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Development of a Technique, Integrating Pressure-Production Data for Fine Tuning of Fault/Flow Baffle Model and Identification of Reservoir Compartmentalization: K-XII Reservoir of Kalol Field, A Case Study

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Abstract

Fault modeling which is an integral part of any reservoir modeling work is the first step towards Structural framework building. Often Fault model generated based on seismic data in time domain is fraught with uncertainties in positioning of fault due to subjectivity of the interpretation. The limitations are of vertical resolution, time-depth conversion of fault mapping and noisy seismic signature at the juncture of two or more lineaments. Hydrodynamic analysis or HDA (with the help of pressure transient and dynamic production data) coupled with log correlation is an important tool in well positioning with respect to fault traces. In addition to that HDA is also helpful to find well connectivity and fault conductivity which in turn defines reservoir connectivity or reservoir compartmentalization. In this study hydrodynamic analysis was applied to K-XII sand of Kalol field to fine tune the fault model generated for Kalol Integrated Reservoir model. The study shows few cases where fault realignment as well as evaluation of fault conductivity was done based on hydrodynamic analysis. In addition to that dynamic data of pressure-production/injection was also used to understand reservoir connectivity.

Introduction

Reservoir compartmentalization in the form of facies change or fault as barrier is an established fact in many of the Oil & Gas fields around the world. This is often a key uncertainty during reservoir characterization and a challenge too during Structural framework building process. The first step in reservoir modeling work is Horizon modeling and fault modeling. Though main input in this work is seismic data, it needs additional tool viz. well log data and dynamic Pressure-Production (P&P) analysis for fine tuning by placing the fault in the right places. The P&P analysis is also useful in understanding Interwell connectivity which is an important part of reservoir management. Since pressure-production/injection data is readily available, numerous methods used this data to estimate interwell communication. The use of pressure-production/injection data for identification of reservoir connectivity is well documented in the work by Parekh. B. et al. (2011), Baker. R (2012) etc.

K-XII of Kalol field is the best reservoir in the field with a recovery of 36% as on 1.4.2013. The performance analysis of K-XII is well documented in the work of Nair, C.V.G. et al. (1988), Kumar, A. et al. (1998), Lohiya, J.P. et al. (1992) and Kanotra, R. et al., (2003).

Present work is a part of the ongoing project on Integrated Reservoir modeling of Kalol Field. The aim of this paper is to demonstrate simple but effective techniques to fine tune the seismic driven fault and Horizon models. This thesis is illustrated by means of case studies of work that was carried out during fault and Horizon modeling of Kalol XII pay.

Workflow

The basic component of the work is given in Figure 1. Initially three Horizons viz Kalol top, K_II_UB and K-VIII_UB or K-IX_Coal_Top were made based on seismic data and well picks. It was followed by making of K-XII top based on well picks and conformable to K-IX_Coal top. For our analysis, wells tested in K-XII were placed on K-XII top map and same has been used for analysis. The case studies are as follows.

1. Fault Placement w.r.t. Wells based on Well Log and Well Performance

This study deals with a normal fault with a throw towards east in the western part of Kalol field (Figure 2). There are two wells KL-98, KL-55 and both were tested in K-XII. KL-98 produced water and was completed in K-IX+X as producer. KL-55 produced Qo@120m3/d during initial testing in K-XII and produced cumulative oil, water and gas of 9885 m3, 448 m3 and 0.81 MMm3 respectively. From March 1973 to April 1993, it was used as Water injection (WI) well at K-XII level. Initial Horizon map developed based on well picks (Figure-2) showed KL-55 on the footwall side but a well log correlation (Figure-3) between KL-98 and KL-55 showed that KL-55 is structurally lower than KL-98 in most of the Kalol levels. It indicates that there could be a possibility of a barrier in between KL-55 and KL-98. Moreover, KL-133, a well in between KL-98 and KL-55 which was tested in K-XII produced mainly gas with cumulative oil, water and gas of 781 m3, 96 m3 and 9.27 MMm3 respectively. Also based on **Figure-4** which depicts SBHP of KL-133 and WI rate plot of KL-55, it may be concluded that WI in KL-55 was non effective in KL-133 as there was no pressure improvement in KL-133. So all these evidence suggest that KL-55 and KL-133 are in different pool. Therefore it was suggested to place KL-55 on the hanging wall of the nearby fault at all Kalol levels.

2. Validation of Well Placements w.r.t fault based on P&P Study

In this study two wells viz. KL-013 and KL-017 were identified for analysis. Pressure vs, time plot (Figure 5) for both the wells indicate that they are in the same pool at K-XII level. Horizon map generated at K-XII level based on well picks (Figure-2) also depict both the well on the same side of the NS Fault..

