Simulation to Support Lucid's Proposed AGI Well Permit Application

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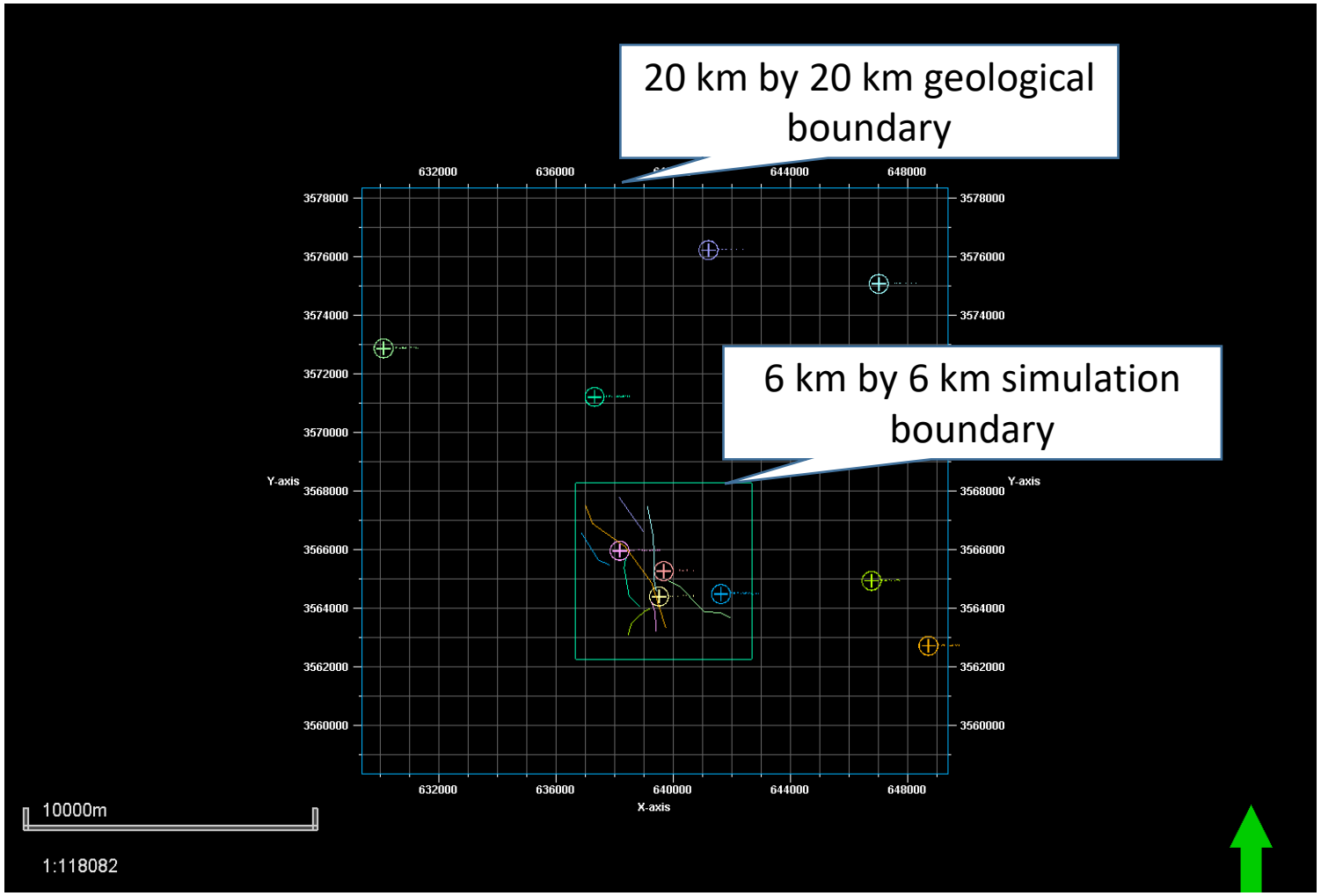
LUCID
Exhibit 6

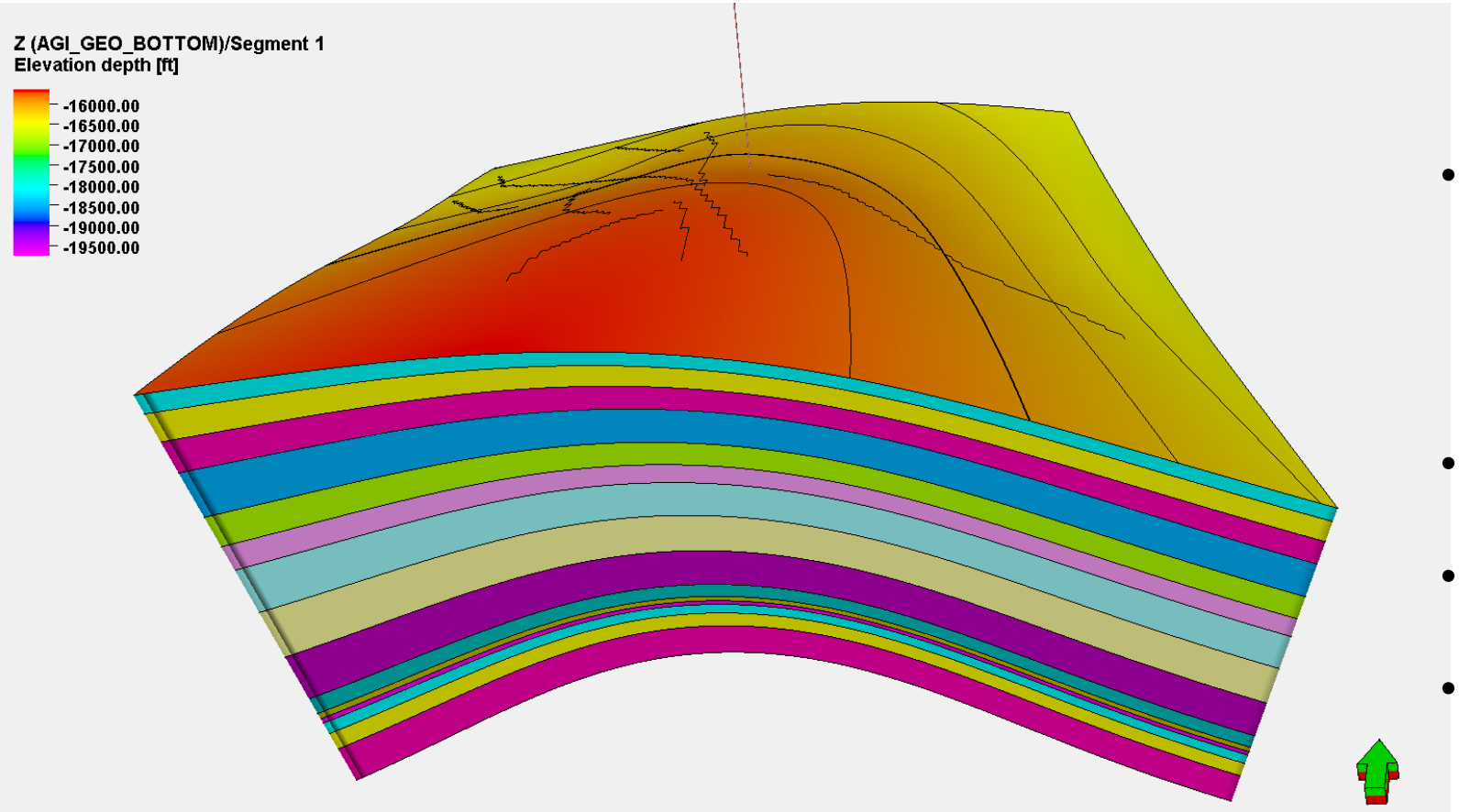
Geological model: Study boundaries



Top view of the studied area that structures the geological model

- A geological model is structured using the well top and bottom data within the 20 km by 20 km area.
- When all the faults are identified, a (6km by 6 km) simulation boundary is used to study the injection activity around the proposed AGI well.
- In the simulation boundary, three SWD wells: Trident, Striker 6 and Deep Thirsty are included, but only Striker 6 is injecting waste water

Structural Modeling



- A 3D view of the model is displaced to illustrate the structure of the formation
- Grid Cells: 119 * 119 *15
- Total Grid Cells: 212415
- Grid Dimensions: 50ft * 50ft

