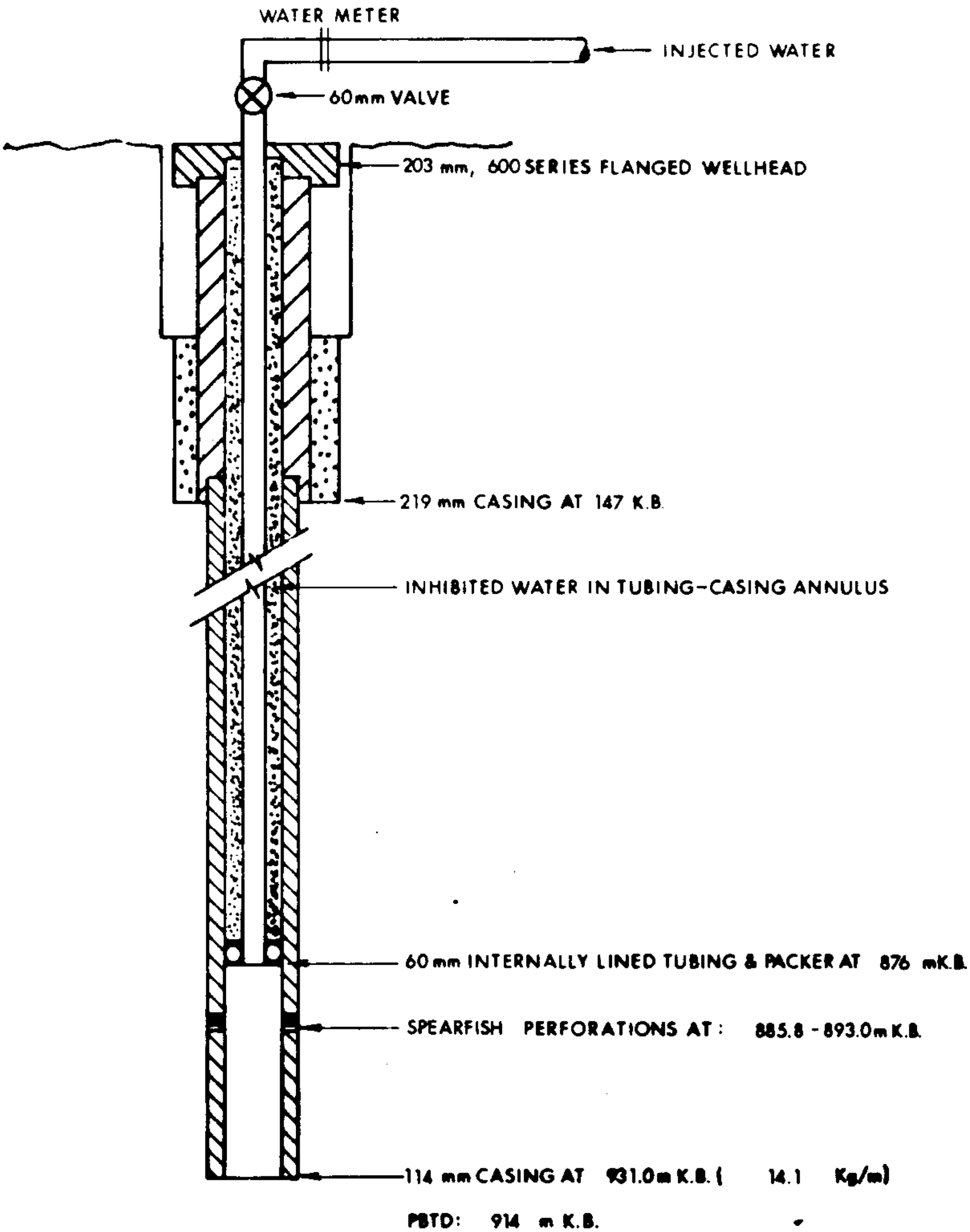
Yours truly,

ENRON OIL CANADA, LTD.

Rick A. Smith
Senior Reservoir Engineer

RAS/njg

PROPOSED INJECTION WELL
SUBSURFACE EQUIPMENT



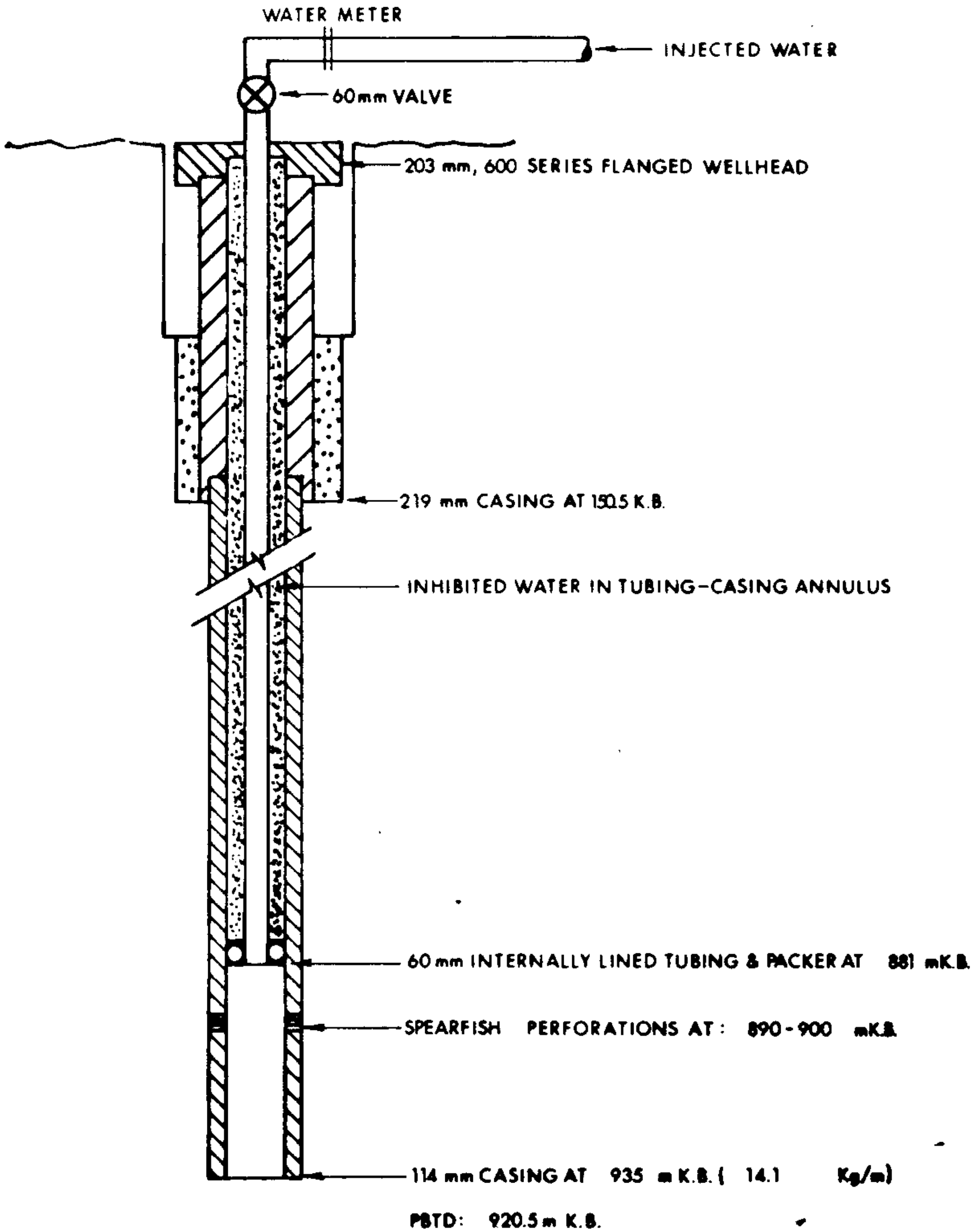
ANDEX OIL CO. LTD.

1501, 300 - 4th AVENUE S.W., CALGARY, ALBERTA PH: 403/261-2040

SCHEMATIC DIAGRAM
ANDEX ET AL WASKADA
11-4-2-25 WPM

DATE: 21-11-86	BY: T. McKAY	FILE NO:
SCALE: NTS	REVISIONS:	

PROPOSED INJECTION WELL
SUBSURFACE EQUIPMENT

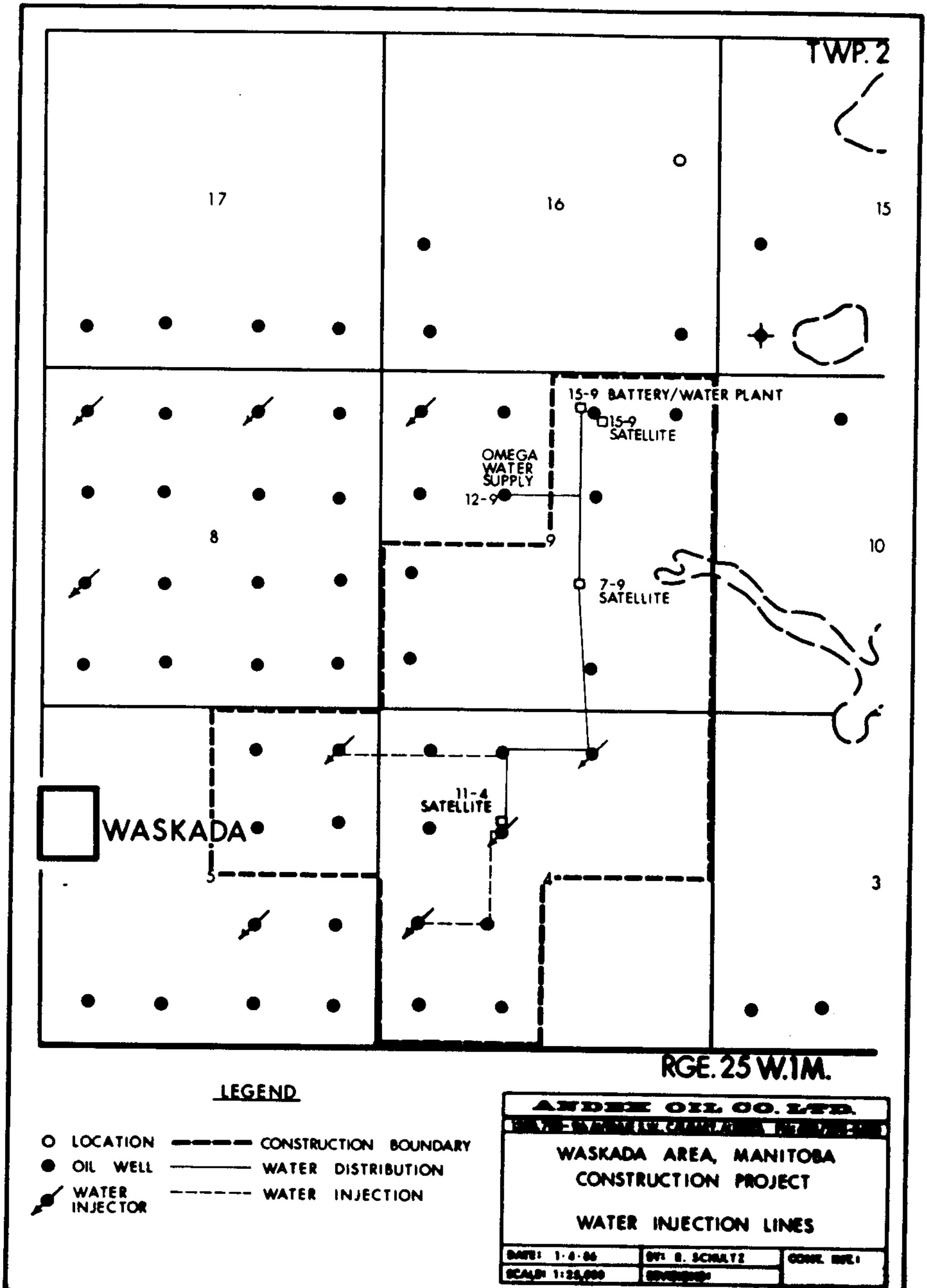


ANDEX OIL CO. LTD.

1501, 500 - 4th AVENUE S.W., CALGARY, ALBERTA PH: 403/261-2040

SCHEMATIC DIAGRAM
ANDEX ET AL WASKADA
5-4-2-25 WPM

DATE: 21-11-86	BY: T. McKAY	FILE NO:
SCALE: NTS	REVISIONS:	



TWP. 2
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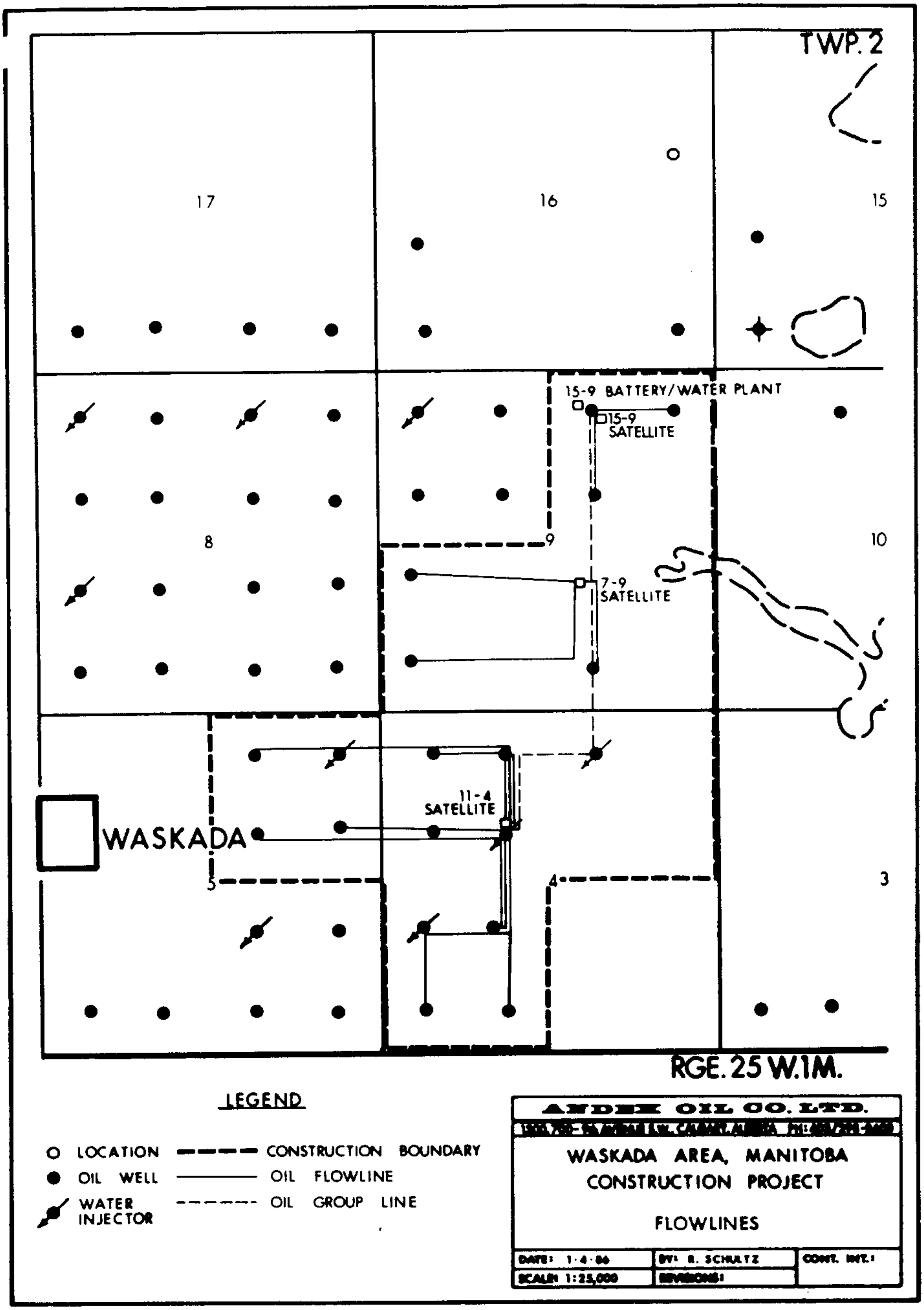
15-9 SATELLITE
OMEGA WATER SUPPLY
12-9
7-9 SATELLITE
11-4 SATELLITE
WASKADA
RGE. 25 W.1M.
LEGEND
LOCATION
OIL WELL
WATER INJECTOR
CONSTRUCTION BOUNDARY
WATER DISTRIBUTION
WATER INJECTION
WASKADA AREA, MANITOBA
CONSTRUCTION PROJECT
WATER INJECTION LINES

MAP No. 3


TWP. 2
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SATELLITE
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SATELLITE
11-4
SATELLITE
WASKADA
RGE. 25 W.1M.
LEGEND
LOCATION
OIL WELL
WATER INJECTOR
CONSTRUCTION BOUNDARY
OIL FLOWLINE
OIL GROUP LINE
OIL CO. LTD.
WASKADA AREA, MANITOBA
CONSTRUCTION PROJECT
FLOWLINES
DATE: 1·4·86
BY: R. SCHULTZ
CONT. INT.:
SCALE: 1:25,000

MAP No. 4

OMEGA
HYDROCARBONS LTD

1300 SUN LIFE PLAZA III
112 - 4th AVENUE S.W.
CALGARY, ALBERTA, CANADA T2P 0H3
TELEPHONE (403) 261-0743

November 28, 1986

Enron Oil Canada Ltd.
1300, 112 - 4th Avenue S.W.
Calgary, Alberta
T2P 3V4

Attention: Mr. R. A. W. Smith, P. Eng.
Senior Reservoir Engineer

Dear Sir:

Re: Intervention To An Application By Enron Oil Canada Ltd. For Pressure Maintenance In Waskada Unit No 16

Following a review of your recently completed reservoir model study, Omega Hydrocarbons Ltd. is of the opinion that the model study results support the concerns outlined in our intervention letter. However, based on a proposed change in injection well locations from 3-4, 12-4, 15-4 and 16-5-2-25 WPM to 5-4, 11-4, 15-4 and 16-5-2-25 WPM, we feel these concerns would be minimized. Attachments 1 and 2 illustrate the changes to the overswept and underswept areas effected by the proposed pressure maintenance project.

Omega Hydrocarbons Ltd. is willing to withdraw its intervention subject to the Manitoba Oil and Natural Gas Conservation Board approving the proposed pressure maintenance project with the revised injection well locations. We prefer to let our formal invention stand until the Board has completed its review in the event further modifications are required which impact on our decision.

It should also be noted that this letter in no way implys that our opinion of the detrimental effects caused by off pattern injection has changed. In this regard we intend to recommend to the Board that the pressure maintenance approval for Waskada Unit No. 16 contain a clause which specifically addresses the situation of premature water breakthrough caused by an off pattern injector.

Considering the negative impact that this senario could have on an offsetting pressure maintenance project we feel the best strategy would be to temporarily suspend injection at the suspect well until a course of action was jointly agreed upon.

Yours truly,

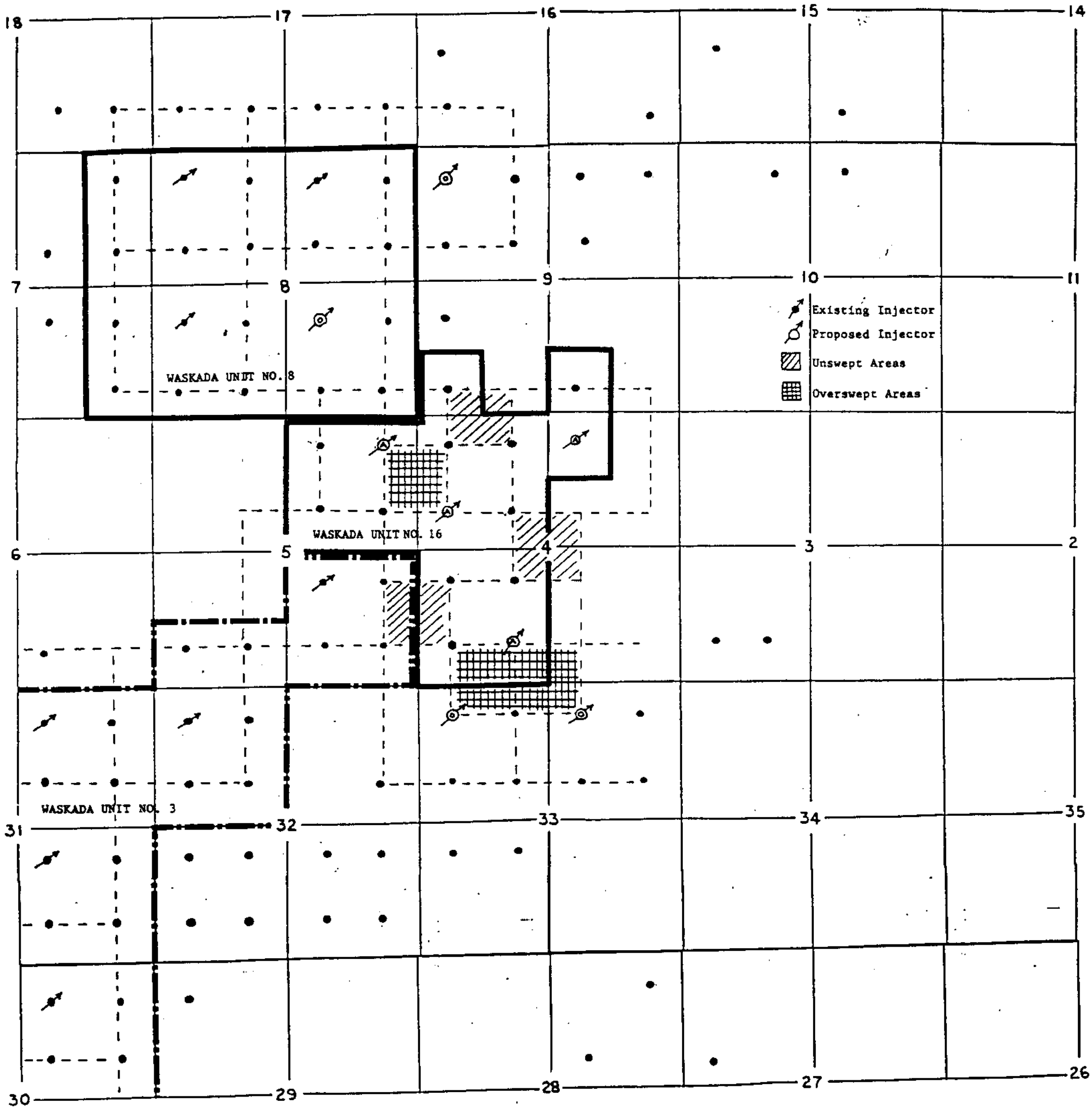
OMEGA HYDROCARBONS LTD.

G. E. Patey
Vice President - Production

cc: Bob Dubreuil - Manitoba Petroleum Branch
Other Waskada Pressure Maintenance
Applications File

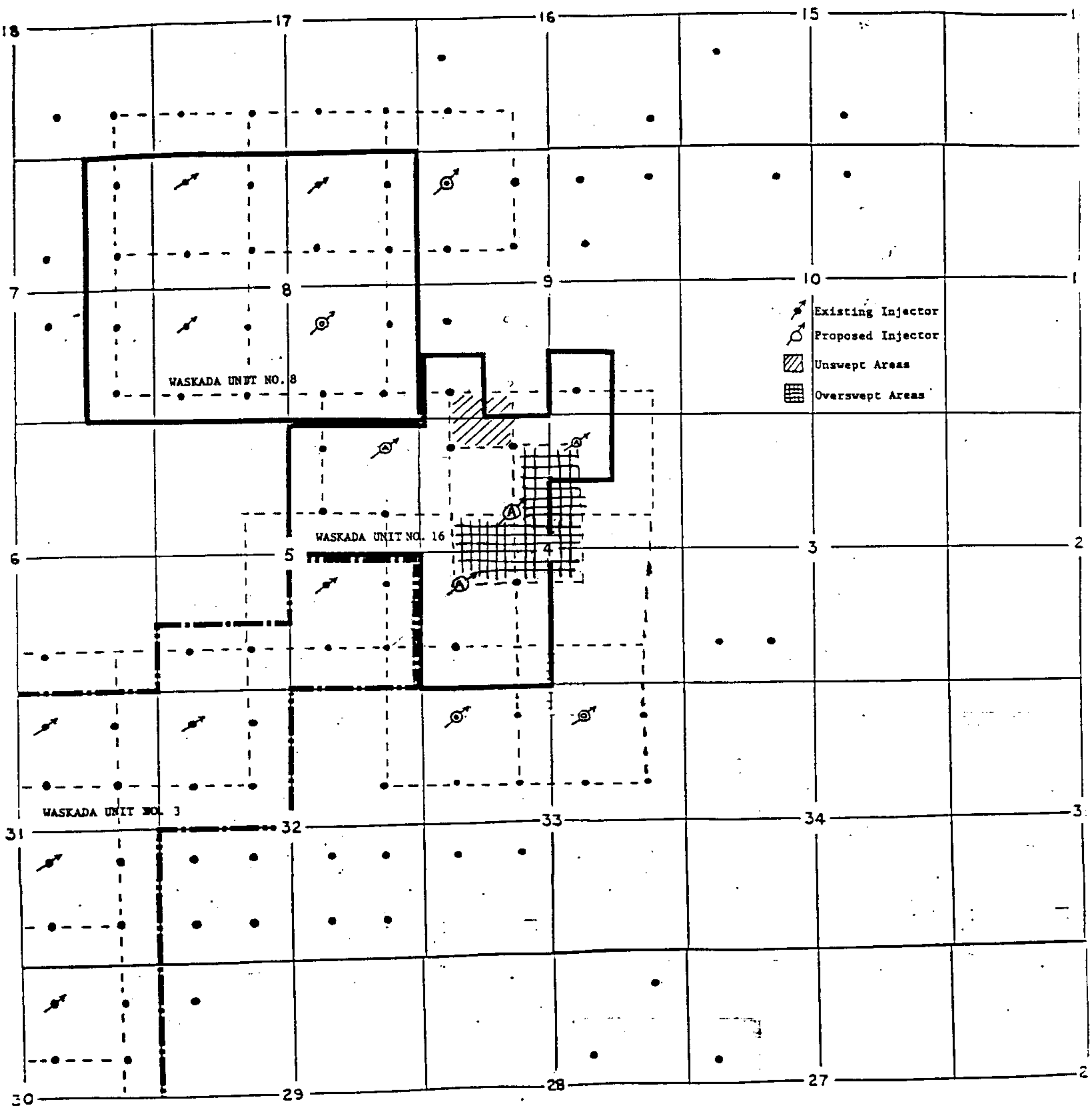
Attachment 1

The Detrimental Effects Caused
By Off Pattern Injection
In Waskada Unit No. 16
(Injectors 3-4, 12-4, 15-4 and 16-5-2-25 WPM)



Attachment 2

The Detrimental Effects Caused
By Off Pattern Injection
In Waskada Unit No. 16
(Injectors 5-4, 11-4, 15-4 and 16-5-2-25 WPM)



OMEGA HYDROCARBONS LTD.
1300 SUN LIFE PLAZA III
112 - 4th AVENUE S.W.
CALGARY, ALBERTA, CANADA T2P 0H3
TELEPHONE (403) 261-0743

November 28, 1986

Enron Oil Canada Ltd.
1300, 112 - 4th Avenue S.W.
Calgary, Alberta
T2P 3V4

Attention: Mr. R. A. W. Smith, P. Eng.
Senior Reservoir Engineer

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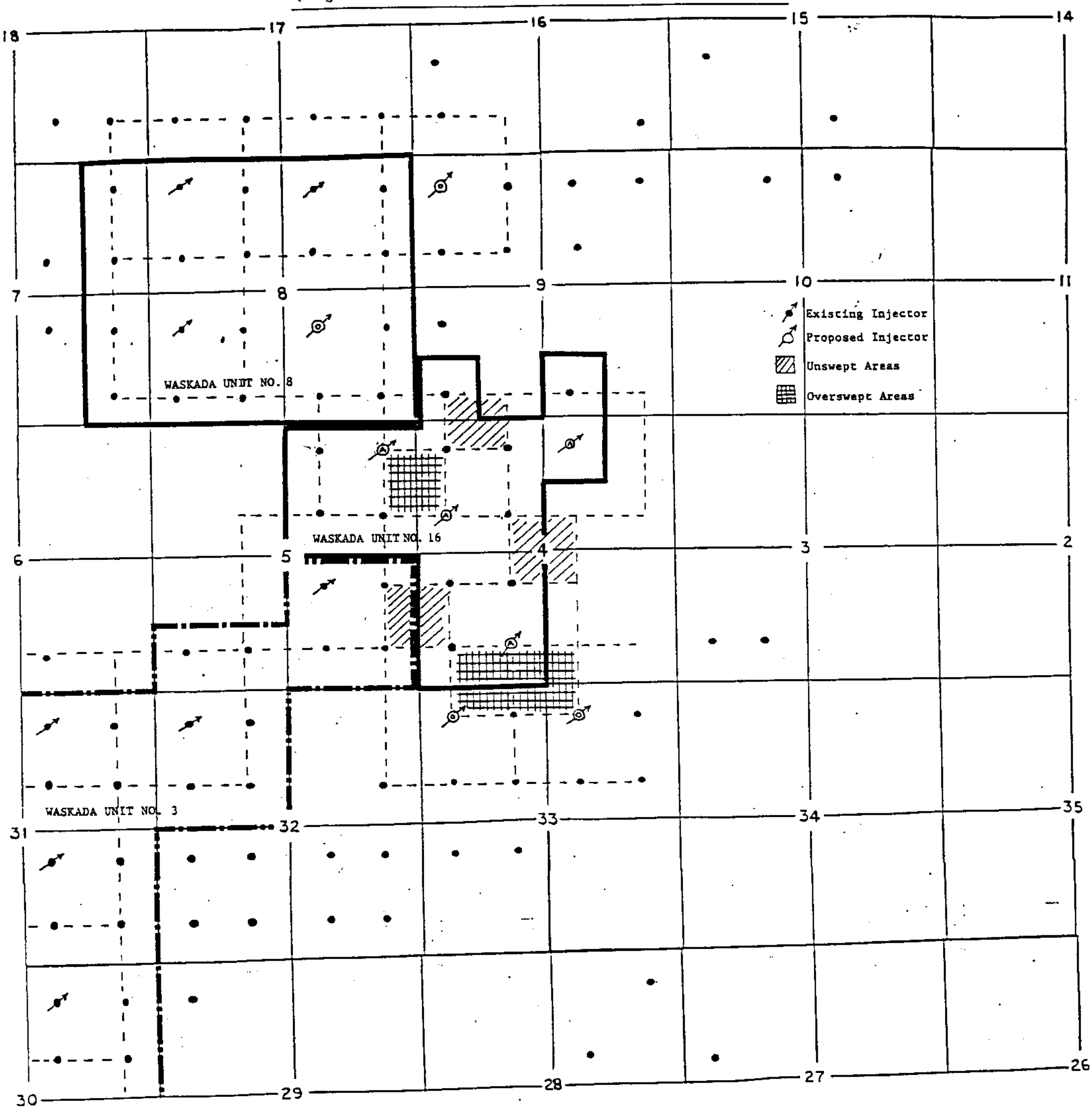
Yours truly,

OMEGA HYDROCARBONS LTD.

