

TUTORIAL #2

This is a NW-SE dipping stratigraphic reservoir with 150 feet of net thickness. The initial OOIP was 54.812 MMSTB as of 1/1/1900. There was no initial gas cap and the associated aquifer was small. Well depths are approximately 7000 ft.

Initial pressure @ -10 ft ss, psia	3000
Initial bubble point pressure, psia	1800
Water-oil contact, ft ss	-400
Net thickness, ft	150
Porosity, percent	20
Horizontal permeability, md	50
Vertical permeability, md	5
Oil gravity, API	35.5
Gas specific gravity	0.65
Reservoir Temperature, F	150
Swirr, fraction	.25
Sorw, fraction	.25
Sgc, fraction	.05
Sorg, fraction	.30

The field was depleted to 1900 psia reservoir pressure as of 1/1/2012. Cumulative oil production was 2.0 MMSTB (3.64% of OOIP) from the four original wells (1-4). A small gas cap was formed with a GOC at -15 ft ss. The aquifer encroached to -250 ft ss. The model will be initialized in COZView at 1900 psia reservoir pressure.

Crestal CO₂ injection was initiated in 1/1/2012. The reservoir pressure needed to be increased to approximately 2600 psia to achieve CO₂-oil miscibility. Two additional crestal wells (5 and 6) were drilled to supplement CO₂ injection and shorten the re-pressuring period. The bottom hole injection pressure was limited to 2800 psia and the production bottom hole pressures were not allowed to fall below 2600 psia. The maximum field (facilities) CO₂ injection capacity was 15 MMSCF/D. The purchased CO₂ was constrained at 9 MMSCF/D. Produced gas was not recycled.

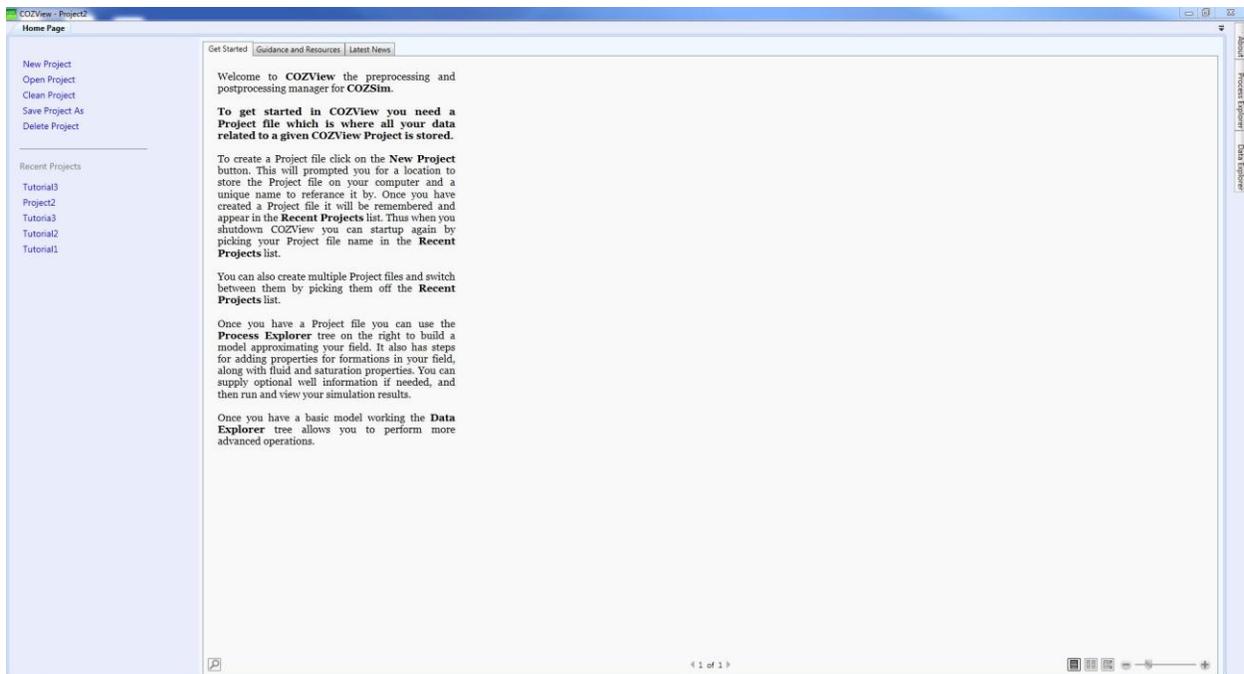
The 15 year simulation prediction resulted in a cumulative incremental oil production was 8.8 MMSTB (16.1% of OOIP). Wells were still producing at 1313 STB/D at the end of the prediction. Cumulative CO2 injection, all of which was from the external source (purchased), was 37.16 BSCF. Cumulative CO2 production was 12.68 BSCF; none of this was recycled. Cumulative hydrocarbon gas production was 3.4 BSCF.

Run time was approximately 30 minutes.

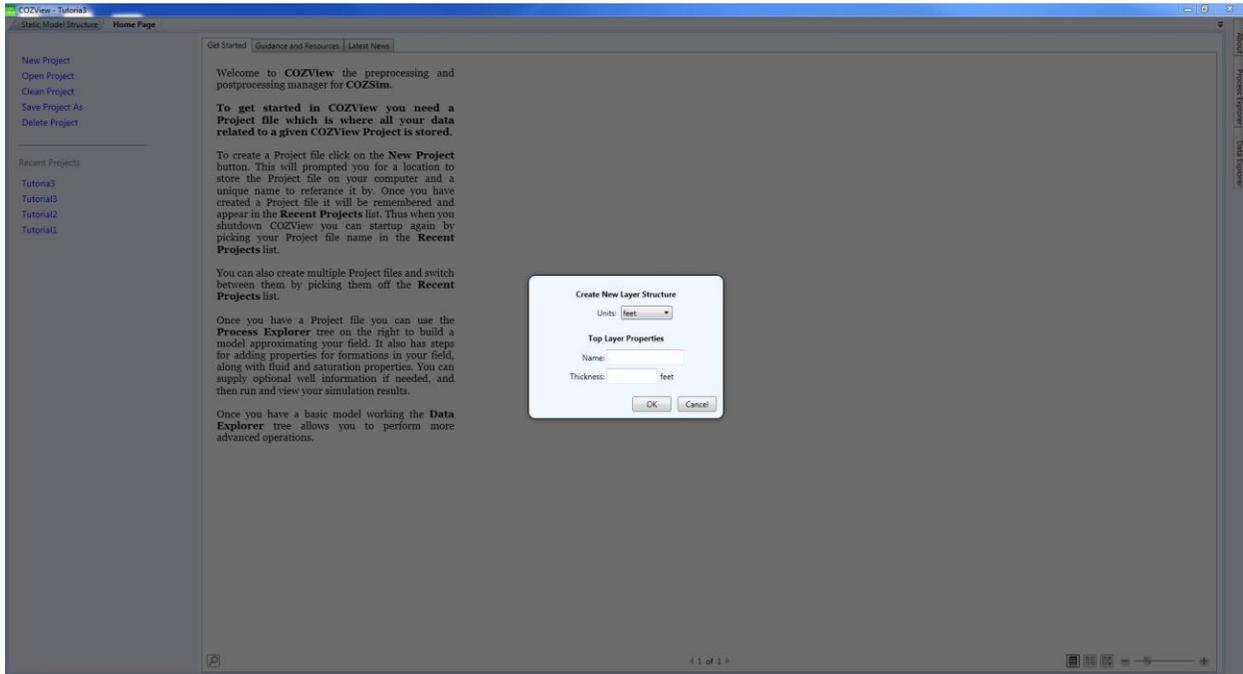
In the course of developing the tutorial examples, some COZView screens may have changed slightly from the views shown in this document. These changes should not impact the model building and simulation process.

Model Building Process

The process starts with creation of a New Project. Select **New Project** and provide a project name on the **Home Page**.

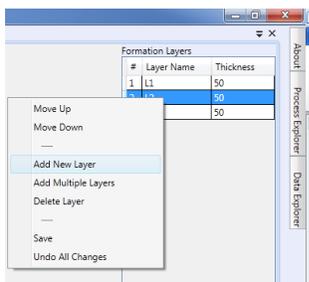


Select **Structure** in the **Static Model** area. *The Create New Layer Structure window will appear. Input a top layer name and the net thickness (50 for this example). **OK** will save the information.*



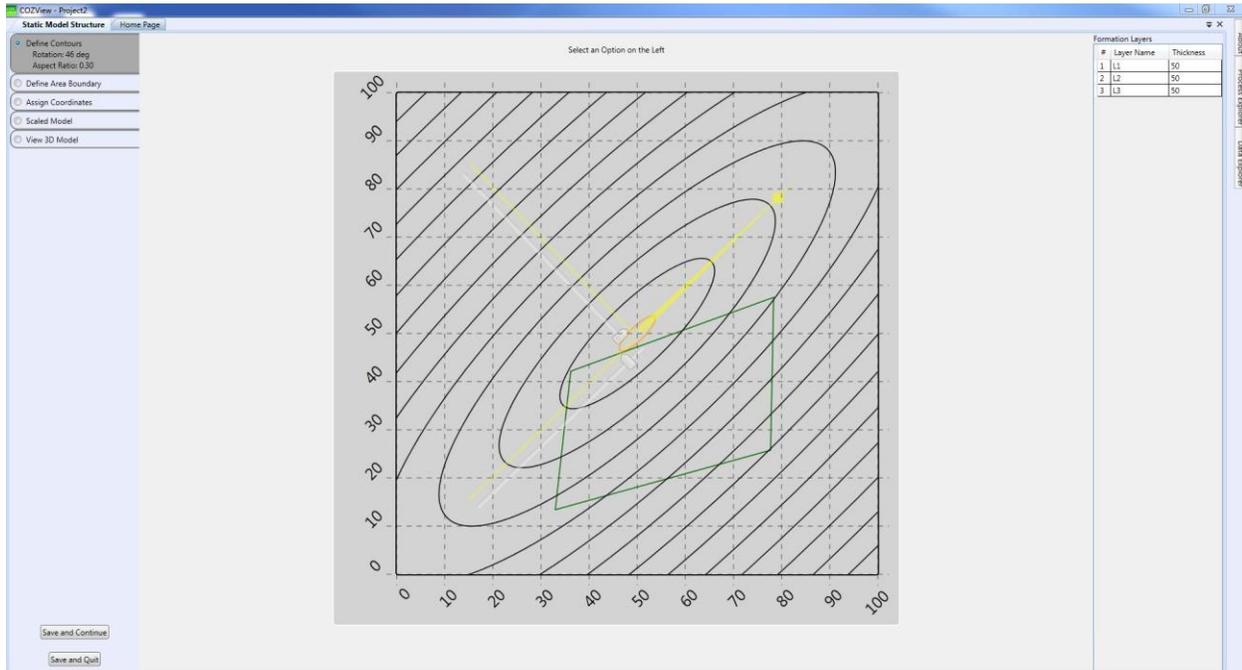
All menus referenced in this tutorial are in the Process Explorer menu area.

