Reservoir simulation for a CO_2 sequestration project

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Abstract

Time-lapse seismic surveys of a reservoir are an effective way to monitor alterations in the dynamic reservoir parameters and the fluid migration regimen during production or injection. The project is a study of a reservoir under a specified injection plan, using updated geological models in time and space. An existing reservoir model was utilized as the base case. The reservoir was chosen from the Wabamun Area Sequestration Project (WASP). The target layer for injection is the Nisku aquifer. It is a Devonian carbonate formation with high capacity (porosity) and injectivity (permeability), capped by the Calmar shale. An injection plan was defined with ten wells and constant bottom-hole injection pressure. The behavior of the reservoir was simulated. After 50 years injection, the CO_2 plume only covered approximately 10% of the top layer of the Nisku aquifer, but pressure changes occurred over the entire reservoir. At 50 years after injection termination, the mass of the plumes did not change meaningfully but pressure equalized across the entire reservoir. The defined plan can store 25% of the expected total CO_2 locally available.

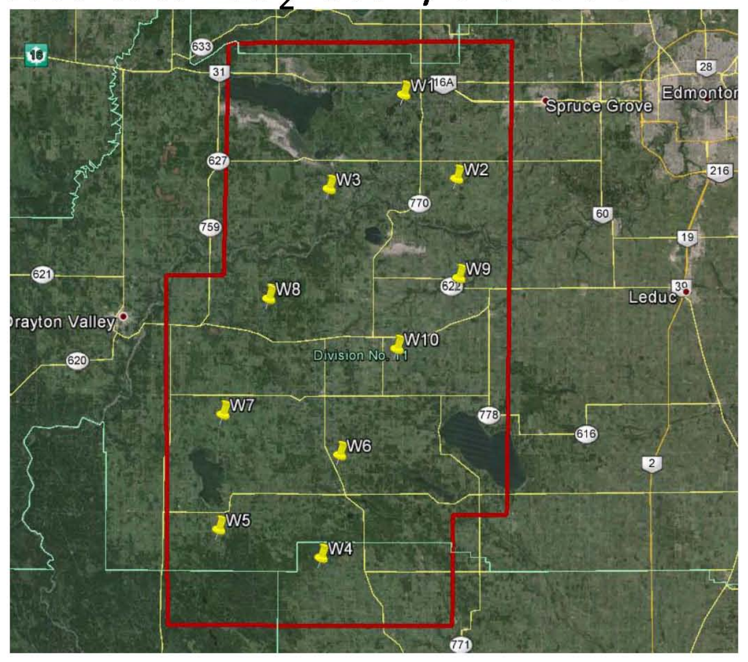

Fig.1. The WASP project area (red rectangular with area equal to 5034 km^2). Yellow points are injector well sites.(satellite image source: Google Earth)

1- Selecting a suitable simulator

The solubility of CO_2 in water, forces us to use a compositional simulator. High cost of the compositional method encourage reservoir modellers to use an algorithm for using black-oil simulation with tuning on PVT data, as developed by Hassanzadeh and et al., (2008). For the current project, with tuning applied to the parameters, it is possible to use Black-oil method for CO_2 injection in saline water.

2- Geometry and Geomodel

The WASP area covers about 5034 km^2.For gridding purposes, surface of the Nisku aquifer was divided to 500x500 m grids and vertically to 30 unequal levels, which in all made more than seven hundred thousand cells (122x193x30).For make a geomodel of the aquifer, data from 79 well log, 13 core data, 199 2D seismic lines, mineralogy data, and twenty two drill stem tests (DST) were main sources (Eisinger et al. , 2009). Figures 3 and 4 demonstrate Porosity and permeability (in x, y and z direction) from geomodel data.