G. E. Patey
Vice President - Production

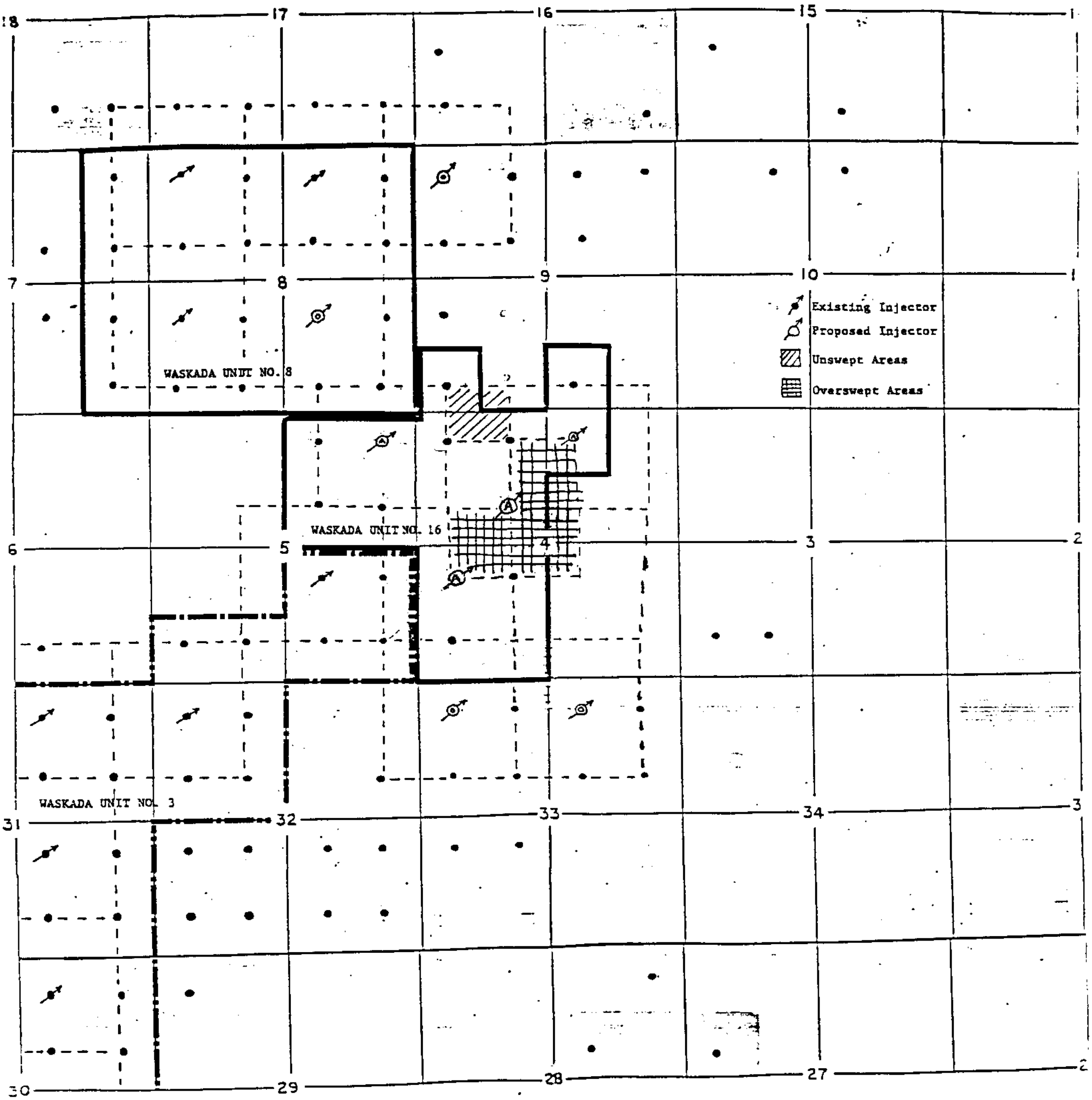
cc: Bob Dubreuil - Manitoba Petroleum Branch
Other Waskada Pressure Maintenance
Applications File

The Detrimental Effects Caused
By Off Pattern Injection
In Waskada Unit No. 16
(Injectors 3-4, 12-4, 15-4 and 16-5-2-25 WPM)



Attachment 2

The Detrimental Effects Caused
By Off Pattern Injection
In Waskada Unit No. 16
(Injectors 5-4, 11-4, 15-4 and 16-5-2-25 WPM)



Manitoba

The Oil and Natural Gas Conservation Board

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

(204) 945-3130

OCT 17 1986

Omega Hydrocarbons Ltd.
1300 Sun Life Plaza III
112 - 4th Avenue S.W.
Calgary, Alberta
T2P 0H3

Attention: Mr. R. A. Brekke,
Production Engineer

Dear Sirs:

Re: Waskada Lower Amaranth A Pool
Proposed Pressure Maintenance - Andex

Your letter of intervention, dated October 6, 1986, regarding the subject application is acknowledged.

The Board recognizes Omega's interest in the subject application, and as such, considers the intervention to be valid.

The Board shares Omega's technical concerns regarding the location of the proposed injectors, and have expressed these concerns to the applicant. The Board will be holding further discussions with Andex in the near future to evaluate the results of further technical studies designed to compare recovery efficiencies assuming differing injector locations. You will be advised in due course of the outcome of these discussions and of the Board's intended course of action in this matter.

Yours sincerely

ORIGINAL SIGNED BY
CHARLES S. KANG

Charles S. Kang

LRD/lk

b.c. Wm. McDonald
B. Ball
Petroleum

OMEGA
HYDROCARBONS LTD.

1300 SUN LIFE PLAZA III
112 - 4th AVENUE S.W.
CALGARY, ALBERTA, CANADA T2P 0H3
TELEPHONE (403) 261-0743

October 6, 1986

The Oil and Natural Gas
Conservation Board
309 Legislative Building
450 Broadway Avenue
Winnipeg, Manitoba
R3C 0V8

**Attention: Mr. Charles S. Kang
Chairman**

Dear Sir:

**Re: Intervention To An Application By
Andex Oil Co. Ltd. For Pressure Maintenance In
Waskada Unit No. 16**

Please find enclosed two (2) copies of a formal Intervention by Omega Hydrocarbons Ltd. to the application indicated above. For information purposes this Intervention has also been sent to the parties identified below.

Yours truly,

OMEGA HYDROCARBONS LTD.

R.A. Brekke, P. Eng.
Petroleum Engineer

cc: B. Dubreuil - Petroleum Branch
R. Smith - Andex Oil Co. Ltd.
Other Waskada Pressure Maintenance
Applications File

IN THE MATTER OF THE MINES ACT AND THE REGULATIONS THEREUNDER

AND

IN THE MATTER OF AN APPLICATION TO THE OIL AND NATURAL GAS CONSERVATION BOARD BY ANDEX OIL CO. LTD. TO CONVERT CERTAIN WELLS IN THE WASKADA OIL FIELD TO WATER INJECTION

INTERVENTION OF OMEGA HYDROCARBONS LTD.

OCTOBER 1, 1986

IN THE MATTER OF THE MINES ACT AND THE REGULATIONS THEREUNDER

AND

IN THE MATTER OF AN APPLICATION TO THE OIL AND NATURAL GAS CONSERVATION BOARD BY ANDEX OIL CO. LTD. TO CONVERT CERTAIN WELLS IN THE WASKADA OIL FIELD TO WATER INJECTION

INTERVENTION OF OMEGA HYDROCARBONS LTD.

1. Omega Hydrocarbons Ltd. (Omega), a body corporate registered to do business in the Province of Manitoba, is actively engaged in the exploration, development and production of petroleum substances in the Province of Manitoba and in particular in the Waskada Oil Field. Omega operates in the order of 400 wells in the Waskada Oil Field many of which are located within unitized areas. Omega has implemented and operates several waterflood schemes within such unitized areas, has conducted model studies and reservoir performance observations respecting the Lower Amaranth Formation and as such has considerable interest, vested and otherwise, in the application by Andex Oil Co. Ltd. (Andex) in the locations of the injection wells within the proposed Waskada Unit No. 16.

2. The technical basis for Omega's Intervention to Andex's Application is as follows:

   (a) Andex's proposed water injection scheme is off pattern and Omega is concerned that optimum oil recovery will not be achieved as a consequence of the locations of the proposed injection wells. Omega is of the view, and this view is well supported by studies which have been done in this regard, that pattern waterflooding is one of the best methods to maximize oil recovery in a given reservoir. Attachment 1 graphically illustrates those areas which will receive excess pressure maintenance and those areas which will receive little or no pressure maintenance using Andex's proposed injection well locations. Omega suggests that at least two separate waterflood predictions be done to investigate ultimate oil recovery under different injection well scenarios, using Andex's reservoir model.

(b) Omega is also concerned with the importance that has been placed on current water cut performance in Andex's injection well selection criteria. Andex assumes that the high water production currently being produced is due to Mississippian communication. Omega's experience in this regard indicates that it can be eliminated or significantly reduced through remedial work, rather than off pattern waterflooding.

3. Omega is prepared to appear before the Oil and Natural Gas Conservation Board to provide further information respecting the application of Andex.

4. All communications relative to this Intervention should be directed to:

Omega Hydrocarbons Ltd.
1300, 112 - 4th Avenue S.W.
Calgary, Alberta
T2P 0H3

Attention: Mr. Richard Brekke

ALL OF WHICH IS RESPECTFULLY SUBMITTED.

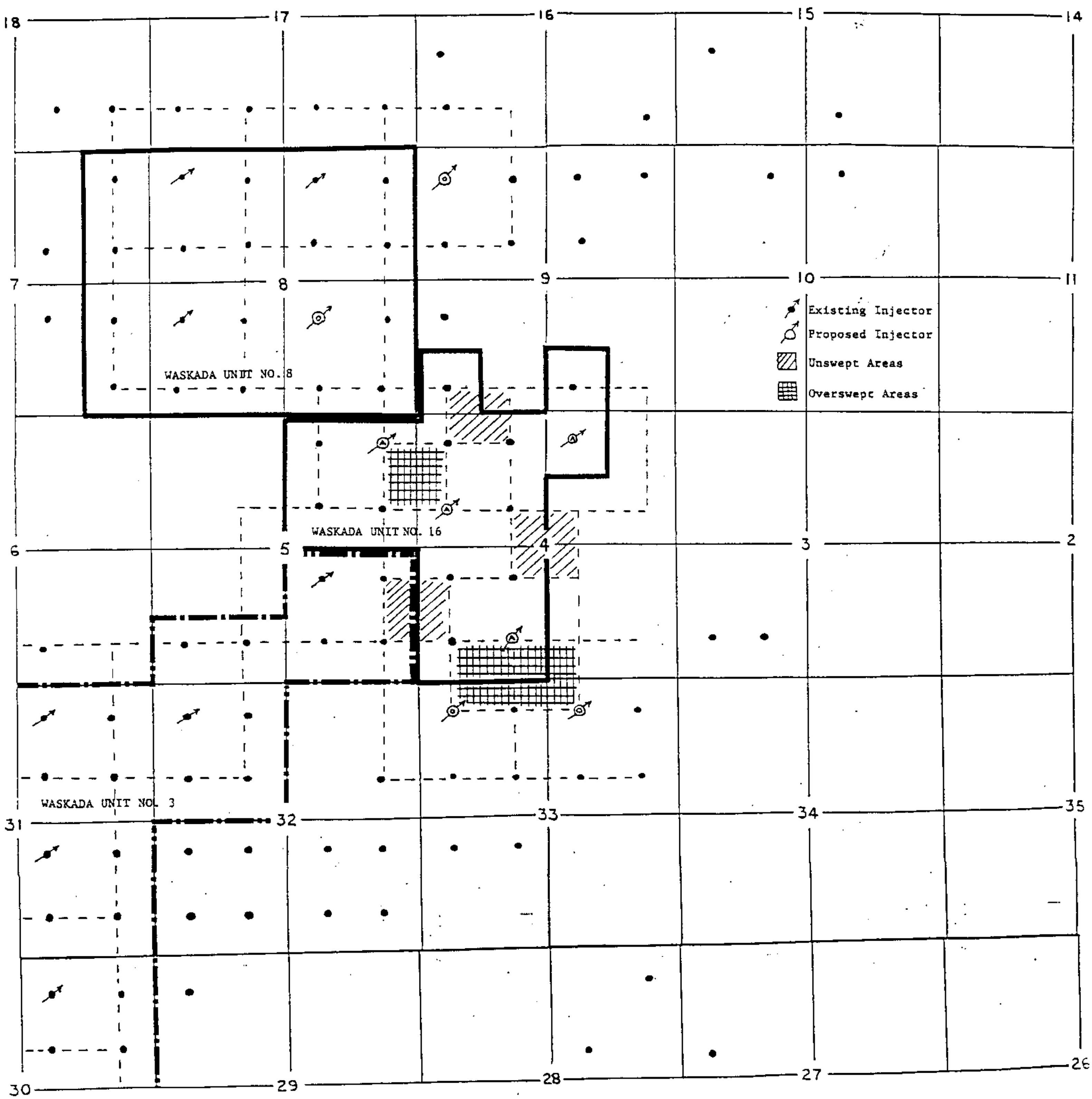
Dated at the City of Calgary, in the Province of Alberta, this 1st day of October, A.D. 1986.

OMEGA HYDROCARBONS LTD.

By: George E. Patey
George E. Patey,
Vice President, Production

ATTACHMENT NO. 1

Waskada Oil Field
The Detrimental Effects
Caused By Off Pattern Injection



MARC

that public convenience will be promoted by the establishment of the proposed service, pursuant to Rule 17 of the Manitoba Transport Board Rules of Practice and Procedure.

In such case, an onus shall be upon any respondent to the application to adduce sufficent evidence to rebut the presumption.

Commentary

This Policy has been determined after consideration of the Regionalization Proposal published for discussion in July, 1985 and matters raised during the hearings on proposed reforms respecting private carriage held last June.

The Policy is intended to encourage general freight carriers in the province to actively attempt to recapture freight presently moving by private carriage. It is expected a number of general freight carriers may be in a position to enhance their overall profitably and thus their ability to provide less-than-truckload service to rural Manitoba by taking advantage of this Policy.

No adverse impact on service to rural Manitoba is anticipated, as the subject freight has already been lost to the for-hire carriage system. However, the Board is prepared to assess any alleged adverse effects on a case-by-case basis, particularly in cases where the private carriage operation may be transitory or has been of short-term duration or may have been established for the purpose of obtaining the benefit of this Policy.

The Policy also allows existing private carrier operations the alternative of for-hire carriage which may presently be precluded them by the impractical requirement to retain over 80 "radial" carriers to serve all rural destinations.

—39

UNDER THE HIGHWAYS PROTECTION ACT AND THE HIGHWAY TRAFFIC ACT

THE HIGHWAY TRAFFIC BOARD

Notice is hereby given that a Hearing of The Highway Traffic Board will be held on Tuesday, October 7, 1986 at 10:00 A.M. in The Agricultural Extension Centre, 1129 Queens Avenue, Brandon, Manitoba.

Under Pedestrian Corridors — Section 78 H.T.A.

163 — PC — 18th Street — City of Brandon

Consideration to be given to the Removal of a Pedestrian Corridor across 18th Street between Brandon Avenue and Aagaard Avenue in the City of Brandon.

Permits — Part I — Section 9 H.P.A. and Part III — Section 17 H.P.A.

L.A. 261-86 — F. H. Bayes — P.T.H. No. 10 and P.R. No. 355 — Town of Minnedosa

Application by F. H. Bayes for a permit to Relocate an Existing Access Driveway onto P.T.H. No. 10 and P.R. No. 355, S.E.¼, Section 10-15-18 West, Town of Minnedosa.

L.A. 277-86 — K. Martin — P.T.H. No. 1 — R.M. of Wallace

Application by K. Martin for a permit to Renovate Pump island and install Two (2) Underground Storage Tanks adjacent to P.T.H. No. 1, N.E.¼, Section 21-12-29 West, R.M. of Wallace.

The Highway Traffic Board will be prepared to consider any submissions regarding the above applications at this hearing. Any persons wishing to make a submission should either contact the Secretary at the Hearing or forward their written submission in advance to: A. Poltaruk, Secretary, The Highway Traffic Board, Room 206-301 Weston Street, Winnipeg, Manitoba.

Phone: 945-8912

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

UNDER THE MINES ACT

Andex Oil Co. Ltd., operator of the proposed Waskada Unit No. 16, has made application under "The Mines Act" to convert the following wells to water injection:

Andex et al Waskada Prov. 3-4-2-25 (WPM)

Andex et al Waskada Prov. 12-4-2-25 (WPM)

Andex et al Waskada Prov. 15-4-2-25 (WPM)

Andex Waskada 16-5-2-25 (WPM)

If no objection or intervention in writing is received by the Board at Room 309, Legislative Building, Winnipeg, Manitoba, R3C 0V8, within 14 days of the publication of this notice, the Board may approve the application.

Dated at Winnipeg, this 10th day of September, 1986.

CHARLES S. KANG,
Chairman.

—39

PUBLIC

UNDER THE M

ERR
RE: THE R.
SALE OF LAND FOR
in Manitoba Gazette No.

Description
Part N.W. as included in Certificate of Title
Twp. 8, Rge. 5E . . . .
Should have read:
Part N.W. as included in Certificate of Title
Twp. 8, Rge. 5E . . . .

Lot 12, Blk. 1, Plan 16737 . . . .
Should have read:
Lot 12, Blk. 1, Plan 16737 . . . .

Lot 7, Blk. 2, Plan 13762 . . . .
Should have read:
Lot 7, Blk. 2, Plan 13762 . . . .

Except Southerly 120 feet, Lot 7, Plan 7011 .
Should have read:
Except Southerly 120 feet, Lot 7, Plan 7011 .

All those portions as are included in Certific
B3377, Lot 46 and 47, Plan 5597 . . . .
Should have read:
All those portions as are included in Certific
B3377, Blk. 46 and 47, Plan 5597 . . . .

South half, North West Quarter, Sec. 22, Twp
Should have read:
South half, North West Quarter, Sec. 23, Twp

All that part of the North half, South Wes
included in Certificate of Title No. H37219,
Rge. 5E . . . .
Should have read:
All that part of the North half, South Wes
included in Certificate of Title No. H32719,
Rge. 5E . . . .

12939—39

RURAL MUNICIP
SALE OF LANDS FOR

By virtue of a warrant issued by The R
the Province of Manitoba, under his hand an
to me directed, and bearing the date of the 13th
on the several parcels of land hereinafter n
taxes due thereon with costs, I do hereby give

a) all taxes that have been in arrears for
of the year in respect of which they were imp

b) the proportion of costs chargeable the

c) such additional amounts as penalties
each month or portion thereof, following the
Manitoba Gazette

are paid, I will on the 31st day of October, 198

SK600S helmet with cage, Micron skates, size 3; Cooperall shell, men's small; CCM hockey pants, size 32-34. D45-2p

MEN'S GOALIE PADS, 32 INCH, excellent condition 200.00. Phone 747-2851 Deloraine. D45-3p

1980 SUZUKI RM 125. OPEN to reasonable offers. Must sell. Phone 747-2663 after 6:00 p.m. Ask for Tim. D45-1c

FLAT GLASS - 3/16 (5 mm), 4 - 20" x 36"; 8 - 30" x 32", 4 - 17" x 30". Phone Bob Arthur 747-2077. D45-2c

1976 TOYOTA COROLLA CAR. Good tires. 77,000 km. $500.00. Phone 658-3567 Goodlands. D45-2p

BUNK BEDS, 2 YEARS OLD. Reg. $650.00, only $200.00 firm. Phone 747-3211 Deloraine. D45-2p

FALL SPECIAL: 1979 YAMAHA 400 XS, low mileage, good condition. $700.00 firm. Phone 747-3211 Deloraine. D45-2p

TIRES ARE AVAILABLE at Frank's Ford Sales in Killarney for cars, trucks, and motorcycles. Call 523-4655. B17-ctf

INVESTMENTS! We have daily quotations on G.I.C.'s and R.R.S.P.'s. For latest rates phone Peter Derksen, Derksen Insurance Agencies. Office 534-6345; residence 534-6774. B31-ctf

INSURANCE! Let us help you with your insurance. Fire, travel, hail, life. For information come to our office or call Derksen Insurance Agencies. Office 534-6345, residence 534-6774. B31-ctf

STEEL BUILDINGS: PERKA BUILDING systems. Straight wall agricultural and commerical buildings, energy efficient, Engineer certified, 40 year warranty, economical. Try the Perka Solution Call (204)873-2638. B37-1p

STEEL BUILDINGS FOR SALE at factory reduced prices. Example: 40 x 60 as low as $6995., 30 x 50 as low as $7152. Other sizes available. Call Miracle Span tollfree 1-800-387-4932. B37-1p

H-HUT 24x120 EACH WING. Divided would make four buildings 24x60 each. To be moved. All or part available. Suggested uses: rink, grain storage, hall, etc. Cedar shingles, lines, insulated and sided. No interior partitions. Contact Allan Marsh 1-854-2912 Pipestone. B37-1p

SATELLITE TELEVISION, MACOM, Teecom, electrohome receivers, mesh spun aluminum and fiberglass dishes. All sizes, good products, phone Niverville Satellite, 1-388-6165 anytime. B37-1p

ornamental trees grown here at your new friendly nursery. West of Killarney water tower on No. 3 Highway. Killarney Nursery, 523-4559. B35-3c

ARE YOU LOOKING FOR A secure investment showing an excellent return? We are offering a ten-suite, high occupancy apartment block in Boissevain. This unit is extremely well constructed and is being offered below replacement cost. Financial statements are on file with listing broker. Call Del Underhill at NRS Martin-Rungay Realty Ltd. for more details. 728-8585 or Res. 826-2263. B35-3c

LOTS FOR SALE: LARGE unserviced lots along Aberdeen Street, reasonably price. Cash or trade for barley, hay or cattle. Call D. Warnez 534-6577. B35-3p

REGISTERED FULLBLOOD AND 7/8 Blonde D'Auatine bulls; well broke child's pony 13 hands; 930 Case tractor with F.E.L.; 9 foot JD mower conditioner; 1976 MF 750 diesel combine; all items priced to sell. Phone 534-6262 or 747-3154 evenings. B35-3c

1969 MINNEAPOLIS MOLINE 4292 combine. Contact G. Wooley 776-2039 or 776-2360. B36-2c

1983 KAWASAKI KX125 DIRT bike. Also 1977 Honda 70 trail bike. Both in good condition. Call 534-6377 after 5:00 p.m. B36-2c

WOOD ELECTRIC FURNACE, for sale, very good condition. Phone 776-2371. B36-2c

SINGLE BED MATTRESSES, for sale, like new. Simmons $150.00. Saxophone, like new $600.00. Phone 725-4864. B36-3p

ONE WOOD BURNING HEATER with automatic thermostat and blower fan. Phone 534-6893 after 5:30 p.m. B36-2p

1975 OLDSMOBILE: LOADED, one owner car, good condition, 455 motor (original) uses no oil. One Super Grange alto saxophone, like new $400.00. Two navy blue jackets, like new. Phone George Peters 534-2388. B36-3p

1983 YAMAHA MAXIM 750, just like new, only 4,500 miles. Asking $2,300. Phone 534-2927 after 6:00 p.m. B36-2p

NEW PLAYPEN FOLDS into a tube. Phone 776-2061. B37-2c

4½ YEAR OLD PERCENTAGE Salers bull,

14 x 66 HOME WITH 13 x 22 addition on basement, 2 car garage wired, 22 x 28 barn, excellent overflowing well water, beautifully landscaped yard. Located on 50 acres of land, 3.5 miles north of St. Rose on all weather road. Phone 778-6614 or 677-4505. B37-1p

1973 JOHN DEERE 6600 Combine always shedded new chopper, concave and clutch, A-1 condition. Will deliver. Phone 526-2774 or 526-2145, Holland, Manitoba. B37-1p

TRAPPERS: GOOD QUALITY LYRES and fox urine. For prices write Ted Gilliland, Box 215, Gainsborough, Saskatchewan S0C 0Z0. Phone 306-685-2287. B37-1p

FARM FOR SALE: 26 ACRES made up of 15 acres of forest, creek, and very nice farmyard. Included is an 1176 square foot bungalow with double garage, a 44 x 48 machine shed, several grain bins and a barn. $85,000. Call Greg at The Land Exchange - LANDEX 885-9284, Winnipeg. B37-1p

10' x 10' GREENHOUSE $149. 1000W Metal Halide $175. Plus 10,000 gardening products, great prices. Send $2 for infopack. Western Water Farms, 1244 Seymour Street, Vancouver, BC V6B 3N9 (604)682-6636. B37-1p

NOTICE

WASKADA OIL FIELD

Andex Oil Co. Ltd., operator of the proposed Waskada Unit No. 16, has made application under "The Mines Act" to convert the following wells to water injection:

Andex et al Waskada
Prov. 3-4-2-25 (WPM)
Andex et al Waskada
Prov. 12-4-2-25 (WPM)
Andex et al Waskada
Prov. 15-4-2-25 (WPM)
Andex Waskada 16-5-2-25 (WPM)

If no objection or intervention in writing is received by the Board at Room 309, Legislative Building, Winnipeg, Manitoba, R3C 0V8, within 14 days of the publication of this notice, the Board may approve the application.

Dated at Winnipeg, this 10th day of September, 1986.

Charles S. Kang,
Chairman

Sept 24/86

CHAUVCO RESOURCES LTD.

750, 202 - 6th AVENUE S W
CALGARY, ALBERTA T2P 2R9
PHONE (403) 237-8646

September 19, 1986

Manitoba Oil and Natural Gas Conservation Board
Room 309,
Legislative Building,
Winnipeg, Manitoba
R3C 0B8

Attention: Mr. Charles S. Kang, Chairman

Gentlemen:

Re: Waskada Oil Field
Water Injection Wells Sec 4 and 5-2-25 WPM

Further to the Notice of September 10th, 1986, Chauvco Resources Ltd as a working owner in Section 5-2-25 WPM has no objection to the conversion of 3-4-2-25, 1-4-2-25, 15-4-2-25 and 16-5-2-25 WPM into water injection wells, provided the lands are successfully unitized.

If you have any questions, please advise.

Yours truly,

CHAUVCO RESOURCES LTD.

E. A. Beaman, P.Eng.
Operations Manager

cc. Andex Oil Co. Ltd
Attention: Rick Schultz

.OUP NAME: ANDEX WASKADA UNIT NO. 16

LIST OF WELLS

(0)04-04-002-25 W1M(0)	(0)05-04-002-25 W1M(0)	(0)06-04-002-25 W1M(0)
(0)11-04-002-25 W1M(0)	(0)12-04-002-25 W1M(0)	(0)13-04-002-25 W1M(0)
(0)14-04-002-25 W1M(0)	(0)09-05-002-25 W1M(0)	(0)10-05-002-25 W1M(0)
(0)15-05-002-25 W1M(0)	(0)16-05-002-25 W1M(0)	(0)04-09-002-25 W1M(0)

*** S T O R E ***

TEST2

MONTH REPORT: 1986-03

ManPB
86-09-12
09:02:20

WELL NAME	HOURS	OIL m3/M	OIL m3/d	WATER m3/M	WATER m3/d	FLUID m3/D	WOR	WATER CUT %
✓ (0)04-04-002-25 W1M(0)	432	140.6	7.8	8.5	0.5	4.8	0.06	5.7
(0)05-04-002-25 W1M(0)	432	172.6	9.6	20.7	1.2	6.2	0.12	10.7
✓ (0)06-04-002-25 W1M(0)	432	132.2	7.3	11.2	0.6	4.6	0.08	7.8
✓ (0)11-04-002-25 W1M(0)	432	46.8	2.6	1.9	0.1	1.6	0.04	3.9
✓ (0)12-04-002-25 W1M(0)	432	107.4	6.0	5.2	0.3	3.6	0.05	4.6
(0)13-04-002-25 W1M(0)	432	113.7	6.3	62.7	3.5	5.7	0.55	35.5
✓ (0)14-04-002-25 W1M(0)	432	64.7	3.6	1.7	0.1	2.1	0.03	2.6
(0)09-05-002-25 W1M(0)	432	196.0	10.9	11.4	0.6	6.7	0.06	5.5
(0)10-05-002-25 W1M(0)	384	21.8	1.4	0.0	0.0	0.7	0.00	0.0
(0)15-05-002-25 W1M(0)	432	25.0	1.4	7.9	0.4	1.1	0.32	24.0
(0)16-05-002-25 W1M(0)	432	35.1	2.0	8.8	0.5	1.4	0.25	20.0

TOTALS FOR THE MONTH:

	HOURS	OIL m3/M	OIL m3/d	WATER m3/M	WATER m3/d	FLUID m3/D	WOR	WATER CUT %
	4704						0.13	
✓ Stressfrac'd.		1055.9		140.0		38.6		11.7

*** STORE ***

TEST2

ANDEX WASKADA UNIT NO. 16

ManPB
86-09-12
08:47:25

MONTH	WELL COUNT PRDN	INJN	P/IN	S/AB	HOURS	OIL m3/M	WATER m3/M	WOR	CUM.OIL m3	CUM.WAT m3	CUM.FLD m3
1984-09	1	0	0	0	552	179.1	43.6	0.24	179.1	43.6	222.7
1984-10	1	0	0	0	504	162.4	71.1	0.44	341.5	114.7	456.2
1984-11	1	0	0	0	624	198.9	196.1	0.99	540.4	310.8	851.2
1984-12	1	0	0	0	744	193.2	196.1	1.02	733.6	506.9	1240.5
1985-01	1	0	0	0	744	177.8	266.8	1.50	911.4	773.7	1685.1
1985-02	1	0	0	0	672	169.7	215.0	1.27	1081.1	988.7	2069.8
1985-03	1	0	0	0	504	110.5	127.7	1.16	1191.6	1116.4	2308.0
1985-04	1	0	0	0	648	174.8	134.1	0.77	1366.4	1250.5	2616.9
1985-05	1	0	0	0	720	188.8	83.4	0.44	1555.2	1333.9	2889.1
1985-06	1	0	0	0	360	92.7	52.9	0.57	1647.9	1386.8	3034.7
1985-07	2	0	0	0	648	141.8	201.9	1.42	1789.7	1588.7	3378.4
1985-08	3	0	0	0	1584	323.3	119.3	0.37	2113.0	1708.0	3821.0
1985-09	4	0	0	0	2184	557.5	132.2	0.24	2670.5	1840.2	4510.7
1985-10	4	0	0	0	2616	767.6	235.4	0.31	3438.1	2075.6	5513.7
1985-11	5	0	0	0	2928	882.7	359.2	0.41	4320.8	2434.8	6755.6
1985-12	7	0	0	0	3768	1017.3	413.3	0.41	5338.1	2848.1	8186.2
1986-01	7	0	0	0	4536	1217.0	358.4	0.29	6555.1	3206.5	9761.6
1986-02	12	0	0	0	6456	1714.3	302.7	0.18	8269.4	3509.2	11778.6
1986-03	11	0	0	1	4704	1055.9	140.0	0.13	9325.3	3649.2	12974.5
SHUT IN											
1986-06	8	0	0	4	1344	373.8	78.8	0.21	9699.1	3728.0	13427.1

September 11, 1986

Queen's Printer
Statutory Publications
200 Vaughan Street

Marc Arbez
Petroleum Engineer
Petroleum Branch
555 - 330 Graham Avenue

MANITOBA GAZETTE

Please have the attached Notice appear in the next issue of the Manitoba Gazette Under The Mines Act.

Marc Arbez

CH/ch

Attachment

Manitoba

The Oil and Natural Gas
Conservation Board

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

(204) 945-3130

NOTICE

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Andex et al Waskada Prov. 12-4-2-25 (WPM)
Andex et al Waskada Prov. 15-4-2-25 (WPM)
Andex Waskada 16-5-2-25 (WPM)

If no objection or intervention in writing is received by the Board at Room 309, Legislative Building, Winnipeg, Manitoba, R3C 0V8, within 14 days of the publication of this notice, the Board may approve the application.

DATED at Winnipeg, this 10th day of September, 1986.

Charles S. Kang,
Chairman

Manitoba

The Oil and Natural Gas
Conservation Board

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Legislative Building
Winnipeg, Manitoba, CANADA
R3C 0V8

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

(204 945-3130

Andex Oil Co. Ltd.
Western Canadian Place
1300, 700 - 9th Avenue S.W.
Calgary, Alberta
T2P 3V4

Attention: Mr. R.A.W. Smith,
Senior Reservoir Engineer

Dear Sirs:

Re: Waskada Lower Amaranth "A" Pool
Pressure Maintenance Application - Unit No. 16

Your application dated August 13, 1986 for approval to convert four wells in the proposed Unit No. 16 to water injection wells is acknowledged.

Upon review of your application, a number of deficiencies are noted.

1. We note that the injection pattern proposed does not conform to the inverted nine spot pattern already in place in the remainder of the Pool and that in fact it is not a regular injection pattern. This raises concerns that areal sweep efficiency in and around the project area will not be optimized. In addition, since other operators in the Pool have agreed to continue development of the existing pattern, regardless of the proximity of injection wells to lease lines, we have concerns that your proposal would result in an inequitable drainage situation.

   In light of the foregoing, you are requested to provide specific technical justification for use of the proposed irregular pattern. Such justification should demonstrate that areal sweep efficiency and correlative rights of the offset owners will not be jeopardized by your proposal.

2. There is some confusion as to whether the well Andex et al Waskada Prov. 15-4-2-25 (WPM) is proposed for conversion to injection. (Map No. 2 of your application shows the well as a proposed injector but the text of the application does not refer to the well). Please clarify the status of this well.

3. The letter from Omega regarding the water supply agreement is not complete (signature page missing).

4. Please clarify whether the reservoir pressure data included in the Engineering Report (Table 6) has been corrected to the Pool datum depth of 440 m subsea.

5. Please provide information regarding the theoretical basis and relevant equations for use of the Claridge analytical model.

Although processing of your application (i.e. - publication of notice) will be commenced, final approval will be withheld pending submission of the information requested herein.

Yours sincerely,

THE OIL AND NATURAL GAS
CONSERVATION BOARD

ORIGINAL SIGNED BY
CHARLES S. KANG

Charles S. Kang,
Chairman

LRD/lk

b.c. Wm. McDonald
B. Ball
Petroleum Branch

Manitoba

Memorandum

Date September 3, 1986

To The Oil and Natural Gas
Conservation Board

Charles S. Kang - Chairman
Wm. McDonald - Deputy Cahirman
B. Ball - Member

From H. Clare Moster
Executive Director
Petroleum Branch

Telephone

Subject

Re: Pressure Maintenance - Waskada Lower Amaranth A Pool

Andex Oil Co. Ltd., as operator of the proposed Waskada Unit No. 16, has made application for approval to conduct pressure maintenance operations in the Waskada Lower Amaranth A Pool. Andex proposes to inject water in the following wells (see Fig. No. 1):

Andex et al Waskada Prov. 3-4-2-25 WPM
Andex et al Waskada Prov. 12-4-2-25 WPM
Andex et al Waskada Prov. 15-4-2-25 WPM
Andex Waskada 16-5-2-25 WPM

Recommendations:

It is recommended that:

1. Notice of the application be published in the Manitoba Gazette and the Deloraine Times and Star and sent to the offsetting interest owners (see Table No. 1). A copy of the proposed notice is attached.

