

**KOLA UNIT NO. 2**  
**WATERFLOOD EOR PROJECT**  
  
**ANNUAL REPORT FOR 2016**

**July 31, 2017**

**Tundra Oil and Gas Partnership**

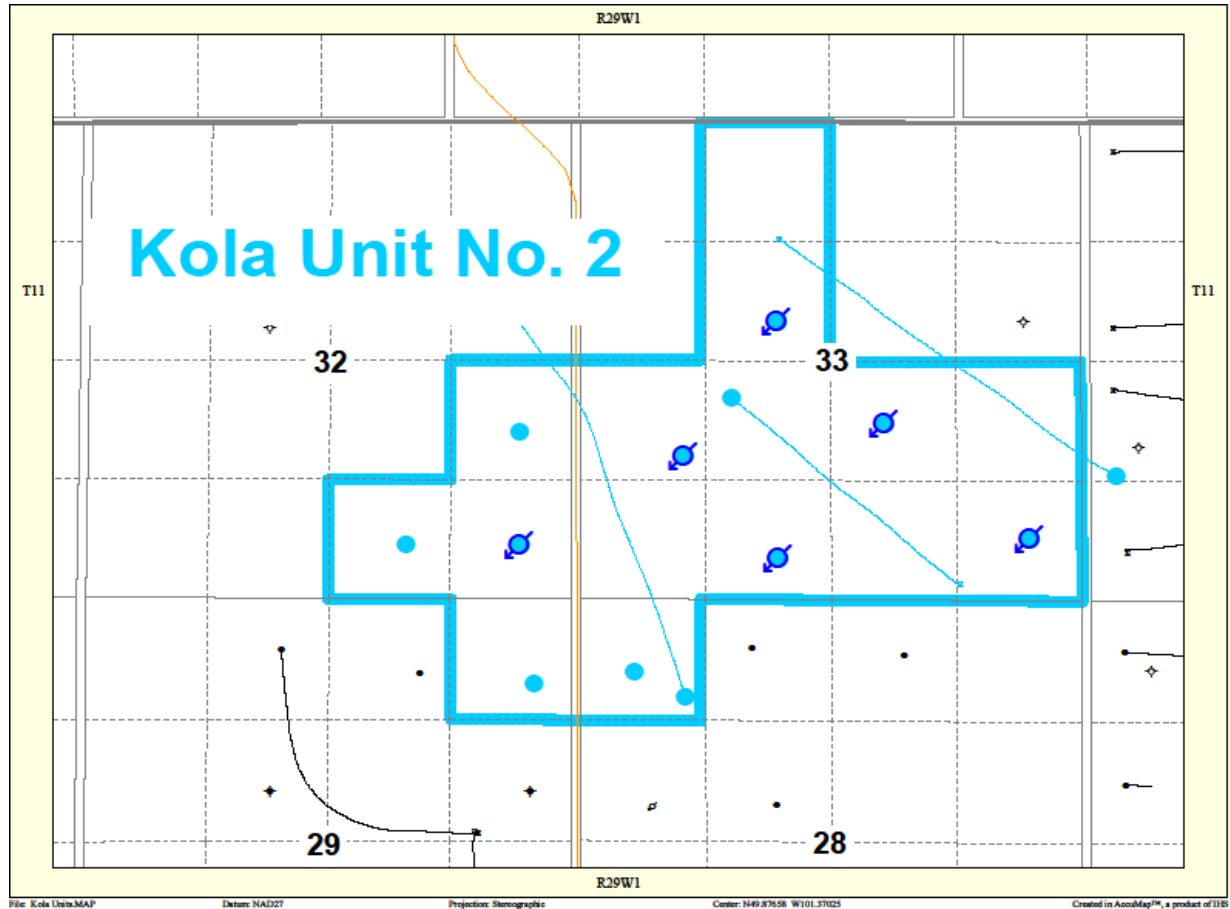
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## **INTRODUCTION**

Kola Unit No. 2 Enhanced Oil Recovery (EOR) Waterflood Project was approved under Waterflood Order No. 4 effective December 1, 1996 with Tundra Oil and Gas Ltd. as Operator. The EOR project area contains 13 wells in 15 LSDs in Township 10, Range 29 W1 as shown in the figure below.

**Figure 1: Kola Unit No. 2 Area Outline**



In accordance with Section 73 of the Manitoba Drilling and Production Regulation, Tundra hereby submits the 2016 Annual Progress Report for Kola Unit No. 2 as required by Waterflood Order No 4.

## DISCUSSION

### Production History

For the wells included in Kola Unit No. 2, production started March 1993 with the 00/16-29-010-29W1/0 well. Oil production peaked at 42.7 m<sup>3</sup>/d in March of 1998. The Unit was producing 18.27 m<sup>3</sup>/d of oil and 23.54 m<sup>3</sup>/d of water in December 2016. The oil production rate, injection rate, and WOR during each month for each injection pattern is presented in Appendix D. The rates and WOR are plotted in Figure 2.