The model building starts with the structural surface of the productive formation. Before beginning the structural model definition, add any additional layers that are required by right-clicking the layer 1 row in the upper right of the **Static Model Structure** screen. Select *Add New Layer* and input the required data. Repeat the process as needed. The total net thickness of 150 ft should be divided equally between three layers for this example.



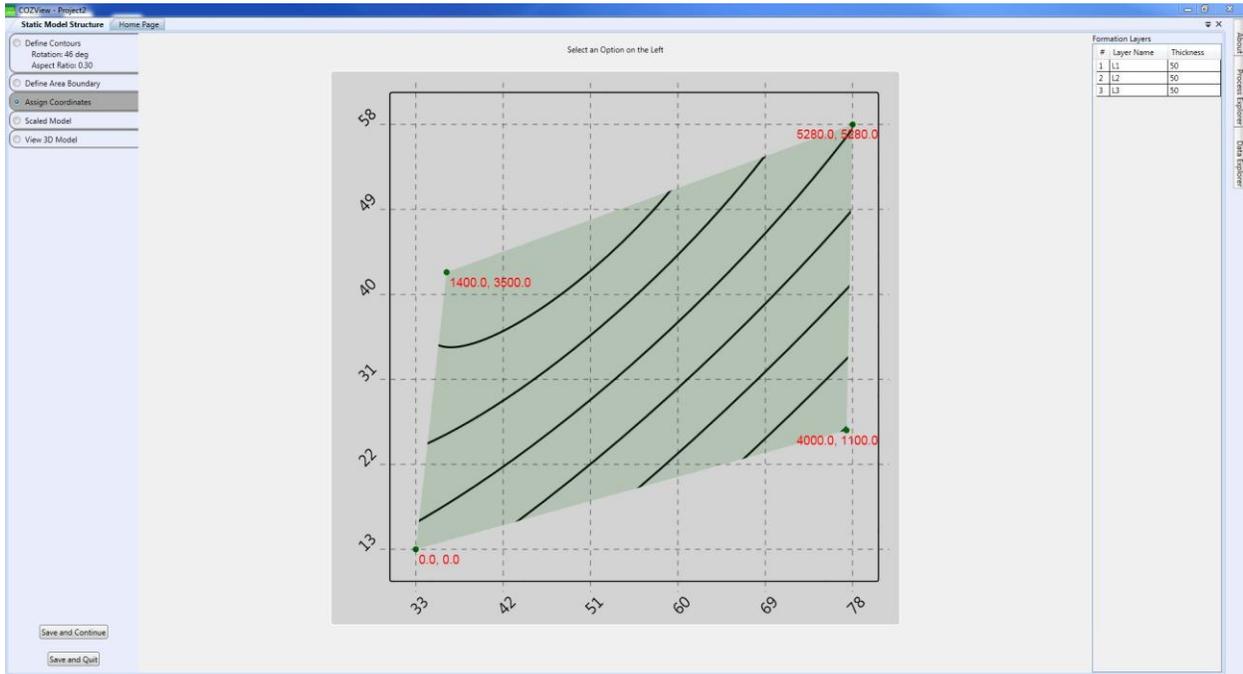
The **Static Model Structure** area allows the user to first *Define Contours* by using the resizing bars and rotation control ball.

This is followed by **Define Area Boundary** (the green area shown below). The simulation model will be the area inside the green boundaries. The user selects the boundary points to reflect the reservoir area on the structure top map.



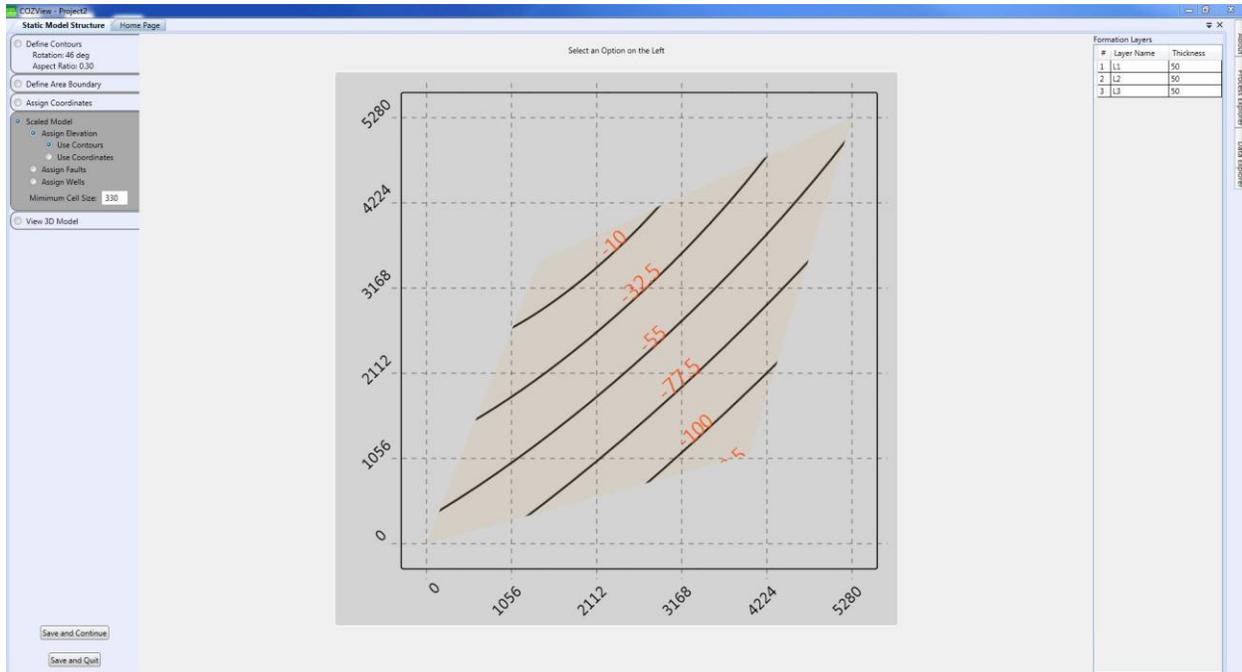
Save and Continue is recommended.

Assign Coordinates allows the user to provide coordinate positions for each of the boundary points provided. These are typically in feet as shown below.



Save and Continue is recommended.

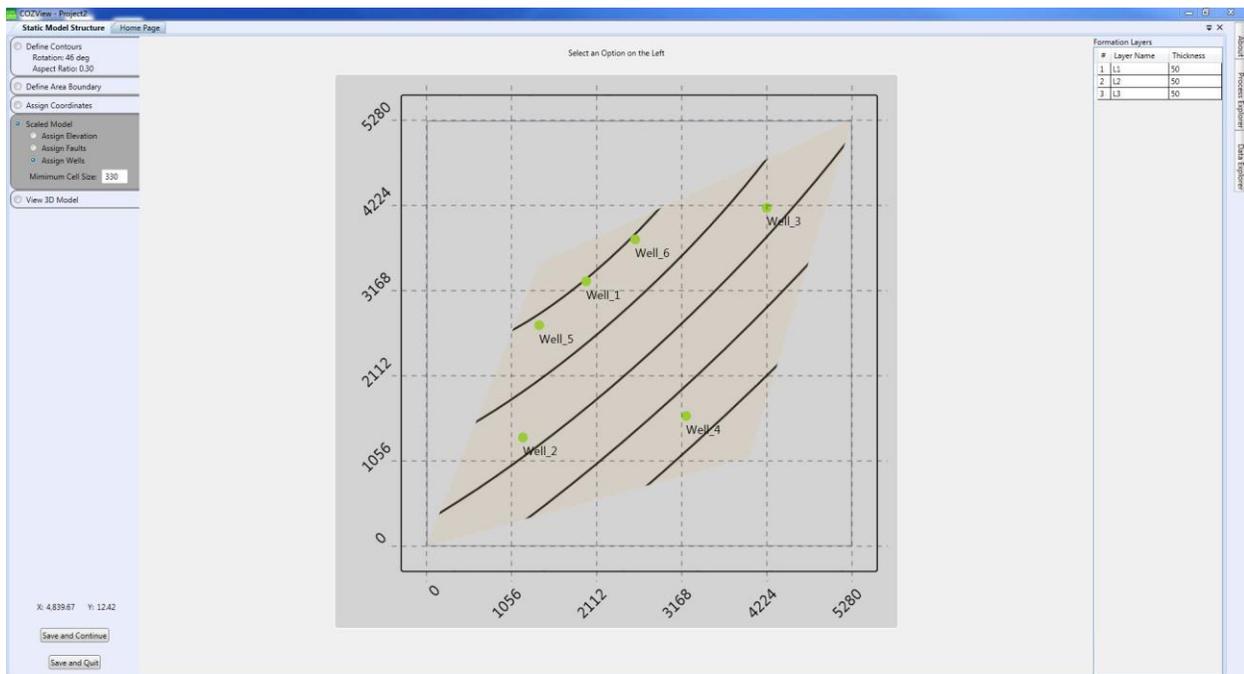
Selection of **Scaled Model** and *Assign Elevation/Use Contours* allows the user to establish the structural contour elevations. A top contour elevation of -10 ft ss and a bottom contour elevation of -100 ft ss establish the contour interval.



Save and Continue is recommended.

