Moonie Oil Field CO_2 EOR Project

Initial Injection Plan 2021

Chapter 13: Assessment of Impact: Receiving Environment

Commercial in Confidence

The Moonie Oil Well 27 (M27)

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13.0 Executive Summary

The oil field injection zone within the Precipice formation “oily water leg” reservoir sitting above the main Precipice formation “main water leg” reservoir and confined by a geological anticline, has been assessed as having no significant impact to the receiving environment, due to:

- The existing disturbed condition of the receiving environment groundwater (the Precipice formation “oily water leg” reservoir) as it has been pumped since 1964 (refer to Chapters 7,8 & 12),

- From an environmental perspective, the Precipice formation reservoir “oily water leg” within the Moonie Anticline has water, oil, oil fractions, and related organic compounds and is unfit for surface use unless treated to ANZACC standards,

- There is no evidence of microbial activity due to:
    - The current chemical condition, temperature and depth of the formation which precludes microbial life,
    - The reservoir pressure is ≥ 2,300 psi at 1.766 km,
    - The oxygen level is severely depleted and shows evidence of ancient scavenging being O^2 <0.3mg/L,
    - No light at 1.6km,
    - No biological biofilm has been detected at the oil refinery.

- Liquid CO_2 injection process (-20C, 330psi) cannot introduce microbes to the formation,

- Given the results of studies and reservoir models that have been completed and the groundwater management plans detailed in this amendment, no significant environmental harm to the receiving environment is expected,

- If any of the field monitoring parameters or thresholds are exceeded, they will be investigated and if conclusive then the contingency plans detailed in Chapter 3 will commence. If a high-risk event occurs, the field will be shut in and the project reassessed, the injection process will stop until risk mitigation measures are put in place to rectify (see Chapter 3: Contingency Methods).

13.1 Introduction

The changes to the oil reservoir have been modelled and localised changes to water quality within the Precipice formation reservoir “oily water leg” are expected, however these changes are not forecast to have a significant impact to the receiving environment.

The receiving environmental aspects include,

- Stygofauna unlikely to be found below 100m, or in hypoxic groundwater (Stygofauna in Australian Groundwater Systems: Extent of Knowledge: Report to the Australian Coal Association Research Program (ACARP) Hose et al (15 July 2015) CSIRO Land & Water Division & Macquarie University).

- Microbes not detected in the oily water and evidence of microbial decomposition and degradation of oil not found in the oily water extract,

- Low O^2 (<0.3mg/L), oxygen has been used up by previous ancient activity and is scarce,

- Natural CO_2 present (5 mol % CO_2) from ancient thermo-intrusive events,

- Temperature in the water column being 60 - 80$^oC^+$,

- Groundwater pH 8.4,

- TDS varies up to 1,800 mg/L,

- Average greater reservoir pressure is 2,330 psi at 1.766 km,

- Solution Gas Oil Ratio of Moonie crude oil, 270 scf/bbl, with an API Gravity of 43-45^o (classified as light oil),

- High sodium absorption ratio, the actual SAR is between 120 to 220,

- Reservoir carbonates levels of 1,362mg/L are (high in comparison to potable water) and free bicarbonates at 760 mg/L,
- Full range of hydrocarbons which are toxic to microbes,
- Receiving environment is sterile, can be > 80°C, pH 6.5 – 5.5 (following injection),
- The Precipice formation "oily water leg" reservoir pressure of 2,198 psi at 1,700m (slightly lower than initial main reservoir pressure at field discovery due to drawdown from artificial lift on wells),
- No evidence from the refinery as to oil quality degradation or presence of any organic material (biofilms) that would suggest the presence of microbes and trigger microbial investigation,
- No evidence from oil fields of tell-tale signs of microbial activity (excessive H_2S gas or organic biofilms),
- Existing "disturbed water" characteristic of the receiving environment conditions by the removal of 67.6Mt of water and oil since 1964,
- Evidence of previous natural CO_2 and hydrothermal fluid alteration i.e., the creation and migration of oil and gas from lower formations being trapped in the anticline, fractured quartz grains, and fracture fills has been observed to occur, with mineral trapping as carbonates in core samples throughout the Surat Basin,
- Anticlinal fault bounded geological structure precludes ingress of new microbes, the oil, water and gas, carbonates and minerals have aggregated in the anticline and in place for 90 Ma,
- Downhole, original microbes which produced some of the oil and gas have long been extinct.
- No evidence of in place oil degradation, conditions preclude presence of active microbes,

- There is evidence of original population presence in the form of prehistoric dinoflagellate exoskeletons (silica base), and also extensive fossilised microbes in core samples,

- Existing wells are sub-artesian and under pressured not able to deliver water to surface on existing pressure (i.e., to receive the oil and water at the surface requires pumping.