2. A deficiency letter requesting specific justification on the proposed water injection pattern and other information be sent to Andex. A draft is attached.

Discussion:

Omega Hydrocarbons Ltd., the major operator in the Waskada Lower Amaranth A Pool, has successfully conducted pressure maintenance by waterflooding in a major portion of the Pool for over 3 years. In response to waterflooding, oil production rate decline has been arrested and in some cases, reversed to show an actual increase in oil production. Computer-simulated model studies of the waterflood operations in the Pool appear to show that waterflooding will result in up to 25% recovery of the oil-in-place. Under normal primary production operations, it is estimated that less than 10% of the oil-in-place can be recovered although there is not enough primary production data available to estimate an oil production drop for the wells in the proposed project area.

Figure No. 1 shows the proposed Unit No. 16 configuration. Andex's application is deficient in regards to some essential information on the proposed water injection pattern. The proposed configuration does not conform to the inverted nine spot waterflood pattern already in existence in the Pool (Omega). This raises concerns regarding optimizing of areal sweep efficiency and of lease line drainage which must be resolved prior to approval of the application. A deficiency letter is attached.

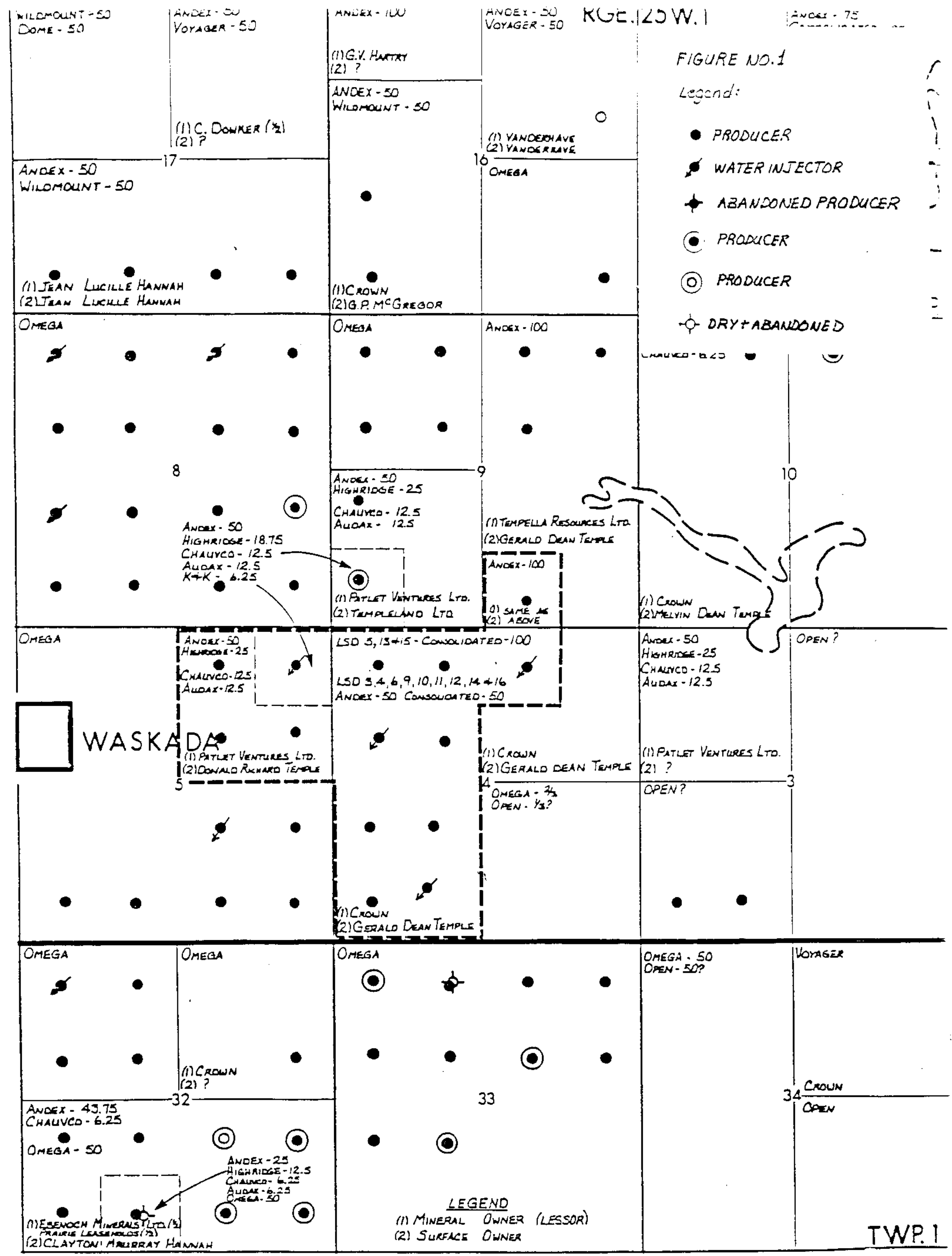
Several offset tracts are operated by other companies (see Figure No. 1). Becuase of this, of above mentioned concerns of lease line drainage and of evidence that waterflooding could affect wells more than one location removed from injection, notice of the application should be published. It is proposed that the notice be published in the Manitoba Gazette and the Deloraine Times and Star and sent to offsetting working interest owners (see Table No. 1).

Completion of the wells and proposed surface facilities are similar to current facilities in use for the Waskada Lower Amaranth A pool Waterflood and are acceptable.

Original Signed By H. C. Moster

H. Clare Moster

MA/LRD/lk



RGE. 25 W.1
FIGURE NO.1
Legend:
PRODUCER
WATER INJECTOR
ABANDONED PRODUCER
PRODUCER
PRODUCER
DRY + ABANDONED
WILDMOUNT - 50
DOME - 50
ANDEX - 50
VOYAGER - 50
ANDEX - 100
(1) G.V. HARTRY
(2) ?
ANDEX - 50
VOYAGER - 50
ANDEX - 75
ANDEX - 50
WILDMOUNT - 50
(1) C. DOWKER (½)
(2) ?
(1) VANDERHAVE
(2) VANDERHAVE
17
16
OMEGA
ANDEX - 50
WILDMOUNT - 50
(1) JEAN LUCILLE HANNAH
(2) JEAN LUCILLE HANNAH
(1) CROWN
(2) G.P. McGREGOR
OMEGA
OMEGA
ANDEX - 100
8
9
10
ANDEX - 50
HIGHRIDGE - 25
CHAUVCO - 12.5
AUDAX - 12.5
ANDEX - 50
HIGHRIDGE - 18.75
CHAUVCO - 12.5
AUDAX - 12.5
K+K - 6.25
(1) TEMPELLA RESOURCES LTD.
(2) GERALD DEAN TEMPLE
ANDEX - 100
(1) PATLET VENTURES LTD.
(2) TEMPLELAND LTD
(1) SAME AS
(2) ABOVE
(1) CROWN
(2) MELVIN DEAN TEMPLE
OMEGA
ANDEX - 50
HIGHRIDGE - 25
CHAUVCO - 12.5
AUDAX - 12.5
LSD 5, 13 + 15 - CONSOLIDATED - 100
LSD 3, 4, 6, 9, 10, 11, 12, 14 + 16
ANDEX - 50 CONSOLIDATED - 50
ANDEX - 50
HIGHRIDGE - 25
CHAUVCO - 12.5
AUDAX - 12.5
OPEN ?
WASKADA
(1) PATLET VENTURES LTD.
(2) DONALD RICHARD TEMPLE
(1) CROWN
(2) GERALD DEAN TEMPLE
(1) PATLET VENTURES LTD.
(2) ?
5
4
3
OMEGA - ⅔
OPEN - ⅓?
OPEN ?
(1) CROWN
(2) GERALD DEAN TEMPLE
OMEGA
OMEGA
OMEGA
OMEGA - 50
OPEN - 50?
VOYAGER
(1) CROWN
(2) ?
32
33
34
CROWN
OPEN
ANDEX - 43.75
CHAUVCO - 6.25
OMEGA - 50
ANDEX - 25
HIGHRIDGE - 12.5
CHAUVCO - 6.25
AUDAX - 6.25
OMEGA - 50
(1) ESENOCH MINERALS LTD. (½)
PRAIRIE LEASEHOLDS (½)
(2) CLAYTON MURRAY HANNAH
LEGEND
(1) MINERAL OWNER (LESSOR)
(2) SURFACE OWNER
TWP. 1

TABLE NO. 1

PROPOSED WASKADA UNIT NO. 16

OFFSETTING WORKING INTEREST OWNERSHIP

Working Interest Owner	Area of Interest
Audax Gas & Oil Ltd.	NW 1/4 3-2-25, SW 1/4 9-2-25
Chauvco Resources Ltd.	NW 1/4 3-2-25, SW 1/4 9-2-25
Highridge Exploration Ltd.	NW 1/4 3-2-25, SW 1/4 9-2-25
Omega Hydrocarbons Ltd.	NE 1/4 32-1-25, 33-1-25, SE 1/4 4-2-25, SE 1/4 5-2-25, W 1/2 5-2-25, 8-2-25

ANDEX OIL CO. LTD.

Western Canadian Place
1300, 700 -9th Avenue S.W.
Calgary, Alberta T2P 3V4
Telephone (403) 298-2600

27 August 1986

The Oil and Natural Gas Conservation Board
#555, 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Attention: Mr. Charles S. Kang,
Chairman

Dear Sir:

Re: Amendment to Waskada Lower Amaranth "A" Pool Pressure Maintenance Application

Andex Oil Co. Ltd. wishes to amend the Pressure Maintenance Application for the Waskada Lower Amaranth "A" Pool with the addition of location 4-9-2-25 W1M. The pre-Unit working interest owners are in unanimous agreement that the location should be included in the Unit boundary. The appropriate map changes have been made and are included.

In addition, Andex is preparing to lay the water injection lines (fibreglass) commencing October 1, 1986. The condition by the landowners in the right-of-way agreement is that construction be completed prior to freeze-up. If we cannot complete the task by November, we will have to delay commencement of line installation until October 1987. We therefore need to have approval on the injector locations before October 1, 1986. The Unit is in unanimous agreement as to the proposed injector locations. Consideration in this matter would be greatly appreciated.

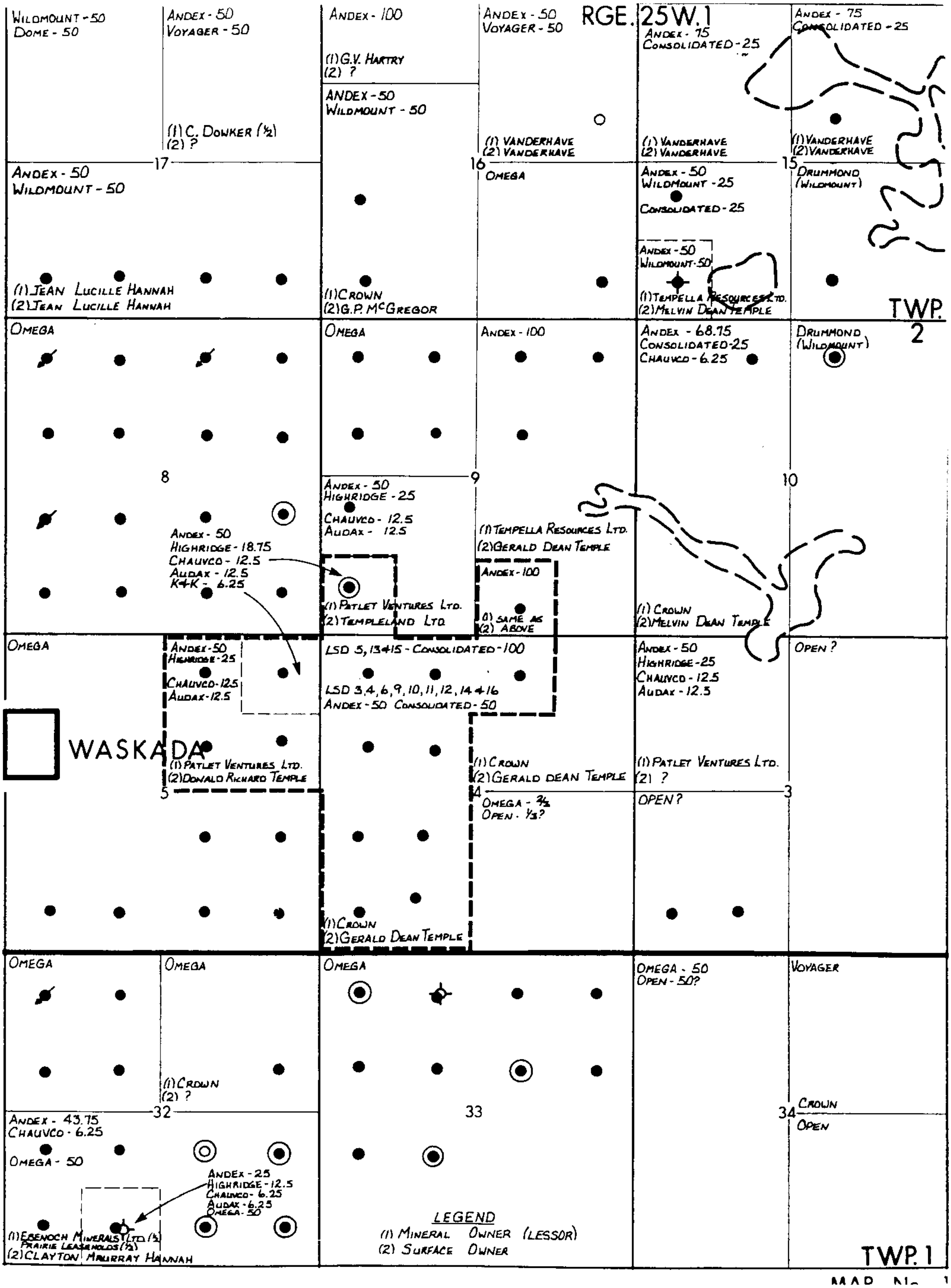
THE OIL AND NATURAL GAS CONSERVATION BOARD MANITOBA

Yours very truly,

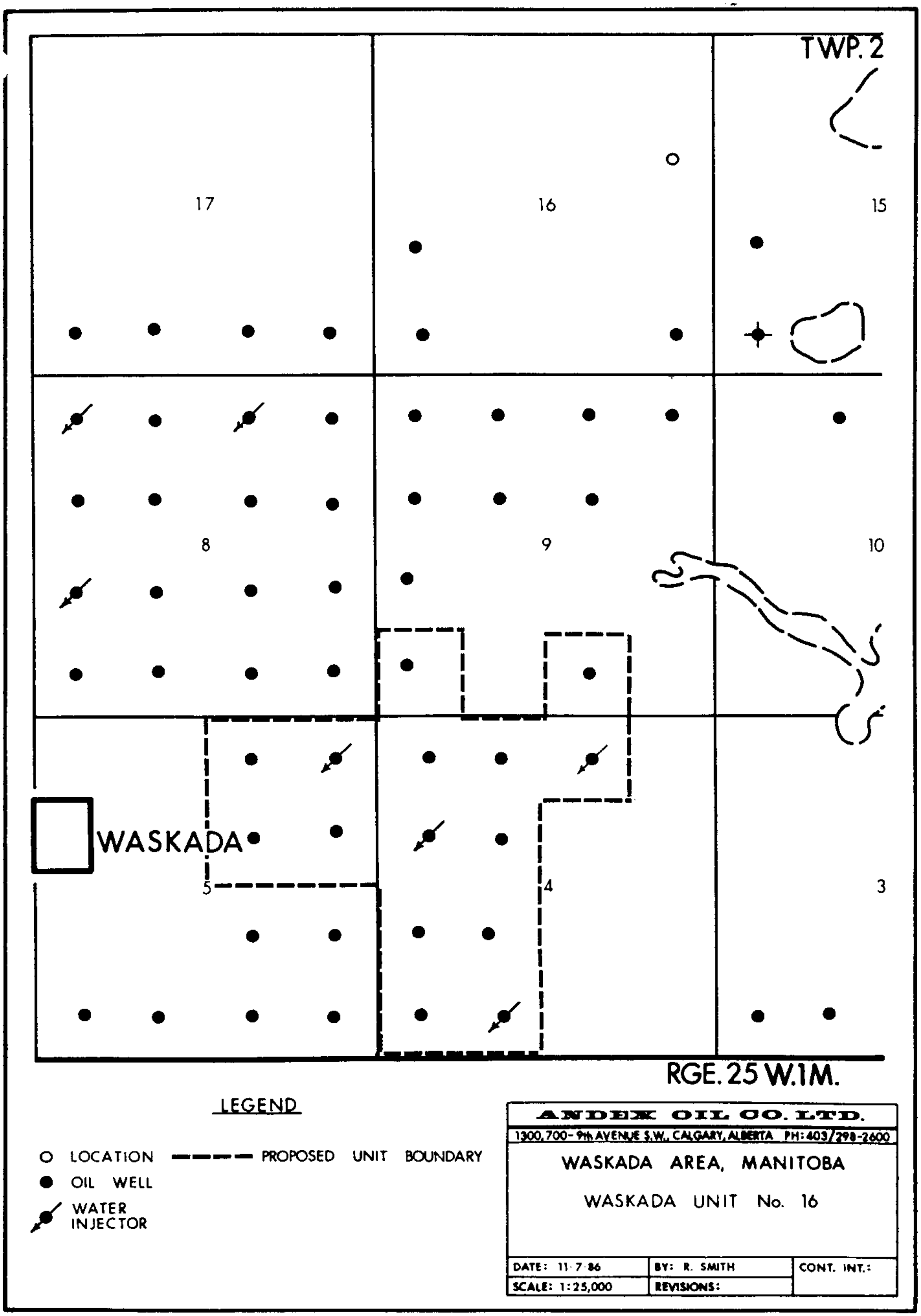
ANDEX OIL CO. LTD.

R.A.W. Smith, P.Eng.
Senior Reservoir Engineer

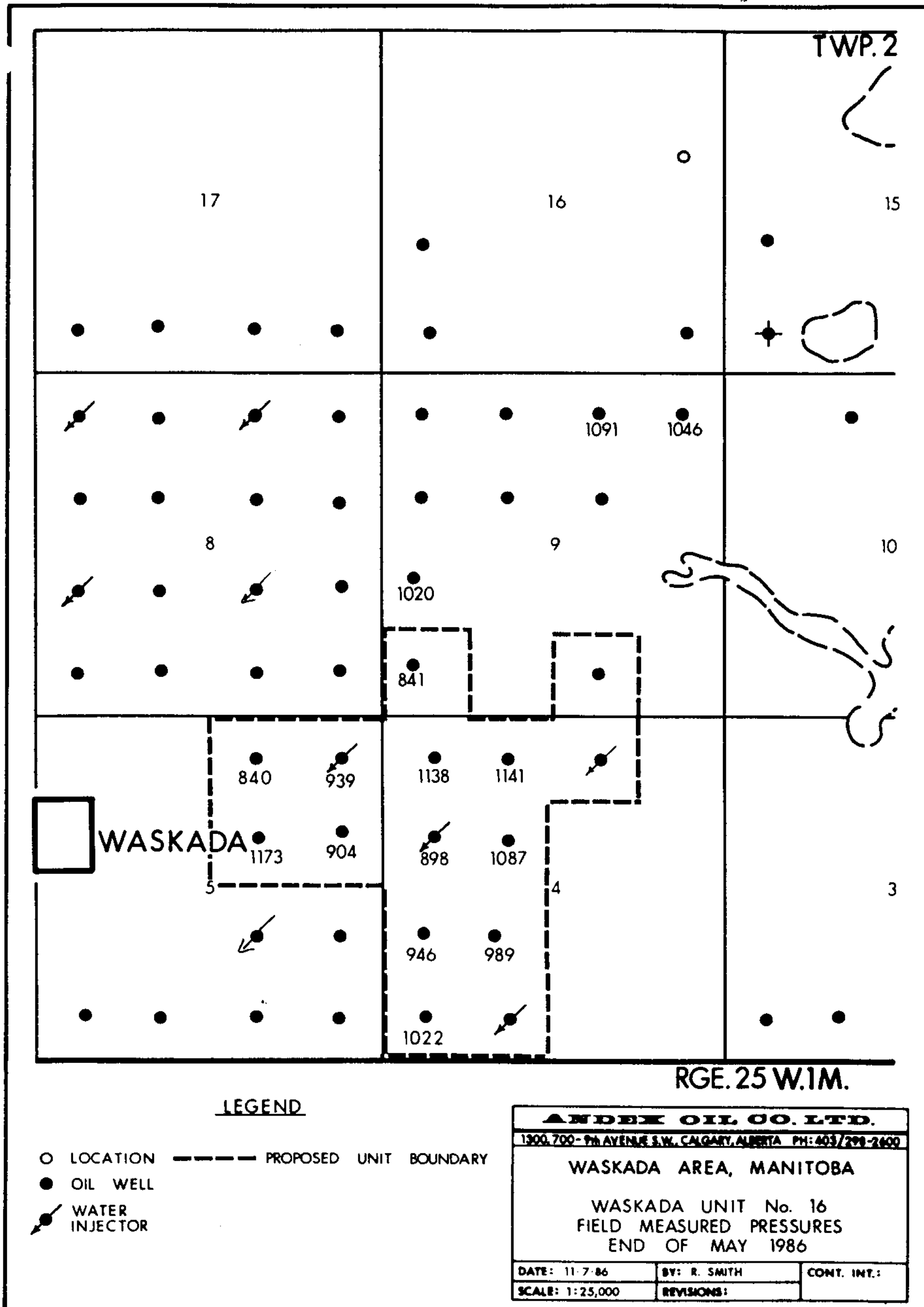
RAWS:pdc
attach
cc: Working Interest Owners
R.A. Schultz
C.R. Haywood



RGE. 25W.1
TWP. 2
TWP. 1
Wildmount - 50
Dome - 50
Andex - 50
Voyager - 50
(1) C. Dowker (½)
(2) ?
Andex - 100
(1) G.V. Hartry
(2) ?
Andex - 50
Wildmount - 50
Andex - 50
Voyager - 50
(1) Vanderhave
(2) Vanderhave
Andex - 75
Consolidated - 25
(1) Vanderhave
(2) Vanderhave
Andex - 75
Consolidated - 25
(1) Vanderhave
(2) Vanderhave
17
16
15
Andex - 50
Wildmount - 50
(1) Jean Lucille Hannah
(2) Jean Lucille Hannah
(1) Crown
(2) G.P. McGregor
Omega
Andex - 50
Wildmount - 25
Consolidated - 25
Andex - 50
Wildmount - 50
(1) Tempella Resources Ltd.
(2) Melvin Dean Temple
Drummond
(Wildmount)
Omega
Omega
Andex - 100
Andex - 68.75
Consolidated - 25
Chauvco - 6.25
Drummond
(Wildmount)
8
9
10
Andex - 50
Highridge - 25
Chauvco - 12.5
Audax - 12.5
Andex - 50
Highridge - 18.75
Chauvco - 12.5
Audax - 12.5
K+K - 6.25
(1) Tempella Resources Ltd.
(2) Gerald Dean Temple
Andex - 100
(1) Same as
(2) Above
(1) Patlet Ventures Ltd.
(2) Templeland Ltd.
(1) Crown
(2) Melvin Dean Temple
Omega
Andex - 50
Highridge - 25
Chauvco - 12.5
Audax - 12.5
LSD 5, 13 & 15 - Consolidated - 100
LSD 3, 4, 6, 9, 10, 11, 12, 14 & 16
Andex - 50 Consolidated - 50
Andex - 50
Highridge - 25
Chauvco - 12.5
Audax - 12.5
Open ?
WASKADA
(1) Patlet Ventures Ltd.
(2) Donald Richard Temple
(1) Crown
(2) Gerald Dean Temple
(1) Patlet Ventures Ltd.
(2) ?
5
4
3
Omega - ⅔
Open - ⅓?
Open ?
(1) Crown
(2) Gerald Dean Temple
Omega
Omega
Omega
Omega - 50
Open - 50?
Voyager
(1) Crown
(2) ?
32
33
34
Crown
Open
Andex - 43.75
Chauvco - 6.25
Omega - 50
Andex - 25
Highridge - 12.5
Chauvco - 6.25
Audax - 6.25
Omega - 50
(1) Ebenoch Minerals Ltd. (½)
Prairie Leaseholds (½)
(2) Clayton Murray Hannah
LEGEND
(1) Mineral Owner (Lessor)
(2) Surface Owner

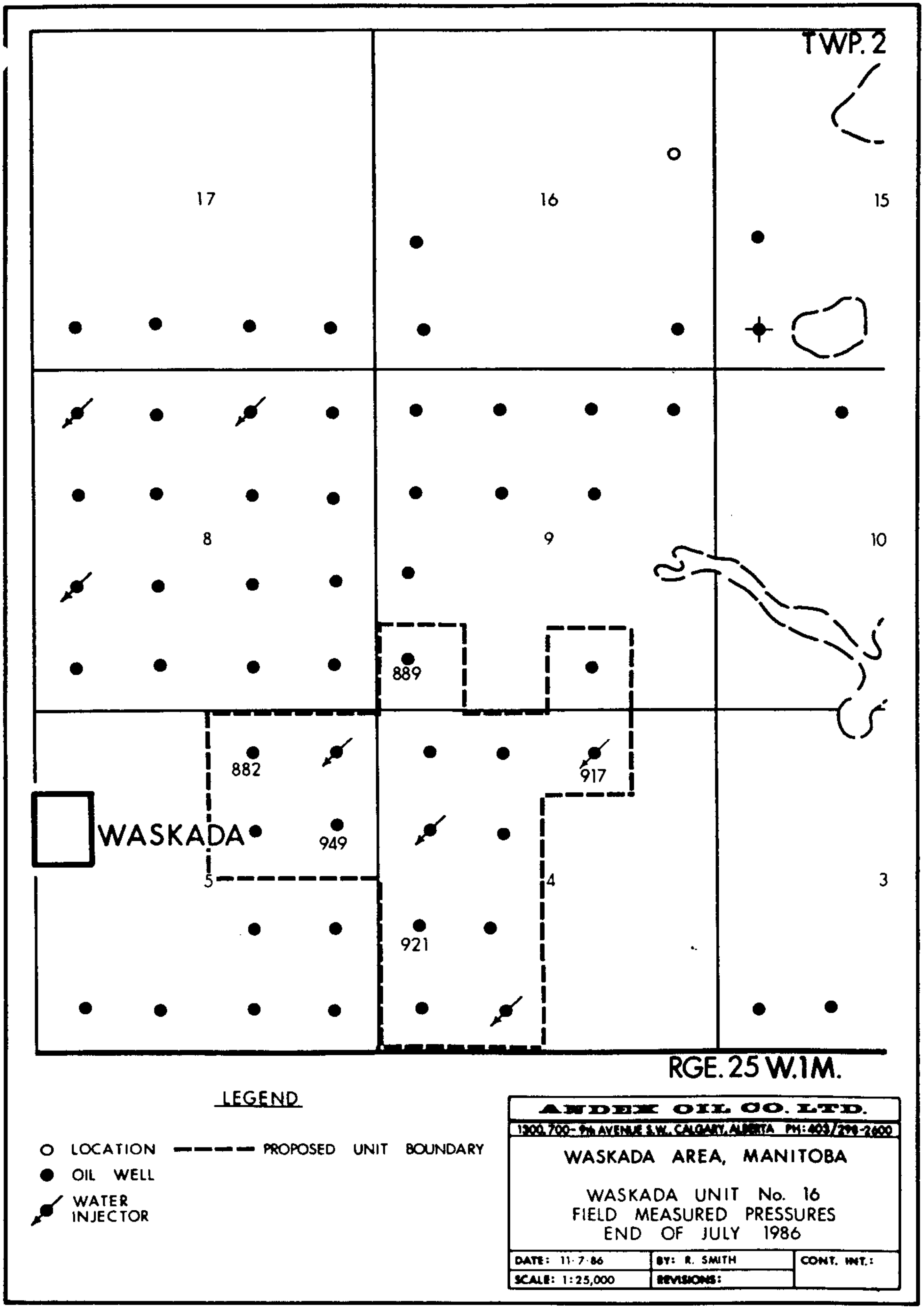

TWP. 2
17
16
15
8
9
10
WASKADA
5
4
3
RGE. 25 W.1M.
LEGEND
LOCATION
OIL WELL
WATER INJECTOR
PROPOSED UNIT BOUNDARY
ANDEX OIL CO. LTD.
1300, 700 - 9th AVENUE S.W., CALGARY, ALBERTA PH: 403/298-2600
WASKADA AREA, MANITOBA
WASKADA UNIT No. 16
DATE: 11-7-86
BY: R. SMITH
CONT. INT.:
SCALE: 1:25,000
REVISIONS:

MAP No. 2



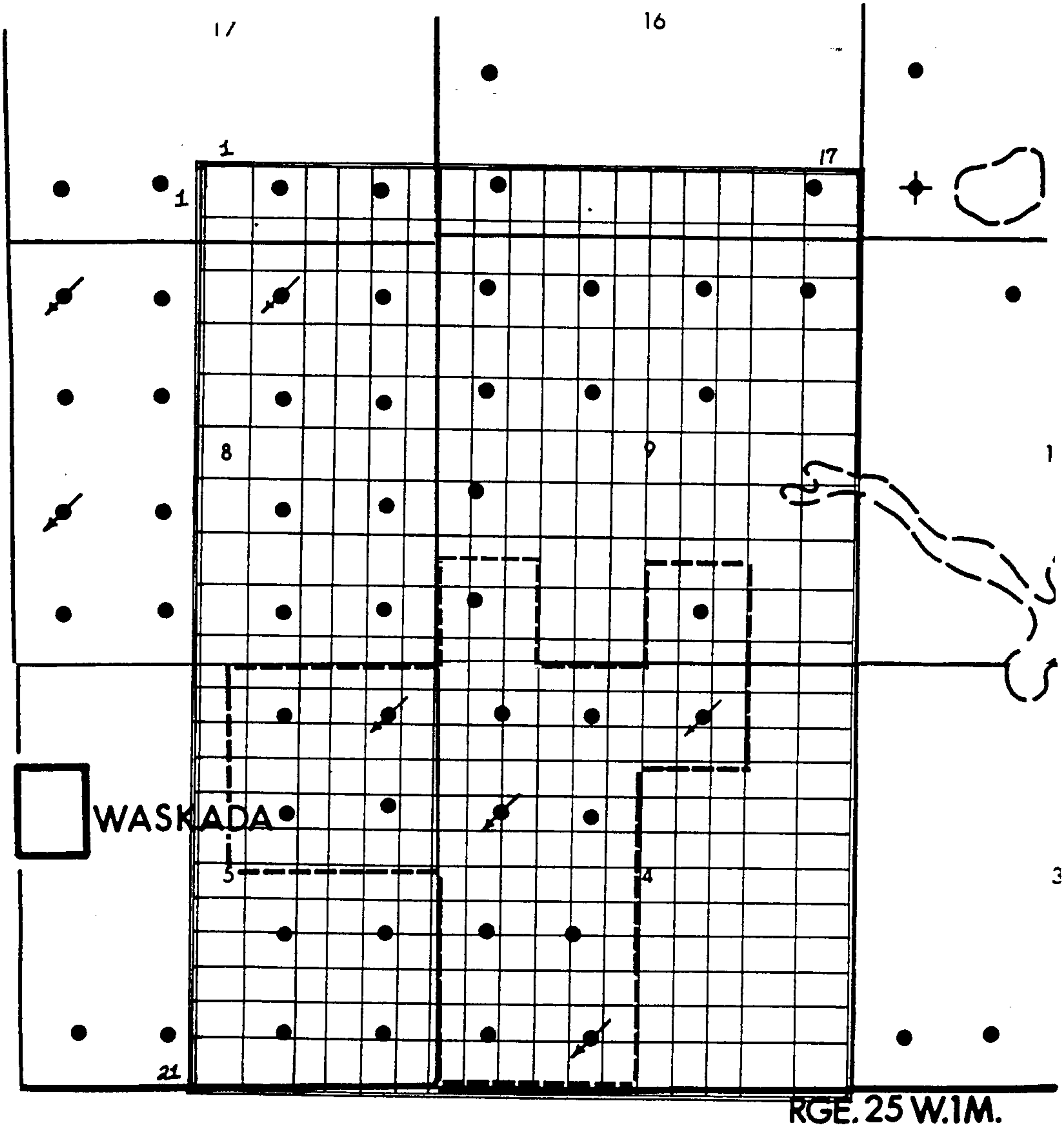
TWP. 2
17
16
15
1091
1046
8
9
10
1020
841
840
939
1138
1141
WASKADA
1173
904
898
1087
5
4
3
946
989
1022
RGE. 25 W.1M.
LEGEND
LOCATION
PROPOSED UNIT BOUNDARY
OIL WELL
WATER INJECTOR
ANDEX OIL CO. LTD.
1300, 700 - 9th AVENUE S.W., CALGARY, ALBERTA PH: 403/298-2600
WASKADA AREA, MANITOBA
WASKADA UNIT No. 16
FIELD MEASURED PRESSURES
END OF MAY 1986
DATE: 11-7-86
BY: R. SMITH
CONT. INT.:
SCALE: 1:25,000
REVISIONS:

MAP No. 5A



TWP. 2
17
16
15
8
9
10
889
882
917
WASKADA
949
5
4
3
921
RGE. 25 W.1M.
LEGEND
LOCATION
PROPOSED UNIT BOUNDARY
OIL WELL
WATER INJECTOR
ANDEX OIL CO. LTD.
1300, 700 - 9th AVENUE S.W., CALGARY, ALBERTA PH: 403/298-2600
WASKADA AREA, MANITOBA
WASKADA UNIT No. 16
FIELD MEASURED PRESSURES
END OF JULY 1986
DATE: 11-7-86
BY: R. SMITH
CONT. INT.:
SCALE: 1:25,000
REVISIONS:

MAP No. 5B



LEGEND

- ○ LOCATION
- ● OIL WELL
- ▬ ▬ ▬ PROPOSED UNIT BOUNDARY

ANDEX OIL CO. LTD.