**Figure 2: Kola Unit No. 2 Production/Injection Rates and WOR vs. Time**

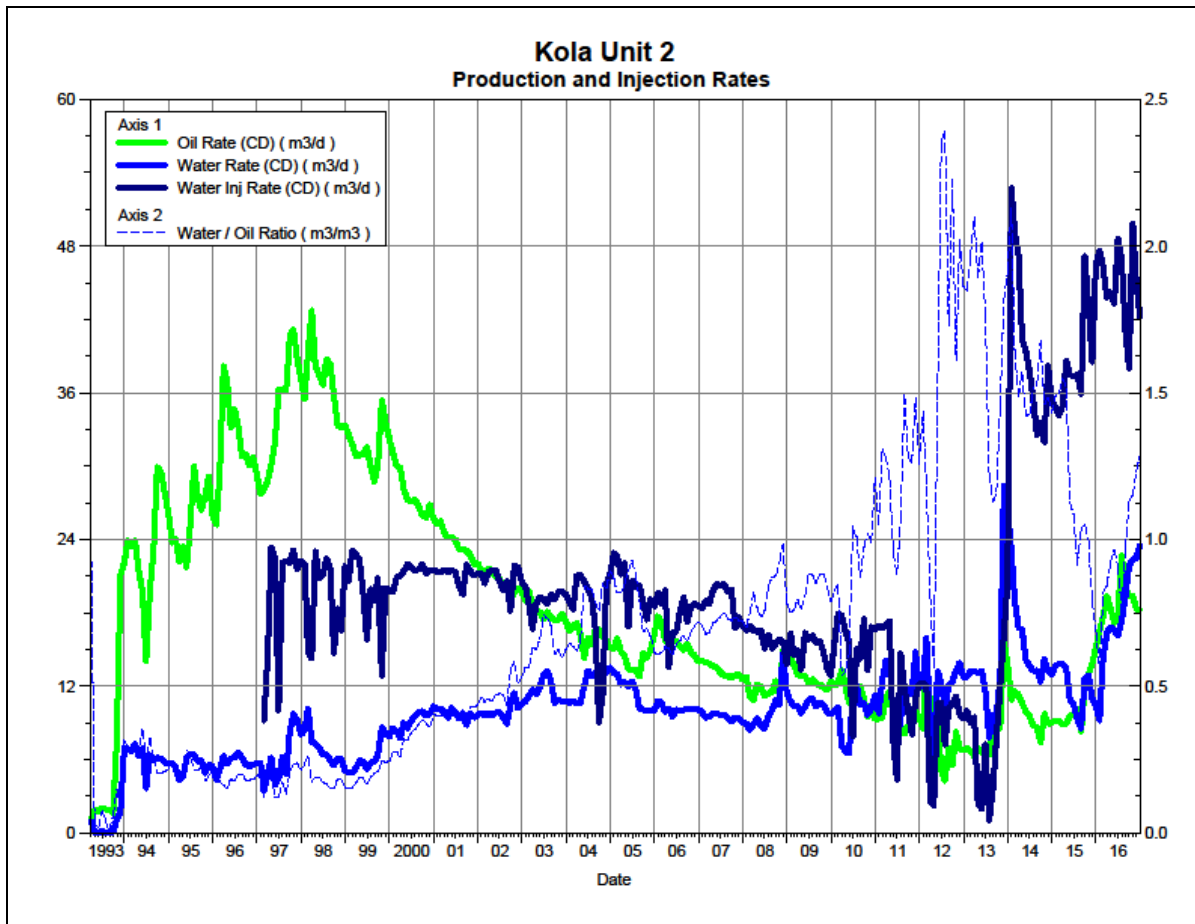
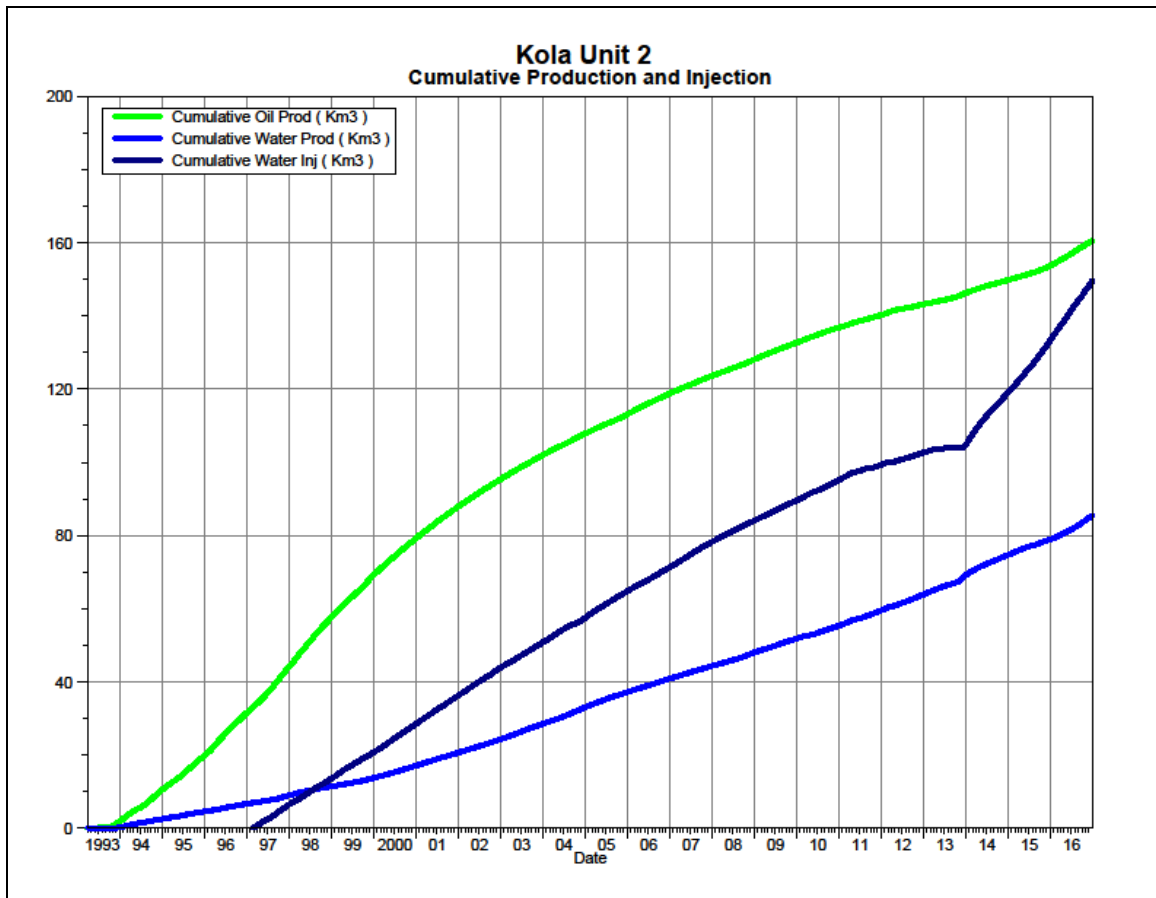