13.2 Water Quality Before and After CO_2 Injection

Table 13-1 below, contrasts the water quality of the receiving environment before and after the CO_2 injection.

Table 13-1, Assessment of Impact on water quality aspects

Existing downhole water quality and characteristics	Conditions following Injection
O_2 Low (<0.3mg/L)	O_2 will remain low
Temperature in the water column from 60 to >80+°C	Temperature will return to equilibrium within the reservoir over time
Severely disturbed water receiving environment caused by the removal of Mtn water and oil, (67.6MMt extracted)	Water condition will remain disturbed with mixed liquid CO_2.
Groundwater pH 8.4	The modelling predicts pH will change within the oily water leg going to pH 5-6 (4-5 using the larger volume 3MMt U of Q injection model), however post injection, over time the pH will return to the average reservoir pH.
TDS varies up to 1,800 mg/L,	No additional solids introduced; no change expected
Reservoir water high in carbonates 1,362 mg/L , free bicarbonates at 760 mg/L (high in comparison to potable water)	Carbonate presence will buffer mild acid reaction chemically trapping CO^2 ions, see Chapter 8: Geochemistry
Full range of hydrocarbons and related organic compounds.	Remain similar, however availability for extraction will reduce over time.
Sterile receiving environment	No microbes will be introduced and conditions for the enhancement of microbial life will not change, the receiving environment will remain sterile

Existing downhole water quality and characteristics	Conditions following Injection
No evidence from refinery as to oil quality degradation or presence of any organic material that would trigger microbial investigation	No microbes will be introduced by the injection of CO_2
No evidence from oil fields of tell-tale signs of microbial activity (gas H_2S or organic biofilms)	No change expected continuing with ongoing monitoring
Reservoir Pressure	Modelling has indicated that no long-term change is expected, continuing with monitoring. Reservoir modelling forecasts that on conclusion of pumping and abandonment of the field the reservoir pressure will return to reservoir conditions close to original.

13.3 Formation of Convection Currents

The potential for the formation of localised convection currents due to temperature fluctuation is nil due to the relatively low vertical permeability (as compared to horizontal permeability), laminar nature and strength of the formation, as is evidenced in the core samples tested by UQ, and dynamic flow conditions during injection and production operations.

CO_2 will be injected at pressure to permeate the formation; the CO_2 remains in a critical state in the oily water leg and reacts miscibly with the oil. While there will be infusion of CO_2 into the rock formation and fluids of the oily water leg, there will be no creation of “currents”, as such, due to the preferential horizontal permeability within the formation and dynamic flow from the injector towards the lower pressure production wells.

13.4 Precipice Formation Reservoir - pH

With this initial project the localised pH reduction is towards neutral and is not expected to precipitate heavy metals as the pH change is toward a neutral state where the minerals and metals are not precipitated but held in solution. Three chemical trapping mechanisms will be operating within the Precipice oily water leg, and this is discussed in Chapter 8 Groundwater Geochemistry.

Predicted dissolution of carbonates and feldspar is consistent with observations from experiments using relative permeability reactions performed as part of the UQ-SDAAP and other projects.

Precipitation of kaolinite, ankerite and smectite has been observed where there has been natural ancient CO_2 induced alteration.

13.5 Effect of Injection - Temperature

Injected CO_2 must be above 31.1°C and a liquid to facilitate the development of a miscible flood front to sweep oil and avoid the occlusion of pore spaces within the Precipice reservoir formation.

UQ predict temperature change within and restricted to the immediate contact area of the injection zone, in time the temperature will return to the original temperature and dependant on the heat of the CO_2 when it is at the injection sand face due to thermal induction.

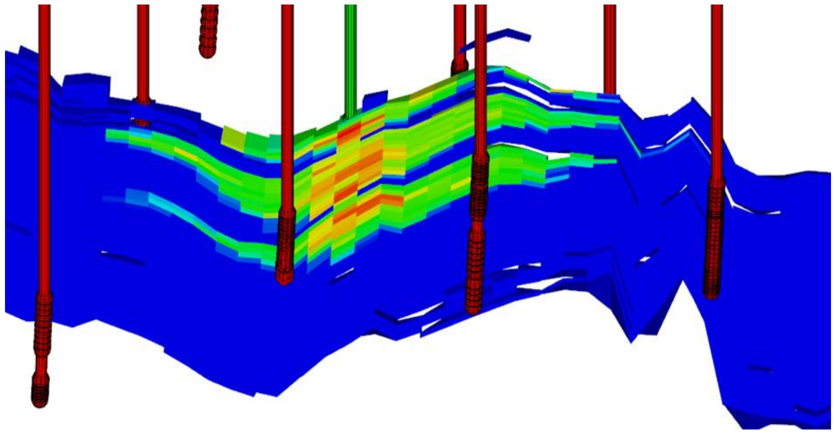
On injection the liquid CO_2 in contact with the reservoir fluid (water and oil), some will mix/dissolve due to its solubility. Interactions between CO_2 and oil can change the properties of the exposed trapped oil, such that the oil swells slightly and its viscosity is reduced, resulting in more oil being mobilized and swept to a producing well (miscible flood process).