1300, 700 - 9th AVENUE S.W., CALGARY, ALBERTA PH: 403/[illegible]

WASKADA AREA, MANITOBA

GRID DEFINITION OF STUDY AREA

JULY 1986

MAP No. 6

ANDEX OIL CO. LTD.

Western Canadian Place
1300, 700 -9th Avenue S.W.
Calgary, Alberta T2P 3V4
Telephone (403) 298-2600

13 August 1986

The Oil and Natural Gas Conservation Board
#555, 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Attention: Mr. Charles S. Kang,
Chairman

Dear Sir:

Re: Waskada Lower Amaranth "A" Pool
Pressure Maintenance Application

With this submission Andex Oil Co. Ltd. hereby makes application to conduct a pressure maintenance scheme by the injection of water into the above mentioned pool. The effective area of the Lower Amaranth "A" pool is shown on Map No. 2 and work is underway to unitize the subject formation. It is proposed that Waskada Unit No. 16 will consist of fourteen tracts and contain Lsds 3-4, 4-4, 5-4, 6-4, 11-4, 12,4, 13-4, 14-4, 15-4, 9-5, 10-5 15-5 16-5 and 2-9-2-25 WPM. Because of additional locations in Section 9 this Unit will probably require a future expansion. The unitization proceedings are underway and we expect to send in a draft copy soon. It should be noted however that there is at this time, a strong reluctance by one of the parties in the NE¼ of Section 5 to proceed with Unitization and waterflooding. It is possible that the area of application could be reduced to exclude the tracts in Section 5.

Andex Oil Co. Ltd. requests permission to inject water into wells; Andex Waskada 12-4-2-25, Andex Waskada 16-5-2-25 and Andex Waskada 3-4-2-25 coincident with the effective date of the new Unit.

Andex Oil Co. Ltd. is involved as a partner in the Waskada Lower Amaranth Unit No. 4 operated by Omega Hydrocarbons Ltd. and for the purposes of modelling the subject pool we have made extensive use of Omega's reservoir study. In the contents of the "Preliminary Engineering Study" we differentiate between that which is used from the Omega study (entitled "Waskada Model Study, Lower Amaranth Pool for Omega Hydrocarbons Ltd. by J. Flores and W. Laurila, May 1983) and that of our own generation. We have also, as much as possible, attempted to verify data taken from the Omega study and indicate where and why we have deviated from their data.

In support of this application, the following items are included:

1) A map showing the surface owners, lessors and lessees in and adjoining the area of application (Map No. 1).

2) A map of the proposed scheme area (Map No. 2) showing status of wells.

3) Maps of the surface facilities, oil lines and water injection lines. (Maps Nos. 3 and 4)

4) Schematic of the injection well completions.

5) Schematic of the Waskada Water Distribution System.

6) Copies of notification to surface owners.

7) A preliminary Engineering Study on the subject pool.

It will be noted on Map No. 2 that we have not proposed a standard pattern arrangement for the injectors. The irregular shape of the project initially dictates some modification to a regular pattern but sufficient locations were chosen to ensure a reasonable producer-injector ratio.

In choosing the best locations we considered the following specific points:

a) to maximize oil swept we considered net pay. Due to the uncertainty of lens continuity we considered a high net pay value as preferable for an injector location.

b) oil productivity was considered as we wish to maximize oil production capability; thus as long as injectivity was considered sufficient for two wells, the preference would be to convert one of the two wells having lower productivity. Injectivity for the Omega injector just to the west at location 15-8-2-25 WPM is summarized as follows:

Location	Initial Oil Rate (m³/day)	Maximum Injection Rate (m³/day)	Average Injection Rate (m³/day)
15-8-1-26 WPM	2.8	89	53 46

Considering cumulative and current voidage, injection rates of 40-60 m³/day will be sufficient for our project. As can be seen from the Omega well the ratio of injectivity rate to oil rate is very large. Looking at injectors further removed from our project is as follows:

July 86 RATES.

Location	Initial Oil Rate (m³/day)	Injection Rate (m³/day)
15-23-1-26 WPM	6.5	62 38.4
13A-24-1-26 WPM	1.3	72 44.7
15-24-1-26 WPM	2.1	82 51.2
5-25-1-26 WPM	6.7	126 45
7-25-1-26 WPM	9.7	106 47
13-25-1-26 WPM	2.0	28 21
15-25-1-26 WPM	2.5	28 13
7-26-1-26 WPM	2.8	57 41

c) Finally we considered the potential of thief zones ie. wells with high water cuts are probably producing Mississippian water (see Engineering Study - July, 1986) and would result in water injection loss to the Mississippian yielding a misleading voidage-replacement balance poor waterflood performance and unnecessary injection costs.

Treated, high pressure injection water will be purchased from Omega Hydrocarbons Ltd. (see copy of agreement attached) and mixed with our produced water prior to injection. It is Andex's understanding that this is the procedure followed by Omega with no apparent compatibility problems. The injection lines will either be internally coated steel or fibreglass pipe to ensure corrosion control. Andex will meter the quantities of injection fluid as per Omega's procedure.

Andex has considered in the interest of reservoir pressure, to inject water using temporary well site injection pumps (once the project status is granted) prior to the installation of injection lines. After the pressure survey was finished (June 23, 1986) we left shut-in wells 5-4, 9-5. 15-5, 15-4 and 4-9-2-25 WPM in consideration of the static reservoir pressure. Andex will monitor voidage and where necessary will shut-in additional wells. Andex's interest is to expedite approval as quickly as possible to avoid unnecessary revenue losses to all concerned. A Preliminary Engineering Report is enclosed and the final report, with simulation results, to follow within three to four weeks.

Yours very truly,

ANDEX OIL CO. LTD.

R.A.W. Smith

R.A.W. Smith, P.Eng.
Senior Reservoir Engineer

RAWS:pdc
attach

cc: Consolidated Pipe Lines Company
Audax Gas & Oil Ltd.
Chauvco Resources Ltd.
Highridge Resources Ltd.
K&K Enterprises Ltd.

OMEGA
HYDROCARBONS LTD.
1300 SUN LIFE PLAZA III
112 - 4th AVENUE S.W.
CALGARY, ALBERTA, CANADA T2P 0H3
TELEPHONE (403) 261-0743

August 8, 1986

Andex Oil Co. Ltd.
1300, 700 - 9th Avenue S.W.
Calgary, Alberta
T2P 3V4

Attention: R.A. Schultz

Dear Sirs:

Re: Purchase of Formation Water

Omega Hydrocarbons Ltd. (Omega) has equipped the well Omega Waskada 2-18-2-25 as a water source well. Andex Oil Co. Ltd. (Andex) has offered to purchase water produced from the Blairmore Formation underlying the said well (the water) and Omega has agreed to sell the water to Andex under the following terms and conditions:

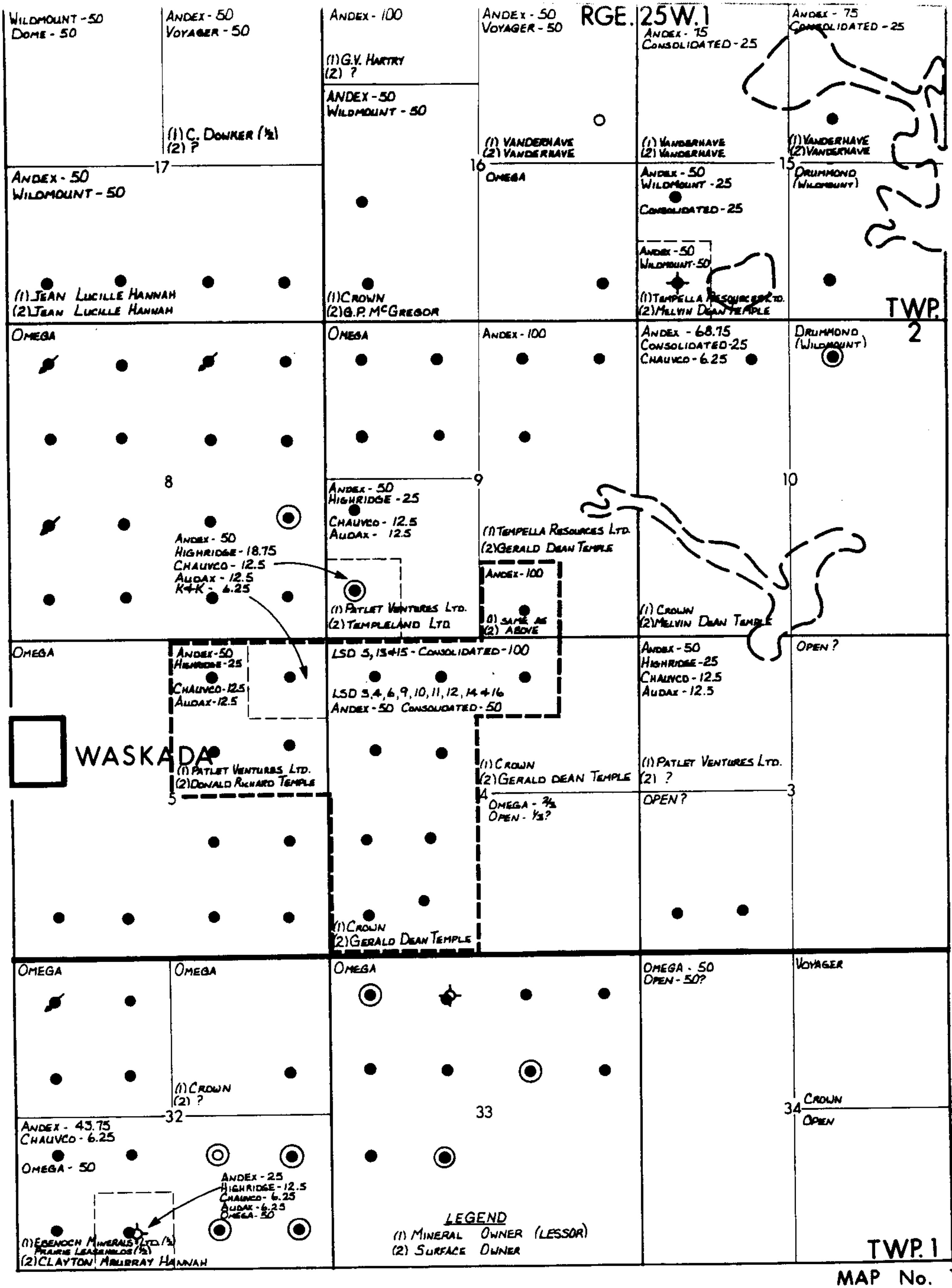
1. The water will be delivered to Andex via pipeline at a presure of at least 9,000 kilopascals (kPa) to a point located in Legal Subdivision Twelve (12) of Section Nine (9), Township Two (2), Range Twenty-five (25), West of the Principal Meridian (WPM) in the Province of Manitoba (point of delivery).

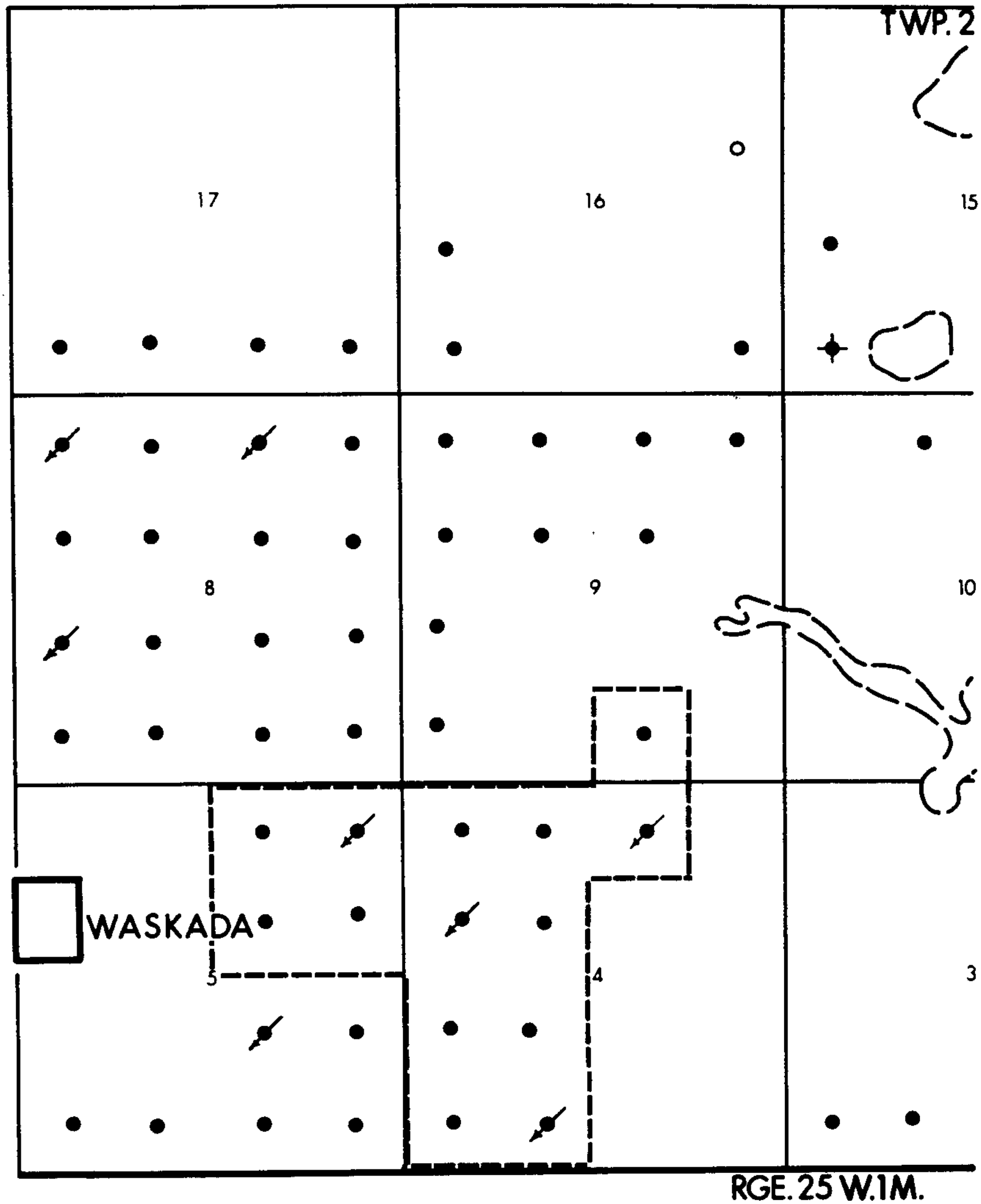
2. All costs and expenses required and necessary to tie-in Andex's pipeline to Omega's pipeline shall be borne by Andex.

3. Omega will endeavour to deliver to Andex its full requirement of water during each and every month of the term hereof (such amount estimated to be one hundred thirty (130) cubic metres per day); provided, however, it reserves the right to limit or discontinue the delivery of water at any time or from time to time immediately after notice of such intention has been given either verbally or in writing to Andex.

4. Andex will obtain any and all governmental permission and authorization required or necessary to accept water from Omega and use the water for its intended purposes.

5. Andex will be charged and will pay to Omega $1.60 per cubic metre for all water delivered to it by Omega at the point of delivery. Payment for the water delivered hereunder will be on the basis of measuring devises of a type appropriate for its intended use which shall be furnished and installed at the point of delivery by Andex. Invoices will be rendered each month and payment made on or before the 20th day of the month following the month in which the invoice was received.


RGE. 25 W. 1
TWP. 2
TWP. 1
WILDMOUNT - 50
DOME - 50
ANDEX - 50
VOYAGER - 50
(1) C. DOWKER (½)
(2) ?
ANDEX - 100
(1) G.V. HARTRY
(2) ?
ANDEX - 50
WILDMOUNT - 50
ANDEX - 50
VOYAGER - 50
(1) VANDERHAVE
(2) VANDERHAVE
ANDEX - 75
CONSOLIDATED - 25
(1) VANDERHAVE
(2) VANDERHAVE
ANDEX - 75
CONSOLIDATED - 25
(1) VANDERHAVE
(2) VANDERHAVE
17
16
15
ANDEX - 50
WILDMOUNT - 50
(1) JEAN LUCILLE HANNAH
(2) JEAN LUCILLE HANNAH
(1) CROWN
(2) G.P. McGREGOR
OMEGA
ANDEX - 50
WILDMOUNT - 25
CONSOLIDATED - 25
ANDEX - 50
WILDMOUNT - 50
(1) TEMPELLA RESOURCES LTD.
(2) MELVIN DEAN TEMPLE
DRUMMOND
(WILDMOUNT)
OMEGA
OMEGA
ANDEX - 100
ANDEX - 68.75
CONSOLIDATED - 25
CHAUVCO - 6.25
DRUMMOND
(WILDMOUNT)
8
9
10
ANDEX - 50
HIGHRIDGE - 25
CHAUVCO - 12.5
AUDAX - 12.5
ANDEX - 50
HIGHRIDGE - 18.75
CHAUVCO - 12.5
AUDAX - 12.5
K+K - 6.25
(1) TEMPELLA RESOURCES LTD.
(2) GERALD DEAN TEMPLE
ANDEX - 100
(1) SAME AS
(2) ABOVE
(1) PATLET VENTURES LTD.
(2) TEMPLELAND LTD.
(1) CROWN
(2) MELVIN DEAN TEMPLE
OMEGA
ANDEX - 50
HIGHRIDGE - 25
CHAUVCO - 12.5
AUDAX - 12.5
LSD 5, 13 & 15 - CONSOLIDATED - 100
LSD 3, 4, 6, 9, 10, 11, 12, 14 & 16
ANDEX - 50 CONSOLIDATED - 50
ANDEX - 50
HIGHRIDGE - 25
CHAUVCO - 12.5
AUDAX - 12.5
OPEN ?
WASKADA
(1) PATLET VENTURES LTD.
(2) DONALD RICHARD TEMPLE
(1) CROWN
(2) GERALD DEAN TEMPLE
(1) PATLET VENTURES LTD.
(2) ?
5
4
3
OMEGA - ⅔
OPEN - ⅓?
OPEN ?
(1) CROWN
(2) GERALD DEAN TEMPLE
OMEGA
OMEGA
OMEGA
OMEGA - 50
OPEN - 50?
VOYAGER
(1) CROWN
(2) ?
32
33
34
CROWN
OPEN
ANDEX - 43.75
CHAUVCO - 6.25
OMEGA - 50
ANDEX - 25
HIGHRIDGE - 12.5
CHAUVCO - 6.25
AUDAX - 6.25
OMEGA - 50
(1) EBENOCH MINERALS LTD. (½)
PRAIRIE LEASEHOLDS (½)
(2) CLAYTON MURRAY HANNAH
LEGEND
(1) MINERAL OWNER (LESSOR)
(2) SURFACE OWNER
MAP No.



LEGEND

- ○ LOCATION
- ● OIL WELL
- WATER INJECTOR
- - - - - PROPOSED UNIT BOUNDARY

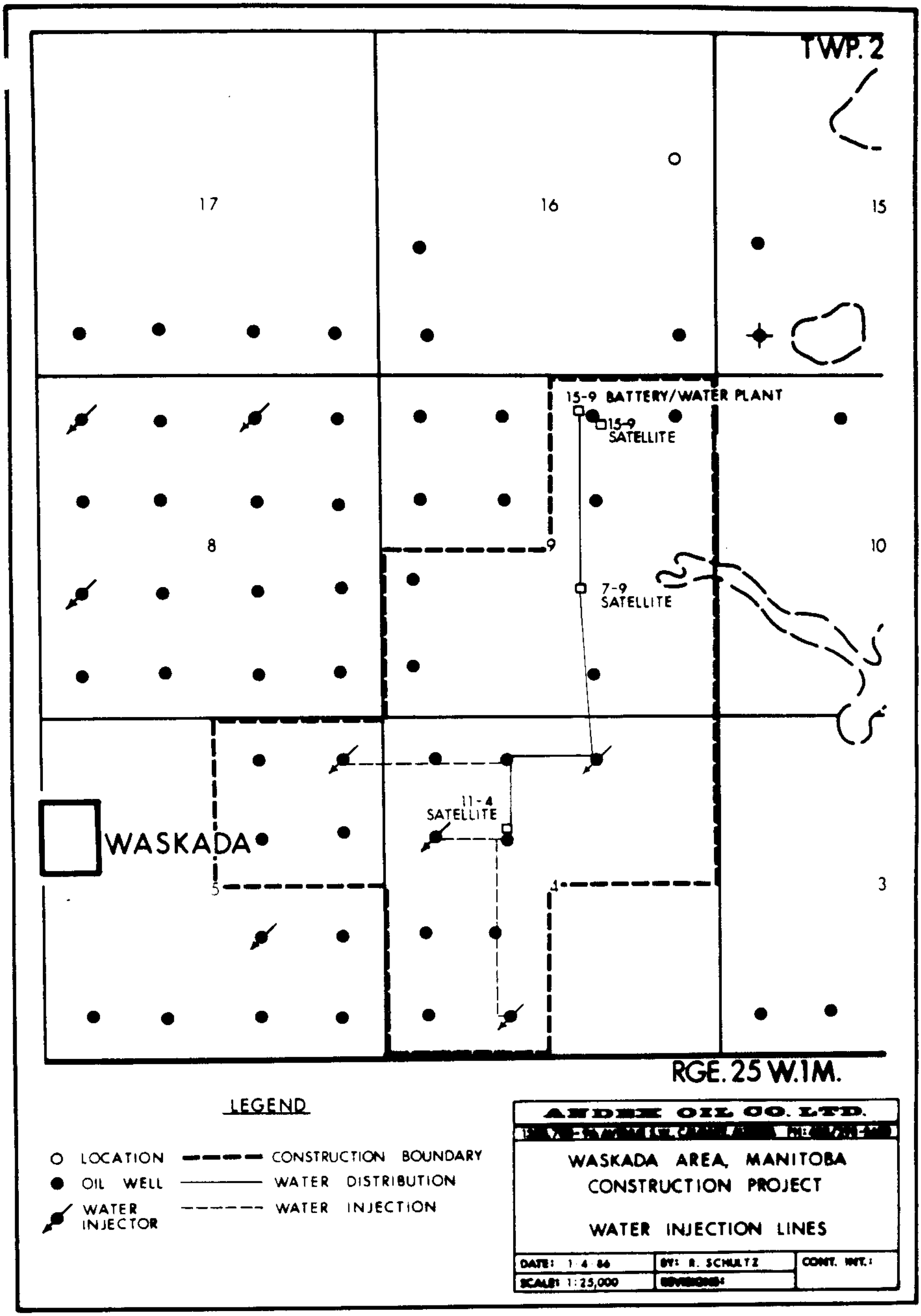
ANDEX OIL CO. LTD.
1300, 700 - 9th AVENUE S.W. CALGARY, ALBERTA PH: 403/[illegible]-2600

WASKADA AREA, MANITOBA

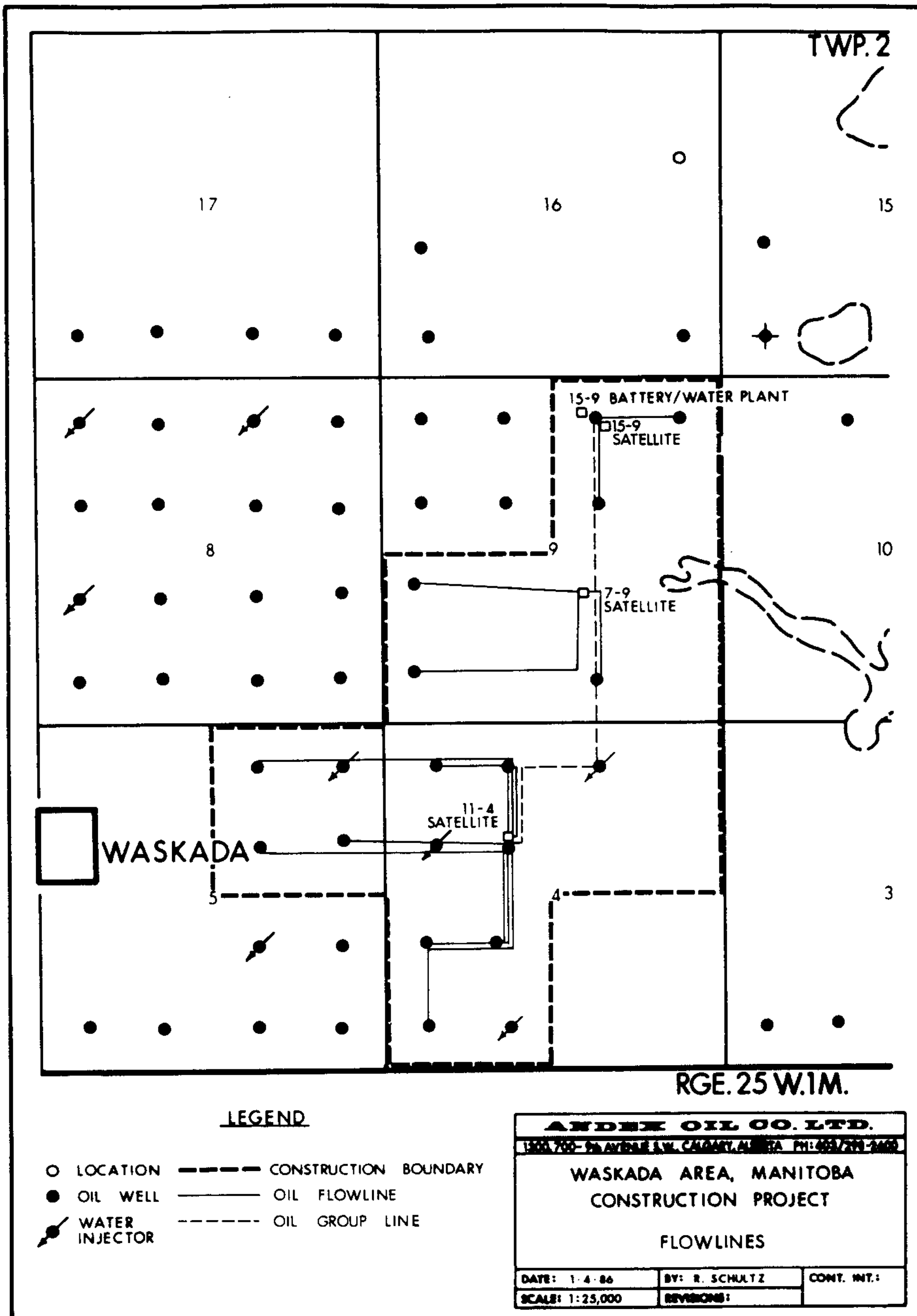
WASKADA UNIT No. 16

DATE: 11·7·86	BY: R. SMITH	CONT. INT.:
SCALE: 1:25,000	REVISIONS:	

MAP No. 2

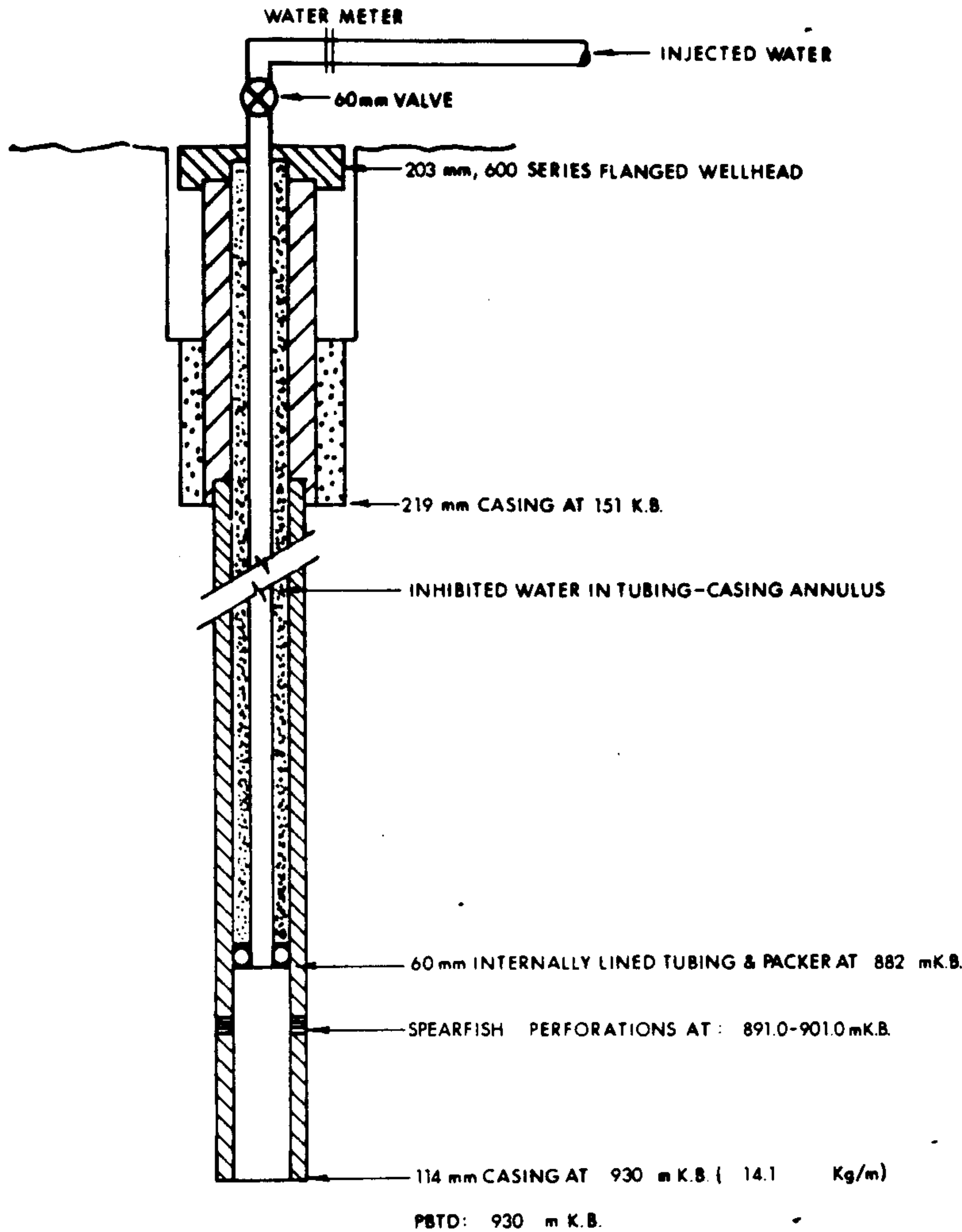

TWP. 2
17
16
15
15-9 BATTERY/WATER PLANT
15-9
SATELLITE
8
9
10
7-9
SATELLITE
11-4
SATELLITE
WASKADA
5
4
3
RGE. 25 W.1M.
LEGEND
LOCATION
OIL WELL
WATER INJECTOR
CONSTRUCTION BOUNDARY
WATER DISTRIBUTION
WATER INJECTION
WASKADA AREA, MANITOBA
CONSTRUCTION PROJECT
WATER INJECTION LINES
DATE: 1 · 4 · 86
BY: R. SCHULTZ
CONT. INT.:
SCALE: 1:25,000

MAP No. 3


TWP. 2
17
16
15
15-9 BATTERY/WATER PLANT
15-9
SATELLITE
8
9
10
7-9
SATELLITE
11-4
SATELLITE
WASKADA
5
4
3
RGE. 25 W.1M.
LEGEND
LOCATION
OIL WELL
WATER INJECTOR
CONSTRUCTION BOUNDARY
OIL FLOWLINE
OIL GROUP LINE
WASKADA AREA, MANITOBA
CONSTRUCTION PROJECT
FLOWLINES
DATE: 1·4·86
SCALE: 1:25,000
BY: R. SCHULTZ
CONT. INT.:

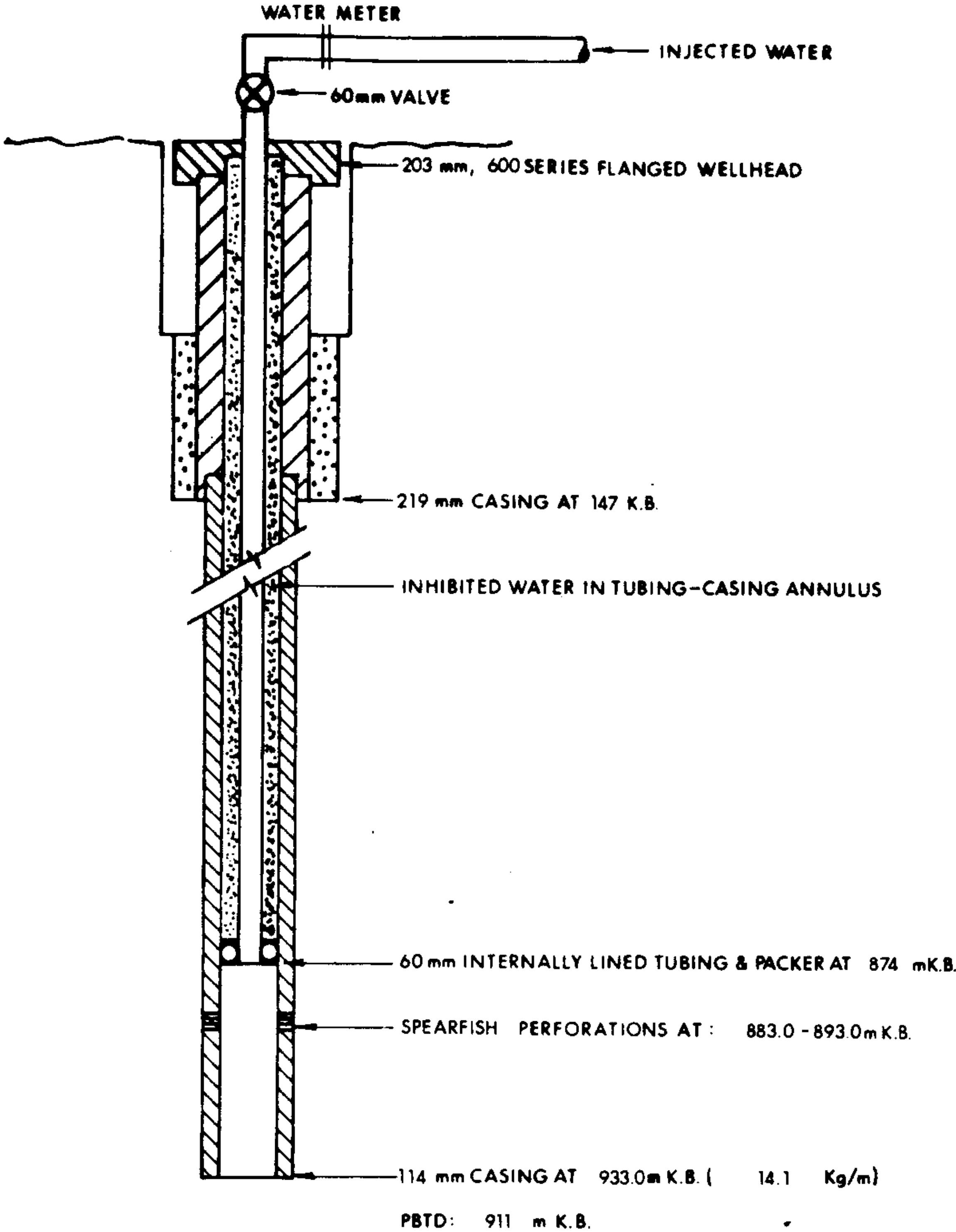
MAP No. 4

PROPOSED INJECTION WELL SUBSURFACE EQUIPMENT



ANDEX OIL CO. LTD.	
1501, 500 - 4th AVENUE S.W., CALGARY, ALBERTA PH: 403/261-2040	
SCHEMATIC DIAGRAM ANDEX ET AL WASKADA 3-4-2-25 WPM	
DATE: 30-7-86	BY: D. STOODLEY
SCALE: NTS	REVISIONS:
FILE NO:	

PROPOSED INJECTION WELL SUBSURFACE EQUIPMENT



ANDEX OIL CO. LTD.

