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WASKADA UNIT NO. 16
(Order No. PM66)

WATERFLOOD PROGRESS REPORT
January 1, through December 31, 1991

ENRON OIL CANADA LTD.

Prepared by:
H.D. Logie

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INTRODUCTION

The Waskada Unit No. 16 pressure maintenance project commenced water injection into that portion of the Lower Amaranth designed and in accordance with Manitoba Energy and Mines Approval No. PM57 dated June 2, 1987. Approval No. PM57 was rescinded on June 7, 1991 and replaced with Approval No. PM66.

The Unit was expanded effective October 1, 1988 at which time fifteen wells were added, five of which are injectors. Water injection commenced December 1, 1988 in the expanded area. The expanded Unit now has thirty-three wells of which twenty-four are oil producers and nine are water injectors.

This report documents the performance of the Enron Waskada Unit No. 16 pressure maintenance project for the period of January 1 to December 31, 1991.

CONCLUSIONS

1. There has been generally good response to pressure maintenance in the project area to December 31, 1991. The recent startup of water injection into offset Waskada Unit No. 17 should have a future positive affect on Waskada Unit No. 16.

2. The fall-off tests completed on the nine injectors indicate that reservoir pressure is being maintained above the bubble point.

3. There appears to be a permeability and frac trend in a northeast to southwest direction in one area of the pool. As a result, the line drive injection pattern could result in a more efficient sweep in the off-trend producers.

4. The supply of water for the pressure maintenance scheme is more than adequate. The original 5-9-2-25 WPM well was recompleted and tied-in as a Swan River (Blairmore) source water well.

5. The present corrosion and chemical program is performing very well with no problems arising during this reporting period. This program will be monitored closely as the scheme matures.

DISCUSSION

Production Performance

The cumulative production from Waskada Unit No. 16 up to December 31, 1991 was 156 830 m^3 of oil and 45 914 m^3 of water. No accurate cumulative gas production numbers are available. Appendix C contains plots of individual wells and a combined Unit performance to date.

Since commencement of water injection in June 1987 and the addition of five injectors in December 1988, the cumulative production up to December 31, 1991 for the total Waskada Unit No. 16 area has been 102 515 m^3 oil and 34 134 m^3 water. The cumulative water injection was 153 562 m^3, resulting in a cumulative voidage replacement ratio of 1.005.

During the reporting period, 24 742 m^3 of oil and 11 353 m^3 of water was produced and 39 652 m^3 of water was injected for a voidage replacement ratio of 0.998. In July 1990, workover operations were carried out on wells 16-4-2-25 WPM and 10-5-2-25 WPM in an attempt to increase productivity by perforating and fracture stimulating an additional Upper Amaranth interval. The 16-4 well exhibited no increase in oil productivity, but the water cut jumped from 1% to 35%. The 10-5 well showed an oil productivity increase from 0.7 m^3/d to 2.5 m^3/d, but at the expense of a water cut jump from 1.5% to 95.% as a result of fracture communication with the Mississippian. The water produced at the 10-5 well in 1991 was approximately 647 m^3/month. In 1991 four wells had evident Lower Amaranth/Mississippian communication water problems; 13-4 (65% water cut), 16-4 (25% water cut), 10-5 (92% water cut), and 4-9 (84% water cut). If we assume a reasonable Lower Amaranth water cut of 10% for these four wells, the water production from Waskada Unit No. 16 would be only 720 m^3 rather than 11 353 m^3. This would result in the favourable voidage replacement ratio of 1.363 for this report period.

This reporting period saw total Unit No. 16 oil productivity decrease by 8.6% to an average rate of 67.8 m^3/cal day for 1991.

	Productivity (m^3/d)	GOR (m^3/m^3)	Water Cut (%)
Prior to Injection	29.1	38.1	24.0
As of December 1988	81.8	41.2	15.7
As of December 1989	80.2	38.3	13.7
As of December 1990	73.9	31.6	44.3
As of December 1991	61.9	47.6	29.1

The sharp rise in water cut shown in December 1990 is due to the unsuccessful 16-4 and 10-5 well recompletions which resulted in Lower Amaranth/Mississippian communication.

To date, only well 1-9 within the Unit has experienced water breakthrough. This well located northeast of the 15-4 injector has been subsequently converted to an injector in the newly expanded Unit area. It should be noted that water was encountered when well 1-9 was initially completed; thus a permeability trend in the northeast to southwest direction is evident in this area of the pool.