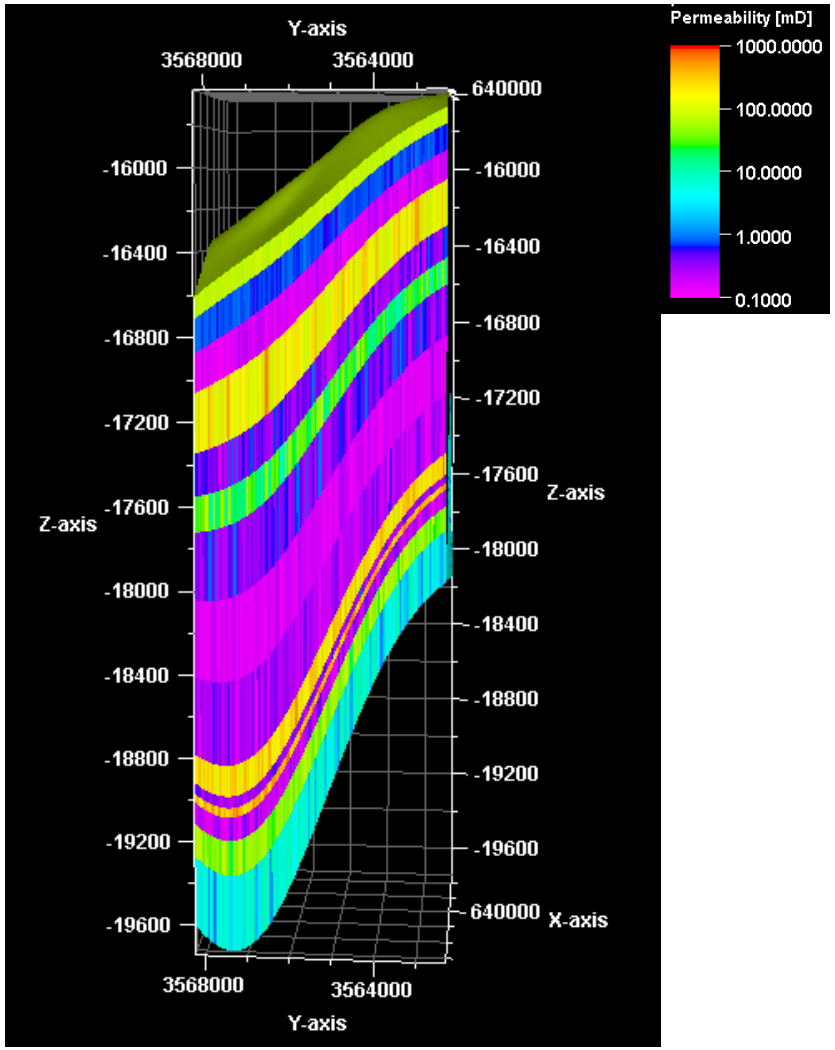
Spatial property distributions

Geological zones and ranges of the properties

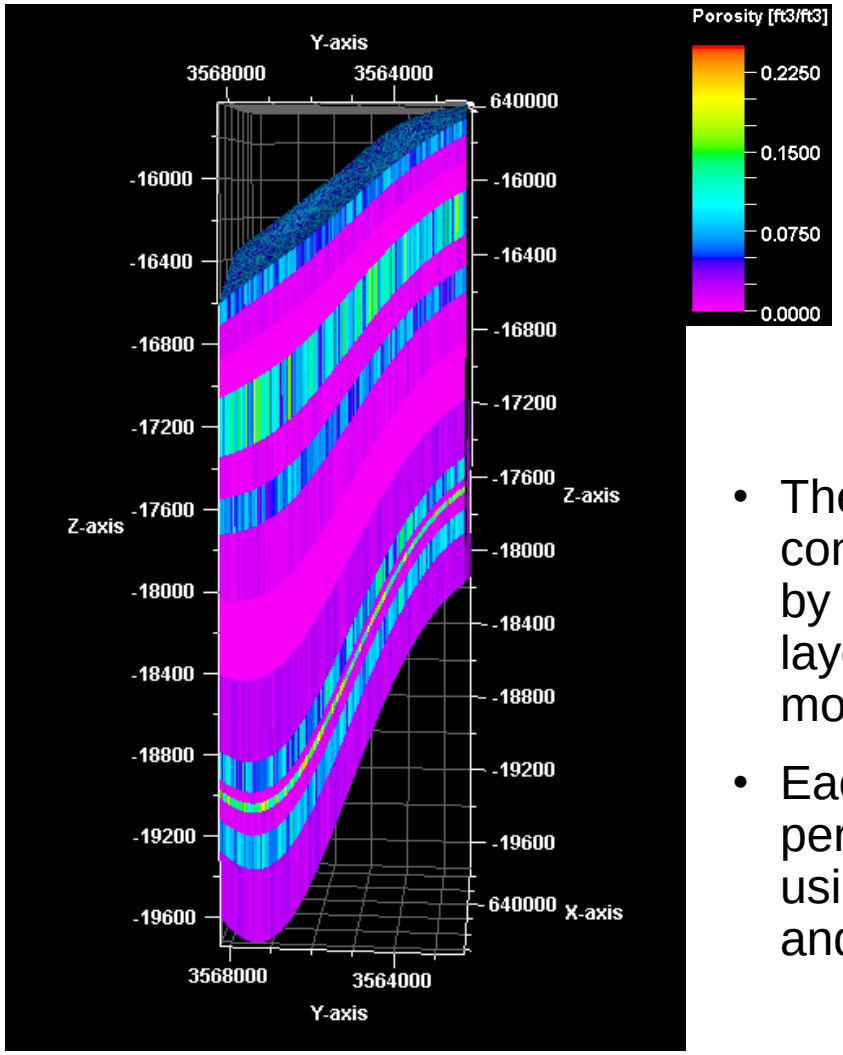
Zone	Depth, ft	Porosity, %		Permeability, md	
		Range	Mean	Range	Mean
ZONE 1	A. 15964 - 16020	1-10%	7%	1-100 md	80 md
	B. 16020 - 16110	0-2%	1%	0.1- 1.0 md	0.75 md
ZONE 2	16110 - 16208	0-0.5%	0%	0.1-0.3 md	0.15 md
ZONE 3	16208 - 16357	4-20%	10%	75-700 md	150 md
ZONE 4	A. 16357- 16464	0-2%	1%	0.1 to 1 md	0.4 md
	B. 16464 - 16566	0-10%	7%	1-100 md	30 md
ZONE 5	16566 - 16744	0-2%	1%	0.1-1 md	0.5 md
ZONE 6	16744 - 16936	0- 0.5%	0%	0.1 to 0.3 md	0.15 md
ZONE 7	16936 - 17149	0-3%	2%	0.1 to 5 md	.025 md
ZONE 8	A. 17149 - 17194	0-15%	8%	10- 700 md	250 md
	B. 17194 - 17215	0-2%	1%	0.1 to 1 md	0.3 md
	C. 17215 - 17280	10-25%	14%	100-700 md	400 md
ZONE 9	A. 17280 - 17360	0-2%	1%	0.1 to 0.5 md	0.2 md
	B. 17360 - 17441	2 -14%	8%	1.0 to 100 md	50 md
ZONE 10	17441 - 17628	0 - 3%	2%	1 to 10 md	0.5 md

- In the table, the mean values and ranges of the porosity and permeability distributions are listed.
- Pseudo-random numbers are generated following log-normal distributions to populate the spatial porosity and permeability distributions of the zones.
- It can be identified that Zone 8C is the most permeable and porous layer for injection activities.

Geological model:



(a)



(b)

- The geological model is structured considering the 10 zones suggested by Geolex and a total of 15 simulation layers are included in the simulation model.
- Each zone is assigned with different permeability and porosity distributions, using the recommended mean, min and max values.

A 3D view of GMV2 shown as permeability (a) and porosity (b) distributions

Hydrodynamic model: fluid properties

- The reservoir is initially saturated with 100% of brine and exhibit hydrostatic equilibrium.
- The injection gas has two components of H_2S and CO_2 with molar fractions of 17% and 83%, respectively.
- Both acid gas compositions are able to dissolve into aqueous phase.
- An irreducible water saturation of 0.17 is used to generated the relative permeability curves for gas/water system.