3. Fault Realignment based on P&P Data

During initial phase of Fault modeling it was observed that at K-XII level, KL-92 and KL-95 are on the opposite side of a NS fault (Figure 2). P&P study indicated that KL-92, KL-95 and KL-27 are in the same pool **(Figure 6).** As a result it was suggested to place well KL-95 on the hanging wall and make all three wells in the same pool.

Map generated based on K-XII well picks (Figure 2) also showed KL-516 and KL-60 on the footwall side of a NS fault and they were placed in the same pool. However log correlation (Figure 7) between KL-516 and KL-60 showed that KL-60 is 30 m down than KL-516 at K-XII. Moreover performance plot (Figure 8) indicate that both the wells are in different pool. Therefore it was suggested to place KL-60 on the hanging wall of the nearby fault.

4 Identification of Sub-Seismic Fault

A comparison between SBHP of KL-417 and KL-516 (Figure 9) indicate that they are in different pool. Though Seismic failed to identify any fault in between (Figure 2), based on pressure plot a sealing fault was suggested in between KL-417 and KL-516 which is planned to be incorporated in the final reservoir model. The study by Nair C.V.G et al. 1988 also suggested possibility of the aforementioned sealing fault.

5. Identification of Non-Sealing Fault

Figure 2 shows a EW Fault near KL-90 with a throw towards south. On this map, KL-90 is on the hanging wall and KL-215 is on the footwall side. KL-90 was completed in K-XII as oil producer from April 1969 to June 1972 and as on 1.6.2013 produced oil, gas and. water of 19287 m3, 2 m3 and 0.665 MMm3 respectively. Subsequently well was converted to WI well on July 1972 and continued till today. The performance plot of KL-215 is given in Figure 10 which shows that there was overall decrease in W.C from Nov 1999 onward with episodic increase in W.C on Jan 2006 and Oct 2009. Figure 11 shows W.C of KL-215 and WI rate of KL-90 with time. This plot indicates that episodic rise in W.C in KL-215 and gradual decrease in W.C in between could be due to change in injection rate in KL-90. Therefore KL-90 and KL-215 may be hydrodynamically connected at K-XII and fault in between may be non sealing.

6. Hydrodynamic continuity between wells inside individual fault blocks

In this study WI effect of the injectors on nearby producers were analyzed based on pressure-production/injection data. This study indirectly indicates that if WI affects a producer then there should not be any fault in between or even if a fault is present then it will be non sealing. The case studies are as follows.

At K-XII level, WI in KL-10 affected KL-425 as there was evidence of increase in WC (Figure 12) and also there was rise in pressure in KL-425 from 92 KSC in July 1992 to 126 KSC in Jan 1999 (Figure 13). Thisin turn indicate hydrodynamic connectivity between KL-10 and KL-425.

The performance analysis of KL-260 along with WI rate of KL-016 as shown in Figure 14 shows that initial WC in KL-260 was 60% which could be due to flooding of the region by WI in KL-016. This in turn suggests that KL-260 is hydrodynamically connected to KL-016.

Hydrodynamic analysis between water injector KL-638 and producers KL-215 and KL-420 (Figure 15) indicate that there was increase in W.C in KL-420 and KL-215 when WI was started KL-638. Therefore it is concluded that KL-638 is connected hydrodynamically to both KL-215 and KL-420.

Summary

The summary of the study is as follows:

1. KL-133 and KL-55 are in different pool at K-XII level and there could be a barrier in between
2. KL-013 and KL-017 are in the same pool and their positions on the present structural map at K-XII top is well justified
3. KL-92, KL-95 and KL-27 are in the same reservoir at K-XII level
4. KL-516 and KL-60 should be in different pool at K-XII level and there could be a barrier in between.
5. There could be a sub-seismic sealing fault in between KL-516 and KL-417 at K-XII level
6. KL-90 and KL-215 are hydrodynamically connected and fault in between could be non-sealing
7. At K-XII level, KL-10 &KL-425, KL-016 &KL-260, KL-638 & KL-420, KL-215 are hydrodynamically connected.

Conclusion

In the Kalol Integrated Reservoir Modeling Work, the Pressure-Production analysis coupled with well log correlation has proved to be a value addition in terms of fine tuning the Geo-Cellular Model of Kalol field.