Assign Wells allows the user to position wells on the structural surface. Once all wells are positioned their KB and TD should be defined (optional). The KB and TD data are

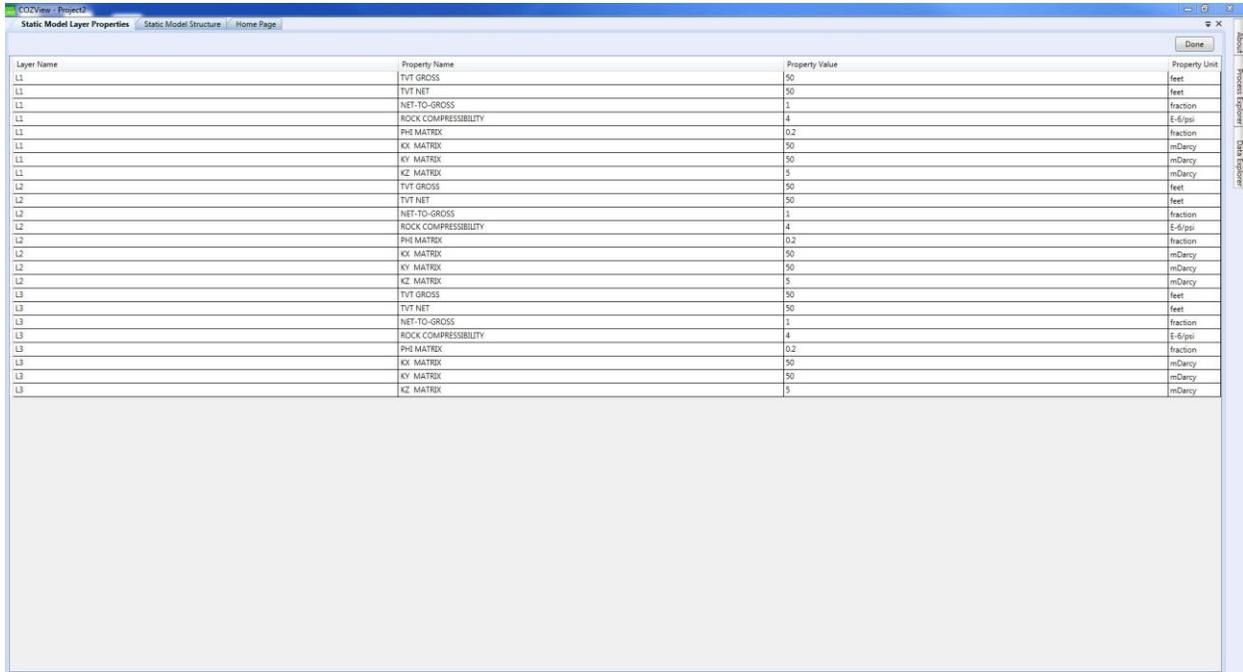
Well	KB	TD
1	7000	7600
2	7200	7400
3	7050	7500
4	7100	7300
5	7000	7500
6	7100	7600



Save and Continue is recommended.

Select **Layer Properties 3D View** to confirm the structural model and well positions in a 3D view.

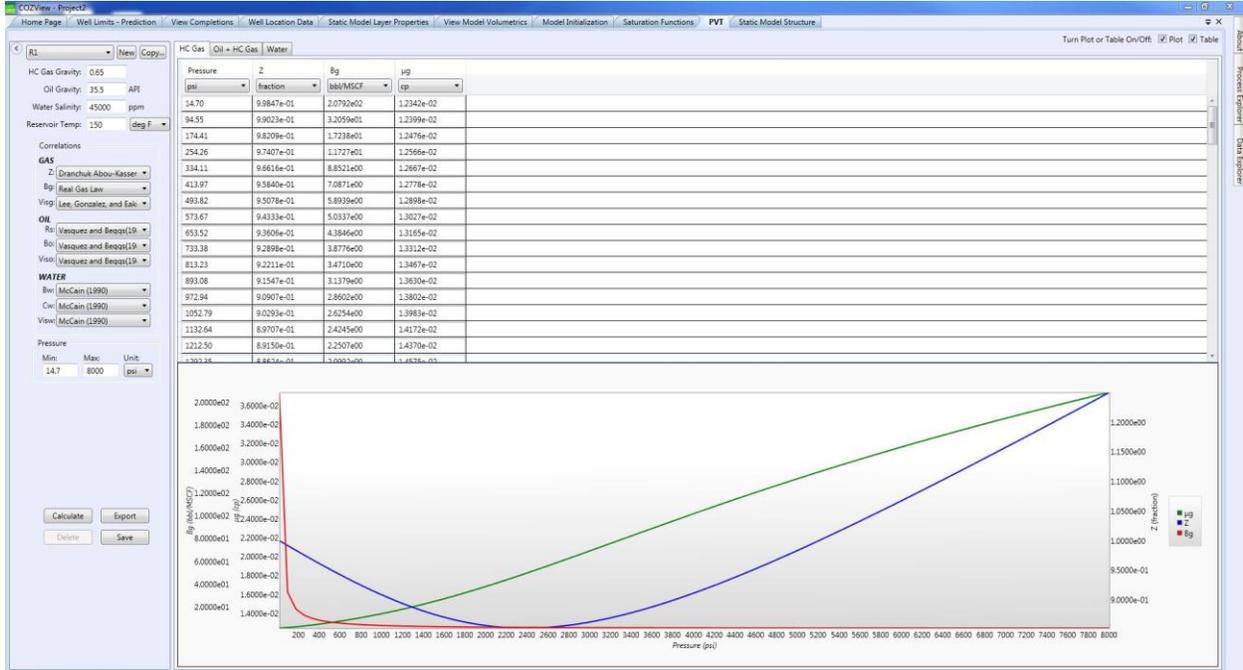
Layer Properties should be selected from the **Static Model** menu area. Values will already be input for the layers previously defined. The default values can be changed if appropriate.



Layer Name	Property Name	Property Value	Property Unit
L1	TVT GROSS	50	feet
L1	TVT NET	50	feet
L1	NET-TO-GROSS	1	fraction
L1	ROCK COMPRESSIBILITY	4	E-6/psi
L1	PHE MATREX	0.2	fraction
L1	KX MATREX	50	mDarcy
L1	KY MATREX	50	mDarcy
L1	KZ MATREX	5	mDarcy
L2	TVT GROSS	50	feet
L2	TVT NET	50	feet
L2	NET-TO-GROSS	1	fraction
L2	ROCK COMPRESSIBILITY	4	E-6/psi
L2	PHE MATREX	0.2	fraction
L2	KX MATREX	50	mDarcy
L2	KY MATREX	50	mDarcy
L2	KZ MATREX	5	mDarcy
L3	TVT GROSS	50	feet
L3	TVT NET	50	feet
L3	NET-TO-GROSS	1	fraction
L3	ROCK COMPRESSIBILITY	4	E-6/psi
L3	PHE MATREX	0.2	fraction
L3	KX MATREX	50	mDarcy
L3	KY MATREX	50	mDarcy
L3	KZ MATREX	5	mDarcy

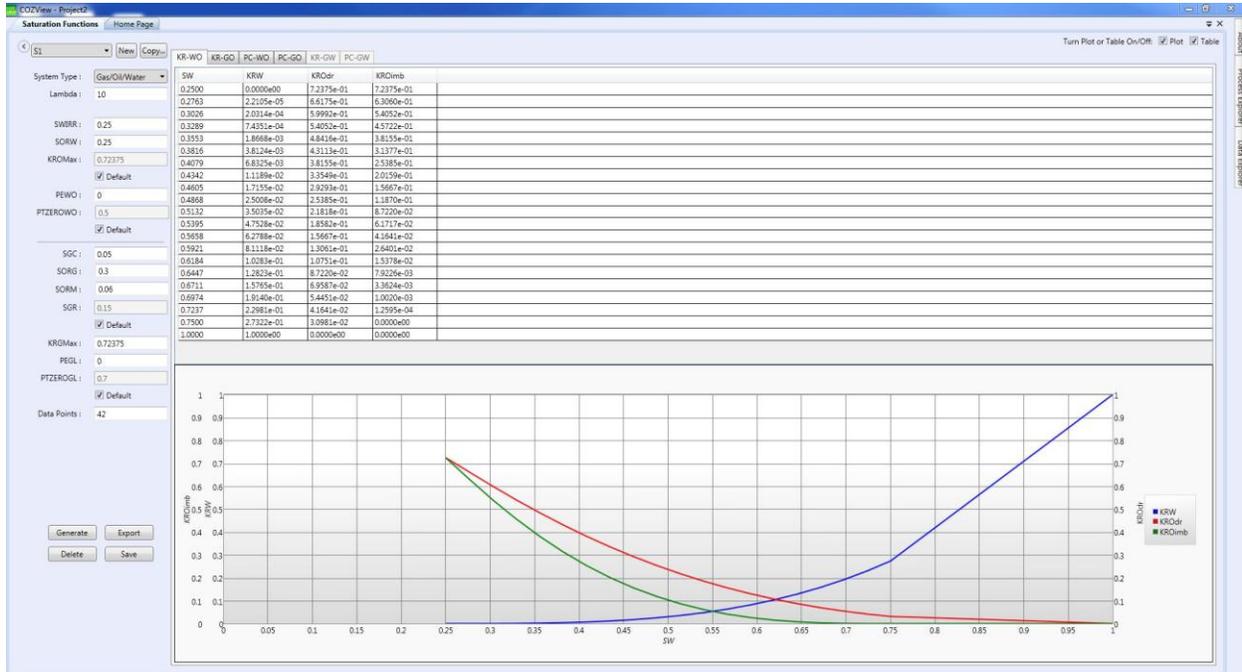
Select **Done** when finished to save the layer properties.

PVT should be selected from the **Fluid and Saturation Properties** menu area. The initial PVT properties screen will be blank. The **New** button should be selected to create a new set of PVT properties (table). The default values must be overridden by the user to create the PVT data shown below when the **Calculate** button is selected.



Select **Save** to save the data.

Saturation Functions should be selected from the **Fluid and Saturation Properties** menu area. The initial Saturation Function properties screen will be blank. The **New** button should be selected to create a new set of Saturation Function properties (table). The default values must be overridden by the user to create the Saturation Function data shown below when the **Generate** button is selected.



Select **Save** to save the data.