13.6 CO_2 Flood Front development over time

The immediate development of a CO_2 flood front and its extension into the rock formation will be controlled by the governed injection volume, pressure from the injection pump located on the surface, temperature and miscibility of the injected fluid. The pressure at surrounding wells will be closely monitored along with the produced “Gas to Oil” ratio (GOR) at the five production wells and the analyses of the actual constituents of the produced oil water sampling undertaken at the evaporation ponds, including pH, ions and CO_2 concentrations as illustrated above.

Figure 13-1 overpage: Illustrates the development of the CO_2 flood front extending from the injection well towards the five-surrounding monitoring/production wells at 12 months.

Figure 13-1, 3D illustration of $scCO_2$ cloud at 12 months



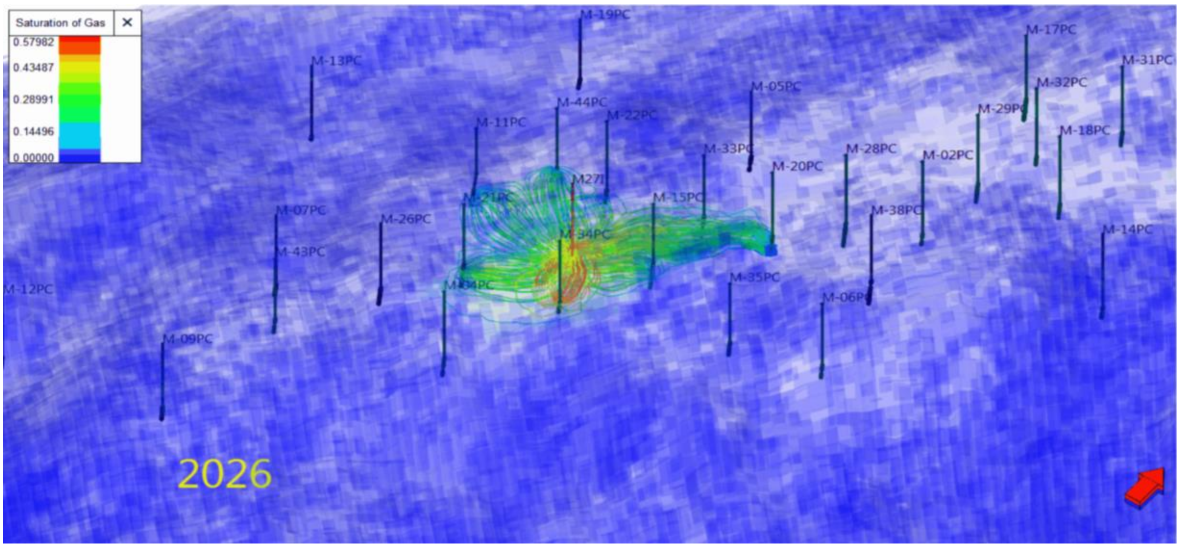
M27 Injection Well (green)

Monitoring wells in Red

13.7 The predictions from the Dynamic Model

The dynamic model forecasts the rate of movement of the CO_2 flood front through the formation. The 2D volumetric expansion and contraction of the CO_2 cloud over a 21-year period is illustrated in Figures 13-2 to 13-5 below. The flood front first expands out to the production wells and then over time contracts post injection.

Figure 13-2, The 2D Volumetric extent of CO_2 flood front at year 3 (2026)



Red, yellow and green depict declining saturated gas levels

Figure 13-3: A Plot of the Pilot Simulated CO_2 flood front 24 months after injection.