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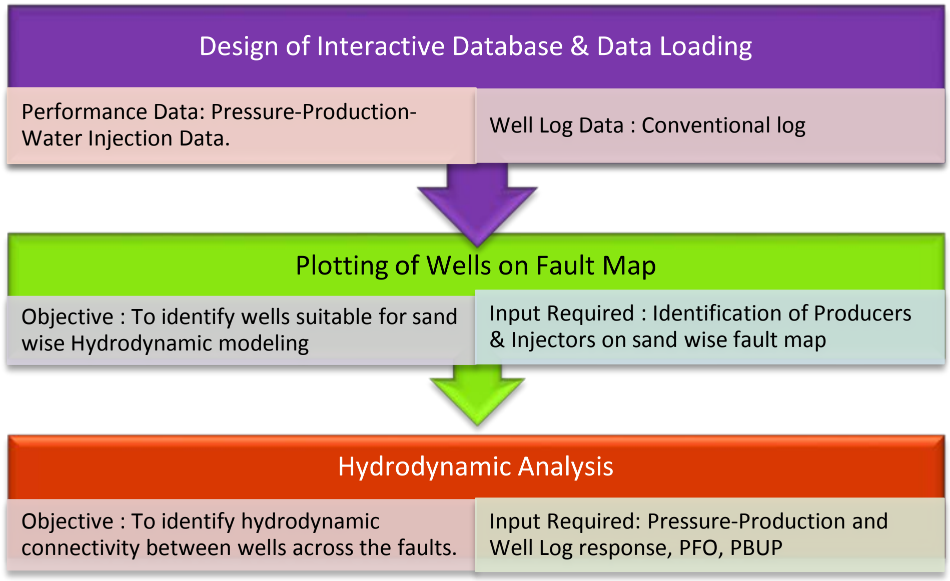