Figure 3 shows the cumulative production for Kola Unit No. 2 to the end of December 2016 as 160.6 e<sup>3</sup>m<sup>3</sup> of oil, and 85.6 e<sup>3</sup>m<sup>3</sup> of water. The cumulative water injected is 149.6 e<sup>3</sup>m<sup>3</sup>. The cumulative volume of oil, and water produced and fluid injected for each injection pattern is presented in Appendix D.

**Figure 3: Kola Unit No. 2 Cumulative Oil, Water and Water Injected vs Time**



### **Waterflood History**

As of December 2016, the Unit has 6 active vertical injectors and 3 injection patterns in place. Water injection started in February 1997. Until November 2013, water had only been injected through the well at 00/01-32-010-29W1/0. In December 2013, 5 vertical producers were converted to injectors to maximize oil recovery and sweep efficiency between wells. In addition, 2 horizontal producers were drilled at 02/13-28-010-29W1/0 and 02/05-34-010-29W1/0. The 02/13-28 well was left openhole and the 02/05-34 well was fracture stimulated and is a cemented liner completion. An overall summary for each injector pattern is presented in Appendix A.

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**

Injected fluid consisted of produced water from the Lodgepole formation, from the unit and surrounding area until November 2013. Injection water for Kola Unit No. 2 is now being provided from the Jurassic source water well at 100/02-25-010-29W1 (2-25). Tundra received approval from the Petroleum Branch in March 2013 to use the 2-25 well as a source water well for waterflood operations. Jurassic-sourced water is pumped from the 2-25 source well to the Daly 12-24-10-29 battery, where it is filtered to 50 microns and then pumped up to injection system pressure.

### **Injection Wellhead Pressures**

The average monthly wellhead injection pressures are summarized in Appendix C, and shows all injection pressures since 2003. The average injection pressure for the Unit was 5563 kPag in 2016.

### **Reservoir Pressure**

Where practical, Tundra is committed to collecting pressure data from newly drilled wells. For Kola Unit No. 2, pressure data for the openhole 02/13-28-010-29W1 well is available. Corrected to a common datum of -450 m SS, for comparison with other units in the area, the reservoir pressure is 2916 kPa(a) (Appendix B).