Hydrodynamic model: Boundary conditions

- The external boundary conditions are specified to be open boundary.
- The simulation work starts from October 2018 when Striker 6 SWD came online, and stop until the end of 2050 for 30-year of acid gas injection simulation.
- The gas injection well injects acid gas at a rate specification of 13 MMSCF/Day.
- The SWD wells inject water using injection history from Oct. 2018 to Feb. 2020. Then, three salt water injection rates are considered in this work:
  1. q_1 = 32,500 STB/day which is the maximum volume of water injection rate
  2. q_2 = 15,000 STB/day which is the medium volume of water injection rate
  3. q_3 = 7,472 STB/day, the minimum volume of water injection rate which is calculated from the average value of the injection history.
- Bottomhole pressure gradient of 0.629 psi/ft calculated from formation Shmin gradient are imposed to all of the injectors.

Simulation Scenarios

This work runs extensive simulation scenarios considering the combination fault characterizations, and SWD injection rates.

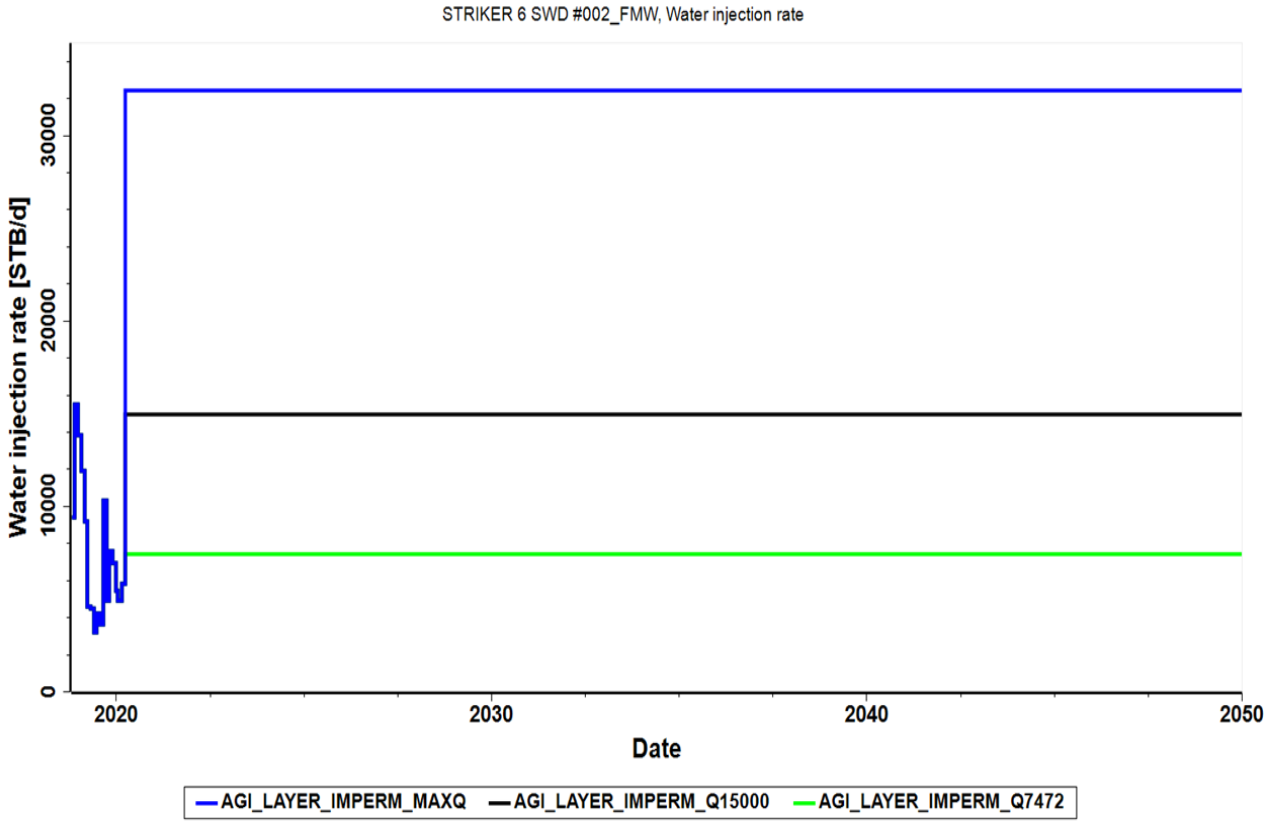
- Fault characterizations:
  1. Simulation run ignoring the impact of the faults (the transmissibility multiplier of faults are 1).
  2. Simulation run considering the faults are impermeable barriers. (the transmissibility multiplier of faults are 0).
- SWD injection rates
  1. q_1 = 32,500 STB/day
  2. q_2 = 15,000 STB/day
  3. q_3 = 7,472 STB/day

Simulation Results:

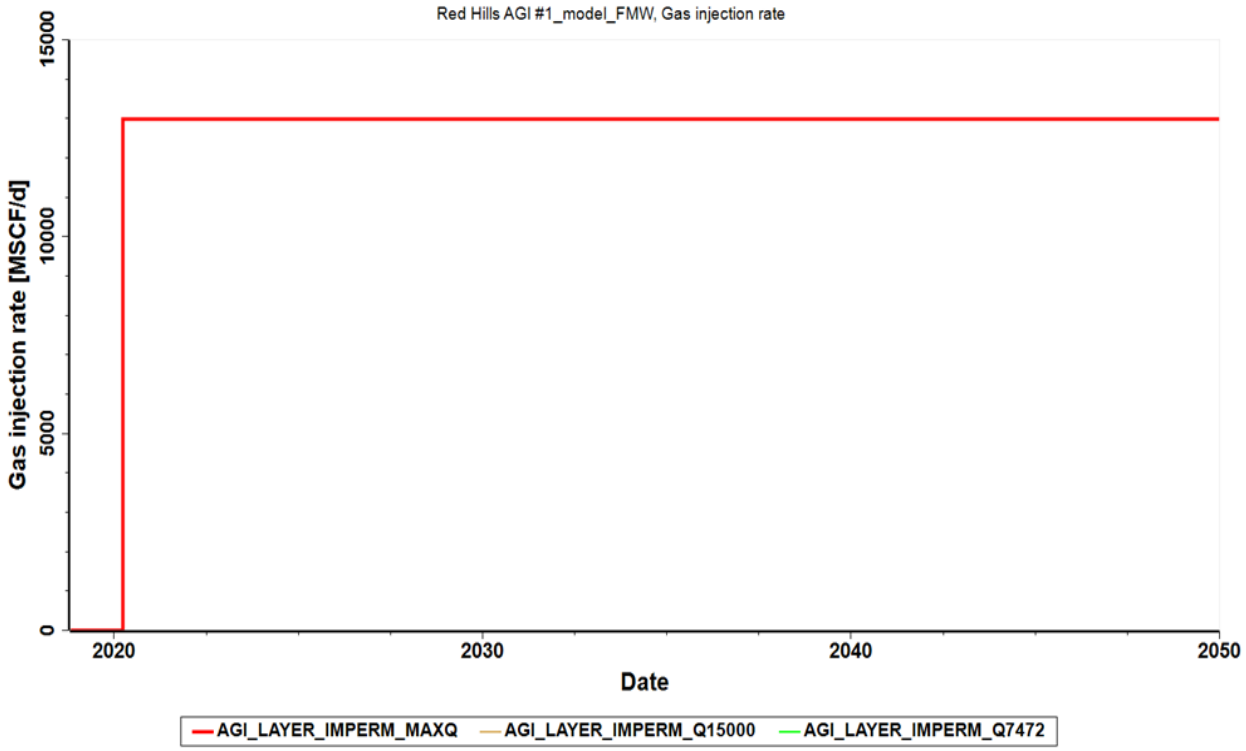
- The simulation results will be presented based on:
  1. For the close fault cases
  2. For the open fault cases
- Each fault characterization case will simulate different SWD injection rates.
- The gas plume displayed in the results are the furthest lateral extend of the gas saturation stacking all the layers.
- The pressure surface distribution are the pressure impact observed at the top layer, where the AGI well plays the most important role.