Fig 1: Integrated Workflow for Hydrodynamic Modeling

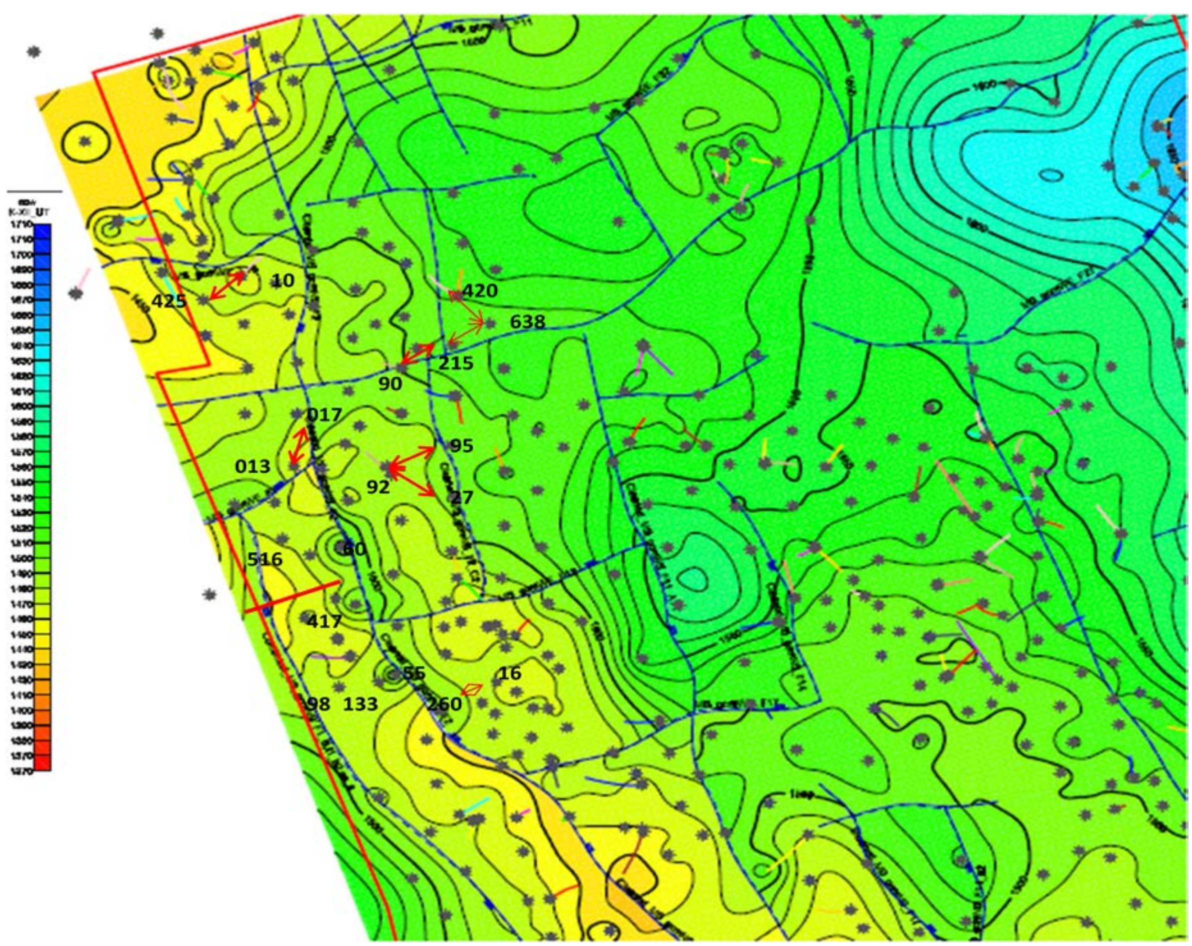

Figure 2: Structure Contour Map at the top of K-XIII Pay

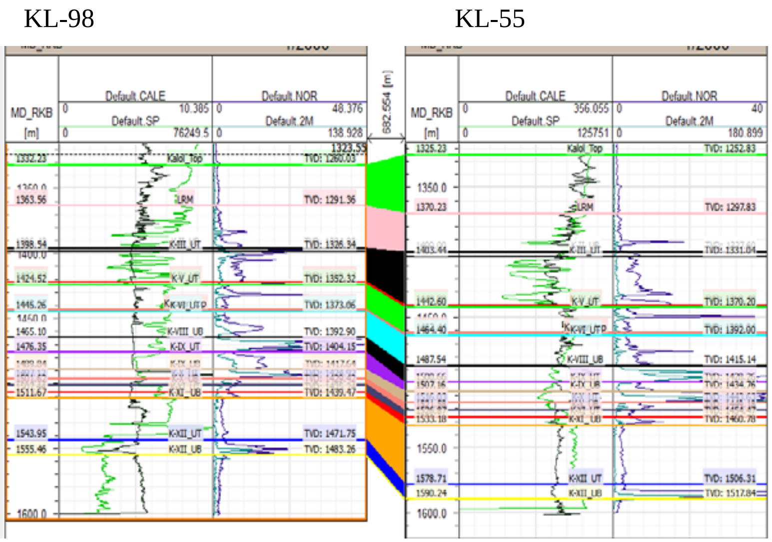

Figure 3: Structural X-Section between KL-98 and KL-55

