

**EAST ROUTLEDGE UNIT NO. 1  
WATERFLOOD EOR PROJECT**

**ANNUAL REPORT FOR 2017**

**June 21, 2018**

**Tundra Oil and Gas**

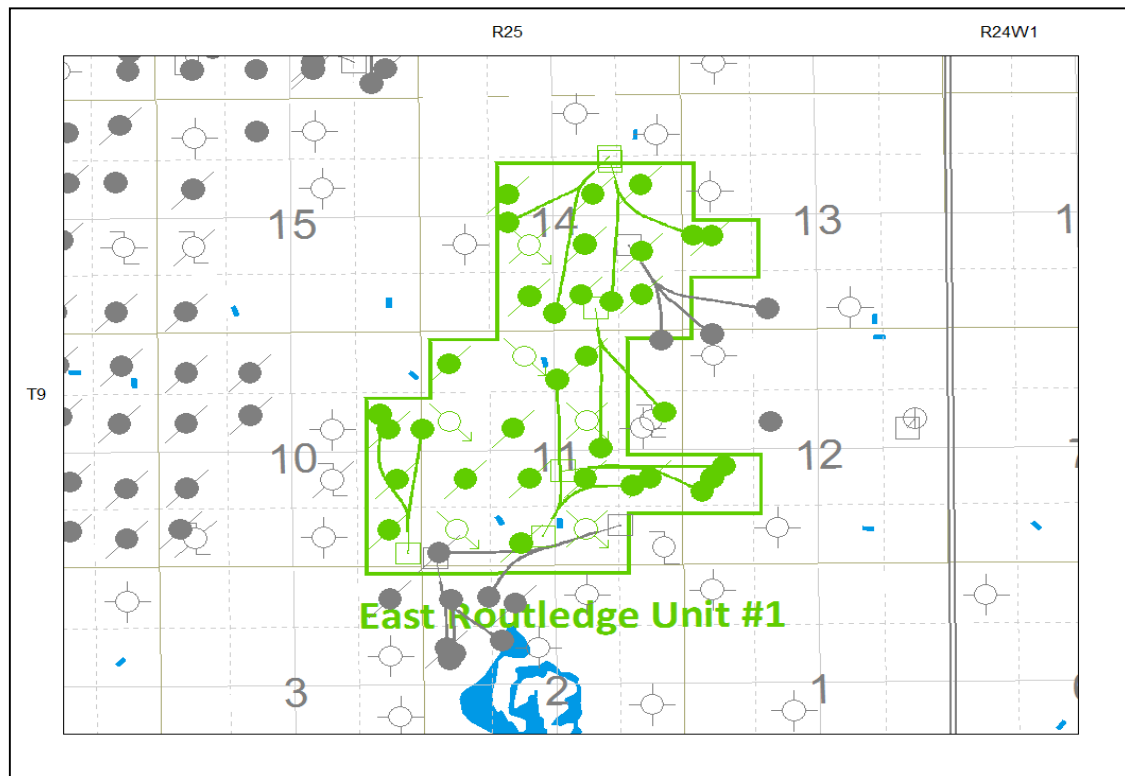
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## **INTRODUCTION**

East Routledge Unit No. 1 Enhanced Oil Recovery (EOR) Waterflood Project was approved under Board Order No. PM 20 effective May 1972 with Samedan Oil of Canada Ltd. as Operator. Tundra Oil and Gas (Tundra) acquired the unit from Topa Resources Ltd. and became operator in April 2002. The EOR project area contains 39 wells in 27 LSDs in Township 9, Range 25 W1 as shown in the figure below. Well list and well status is available in Appendix A.

**Figure 1: East Routledge Unit No. 1 Area Outline**



In accordance with Section 73 of the Manitoba Drilling and Production Regulation, Tundra hereby submits the 2017 Annual Progress Report for East Routledge Unit No. 1 as required by Broad Order No. PM 20.

## **DISCUSSION**

### **Production History**

For the wells included in East Routledge Unit No. 1, production started January 1964 with the 00/07-11-009-25W1/0 well. Oil production peaked at 140 m<sup>3</sup>/d in March 1968. The Unit was producing 6.16 m<sup>3</sup>/d of oil and 510.27 m<sup>3</sup>/d of water in December 2017. The water oil ratio (WOR) averaged 95.4 m<sup>3</sup>/m<sup>3</sup> in 2017. The rates and WOR are plotted in Figure 2.

