COMPUTER MODELLING GROUP LTD.

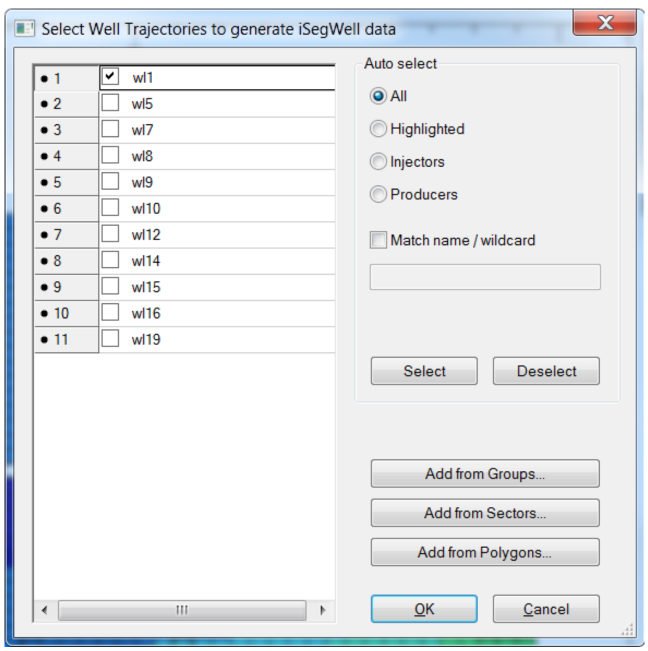
iSegWell Tutorial

Builder & IMEX Tutorial 2021

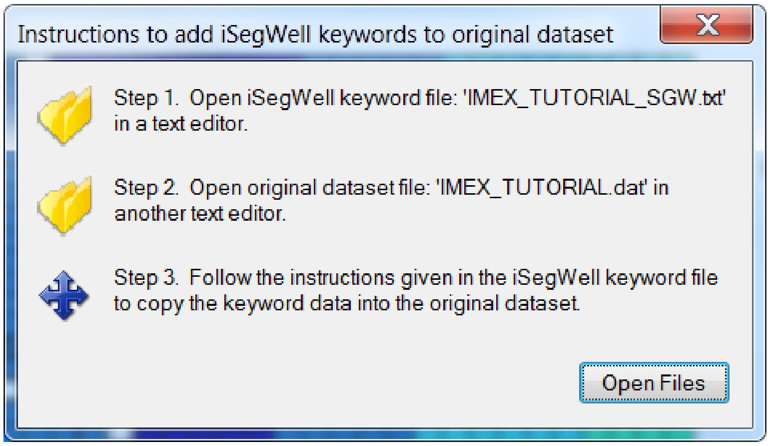
Exercise 1: Using the Builder Help File to Create a Simple iSegWell

Currently Builder does not have a GUI to support iSegWell, but is does have the ability to aid the user in converting the current well into an iSegWell. It requires the well to have a trajectory. This exercise will demonstrate the procedure required to convert existing simulator wells into iSegWells.

1. Open the dataset **IMEX_TUTORIAL_HM_Matched.dat** in Builder.
2. Under the **Wells & recurrent** menu select **Well>Create Trajectories from Completions (PERF).**
3. Click **OK.**
4. Select **Well | Create iSegWell Keyword Helper File**. The **Select Well Trajectories to generate iSegWell data** dialog box will automatically be displayed, through which you can select the wells for which you want to create the iSegWell keyword file. For this example, select ‘wl1’



5. Click **OK** and then in the window that appears save the help file as **IMEX_TUTORIAL_HM_Matched_SGW.txt.** Builder has generated a text file containing the keywords necessary to define our iSegWell.
6. After saving the following window will appear:



Follow the instructions in the window.

7. Select **Open Files.** This should open the dataset in a text editor as well as the helper file in a text editor.
8. Follow the instructions in the **Keyword Helper** file by copying the appropriate iSegWell keywords to the appropriate section of the dataset. Also be sure to delete the perforations keywords as outlined in the Helper file.
9. Once complete the dataset should look similar to the following:

```
RUN
DATE 1993 1 1
**
WELL  'wl1'
PRODUCER 'wl1'
OPERATE  MAX  STL  263.0010071  CONT
OPERATE  MIN  BHP  200.0  CONT

      WB-PDMETHOD 'Flow-Grav Method'
          BEGIN
           TYPE FLOW-GRAV
           FMULT 1.0
          END


          WIMETHOD 'SGEOA Method'
          BEGIN
           TYPE SGEOA 1.0
           SGRADIUS 0.3
          END

WELLSITE 'WELLSITE-wl1'


          BRANCH 'BRANCH-wl1' CONNECT-TO 'WELLSITE-wl1' AT          0.00
          BEGIN
          **        x             y             z          md
                  472.76       -181.91         0.00        0.00
                  472.76       -181.91      1553.24     1553.24
                  472.76       -181.91      1559.40     1559.40
                  472.76       -181.91      1565.56     1565.56
                  472.76       -181.91      1571.71     1571.71
                  472.76       -181.91      1577.85     1577.85
                  472.76       -181.91      1582.50     1582.50
                  472.76       -181.91      1585.67     1585.67
                  472.76       -181.91      1588.83     1588.83
                  472.76       -181.91      1592.00     1592.00
                  472.76       -181.91      1595.18     1595.18
                  472.76       -181.91      1600.17     1600.17
                  472.76       -181.91      1620.53     1620.53
                  472.76       -181.91      1627.30     1627.30
                  472.76       -181.91      1637.36     1637.36
                  472.76       -181.91      1650.68     1650.68
                  472.76       -181.91      1663.79     1663.79
                  472.76       -181.91      1676.60     1676.60
                  472.76       -181.91      1689.32     1689.32
          END


          WB-PDPOINTS 'BRANCH-wl1'
          BEGIN
                    0.00  'Flow-Grav Method'  'Flow-Grav Method'
          END


          WIPOINTS 'BRANCH-wl1'
          BEGIN
                    0.00  'SGEOA Method'
          END


          WB-BLOCKBDYS 'BRANCH-wl1'
          BEGIN
          ** UBA        x-entry     y-entry     z-entry     md-entry          x-exit      y-exit      z-exit      md-exit
           40 11 1       472.76     -181.91     1550.16     1550.16           472.76     -181.91     1556.32     1556.32
           40 11 2       472.76     -181.91     1556.32     1556.32           472.76     -181.91     1562.48     1562.48
           40 11 3       472.76     -181.91     1562.48     1562.48           472.76     -181.91     1568.63     1568.63
           40 11 4       472.76     -181.91     1568.63     1568.63           472.76     -181.91     1574.78     1574.78
           40 11 5       472.76     -181.91     1574.78     1574.78           472.76     -181.91     1580.92     1580.92
           40 11 6       472.76     -181.91     1580.92     1580.92           472.76     -181.91     1584.08     1584.08
           40 11 7       472.76     -181.91     1584.08     1584.08           472.76     -181.91     1587.25     1587.25
           40 11 8       472.76     -181.91     1587.25     1587.25           472.76     -181.91     1590.41     1590.41
           40 11 9       472.76     -181.91     1590.41     1590.41           472.76     -181.91     1593.59     1593.59
           40 11 10       472.76     -181.91     1593.59     1593.59           472.76     -181.91     1596.78     1596.78
           40 11 11       472.76     -181.91     1596.78     1596.78           472.76     -181.91     1603.56     1603.56
           40 11 12       472.76     -181.91     1603.56     1603.56           472.76     -181.91     1610.35     1610.35
           40 11 13       472.76     -181.91     1610.35     1610.35           472.76     -181.91     1617.14     1617.14
           40 11 14       472.76     -181.91     1617.14     1617.14           472.76     -181.91     1623.92     1623.92
           40 11 15       472.76     -181.91     1623.92     1623.92           472.76     -181.91     1630.69     1630.69
           40 11 16       472.76     -181.91     1630.69     1630.69           472.76     -181.91     1644.03     1644.03
           40 11 17       472.76     -181.91     1644.03     1644.03           472.76     -181.91     1657.33     1657.33
           40 11 18       472.76     -181.91     1657.33     1657.33           472.76     -181.91     1670.25     1670.25
           40 11 19       472.76     -181.91     1670.25     1670.25           472.76     -181.91     1682.96     1682.96
           40 11 20       472.76     -181.91     1682.96     1682.96
          END


          SGWASSIGN 'SGW-BRANCH-wl1' TO 'wl1'
            WELGEO 'wl1'
                   WFRAC          1.00


                  WB-PFINTVLS 'BRANCH-wl1'
                  BEGIN
                       1550.16       1603.56
                       1610.35       1617.14
                       1623.92       1682.96
                  END


                  PF-ISETTING
                  BEGIN
                   'BRANCH-wl1'        1550.16       1603.56       1.0
                   'BRANCH-wl1'        1610.35       1617.14       0.0
                   'BRANCH-wl1'        1623.92       1682.96       1.0
          END

DATE 1993 2  1.00000
```