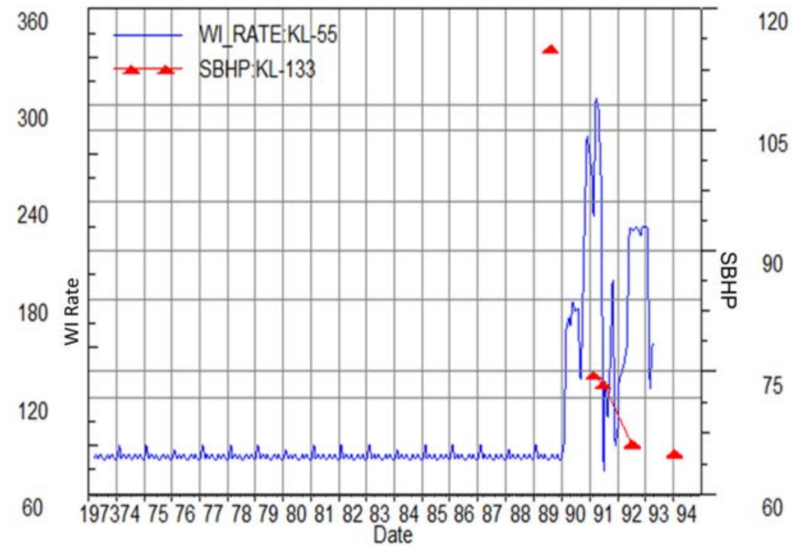

Figure 4: Plot for Pressure of KL-133 and WI rate of KL-55

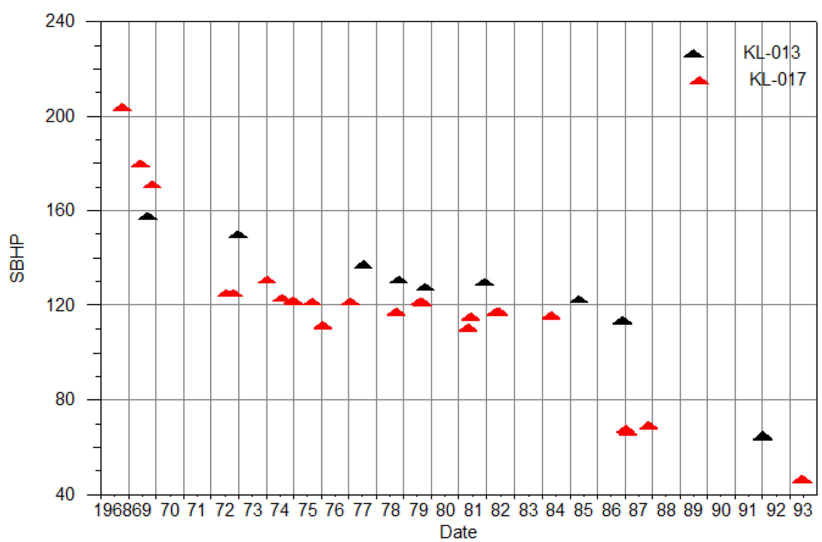

Figure 5: Pressure Plot for KL-013 and KL-017

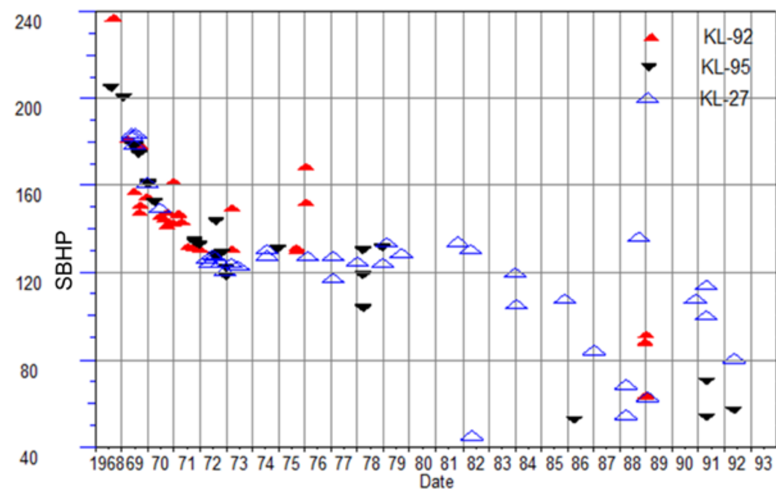

Figure 6: Pressure Plot of KL-92, 95 and 27