Prior to conversion, Tundra identified the 00/05-33 and 00/07-33 vertical wells, which were drilled in 1996 and 1998 respectively, as good candidates for collecting pressure data. In November 2013, the 00/05-33 and 00/07-33 vertical wells were shut-in and pressure buildup data was collected. The reservoir pressure for 00/05-33 was 1577 kPa(a) suggesting a depleted reservoir. The quality of the data collected from the 00/07-33 well was questionable and therefore not analyzed.

### **Well Servicing**

Table 1 lists the maintenance that was required in Kola Unit No. 2 in 2016.

**Table 1: Service and Maintenance in Kola Unit No. 2**

<b>UWI</b>	<b>Date</b>	<b>Workover</b>
100.08-32-010-29W1.00	12-Aug-16	Pump Change

### **Voidage Replacement**

Cumulative voidage for the Kola Unit No. 2 was 0.581 in December 2016. Plots of the Voidage Replacement Ratio on a monthly and cumulative basis for each injection pattern is presented in Appendix D.

### **Waterflood Performance Discussion**

The OOIP of Kola Unit No. 2 is estimated at 1,190.0 e<sup>3</sup>m<sup>3</sup>. The recovery factor was 13.5% based on 160.56 e<sup>3</sup>m<sup>3</sup> of cumulative oil recovered to the end of 2016. The ultimate expected recoverable reserve based on decline analysis is 238.5 e<sup>3</sup>m<sup>3</sup> or an ultimate recovery factor of 20.0%.

The overall performance of this waterflood has been good as indicated by an expected recovery factor of 20.0%, beyond the primary recovery factor. Waterflood response is clearly evident in wells in the western part of the Unit. It should be easy to maintain a cumulative voidage of unity. There have been no water breakthrough issues.

Trends in production are very stable and mature. It is expected that the present oil trend starts to have a higher decline in the next 2-3 years, when the sweep efficiency starts to deteriorate and signs of breakthrough are apparent. The waterflood performance will likely be improved significantly by the addition of the 5 vertical injectors in the east part of the Unit where recovery has been enhanced mainly by the addition of a horizontal well. Also, facility enhancements in the area may play a role in future optimization.

## **List of Appendices**

Appendix A: Injection Pattern Summary

Appendix B: Reservoir Pressure Summary

Appendix C: Average Monthly Injection Wellhead Pressures

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

00/01-32-010-29W1/0

00/05-33-010-29W1/0

00/07-33-010-29W1/0



## Appendix A

**Kola Unit No. 2 Pattern Summary as of December 2016**[illegible]

**APPENDIX B**

**Kola Unit No. 2 - Pressure Summary**

Location	Test Date	Final Pressure (kPaa)	MPP (mTVD)	KB	Datum Depth	Gradient	Pressure @ -450 masl	Comments
102/13-28-010-29W1/0	Sep 25 - Oct 5, 2013	1893.74	863.03	537.00	-450	8.25	2916	