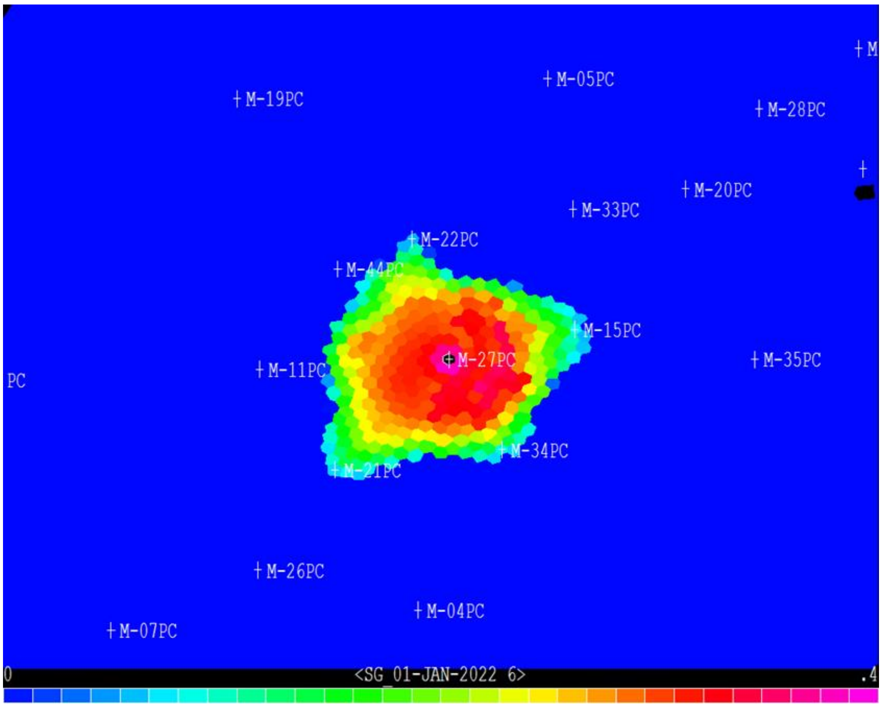
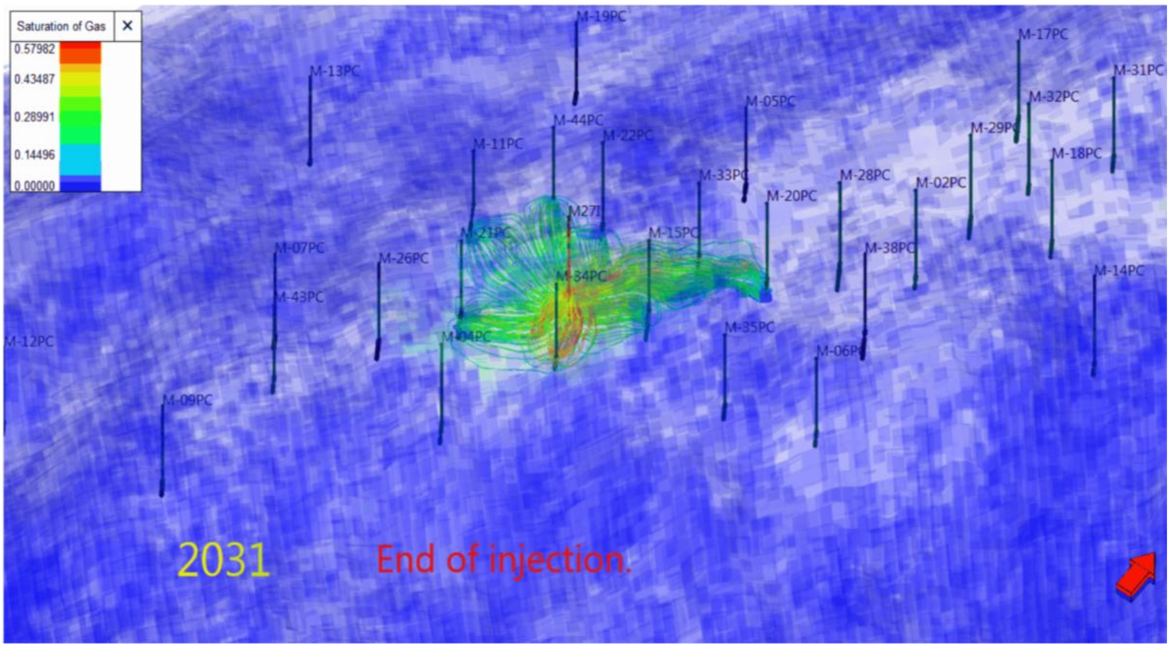