Simulation Results: with the faults closed

Well performance

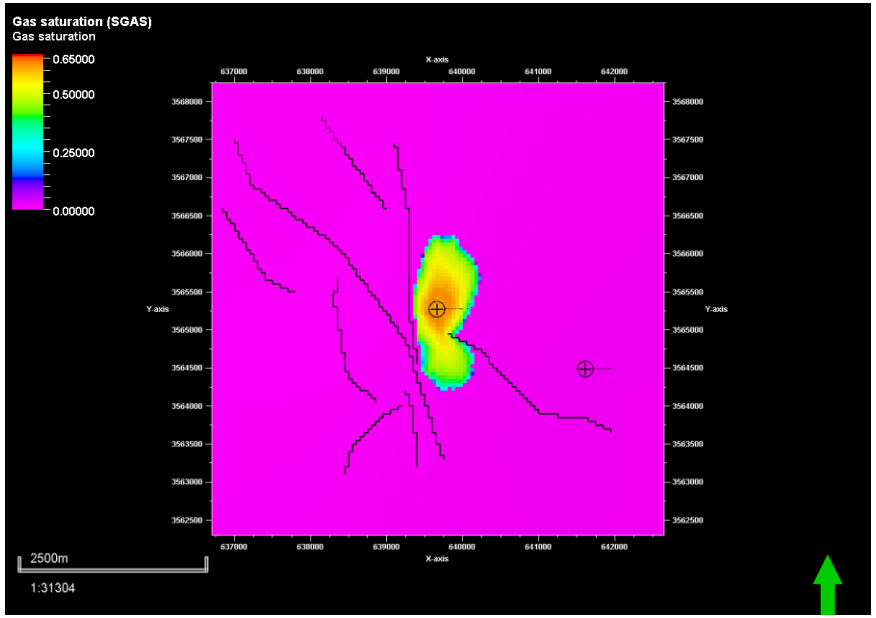


SWD well injection rates

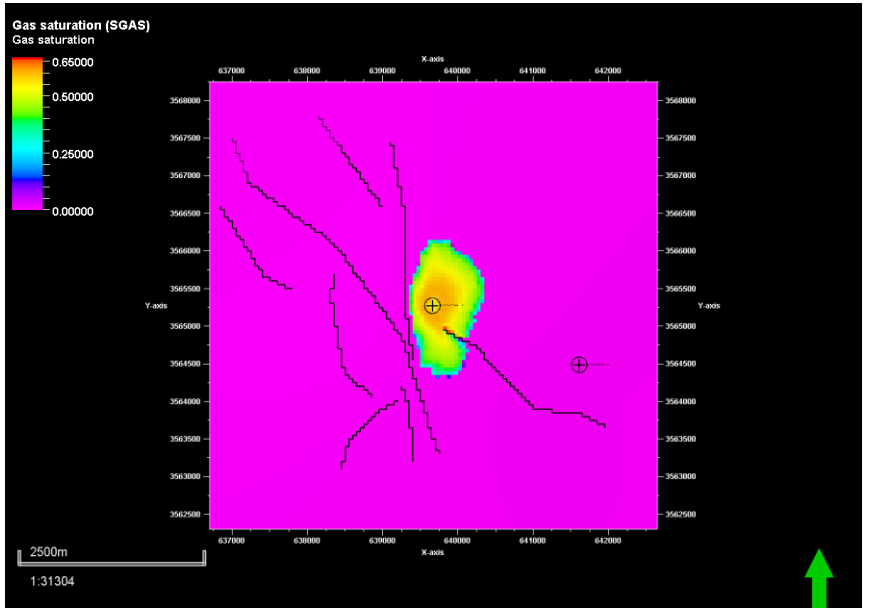


AGI well injection rates

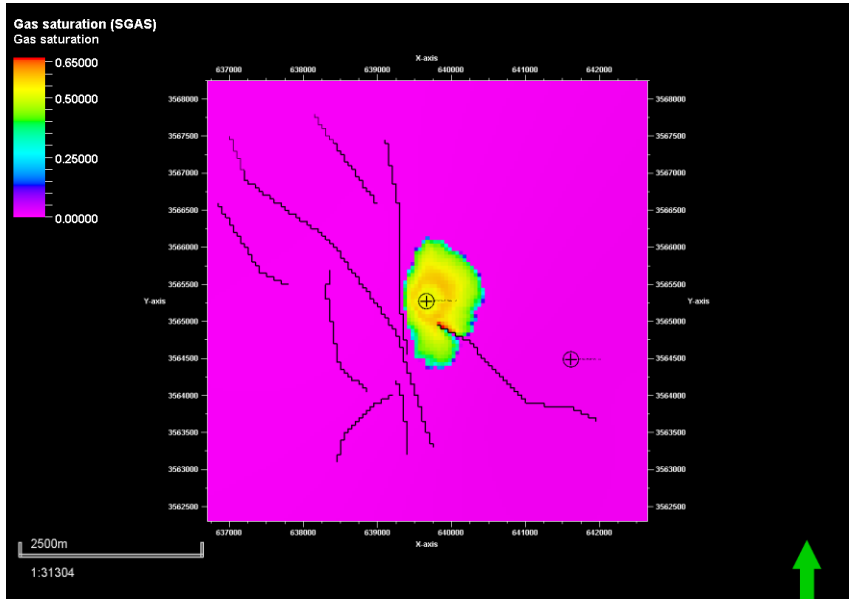
Simulation Results: with the faults closed



Acid gas plume when qw=32,500 STB/day



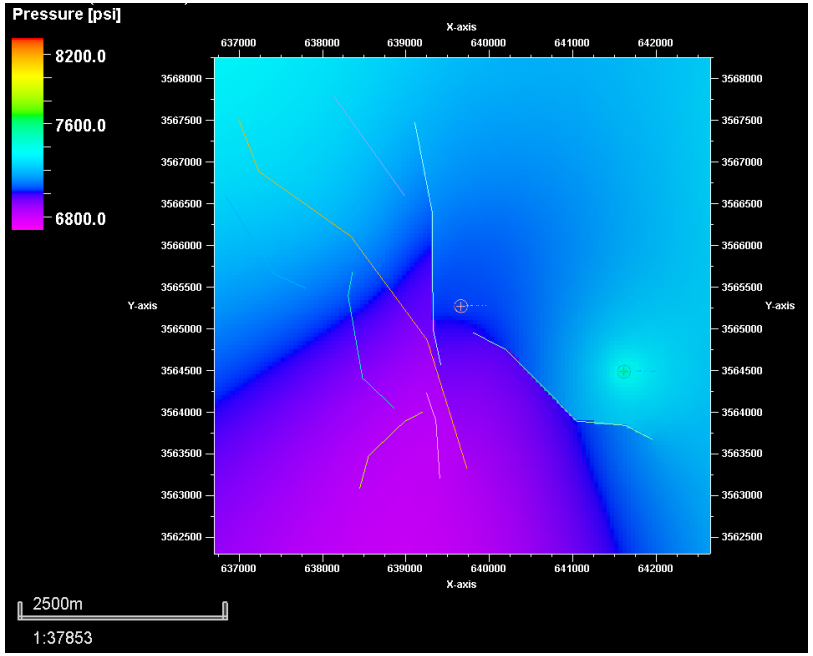
Acid gas plume when qw=15,000 STB/day



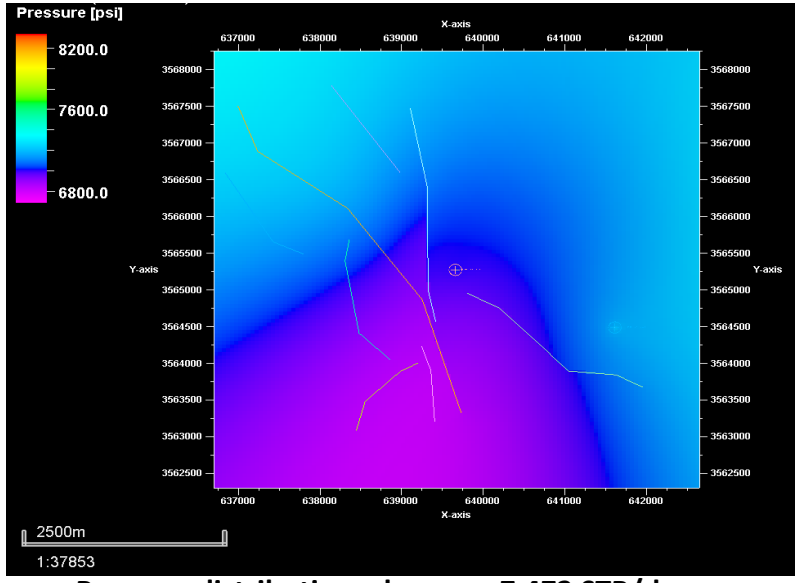
Acid gas plume when qw=7,472 STB/day

- The acid gas plume distributions after 30-years of acid gas injection are shown for different SWD injection rates.
- Also, it can be illustrated that the gas plume is still far from reaching the edge of the 6 km by 6 km area.