1501, 300 - 4th AVENUE S.W., CALGARY, ALBERTA PH: 403/261-2040

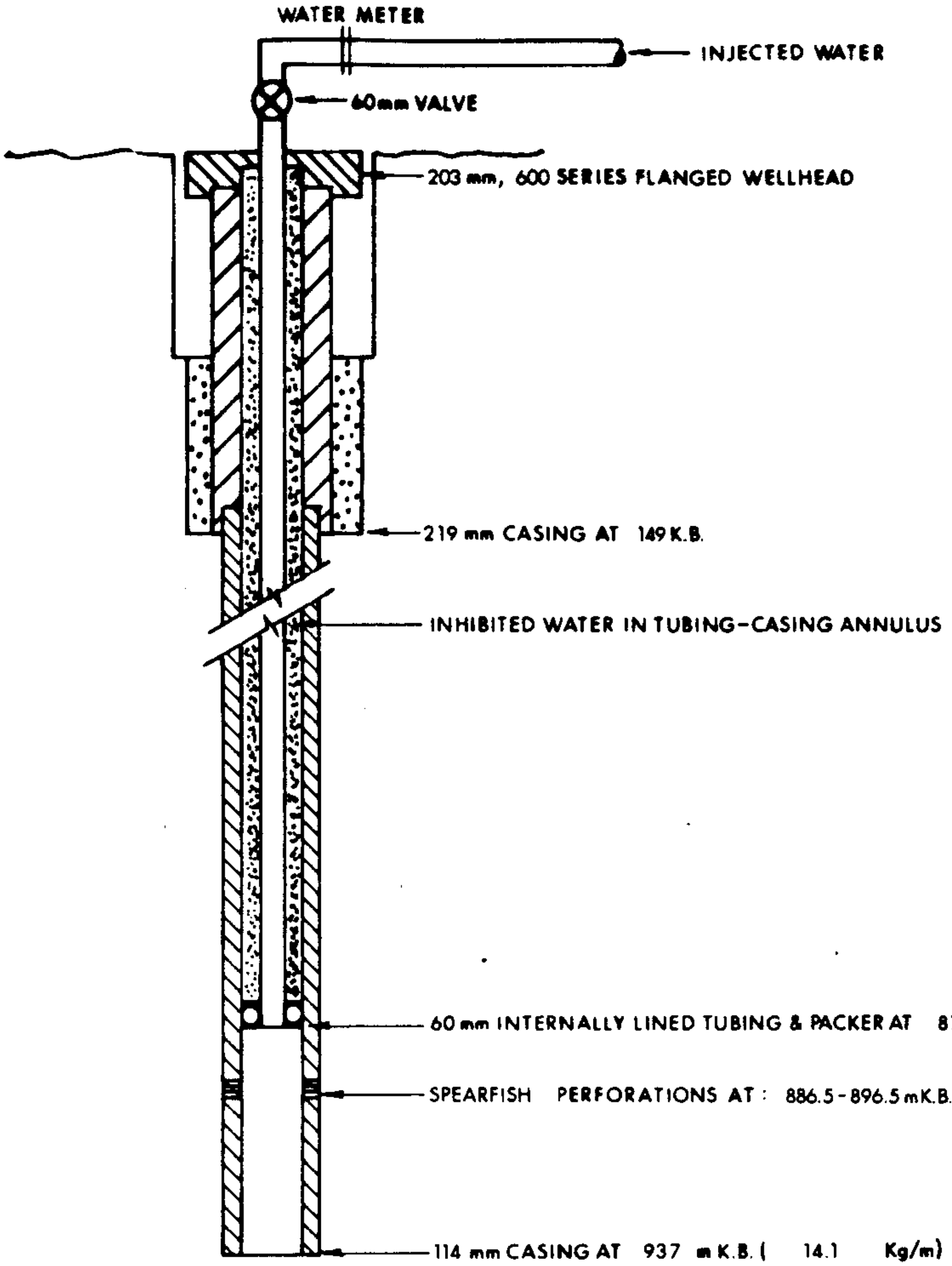
SCHEMATIC DIAGRAM

ANDEX ET AL WASKADA

12-4-2-25 WPM

DATE: 30-7-86	BY: D. STOODLEY	FILE NO:
SCALE: NTS	REVISIONS:	

PROPOSED INJECTION WELL
SUBSURFACE EQUIPMENT



PBTD: 935 m K.B.

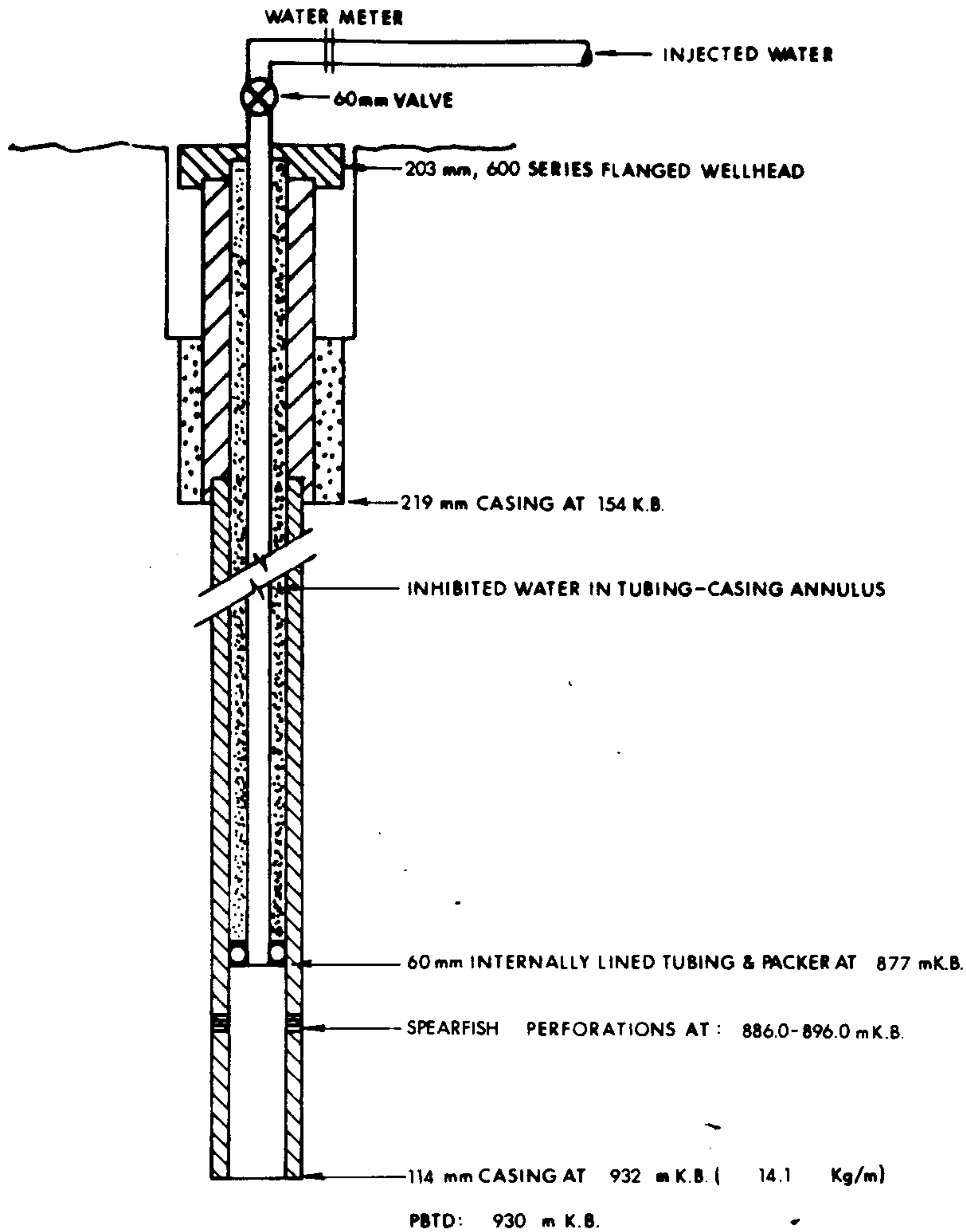
ANDEX OIL CO. LTD.

1501, 300 - 4th AVENUE S.W., CALGARY, ALBERTA PH: 403/261-2040

SCHEMATIC DIAGRAM
ANDEX ET AL WASKADA
15-4-2-25 WPM

DATE: 30-7-86	BY: D. STOODLEY	FILE NO:
SCALE: NTS	REVISIONS:	

PROPOSED INJECTION WELL
SUBSURFACE EQUIPMENT



ANDEX OIL CO. LTD.

1501, 300 - 4th AVENUE S.W., CALGARY, ALBERTA PH: [illegible]

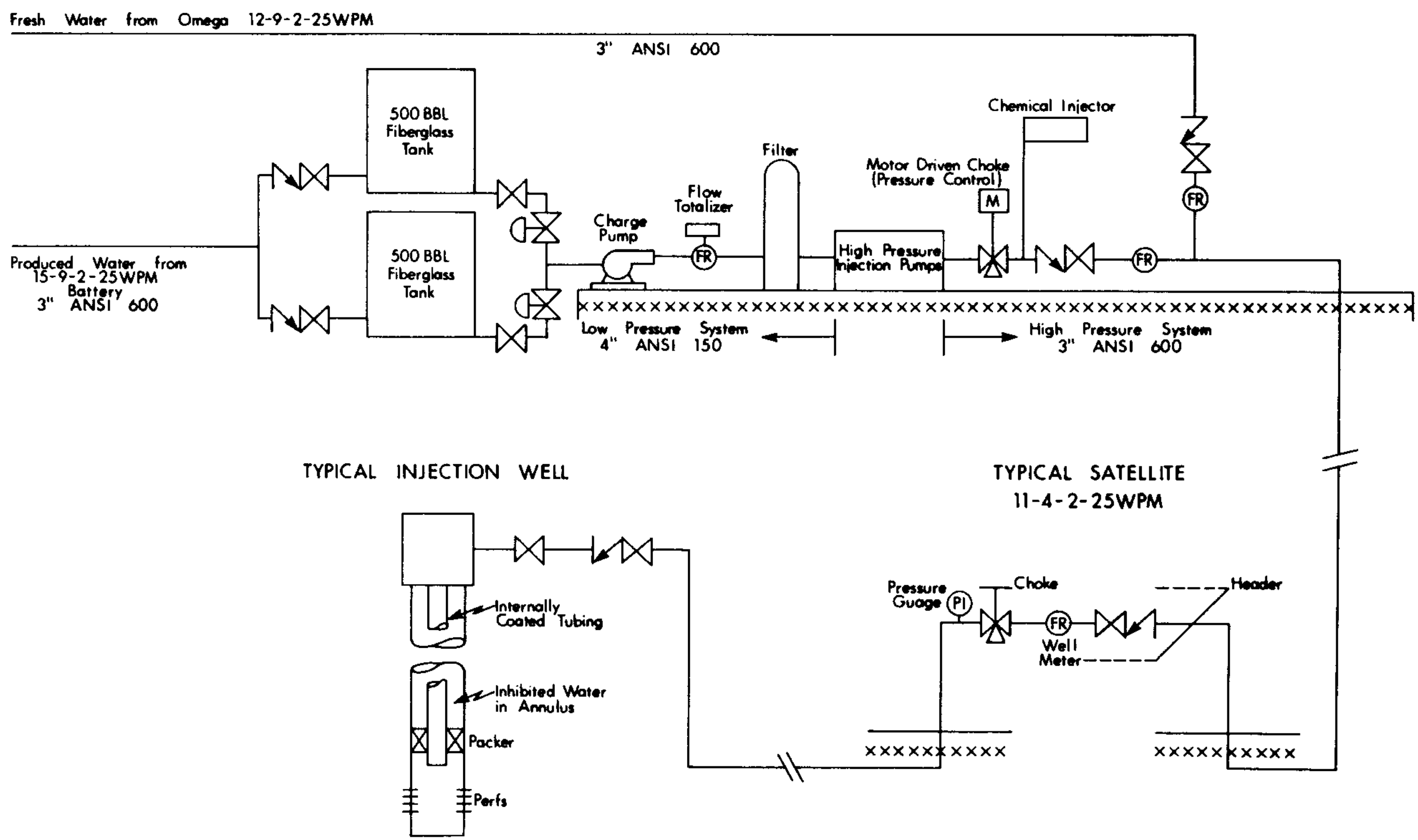
SCHEMATIC DIAGRAM

ANDEX ET AL WASKADA

16-5-2-25 WPM

DATE: 30·7·86	BY: D. STOODLEY	FILE NO:
SCALE: NTS	REVISIONS:	

ANDEX OIL CO. LTD.
WASKADA WATER DISTRIBUTION SYSTEM



ANDEX OIL CO. LTD.
Western Canadian Place
1300, 700 -9th Avenue S.W.
Calgary, Alberta T2P 3V4
Telephone (403) 298-2600

July 30, 1986

Province of Manitoba
Manitoba Energy and Mines
Petroleum Branch
550, 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Re: Clause (D) Enhanced Recovery Operations
W½ and Lsd. 15 of Sec. 4, Twp. 2, Rge. 25, WPM
Lsd. 2 of Sec. 9, Twp. 2, Rge. 25, WPM

I, GERALD DEAN TEMPLE, Surface Owner within Andex Oil Co. Ltd.'s proposed waterflood scheme area do hereby advise that I have been notified concerning Andex Oil Co. Ltd.'s intentions for the installation of a waterflood project.

E. J. Burrows
Witness

Gerald D. Temple
GERALD DEAN TEMPLE

ANDEX OIL CO. LTD.

Western Canadian Place
1300, 700 -9th Avenue S.W.
Calgary, Alberta T2P 3V4
Telephone (403) 298-2600

July 30, 1986

Province of Manitoba
Manitoba Energy and Mines
Petroleum Branch
550, 330 Graham Avenue
Winnipeg, Manitoba
R3C 4E3

Re: Clause (D) Enhanced Recovery Operations
NE¼ Sec. 5, Twp. 2, Rge. 25, WPM

I, DONALD RICHARD TEMPLE, Surface Owner within Andex Oil Co. Ltd.'s proposed waterflood scheme area do hereby advise that I have been notified concerning Andex Oil Co. Ltd.'s intentions for the installation of a waterflood project.

E. Burrows
Witness

Donald R. Temple
DONALD RICHARD TEMPLE

PRELIMINARY ENGINEERING STUDY
PROPOSED WASKADA LOWER AMARANTH
UNIT NO. 16

July 1986

Prepared by:

R.A.W. Smith, P.Eng.

T. McKay, EIT

PRELIMINARY ENGINEERING STUDY
PROPOSED WASKADA LOWER AMARANTH
UNIT NO. 16

Table of Contents

DISCUSSION - INPUT DATA

The input data for the simulation study has been reviewed and summarized as follows:

PVT Data

Our starting point was the data used by Computer Modelling Group (CMG) in their study for Omega Waskada Model Study, Lower Amaranth pool for Omega Hydrocarbons Ltd. by J. Flores and W. Laurila, May 1983. Table No. 1 is a summary of the Omega PVT functions found on Page 38 of the aforementioned study. Unfortunately only the saturated data (above and below the bubble point) was included so we had to generate the undersaturated data. For example, Figure No. 1, the oil viscosity data shows the Core Lab data used by Omega (red circles) plus an additional point added (blue star) to aid in smoothing interpolated data (this is more obvious in the Rs and Bo data).

The undersaturated data was added by Andex by using the Vasquez-Beggs correlation to match the bubble point data point (see enclosed Tables 2A and 2B). Note that to obtain a match we had to increase the actual oil API from 37 to 45.74, decrease the solution GOR from 288 Scf/STB to 133 SCF/STB and assume the solution gas gravity is 0.55 which is pure methane. (This is essentially equivalent to a specific gravity of 0.60 and nitrogen content of 10%.)

The decrease in solution GOR is interesting in that Omega's simulation forecasts of gas injection assumed certain quantities of available gas from solution. However actual quantities were much less necessitating a premature conversion of gas injectors to water injectors.

It is proposed that the Rs data as shown on Figure No. 4 be used initially for history matching but to be reduced as needed. A solution gas gravity of 0.60 with 10% nitrogen content matches the gas data on Table No. 1 fairly well as shown on Figure No. 2. The gas PVT data as proposed by Andex is included in Table No. 3. Actual composition of the gas was not available but additional discussion has indicated that there is 10% nitrogen mole fraction and as discussed above, a specific gravity of 0.60 with the nitrogen gives an acceptable overall match. The comparisons of oil formation volume factor (Bo) gas in solution (Rs) and gas viscosity are presented in Figures 3, 4 and 5 respectively. Our intention is to use the correlation curve of CARR et al for gas viscosity.

General Data in connection with the above is as follows:

Initial pressure:	1,258 psia
Reservoir temperature:	113°F (45°C)
Oil API gravity:	37°
Specific gravity of oil:	0.8398
Density of oil:	52.37 (lbm/ft^3)
Specific gravity of gas:	0.55
Gas density:	0.04202 (lbm/ft^3)
Gas impurities (nitrogen):	10%

Grid Data

All the well data is included on Table No. 4. Table No. 5 is a specific summary of core data only. Three zones of good, medium and poor permeability were determined using the technique as illustrated on Table No. 5. To determine the magnitude of the three individual permeability qualities, a ratio of good to medium to poor needed to be established. Each core was analysed individually for this ratio using representative points from each group. It will be assumed that vertical permeability is zero for each layer, thus simulating an effective anhydrite lens between each zone. Each layer is assumed to have the same net pay (ie. one third of total net pay for each well location).

Net pay is calculated from core data for the interval that was cored and then log data is used for the rest of the Spearfish interval in the subject well. Net pay from log analysis for wells with (ie. core covers only part of the subject zone) and without core, was determined using a sonic-inverted gamma ray overlay with an 80 API unit cutoff (see Exhibit B for example). This appeared to give the best correlation between core and log analysis. Figure No. 8 shows the extent of agreement; unfortunately the thin beds and complex lithology precludes better agreement. Logs are included for 13-4-2-25 WPM (showing tops and bottoms of the cored interval perforations, etc.) and the overlay Gamma Ray/Sonic results both being presented in Exhibit B. A geologic summary of formation tops, etc. for all wells is included on Table No. 6.

Relative Permeability and Capillary Pressure Data

The relative permeability data from the CMG report is plotted on Figures 6 and 7 against equivalent curves generated from a correlation by HONARPOUR et al. We used the same end points as the Omega data but were concerned by the optimistic shape of the Krog curve. Primary recovery using a Tracy prediction model yields 19% and 31% primary recovery for abandonment pressures of 200 and 100 psia respectively (using Omega Krog data). Indeed an independent review by the D&S Group, September 19, 1983, stated; "The recovery under gas displacement appears to be overstated." We propose using the correlation curves of Krog for initial history matching.

Capillary pressure data as shown on Figure No. 9 demonstrates that our choice does not coincide with the CMG report.

Table No. 7, a summary of fracture stimulation treatments and water cut percent after the frac and then after a cement squeeze if required, shows that for wells that required only a stress frac (ie. very small frac confined to the wellbore vicinity only) the water cut values are low. This indicates that perhaps most of the Lower Amaranth water production to date in our project area, has been Mississippian. Thus we have somewhat arbitrarily modified the Pc curve as shown on Figure 9 and then adjusted the water/oil contact depth to achieve water cut values that are more in harmony with the results of the wells that were stress fraced.

Pressure Data

An initial pressure was unavailable so the value of 1,258 psia as used in the CMG study was adopted. At the end of spring breakup 1986 with three months of shut in, four static gradients were run May 29-30, 1986, as well as several acoustic pressure surveys for the entire suite of wells within the study area. Table No. 6 is a summary of the pressure data; data in the last column will be used to history match the shut in period of the pool.

It is felt that the pressure data is probably the most reliable check for history matching purposes since GOR values are not available and water cut data is questionable due to communication with the Mississippian formation. Map Nos. 5A and 5B summarize the pressure survey data of Table No. 6.

Oil-in-Place and Gas-in-Place

The hydrocarbon values for both the area of application and the study area are summarized as follows:

Scheme Area		Simulation Study Area
Area (acres)	560	2,100
Oil-in-Place (MSTB)	6,437	21,923
Gas-in-Place (MMscf)	2,355	8,020
Free Gas-in-Place (mmscf)	0	0

Waterflood Recoveries

Using the core data of wells within Section 4 of the scheme area as input for the Claridge analytical model, the recovery calculated is 63.5% of recoverable OOIP for a WOR cutoff of 20. This value assumes a pattern continuity factor and a sweep efficiency of 1.00. The overall recovery for example would be reduced to 35.6% if the factors were actually 0.7 and 0.8 respectively. The details of the Claridge analysis as well as corresponding plots are included in Exhibit A. For verification of the assumption of equal pay thicknesses for layers 1-3 to be used in the simulation model, the plot of recovery vs permeability was examined. With the core data in descending order (by permeability) a high, medium and low group were set apart with equal pay. The permeability dividing the three groups is plotted on the recovery vs permeability plot and these lines fall at the first shoulder and inflection point which indicates that an equal pay distribution for three layers is probably reasonable. Although the area in question is being studied with a 3-D black oil model, the results have been delayed as we wish to add the core data and productivity of well locations 3-4 and 2-9 recently drilled. The overlay grid for the 3-D model is on Map No. 6.

TABLES

TABLE No. 1

OMEG-PVT.MP

WASKADA SPEARFISH

PRESSURE (kPaa)	PRESSURE (Psia)	SOLUTION GAS (m3/m3)	SOLUTION GAS (SCF/STB)	Bo (Rm3/Sm3)	Bo (RB/STB)	Bg (Rm3/Sm3)	Bg (RB/SCF)
101	15	0.00	0.00	1.025	1.025	1	0.177214
958	139	29.35	165.62	1.119	1.119	0.10363	0.018364687
1413	205	34.86	196.72	1.135	1.135	0.07179	0.012722193
2082	302	39.84	224.82	1.147	1.147	0.04929	0.008734878
2813	408	44.29	249.93	1.156	1.156	0.03658	0.006482488
3482	505	47.49	267.99	1.163	1.163	0.02963	0.005250851
4220	612	51.04	288.02	1.17	1.17	0.02488	0.004409084
6895	1000	66.50	375.26	1.189	1.189	0.01543	0.002734412
10342	1500	81.50	459.91	1.208	1.208	0.01046	0.001853658

PRESSURE (kPaa)	PRESSURE (Psia)	OIL VISCOSITY (CP)	GAS VISCOSITY (CP)
101	15	2.9040	0.0102
958	139	2.0000	0.0106
1413	205	1.5480	0.0108
2082	302	1.4320	0.0110
2813	408	1.3670	0.0113
3482	505	1.3190	0.0115
4220	612	1.2850	0.0118
6895	1000	1.2000	0.0128
10342	1500	1.1400	0.0140

TABLE 2A

WASKADA SPEARFISH OIL VISCOSITY ABOVE THE BUBBLE POINT

EMPIRICAL HYDROCARBON FLUID PROPERTIES
------------RESERVOIR OIL------------

INPUT PARAMETERS
TEMPERATURE =113.00 [F.]
OIL GRAVITY = 45.74 API.
SOLUTION GOR = 133.1 [SCF/BBL]
SOLUTION GAS GRAVITY = .55

SEPARATOR PRESSURE = 100.0 [PSIA]
SEPARATOR TEMPERATURE= 60.0 [F.]

VASQUEZ-BEGGS CORRELATION PREDICTIONS

CALCULATED PROPERTIES AT THE BUBBLE POINT PRESSURE ARE
BUBBLE POINT PRESSURE = 612.09 [PSIA]
FORMATION VOLUME FACTOR = 1.1119
OIL COMPRESSIBILITY = 1.814E-05 1/ [PSIA]
DEAD OIL VISCOSITY = 2.342 [CP.]
LIVE OIL VISCOSITY = 1.285 [CP.]

PRESSURE [PSIA]	BO [RB/BBL]	RS [SCF/BBL]	CO [1/PSIA]	UO [CP]
2100	1.1032	133.09	5.286E-06	1.622
2000	1.1034	133.09	5.551E-06	1.590
1900	1.1036	133.09	5.843E-06	1.560
1800	1.1038	133.09	6.167E-06	1.530
1700	1.1040	133.09	6.530E-06	1.502
1600	1.1043	133.09	6.938E-06	1.475
1500	1.1046	133.09	7.401E-06	1.449
1400	1.1050	133.09	7.929E-06	1.425
1300	1.1054	133.09	8.539E-06	1.401
1200	1.1059	133.09	9.251E-06	1.380
1100	1.1064	133.09	1.009E-05	1.360
1000	1.1071	133.09	1.110E-05	1.341
900	1.1080	133.09	1.233E-05	1.324
800	1.1090	133.09	1.388E-05	1.309
700	1.1104	133.09	1.586E-05	1.295
600	1.1104	129.98	1.823E-05	1.297
500	1.0985	104.68	1.935E-05	1.409
400	1.0869	80.32	2.115E-05	1.541
300	1.0760	57.09	2.432E-05	1.700
200	1.0656	35.28	3.103E-05	1.891
100	1.0563	15.50	5.217E-05	2.115

TABLE 2B

WASKADA SPEARFISH OIL VISCOSITY ABOVE THE BUBBLE POINT

EMPIRICAL HYDROCARBON FLUID PROPERTIES
------------RESERVOIR OIL-------------

INPUT PARAMETERS

TEMPERATURE	= 45.00	[C.]
OIL GRAVITY	= 45.74	API.
SOLUTION GOR	= 23.7	[M3/M3]
SOLUTION GAS GRAVITY	= .55	

SEPARATOR PRESSURE	= 689.5	[kPa]
SEPARATOR TEMPERATURE	= 15.6	[C.]