## Appendix C

### Average Monthly Injection Pressure (kPag)

	Injection Pressure		Injection Pressure	Injection Pressure							Injection Pressure						
Month	100/01-32	Month	100/01-32	Month	100/01-32	100/01-33	100/03-33	100/05-33	100/07-33	100/11-33	Month	100/01-32	100/01-33	100/03-33	100/05-33	100/07-33	100/11-33
Jan-02	-	Jan-06	70806	Jan-10	11123	-	-	-	-	-	Jan-14	6681	1217	-50	-62	-34	696
Feb-02	-	Feb-06	10377	Feb-10	10461	-	-	-	-	-	Feb-14	6779	2914	-64	-67	341	2376
Mar-02	-	Mar-06	10549	Mar-10	10516	-	-	-	-	-	Mar-14	6800	3861	138	-81	1600	3712
Apr-02	-	Apr-06	9327	Apr-10	10530	-	-	3998	-	-	Apr-14	6800	3998	1136	-83	2456	3938
May-02	-	May-06	9342	May-10	10477	-	-	-	-	-	May-14	6800	3987	2539	-78	3244	3405
Jun-02	-	Jun-06	10483	Jun-10	5193	-	-	-	-	-	Jun-14	6800	4001	3109	-54	3713	3972
Jul-02	-	Jul-06	10529	Jul-10	9852	-	-	-	-	-	Jul-14	6800	4002	3721	-66	3986	3718
Aug-02	5529	Aug-06	10465	Aug-10	9461	-	-	-	-	-	Aug-14	6800	4000	3426	-85	3956	3933
Sep-02	10082	Sep-06	10440	Sep-10	10357	-	-	-	-	-	Sep-14	6800	4005	3998	-84	3999	3916
Oct-02	10082	Oct-06	10263	Oct-10	10187	-	-	-	-	-	Oct-14	6800	3999	4001	-85	3996	4005
Nov-02	10082	Nov-06	10599	Nov-10	10654	-	-	3998	-	-	Nov-14	6760	3998	3999	-89	4002	3930
Dec-02	10082	Dec-06	10516	Dec-10	10723	-	-	-	-	-	Dec-14	6710	3998	3737	-88	3965	3591
Jan-03	9998	Jan-07	10574	Jan-11	10152	-	-	-	-	-	Jan-15	6800	4001	3759	-93	4001	3818
Feb-03	10097	Feb-07	10468	Feb-11	10108	-	-	-	-	-	Feb-15	6800	3433	3751	-92	4000	3899
Mar-03	10144	Mar-07	10300	Mar-11	10216	-	-	3283	-	-	Mar-15	6800	3283	3868	112	4000	1098
Apr-03	10061	Apr-07	10347	Apr-11	10100	-	-	-	-	-	Apr-15	6665	3996	4000	229	3999	3801
May-03	9940	May-07	10301	May-11	9526	-	-	-	-	-	May-15	6500	4000	4002	581	3997	3630
Jun-03	9940	Jun-07	10301	Jun-11	5603	-	-	-	-	-	Jun-15	6772	3999	3999	980	4002	3581
Jul-03	9940	Jul-07	10333	Jul-11	6871	-	-	4000	3997	-	Jul-15	6802	4000	3997	934	4002	3899
Aug-03	9940	Aug-07	10300	Aug-11	9632	-	-	-	-	-	Aug-15	6232	2776	3994	1065	4448	2428
Sep-03	9913	Sep-07	10301	Sep-11	0	-	-	-	-	-	Sep-15	6665	5752	4004	1322	5382	4562
Oct-03	9825	Oct-07	10301	Oct-11	8397	-	-	5894	-	-	Oct-15	6465	5894	3604	1244	5570	5533
Nov-03	9825	Nov-07	10221	Nov-11	9000	-	-	-	-	-	Nov-15	2457	5998	3847	1724	6000	5935
Dec-03	9825	Dec-07	10200	Dec-11	9000	-	-	-	-	-	Dec-15	1547	5739	1075	1550	5999	5079
Jan-04	9825	Jan-08	10200	Jan-12	8935	-	-	-	-	-	Jan-16	4612	6001	4328	1730	5931	5984
Feb-04	9825	Feb-08	10180	Feb-12	8900	-	-	-	4498	-	Feb-16	4744	5999	4498	1848	5594	5999
Mar-04	9825	Mar-08	10101	Mar-12	8900	-	-	-	-	-	Mar-16	5082	5961	4862	1914	5715	5927
Apr-04	9825	Apr-08	10124	Apr-12	8900	-	-	-	-	-	Apr-16	5463	5997	4981	2152	5984	5967
May-04	9825	May-08	10190	May-12	8900	-	-	-	-	-	May-16	5388	5986	4990	2362	5974	5965
Jun-04	9825	Jun-08	10200	Jun-12	8900	-	-	-	-	-	Jun-16	5399	5963	5744	3195	5920	5921
Jul-04	9825	Jul-08	10200	Jul-12	8900	-	-	-	-	-	Jul-16	5422	5039	5824	3660	6002	5933
Aug-04	9825	Aug-08	10135	Aug-12	8661	-	-	-	-	-	Aug-16	5304	1878	5999	3987	5995	2473
Sep-04	10182	Sep-08	9934	Sep-12	1500	-	-	2044	-	-	Sep-16	5435	2044	1450	3980	5981	5979
Oct-04	9927	Oct-08	10001	Oct-12	1500	-	-	-	-	-	Oct-16	5478	5994	5585	4003	6000	5933
Nov-04	9190	Nov-08	10001	Nov-12	1500	-	-	-	-	-	Nov-16	5485	5997	5998	4000	6000	6003
Dec-04	9190	Dec-08	10001	Dec-12	1500	-	-	-	-	-	Dec-16	5469	6001	5999	4001	5907	6000
Jan-05	9190	Jan-09	10001	Jan-13	1500	-	-	-	-	-							
Feb-05	9659	Feb-09	10001	Feb-13	1500	-	-	-	-	-							
Mar-05	10200	Mar-09	10001	Mar-13	1500	-	-	-	-	-							
Apr-05	10200	Apr-09	10001	Apr-13	1500	-	-	-	-	-							
May-05	10200	May-09	10001	May-13	1500	-	-	-	-	-							
Jun-05	10173	Jun-09	10007	Jun-13	6458	-	-	-	-	-							
Jul-05	10369	Jul-09	10201	Jul-13	10250	-	-	-	-	-							
Aug-05	10526	Aug-09	10200	Aug-13	10250	-	-	-	-	-							
Sep-05	10727	Sep-09	10200	Sep-13	10250	-	-	-	-	-							
Oct-05	10800	Oct-09	10284	Oct-13	10250	-	-	-	-	-							
Nov-05	20120	Nov-09	10487	Nov-13	10250	-	-	-	-	-							
Dec-05	104000	Dec-09	11032	Dec-13	8431	-17	-39	-45	-23	20							