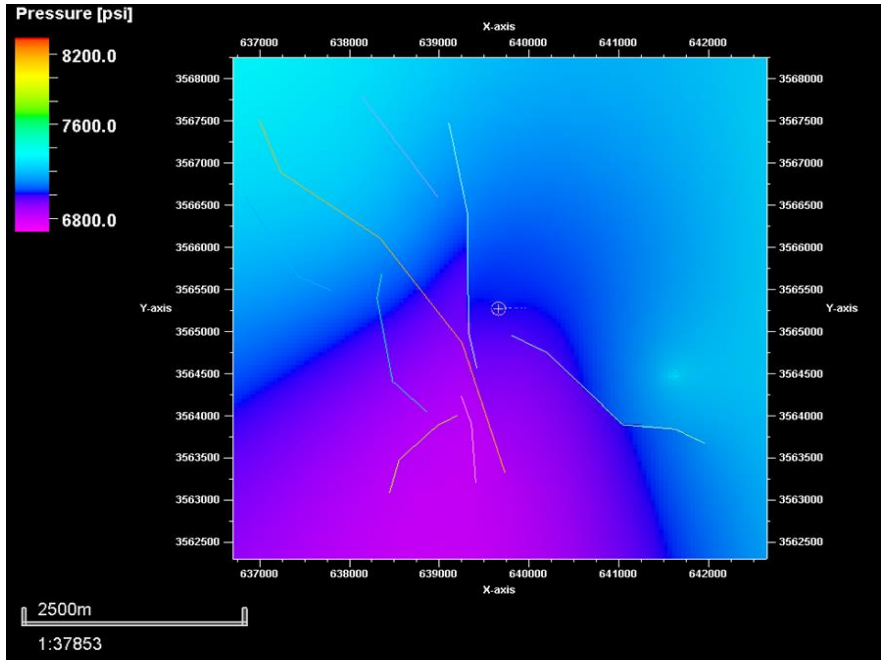
Simulation Results: with the faults closed



Pressure distribution when qw=32,500 STB/day



Pressure distribution when qw=7,472 STB/day

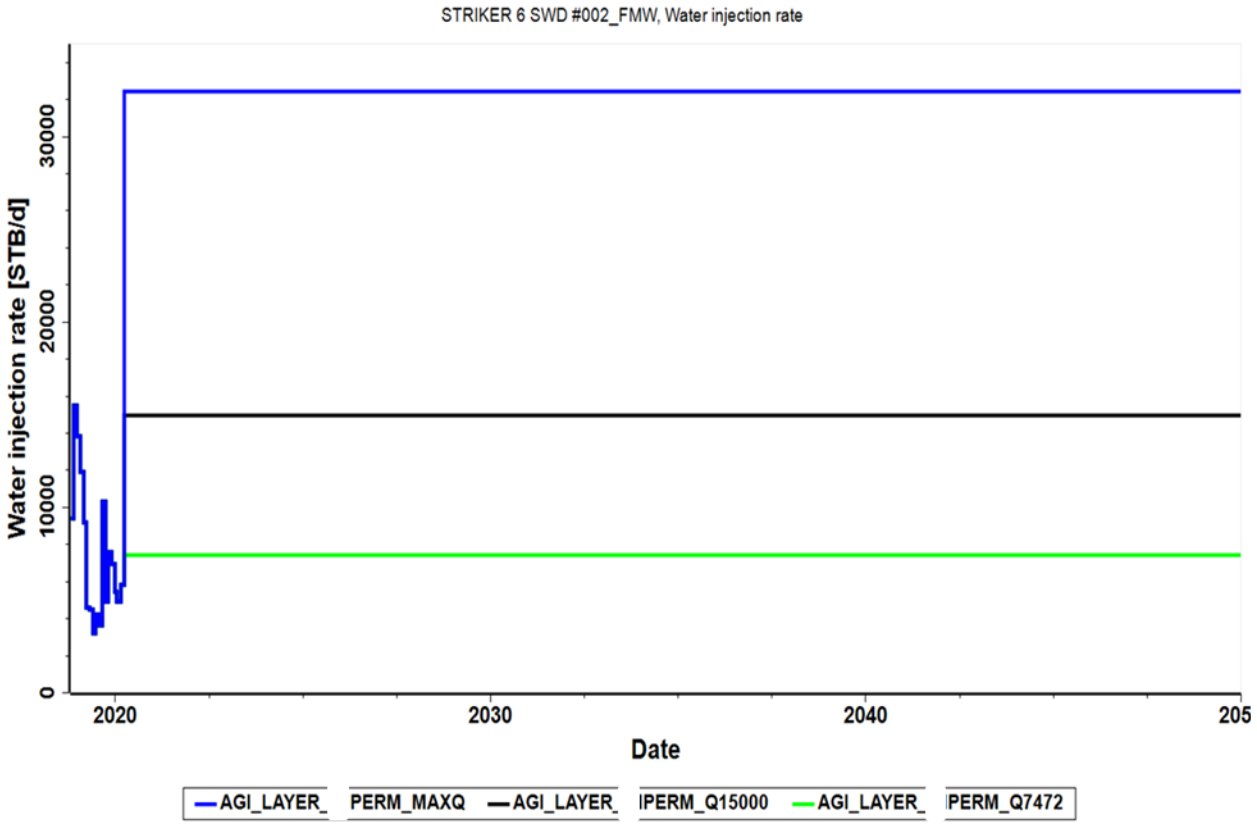


Pressure distribution when qw=15,000 STB/day

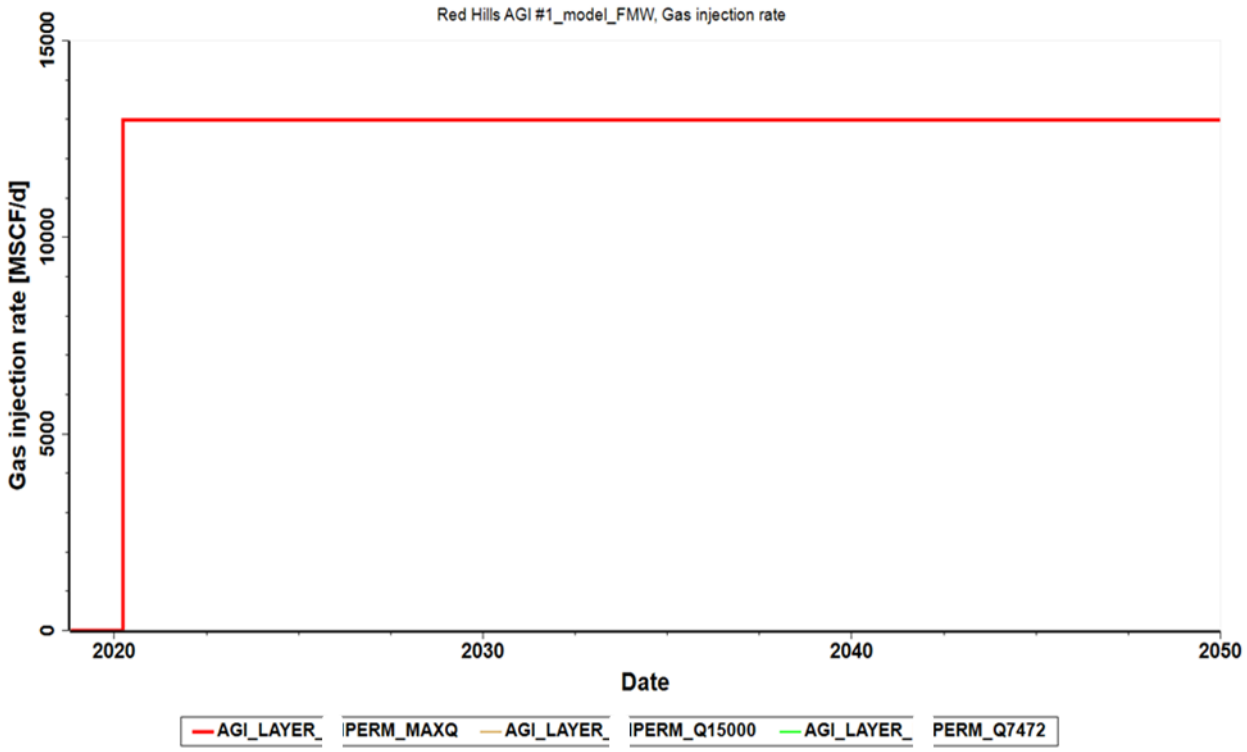
- The pressure distributions after 30-years of acid gas injection are shown for different SWD injection rates.
- It can be observed that the SWD introduces much more severe pressure increments to the system than the AGI well.