Model Initialization should be selected from the **Verify Model** menu area. This screen will initially be blank. The user can verify the volumetrics of the model that has been created by inputting appropriate values in the data fields. Initially the volumetrics of the model can be checked for the original conditions (1/1/1990), if desired. This requires identification of the Fluid PVT and Saturation Function tables previously defined. The following data would be input for the current conditions at 1/1/2012.

Initialization Date 1/1/2012

Model Type 3 phase

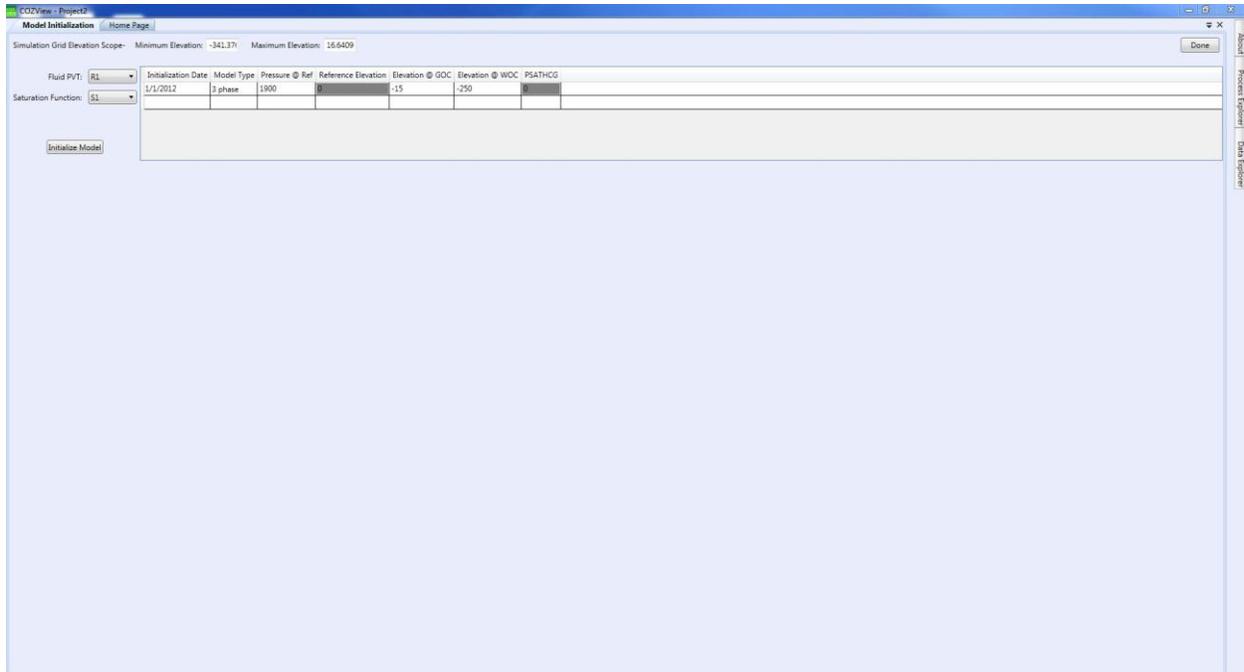
Pressure @Ref 1900

Elevation @ GOC -15

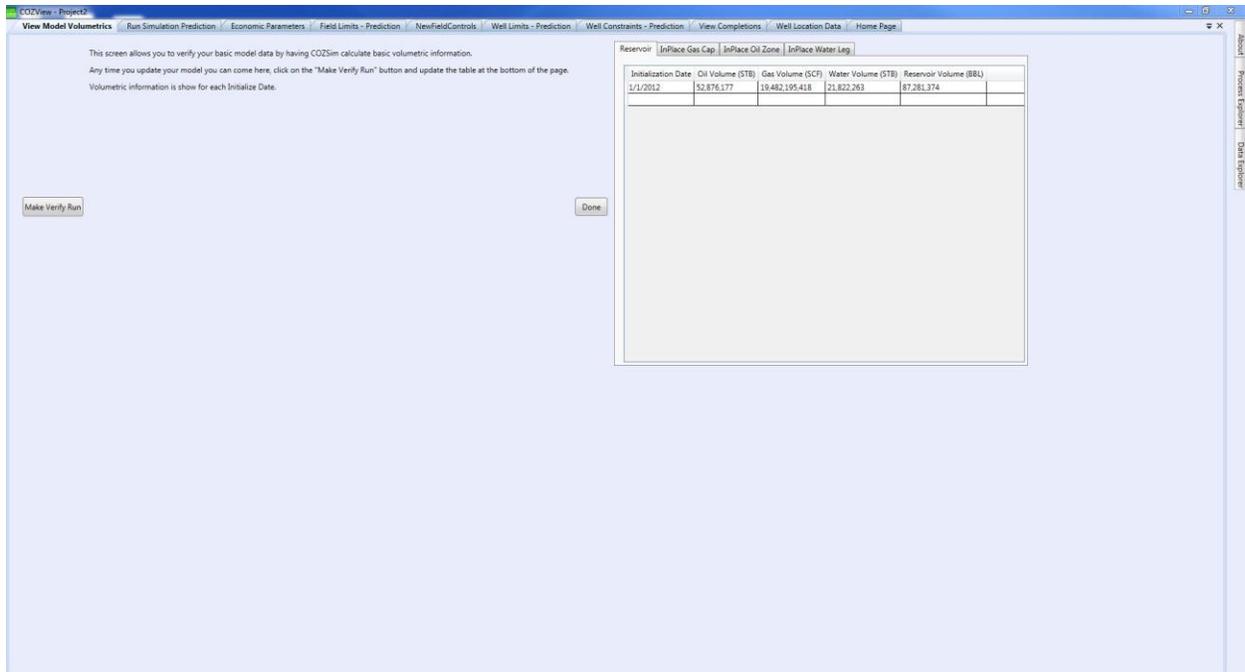
Elevation @ WOC -250

Selection of **Initialize Model** will provide the results of the volumetric calculation on the **Model Volumetrics** screen. A brief view of the **Simulator Runner** window will appear before the volumetrics are reported. If initial conditions (1/1/1990) are run, an OOIP of approximately 54.812 MMSTB should be reported subject to differences in the user defined model and this example.

The screen below shows the current conditions (1/1/2012) **Model Initialization** data. Selection of **Initialize Model** will provide the results of the volumetric calculation on the **Model Volumetrics** screen.



An OIP of approximately 52.876 MMSTB should be reported subject to differences in the user defined model and this example.

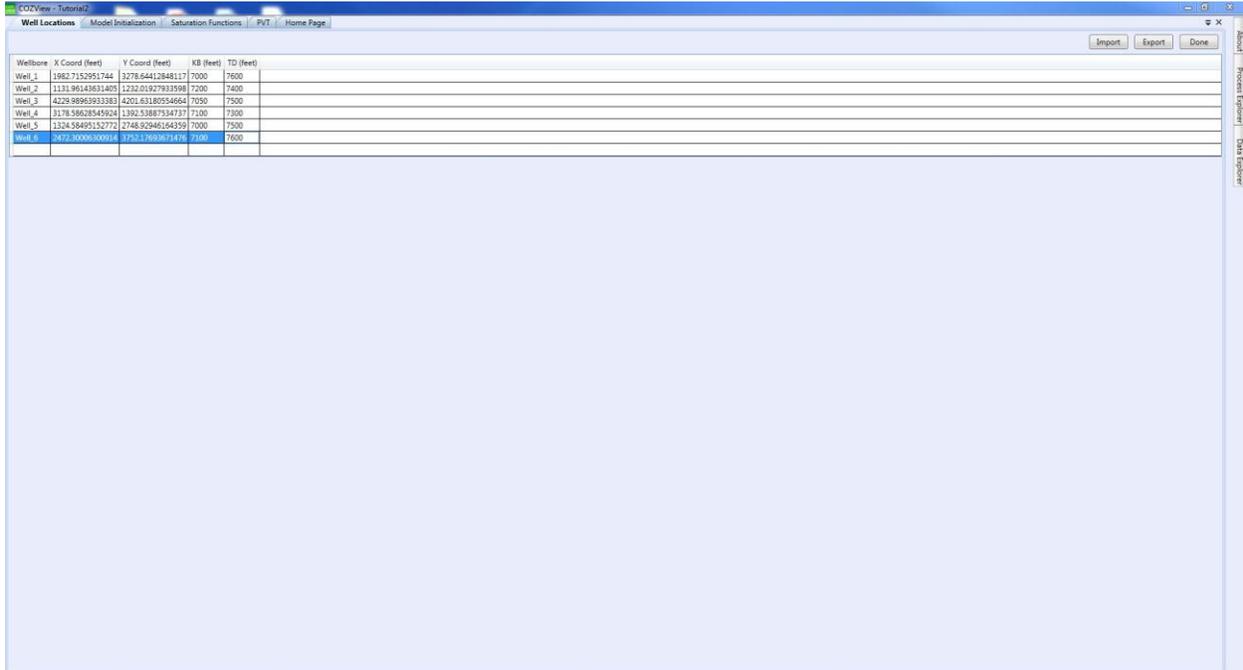


If the user is not satisfied with the volumetric values calculated, changes to the model data created to this point can be made and saved and new volumetrics calculated.

Select **Done** when finished.

The following steps will define well and field operating conditions for the prediction case to be run.

Select **Well Locations** from the **Well Data** menu area to verify previously input well locations, KB elevations and TD. This is generally informational reporting only. If additional wells are required, the user should return to the **Static Model** menu area and interactively locate the new well(s). KB and TD values can be change if required.



The screenshot shows the 'Well Locations' window in CO2View. The window has a title bar 'CO2View - Tutorial2' and a menu bar with 'Well Locations', 'Model Initialization', 'Saturation Functions', 'PVT', and 'Home Page'. On the right side, there are buttons for 'Import', 'Export', and 'Done'. The main area contains a table with the following data:

Wellbore	X Coord (feet)	Y Coord (feet)	KB (feet)	TD (feet)
Well_1	1982.7152951744	3278.64412848117	7000	7600
Well_2	1131.96143631409	1232.01927893598	7200	7400
Well_3	4229.98963933383	4201.63180554664	7050	7500
Well_4	3178.58628549924	1392.53687514737	7100	7300
Well_5	1328.56492152272	2748.92946556259	7000	7500
Well_6	2472.30096000934	3752.12693614746	7100	7600

Select **Done** to save.