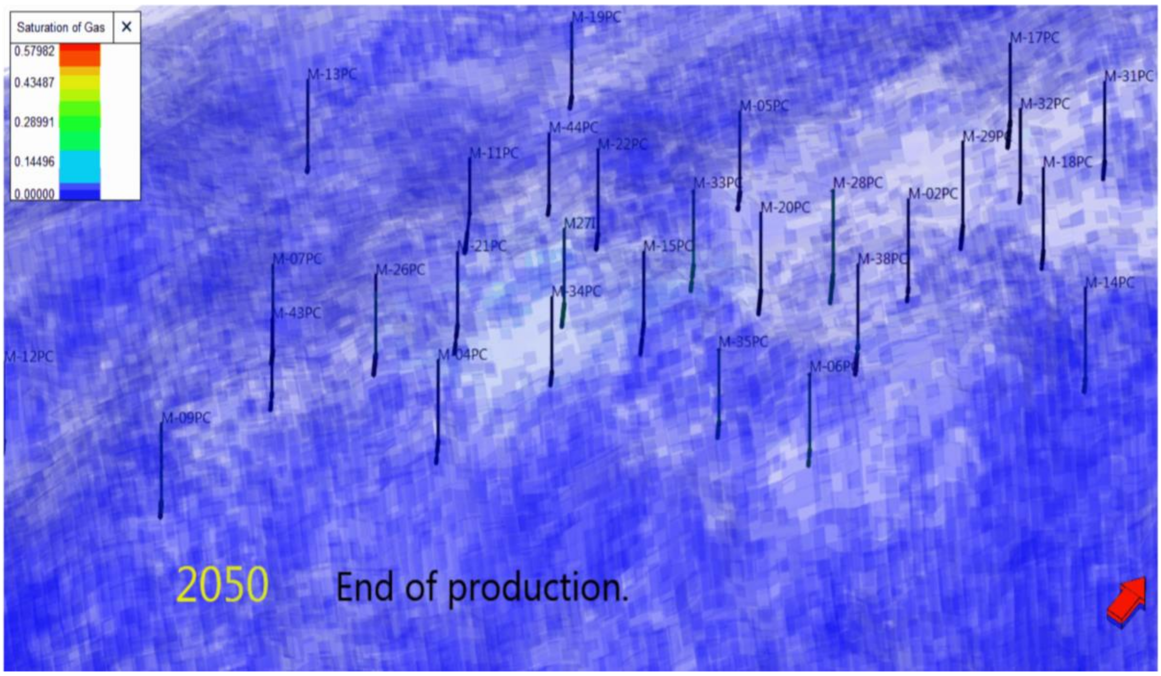