Simulation Results: with the faults open

Well performance

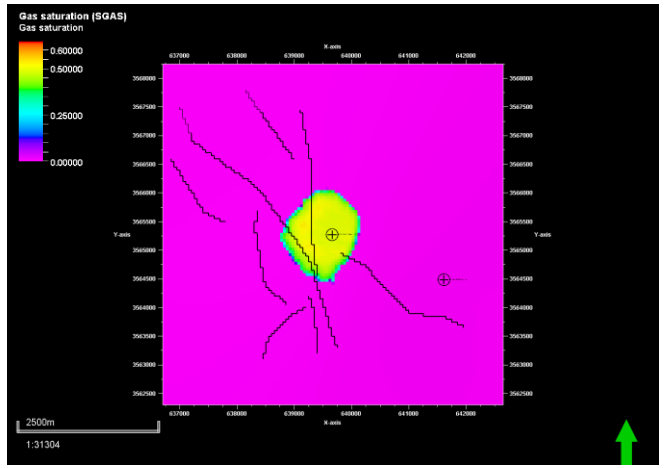


SWD well injection rates

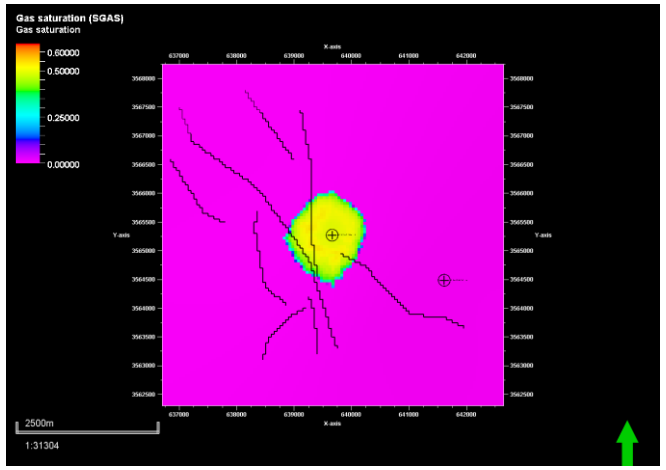


AGI well injection rates

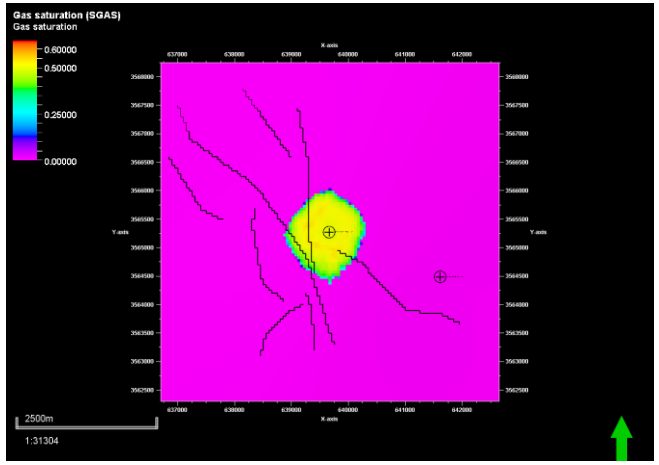
Simulation Results: with the faults Open



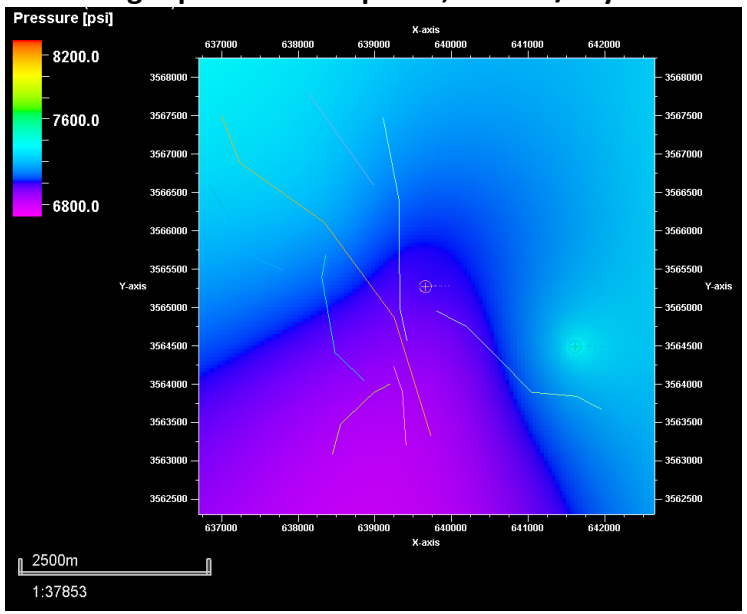
Acid gas plume when qw=32,500 STB/day



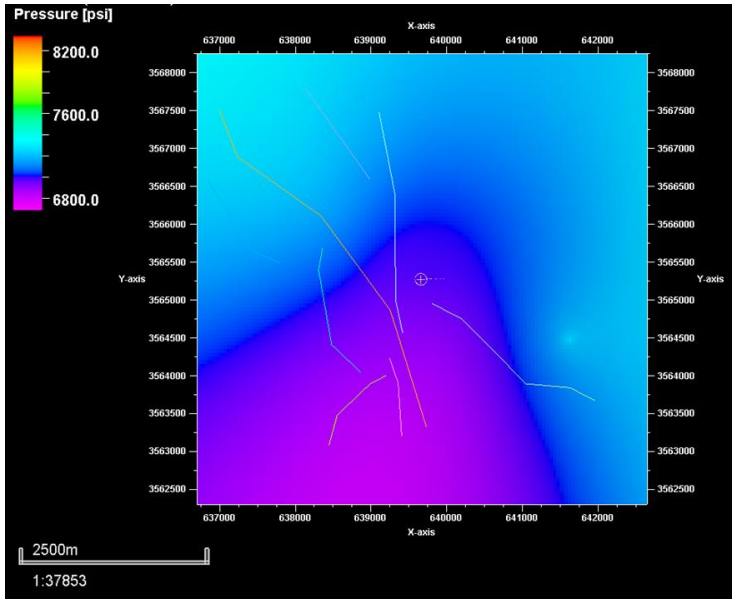
Acid gas plume when qw=15,000 STB/day



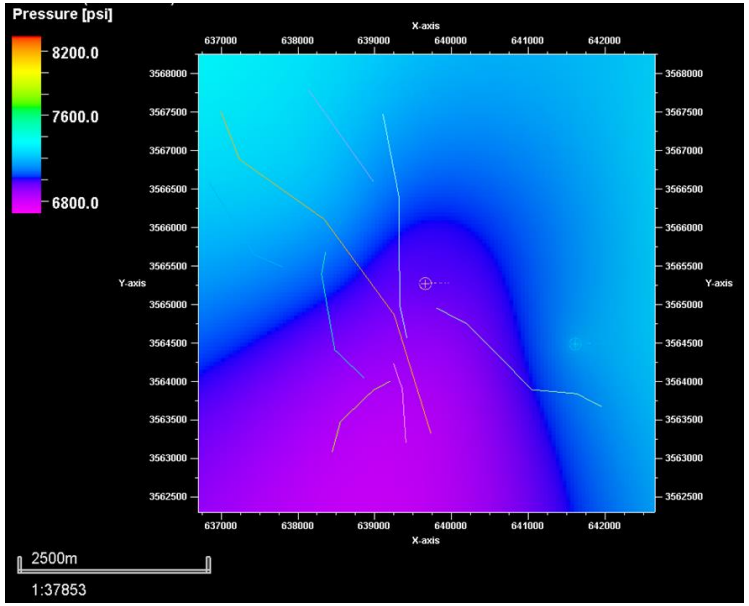
Acid gas plume when qw=7,472 STB/day



Pressure distribution when qw=32,500 STB/day



Pressure distribution when qw=15,000 STB/day



Pressure distribution when qw=7,472 STB/day

Geomechanical model Setup

The following elastic properties are assigned to the rock materials

- For the injection zone:
  - Young's Modulus 1.5×10^7 kpa
  - Poisson Ratio: 0.25
  - Rock density, 2650 kg/m^3
- For the cap/base rocks and side burdens
  - Young's Modulus 3.6×10^7 kpa
  - Poisson Ratio: 0.2
  - Rock density, 2550 kg/m^3

Also, the Mohr-Coulomb is selected as the yield criteria.