VASQUEZ-BEGGS CORRELATION PREDICTIONS

CALCULATED PROPERTIES AT THE BUBBLE POINT PRESSURE ARE

BUBBLE POINT PRESSURE	= 4220.26	[kPa]
FORMATION VOLUME FACTOR	= 1.1119	
OIL COMPRESSIBILITY	= 2.630E-06	1/ [kPa]
DEAD OIL VISCOSITY	= 2.342	[mPa*s]
LIVE OIL VISCOSITY	= 1.285	[mPa*s]

PRESSURE [kPA]	BO [RM3/M3]	RS [M3/M3]	CO [1/kPa]	UO [mPa*s]
14220	1.1033	23.70	7.807E-07	1.610
13220	1.1035	23.70	8.397E-07	1.565
12220	1.1039	23.70	9.084E-07	1.522
11220	1.1042	23.70	9.894E-07	1.482
10220	1.1047	23.70	1.086E-06	1.445
9220	1.1052	23.70	1.204E-06	1.410
8220	1.1059	23.70	1.351E-06	1.378
7220	1.1068	23.70	1.538E-06	1.350
6220	1.1079	23.70	1.785E-06	1.324
5220	1.1095	23.70	2.127E-06	1.303
4220	1.1119	23.70	2.629E-06	1.285
3220	1.0946	17.19	2.879E-06	1.450
2220	1.0783	11.06	3.399E-06	1.663
1220	1.0634	5.43	4.891E-06	1.940
220	1.0508	0.71	2.110E-05	2.278

TABLE No. 3

```
**********************************
*         SWEET OR SOUR          *
*                                *
*         GAS PROPERTIES         *
*                                *
*        VERSION -  1.1          *
**********************************
```

DATE : 08-12-1986

TIME : 16:17:49

FOR

WASKADA SPEARFISH ZONE

```
INPUT .. GAS SPECIFIC GRAVITY = 0.600
         RESERVOIR TEMPERATURE = 113 (DEG F)
         MOLE % CONTENT OF H2S =  0.000 %
         MOLE % CONTENT OF CO2 =  0.000 %
         MOLE % CONTENT OF N2  = 10.000 %
         CORRECTED EST. PSEUDO CRITICAL PRESSURE =  655.6 (PSIA)
         CORRECTED EST. PSEUDO CRITICAL TEMPERATURE =  334.0 (DEG R)
```

NOTE: ACID GAS CORRECTIONS APPLIED TO pTc,pPc and Gas Viscosity

NOTE: VISCOSITY CORRELATION IS CARR et al (Sweet or Sour Gas)

PRESSURE (PSIA)	COMPRESS FACTOR Z	GAS FVF 1/E (RCF/SCF)	GAS FVF Bg (RB/SCF)	GAS COMPRESS. Cg (1/PSI)	GAS GRADIENT (PSI/ft)	GAS VISCOSITY (CP)
14.65	0.998559	1.100400	0.195993	0.683578D-01	0.0003	0.108862D-01
100	0.990239	0.159865	0.028474	0.100977D-01	0.0020	0.123046D-01
200	0.980667	0.079160	0.014099	0.509657D-02	0.0040	0.123919D-01
300	0.971307	0.052270	0.009310	0.342853D-02	0.0061	0.124288D-01
400	0.962183	0.038834	0.006917	0.259351D-02	0.0082	0.125026D-01
500	0.953322	0.030781	0.005482	0.209149D-02	0.0103	0.126144D-01
600	0.944749	0.025420	0.004528	0.175578D-02	0.0125	0.127575D-01
700	0.936494	0.021598	0.003847	0.151493D-02	0.0147	0.129259D-01
800	0.928585	0.018739	0.003338	0.133320D-02	0.0170	0.131148D-01
900	0.921052	0.016522	0.002943	0.119075D-02	0.0193	0.133209D-01
1000	0.913923	0.014754	0.002628	0.107567D-02	0.0216	0.135415D-01
1100	0.907229	0.013315	0.002372	0.980378D-03	0.0239	0.137747D-01
1200	0.900997	0.012122	0.002159	0.899835D-03	0.0262	0.140190D-01
1300	0.895254	0.011118	0.001980	0.830564D-03	0.0286	0.142734D-01
1400	0.890023	0.010263	0.001828	0.770097D-03	0.0310	0.144572D-01
1500	0.885324	0.009529	0.001697	0.716651D-03	0.0334	0.147425D-01
1600	0.881177	0.008891	0.001584	0.668885D-03	0.0358	0.150305D-01
1700	0.877594	0.008334	0.001484	0.625810D-03	0.0382	0.153198D-01
1800	0.874584	0.007844	0.001397	0.586669D-03	0.0406	0.156096D-01
1900	0.872153	0.007411	0.001320	0.550880D-03	0.0429	0.158997D-01
2000	0.870299	0.007025	0.001251	0.517991D-03	0.0453	0.161900D-01
2100	0.869019	0.006681	0.001190	0.487646D-03	0.0476	0.164805D-01
2200	0.868303	0.006372	0.001135	0.459564D-03	0.0499	0.167714D-01
2300	0.868141	0.006094	0.001085	0.433510D-03	0.0522	0.170629D-01
2400	0.868518	0.005842	0.001041	0.409296D-03	0.0545	0.173550D-01
2500	0.869415	0.005614	0.001000	0.386762D-03	0.0567	0.176479D-01
2600	0.870813	0.005407	0.000963	0.365771D-03	0.0588	0.179418D-01
2700	0.872690	0.005218	0.000929	0.346203D-03	0.0610	0.182367D-01
2800	0.875025	0.005045	0.000899	0.327952D-03	0.0631	0.185328D-01
2900	0.877793	0.004887	0.000870	0.310917D-03	0.0651	0.188300D-01
3000	0.880971	0.004741	0.000844	0.295012D-03	0.0671	0.191285D-01

TABLE No. 3 cont'd

```
*********************************
*        SWEET OR SOUR          *
*                               *
*        GAS PROPERTIES         *
*                               *
*        VERSION -  1.1         *
*********************************
```

DATE : 08-12-1986

TIME : 16:17:53

FOR

WASKADA SPEARFISH ZONE

INPUT .. GAS SPECIFIC GRAVITY = 0.600
RESERVOIR TEMPERATURE = 113 (DEG F)
MOLE % CONTENT OF H2S = 0.000 %
MOLE % CONTENT OF CO2 = 0.000 %
MOLE % CONTENT OF N2 = 10.000 %
CORRECTED EST. PSEUDO CRITICAL PRESSURE = 655.6 (PSIA)
CORRECTED EST. PSEUDO CRITICAL TEMPERATURE = 334.0 (DEG R)

NOTE: ACID GAS CORRECTIONS APPLIED TO pTc,pPc and Gas Viscosity

NOTE: VISCOSITY CORRELATION IS CARR et al (Sweet or Sour Gas)

PRESSURE (PSIA)	COMPRESS FACTOR Z	GAS FVF 1/E (RCF/SCF)	GAS FVF Bg (RB/SCF)	GAS COMPRESS. Cg (1/PSI)	GAS GRADIENT (PSI/ft)	GAS VISCOSITY (CP)
3100	0.884537	0.004606	0.000820	0.280154D-03	0.0691	0.194282D-01
3200	0.888469	0.004482	0.000798	0.266268D-03	0.0710	0.197291D-01
3300	0.892745	0.004367	0.000778	0.253285D-03	0.0728	0.200313D-01
3400	0.897344	0.004261	0.000759	0.241139D-03	0.0747	0.203346D-01
3500	0.902247	0.004162	0.000741	0.229770D-03	0.0764	0.206391D-01
3600	0.907433	0.004069	0.000725	0.219122D-03	0.0782	0.209447D-01
3700	0.912887	0.003983	0.000709	0.209147D-03	0.0799	0.212513D-01
3800	0.918589	0.003903	0.000695	0.199788D-03	0.0815	0.215588D-01
3900	0.924524	0.003827	0.000682	0.191005D-03	0.0831	0.218672D-01
4000	0.930678	0.003756	0.000669	0.182757D-03	0.0847	0.221764D-01
4100	0.937036	0.003690	0.000657	0.175006D-03	0.0862	0.224861D-01
4200	0.943585	0.003627	0.000646	0.167716D-03	0.0877	0.227965D-01
4300	0.950314	0.003568	0.000635	0.160858D-03	0.0892	0.231072D-01
4400	0.957210	0.003512	0.000626	0.154395D-03	0.0906	0.234183D-01
4500	0.964263	0.003459	0.000616	0.148303D-03	0.0920	0.237295D-01
4600	0.971462	0.003409	0.000607	0.142557D-03	0.0933	0.240409D-01
4700	0.978800	0.003362	0.000599	0.137135D-03	0.0946	0.243521D-01
4800	0.986265	0.003317	0.000591	0.132009D-03	0.0959	0.246632D-01
4900	0.993852	0.003274	0.000583	0.127164D-03	0.0972	0.249740D-01
5000	1.001552	0.003234	0.000576	0.122582D-03	0.0984	0.252843D-01
5100	1.009358	0.003195	0.000569	0.118241D-03	0.0996	0.255940D-01
5200	1.017263	0.003158	0.000563	0.114130D-03	0.1007	0.259030D-01
5300	1.025261	0.003123	0.000556	0.110232D-03	0.1019	0.262111D-01
5400	1.033347	0.003089	0.000550	0.106534D-03	0.1030	0.265183D-01
5500	1.041514	0.003057	0.000545	0.103024D-03	0.1041	0.268243D-01
5600	1.049759	0.003026	0.000539	0.996859D-04	0.1051	0.271290D-01
5700	1.058075	0.002997	0.000534	0.965139D-04	0.1062	0.274323D-01
5800	1.066459	0.002968	0.000529	0.934960D-04	0.1072	0.277341D-01
5900	1.074906	0.002941	0.000524	0.906229D-04	0.1082	0.280342D-01
6000	1.083413	0.002915	0.000519	0.878858D-04	0.1091	0.283324D-01

SIMPAR.MET

TABLE No. 4

WASKADA, MANITOBA
SPEARFISH FORMATION
SIMULATION PARAMETERS

WELL LOCATION	MID.PT PERFS (mKB)	WELL CORED ?	TOTAL NET PAY (m)	NET PAY PER ZONE (m)	CORE POROSITY (%)	LOG POROSITY (%)	CORE PERM.(Kh) (md)**	K(h) LAYER 1	K(h) LAYER 2	K(h) LAYER 3
3-4-2-25W1	896.0	YES	5.8	1.93	16.9		2.19	3.6	1.9	1.1
4-4-2-25W1	897.5		3.83	1.28		16.0				
5-4-2-25W1	895.0		3.10	1.03		15.0				
6-4-2-25W1	890.5		3.63	1.21		16.0				
11-4-2-25W1	889.4	YES	5.94	1.98	15.5		13.79	33.5	6.2	1.7
12-4-2-25W1	888.0		2.60	0.87		16.0				
13-4-2-25W1	884.5	YES	5.40	1.80	17.5		9.35	23.0	3.4	1.7
14-4-2-25W1	891.0		4.80	1.60		17.0				
15-4-2-25W1	891.5	YES	7.76	2.59	16.6		4.38	10.3	1.9	0.9
9-5-2-25W1	890.0		3.70	1.23		16.0				
10-5-2-25W1	890.0	YES	1.96	0.65	12.9		2.61	4.3	1.9	1.6
15-5-2-25W1	893.0		2.89	0.96	14.9		7.73	20.6	1.7	0.9
16-5-2-25W1	891.0	YES	6.31	2.10	16.0		1.92	2.5	2.2	1.1
2-9-2-25W1	890.0	YES	6.59	2.20	14.4		3.04	5.8	2.1	1.1
4-9-2-25W1	887.5	YES	3.48	1.16	15.3		25.55	60.7	10.8	5.1
5-9-2-25W1	886.0	YES	7.57	2.52	15.4		3.46	5.7	2.8	1.8
10-9-2-25W1	884.0	YES	2.60	0.87	16.1		4.17	6.5	4.0	2.0
15-9-2-25W1	882.8		3.93	1.31		17.0				
16-9-2-25W1	882.0	YES	4.90	1.63	16.9		17.62	42.5	8.5	1.9
14-10-2-25W1	875.5	YES	3.10	1.03	15.3		6.94	15.6	3.5	1.7
5-15-2-25W1	874.0		4.67	1.56		16.0				

NOTE:** ARITHMETIC WEIGHTED AVERAGE FOR CORE

TABLE No. 5

COREDATA.SIM

CORE DATA
WASKADA, MANITOBA
SPEARFISH FORMATION

WELL LOCATION	FRACTION OF TOTAL INTERVAL CORED	NET PAY of CORED INTERVAL (m)	NET PAY per ZONE of CORED INTERVAL (ft)	CORE POROSITY (%)	CORE HORIZONTAL PERM. (md) ** (KHavg)	RATIO OF GOOD/MED/POOR (md) (Kg/Km/Kp)	EST.AVG. K(h) GOOD ZONE (md) *** Kgood	EST.AVG. K(h) MEDIUM ZONE (md) *** Kmed	EST.AVG. K(h) POOR ZONE (md) *** Kpoor
3-4-2-25W1	0.70	5.78	6.32	16.9	2.19	4.8/2.5/1.4	3.6	1.9	1.1
11-4-2-25W1	0.72	5.94	6.50	15.5	13.80	49/9/2.5	33.5	6.2	1.7
13-4-2-25W1	0.71	4.85	5.30	17.5	9.40	20.6/3/1.5	23.0	3.4	1.7
15-4-2-25W1	0.76	7.76	8.49	16.6	4.38	28/5.2/1.5	10.3	1.9	0.9
10-5-2-25W1	0.68	1.96	2.14	12.9	2.61	6/2.65/2.2	4.3	1.9	1.6
15-5-2-25W1	0.63	2.89	3.16	14.9	7.73	32/2.7/1.4	20.6	1.7	0.9
16-5-2-25W1	0.72	6.31	6.90	16.0	1.92	2.8/2.5/1.2	2.5	2.2	1.1
2-9-2-25W1	0.67	6.59	7.21	14.4	3.04	6.6/2.4/1.2	5.8	2.1	1.1
4-9-2-25W1	0.95	3.48	3.81	15.3	25.60	84/15/7	60.7	10.8	5.1
5-9-2-25W1	0.68	7.57	8.28	15.4	3.46	7/3.5/2.25	5.7	2.8	1.8
10-9-2-25W1	0.63	2.60	2.84	16.1	4.2	7.3/4.5/2.2	6.5	4.0	2.0
16-9-2-25W1	0.67	4.90	5.36	16.9	17.60	40/8/1.75	42.5	8.5	1.9
14-10-2-25W1	0.91	3.10	3.39	15.3	6.94	18/4/2	15.6	3.5	1.7

NOTE : ** WEIGHTED AVERAGE; 1.0 md CUTOFF

***technique as follows :

knowing ... KHavg = (Kgood*hT/3 + Kmed*hT/3 + Kpoor*hT/3) ASSUMING EQUAL ZONE THICKNESS
then calculate
A = Km/Kg (RATIO ESTIMATED FROM SELECTED CORE POINTS)
B = Kp/Kg (RATIO ESTIMATED FROM SELECTED CORE POINTS)

then calculate (assuming equal zone thickness)
Kgood = 3*KHavg/(1.0 + A + B)
Kmed = A*Kgood
Kpoor = B*Kgood

TABLE No. 6

WASKPRES.SUM

WASKADA PRESSURE SUMMARY

WELL LOCATION	MAY 28 or JUNE 4 ACOUSTIC PRESSURE Pws (PSIA)	JUNE 10 or JUNE 17 ACOUSTIC PRESSURE Pws (PSIA)	JUNE 18 ACOUSTIC PRESSURE Pws (PSIA)	JUNE 23 ACOUSTIC PRESSURE Pws (PSIA)	JULY 31 ACOUSTIC PRESSURE Pws (PSIA)	STATIC GRADIENTS (PSIA)	ESTIMATED * ACTUAL PRESS. MAY 30 1986 Pws (PSIA)	ESTIMATED * ACTUAL PRESS. JULY 31 1986 Pws (PSIA)
4-4-2-25W1	1022	1027	---	---	---		1022	
5-4-2-25W1	946	967	---	---	921		946	921
6-4-2-25W1	991	---	1007	---	---	989	989	
11-4-2-25W1	1087	---	1169	---	---		1087	
12-4-2-25W1	898	919	---	---	---		898	
13-4-2-25W1	929	---	1245	1174	---	1138	1138	
14-4-2-25W1	1141	1160	---	---	---		1141	
15-4-2-25W1	661	688	---	---	917		---	917
9-5-2-25W1	911	---	915	---	949	904	904	949
10-5-2-25W1	1173	1188	---	---	---		1173	
15-5-2-25W1	786	850	---	---	882		840	882
16-5-2-25W1	939	927	973	---	---		939	
4-9-2-25W1	---	832	855	---	889		841	889
5-9-2-25W1	---	1023	1020	---	---		1020	
10-9-2-25W1	---	919	1257	1247	---		---	
15-9-2-25W1	---	1091	1111	---	---		1091	
16-9-2-25W1	1094	---	1065	---	---	1046	1046	
14-10-2-25W1	---	---	1223	---	---		---	
5-15-2-25W1	---	---	---	---	---		**	
10-15-2-25W1	1286	1294	---	---	---		---	

NOTES : * AS OF JUNE 20/86
** WELL PRODUCED DURING TEST PERIOD

TABLE No. 7

MANITOBA - SPEARFISH FRACS AND REMEDIAL WORK

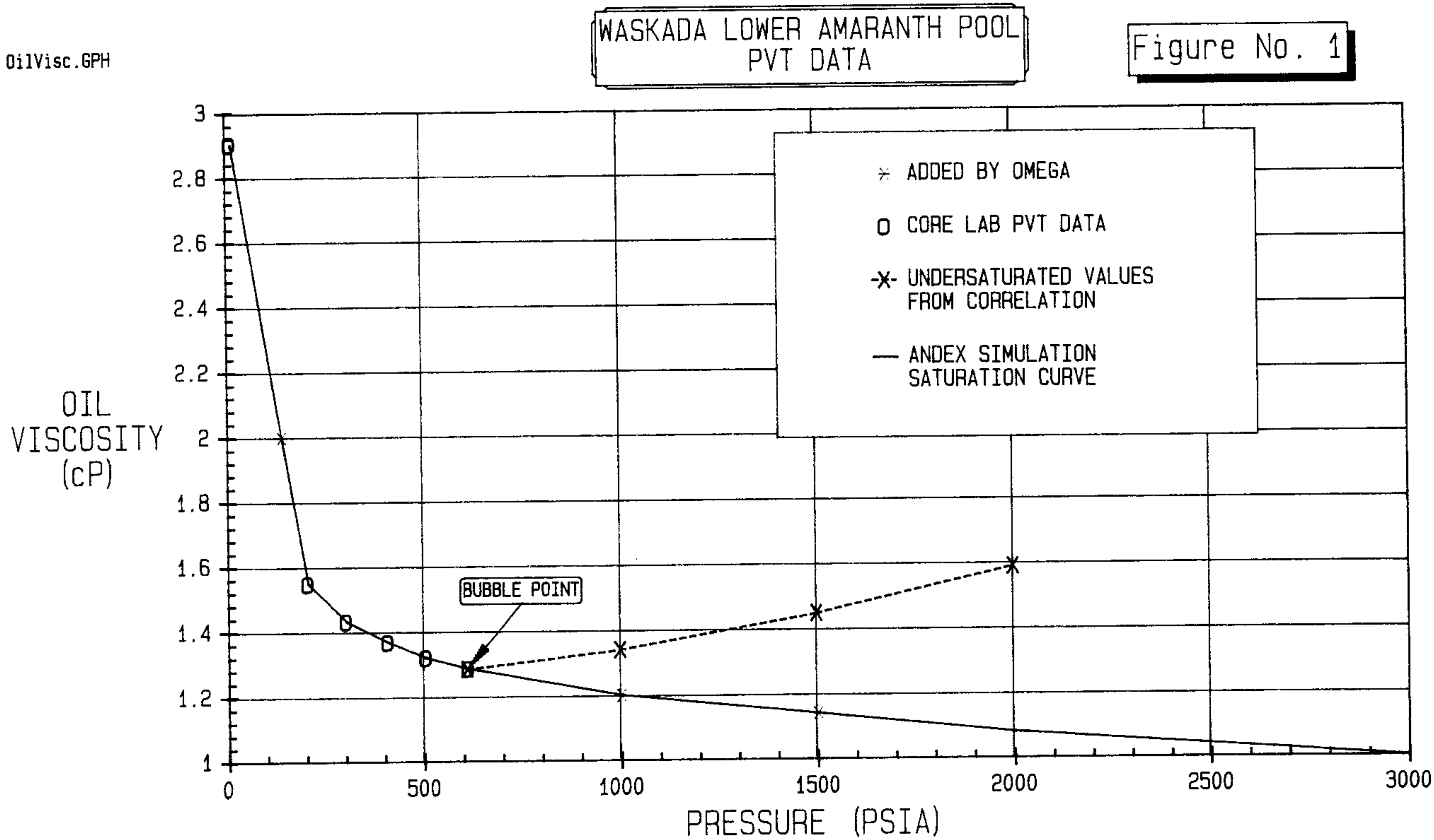
Location	Date of Frac /Stress Frac	FRAC JOB Size (tonnes)	FRAC JOB Rate (m^3/min)	FRAC JOB Average Pressure (kPa)	PRODUCTION AFTER BOPD	PRODUCTION AFTER Water Cut (%)	CEMENT SQUEEZES Date	CEMENT SQUEEZES Size (Tonnes)	PRODUCTION AFTER BOPD	PRODUCTION AFTER Water Cut (%)	Comments
7-28-1-25	September 2, 1985	2.0	1.0	21 000	43.0	22.0					
5-4-2-25	August 25, 1985	3.0	1.0	17 500	77.0	6.0					
13-4-2-25	September 24, 1985	3.0	1.0	21 000	63.0	29.0					
15-4-2-25	August 27, 1985	3.0	0.9	21 000	24.0	10.0					
9-5-2-25	November 10, 1985	3.0	1.0	21 000	75.0	5.0					
10-5-2-25	December 1, 1985	3.0	0.8	21 000	0.0	100.0	December 18, 1985	27	10	10	
15-5-2-25	December 9, 1985	3.0	1.0	19 000	10.0	10.0					
16-5-2-25	July 3, 1985	3.0	1.2	25 000	0.0	100.0	July 18, 1985	28	26	26	
4-9-2-25	July 7, 1984	10.0	1.9	11 000	9.0	95.0	September 7, 1984	10	65	30	R/A tracer run with frac, results s[hand]Showed good frac[/hand]
5-9-2-25	January 29, 1985 May 8, 1985	2.3 5.0	1.0 1.5	8 000 7 000	16.0 4.5	7.0 84.0	June 20, 1985	28	6	80	
16-9-2-25	July 18, 1985	3.0	1.1	23 000	38.0	10.0					
14-10-2-25	January 10, 1986	3.0	1.0	20 000	0.0	50.0	January 26, 1986				
5-15-2-25	January 7, 1986	3.0	1.0	20 000	40.0	40.0					
2-17-2-25	November 8, 1985	2.0	1.0	28 000	5.0	94.0	October 16, 1984 December 13, 1985	25 27	22 10	45 50	
15-9-2-25	January 23, 1986	2.0	0.8	13 500	15.0	20.0					
12-4-2-25	January 28, 1986	2.0	0.6	15 000	50.0	10.0					
11-4-2-25	February 1, 1986	-	-	-	20.0	3.0					Stress frac only.
14-4-2-25	February 12, 1986	-	-	-	40.0	0.1					Stress frac only.
6-4-2-25	February 17, 1986	-	-	-	65.0	3.0					Stress frac only.
4-4-2-25	February 14, 1986	-	-	-	48.0	2.0					Stress frac only.
10-9-2-25	March 11, 1986	-	-	-							Stress frac only.
10-15-2-25	March 9/March 8, 1986	2.0	0.7	15 000							Stress frac and sand frac.

Revision #1: March 17, 1986
MARCH/ds014

FIGURES

OilVisc.GPH

Figure No. 1



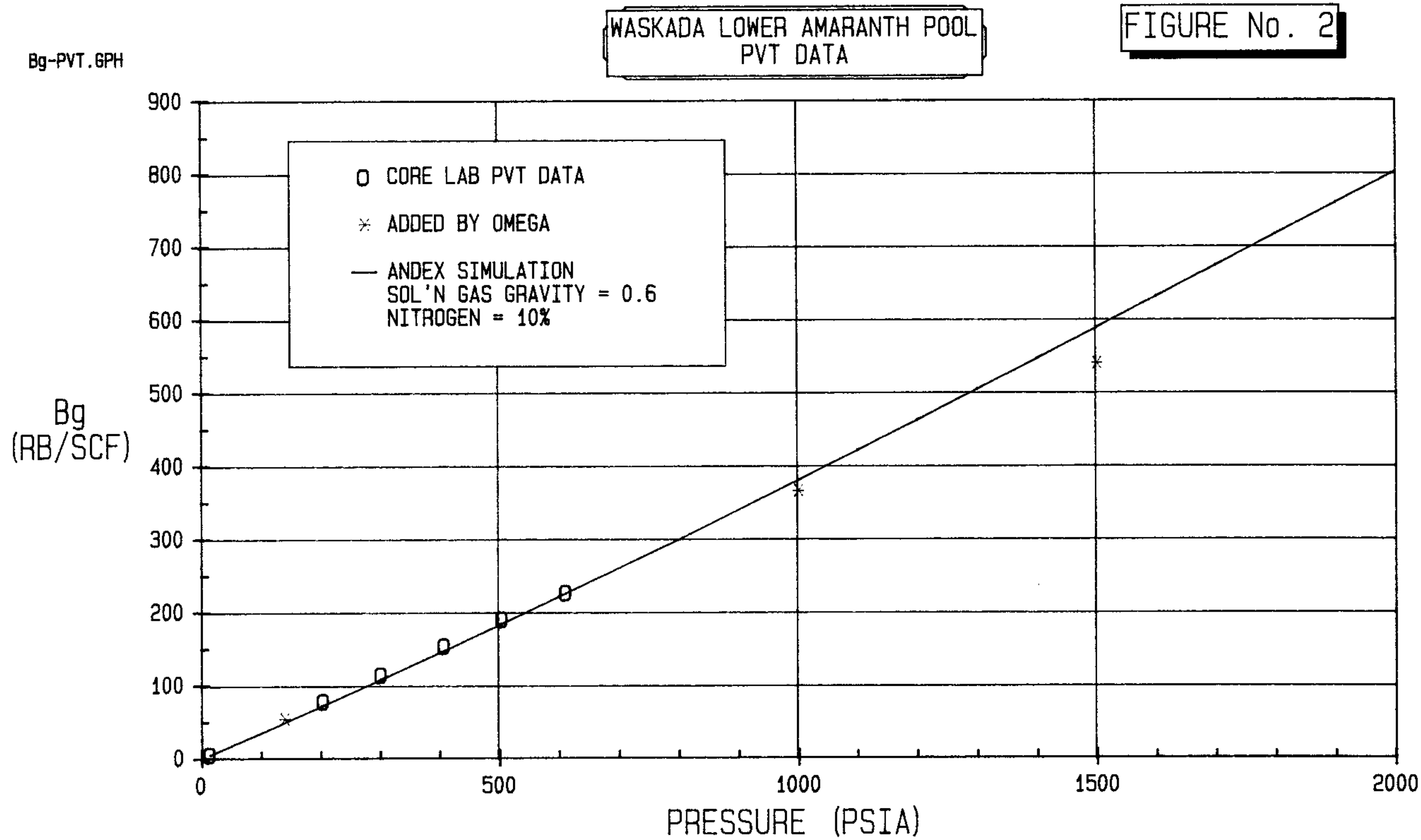
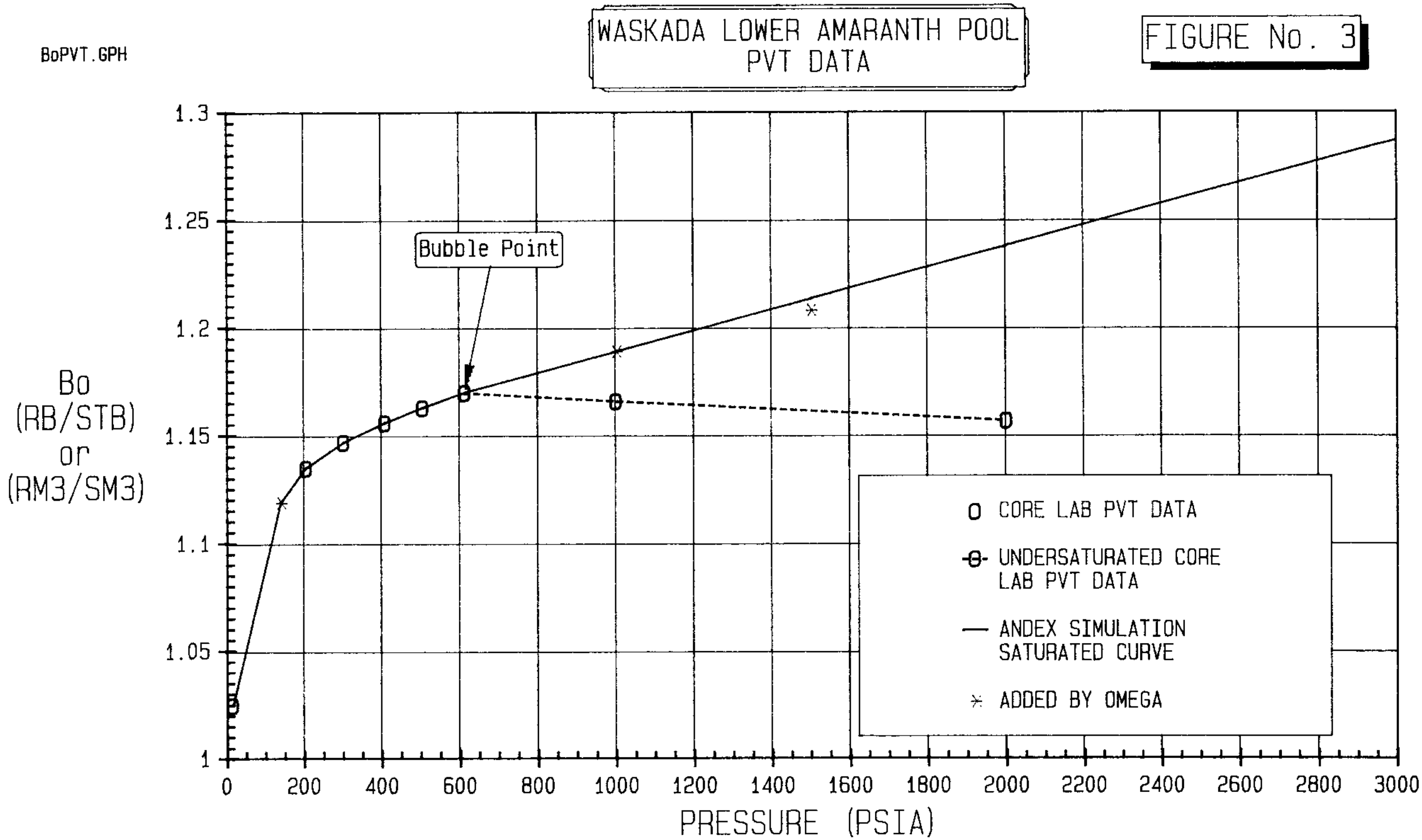

Bg-PVT.GPH
WASKADA LOWER AMARANTH POOL
PVT DATA
Bg
(RB/SCF)
PRESSURE (PSIA)
O CORE LAB PVT DATA
* ADDED BY OMEGA
— ANDEX SIMULATION
SOL'N GAS GRAVITY = 0.6
NITROGEN = 10%
0
100
200
300
400
500
600
700
800
900
0
500
1000
1500
2000