10. To avoid getting several warning messages in the .log file comment out the following lines. This will ensure that the appropriate ranges are perforated.

```
     WB-PFINTVLS 'BRANCH-wl1'
     BEGIN
          1550.16       1603.56
**        1603.56       1617.14
          1623.92       1695.69
     END

**   PF-ISETTING
**   BEGIN
**        'BRANCH-wl1'       1550.16       1603.56       1.0
**        'BRANCH-wl1'       1603.56       1617.14       0.0
**        'BRANCH-wl1'       1623.92       1695.69       1.0
**   END
```

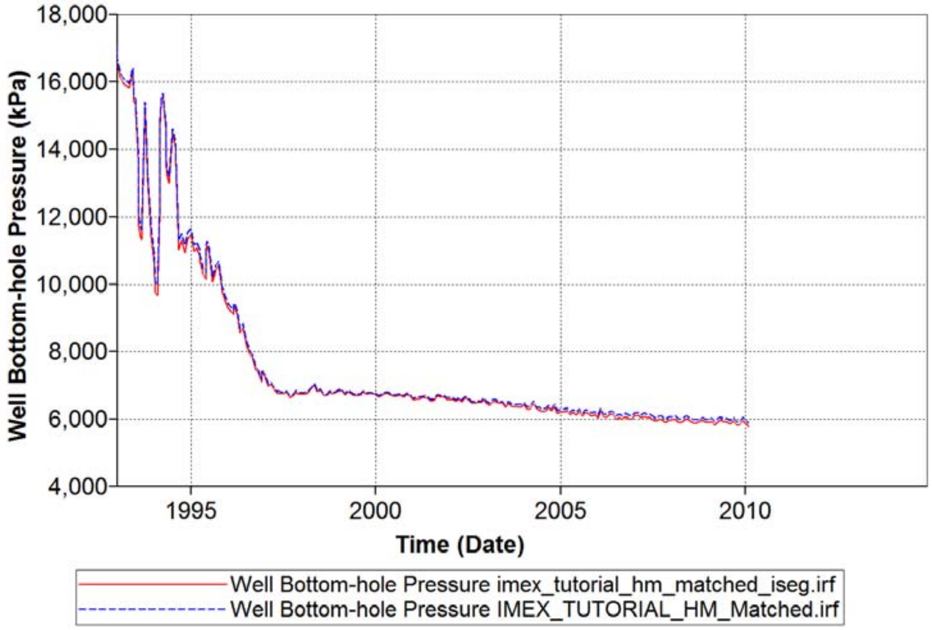
Commenting out the above lines will not change the results. The well index multiplier of 0 provided in the PF-ISETTING keyword will result in several warnings in the dataset. If the lines are not commented the following warnings will appear:

```
===================== WARNING (from subroutine: SETPRF) ======================
  Well 'wl1' # 1, Layer # 23 has a zero well index.
  This is usually caused by perfing a zero permeability block. Layer will be closed
==============================================================================
```

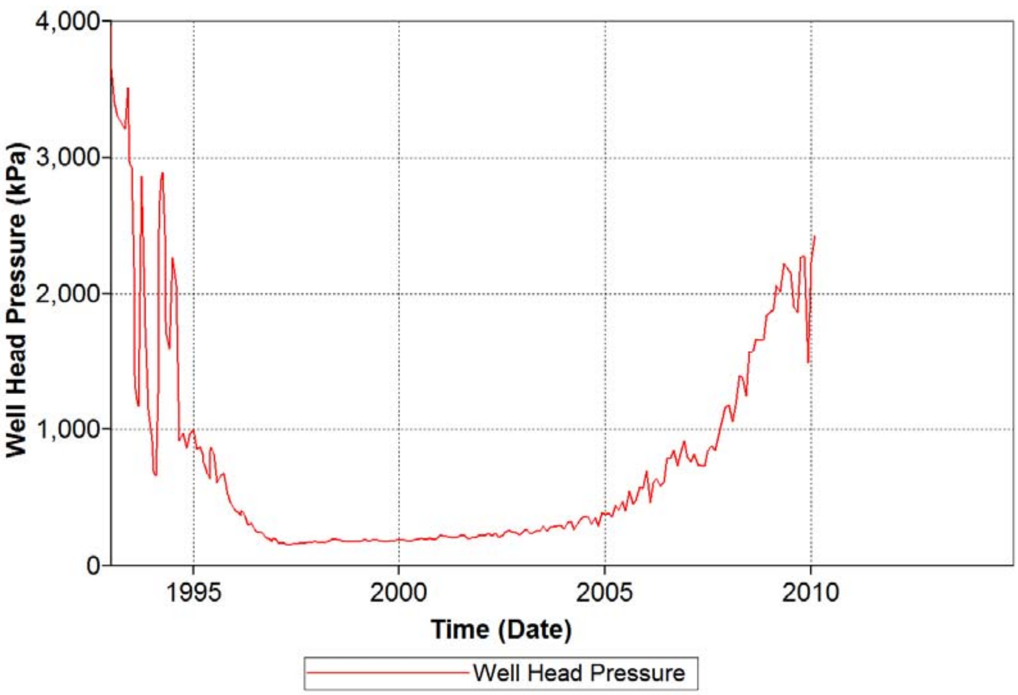
11. Remove the following keywords at the top of the dataset:

```
RESTART_SR2 MAIN
```

12. Save the dataset as **IMEX_TUTORIAL_HM_Matched_iseg.dat.**
13. After running the dataset, compare the results between the isegwell case and the original model. This will validate the use of the iSegWell model.



Since the models are both running on historical rates, the well bottom hole pressure is compared. In this case there is not much difference between the two cases. This is to be expected because we have not introduced any complex features yet by adding iSegWell. Through iSegWell we can introduce different features such as multiple tubings, equipment such as pumps and flow control devices. We can also model the well to surface this can be seen by plotting the Well Head Pressure for the iSegWell case.



Introducing a Frictional Pressure Drop Method

14. Open the dataset in a text editor and scroll down to the keyword **WB-PDMETHOD**. This keyword controls the pressure drop method used in the iSegwell calculation. Currently the **Flow-Grav** method is being used. In this method only gravity head is taken into account in the pressure drop along the wellbore.
15. Change the Type from **FLOW-GRAV** to be **MOMENTUM**.

```
WB-PDMETHOD 'Flow-Grav Method'
BEGIN
 TYPE MOMENTUM
 FMULT 1.0
END
```

The momentum based pressure drop method is a mechanistic based pressure drop method that takes into account gravity, friction and acceleration. It calculates the frictional pressure drop by first determined the flow regime based on the superficial gas and liquid velocity.