Voidage Calculations

Appendix B and Table 1 depict the pressure history of the wells in Waskada Unit No. 16. As can be seen, recent pressure surveys indicate that the Unit area is above the bubble point pressure of 4 220 kPa.

Voidage calculations show that the scheme is only at 0.796 voidage replacement ratio since project inception. But fall-off tests performed on injectors indicate that the average reservoir pressure is much higher. Some of the discrepancies between pressure and VRR can be attributed to:

a) Mississippian water production in wells 13-4, 16-4, 10-5, and 4-9 being included in voidage calculations.

b) Mississippian water influx supplying some pressure maintenance.

c) Due to the extreme heterogeneous nature of the Lower Amaranth, the pressures measured in the vicinity of the injection wells may not be totally indicative of average reservoir pressure within the project area.

d) The Lower Amaranth is a blanket sand; thus there is pressure maintenance in offset non-producing areas which is not included in the model as well as pressure depletion in offset areas is not included in the Unit's voidage calculations.

The following table summarizes Unit No. 16 voidage replacement for the reporting period and cumulative to date.

	Withdrawals (Rm^3)	Replacements (Rm^3)	VRR
Reporting Period*	39 682	39 617	0.998
Cumulative Since Production Started	230 085	153 706	0.668

* Unit Expansion October 1, 1988

Over the next report period, injection rates in the injectors will be maintained at a VRR greater than 1.0.

Corrosion and Scale Prevention Program

The Waskada Unit facilities are currently being protected from corrosion and scale by chemical and cathodic protection programs. These programs are providing adequate protection which are further detailed below:

a) Cathodic Protection - Wells and Pipelines:

All producing wells and flowlines along with injection wells and water lines are being cathodically protected against corrosion. Each facility is monitored for proper electrical current every two months. With the exception of minor interruptions in current flow to a few flowlines and well casings, all systems are operating normally providing proper protection to metal surfaces. No additional cathodic protection was added to the Unit in 1991.

b) 15-9-2-25 Battery:

A chemical program consisting of corrosion and scale inhibitors has provided adequate prevention all year. The monitoring of battery facilities continues to show only minor corrosion and scale potential.

c) 15-9-2-25 Water Injection Plant:

The water injection facility has the greatest potential for corrosion and/or scale problems; however, the current chemical prevention program appears to be providing proper protection. Continued monitoring and full control of water supply will help ensure system wide protection against failures. Tank modifications with additional baffles were added to the water injection system which greatly improved the water filter system.

d) Producing and Injection Wells/Flowlines:

The current monitoring program has shown very little corrosion/scale activity in the Unit. Enron is currently using paraffin dispersants to control wax in pumping oilwells. This has

significantly reduced hot oiling at this time. The bacteria in the water system is being controlled by an effective biocide chemical program.

1991 Well Servicing

1.	4-9-2-25	BHP change - January
2.	A5-9-2-25	BHP change - March
3.	4-9-2-25	Hot oil - December
4.	12-4-2-25	Hot oil - December