Geomechanical model – Boundary Condition

Density-based condition

Normal faulting Regime [Sv > SHmax > Shmin]

Vertical Stress gradient = 1.5 psi/ft

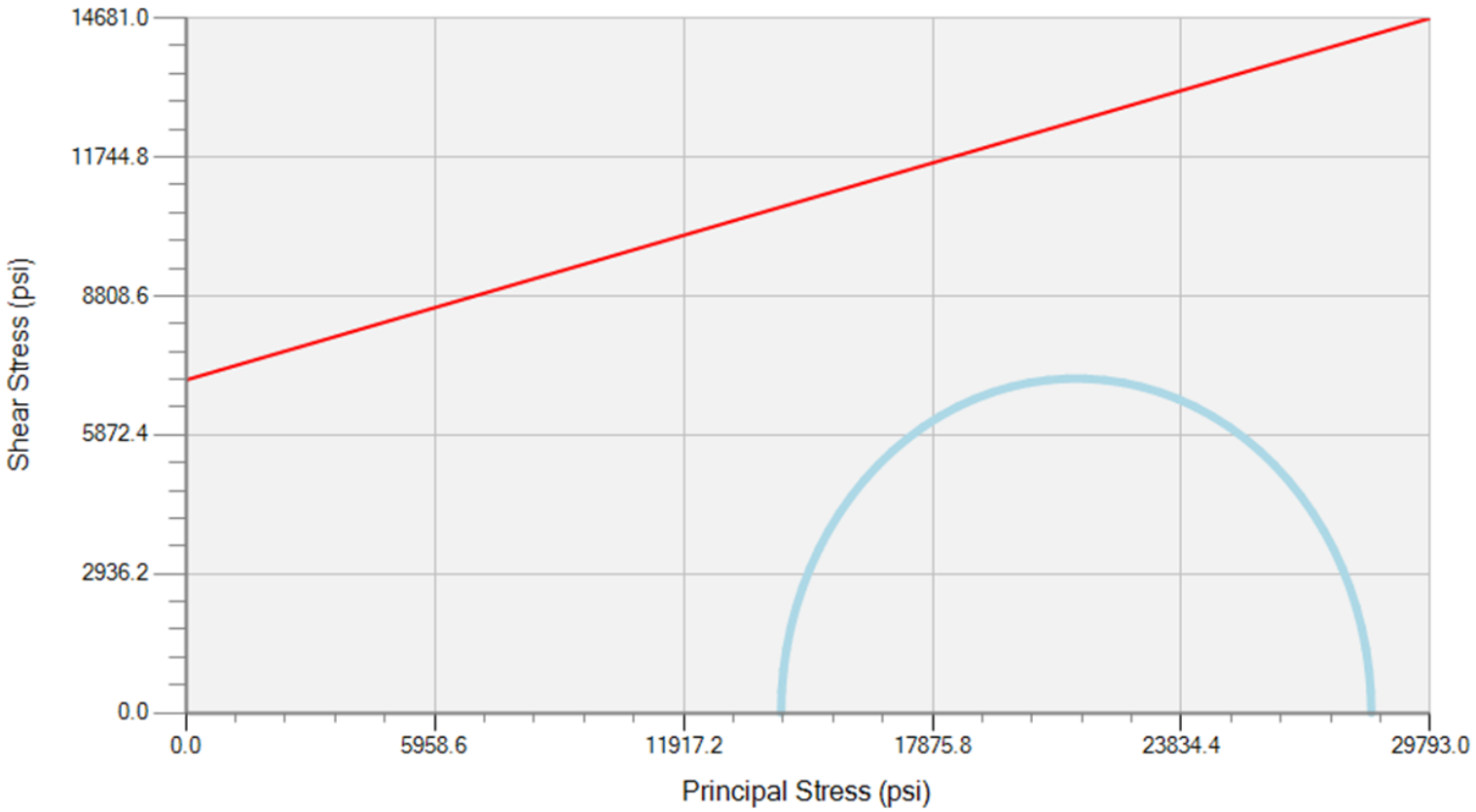
Minimum Horizontal Stress gradient= 0.629 psi/ft

Maximum Horizontal Stress gradient = 0.882 psi/ft

Shmin Azimuth = 95 degrees

SHmax Azimuth= 5 degrees

Simulation Results: Geomechanical effects



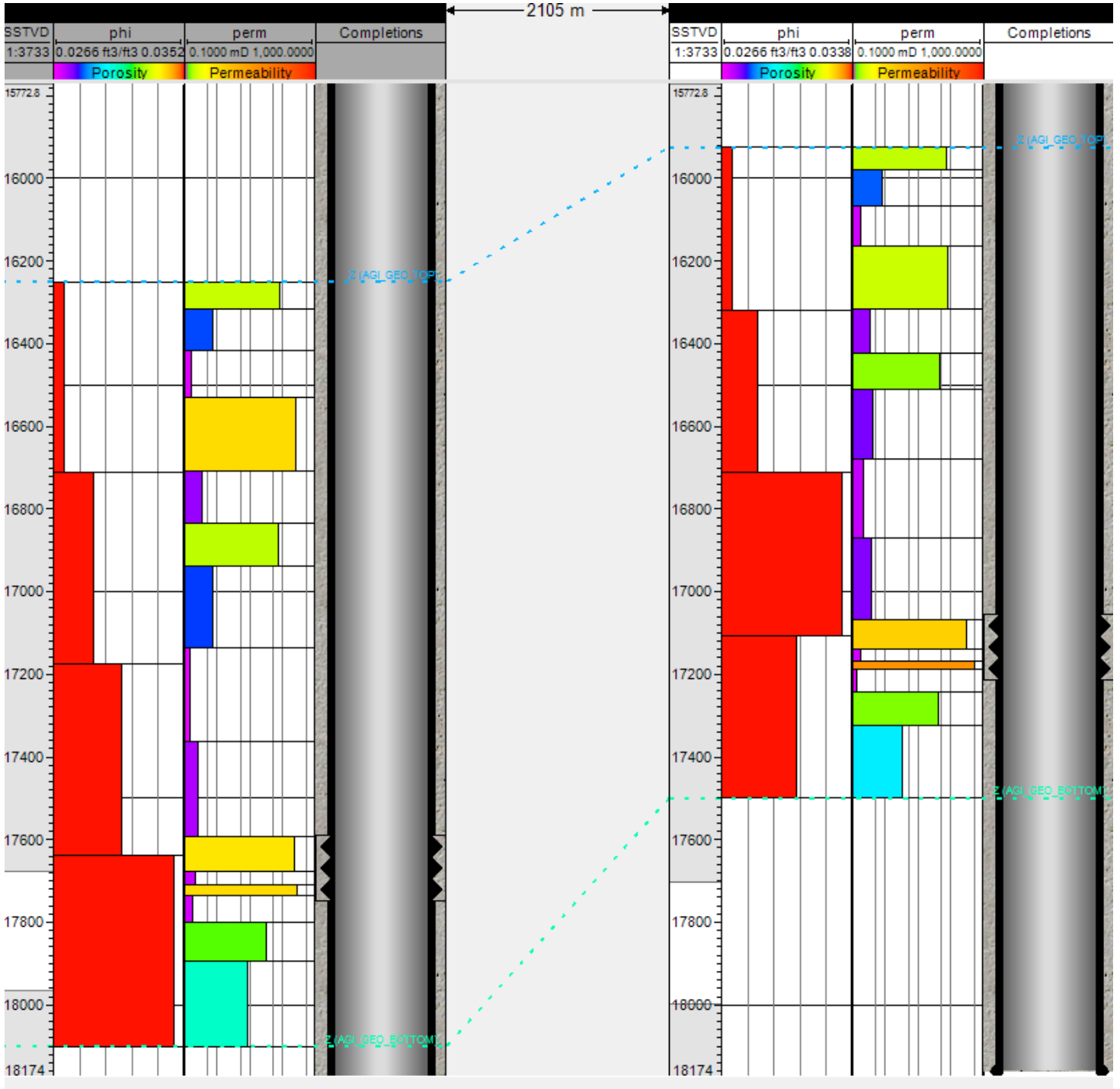
Mohr Circles at the AGI well

- Moreover, a coupled geomechanical simulation is processed based on the impermeable fault case with maximum SWD well injection rate is performed to investigate the impact of the injection activity to the tectonic stability of the reservoir.
- The Mohr circles sampled at the injection well location of different time-steps are shown.
- Although the size of the Mohr circles becomes larger as the injection processes, the impact brought by the AGI well is still far from meeting the mechanical failure criteria, which confirms a mechanical safety of the AGI project.