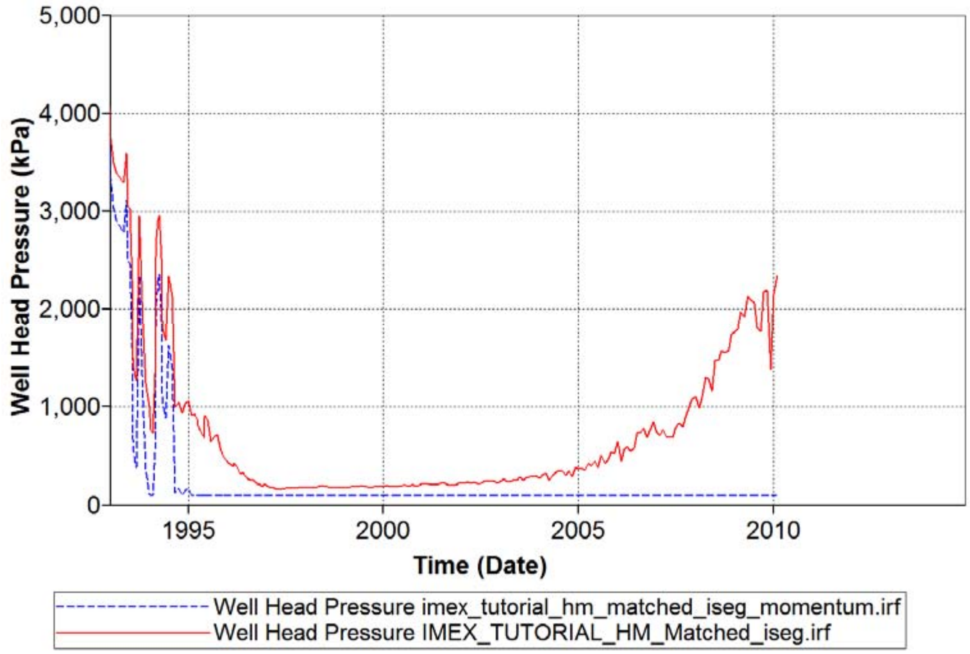
16. Below the TYPE keyword enter the keyword **IRADIUS** followed by **0.0762.** Also enter a value of **0.001** for the relative roughness with the keyword **RROUGH**. These are the minimum input requirements for the Momentum pressure drop method.

```
WB-PDMETHOD 'Flow-Grav Method'
BEGIN
 TYPE MOMENTUM
 IRADIUS 0.0762
 RROUGH 0.001
 FMULT 1.0
END
```

NOTE: Currently we have named the pressure drop method as 'Flow-Grav Method'. This is not linked to the pressure drop method type and is a custom identifier that the user inputs (For this case Builder named it for us). We do not need change the name of the method for this case. This is because the method we have called 'Flow-Grav Method' is already being applied to the wellbore with the keyword **WB-PDPOINTS.**

17. Save the dataset and run the file in IMEX. Plotting the **Well Head Pressure** shows that the model is not able to realistically meet the historical rate data. The internal minimum

well head pressure of 101 kPa has been reached. Therefore we will need to introduce a form of artificial lift such as a pump or gas lift.



Adding in lift gas

18. Open the dataset in a text editor and scroll down to the **RUN** section.
19. Enter in the following Well definition for the gas lift injector.

```
WELL  'wl1_inj'
INJECTOR 'wl1_inj'
INCOMP GAS
OPERATE  MAX  STG  30000  CONT REPEAT
OPERATE  MAX BHP  20000.0  CONT REPEAT
```

20. The injector well will be a tubing string. This will require a Pressure drop method definition. This can be done with the keyword **TS-PDMETHOD**. Enter the following below the pressure drop method for the wellbore (**WB-PDMETHOD**):

```
*TS-PDMETHOD 'PD_tubing'
*BEGIN
  *TYPE *MOMENTUM
          IRADIUS 0.03
        RROUGH 0.001
```

```
      FMULT 1.0
 *END
```

21. Scroll down to below the WIPOINTS keyword. First enter the tubing string end pressure drop method. We will assume laminar flow:

```
*TE-PDMETHOD 'TBE-meth1'
*POISEU  0.03  0.0762  1.0
```

NOTE: For tubing string ends a pressure drop of zero cannot be specified.

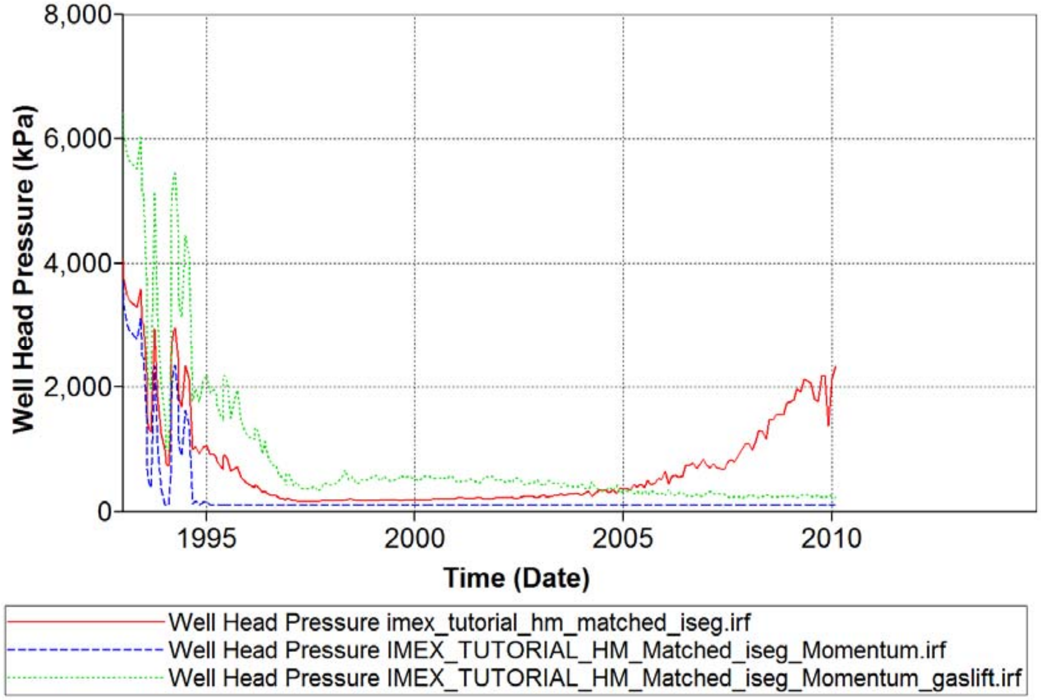
22. Enter in the Tubing String location as well as the application of the tubing string pressure drop method. This is done with the keywords TSTRING and TS-PDPOINTS:

```
*TSTRING 'INJ1-Tube'
*START-AT 'BRANCH-wl1'    0.0 *OPEN 'ZERO'
*END-AT   'BRANCH-wl1' 1500.  *OPEN 'TBE-meth1'


TS-PDPOINTS 'INJ1-Tube'
*BEGIN
  0. 'PD_tubing' 'PD_tubing'
*END
```

23. Finally apply the tubing string to the simulator well.

```
SGWASSIGN 'SGW-INJ1-Tube' *TO 'wl1_inj'
```

24. Save the dataset and run it in IMEX. Plotting the well head pressure will show us that we are now able to meet the historical rate data without violating the minimum well head pressure.



Currently the depth of the lift gas string has been set to a depth of 1500 m. The depth along with the rate of gas are two parameters that can be optimized when using lift-gas. The ability to use lift-gas will also be highly dependent on the availability of gas.

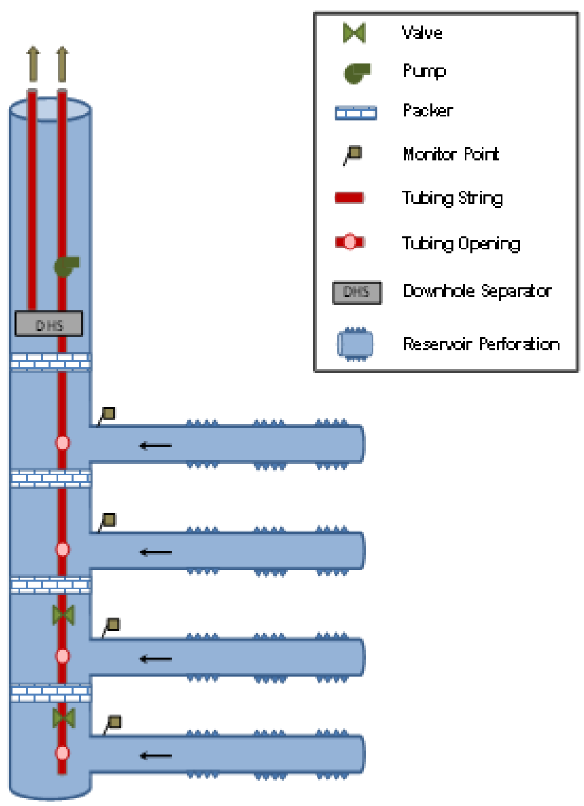
Exercise 2: Multilateral Well with Passive and Active FCD control

This exercise is based on CASE STUDY 1,which can be found in Appendix 5 of the iSegWell Manual. The purpose of the exercise is to demonstrate the use of many of the features in iSegWell. Currently iSegWell is text editor based so this is take home exercise for those who are interested in doing wellbore modeling in IMEX.