1991 Workovers

NIL

RECOMMENDATIONS

1. Continue to monitor present corrosion program.

2. Continue to monitor and maintain injection pressure below 9 000 kPag.

3. Continue to monitor production wells on the northeast/southwest trend with nearby injectors.

4. A paraffin dispersant should be used to keep tubulars clean.

TABLE 1

WASKADA UNIT NO. 16
PRESSURE SURVEYS

Location	Shut-in Date	Date of Survey	Type of Survey	Pressure @ Datum Depth -440 m Subsea (kPa)
6-4-2-25	March 31, 1986	May 29, 1986	Static Gradient	6 931.0
13-4-2-25	March 31, 1986	May 29, 1986	Static Gradient	8 051.0
9-5-2-25	March 31, 1986	May 30, 1986	Static Gradient	6 345.5
5-4-2-25	April 29, 1987	June 1, 1987	Static Gradient	3 577.0
11-4-2-25	April 28, 1987	June 1, 1987	Static Gradient	5 312.0
15-4-2-25	April 29, 1987	June 1, 1987	Static Gradient	7 587.5
16-5-2-25	May 5, 1987	June 1, 1987	Static Gradient	4 808.0
5-4-2-25	December 7-30, 1987		Fall-off	8 733.0
11-4-2-25	December 7-January 7, 1988		Fall-off	10 928.0
15-4-2-25	December 7-February 16, 1988		Fall-off	11 098.0
16-5-2-25	December 7-January 4, 1988		Fall-off	10 283.0
1-9-2-25	July 5, 1988	November 21, 1988	Static Gradient	10 724.0
6-9-2-25	August 22, 1988	November 21, 1988	Static Gradient	4 309.0
10-9-2-25	August 22, 1988	November 21, 1988	Static Gradient	5 236.0
16-9-2-25	August 22, 1988	November 21, 1988	Static Gradient	4 701.0
5-10-2-25	August 2, 1988	November 21, 1988	Static Gradient	5 433.0
5-4-2-25	December 5-19, 1988		Fall-off	7 436.0
11-4-2-25	December 5-January 13, 1989		Fall-off	8 017.0
15-4-2-25	December 5-February 1, 1989		Fall-off	10 303.0
16-5-2-25	December 5-January 13, 1989		Fall-off	9 921.0
1-9-2-25	June 5-26, 1989		Fall-off	* 15 962.0
6-9-2-25	June 5-26, 1989		Fall-off	7 831.0
10-9-2-25	June 5-26, 1989		Fall-off	8 190.0

Location	Shut-in Date	Date of Survey	Type of Survey	Pressure @ Datum Depth -440 m Subsea (kPa)
16-9-2-25	June 5-26, 1989		Fall-off	7 966.0
5-4-2-25	December 5-27, 1989		Fall-off	7 211.0
11-4-2-25	December 5-January 2, 1990		Fall-off	7 410.0
15-4-2-25	December 5-27, 1989		Fall-off	13 935.0
16-5-2-25	December 5-27, 1989		Fall-off	9 862.0
1-9-2-25	June 19-July 31, 1990		Fall-off	* 17 300.0
6-9-2-25	June 19-July 31, 1990		Fall-off	9 063.0
10-9-2-25	June 19-July 31, 1990		Fall-off	5 488.0
16-9-2-25	June 19-July 31, 1990		Fall-off	9 010.0
5-10-2-25	June 19-July 31, 1990		Fall-off	7 034.0
5-4-2-25	May 14-June 4, 1991		Fall-off	8 740.0
11-4-2-25	March 5-June 4, 1991		Fall-off	7 210.0
15-4-2-25	March 5-June 4, 1991		Fall-off	12 300.0
16-5-2-25	March 5-25, 1991		Fall-off	10 300.0
1-9-2-25	May 14-June 4, 1991		Fall-off	11 070.0
6-9-2-25	June 25-July 15, 1991		Fall-off	11 140.0
10-9-2-25	June 25-July 15, 1991		Fall-off	6 510.0
16-9-2-25	June 25-July 15, 1991		Fall-off	11 650.0
5-10-2-25	May 14-June 4, 1991		Fall-off	8 240.0

* Anomalously high due to interference from 15-4 injector.

NOTE: All pressures are absolute and corrected to a datum of -440 m subsea.

TABLE 2

WASKADA UNIT NO. 16
INJECTION PERFORMANCE SUMMARY
FOR 1991

Location	Yearly Injection (m^3)	Pattern Voidage (Rm^3)	Replacement (Rm^3)	Total 1991 VRR
5-4-2-25	9 606.6	4 206.1	9 604.3	2.283
11-4-2-25	410.5	2 782.6	410.1	0.147
15-4-2-25	3 467.6	2 966.9	3 483.6	1 .174
16-5-2-25 *	8 731.4	13 561.2	8 741.2	0.645
1-9-2-25	730.4	1 918.2	725.2	0.378
6-9-2-25	8 241.7	6 090.4	8 218.6	1.349
10-9-2-25	1 574.1	2 482.9	1 567.2	0.631
16-9-2-25	4 448.7	3 419.7	4 430.8	1.296
5-10-2-25	2 441.0	2 253.8	2 435.6	1.081
Total Project	39 652.0	39 681.8	39 616.6	0.998

* 1. Pattern voidage affected significantly by large Mississippian water production from well 10-5-2-25 (95% water cut).

2. For continuity, the water injection patterns were not changed during this report period. 1-9, 16-9 and 5-10 injection well patterns will be changed for the next reporting period to account for the startup of injection into Waskada Unit No. 17 on October 25, 1991.