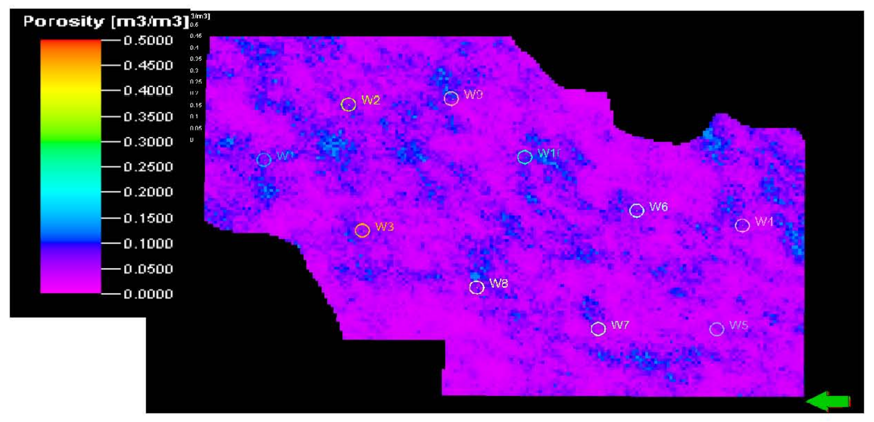

FIG.3. Porosity of the top layer in the aquifer

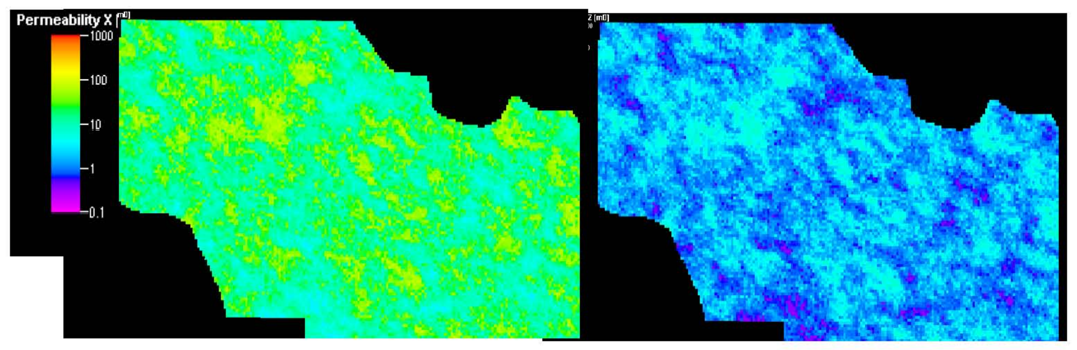

FIG.4. Permeability in XY (left) and Z direction (right) for the first layer of the aquifer

3- Injection schedule

This model has ten injection wells that are parallel to the two sides of the area with a NE to SW trend. All 30 horizons of aquifer are open to injection in wells and the well bottom pressure was held constant at 40 MPa. The injection was scheduled for 50 years and also for another 50 years for the prediction of plume movement and the fate of the pressure in the reservoir.

Simulation Results : 1- *Capacity*

The total capacity of the field (after 50 years) is about 132 billion cubic meters. This volume is about 25% of the expected total CO_2 locally available for sequestration(20 Mt/year).

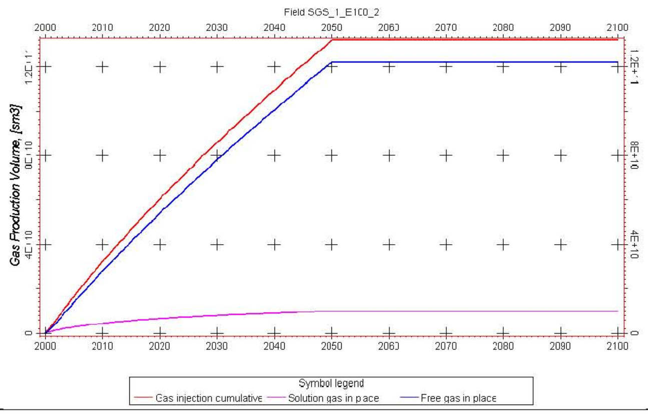

FIG.5. Total gas injection volume and fraction of free gas and solution gas in the reservoir

Simulation Results : 2- *Water and Gas saturation*

The surface area of the plumes after injection period is between 25 to 65 km^2,and there are no interference between plums.

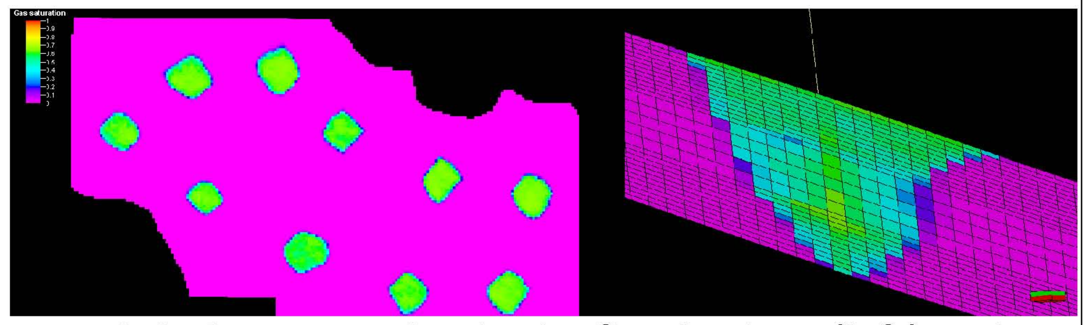

FIG.6. Gas saturation in the first horizon (left) and saturation in well No. 8 (vertical section, right)