The well is a multilateral well with four horizontal segments. Each leg of the well terminates in a different layer of the reservoir but all of them produce through a common vertical wellbore. The formation permeability varies significantly between layers. The vertical wellbore contains packers which isolate each leg.

The goal of the case study is to achieve uniform production from each of the multilaterals. The case study will introduce the user to the basic application of iSegWell keywords, and specifically, to modeling passive and active control of FCDs to achieve similar productive levels between the four legs.

Below is a diagram of the well bore configuration:



Implementing iSegWell Keywords

1. Open the data set **isegwell_basecase.dat** in a text editor.
2. Scroll down to the Wells and Recurrent section (**RUN** keyword). After the keyword ***BHPHEADINIT** and before the keyword **TIME 1**, enter the well site name:

```
*WELLSITE 'Site1'
```

3. Using the **BRANCH** keyword, enter the main main branch (**'Site1-Main-Branch'**) of the iSegWell:

```
*BRANCH 'Site1-Main-Trunk' *CONNECT-TO 'Site1' *AT 0.0
*BEGIN
     0.00       0.00       0.00       0.00
     0.00       0.00       9660.00    9660.00
*END
```

4. Using the **BRANCH** keyword enter iSegWell child branches, which connect to the main branch at the points shown in the diagram:

```
*BRANCH 'Site1-L1' *CONNECT-TO 'Site1-Main-Trunk' *AT
9000.00
*BEGIN
     0.00       0.00       9000.00    9000.00
     5400.00    0.00       9000.00    14400.00
*END

*BRANCH 'Site1-L2' *CONNECT-TO 'Site1-Main-Trunk' *AT
9220.00
*BEGIN
     0.00       0.00       9220.00    9220.00
     5400.00    0.00       9220.00    14620.00
*END

*BRANCH 'Site1-L3' *CONNECT-TO 'Site1-Main-Trunk' *AT
9440.00
*BEGIN
     0.00       0.00       9440.00    9440.00
     5400.00    0.00       9440.00    14840.00
*END
```

```
*BRANCH 'Site1-L4' *CONNECT-TO 'Site1-Main-Trunk' *AT
9660.00
*BEGIN
     0.00      0.00      9660.00   9660.00
     5400.00   0.00      9660.00   15060.00
*END
```

5. Using the keyword **PACKERS**, enter packers in the main branch, at the points shown in the diagram:

```
*PACKERS 'Site1-Main-Trunk'
*BEGIN
     5895.0
     5905.0
     8940.0
     9160.0
     9380.0
     9600.0
*END
```

6. Using the keyword **TSTRING**, enter (two) tubing strings by defining their names, starting and ending points, and whether the ending points are initially open or closed:

```
*TSTRING 'Site1-Second-TS'
     *START-AT 'Site1-Main-Trunk' 5900.00 *OPEN 'ZERO'
*END-AT 'Site1-Main-Trunk' 6100.00 *OPEN 'ZERO'

*TSTRING 'Site1-Main-TS'
     *START-AT 'Site1-Main-Trunk' 0.00 *OPEN 'ZERO'
*END-AT 'Site1-Main-Trunk' 9660.00 *CLOSED
```

7. Using ***WB-PDMETHOD** and ***TS-PDMETHOD** respectively, define the pressure drop methods for wellbore branches and tubing strings. The pressure drop method for main vertical branch and tubing will be the Drift-Flux method and the Aziz-Govier well friction model will be used for the horizontal branches.

```
** For horizontal wellbores in narrower horizontal
branches which are without tubing strings.
*WB-PDMETHOD 'wbpmeth1'
*BEGIN
     *TYPE AZIZ-GOVIER
     *IRADIUS 0.2083
```

```
        *RROUGH 0.01
        *SFCTENS 30.0
        *FMULT 1.
*END

** For vertical wellbore in 'Site1-Main-Trunk' branch.
*WB-PDMETHOD 'wbpmeth2'
*BEGIN
        *TYPE DRIFT-FLUX
        *IRADIUS 0.333
        *RROUGH 0.01
        *SFCTENS 30.0
        *FMULT 1.
*END

** For vertical tubing string.
*TS-PDMETHOD 'tspmeth1'
*BEGIN
        *TYPE DRIFT-FLUX
        *IRADIUS 0.2083
        *RROUGH 0.000001
        *SFCTENS 30.0
        *FMULT 1.
*END
```

Note: The above is not intended to suggest that one pressure drop method is better than another for vertical or horizontal branches.

8. After defining the pressure drop methods the next step is to assign these methods to the wellbore through the keywords, **TS-PDPOINTS** and **WB-PDPOINTS**.

```
*TS-PDPOINTS 'Site1-Main-TS'
*BEGIN
        0.0       'tspmeth1'     'tspmeth1'
        9660.0    'tspmeth1'     'tspmeth1'
*END

*TS-PDPOINTS 'Site1-Second-TS'
*BEGIN
        5900      'tspmeth1'     'tspmeth1'
        6100      'tspmeth1'     'tspmeth1'
*END
```

```
*WB-PDPOINTS 'Site1-Main-Trunk'
*BEGIN
     0.0       'wbpmeth2'     'wbpmeth2'
     9660.0    'wbpmeth2'     'wbpmeth2'
*END

*WB-PDPOINTS 'Site1-L1'
*BEGIN
     9000.0    'wbpmeth1'     'wbpmeth1'
*END

*WB-PDPOINTS 'Site1-L2'
*BEGIN
     9220.0    'wbpmeth1'     'wbpmeth1'
*END

*WB-PDPOINTS 'Site1-L3'
*BEGIN
     9440.0    'wbpmeth1'     'wbpmeth1'
*END

*WB-PDPOINTS 'Site1-L4'
*BEGIN
     9660.0    'wbpmeth1'      'wbpmeth1'
*END
```

9. Similar to defining and applying the pressure drop methods the next step is to define the well index methods. This will be done in a similar way, where the methods used is first defined with the keyword **WIMETHOD:**

```
*WIMETHOD 'wimeth1'
*BEGIN
     *TYPE *SGEOA 1.0
     *SGRADIUS 0.2083
     *END

*WIMETHOD 'wimeth2'
*BEGIN
     *TYPE *SGEOA 1.0
     *SGRADIUS 0.333
*END
```

The first method is for the horizontal branches and the second method is for the vertical section of the wellbore. Both sections will use the anisotropic version of Peaceman's equation and the only difference between the two methods is the well radius used for the calculations.