Select **Completions** from the **Well Data** area to view and alter the well completions if appropriate. Initially all wells are assumed to be completed in all layers. The *Active check box* can be unchecked for any well layer completion, if desired. No completion changes were made to the default values for this example.

It is important to keep track of the dates shown in the various well and field control screens. These must be consistent with the Initialization Date (start date for the prediction simulation run). These dates should be changed if necessary.

Well	I Coordinate	J Coordinate	K Coordinate	Active?	Open Date	So	Sw	Sg
Well_1	6		1	<input checked="" type="checkbox"/>	1/1/2012	0.649	0.250	0.101
Well_1	6		2	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_1	6		3	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_2	12		1	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_2	12		2	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_2	12		3	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_3	4		1	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_3	4		2	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_3	4		3	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_4	10		1	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_4	10		2	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_4	10		3	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_5	8		1	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_5	8		2	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_5	8		3	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_6	5		1	<input checked="" type="checkbox"/>	1/1/2012	0.789	0.250	0.041
Well_6	5		2	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000
Well_6	5		3	<input checked="" type="checkbox"/>	1/1/2012	0.750	0.250	0.000

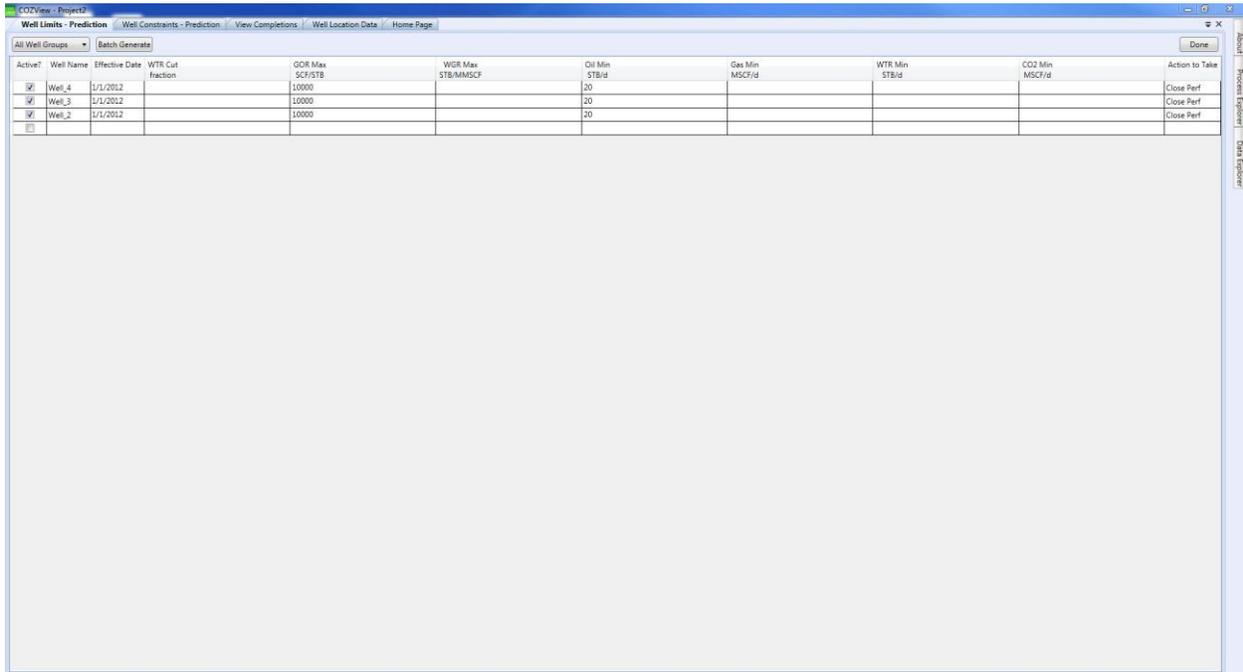
If any changes are made to the completion select **Done** to save.

Select **Well Constraints** from the **Prediction/Well Parameters** menu area. This screen will initially be blank. The **Batch Generate** button is a fast way to input values for multiple wells. The user can input the values noted below for the GAS/CO2 Injection wells and separately for the Liquid Producer wells.

Active?	Well Name	Effective Date	Well Type	Oil Rate STB/d	Water Rate STB/d	Gas Rate MSCF/d	Liquid Rate STB/d	Water Inj Rate STB/d	Gas Inj Rate MSCF/d	BHP
<input checked="" type="checkbox"/>	Well_2	1/1/2012	Liquid Producer				600			2600
<input checked="" type="checkbox"/>	Well_3	1/1/2012	Liquid Producer				600			2600
<input checked="" type="checkbox"/>	Well_4	1/1/2012	Liquid Producer				600			2600
<input checked="" type="checkbox"/>	Well_5	1/1/2012	GAS/CO2 Injection						3000	2800
<input checked="" type="checkbox"/>	Well_5	1/1/2012	GAS/CO2 Injection						3000	2800
<input checked="" type="checkbox"/>	Well_6	1/1/2012	GAS/CO2 Injection						3000	2800

Select **Done** to save.

Select **Well Limits** from the **Prediction/Well Parameters** menu area. This screen will initially be blank. The **Batch Generate** button is a fast way to input the values noted below for multiple wells.

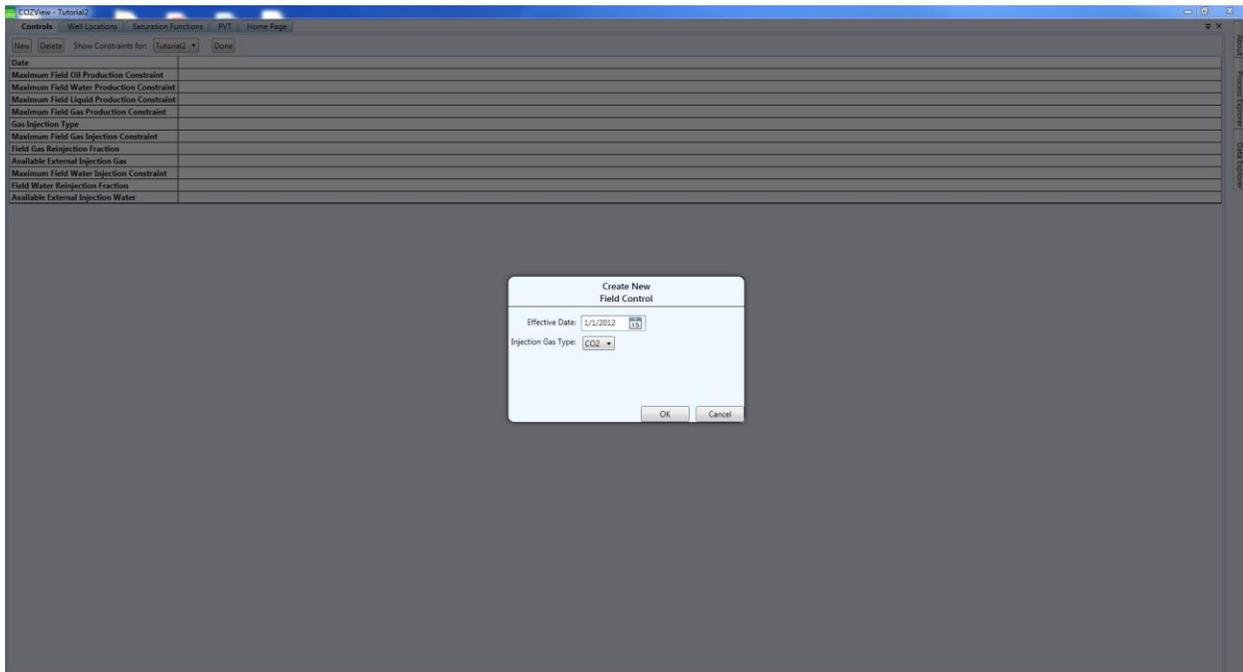
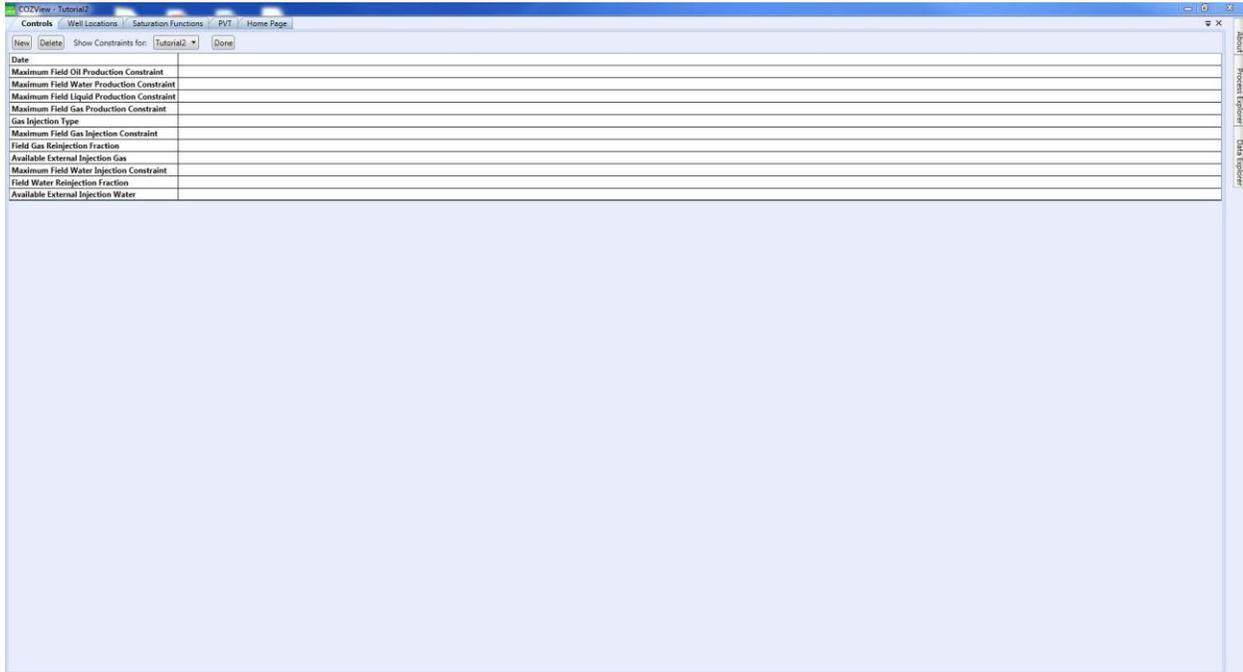


Click **Done** to save.