APPENDIX A

ENRON WASKADA UNIT No.16 WATERFLOOD EVALUATION

FOR THE MONTH OF : DECEMBER 1991

UNIT No. 16

	MONTHLY	CUMULATIVE	CUMULATIVE SINCE INJECTION START-UP
OIL PRODUCTION (M3)	1918.7	156806.5	131198.9
GOR (M3/M3)	47.6	32.3	
WATER CUT (%)	29.1	22.9	
WITHDRAWLS (RM3)	3223.8	230085.5	191735.3
REPLACEMENTS (RM3)	3343.0	153706.4	153706.4
VOIDAGE (RM3)	119.2	-76379.1	-39340.4
REPLACEMENT RATIO	1.0370	0.6680	0.7962
NO. OF PROD. WELLS	24		
OIL RATE (M3/CAL.DAY)	61.9		

PROJECT NO. 2

	MONTHLY	CUMULATIVE
OIL PRODUCTION (M3)	147.6	18409.0
GOR (M3/M3)	42.7	16.0
WATER CUT (%)	17.0	28.5
WITHDRAWLS (RM3)	202.6	28849.9
REPLACEMENTS (RM3)	0.0	0.0
VOIDAGE (RM3)	-202.6	-28849.9
REPLACEMENT RATIO	0.0000	0.0000
NO. OF PROD. WELLS	2	
OIL RATE (M3/CAL.DAY)	4.8	

WATERFLOOD SUMMARY

	MONTHLY	CUMULATIVE
OIL PRODUCTION (M3)	2066.3	175215.5
GOR (M3/M3)	47.3	30.6
WATER CUT (%)	28.3	23.6
WITHDRAWLS (RM3)	3426.4	258935.5
REPLACEMENTS (RM3)	3343.0	153706.4
VOIDAGE (RM3)	-83.3	-105229.1
REPLACEMENT RATIO	0.9757	0.5936
NO. OF PROD. WELLS	26	
OIL RATE (M3/CAL.DAY)	66.7	

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

DECEMBER 1991

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	732	24.0	0.79	1886.0	2.2	91.67	74.4	0.2	0.83	97.6	OK
4-4-2-25WPM	684	126.2	4.43	10083.2	3.7	29.32	234.7	1.6	1.25	201.2	OK
6-4-2-25WPM	732	179.9	5.90	15473.9	6.2	34.46	486.0	2.1	1.15	241.9	OK
9-4-2-25WPM	732	43.3	1.42	2381.9	2.9	66.97	87.0	0.4	0.92	60.6	OK
10-4-2-25WPM	732	53.9	1.77	4038.8	2.4	44.53	125.4	0.7	1.28	80.2	OK
12-4-2-25WPM	592	51.5	2.09	6166.4	1.7	33.01	134.9	0.6	1.15	198.0	OK
13-4-2-25WPM	732	25.6	0.84	4161.2	2.8	109.38	99.2	46.3	64.39	4919.8	OK