The WI methods are applied through the keyword **WIPOINTS:**

```
*WIPOINTS 'Site1-Main-Trunk'
*BEGIN
     0.0       'wimeth2'
     9660.0    'wimeth2'
*END

*WIPOINTS 'Site1-L1'
*BEGIN
     9000.0    'wimeth1'
*END

*WIPOINTS 'Site1-L2'
*BEGIN
     9220.0    'wimeth1'
*END

*WIPOINTS 'Site1-L3'
*BEGIN
     9440.0    'wimeth1'
*END

*WIPOINTS 'Site1-L4'
*BEGIN
     9660.0    'wimeth1'
*END
```

10. Using ***WB-PFINTVLS**, define perforation intervals for the main wellbore and child branches:

```
*WB-PFINTVLS 'Site1-L1'
*BEGIN
     9750.0    10050.0
     11550.0   11850.0
     13350.0   13650.0
*END
```

```
*WB-PFINTVLS 'Site1-L2'
*BEGIN
     9970.0    10270.0
     11770.0   12070.0
     13570.0   13870.0
*END

*WB-PFINTVLS 'Site1-L3'
*BEGIN
     10190.0   10490.0
     11990.0   12290.0
     13790.0   14090.0
*END

*WB-PFINTVLS 'Site1-L4'
*BEGIN
     10410.0   10710.0
     12210.0   12510.0
     14010.0   14310.0
*END
```

11. With the keyword ***SGRPFINRLUMP**, add the perforation intervals defined in the previous step to report lumps. This will allow the simulator to report well parameters based on the individual child branches. This will appear as a special output in Results Graph and which will be defined in the specific outputs in the I/O control section later in the tutorial.

```
*SGRPFINRLUMP 'rlump-l1'
*BEGIN
     'Site1-L1' 9750.0   13650.0   1.0
*END

*SGRPFINRLUMP 'rlump-l2'
*BEGIN
     'Site1-L2' 9970.0   13870.0   1.0
*END

*SGRPFINRLUMP 'rlump-l3'
*BEGIN
```

```
     'Site1-L3' 10190.0  14090.0   1.0
*END

*SGRPFINRLUMP 'rlump-l4'
*BEGIN
     'Site1-L4' 10410.0  14310.0   1.0
*END
```

12. Next, define the pressure drop method that will apply to the tubing string openings. This is done with the keyword **TO-PDMETHOD.**

```
*TO-PDMETHOD 'to-meth1'
*CONST 0.5

*TO-PDMETHOD 'to-meth2'
*FCD-ORIF 1.0 0.25 0.0416 0.25 80.0 1.4 0.85 1
```

For this model, two pressure drop methods for tubing openings have been defined. One is based on a constant pressure drop, and the second is based on defining an FCD.

13. In this step define the location of the tubing openings, type of opening, status and apply the pressure drop methods defined in step 12. For the first exercise only the first pressure drop method will be used. In a later exercise the effects of using FCDs at these locations will be seen.

```
*TOPENS 'Site1-Main-TS'
*BEGIN
     5900.1  *FLOWPORT  *OPEN  'to-meth1'
     9000.0  *FLOWPORT  *OPEN  'to-meth1'
     9220.0  *FLOWPORT  *OPEN  'to-meth1'
     9440.0  *FLOWPORT  *OPEN  'to-meth1'
     9659.9  *FLOWPORT  *OPEN  'to-meth1'
*END
```

14. The keyword **TS-EQMETHOD** is used to define the equipment methods that will apply to tubing string equipment. I n the dataset, enter the following:

```
*TS-EQPMETHOD 'dp-pump1'
*PUMP *PUMP1 880.0
```

In the syntax above, a pump has been defined with a maximum pressure boost of **880** psi. With the PUMP1 method selected the pressure increase across the pump is defined as

$$\Delta P = \min\left(\Delta P_{max}, \frac{Power}{Q}\right)$$

15. Below the Pump definition define:
    a. For each piece of equipment installed in the iSegWell, its position, type, pressure drop method, and settings (***TS-EQPT**).
    b. Setting of tubing string equipment and openings (***TS-EQSETTING**).

```
*TS-EQPT 'Site1-Main-TS'
*BEGIN
     6000.0  *PUMP  'dp-pump1'  'dp-pump1'  -1
*END

*TS-EQSETTING
*BEGIN
     *PUMP  'Site1-Main-TS'  6000.0  40.00
*END

*TS-EQSETTING
*BEGIN
     *TUBING-OPENING 'Site1-Main-TS' 9000.0 1.0
     *TUBING-OPENING 'Site1-Main-TS' 9220.0 1.0
     *TUBING-OPENING 'Site1-Main-TS' 9440.0 1.0
     *TUBING-OPENING 'Site1-Main-TS' 9659.9 1.0
*END
```

In the text above, a pump has been positioned and specified in the tubing string ***'Site1-Main-TS'***. The power of the pump is defined as **40** HP. Also, the location and settings for the four tubing string openings is defined.

16. The next step is to specify a down-hole separator. This will be done in the following 3 sub-steps. For this exercise the down-hole separator will completely separate the liquid from the gas.
    a. Using ***DHS-PDMETHOD,** specify the pressure-drop methods available for down-hole separators. In the dataset, enter:

```
*DHS-PDMETHOD 'dhs-dp1'
```

```
*ZERO
```

b. Using ***DHS-TABLE**, specify the separation tables available for down-hole separators. In the dataset, enter:

```
*DHS-TABLE 'dhs-tab1'
*BEGIN
     OIL   1 0 0
     WATER 1 0 0
     GAS   0 1 0
*END
```

c. Use ***DWNHSEP** to specify the properties (separation table, pressure drop method, and outlets) of the down-hole separators. For this case study, we have a down-hole separator at a measured depth of **6100** ft. in tubing string '**Site1-Main-TS'**, which we define as follows:

```
*DWNHSEP 'Site1-Main-TS' 6100
*BEGIN
     *TABLE 'dhs-tab1'
     *PDROP 'dhs-dp1'
     *OUTLET2 'Site1-Second-TS'
     *OUTLET3 'Site1-Main-TS'
*END
```

17. Using ***WB-BLOCKBDYS**, enter the block boundaries for all branches in the iSegWell.

Until the associated block boundaries are defined, ***WB-PFINTVLS** will not be active.

For this case study:

```
*WB-BLOCKBDYS 'Site1-L1'
*BEGIN
 5 8 2 0.0    0.0 9000.0 9000.0  450.0 0.0  9000.0 9450.0
 6 8 2 450.0  0.0 9000.0 9450.0  1350.0 0.0 9000.0 10350.0
 7 8 2 1350.0 0.0 9000.0 10350.0 2250.0 0.0 9000.0 11250.0
 8 8 2 2250.0 0.0 9000.0 11250.0 3150.0 0.0 9000.0 12150.0
 9 8 2 3150.0 0.0 9000.0 12150.0 4050.0 0.0 9000.0 13050.0
10 8 2 4050.0 0.0 9000.0 13050.0 4950.0 0.0 9000.0 13950.0
11 8 2 4950.0 0.0 9000.0 13950.0 5400.0 0.0 9000.0 14400.0
*END

*WB-BLOCKBDYS 'Site1-L2'
*BEGIN
 5 8 6 0.0    0.0 9220.0 9220.0  450.0  0.0 9220.0 9670.0
 6 8 6 450.0  0.0 9220.0 9670.0  1350.0 0.0 9220.0 10570.0
 7 8 6 1350.0 0.0 9220.0 10570.0 2250.0 0.0 9220.0 11470.0
 8 8 6 2250.0 0.0 9220.0 11470.0 3150.0 0.0 9220.0 12370.0
```

```
 9 8 6 3150.0 0.0 9220.0 12370.0 4050.0 0.0 9220.0 13270.0
10 8 6 4050.0 0.0 9220.0 13270.0 4950.0 0.0 9220.0 14170.0
11 8 6 4950.0 0.0 9220.0 14170.0 5400.0 0.0 9220.0 14620.0
*END

*WB-BLOCKBDYS 'Site1-L3'
*BEGIN
 5 8 10 0.0    0.0 9440.0 9440.0  450.0  0.0 9440.0 9890.0
 6 8 10 450.0  0.0 9440.0 9890.0  1350.0 0.0 9440.0 10790.0
 7 8 10 1350.0 0.0 9440.0 10790.0 2250.0 0.0 9440.0 11690.0
 8 8 10 2250.0 0.0 9440.0 11690.0 3150.0 0.0 9440.0 12590.0
 9 8 10 3150.0 0.0 9440.0 12590.0 4050.0 0.0 9440.0 13490.0
10 8 10 4050.0 0.0 9440.0 13490.0 4950.0 0.0 9440.0 14390.0
11 8 10 4950.0 0.0 9440.0 14390.0 5400.0 0.0 9440.0 14840.0
*END

*WB-BLOCKBDYS 'Site1-L4'
*BEGIN
 5 8 14 0.0    0.0 9660.0 9660.0  450.0  0.0 9660.0 10110.0
 6 8 14 450.0  0.0 9660.0 10110.0 1350.0 0.0 9660.0 11010.0
 7 8 14 1350.0 0.0 9660.0 11010.0 2250.0 0.0 9660.0 11910.0
 8 8 14 2250.0 0.0 9660.0 11910.0 3150.0 0.0 9660.0 12810.0
 9 8 14 3150.0 0.0 9660.0 12810.0 4050.0 0.0 9660.0 13710.0
10 8 14 4050.0 0.0 9660.0 13710.0 4950.0 0.0 9660.0 14610.0
11 8 14 4950.0 0.0 9660.0 14610.0 5400.0 0.0 9660.0 15060.0
*END
```