# Pattern: 00/01-32-010-29Inj Set: KolaUnit#2

Oil Formation Vol Factor : 1.07100 m3/m3

Water Formation Vol Factor : 1.00150 m3/m3

Water / Oil Ratio : 6.91 m3/m3

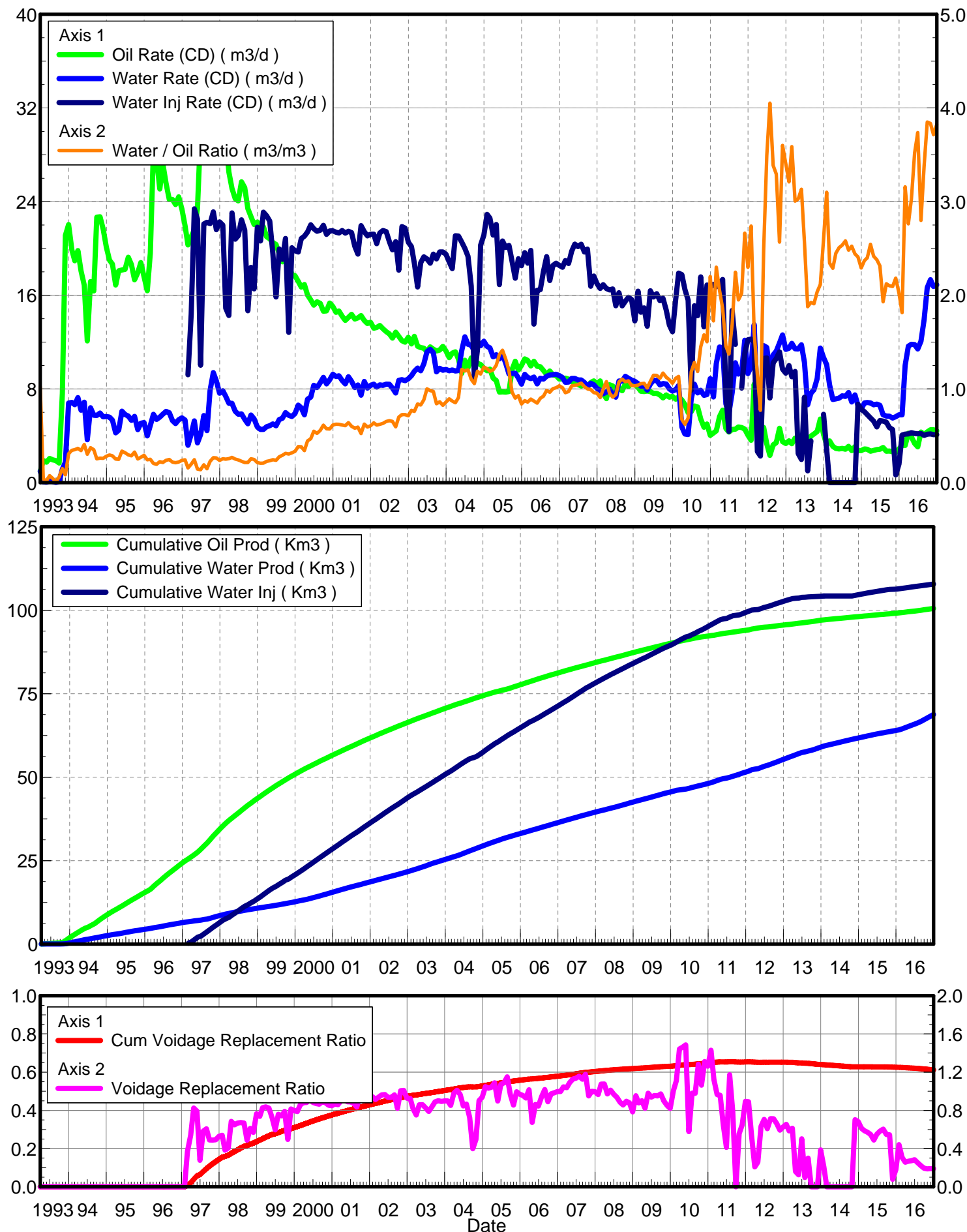
Operator: TUNDRA\_OIL\_&\_GAS\_LIMITED

Oil Rate (CD) : 3.05 m3/d

Water Rate (CD) : 19.21 m3/d

Water Inj Rate (CD) : 4.00 m3/d

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# Pattern: 00/05-33-010-29Inj Set: KolaUnit#2