14-4-2-25WPM	732	58.8	1.93	4170.9	3.3	56.12	129.1	0.7	1.18	107.3	OK
16-4-2-25WPM	732	35.6	1.17	3301.8	1.9	53.37	112.1	10.7	23.11	360.2	OK
9-5-2-25WPM	732	177.5	5.82	18515.2	6.9	38.87	557.6	2.2	1.22	392.0	OK
10-5-2-25WPM	732	51.3	1.68	2208.3	2.7	52.63	72.7	556.1	91.55	13767.2	OK
15-5-2-25WPM	732	28.6	0.94	2342.4	2.9	101.40	82.3	0.2	0.69	196.4	OK
2-9-2-25WPM	732	57.7	1.89	5576.6	3.2	55.46	220.6	1.1	1.87	298.3	OK
3-9-2-25WPM	732	228.7	7.50	13121.5	11.8	51.60	530.6	2.8	1.21	212.4	OK
4-9-2-25WPM	528	30.7	1.40	5884.8	2.4	78.18	108.9	148.1	82.83	19009.2	OK
5-9-2-25WPM	644	35.5	1.32	2338.2	2.6	73.24	90.9	0.2	0.56	3328.5	OK
7-9-2-25WPM	732	203.3	6.67	10903.7	11.3	55.58	439.0	2.5	1.21	169.0	OK
8-9-2-25WPM	732	60.6	1.99	3324.8	3.0	49.50	98.2	1.4	2.26	133.7	OK
9-9-2-25WPM	732	158.1	5.18	9101.3	5.5	34.79	292.0	1.8	1.13	150.7	OK
15-9-2-25WPM	712	32.6	1.10	2490.9	0.8	24.54	57.1	0.3	0.91	153.2	OK
4-10-2-25WPM	744	23.2	0.75	1444.6	0.0	0.00	3.0	2.9	11.11	168.5	OK
12-10-2-25WPM	732	133.0	4.36	8669.2	4.5	33.83	373.3	2.3	1.70	172.3	OK
13-10-2-25WPM	732	89.4	2.93	5527.7	3.7	41.39	163.0	1.4	1.54	131.2	OK
14-10-2-25WPM	732	9.7	0.32	1492.9	3.0	309.28	43.2	0.0	0.00	456.9	OK
		1918.7	64.16	156806.5	91.4	47.64	5068.3	786.6	29.08	46670.6	
PROJECT NO 2											
11-10-2-25WPM	0	0.0	0.00	3313.7	0.0	0.00	53.6	0.0	0.00	96.5	SUSPENDED
3-15-2-25WPM	708	74.8	2.54	3940.3	3.1	41.44	60.1	1.1	1.45	115.1	OK
4-15-2-25WPM	0	0.0	0.00	1727.2	0.0	0.00	41.1	0.0	0.00	90.8	SUSPENDED
5-15-2-25WPM	732	72.8	2.39	9427.8	3.2	43.96	140.0	29.1	28.56	7035.8	OK
		147.6	4.92	18409.0	6.3	42.68	294.8	30.2	16.99	7338.2	
TOTAL OF ALL WELLS		2066.3	69.09	175215.5	97.7	47.28	5363.1	816.8	28.33	54008.8	