**Figure 2: East Routledge Unit No. 1 Production/Injection Rates and WOR vs. Time**

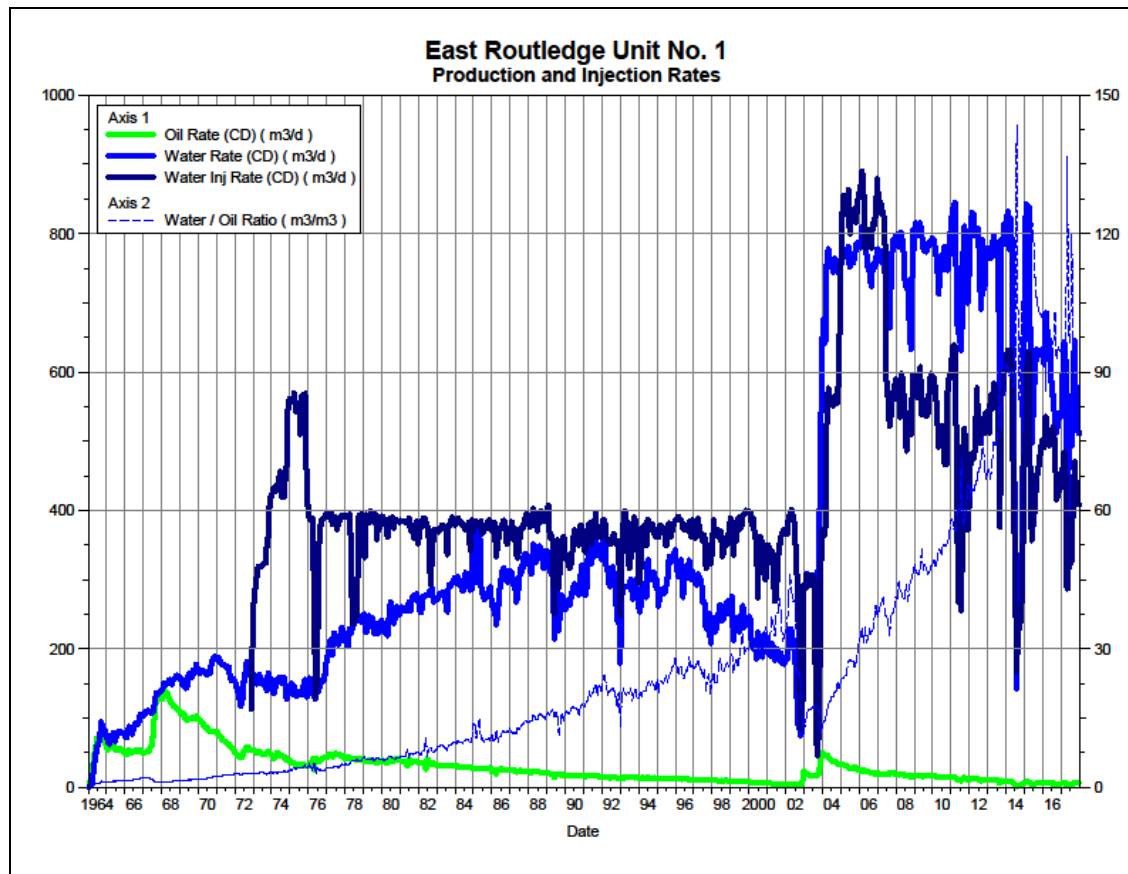
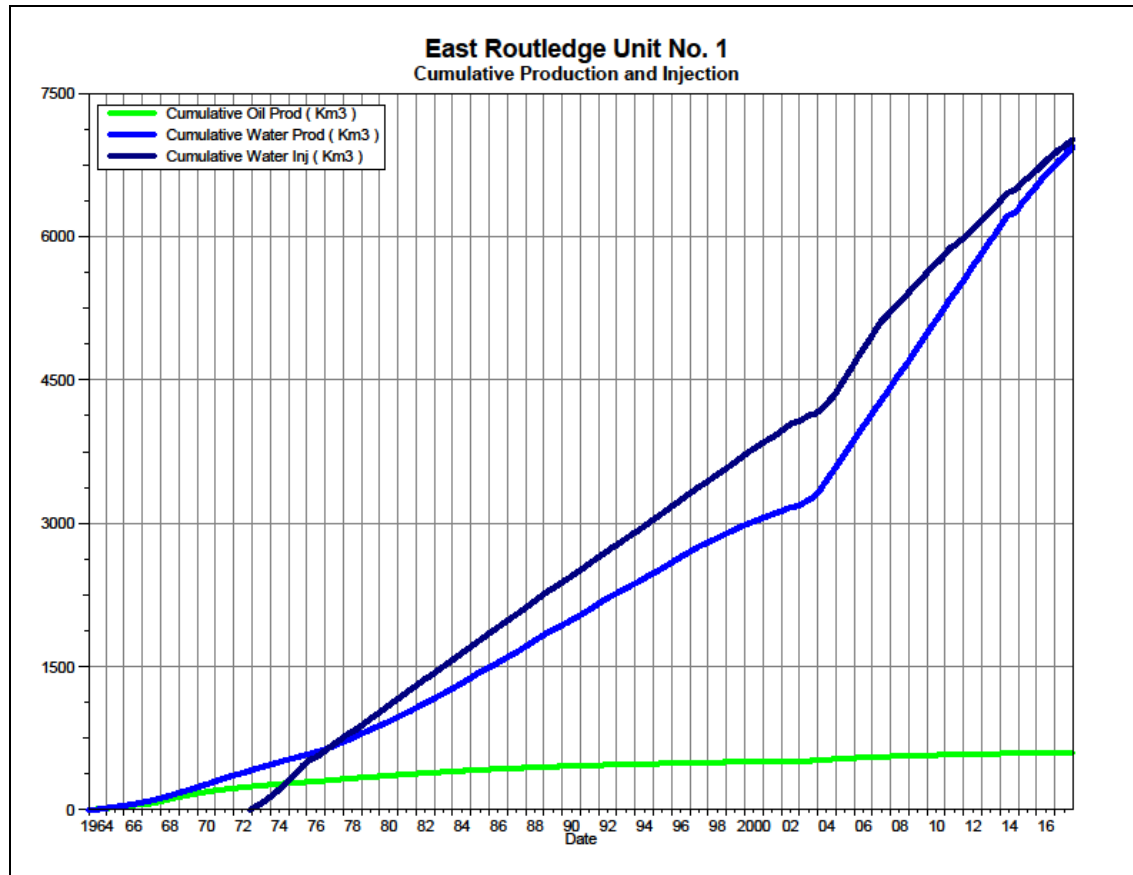


Figure 3 shows the cumulative production for East Routledge Unit No. 1 to the end of December 2017 as 598.0 e<sup>3</sup>m<sup>3</sup> of oil, and 6940.7 e<sup>3</sup>m<sup>3</sup> of water. The cumulative water injected is 7017.0 e<sup>3</sup>m<sup>3</sup>.