Figure 13-4, The 2D Volumetric extent of the CO_2 flood front at Year 9 (2031) End of Injection



Red, yellow and green depict declining saturated gas levels

Figure 13-5, The 2D Volumetric extent of the CO_2 flood front at 2050 (End of Full Field Production)



Red, yellow and green depict declining saturated gas levels

13.8 3D Volume Injection Models

The 3D model prediction of CO_2 saturation within the Moonie Oil formation over time

Figures 12-6, 12-7, and 12-8 below, illustrates in 3D the saturation of CO_2 within the Precipice formation "oily water leg" reservoir over time.

Figure 13-6, The 3D saturation of CO_2 at year 3 (2026)

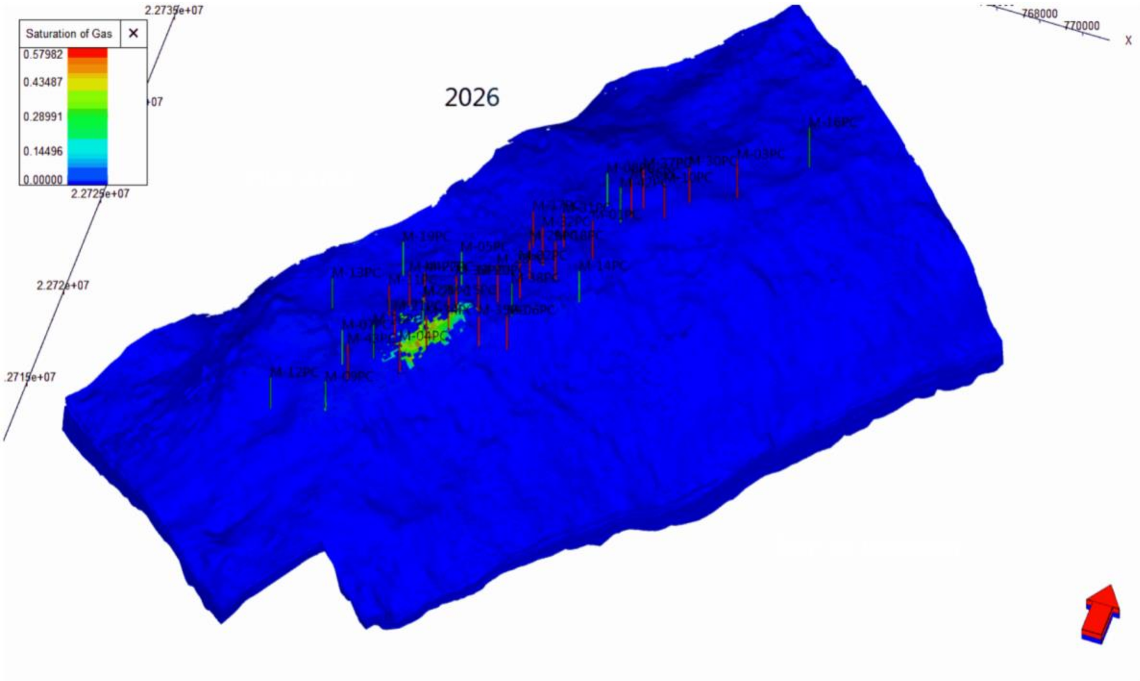


Figure 13-7, The 3D saturation of CO_2 at year 9 (2031) End of Injection

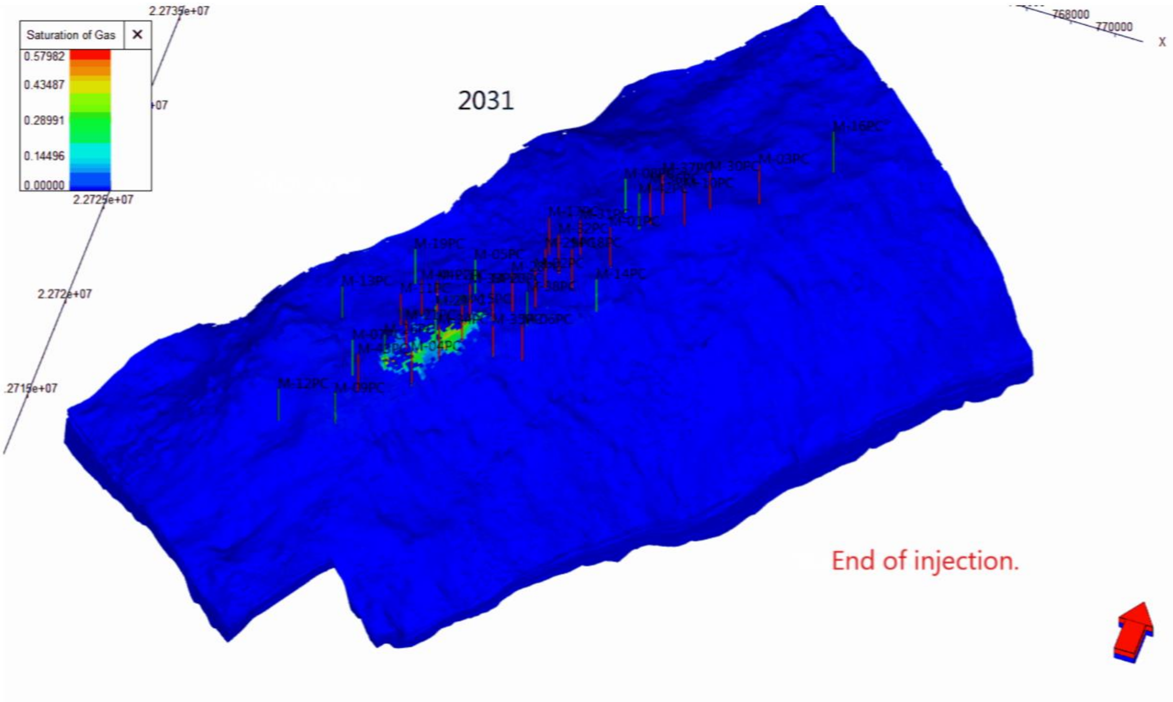
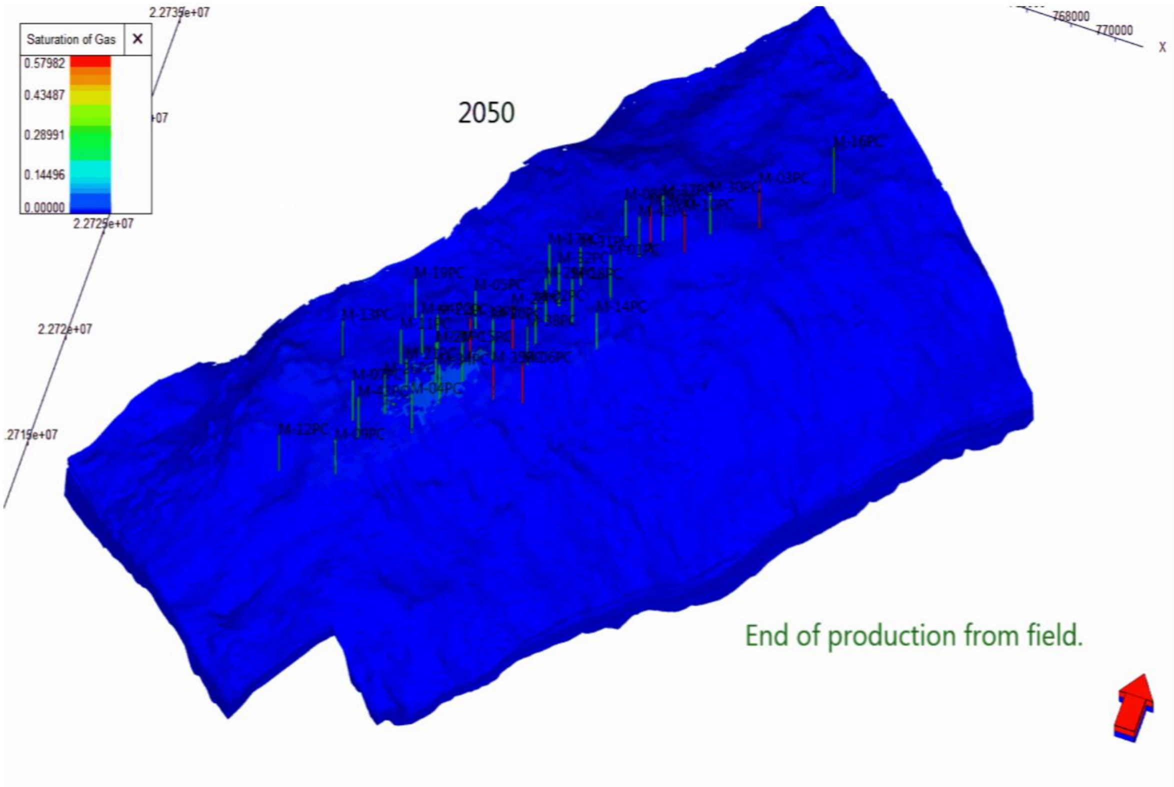