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	690	950.7	33.07	37779.7	9000.0	17705.5	0.00282499	OK
11-4-2-25WPM	338	47.1	3.34	4858.7	9000.0	17647.1	0.00028714	OK
15-4-2-25WPM	476	234.6	11.83	13169.4	8100.0	16776.3	0.00109765	OK
16-5-2-25WPM	714	913.1	30.69	36243.8	8795.0	17461.6	0.00267785	OK
1-9-2-25WPM	308	15.1	1.18	3684.4	9000.0	17608.2	0.00010136	OK
6-9-2-25WPM	714	580.0	19.50	27119.2	9000.0	17617.9	0.00167808	OK
10-9-2-25WPM	714	200.5	6.74	6159.6	9000.0	17559.6	0.00058302	OK
16-9-2-25WPM	714	254.5	8.55	16778.7	8970.0	17510.1	0.00074323	OK
5-10-2-25WPM	714	137.5	4.62	7456.8	9000.0	17530.4	0.00040084	OK
NO INJECTOR	0	0.0	0.00	0.0	0.0	0.0	0.00000000	NO INJECTOR
		3333.1	119.52	153250.3				

ENRON WASKADA UNIT No.16 WATERFLOOD
INJECTION PATTERN SUMMARY

DECEMBER 1991

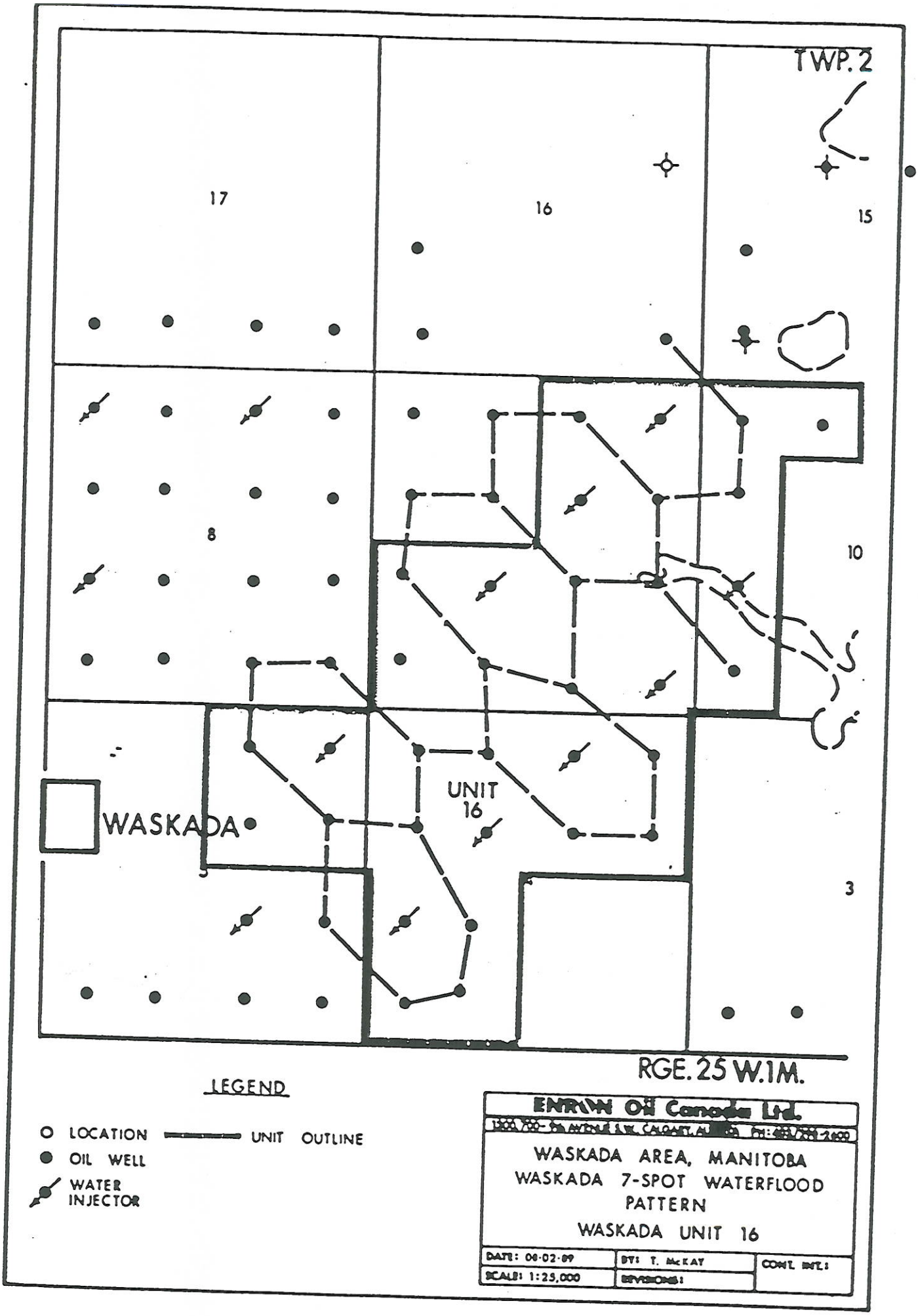
PATTERN NO. 1 5-4-2-25WPM

WELL	PERC. OF WELL IN PATTERN (%)	WITHDRAWALS MONTHLY (RM3)	WITHDRAWALS CUM. (RM3)
3-4-2-25WPM	100.00	46.3	2299.5
4-4-2-25WPM	100.00	148.9	11972.5
6-4-2-25WPM	50.00	106.1	9153.1
12-4-2-25WPM	37.50	22.8	2773.9
9-5-2-25WPM	25.00	52.4	5501.8
5-4-2-25WPM	100.00	0.0	4969.5
		376.4	36670.3