**Figure 3: East Routledge Unit No. 1 Cumulative Oil, Water and Water Injected vs. Time**



### **Waterflood History**

As of December 2017, the Unit has 3 active vertical injectors. Water injection started in August 1964. The injector in the northernmost pattern 00/06-14-009-25W1 was abandoned in 2003. An overall summary for each injector pattern is presented in Appendix C.

Any future revisions to the waterflood development or surveillance plan would be based on new production or performance response data, technical studies, or observed reservoir behavior and reserves recovery interpretations.

## **Waterflood EOR Operating Strategy and Performance**

### **Water Source and Quality**

Currently there is no source water being used at East Routledge Unit No. 1. Produced water is re-injected back into the formation after filtration.

### **Injection Wellhead Pressures**

The average monthly wellhead injection pressures for each injection well are summarized in Appendix B, and show all injection pressures since 2003. Average pressure for the injectors is as follows: 3201 kPag for 00/04-11-009-25W1/00, 1995 kPag for 00/12-11-009-25W1/00 and 3146 kPag for 00/14-11-009-25W1/00.

### **Reservoir Pressure**

No reservoir pressure measurements were taken at East Routledge Unit No. 1 in 2017.

### **Well Servicing**

Table 1 lists the maintenance that was required in East Routledge Unit No. 1 in 2017.

**Table 1: Service and Maintenance in East Routledge Unit No. 1**

102.05-13-009-25W1.00	Pump Change	01/16/2017
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### **Voidage Replacement**

Cumulative voidage for East Routledge Unit No. 1 is 0.926 as of December 2017. Tundra hopes to maintain this cumulative VRR, by keeping water injection at its current rate for the foreseeable future. Plots of the Voidage Replacement Ratio on a monthly and cumulative basis for each injection pattern are presented in Appendix D.

### **Waterflood Performance Discussion**

OOIP for East Routledge Unit No. 1 is 1684.0 e<sup>3</sup>m<sup>3</sup>. Current recovery factor within the Unit is approximately 35.5%. Ultimate recovery factor for the East Routledge Unit No. 1 is estimated to approach 40% by decline analysis. The flood has significantly outperformed the predicted estimated ultimate recovery factor of 31.5% predicted in June 1988.

Overall this waterflood has been extremely effective as evident by the significantly high estimated ultimate recovery factor. Two major factors have contributed to the Unit's high recovery. The first is time; this is a mature waterflood that has been in operation and managed relatively well for nearly 40 years. The unit has been producing at watercuts close to 95% for the last 20 years indicating that the flood is in the late stages of its production life, post water breakthrough, etc.

The second major factor that has led to such a high recovery factor has to do with development that occurred in 2002-2003 when horizontal drilling technology was applied to the unit. When horizontal wells were drilled into the unit, unit production increased nearly 10 fold. A portion of the reserves recovered by each horizontal well can be attributed to production acceleration, however, with such a dramatic effect on the units overall production, it is clear that incremental reserves were also encountered when the horizontal wells were drilled. These incremental reserves have also contributed to the Units overall high recovery factor.

Tundra has no definite plans to significantly alter the way in which the waterflood at East Routledge Unit No. 1 is currently operating; i.e. no drilling plans. The focus at this phase in the pools development is really acceleration of long-life post water breakthrough (high WCT) reserves; in the foreseeable future Tundra will focus on smaller capex items such as pump up-sizes and potentially 1-2 electrical submersible pump installations.

## **List of Appendices**

Appendix A: Well Name and Well Status

Appendix B: Monthly Injection Wellhead Pressures

Appendix C: Injection Pattern Summary

Appendix D: Injection Pattern Production/Injection Rates, Cumulative and VRR Plots  
for the following injectors:

00/04-11-009-25W1/00

00/12-11-009-25W1/00

00/06-14-009-25W1/00

## Appendix A

UWI	Surface Location	Well Status
100/01-10-009-25W1/00		ABD Producer
100/08-10-009-25W1/00		ABD Producer
100/09-10-009-25W1/00		ABD Producer
102/09-10-009-25W1/00	01-10-009-25W1	Capable of OIL Prod
102/09-10-009-25W1/02	01-10-009-25W1	Capable of OIL Prod
100/02-11-009-25W1/00		ABD WTR Injection
100/03-11-009-25W1/00		ABD Producer
100/04-11-009-25W1/00		WTR Injection
100/05-11-009-25W1/00		ABD Producer
100/06-11-009-25W1/00		ABD Producer
100/07-11-009-25W1/00		ABD Producer
100/08-11-009-25W1/00		ABD Producer
102/08-11-009-25W1/00	03-11-009-25W1	ABD Producer
103/09-11-009-25W1/02	02-14-009-25W1	Capable of OIL Prod
100/10-11-009-25W1/00		ABD WTR Injection
102/10-11-009-25W1/00	02-14-009-25W1	Capable of OIL Prod
100/11-11-009-25W1/00		ABD Producer
100/12-11-009-25W1/00		WTR Injection
100/13-11-009-25W1/00		ABD Producer
100/14-11-009-25W1/00		WTR Injection
100/15-11-009-25W1/00		ABD Producer
102/15-11-009-25W1/02	03-11-009-25W1	ABD Producer
100/05-12-009-25W1/00		ABD Producer
102/05-12-009-25W1/00	07-11-009-25W1	Capable of OIL Prod
103/05-12-009-25W1/02	07-11-009-25W1	Capable of OIL Prod
100/05-13-009-25W1/00		ABD Producer
102/05-13-009-25W1/00	10-14-009-25W1	Capable of OIL Prod
100/01-14-009-25W1/00		ABD Producer
100/02-14-009-25W1/00		ABD Producer
102/02-14-009-25W1/00	10-14-009-25W1	Capable of OIL Prod
102/02-14-009-25W1/02	10-14-009-25W1	Capable of OIL Prod
100/03-14-009-25W1/00		ABD Producer
100/06-14-009-25W1/00		ABD WTR Injection
102/06-14-009-25W1/02	10-14-009-25W1	Capable of OIL Prod
100/07-14-009-25W1/00		ABD Producer
100/08-14-009-25W1/00		ABD Producer
100/09-14-009-25W1/00		ABD Producer
100/10-14-009-25W1/00		ABD Producer
100/11-14-009-25W1/00		ABD Producer