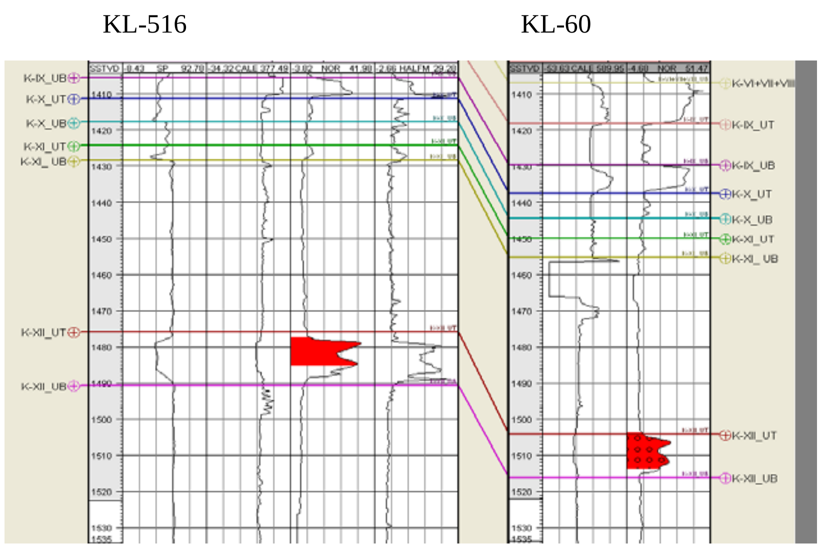

Figure 7: Structural X-Section between KL-516 & KL-60

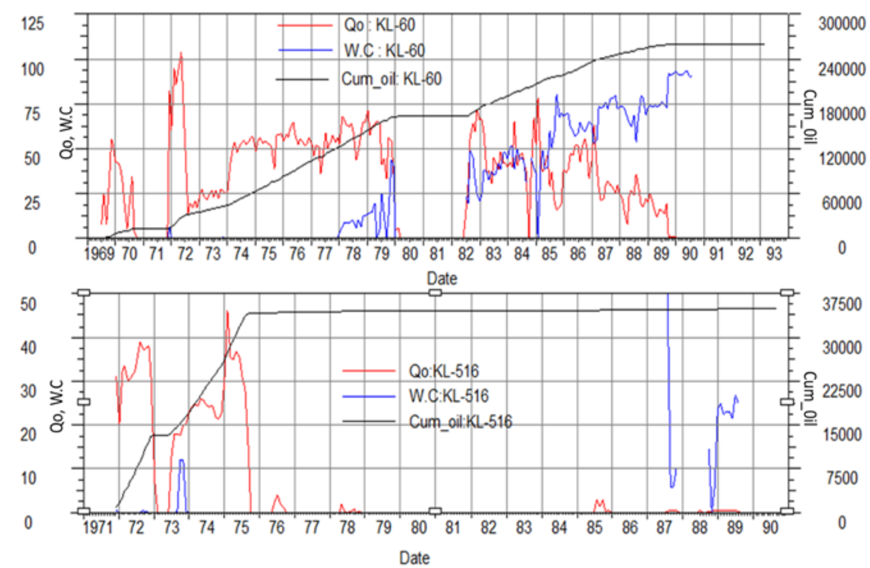

Figure 8: Performance plot of KL-60 and 516

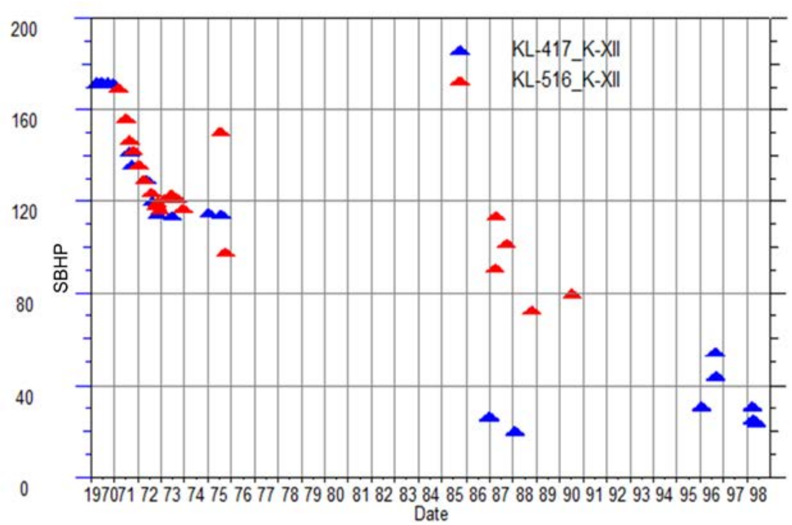