Select **Field (Facility) Controls** from the **Prediction Period/Field Parameters** menu area. Click **New** to select a date at which Field Controls are to become effective. The user can specify Production Controls and Injection Controls for the field. Select “CO2” for the **Injection Gas Type**.

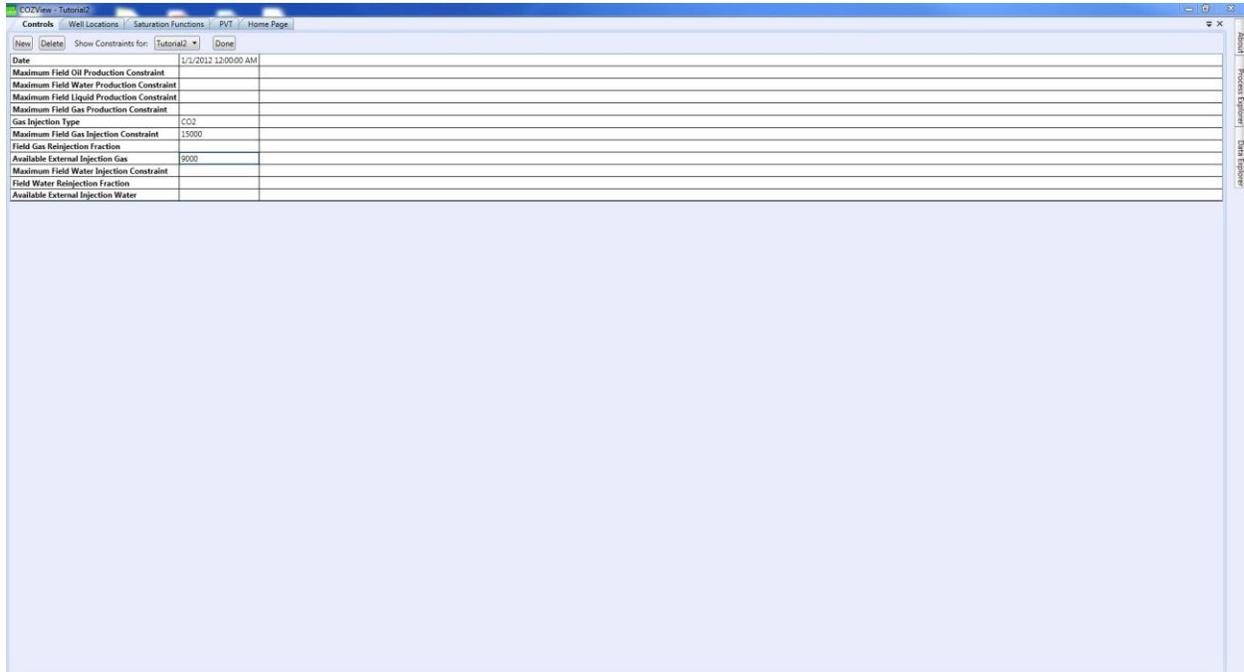
Effective Date 1/1/2012

Injection Gas Type CO2



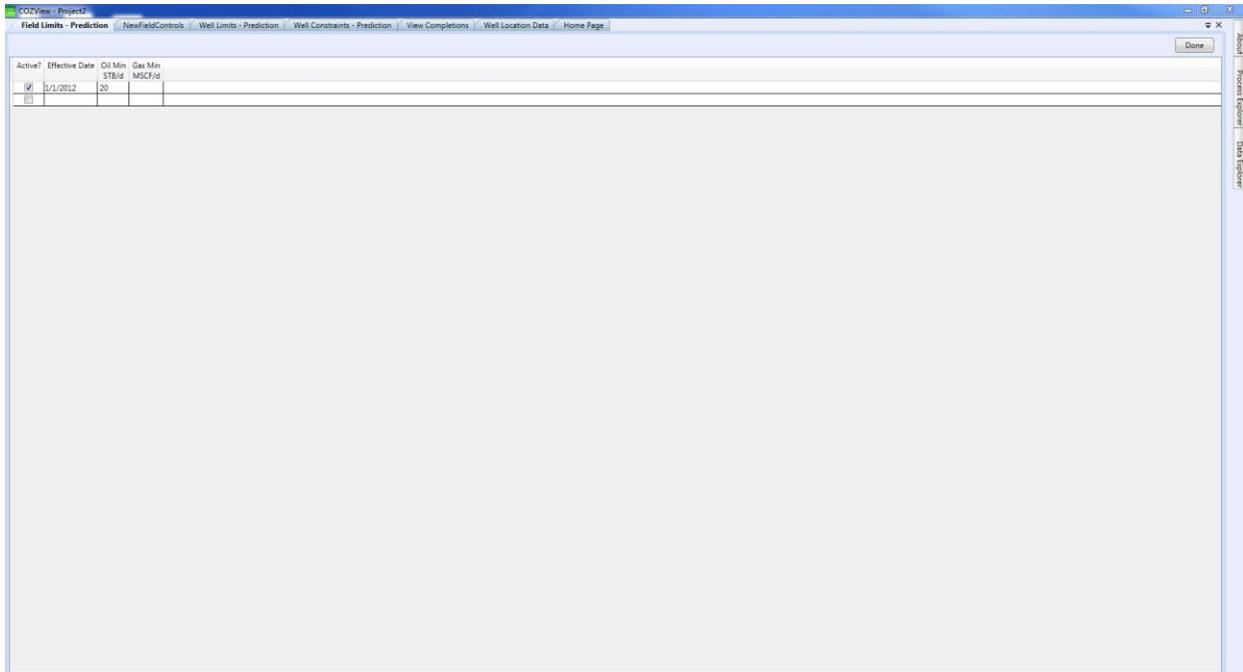
Select **OK** to continue.

The Maximum Field Gas Injection Constraint in this case is 15,000 MSCF/D and the Available External Gas Injection Gas is 9000 MSCF/D.



Select **Done** to save.

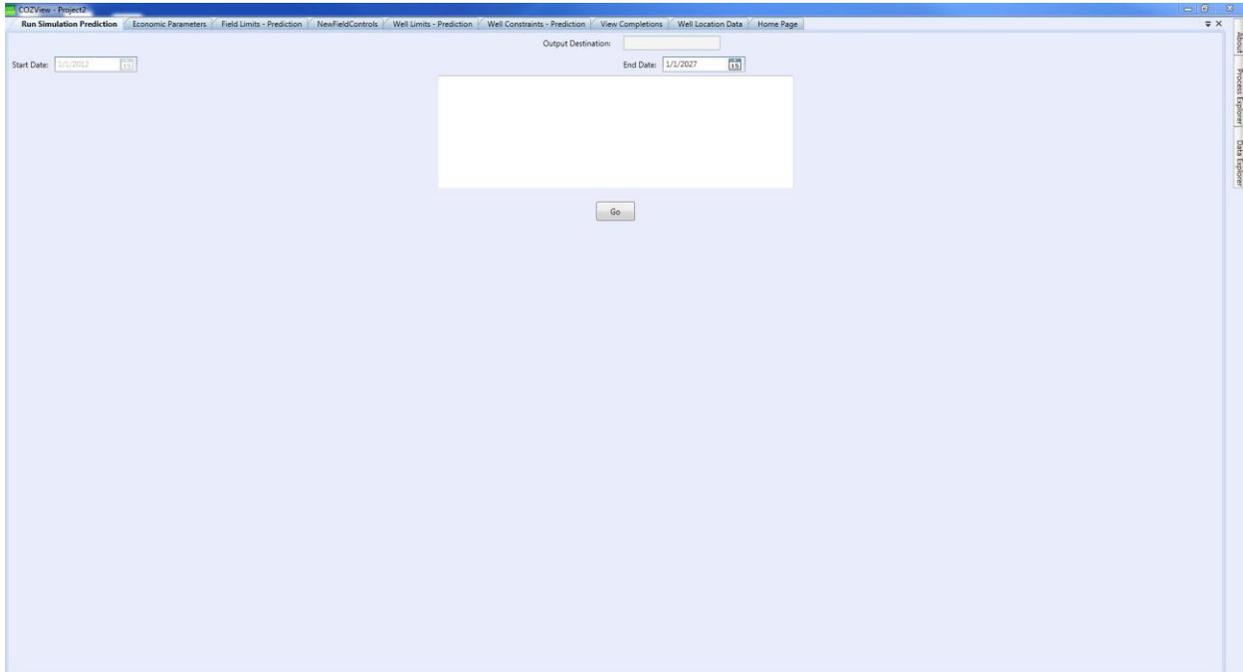
Select **Limits** from the **Prediction Period/Field Parameters** menu area. Check the **Active** box and input appropriate values. It is always wise to have a field limit specified such that the simulation run will stop when the field limit is reached.



Select **Done** to save.

It is prudent at this stage to return to the various well and field parameter screen to insure that data, particularly dates, are set appropriately.

Select **Run Simulation**. The **Model Initialization** date will be shown in the **Start Date** box. If this is not correct, return to the **Model Initialization** screen and reset the date, rerun volumetrics and save. The user must provide a value in the **End Date** box. This must be at least one month after the **Start Date**. 1/1/2027 was used for this example.