## Appendix B

Month	Injection Pressure			
	100/04-11	100/12-11	100/14-11	100/06-14
Jan-06	3148	2061	5619	-
Feb-06	3357	2636	5404	-
Mar-06	3337	3171	5687	-
Apr-06	3027	2933	5193	-
May-06	3303	2039	5598	-
Jun-06	3394	2000	6033	-
Jul-06	3531	2000	6045	-
Aug-06	3332	2000	5929	-
Sep-06	3448	2000	6107	-
Oct-06	3624	2000	6194	-
Nov-06	3600	2000	6000	-
Dec-06	3600	1971	6058	-
Jan-07	3600	1900	6200	-
Feb-07	3600	1900	6200	-
Mar-07	3584	1900	6200	-
Apr-07	3475	1900	6200	-
May-07	3431	1958	6084	-
Jun-07	4270	2125	5793	-
Jul-07	4685	2310	5368	-
Aug-07	4027	2121	5076	-
Sep-07	3955	2100	5200	-
Oct-07	4202	2100	5626	-
Nov-07	4193	2100	5567	-
Dec-07	4215	2194	5597	-
Jan-08	4203	2200	5600	-
Feb-08	4179	2200	5510	-
Mar-08	4203	2200	5413	-
Apr-08	4207	2200	5513	-
May-08	4052	2200	5426	-
Jun-08	3940	2190	5257	-
Jul-08	3400	2155	4423	-
Aug-08	3865	2200	5116	-
Sep-08	3857	2137	4850	-
Oct-08	3965	2161	4416	-
Nov-08	4523	2200	5223	-
Dec-08	4658	2200	5200	-
Jan-09	4210	2200	5035	-
Feb-09	4014	2200	4882	-
Mar-09	4274	2200	5303	-
Apr-09	4253	2200	5400	-
May-09	3723	2168	4790	-
Jun-09	3753	2287	4393	-
Jul-09	3845	2284	4445	-
Aug-09	3974	2200	4348	-
Sep-09	4000	2200	4593	-
Oct-09	4010	2200	4400	-
Nov-09	4110	2200	4353	-
Dec-09	4097	2200	4394	-

Month	Injection Pressure			
	100/04-11	100/12-11	100/14-11	100/06-14
Jan-10	4119	2200	4400	-
Feb-10	4007	2200	4400	-
Mar-10	4016	2266	4406	-
Apr-10	4057	2430	4437	-
May-10	4074	2465	4432	-
Jun-10	4123	2430	4433	-
Jul-10	4042	2223	4342	-
Aug-10	3758	1803	3839	-
Sep-10	3753	1920	4300	-
Oct-10	4184	1923	4865	-
Nov-10	4230	1900	5033	-
Dec-10	4158	1900	5000	-
Jan-11	4435	1900	5097	-
Feb-11	4518	1900	5071	-
Mar-11	4590	1900	5200	-
Apr-11	4213	1900	4360	-
May-11	3616	1900	3800	-
Jun-11	3200	1900	3800	-
Jul-11	3200	1900	3800	-
Aug-11	4139	1900	3800	-
Sep-11	4800	1900	3800	-
Oct-11	4742	1900	3800	-
Nov-11	4260	1900	3800	-
Dec-11	4455	1900	3800	-
Jan-12	4768	1900	3800	-
Feb-12	4972	1900	3800	-
Mar-12	5013	1900	3800	-
Apr-12	4760	1900	3800	-
May-12	4135	1900	3761	-
Jun-12	3833	1900	3800	-
Jul-12	3752	1900	3658	-
Aug-12	4006	1900	3781	-
Sep-12	4387	1900	3800	-
Oct-12	4400	1900	3800	-
Nov-12	4400	1900	3800	-
Dec-12	4400	1900	3800	-
Jan-13	4400	1900	3800	-
Feb-13	4400	1900	3800	-
Mar-13	4400	1900	3800	-
Apr-13	4400	1900	3800	-
May-13	4400	1900	3800	-
Jun-13	4400	1900	3800	-
Jul-13	4400	1900	3800	-
Aug-13	4400	1900	3800	-
Sep-13	4400	1900	3800	-
Oct-13	4400	1900	3800	-
Nov-13	4400	1900	3800	-
Dec-13	4400	1900	3800	-