TOTAL MONTH'S VOIDAGE = 376.4
TOTAL MONTH'S REPLACEMENT = 953.5
MONTH'S REPLACEMENT RATIO = 2.53299

TOTAL CUMULATIVE VOIDAGE = 36670.3
TOTAL CUMULATIVE REPLACEMENT = 37892.1
CUMULATIVE REPLACEMENT RATIO = 1.03332

APPENDIX B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17
16
15
8
10
3
UNIT
16
WASKADA
RGE. 25 W.1M.
LEGEND
LOCATION
OIL WELL
WATER INJECTOR
UNIT OUTLINE
ENRON Oil Canada Ltd.
WASKADA AREA, MANITOBA
WASKADA 7-SPOT WATERFLOOD
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WASKADA UNIT 16
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BY: T. McKAY
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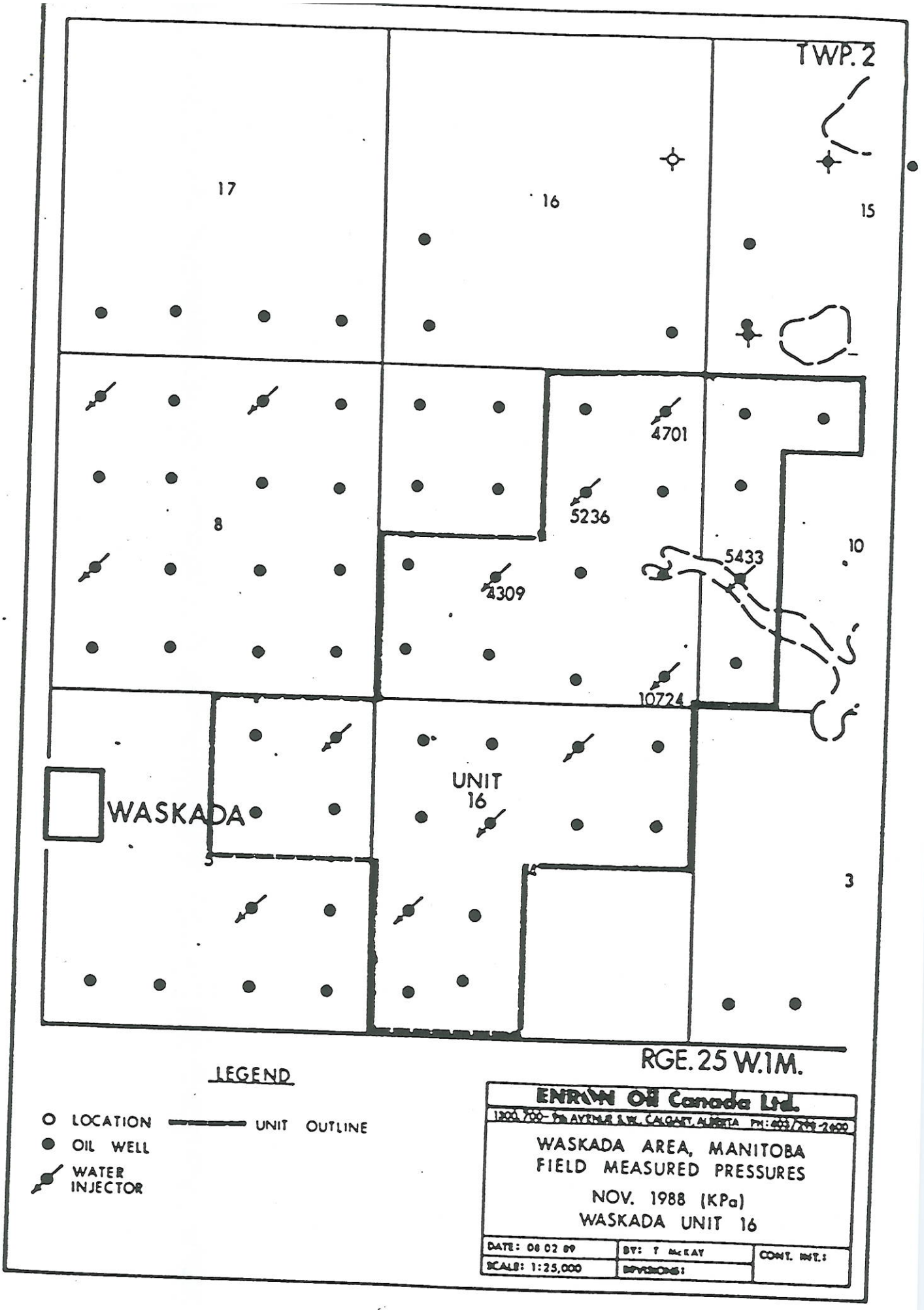
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UNIT
16
WASKADA
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3