18. The last step in specifying the iSegWell definition is to assign the segmented well to a simulator well using ***SGWASSIGN:**

```
*SGWASSIGN 'SGW-Site1-Main-TS' *TO 'Multi-lat'
```

Outputs for iSegWell

19. Once the iSegWell is defined we need to output information to the .out file. This is done with the following keyword:

```
*SGINFO 1
```

20. Scroll to the top of the dataset and add the following set of keywords to the I/O control section. They can be placed directly below the line containing **OUTSRF GRID:**

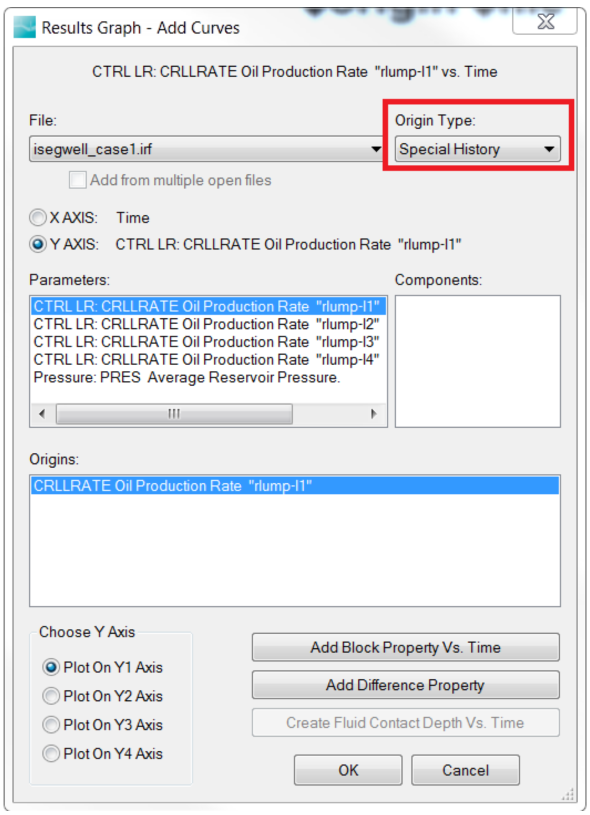
```
*OUTSRF *SPECIAL 'rlump-l1'  *CRLLRATE *PROD *OIL
*OUTSRF *SPECIAL 'rlump-l2'  *CRLLRATE *PROD *OIL
*OUTSRF *SPECIAL 'rlump-l3'  *CRLLRATE *PROD *OIL
```

```
*OUTSRF *SPECIAL 'rlump-l4'  *CRLLRATE *PROD *OIL
```

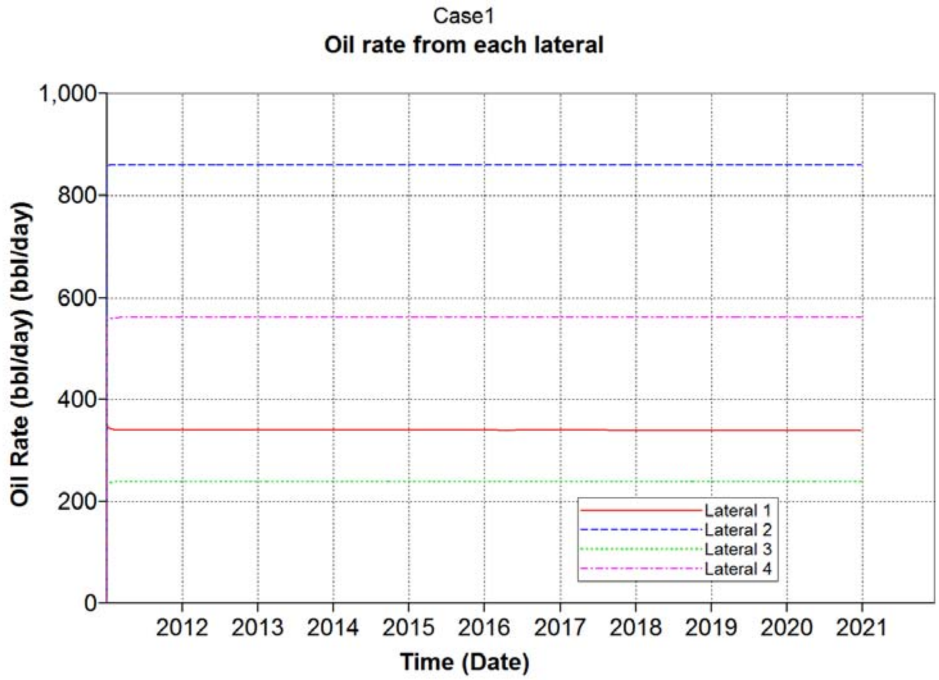
The above keywords will allow the simulator to write the producing oil rate for each branch (lump) to the sr2 files to be viewed in results graph. When outputting information for lumped layers, the user is required to select the desired parameters before running the simulation. Outputs associated with layer lumping is not unique to iSegWell and information on what can be outputted can be found in the **Control Layer Lumping Option** in the IMEX manual.

Running and Viewing Results

21. Save the Dataset as **isegwell_case1.dat**
22. Run the dataset in IMEX.
23. In Results Graph, create a graph, showing the oil rate from each lateral. These parameters can be plotted by selecting the origin **Special History** in the **Add Curve Window.**



With no flow control applied to the tubing openings, and the tubing openings for all laterals set to *1.0*, the oil rate from each lateral is as follows:



As shown, the oil rates from the laterals are quite different, with flow dependent on formation permeability.

Applying Passive Flow Control

In order to get the model to produce evenly amongst the layers flow control devices can be used. This exercise will apply passive flow control by adjusting the tubing openings to balance the flow.