Month	Injection Pressure			
	100/04-11	100/12-11	100/14-11	100/06-14
Jan-14	4400	1900	3800	-
Feb-14	4400	1900	3800	-
Mar-14	4450	2000	3750	-
Apr-14	4450	2000	3750	-
May-14	4450	2000	3750	-
Jun-14	4450	2000	3750	-
Jul-14	4450	2000	3750	-
Aug-14	4450	2000	3750	-
Sep-14	4450	2000	3750	-
Oct-14	4450	2000	3750	-
Nov-14	4450	2000	3750	-
Dec-14	4450	2000	3750	-
Jan-15	4248	1919	3952	-
Feb-15	4200	1900	4000	-
Mar-15	4200	1900	4000	-
Apr-15	4200	1997	4000	-
May-15	4200	2000	3826	-
Jun-15	4200	2000	3023	-
Jul-15	4200	2000	3645	-
Aug-15	3981	1977	3890	-
Sep-15	3800	2000	3800	-
Oct-15	3677	1969	3800	-
Nov-15	3600	1950	3800	-
Dec-15	3600	1950	3800	-
Jan-16	3600	1940	3800	-
Feb-16	3600	1900	3800	-
Mar-16	3600	1900	3800	-
Apr-16	3600	1900	3800	-
May-16	3581	1918	3626	-
Jun-16	4182	2010	3670	-
Jul-16	4185	1994	3987	-
Aug-16	4000	2000	4000	-
Sep-16	4000	2000	4000	-
Oct-16	4000	2000	4000	-
Nov-16	4000	2000	4000	-
Dec-16	4000	2000	4000	-
Jan-17	3981	1997	3948	-
Feb-17	3700	1950	3200	-
Mar-17	3700	1950	3200	-
Apr-17	3700	1983	2720	-
May-17	3700	2050	2032	-
Jun-17	1500	2008	3377	-
Jul-17	950	2000	3190	-
Aug-17	2532	2000	3419	-
Sep-17	3980	2000	3750	-
Oct-17	3634	2000	3155	-
Nov-17	3633	2000	2957	-
Dec-17	3406	2000	2806	-