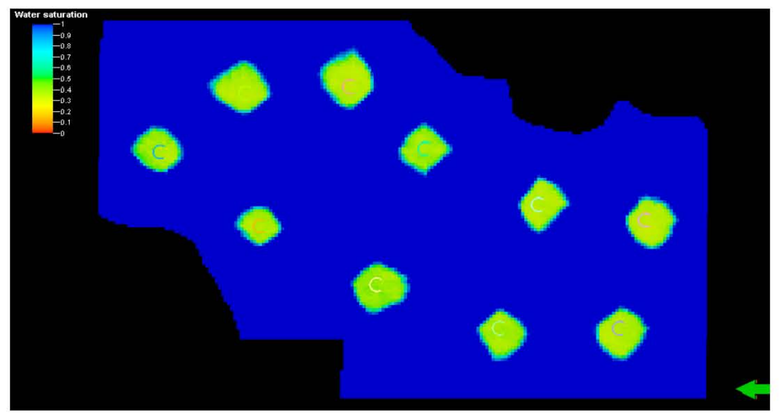

FIG.7. Water saturation after 50 years

Simulation Results : 3- *Pressure*

For the Nisku aquifer as a reservoir, in the first years of injection, the pressure distribution is mainly around the injection wells. Figure 17 illustrates the pressure distribution in the reservoir after two years of injection. However, after 25 years it is completely distributed in the reservoir as it is shown in the top left part of Figure 8. After 50 years when injection stops, the pressure distribution seems constant and equalized across the entire reservoir (Figure 8 bottom left). Total gas flow for WASP, in the first months of injection falls down immediately. During long-term injection, the flow rate decreases gently.

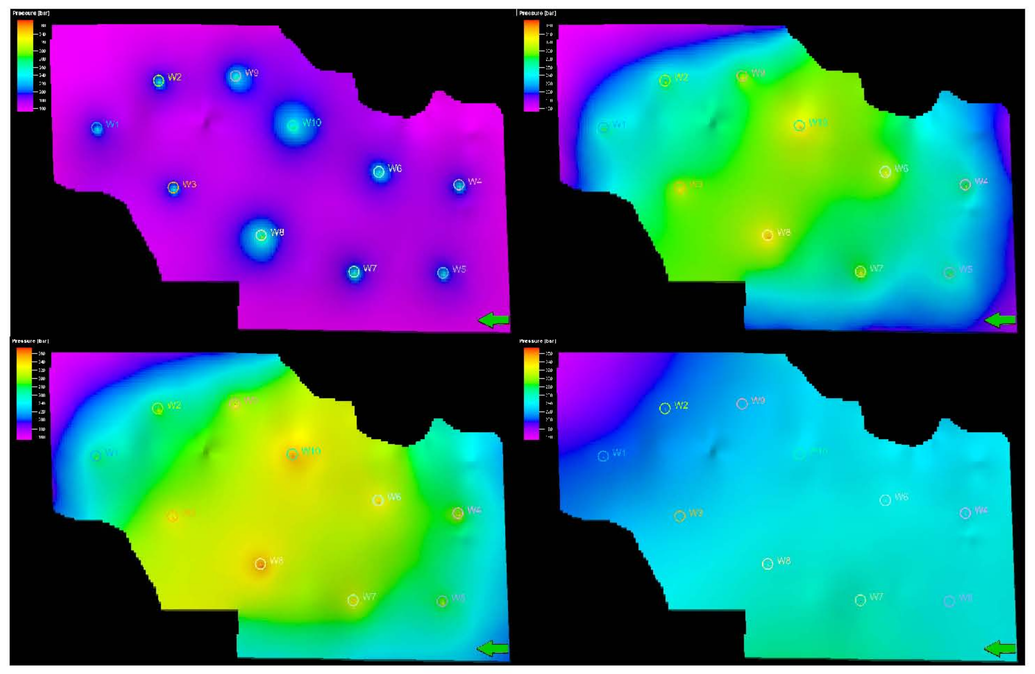

FIG.17. Pressure in the second (upper left), 25th (upper right), 50th (lower left) and after 100 years of injection (lower right)

CONCLUSIONS

The injection make a funnel shape of gas around wells shaft that radius of gas distribution is various from 1700 m to 6000 m in the top horizon of aquifer, so there is no interference between the gas plumes. In the average estimation, each well involves 45 km^2 an average for a 50 year injection, up to 100 wells can inject CO_2 without any interference between their plums in this aquifer, but should consider reservoirs pressure change and limitations.

The capacity of each well is change by the medium's porosity and permeability around each well and changes from 6 to 22 billion sm^3. The total capacity of the field in the present model is about 132 billion sm^3 that just covers about 25 percent of the storage expectance.

In the next stage, geophysical model for each cell will be created during injection and it will expand for the reservoir and will describe our expectance of time lapse observing, also this research has a glance at geomechanical changes in reservoir and effects.

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