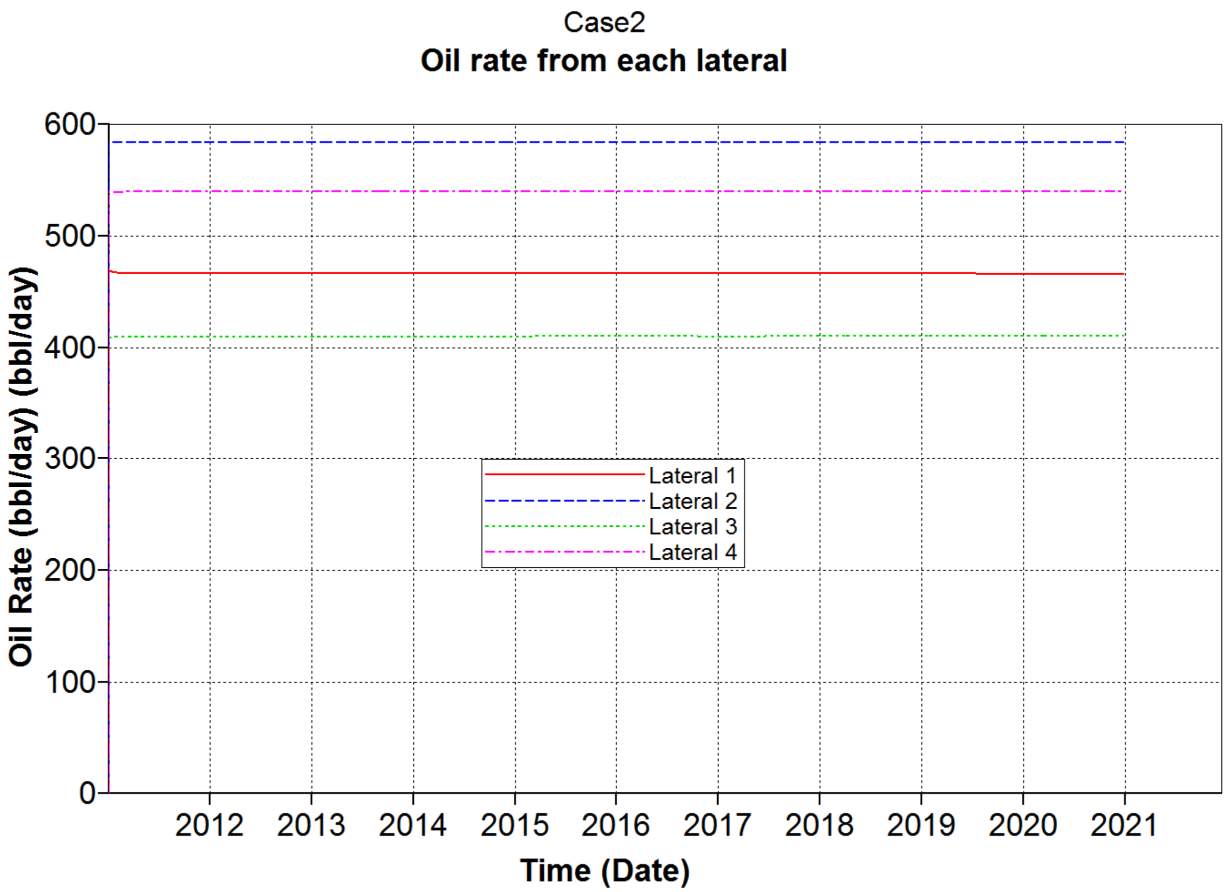
24. Re-open the dataset **isegwell_case1.dat** in a text editor.
25. To specify passive flow control, first edit ***TOPENS** to apply pressure drop method **‘to-meth2’** to the tubing string openings. **‘to-meth2’** is defined by ***TO-PDMETHOD** as an orifice equipment pressure drop calculation method. The change is highlighted in red:

```
*TOPENS 'Site1-Main-TS'
*BEGIN
    5900.1 *FLOWPORT *OPEN 'to-meth1'
    9000.0 *FLOWPORT *OPEN 'to-meth2'
    9220.0 *FLOWPORT *OPEN 'to-meth2'
    9440.0 *FLOWPORT *OPEN 'to-meth2'
    9659.9 *FLOWPORT *OPEN 'to-meth2'
*END
```

26. In addition to changing the opening method, change the keyword *TS-EQSETTING to set the tubing string openings to a maximum opening setting value of **0.8**:

```
*TS-EQSETTING
*BEGIN
     *TUBING-OPENING 'Site1-Main-TS' 9000.0 0.8
     *TUBING-OPENING 'Site1-Main-TS' 9220.0 0.8
     *TUBING-OPENING 'Site1-Main-TS' 9440.0 0.8
     *TUBING-OPENING 'Site1-Main-TS' 9659.9 0.8
*END
```

27. Save the dataset as **isegwell_case2.dat** and run it in **IMEX.**
28. Open the **.irf** in results graph and create a plot with the same four curves as before, showing the oil rater from each lateral.



As shown, with passive flow control, the production levels are brought closer together. The reduction in flow from Lateral 2 allows the flow from the other laterals to increase; however, they are still not equal. In the next steps, we will model active flow control by first specifying monitor points, then using the outputs of these monitor points to control the flow control devices.

Applying Active Flow Control

29. Open the dataset isegwell_case2.dat into a text editor.
30. In this case study, we have four monitoring points, all of them in wellbore branches. Use ***SGMON-WBPT** to define the name and location of the monitoring points in the wellbore branch. Enter the following in the dataset, before the second **TIME** keyword:

```
*SGMON-WBPT
*BEGIN
     'wbmonpt-L1' 'Site1-L1' 9000.01
     'wbmonpt-L2' 'Site1-L2' 9220.01
     'wbmonpt-L3' 'Site1-L3' 9440.01
     'wbmonpt-L4' 'Site1-L4' 9660.01
*END
```

Note: If monitoring points were installed in tubing strings, we would have used ***SGMON-TSPT** to specify them.

31. Use *SGMON-TSSET to define the equipment (name, position) that will be acted upon by the monitor, and the action itself. In the dataset enter:

```
SGMON-TSSET 'meqpset-L1'
*BEGIN
  *TUBING-OPENING 'Site1-Main-TS' 9000 incr -0.05
*END

*SGMON-TSSET 'meqpset-L2'
*BEGIN
  *TUBING-OPENING 'Site1-Main-TS' 9220 incr -0.05
*END

*SGMON-TSSET 'meqpset-L3'
*BEGIN
  *TUBING-OPENING 'Site1-Main-TS' 9440 incr -0.05
*END

*SGMON-TSSET 'meqpset-L4'
*BEGIN
  *TUBING-OPENING 'Site1-Main-TS' 9659.9 incr -0.05
```

```
*END

*SGMON-TSSET 'peqpset-L1'
*BEGIN
  *TUBING-OPENING 'Site1-Main-TS' 9000 incr +0.05
*END

*SGMON-TSSET 'peqpset-L2'
*BEGIN
  *TUBING-OPENING 'Site1-Main-TS' 9220 incr +0.05
*END

*SGMON-TSSET 'peqpset-L3'
*BEGIN
  *TUBING-OPENING 'Site1-Main-TS' 9440 incr +0.05
*END

*SGMON-TSSET 'peqpset-L4'
*BEGIN
  *TUBING-OPENING 'Site1-Main-TS' 9659.9 incr +0.05
*END
```

In the above, we have defined actions to increment the setting value of the individual openings in tubing string **'Site1-Main-TS'**, either by **-0.05** (reduce by 5%) or by +**0.05** (increase by 5%). The setting value, which will then be applied using ***TS-EQSETTING**, is a multiplier for the overall pressure drop across the tubing opening.

Note: In some cases, the monitor point will not act on any equipment, in which case, this step would not be required.

32. Use *__SGMONITOR__ to specify the test that will be conducted and the actions that will be taken when certain conditions occur. In the dataset, enter:

```
*SGMONITOR 'msgmon-L1'
*BEGIN
  TYPE wellbore
  POINT 'wbmonpt-L1'
  VARIABLE ratequot 1 0 0 1 0 0 0
  VALUE max 600
```