## Appendix C

### East Routledge Unit No. 1 Injector Pattern Summary as of December 2017

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## **Appendix D**

### **Rates and VRR Plots**

# Pattern: 00/04-11-009-25Inj Set: ERoutledgeUnit#1

Oil Formation Vol Factor : 1.07100 m3/m3

Oil Rate (CD) : 0.83 m3/d

Water Formation Vol Factor : 1.00150 m3/m3

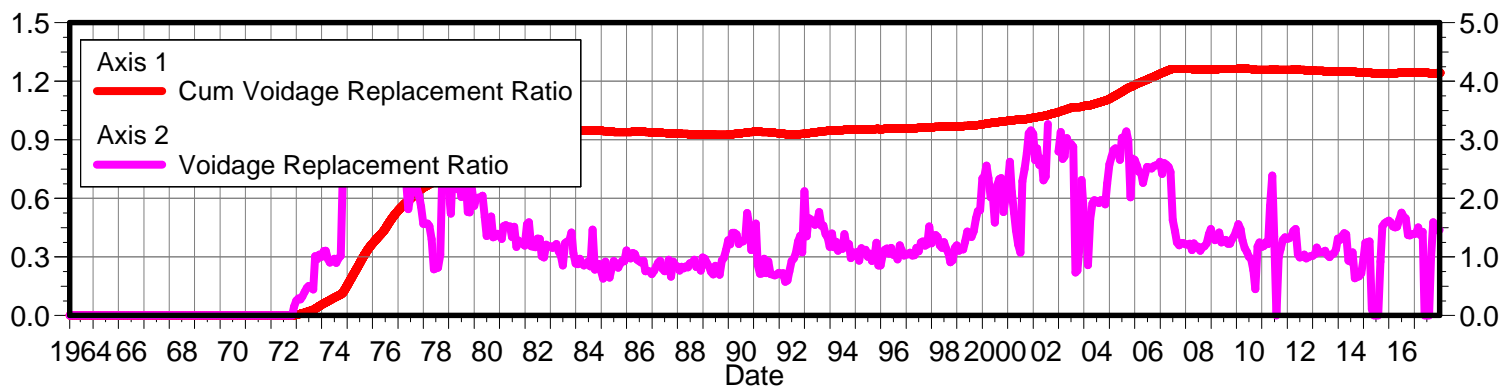
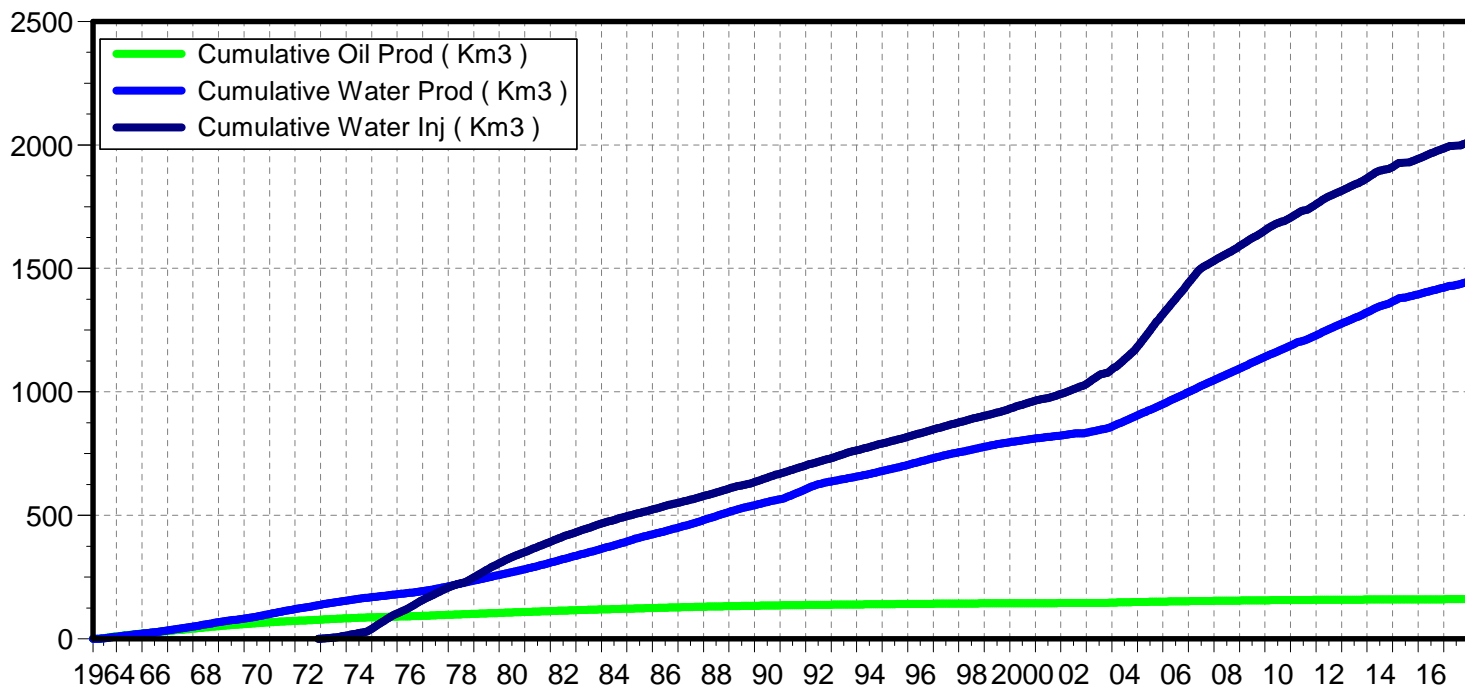
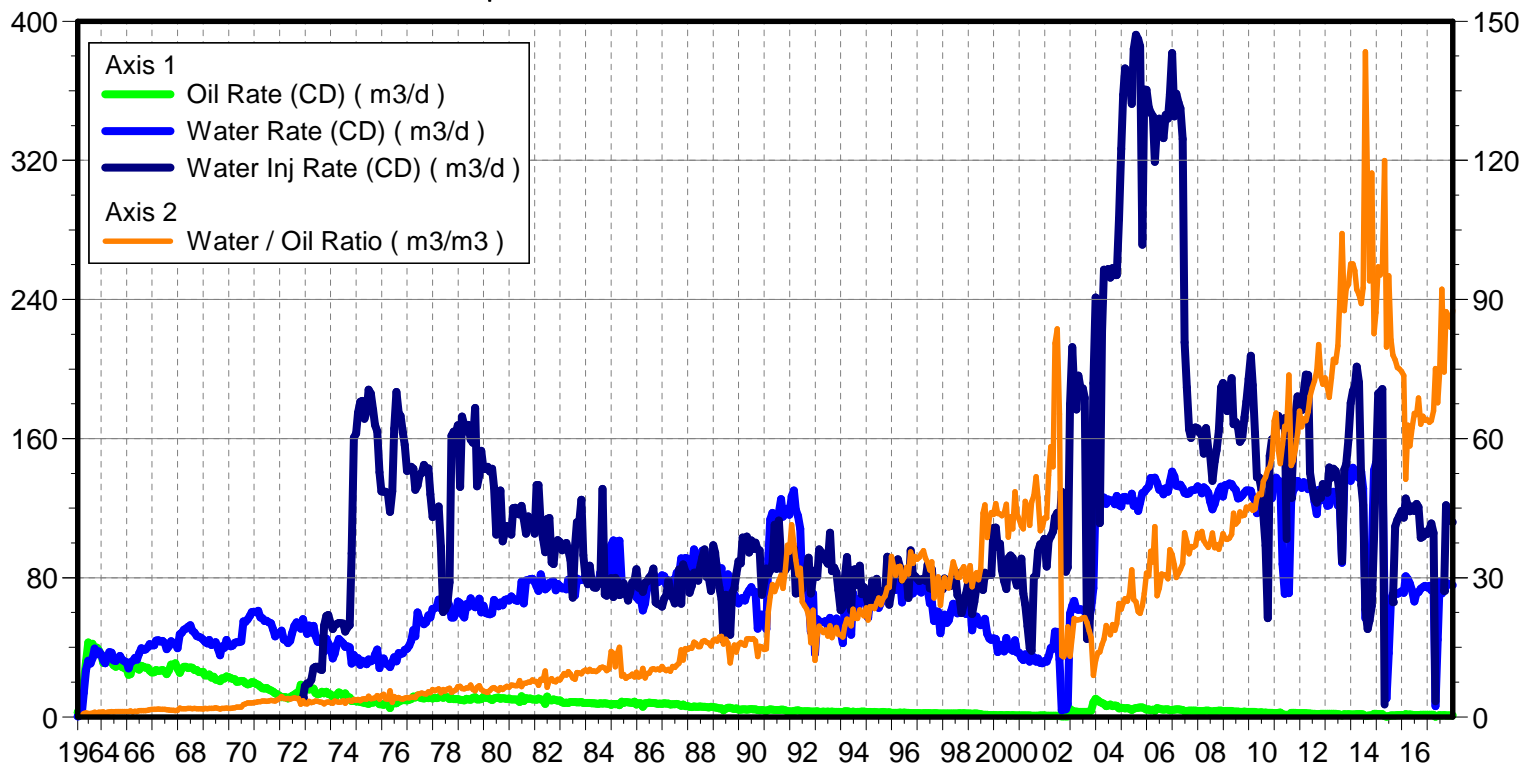
June 20, 2018