RGE. 25 W.1M.
LEGEND
LOCATION
UNIT OUTLINE
OIL WELL
WATER INJECTOR
ENRON Oil Canada Ltd.
WASKADA AREA, MANITOBA
FIELD MEASURED PRESSURES
NOV. 1988 (KPa)
WASKADA UNIT 16
DATE: 08 02 89
BY: T McKAY
CONT. INT.:
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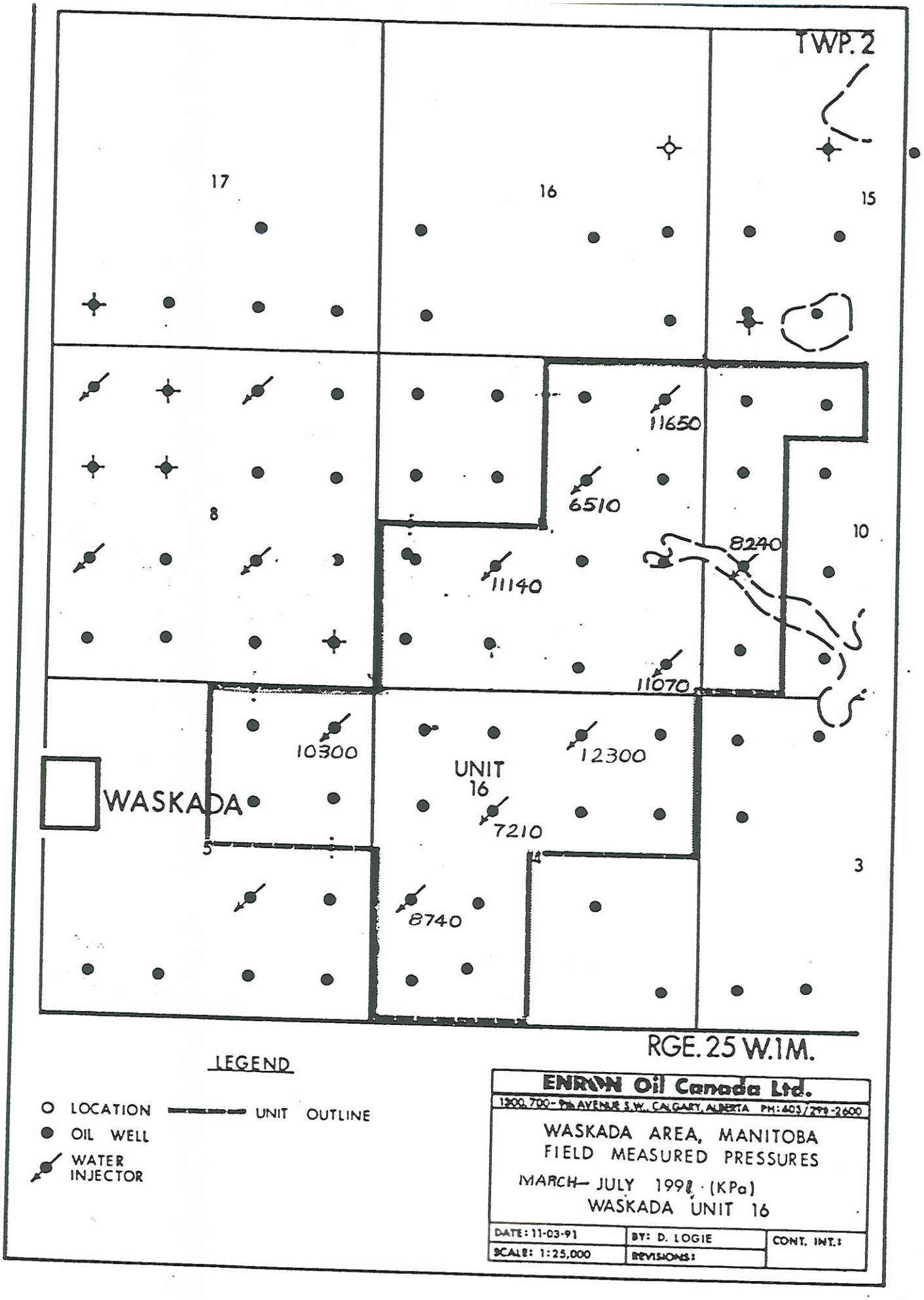
REVISIONS:



LEGEND

- LOCATION
- OIL WELL
- WATER INJECTOR
- UNIT OUTLINE

ENRON Oil Canada Ltd.

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

WASKADA AREA, MANITOBA
FIELD MEASURED PRESSURES
MARCH – JULY 1991 (KPa)
WASKADA UNIT 16

DATE: 11-03-91	BY: D. LOGIE	CONT. INT.:
SCALE: 1:25,000	REVISIONS:	

APPENDIX C

WASKADA UNIT # 16

03/05/92 15:26

Data 8409-9112
Operator :
Field :
Zone/Pool:

Type :

Cum Oil	m3	156877
Cum Gas	E3m3	4679
Cum Water	m3	45399