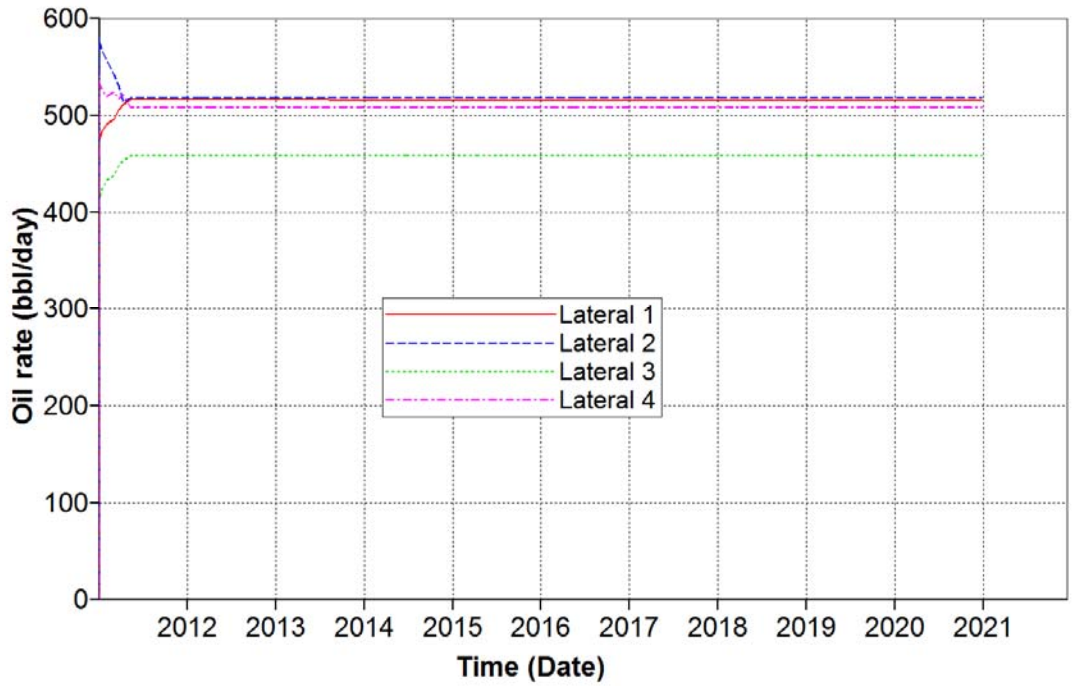
```
  ACTION eqptset 'meqpset-L1'
*END

*SGMONITOR 'msgmon-L2'
*BEGIN
  TYPE wellbore
  POINT 'wbmonpt-L2'
  VARIABLE ratequot 1 0 0 1 0 0 0
  VALUE max 600
  ACTION eqptset 'meqpset-L2'
*END

*SGMONITOR 'msgmon-L3'
*BEGIN
  TYPE wellbore
  POINT 'wbmonpt-L3'
  VARIABLE ratequot 1 0 0 1 0 0 0
  VALUE max 600
  ACTION eqptset 'meqpset-L3'
*END

*SGMONITOR 'msgmon-L4'
*BEGIN
  TYPE wellbore
  POINT 'wbmonpt-L4'
  VARIABLE ratequot 1 0 0 1 0 0 0
  VALUE max 600
  ACTION eqptset 'meqpset-L4'
*END

*SGMONITOR 'psgmon-L1'
*BEGIN
  TYPE wellbore
  POINT 'wbmonpt-L1'
  VARIABLE ratequot 1 0 0 1 0 0 0
  VALUE min 400
  ACTION eqptset 'peqpset-L1'
  *END

*SGMONITOR 'psgmon-L2'
*BEGIN
```

```
  TYPE wellbore
  POINT 'wbmonpt-L2'
  VARIABLE ratequot 1 0 0 1 0 0 0
  VALUE min 400
  ACTION eqptset 'peqpset-L2'
*END

*SGMONITOR 'psgmon-L3'
*BEGIN
  TYPE wellbore
  POINT 'wbmonpt-L3'
  VARIABLE ratequot 1 0 0 1 0 0 0
  VALUE min 400
  ACTION eqptset 'peqpset-L3'
*END

*SGMONITOR 'psgmon-L4'
*BEGIN
  TYPE wellbore
  POINT 'wbmonpt-L4'
  VARIABLE ratequot 1 0 0 1 0 0 0
  VALUE min 400
  ACTION eqptset 'peqpset-L4'
*END
```

In the above example, consider monitor '**psgmon-L3'** which is located in the wellbore at monitoring point '**wbmonpt-L3'** which in turn, is located in branch '**Site1-L3'** at a measured depth of **9440.01**. If the measured rate quotient falls below **400**, the monitor will initiate action '**peqpset-L3'** to increment the tubing string opening setting value (increasing the setting value will decrease the pressure drop) in tubing string '**Site1-Main-TS'** at a measured depth of **9440**, by +**0.05** (+5%).

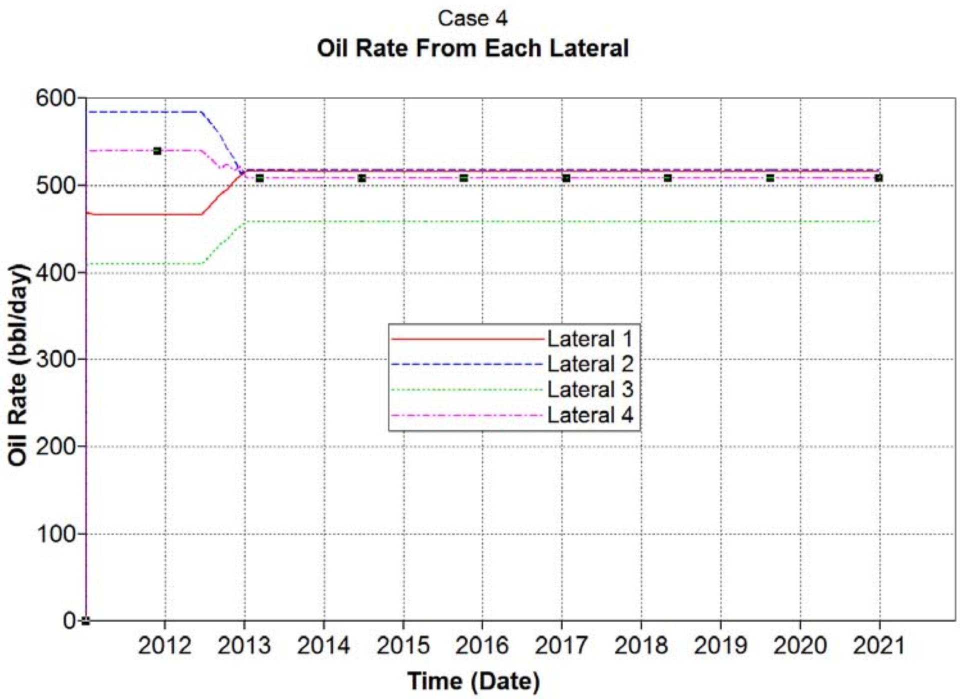
33. Save the dataset as **isegwell_case3.dat** and run it in **IMEX**. Below are the results

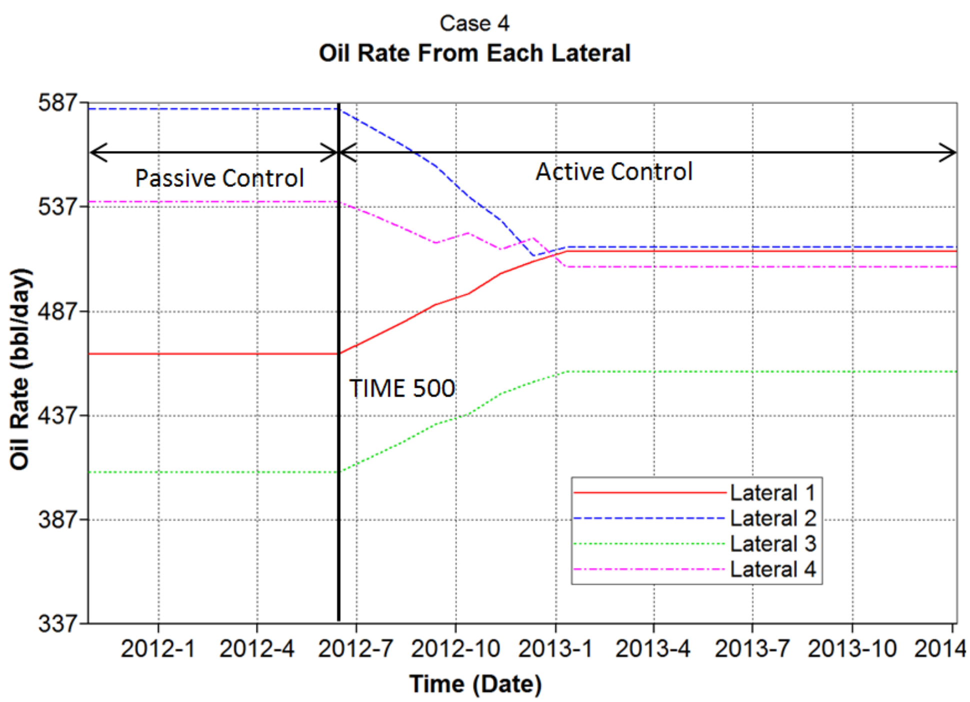
Case 3
Oil Rate from each lateral



As shown, with active flow control, the production levels are immediately brought closer together, from the levels resulting from passive flow control. In the next step, the effect of delaying the initiation of active control will be observed.

34. To delay the active control, the monitor keywords need to be moved to a later date. Move the *__SGMON-WBPT__, *__SGMON-TSSET__, and *__SGMONITOR__ entries in the dataset to follow *__TIME 500__. This will delay the active control in the simulation until 500 days from the start. The first 500 days will be under passive control.
35. Save the dataset as **isegwell_case4.dat** and run it in IMEX.
36. The production rate from each lateral is shown in the two images below:





As shown, with delayed active flow control, the production levels start out at those set by the passive flow control then, after time ***TIME 500**, active flow control takes over, and brings the production flow levels closer together.