Figure 9: Comparison of SBHP for KL-417 and KL-516

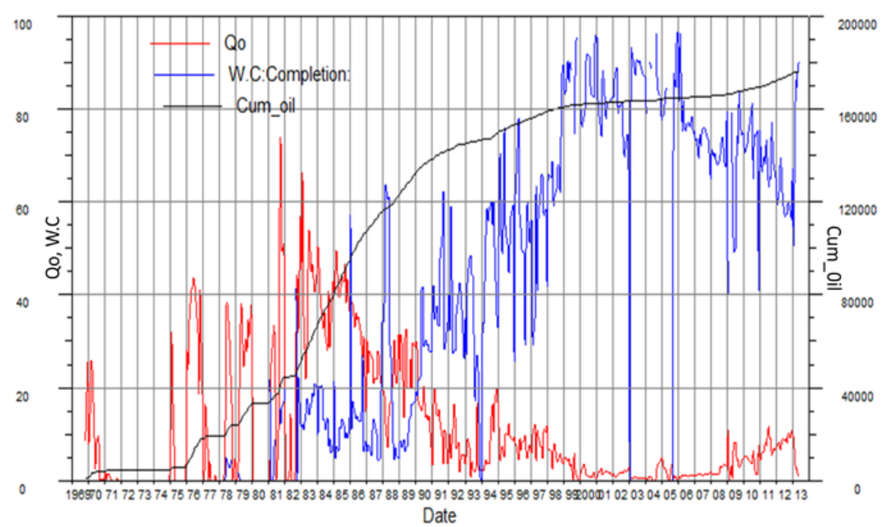

Figure 10: Performance Plot of KL-215

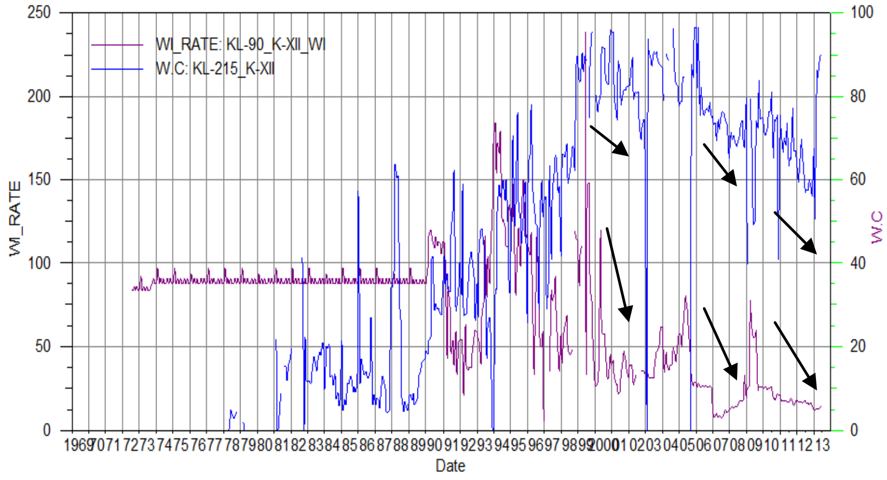

Figure 11: Decrease in W.C in KL-215 is attributed to the decrease in WI rate in KL-90