Figure 13-8, The 3D saturation of CO2 at year 21 (2050) post injection (End of Full Field Production).



13.9 2D Vertical section through the Moonie Oil Field illustrating CO_2 saturation over time

The following three Figures illustrate the CO_2 flood front at 3 years (2026), at the end of the injection period in 2031 and at the end of production 2050. The figures also illustrate the position of the initial oil water contact in 1963. The CO_2 flood front remains considerably higher than this interface throughout the project.

Figure 13-9, 2D Vertical section through the Moonie Oil Field depicting flood front position at year 3 (2026)

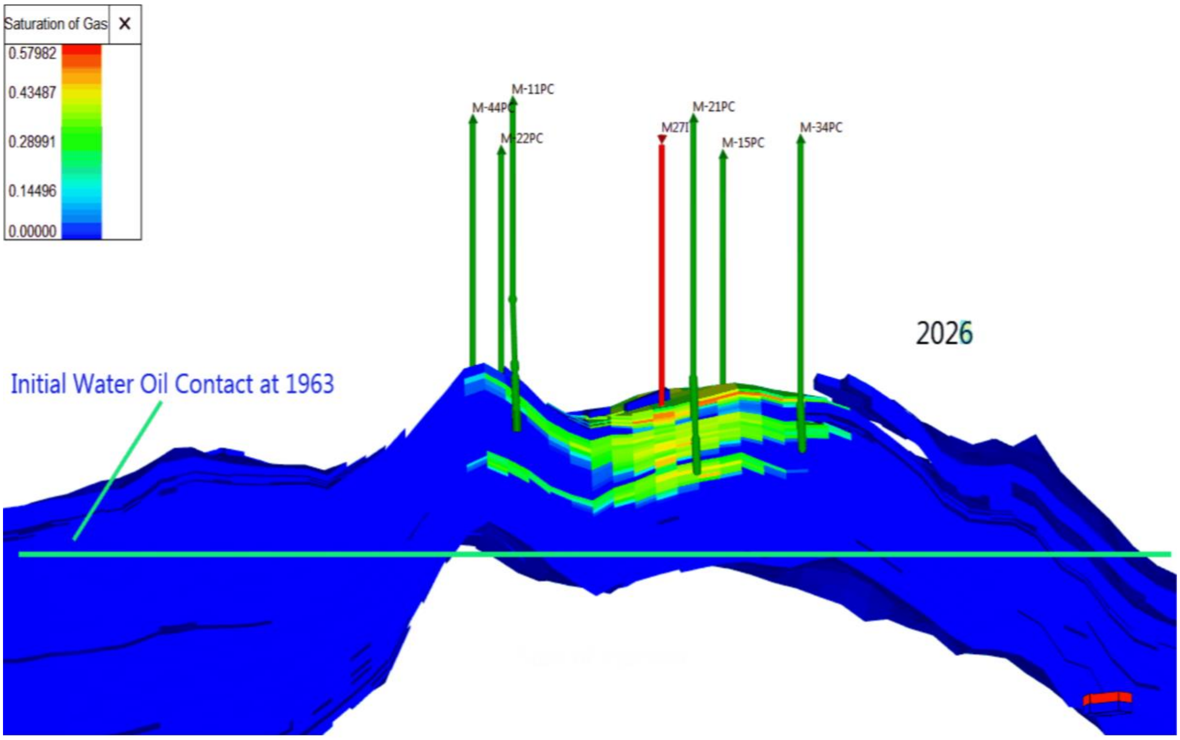


Figure 13-10, 2D Vertical section through the Moonie Oil Field depicting flood front position at end of injection (2031)

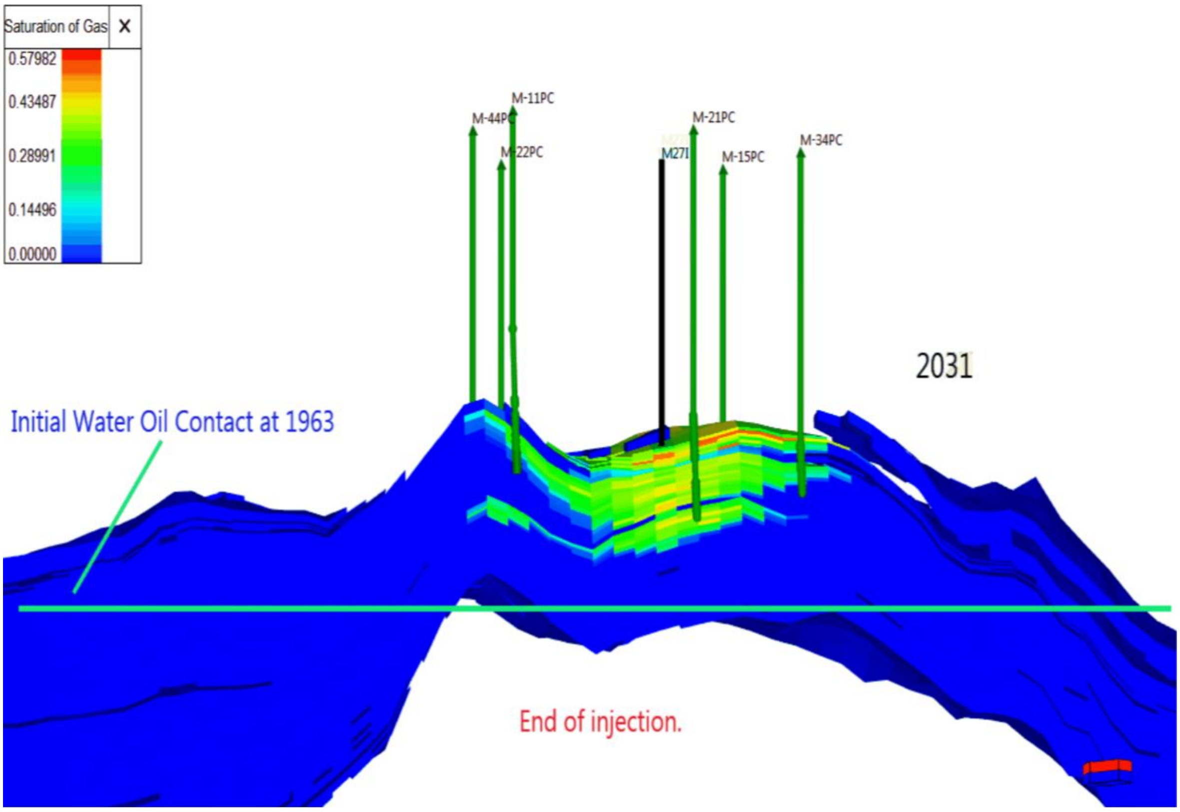


Figure 13-11, 2D Vertical section through the Moonie Oil Field depicting flood front position at end of full field production (2050)