FIGURE No. 2

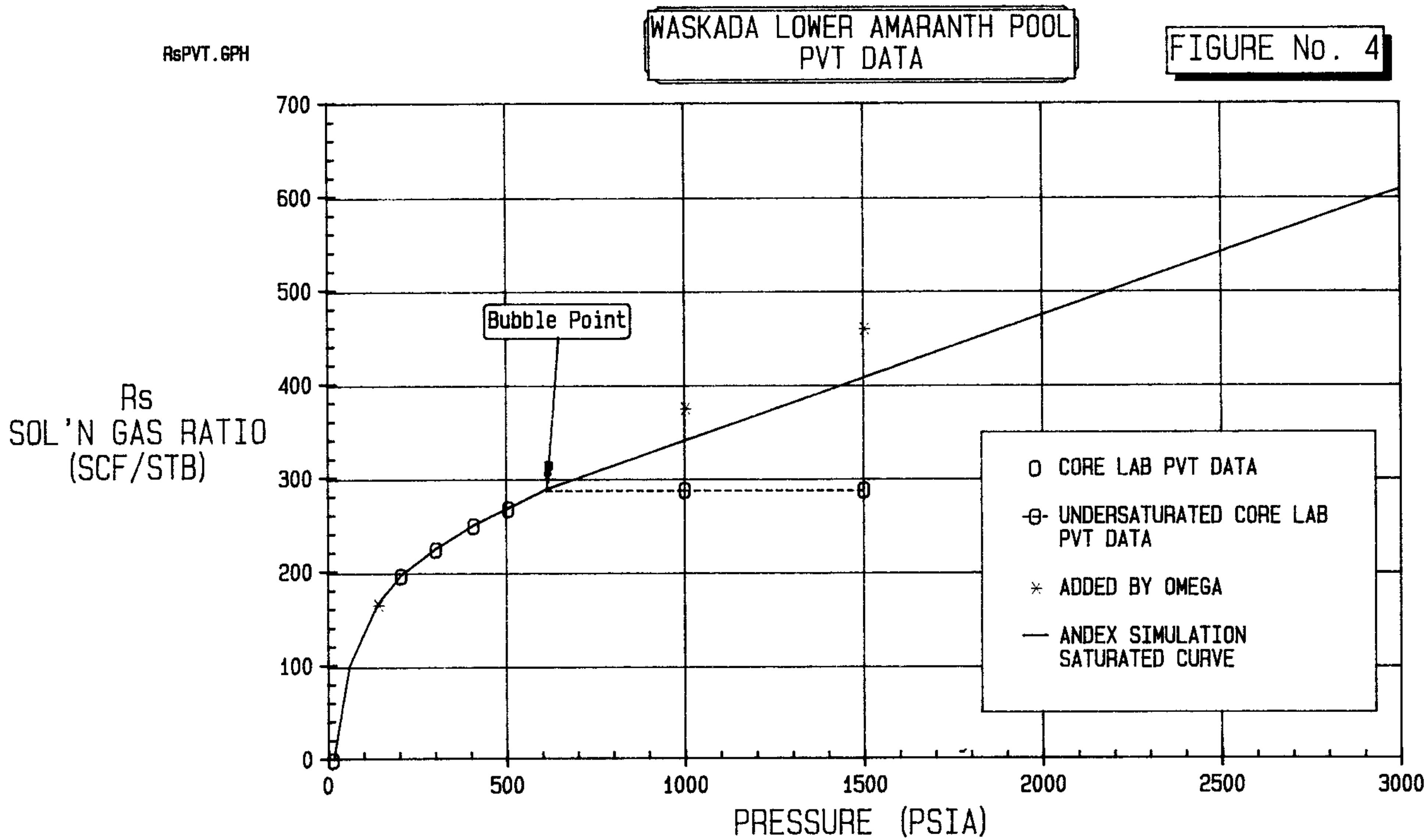
BoPVT.GPH

FIGURE No. 3



RsPVT.GPH

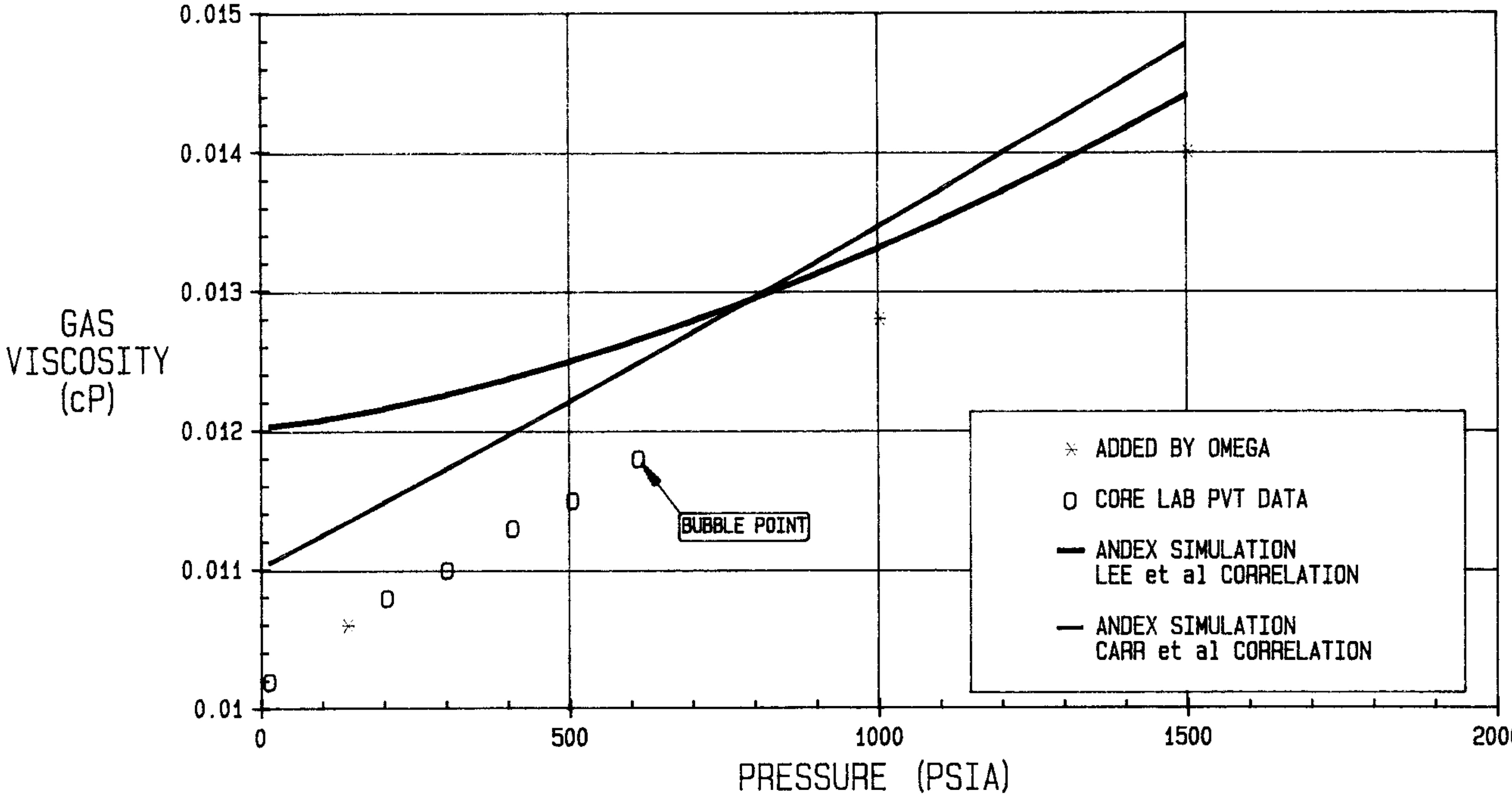
FIGURE No. 4



GasVisc.GPH

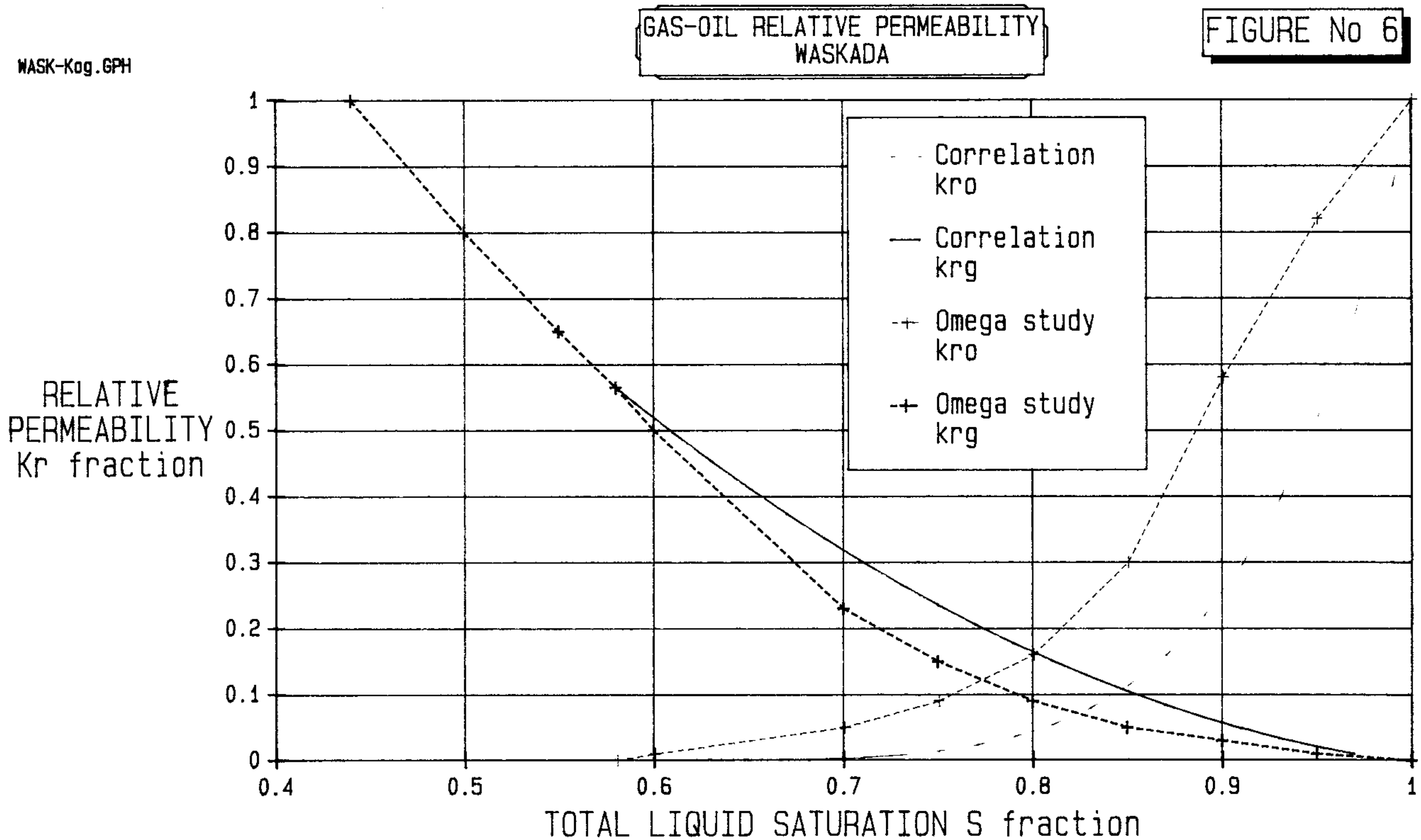
WASKADA LOWER AMARANTH POOL
PVT DATA

Figure No. 5



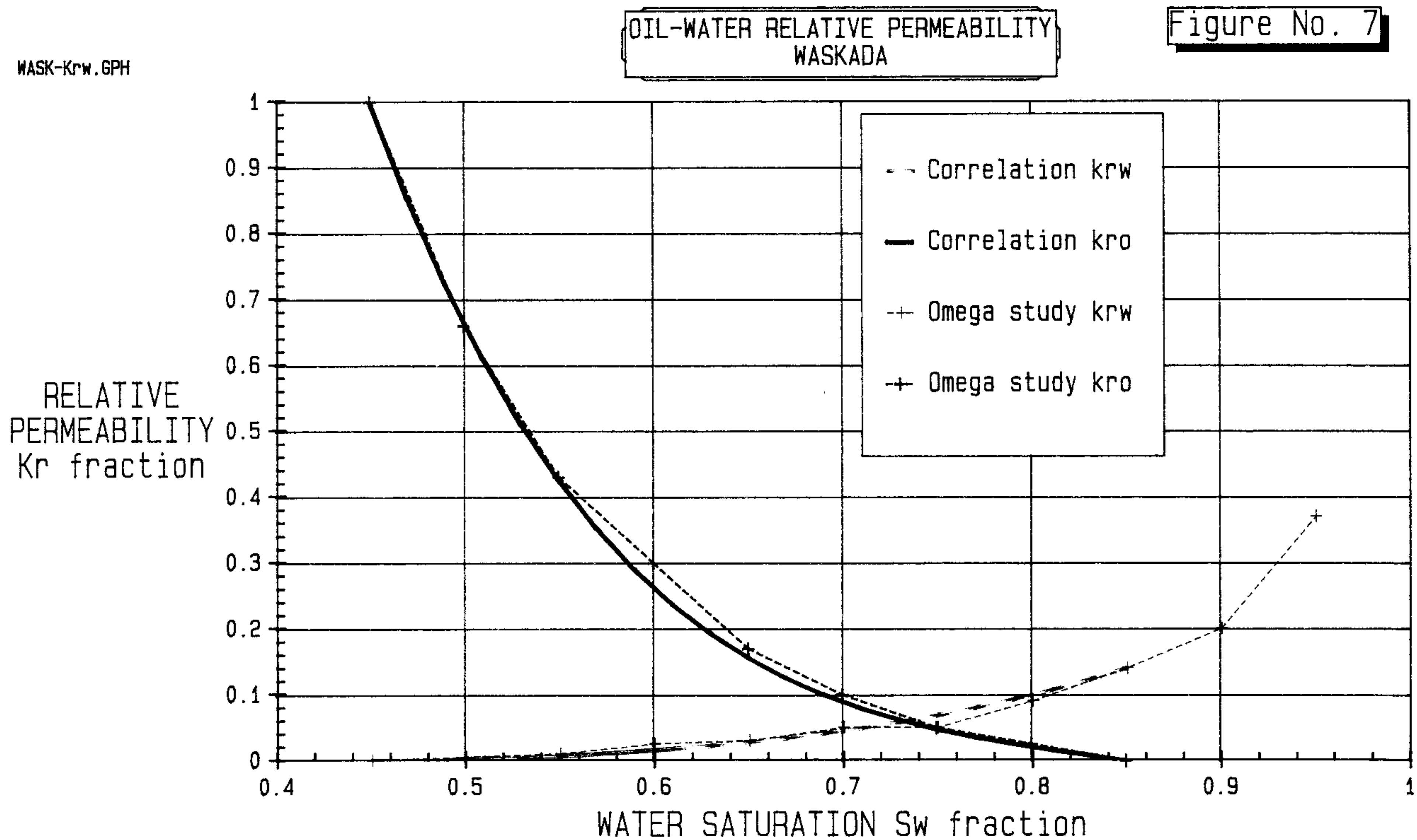
WASK-Kog.GPH

FIGURE No 6



WASK-Krw.GPH

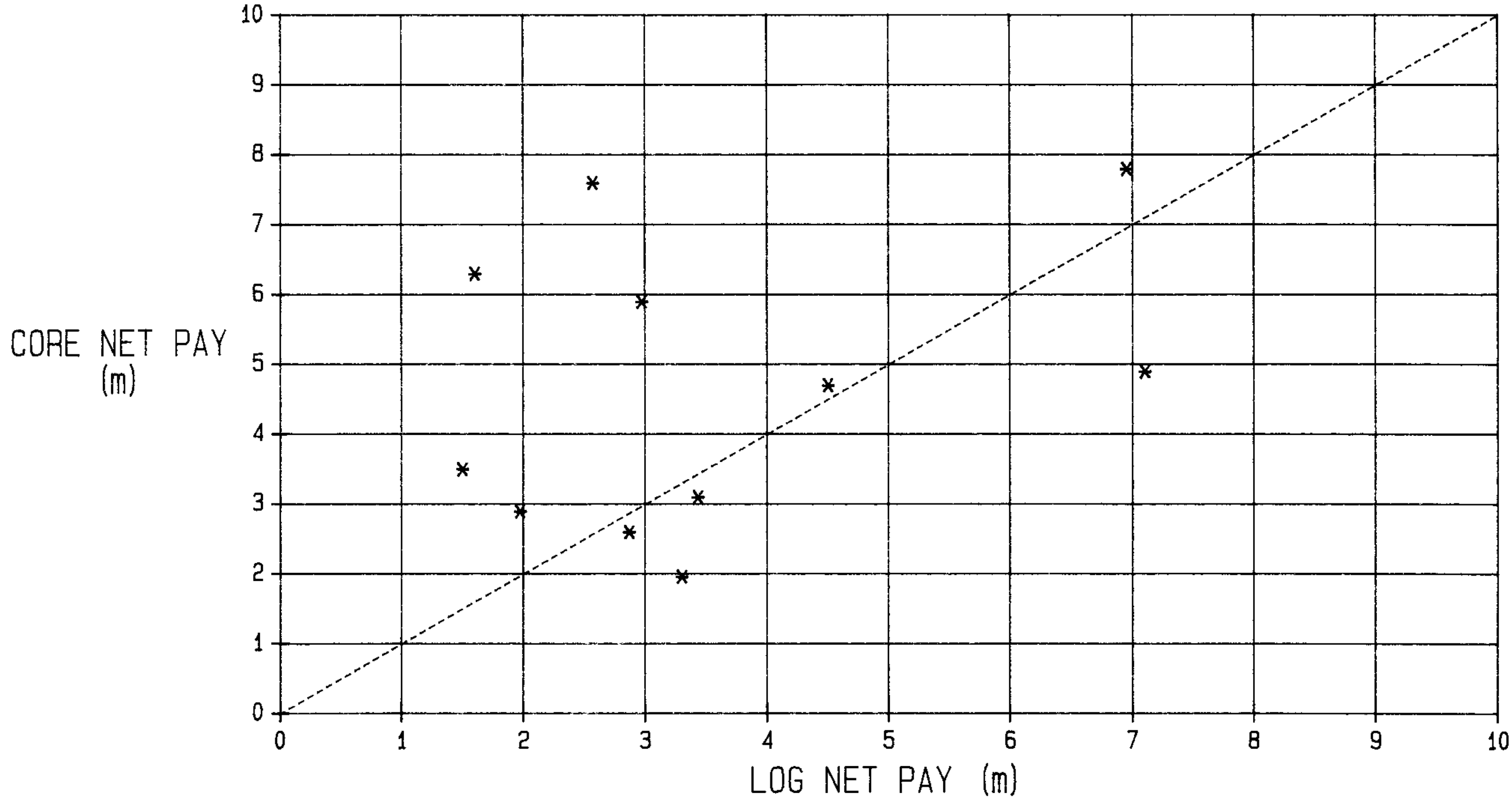
Figure No. 7



CORVSLOG.GPH

WASKADA SPEARFISH
CORE NET PAY VS LOG NET PAY

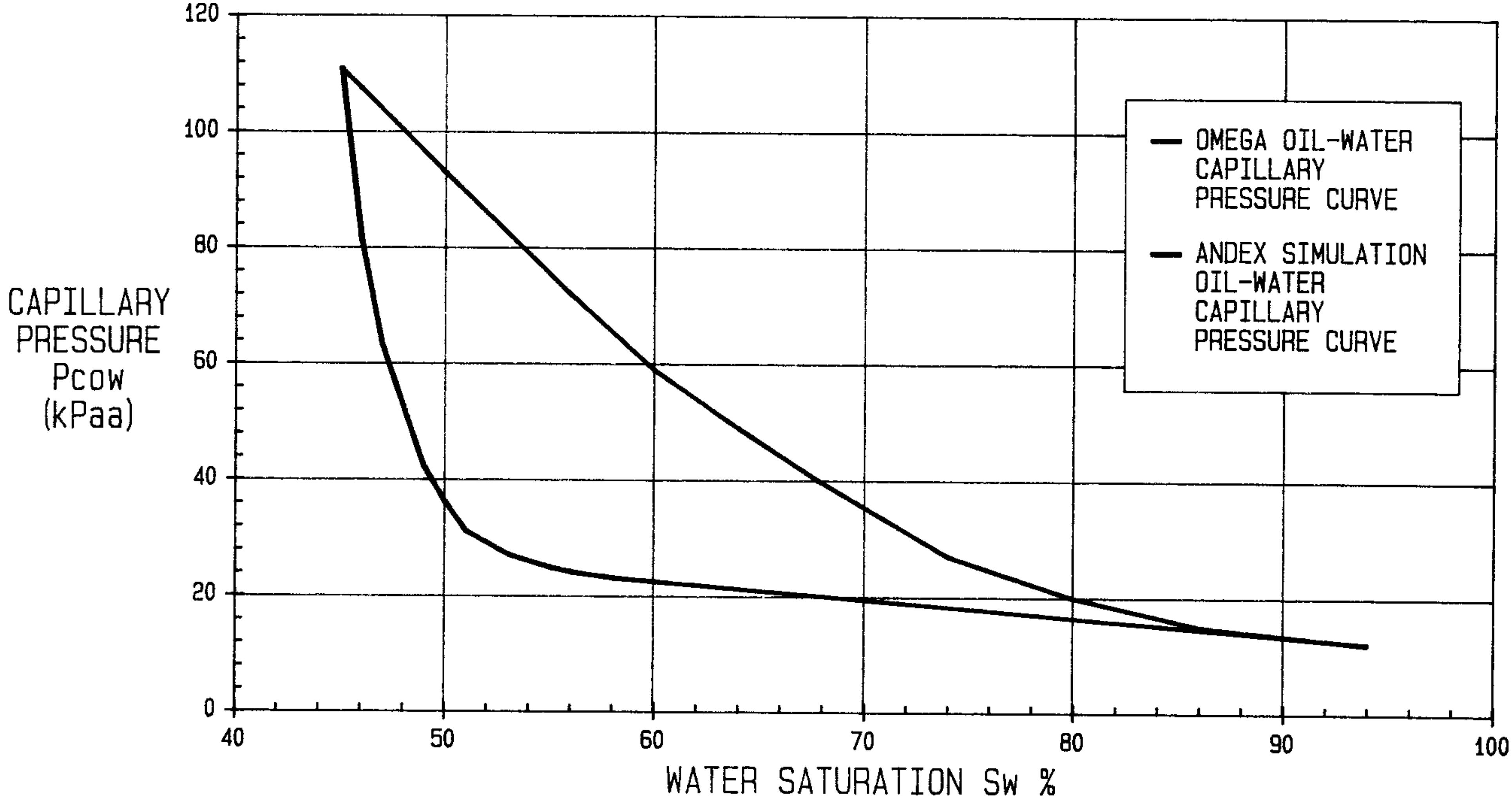
Figure No. 8



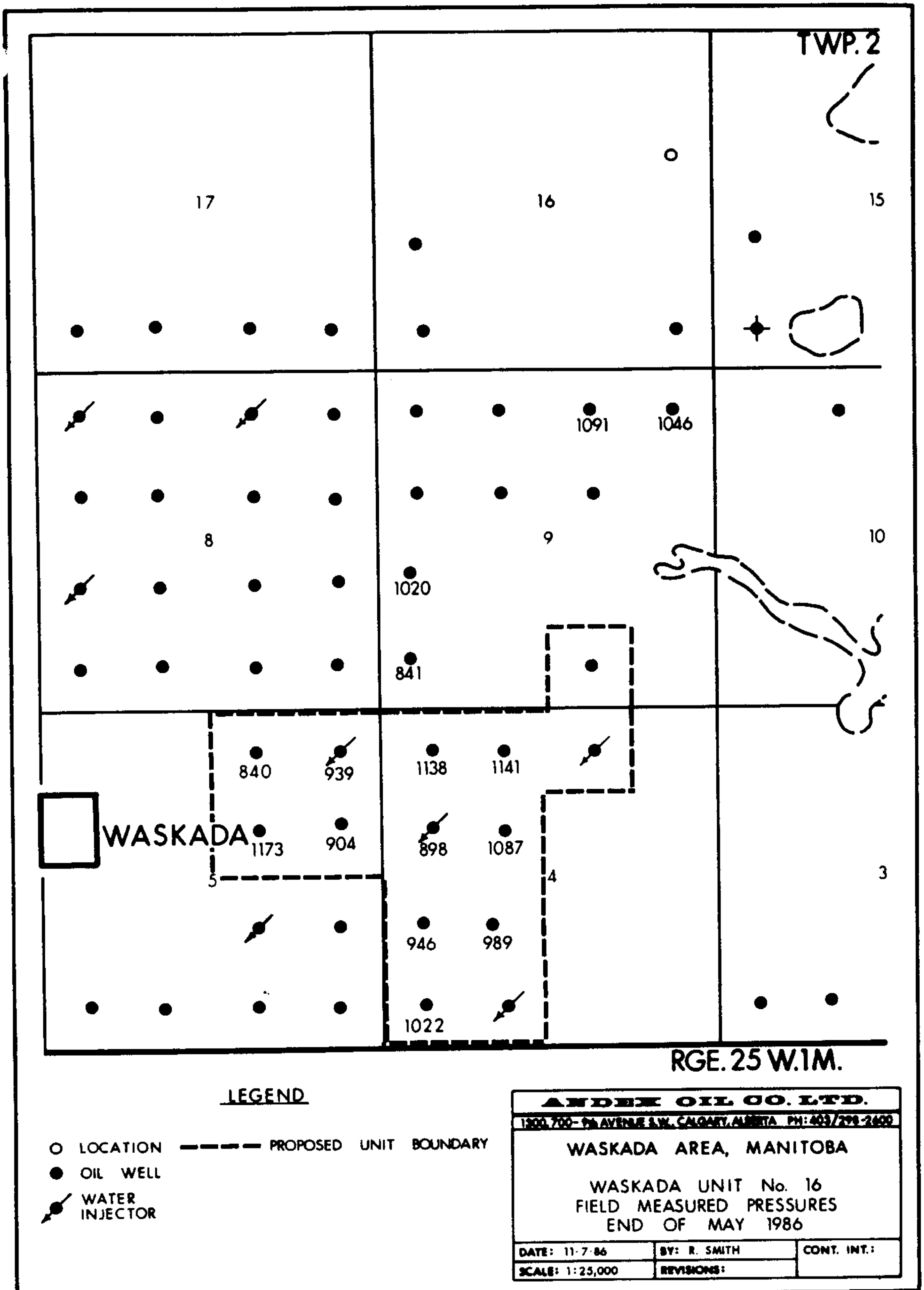
CAP-PRES.GPH

WASKADA SPEARFISH OIL-WATER CAPILLARY PRESSURE CURVE

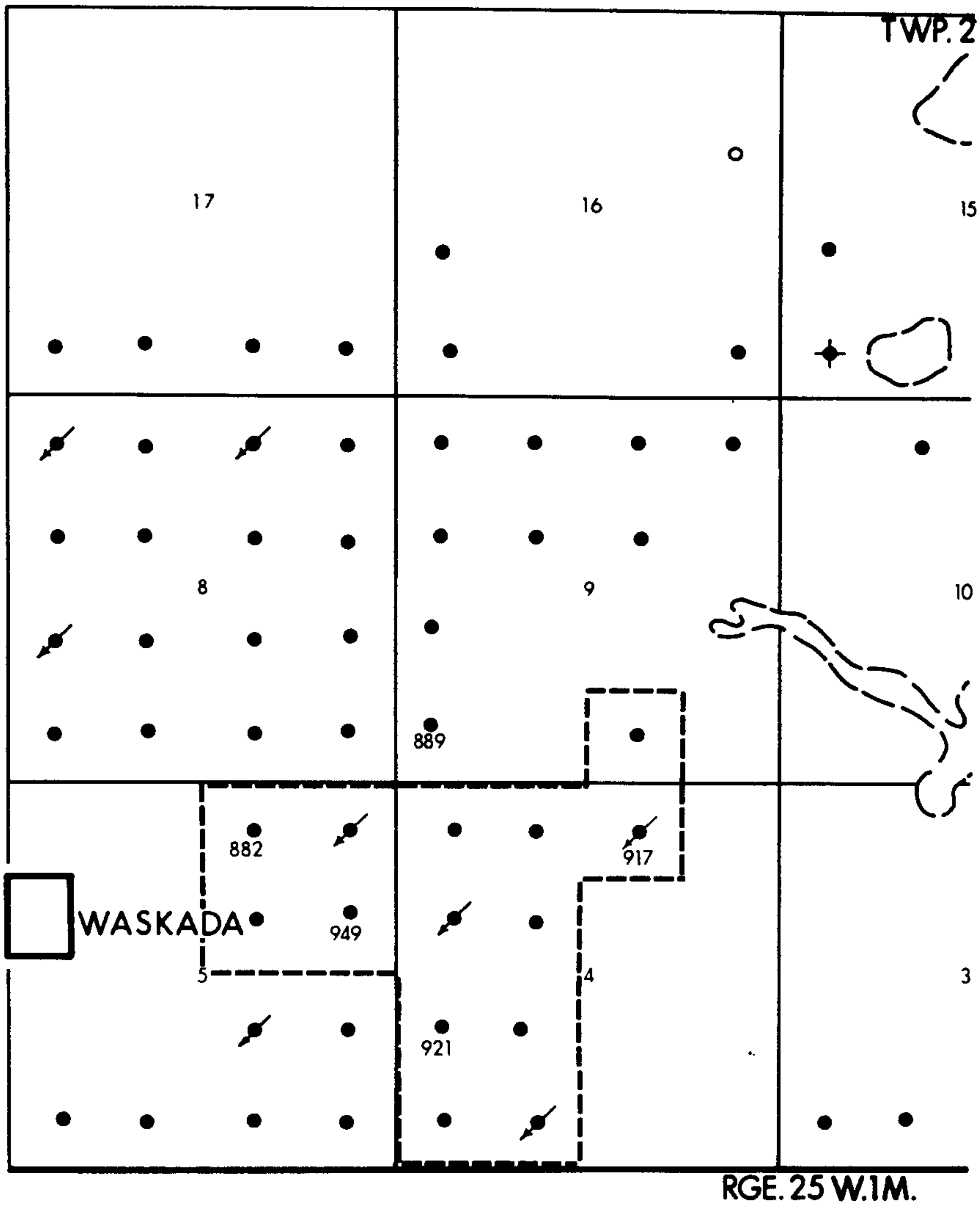
Figure No. 9



MAPS


TWP. 2
17
16
15
1091
1046
8
9
10
1020
841
840
939
1138
1141
WASKADA
1173
904
898
1087
5
4
3
946
989
1022
RGE. 25 W.1M.
LEGEND
LOCATION
PROPOSED UNIT BOUNDARY
OIL WELL
WATER INJECTOR
ANDEX OIL CO. LTD.
WASKADA AREA, MANITOBA
WASKADA UNIT No. 16
FIELD MEASURED PRESSURES
END OF MAY 1986
DATE: 11-7-86
BY: R. SMITH
CONT. INT.:
SCALE: 1:25,000
REVISIONS:

MAP No. 5A



LEGEND

- ○ LOCATION
- ● OIL WELL
- WATER INJECTOR
- PROPOSED UNIT BOUNDARY

ANDEX OIL CO. LTD.

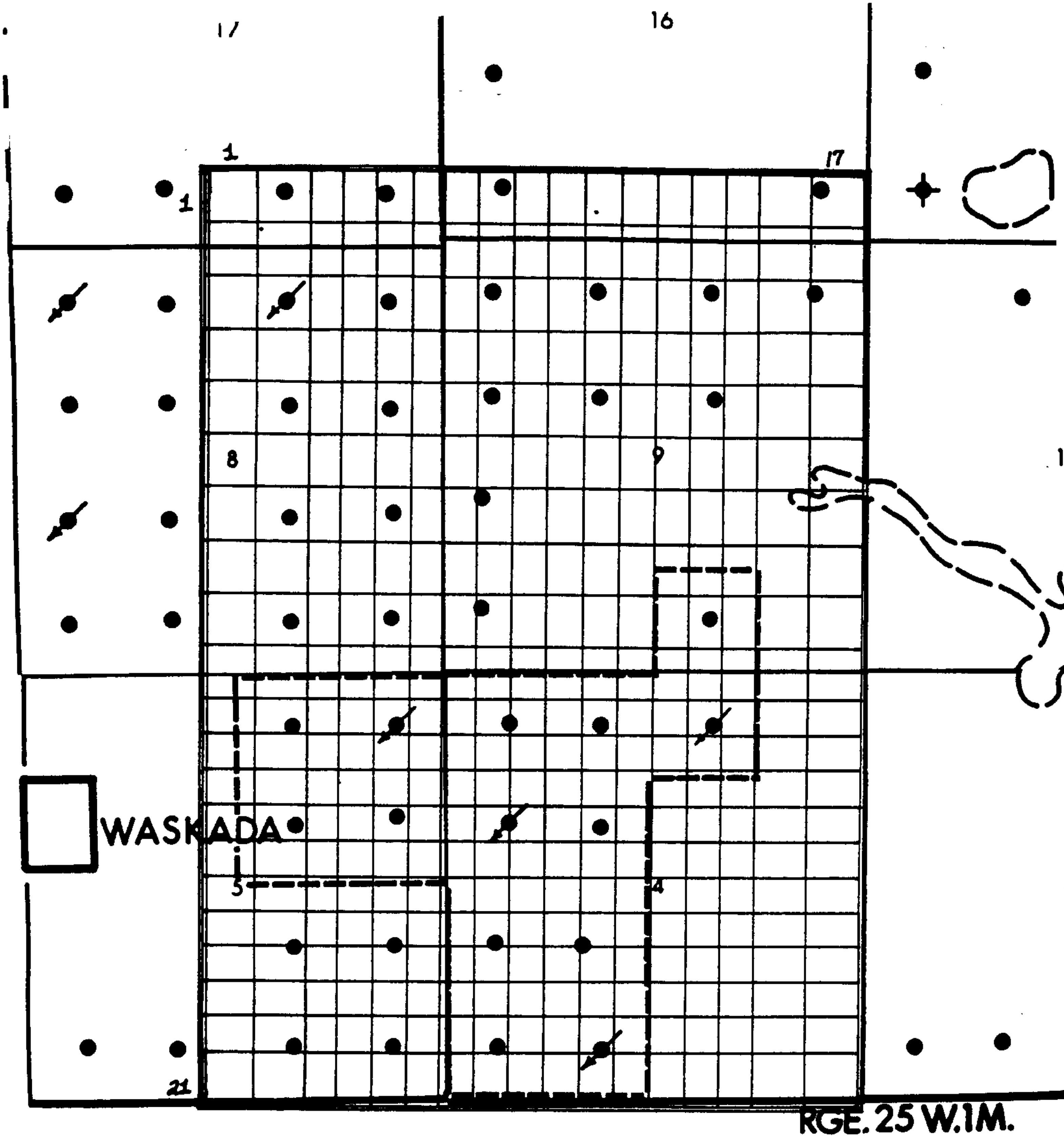
1300, 700 - 9th AVENUE S.W., CALGARY, ALBERTA PH: [illegible]

WASKADA AREA, MANITOBA

WASKADA UNIT No. 16
FIELD MEASURED PRESSURES
END OF JULY 1986

DATE: 11·7·86	BY: R. SMITH	CONT. INT.:
SCALE: 1:25,000	REVISIONS:	

MAP No. 5B



LEGEND

○ LOCATION
● OIL WELL
— — — PROPOSED UNIT BOUNDARY

ANDEX OIL CO. LTD.

1300, 700 - 9th AVENUE S.W., CALGARY, ALBERTA PH: 403/299-2600

WASKADA AREA, MANITOBA

GRID DEFINITION OF STUDY AREA

JULY 1986

MAP No. 6

EXHIBIT A

D&S GROUP

CORE DATA EVALUATION

WELL NAME : WASKADA
LOCATION : SECTION 4 COMPOSITE CORE ANALYSIS
ZONE : SPEARFISH

07-09-1986

DISPLACEMENT INPUT DATA

THIS DISPLACEMENT DATA SET EVALUATES THE DISPLACEMENT OF OIL BY WATER IN THE CORE DESCRIPTION FOR WELL WASKADA, LOCATED AT SECTION 4 COMPOSITE CORE ANALYSIS AND COMPLETED IN THE SPEARFISH . THE WELL HAS BEEN ASSIGNED A DRAINAGE AREA OF 40 ACRES (ac.) AND A PATTERN CONTINUITY FACTOR OF 70 PERCENT. THE IMPORTANT DATA USED IN THE DISPLACEMENT EVALUATION ARE SUMMARIZED BELOW :

CONNATE WATER SATURATION (Swc) = .45
RESIDUAL RESERVOIR OIL SATURATION (Sfr) = .15

RESERVOIR OIL VISCOSITY = 1.4 cp.
RESERVOIR OIL FORMATION VOLUME FACTOR = 1.16 RB/STB
RESERVOIR OIL RELATIVE PERMEABILITY AT Swc = 1

DISPLACING WATER VISCOSITY = .7 cp.
DISPLACING WATER FORMATION VOLUME FACTOR = 1 RB/STB
DISPLACING WATER RELATIVE PERMEABILITY AT Sfr = .1222

EFFECTIVE MOBILITY RATIO OF THE DISPLACEMENT IS = .2444
INCREMENTAL INJECTION VOLUMES FOR OUTPUT = 0.050 FLOODABLE HCPV
ECONOMIC LIMIT WOR = 20

THE ORIGINAL OIL-IN-PLACE IS 2886451 BBL .
THE MAXIMUM DISPLACEABLE OIL-IN-PLACE IS 1469466 BBL .) 51%

CORE EVALUATION SUMMARY

TOTAL CORED INTERVAL	= 134.81 ft.
TOTAL CORE POROSITY-THICKNESS	= %1961.78 %- ft.
TOTAL CORE PERMEABILITY-THICKNESS	= 643.14 md.- ft.
AVERAGE CORE POROSITY	= 14.55 PERCENT
AVERAGE CORE PERMEABILITY (ARITH)	= 4.77 md.
AVERAGE CORE PERMEABILITY (LOG)	= 1.89 md.
DYKSTRA-PARSONS COEFFICIENT	= 0.76
LORENZ COEFFICIENT	= 0.69

CALCULATED THEORETICAL RECOVERY	= 0.635 FRACTION OF OOIP
CALCULATED POROSITY CUTOFF	= 1.91 PERCENT
CALCULATED PERMEABILITY CUTOFF	= 0.13 md.