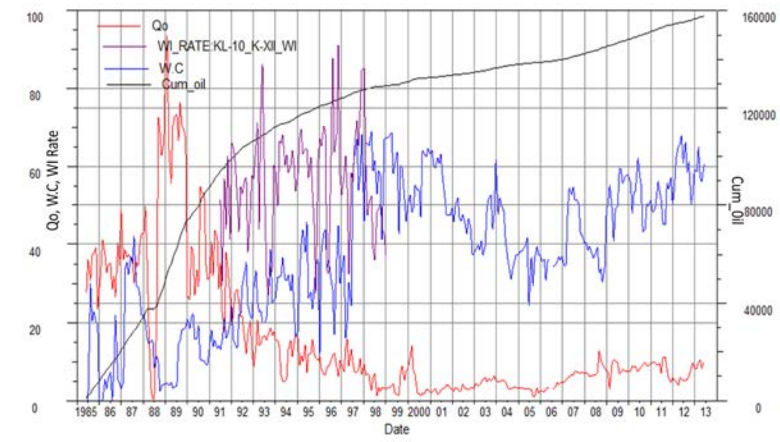

Figure 12: Performance plot of KL-425 along with WI rate of KL-10

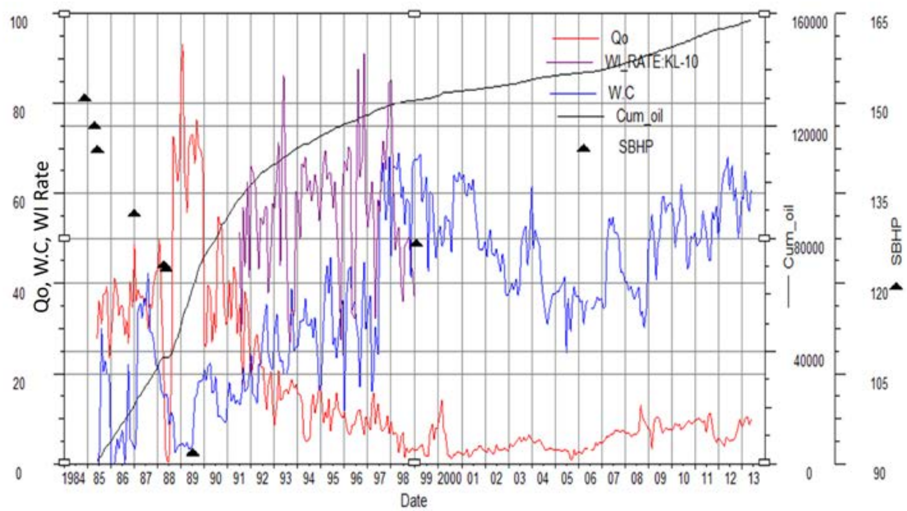

Figure 13: WI rate of KL-10 and SBHP, W.C , Qo plot of KL-425

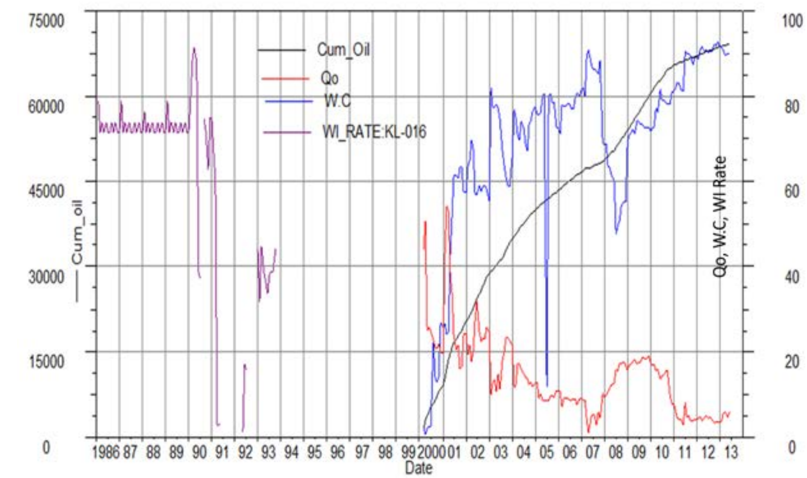

Figure 14: Performance Plot of KL-260 and WI rate of KL-016

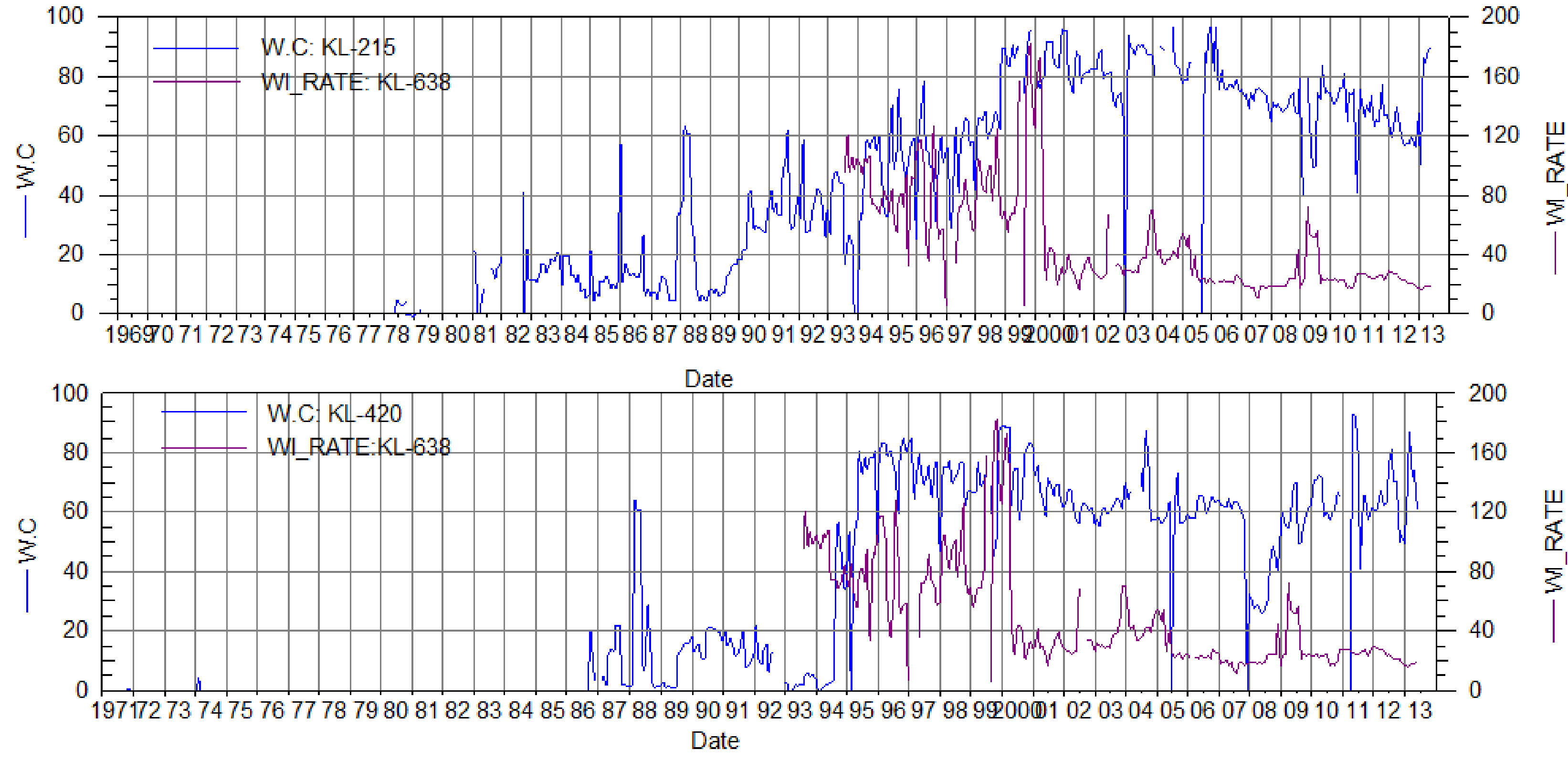

Figure 15: Plot of W.C of KL-215, 420 and WI rate of KL-638