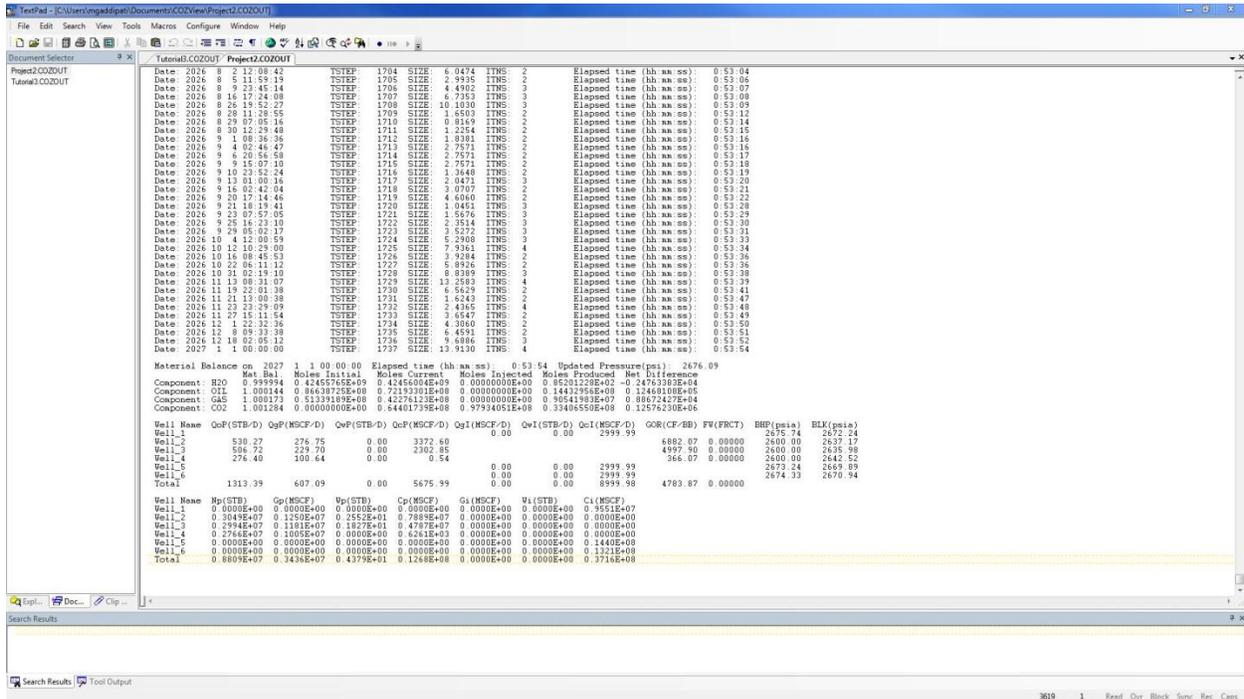
Select **Go** to initiate the simulation run.

The Simulator Runner window will appear and update the CPU activity for the simulation run. **DO NOT** close the Simulator Runner window during the simulation run. It can be minimized. Closing the Simulator runner window will stop the simulation run.

DO NOT close COZView during the simulation run. It can be minimized. Closing COZView will not stop the simulation run, but the simulation results will not be loaded at the conclusion of the simulation run. **DO NOT** change projects in COZView during a simulation run for this same reason. **DO NOT** turn the computer off during the simulation run. All simulation results will be lost.

Two files are created early during the simulation run which may help the user track the progress of the simulation run. These are stored in the COZView directory along with various project database and result files. The files are *Projectname.COZOUT* and *Projectname.COZDAT*. The .COZDAT file is the input data “deck” prepared by COZView for COZSim. The .COZOUT file reports well production and injection activity for each timestep during the simulation run. It is update frequently. Both of these files can be opened with a Text editor. The .COZDAT file can be reviewed to assure that the data “deck” is setup as the user anticipated. The .COZOUT file can be reviewed as the simulation run progresses. If the results are not as anticipated the run can be stopped in the **Simulator Runner** window.

An example of the .COZOUT file at the end of this simulation run is shown below.



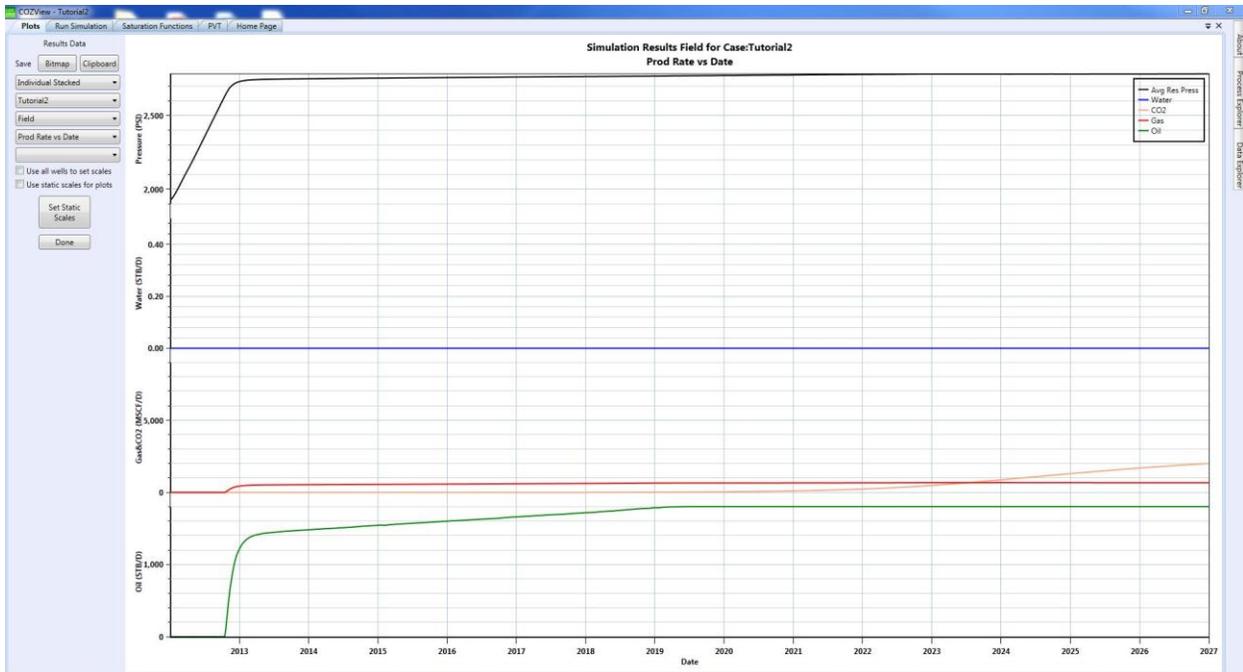
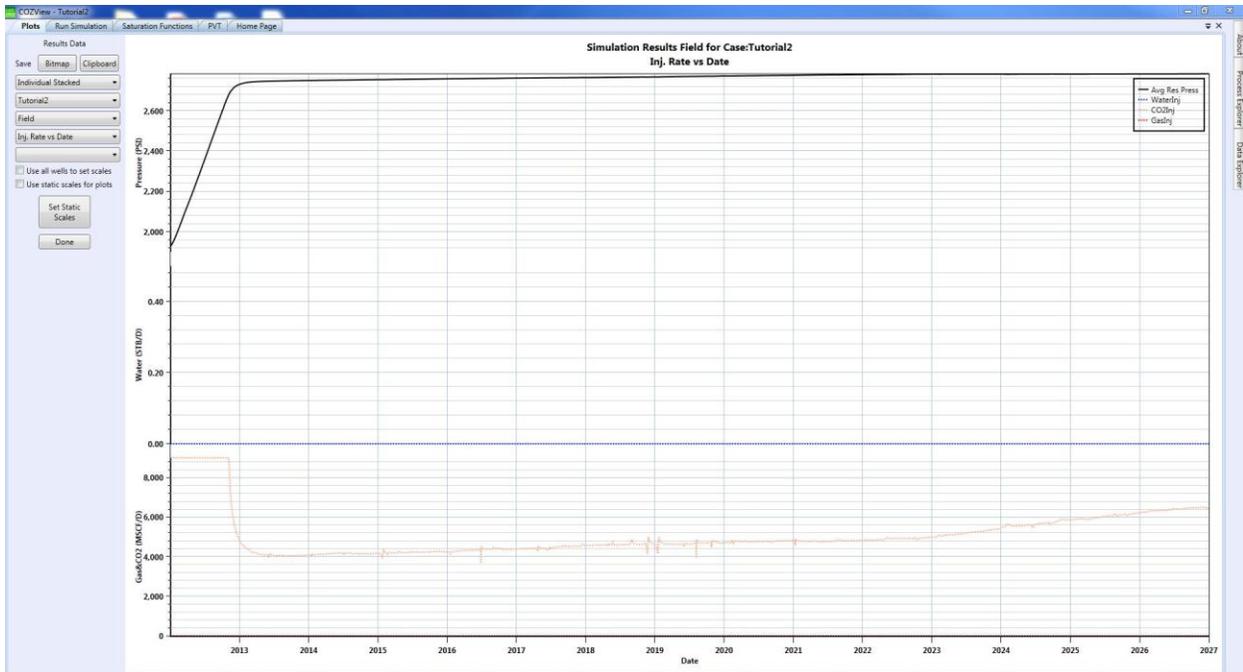
DO NOT delete or change these files during the simulation run. If the same project is re-run with changes to some parameters, these files will be overwritten.

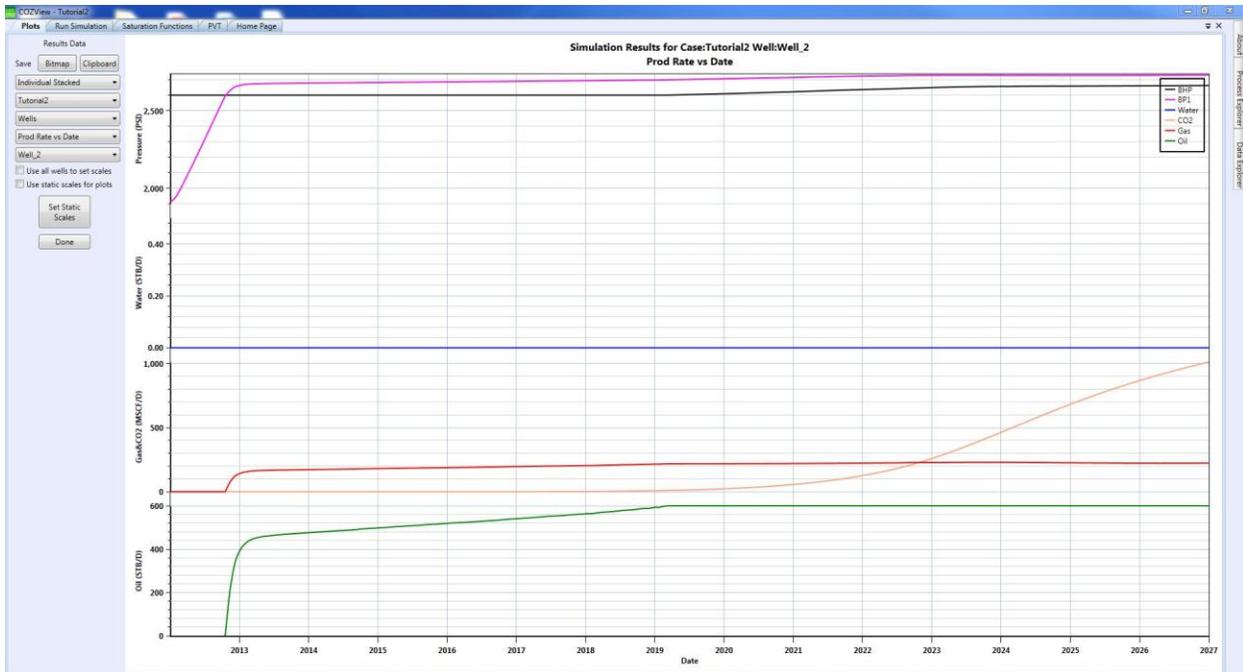
When the **Simulation Runner** window disappears, the simulation run has completed.