Oil Formation Vol Factor : 1.07100 m3/m3

Water Formation Vol Factor : 1.00150 m3/m3

Water / Oil Ratio : 1.19 m3/m3

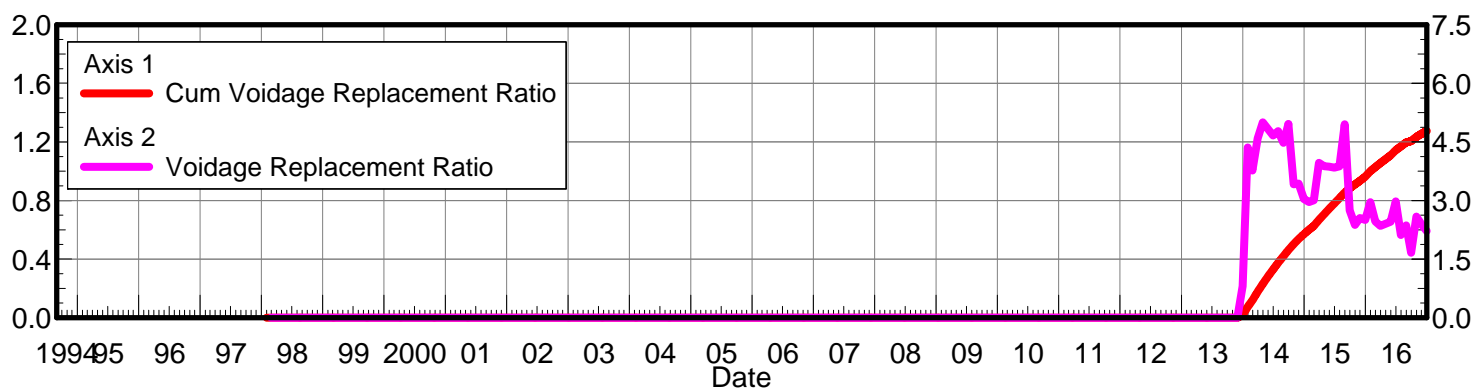
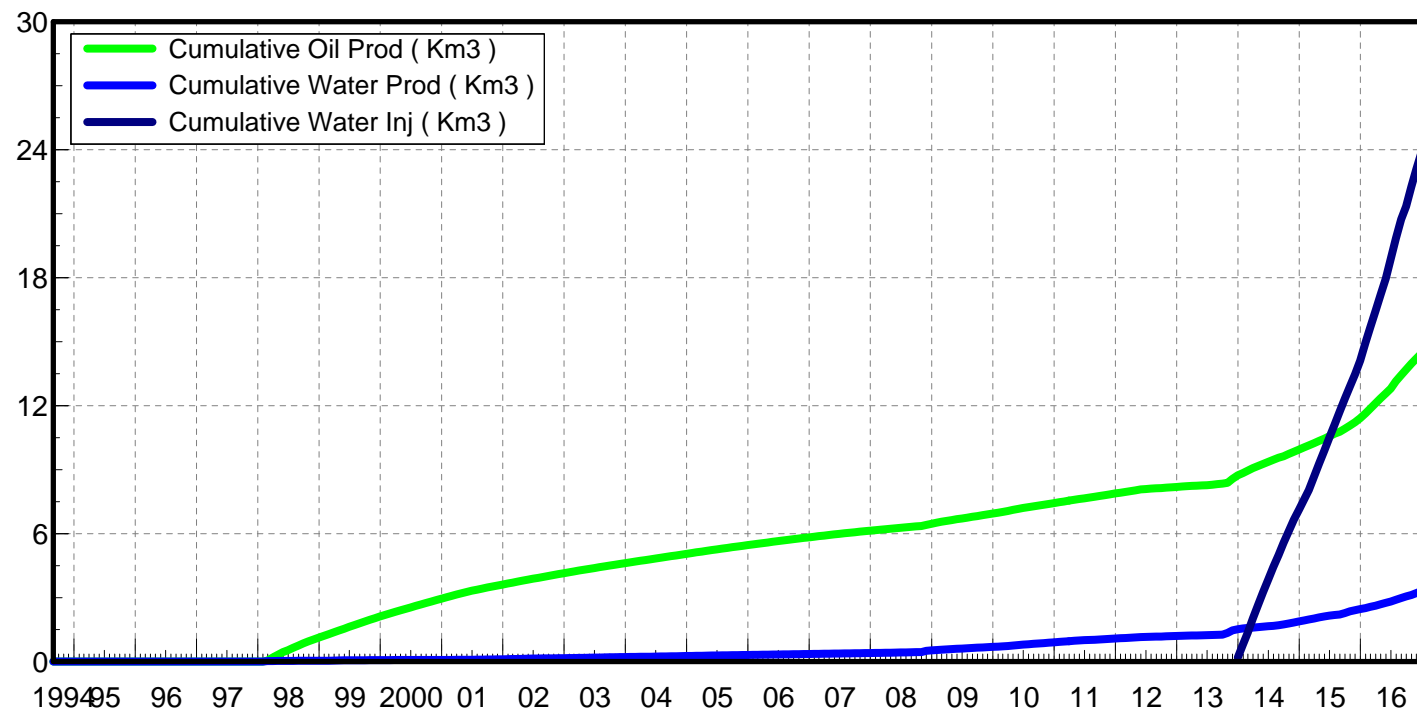
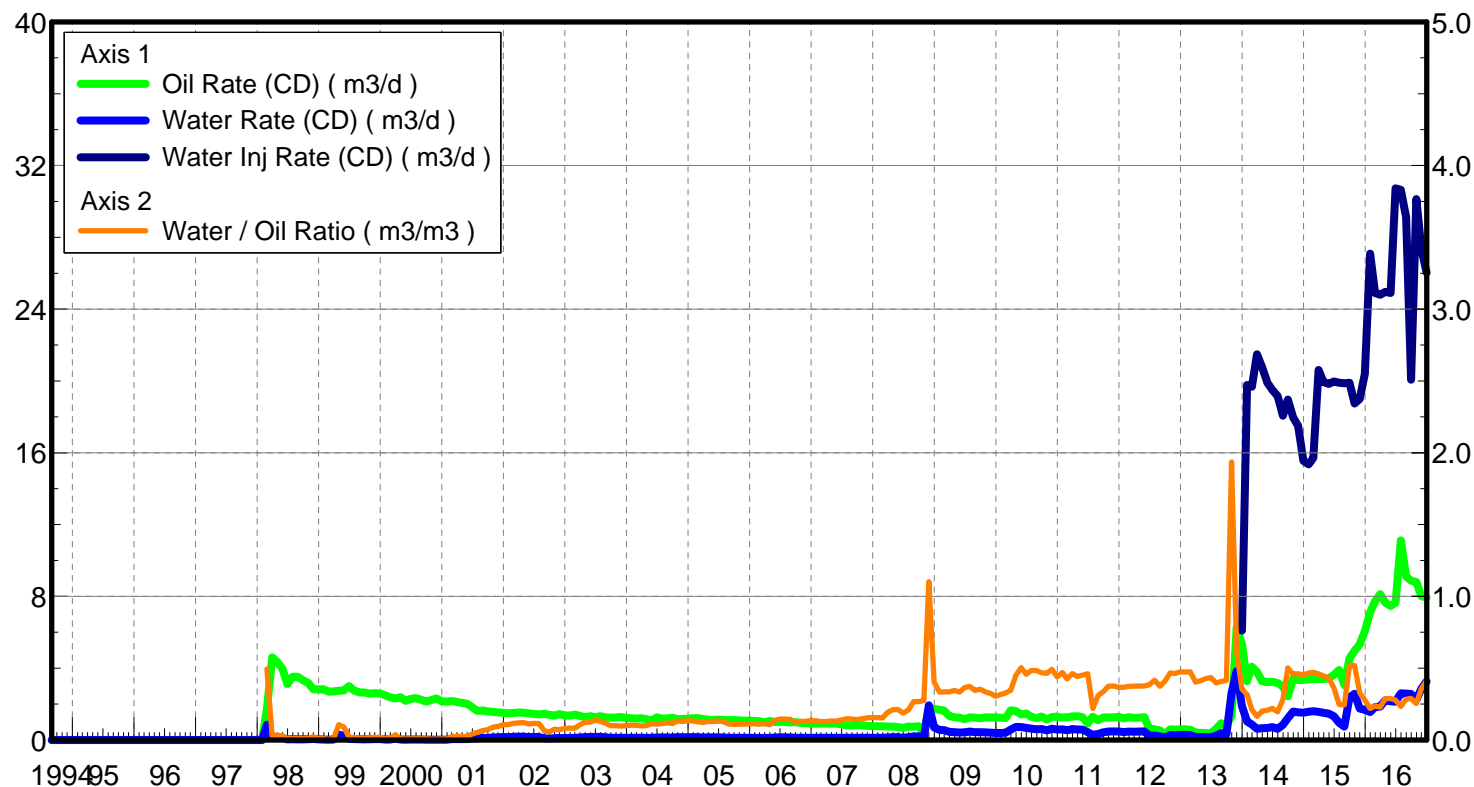
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Operator: TUNDRA\_OIL\_&\_GAS\_LIMITED

Oil Rate (CD) : 5.30 m3/d

Water Rate (CD) : 5.55 m3/d

Water Inj Rate (CD) : 17.67 m3/d



# Pattern: 00/07-33-010-29Inj Set: KolaUnit#2

Oil Formation Vol Factor : 1.07100 m3/m3

Water Formation Vol Factor : 1.00150 m3/m3

Water / Oil Ratio : 0.77 m3/m3

Operator: TUNDRA\_OIL\_&\_GAS\_LIMITED

Oil Rate (CD) : 4.66 m3/d

Water Rate (CD) : 4.07 m3/d

Water Inj Rate (CD) : 10.53 m3/d

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