Water Rate (CD) : 74.65 m3/d

Water / Oil Ratio : 93.84 m3/m3

Operator: TUNDRA\_OIL\_AND\_GAS\_PARTNER

Water Inj Rate (CD) : 112.20 m3/d



# Pattern: 00/12-11-009-25Inj Set: ERoutledgeUnit#1

Oil Formation Vol Factor : 1.07100 m3/m3

Water Formation Vol Factor : 1.00150 m3/m3

Water / Oil Ratio : 84.79 m3/m3

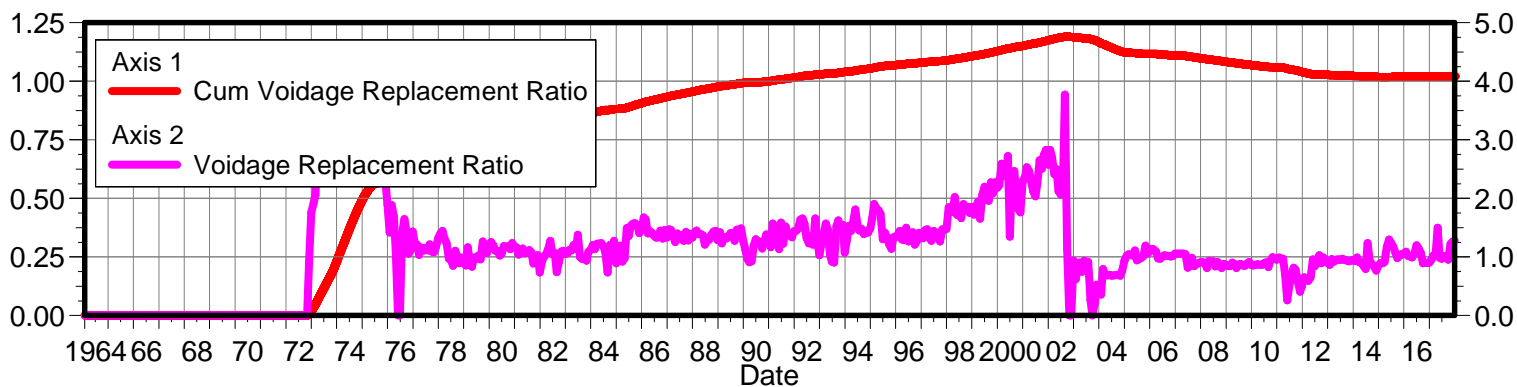
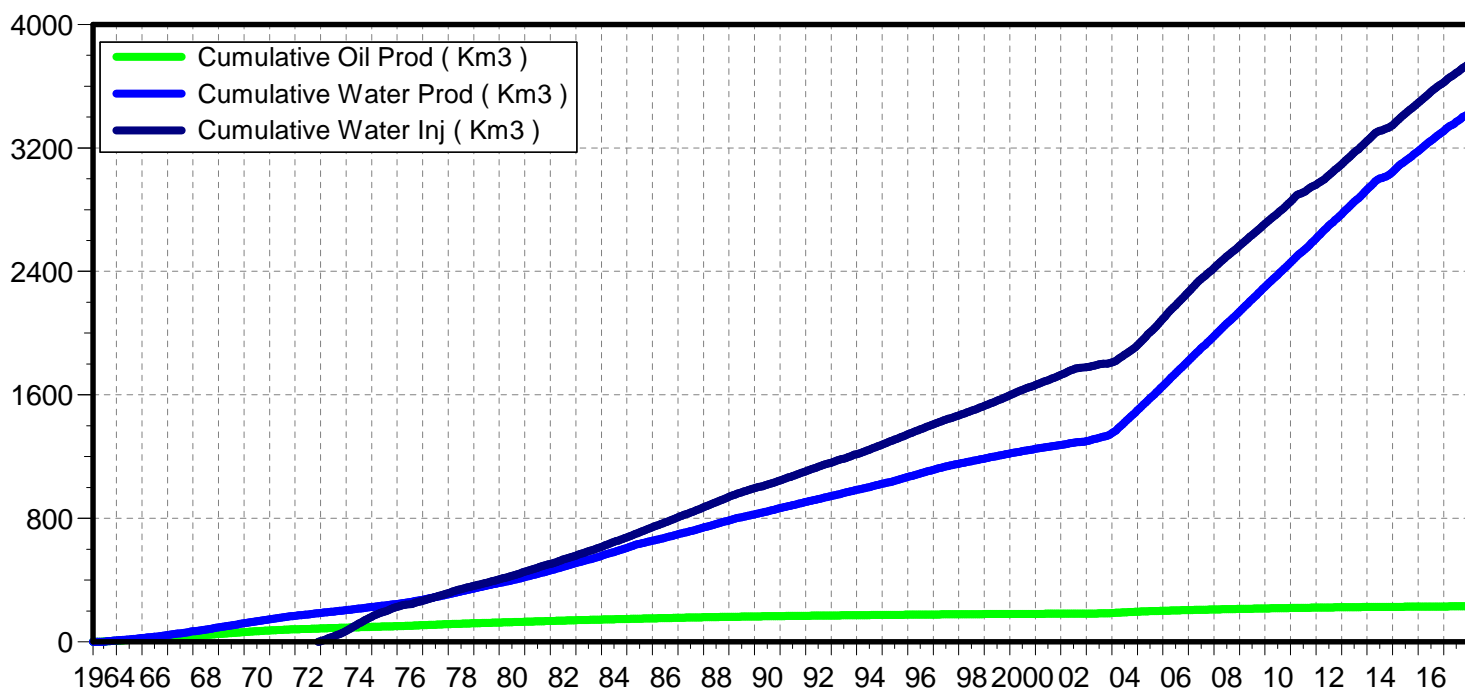
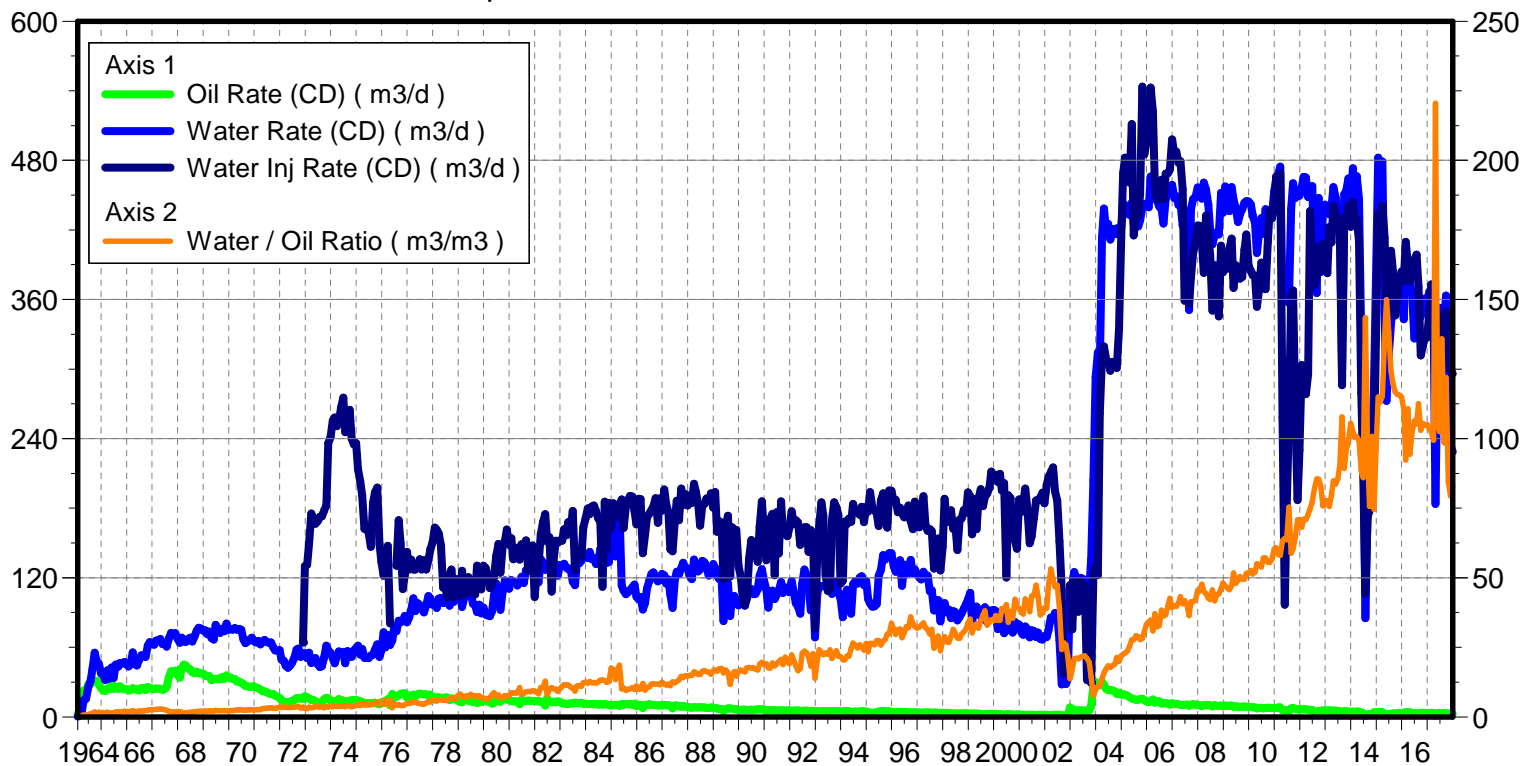
June 20, 2018

Operator: TUNDRA\_OIL\_AND\_GAS\_PARTNER

Oil Rate (CD) : 2.84 m3/d

Water Rate (CD) : 232.46 m3/d

Water Inj Rate (CD) : 288.85 m3/d



# Pattern: 00/06-14-009-25Inj Set: ERoutledgeUnit#1

Oil Formation Vol Factor : 1.07100 m3/m3

Water Formation Vol Factor : 1.00150 m3/m3

Water / Oil Ratio : 81.40 m3/m3

June 20, 2018

Operator: TUNDRA\_OIL\_AND\_GAS\_PARTNER

Oil Rate (CD) : 2.28 m3/d

Water Rate (CD) : 200.53 m3/d

Water Inj Rate (CD) : 5.05 m3/d