At the completion of the simulation run two small windows will appear which advise the user that the Map and PLT (plot) results are being loaded into COZView.

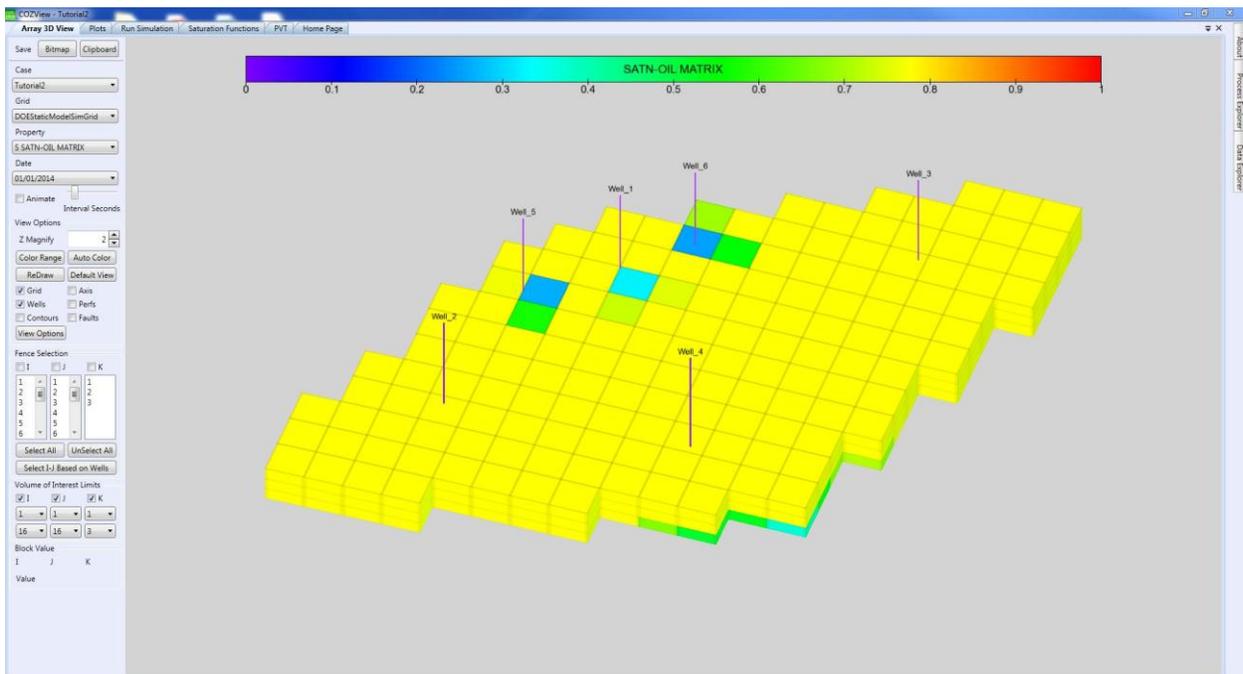
Select **Plots** from the **Simulation Results** area. This will give the user access to various simulation plots for the wells and field. A sample of the available plots for this prediction simulation is shown below.

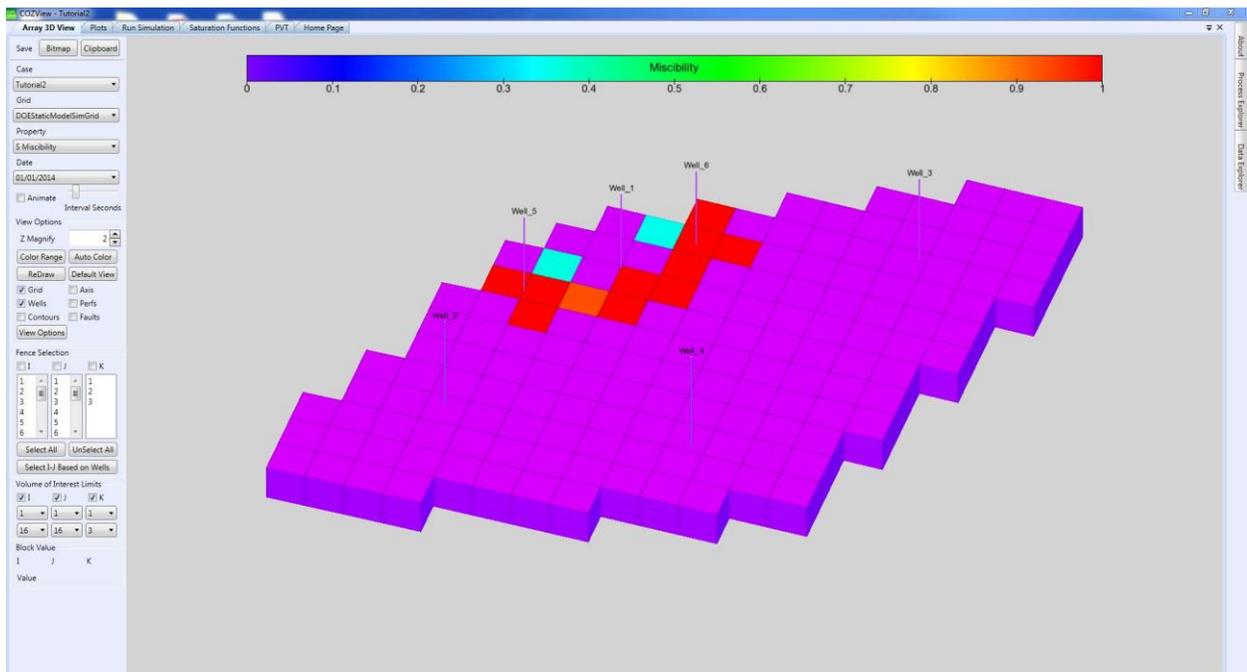
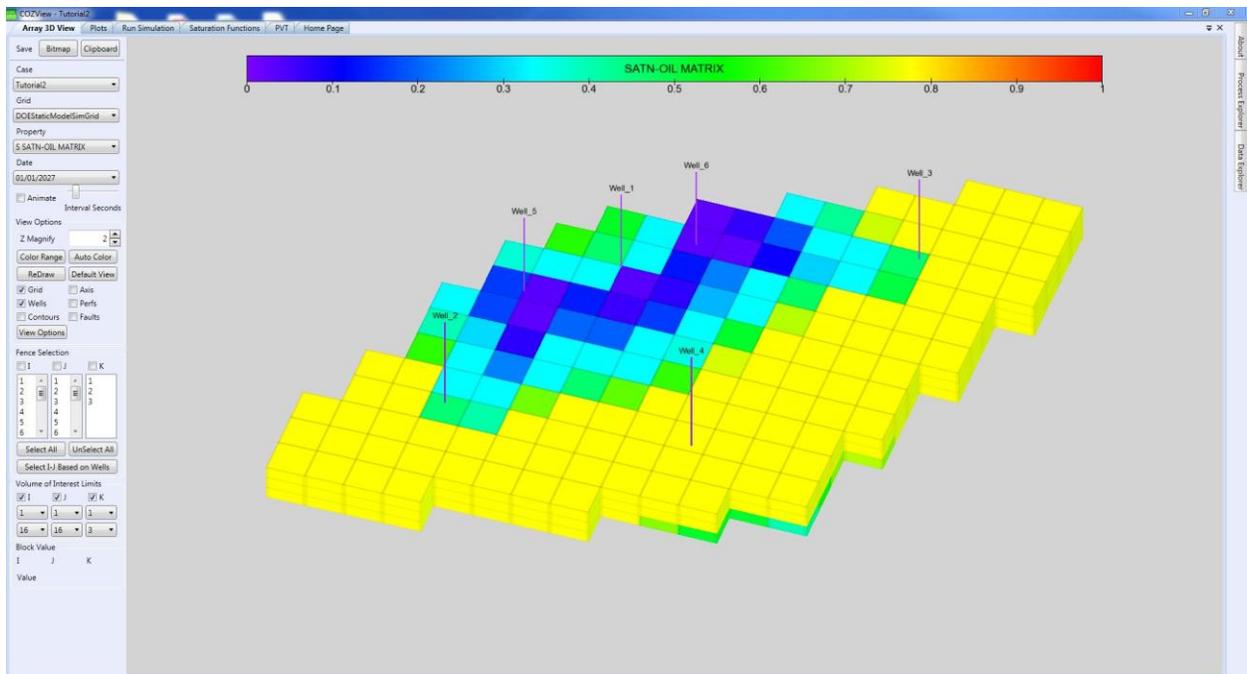
It has been found prudent to close all menu tabs except the **Home Page** and save data as may be requested before selecting any of the **Simulation Results** menus. This assures that the plot, map and table files are refreshed and prior results are not shown in error.





Select **Array 3D View** from the **Simulation Results** area. This will give the user access to various simulation maps for the field. A sample of the available maps for this prediction simulation is shown below.





The user can also select **Tables** from the **Simulation Results** area. This will provide access to tabular simulation results for wells and the field. These tables can be exported to .csv files for use in spreadsheet applications.

It is also noted that any plot displays can be saved to Bitmap files or to the Clipboard for pasting into report documents. Any map displays can be saved to Bitmap files.