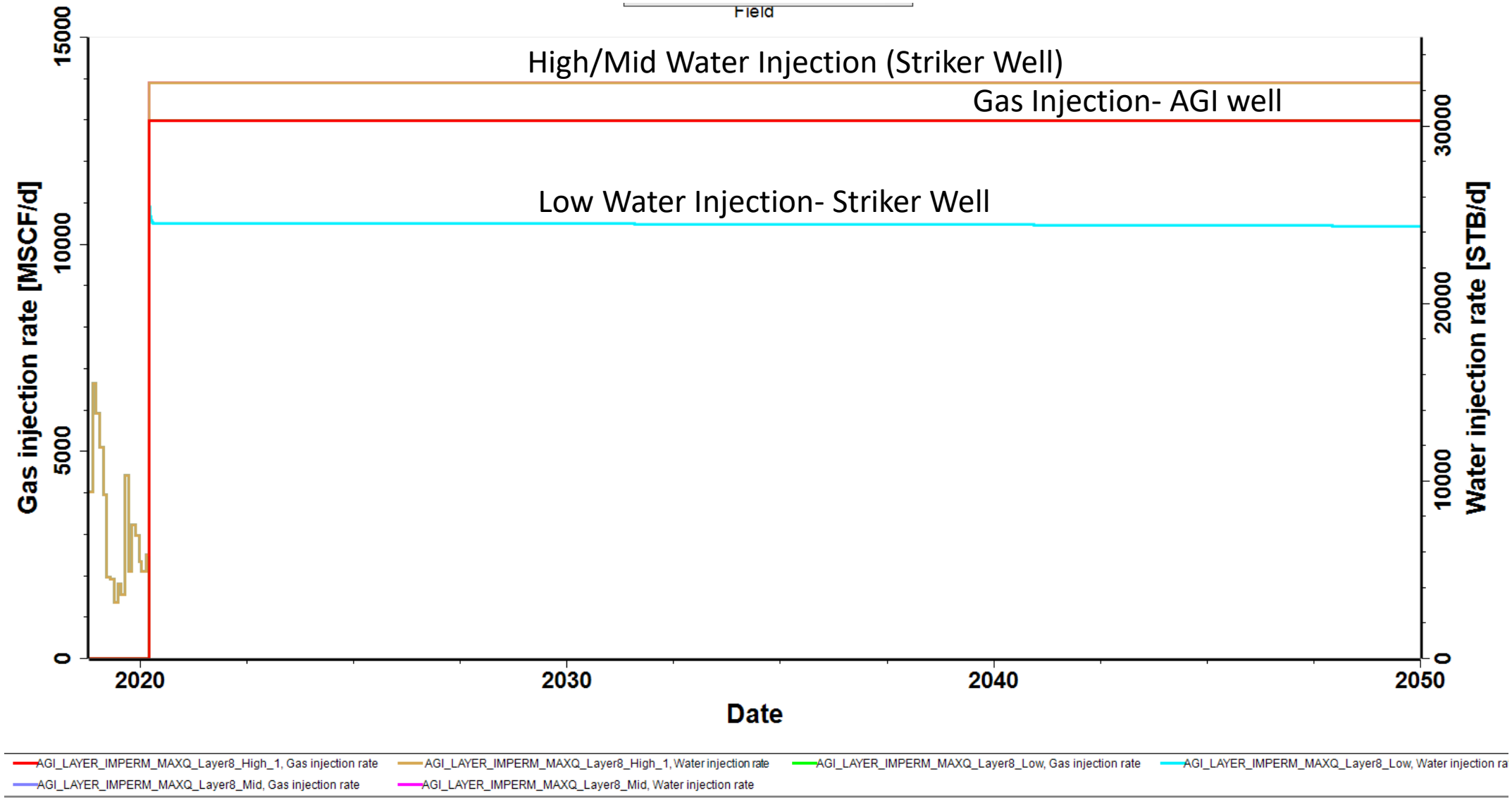
Other Scenarios: Sensitivity analysis of BHP

Completed Zone 8 to study effects of imposed BHP on injection

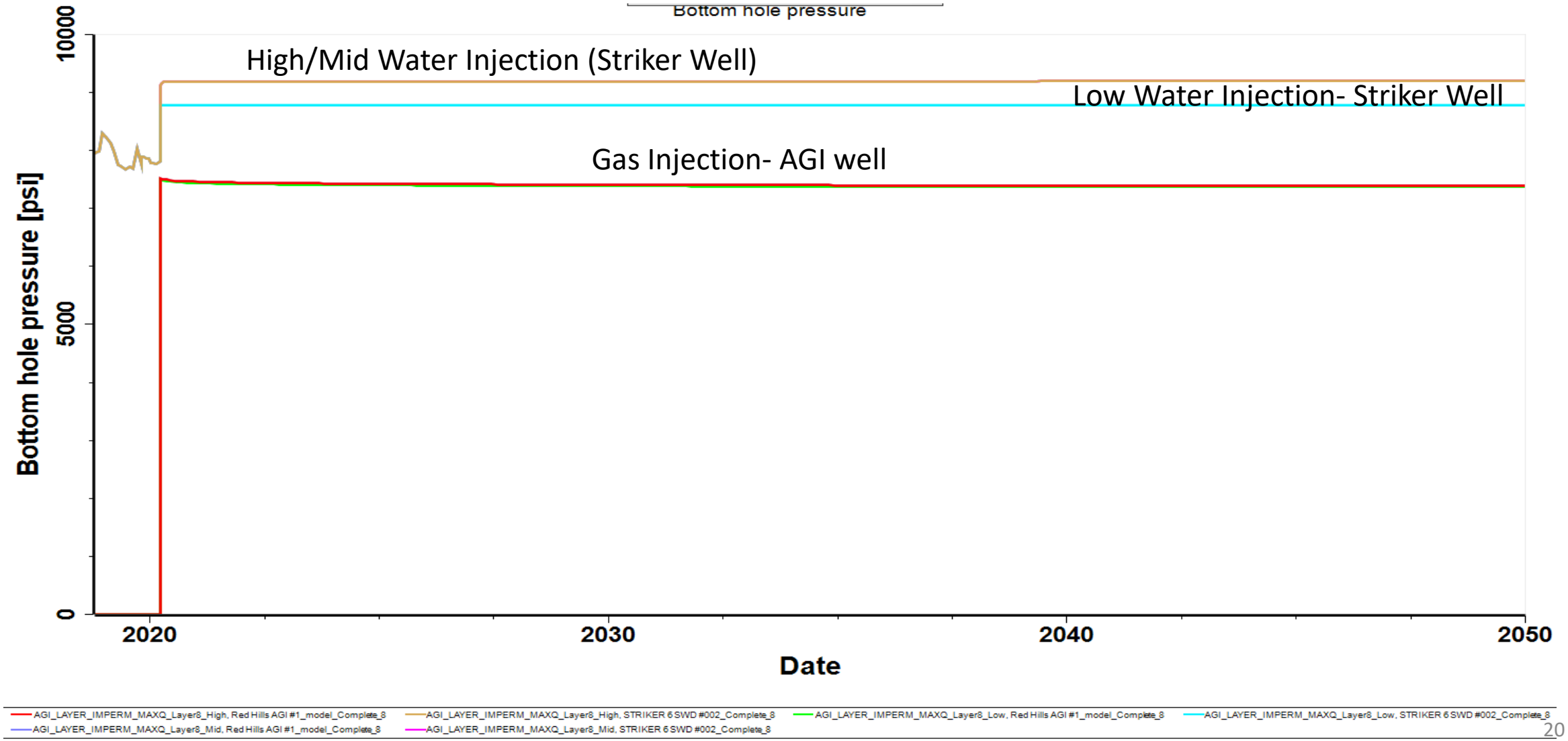
- High = 0.88 psi/ft
- Mid = 0.63psi/ft
- Low = 0.5 psi/ft



Injection Profile @ Various Injection BHP Constraint



Pressure Profile @ Various Injection BHP Constraint



Summaries

- The hydrodynamic model confirms the proposed injection volume of 13MM scf/Day of acid gas over a 30-year injection period.
- The nearby SWD wells would bring more significant pressure increments than the acid gas injection.
- The AGI project would bring no impact to the current hydrocarbon production wells. Both the acid gas plume and the pressure front of the AGI injection activities would not reach to the producer.
- The lateral extends of the gas plume is constrained within a safe region, which confirms that the Devonian formation is a good candidate for fluid disposal.
- Different injection and completion schemes support safe injection and containment of injected acid gas

3D Fault Mapping