CALCULATED POROSITY-PERMEABILITY CORRELATION PERM=10^(A+B*POR)

A= -1.06465 B= 0.09217

CALCULATED RECOVERY-PERMEABILITY CORRELATION

REC=(DPV/(1-SWC))*(1-.5*EXP(-C*PERM^D)*(1+(1+C*PERM^D)^2))

C= 3.99677 D= 0.57926

CALCULATED CORE PROPERTIES USING CALCULATED CUTOFFS

NET PAY THICKNESS	= 130.21 ft.
NET POROSITY-THICKNESS	= 1934.2 %- ft.
NET PERMEABILITY-THICKNESS	= 642.9 md.- ft.
AVERAGE EFFECTIVE POROSITY	= 14.85 %
AVERAGE EFFECTIVE PERMEABILITY	= 4.9 md.

CORE DATA AND RECOVERY SUMMARY

LAYER	DEPTH ft.	THICKNESS ft.	PERMEABILITY md.	POROSITY %	RECOVERY (% OOIP)
1	2625.46	1.64	0.85	15.90	44.8432
2	2627.10	1.64	1.07	13.10	63.5344
3	2628.74	1.64	0.74	13.30	46.6718
4	2630.38	1.64	1.74	15.50	68.8864
5	2631.86	1.31	3.76	17.40	71.7437
6	2633.17	1.31	0.89	13.60	54.2635
7	2634.48	1.31	0.81	11.30	58.8283
8	2635.79	1.31	0.33	15.20	18.2115
9	2636.94	0.98	2.69	15.10	71.3137
10	2637.76	0.66	0.90	14.30	52.2148
11	2638.58	0.98	3.78	15.20	71.9617
12	2639.40	0.66	2.94	14.70	71.5930
13	2640.22	0.98	1.42	16.70	64.5871
14	2641.37	1.31	0.73	14.00	43.7390
15	2642.60	1.15	1.34	14.70	66.0790
16	2643.83	1.31	2.17	14.30	70.7769
17	2645.39	1.80	0.67	14.10	39.8593
18	2646.62	0.66	2.24	13.60	71.0771
19	2647.36	0.82	0.34	14.70	19.4015
20	2648.26	0.98	0.80	14.10	47.5932
21	2649.25	0.98	6.29	17.40	72.3186
22	2650.48	1.48	0.82	16.80	40.9429
23	2652.03	1.64	2.42	14.40	71.1421
24	2653.59	1.48	0.26	13.10	16.6485
25	2654.99	1.31	1.99	13.00	70.8118
26	2656.38	1.48	0.03	4.70	5.3542
27	2657.69	1.15	12.07	17.00	72.5833
28	2658.92	1.31	6.45	14.90	72.4207
29	2660.56	1.97	4.79	14.50	72.2539
30	2661.96	0.82	1.39	16.30	64.6569
31	2662.53	0.33	1.01	12.30	63.6824
32	2663.17	0.95	1.64	13.80	69.3787
33	2663.89	0.49	5.00	20.50	71.9352
34	2664.63	0.98	8.63	16.40	72.5009
35	2665.53	0.82	20.57	16.30	72.6652
36	2666.44	0.98	8.70	11.80	72.5912
37	2667.26	0.66	81.58	23.80	72.7122
38	2668.08	0.98	57.89	23.70	72.7030
39	2669.06	0.98	34.73	19.60	72.6890
40	2669.96	0.82	8.19	11.20	72.5895
41	2670.87	0.98	1.03	7.80	70.0978
42	2671.60	0.49	0.88	7.40	69.3839
43	2672.18	0.66	3.38	6.50	72.4967
44	2673.08	1.15	5.12	14.70	72.2932
45	2674.23	1.15	25.15	16.10	72.6815
46	2675.38	1.15	5.02	17.30	72.1399
47	2676.52	1.15	2.15	15.20	70.4648
48	2677.67	1.15	0.03	8.90	2.8275
49	2678.74	0.98	0.42	11.20	31.4561
50	2679.89	1.31	0.95	8.20	69.1692

CORE DATA AND RECOVERY SUMMARY

LAYER	DEPTH ft.	THICKNESS ft.	PERMEABILITY md.	POROSITY %	RECOVERY (% OOIP)
51	2681.12	1.15	4.34	12.70	72.2795
52	2682.27	1.15	10.83	17.20	72.5549
53	2683.50	1.31	1.55	16.80	66.3016
54	2684.73	1.15	2.88	16.10	71.3250
55	2686.20	1.80	2.44	15.20	70.9894
56	2688.09	1.97	2.60	17.50	70.6888
57	2690.14	2.13	1.30	18.00	59.1605
58	2692.03	1.64	49.91	23.60	72.6975
59	2693.91	2.13	3.95	13.10	72.1766
60	2695.55	1.15	9.94	13.20	72.5954
61	2696.78	1.31	12.38	22.70	72.5129
62	2698.10	1.31	10.01	20.40	72.4751
63	2699.74	1.97	0.51	8.50	50.3298
64	2701.70	1.97	0.09	5.30	14.2443
65	2703.67	1.97	1.30	9.40	70.3520
66	2705.72	2.13	0.27	12.50	18.1187
67	2707.86	2.13	1.19	11.70	67.7954
68	2710.07	2.30	1.82	14.90	69.5875
69	2711.71	0.98	0.78	12.80	50.8170
70	2712.53	0.66	0.17	7.40	19.2704
71	2713.52	1.31	1.58	13.00	69.5507
72	2714.75	1.15	0.82	6.50	69.8125
73	2715.98	1.31	1.20	14.10	64.6088
74	2717.37	1.48	3.59	24.80	70.5738
75	2719.17	2.13	1.06	14.80	58.7910
76	2720.98	1.48	6.40	12.30	72.4969
77	2722.62	1.80	1.93	14.10	70.2980
78	2724.42	1.80	1.02	13.80	60.1339
79	2727.57	4.49	0.93	13.10	58.3900
80	2731.92	4.20	1.52	18.10	64.2776
81	2735.99	3.94	2.29	18.10	69.8317
82	2739.52	3.12	2.81	17.70	70.9499
83	2743.04	3.94	5.11	19.20	72.0467
84	2745.91	1.80	2.41	18.40	70.0495
85	2747.80	1.97	1.28	11.20	69.0503
86	2749.28	0.98	1.60	13.40	69.4158
87	2750.51	1.48	2.59	12.90	71.6012
88	2752.23	1.97	0.60	10.30	48.8639
89	2753.97	1.51	28.10	10.90	72.7047
90	2755.28	1.12	4.94	20.30	71.9320
91	2756.54	1.41	4.81	12.80	72.3434
92	2758.35	2.20	0.92	10.00	66.2500

PSEUDO RELATIVE PERMEABILITY CALCULATIONS

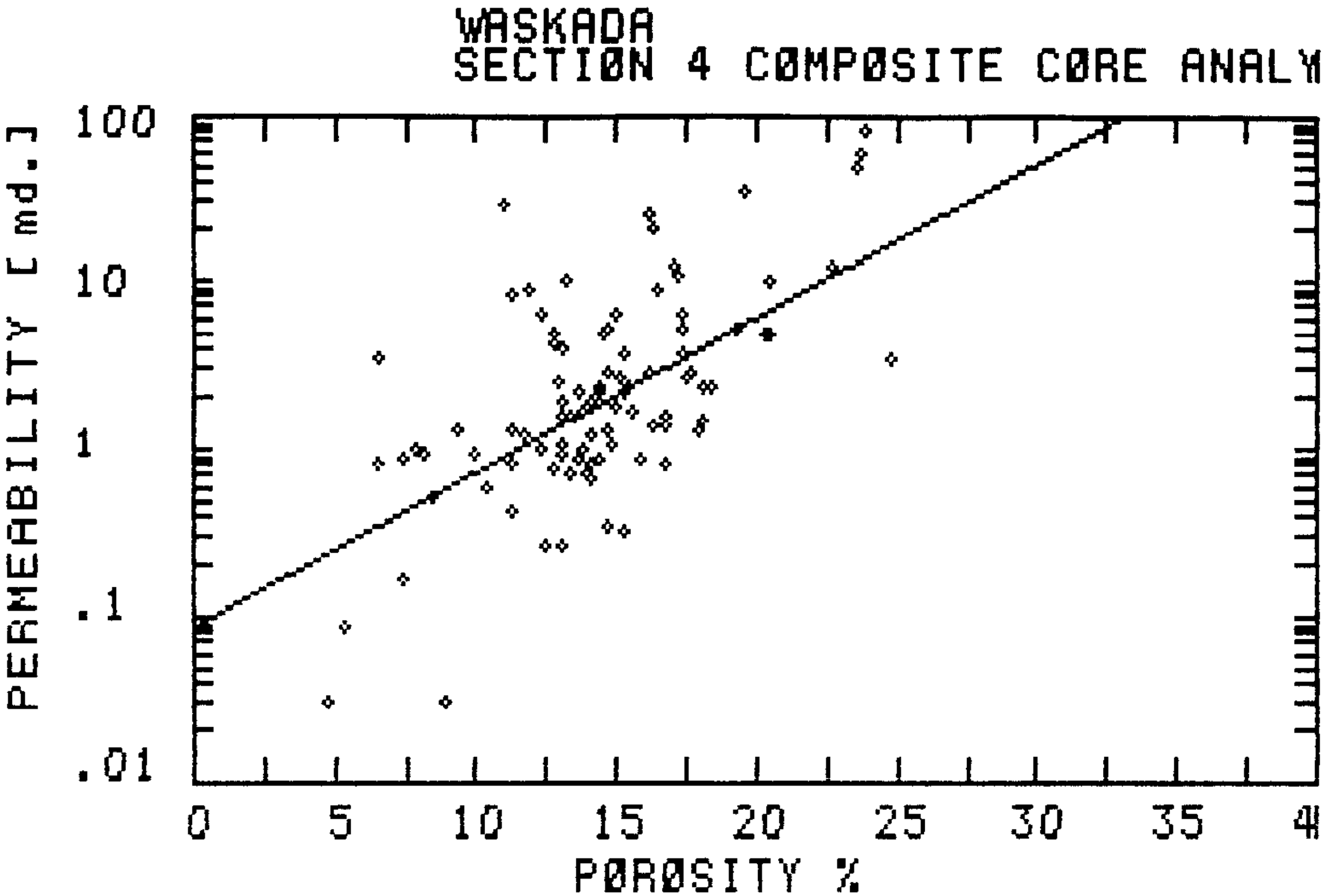
AVERAGE OIL SATURATION	WOR	FRACTIONAL FLOW TO WATER	WATER RELATIVE PERM	OIL RELATIVE PERM
0.5225	0.0009	0.0009	0.0002	0.3701
0.4980	0.1219	0.1086	0.0200	0.3290
0.4803	0.5521	0.3557	0.0722	0.2615
0.4652	0.8209	0.4508	0.0933	0.2273
0.4509	0.9213	0.4795	0.0972	0.2111
0.4372	1.0149	0.5037	0.0998	0.1967
0.4246	1.1823	0.5418	0.1061	0.1795
0.4129	1.3350	0.5717	0.1102	0.1652
0.4020	1.5268	0.6042	0.1152	0.1508
0.3918	1.6959	0.6291	0.1180	0.1392
0.3820	1.8210	0.6455	0.1185	0.1302
0.3728	1.9840	0.6649	0.1199	0.1209
0.3641	2.1636	0.6839	0.1212	0.1120
0.3558	2.3142	0.6983	0.1213	0.1048
0.3479	2.4756	0.7123	0.1213	0.0980
0.3405	2.6939	0.7293	0.1221	0.0907
0.3334	2.8922	0.7431	0.1222	0.0845
0.3266	3.0458	0.7528	0.1222	0.0802
0.3201	3.2255	0.7633	0.1222	0.0758
0.3138	3.3665	0.7710	0.1222	0.0726
0.3077	3.5373	0.7796	0.1222	0.0691
0.3019	3.6839	0.7865	0.1222	0.0663
0.2961	3.8138	0.7923	0.1222	0.0641
0.2906	3.9646	0.7986	0.1222	0.0616
0.2853	4.1572	0.8061	0.1222	0.0588
0.2802	4.3776	0.8140	0.1222	0.0558
0.2753	4.7009	0.8246	0.1222	0.0520
0.2707	4.9610	0.8322	0.1222	0.0493
0.2663	5.1860	0.8383	0.1222	0.0471
0.2621	5.5381	0.8470	0.1222	0.0441
0.2580	5.8216	0.8534	0.1222	0.0420
0.2542	6.1798	0.8607	0.1222	0.0395
0.2506	6.6377	0.8691	0.1222	0.0368
0.2472	7.0560	0.8759	0.1222	0.0346
0.2439	7.4429	0.8816	0.1222	0.0328
0.2408	7.8626	0.8872	0.1222	0.0311
0.2379	8.4908	0.8946	0.1222	0.0288
0.2351	8.7068	0.8970	0.1222	0.0281
0.2324	9.0509	0.9005	0.1222	0.0270
0.2298	9.9103	0.9083	0.1222	0.0247
0.2274	10.1044	0.9099	0.1222	0.0242
0.2249	10.2613	0.9112	0.1222	0.0238
0.2225	10.5432	0.9134	0.1222	0.0232
0.2202	10.9549	0.9164	0.1222	0.0223
0.2180	11.4836	0.9199	0.1222	0.0213
0.2160	12.1656	0.9240	0.1222	0.0201
0.2140	13.4080	0.9306	0.1222	0.0182
0.2122	13.6649	0.9318	0.1222	0.0179
0.2103	13.7609	0.9323	0.1222	0.0178
0.2085	14.1747	0.9341	0.1222	0.0172
0.2068	14.8494	0.9369	0.1222	0.0165
0.2051	15.5721	0.9397	0.1222	0.0157
0.2035	16.2968	0.9422	0.1222	0.0150
0.2020	17.0945	0.9447	0.1222	0.0143
0.2005	18.0058	0.9474	0.1222	0.0136

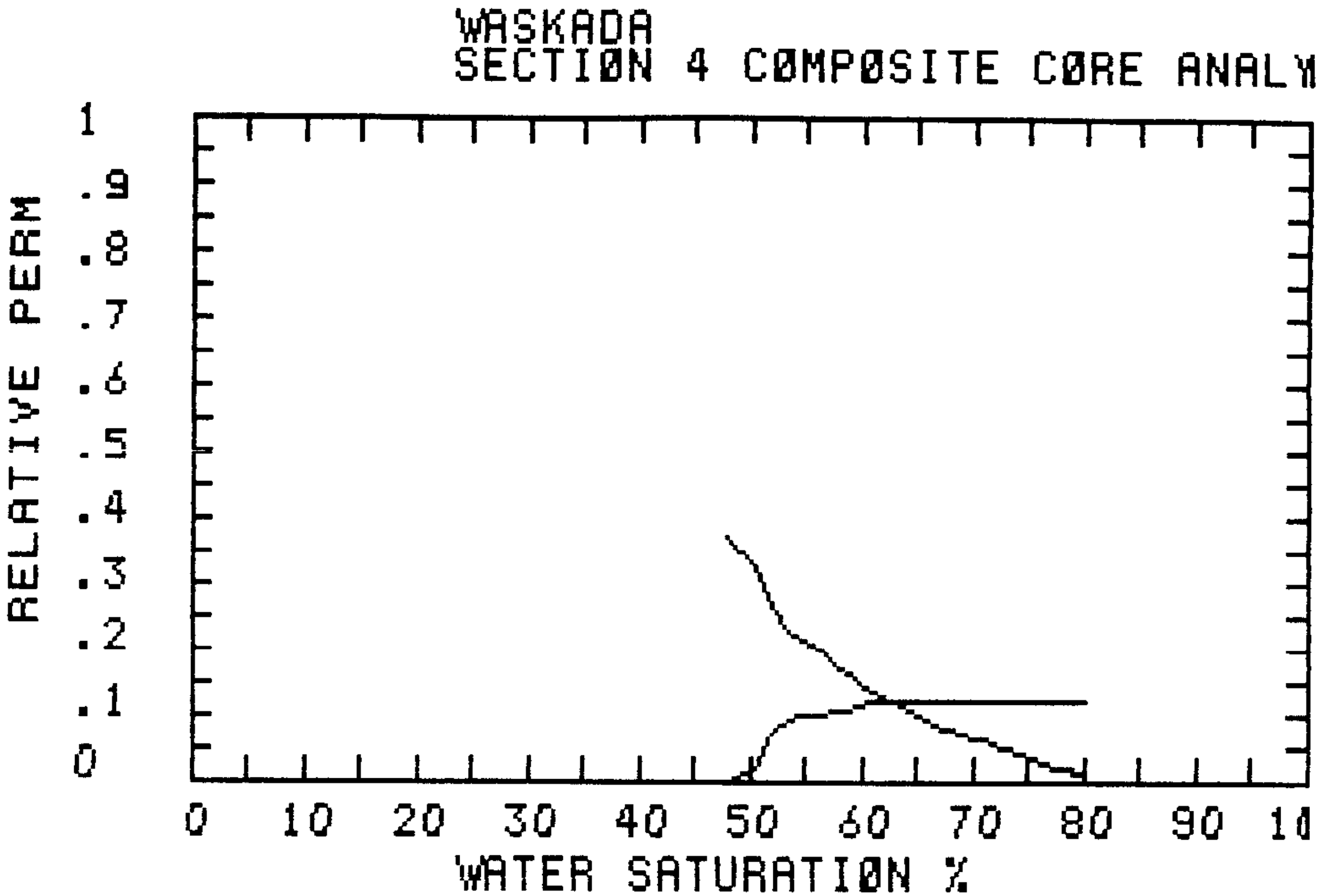
DISPLACEMENT RESULTS

WATER INJ (FHCPV)	OIL REC (%FOIP)	OIL PROD BBL	OIL RATE BBL /D	WOR
0.05	4.996	100939.2	276.5	0.00
0.10	9.453	190990.8	246.7	0.14
0.15	12.674	256079.8	178.3	0.64
0.20	15.420	311561.3	152.0	0.95
0.25	18.022	364144.0	144.1	1.07
0.30	20.504	414282.4	137.4	1.18
0.35	22.795	460574.8	126.8	1.37
0.40	24.936	503840.8	118.5	1.55
0.45	26.915	543823.2	109.5	1.77
0.50	28.770	581297.2	102.7	1.97
0.55	30.542	617109.6	98.1	2.11
0.60	32.218	650965.5	92.8	2.30
0.65	33.798	682899.4	87.5	2.51
0.70	35.307	713382.0	83.5	2.68
0.75	36.746	742449.6	79.6	2.87
0.80	38.099	769798.6	74.9	3.12
0.85	39.384	795754.5	71.1	3.35
0.90	40.620	820725.3	68.4	3.53
0.95	41.803	844633.8	65.5	3.74
1.00	42.948	867770.1	63.4	3.91
1.05	44.050	890035.6	61.0	4.10
1.10	45.117	911604.3	59.1	4.27
1.15	46.156	932591.0	57.5	4.42
1.20	47.163	952940.2	55.8	4.60
1.25	48.133	972529.4	53.7	4.82
1.30	49.063	991315.8	51.5	5.08
1.35	49.940	1009036.6	48.6	5.45
1.40	50.778	1025984.4	46.4	5.75
1.45	51.587	1042315.8	44.7	6.02
1.50	52.351	1057767.8	42.3	6.42
1.55	53.084	1072577.5	40.6	6.75
1.60	53.781	1086648.3	38.6	7.17
1.65	54.435	1099875.5	36.2	7.70
1.70	55.056	1112415.9	34.4	8.18
1.75	55.648	1124381.8	32.8	8.63
1.80	56.212	1135780.9	31.2	9.12
1.85	56.739	1146425.5	29.2	9.85
1.90	57.254	1156833.3	28.5	10.10
1.95	57.752	1166884.6	27.5	10.50
2.00	58.210	1176144.3	25.4	11.50
2.05	58.660	1185242.1	24.9	11.72
2.10	59.104	1194213.3	24.6	11.90
2.15	59.538	1202965.1	24.0	12.23
2.20	59.956	1211415.8	23.2	12.71
2.25	60.356	1219508.4	22.2	13.32
2.30	60.736	1227181.9	21.0	14.11
2.35	61.083	1234193.8	19.2	15.55
2.40	61.424	1241082.6	18.9	15.85
2.45	61.763	1247926.8	18.8	15.96
2.50	62.092	1254584.3	18.2	16.44

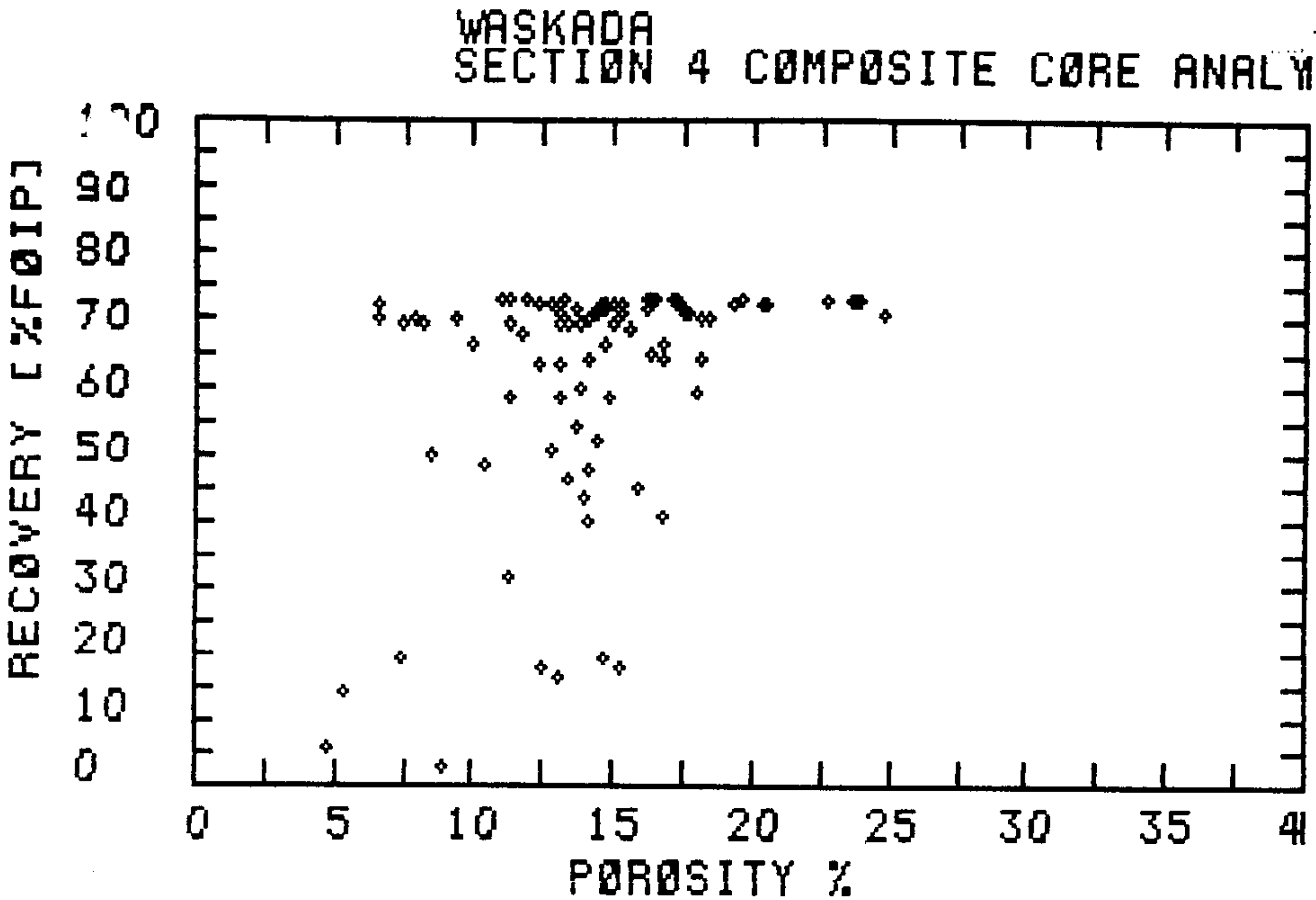
DISPLACEMENT RESULTS

WATER INJ (FHCPV)	OIL REC (%FOIP)	OIL PROD BBL	OIL RATE BBL /D	WOR
2.55	62.408	1260958.4	17.5	17.23
2.60	62.709	1267054.5	16.7	18.06
2.65	62.999	1272895.3	16.0	18.90
2.70	63.275	1278478.5	15.3	19.83
2.75	63.538	1283794.0	14.6	20.89


WASKADA
SECTIØN 4 CØMPØSITE CØRE ANALY
PERMEABILITY [md.]
100
10
1
.1
.01
0
5
10
15
20
25
30
35
4
PØRØSITY %



WASKADA
SECTIØN 4 CØMPØSITE CØRE ANALY
RELATIVE PERM
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
0
10
20
30
40
50
60
70
80
90
10
WATER SATURATIØN %


WASKADA
SECTION 4 COMPOSITE CORE ANALY
RECOVERY [%FOIP]
POROSITY %
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25
30
35

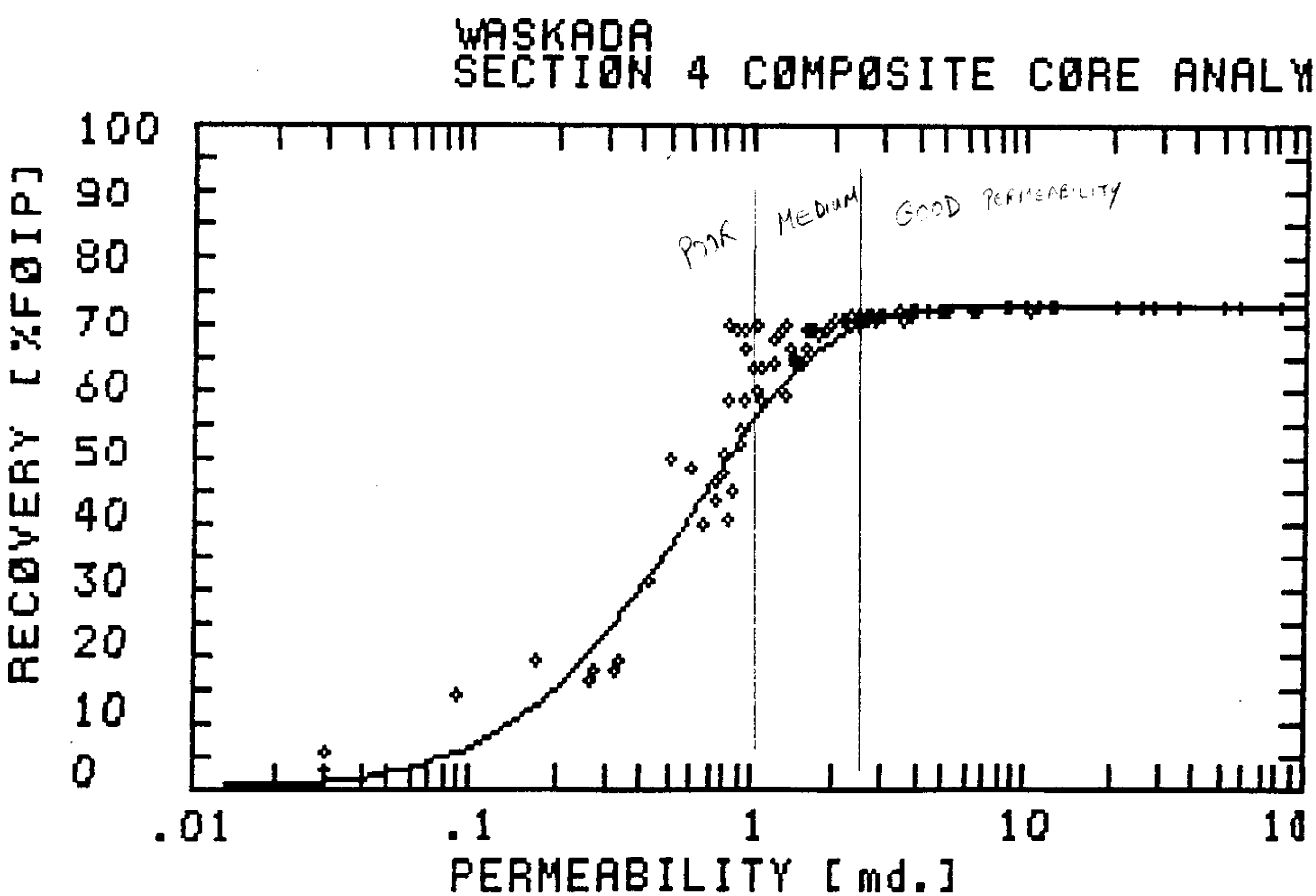
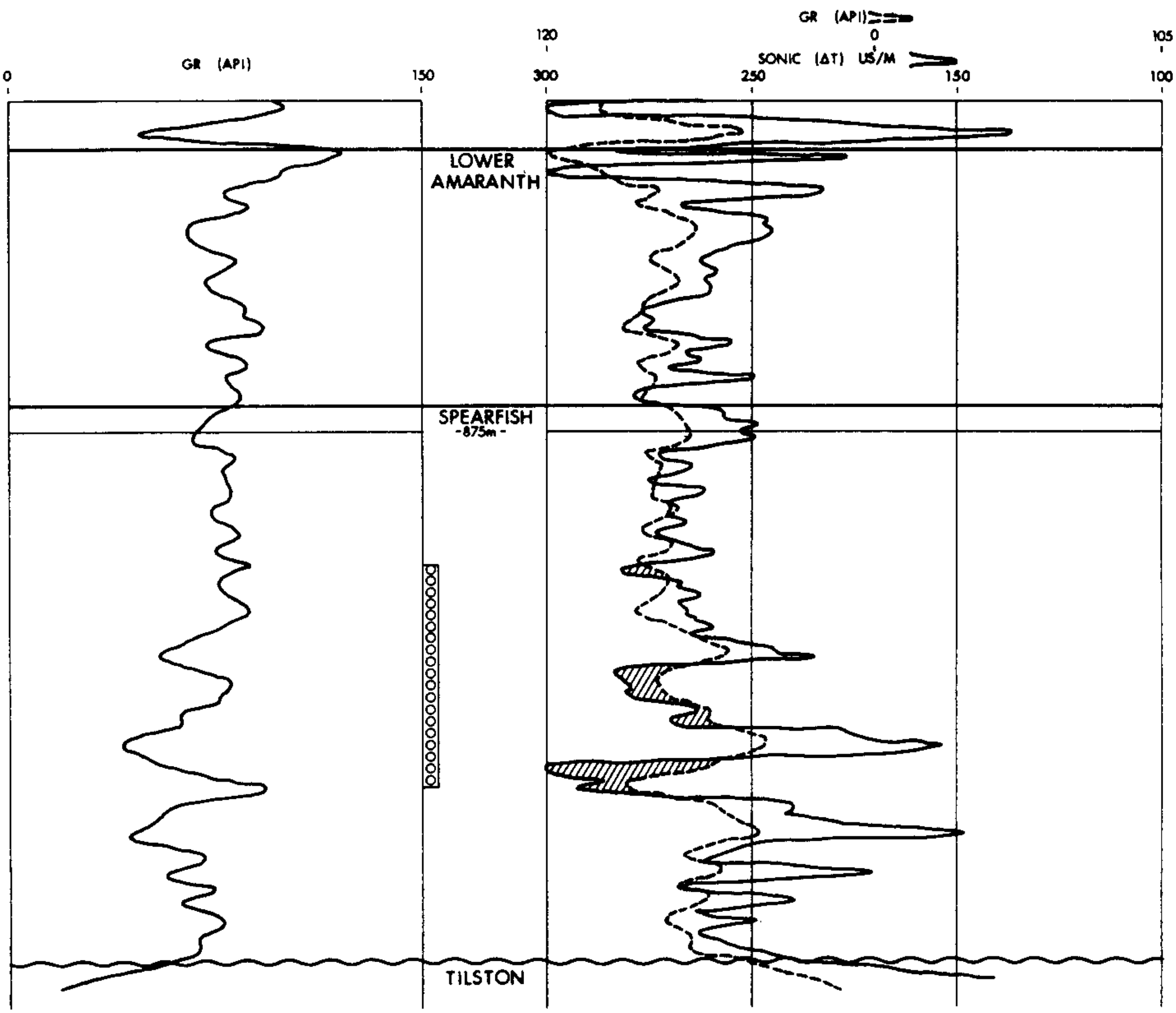

WASKADA
SECTION 4 COMPOSITE CORE ANALY
RECOVERY [%FOIP]
PERMEABILITY [md.]
POOR
MEDIUM
GOOD PERMEABILITY
0
10
20
30
40
50
60
70
80
90
100
.01
.1
1
10

EXHIBIT B

OVERLAY
WELL: 13-4-2-25W1M
WASKADA
CORE NET PAY 4.7m
OVERLAY NET PAY 4.5m



TYPICAL WELL LOGS

WELL: 13-4-2-25W1M

WASKADA LOWER AMARANTH SAND