Carpentaria Pilot Project – catalyst for Australia's shale gas boom

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Introduction

Empire Energy Group Limited (Empire) operates unconventional shale gas assets in the Northern Territory through its subsidiary Imperial Oil and Gas Pty Limited (Imperial). In early 2010, Imperial recognised the petroleum potential of the marine organic-rich shales of the McArthur Basin and secured seven licence applications in the Northern Territory, two of which have subsequently been granted (EP184 and EP187). Although the Palaeoproterozoic shales of the McArthur Basin were the original sphere of interest, it is the younger Beetaloo Sub-basin Mesoproterozoic shales, specifically the Amungee Member of the Velkerri Formation, that have become the focus in EP187 (**Figure 1**) and other parts of the Beetaloo Sub-basin. The Amungee Member contains four stacked shale-gas reservoirs, listed in depositional order: the A, Intra A/B, B, and C Shales. The A, B, and C Shales are organic-rich marine shales, whereas the Intra A/B is a hybrid shale – tight gas play (**Figure 2**).

During 2021, Empire acquired additional assets (EP167, EP168, EP169, EP198) in the greater McArthur Basin from Pangaea (NT) and Energy & Minerals Group (EMG), increasing Empire's holdings within the Beetaloo Sub-basin to an area of over 4000 square kilometres (>1 000 000 acres). However, EP187 has remained the company's primary focus of exploration and appraisal activity.

This paper is a summary of Imperial's activities over the last six years, a program of seismic acquisition, vertical and lateral drilling, fracture stimulation and testing, which has put the company on a path to becoming the first gas producer in the Beetaloo Sub-basin with its Carpentaria Pilot Project (**Figure 3**).

Background

Exploration for conventional petroleum commenced in the Beetaloo Sub-basin in the 1980s and early 1990s with a switch to exploration for unconventional resources,

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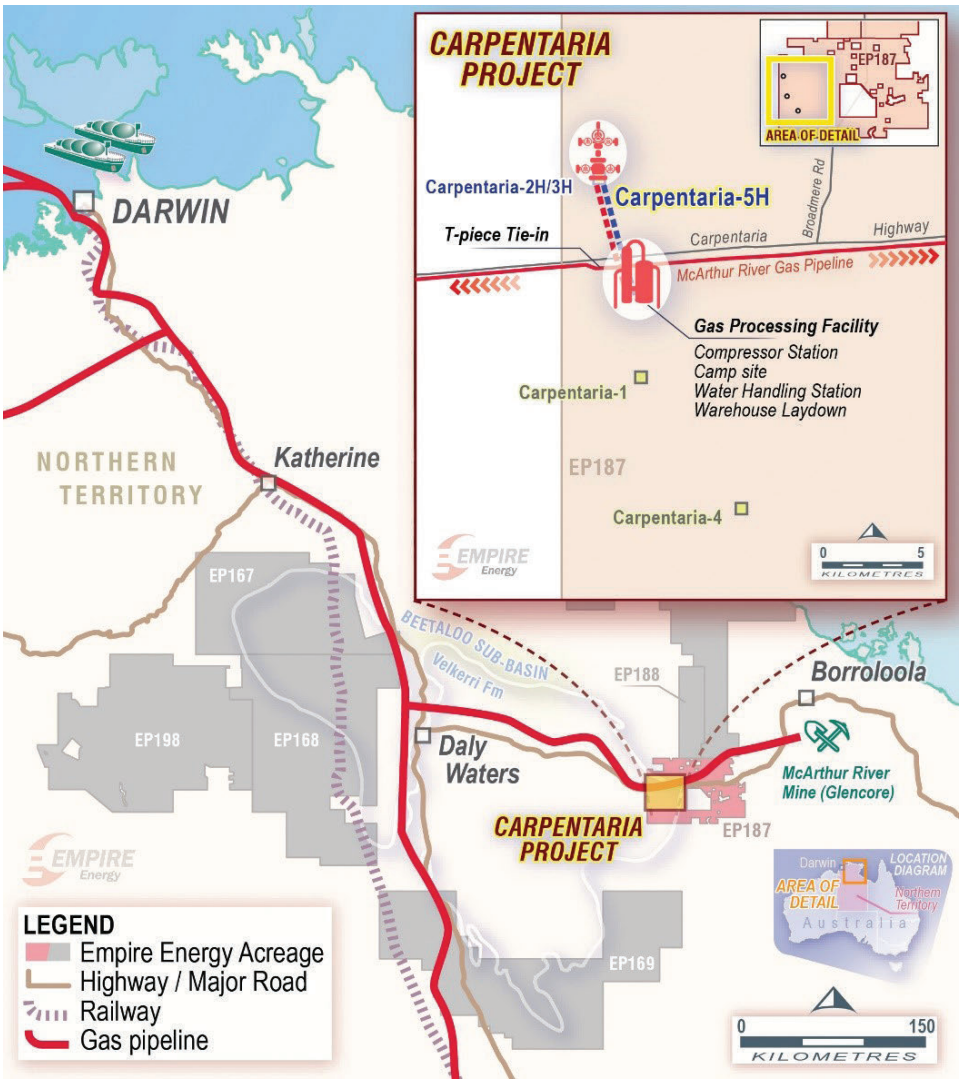

Figure 1. Location of Empire Energy Group's Carpentaria shale-gas project in northeast Northern Territory.

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specifically shale gas, in the early 2010s. Initially, the shale-gas exploration wells were vertical with limited testing and were focussed on information gathering to quantify and rank the various reservoirs. This led all operators in the basin to focus appraisal efforts on the B Shale. Currently the focus is on horizontal drilling, fracture stimulation, and production testing (**Figure 4**) to determine factors such as gas rates, decline curves and recoverable volumes, all of which have a bearing on the commercial viability of the play. The concentrated appraisal of the B Shale reservoir has accelerated the path to gas production in the Beetaloo Sub-basin, leaving other reservoirs to be appraised and developed once cash flow from B Shale gas production has been established.

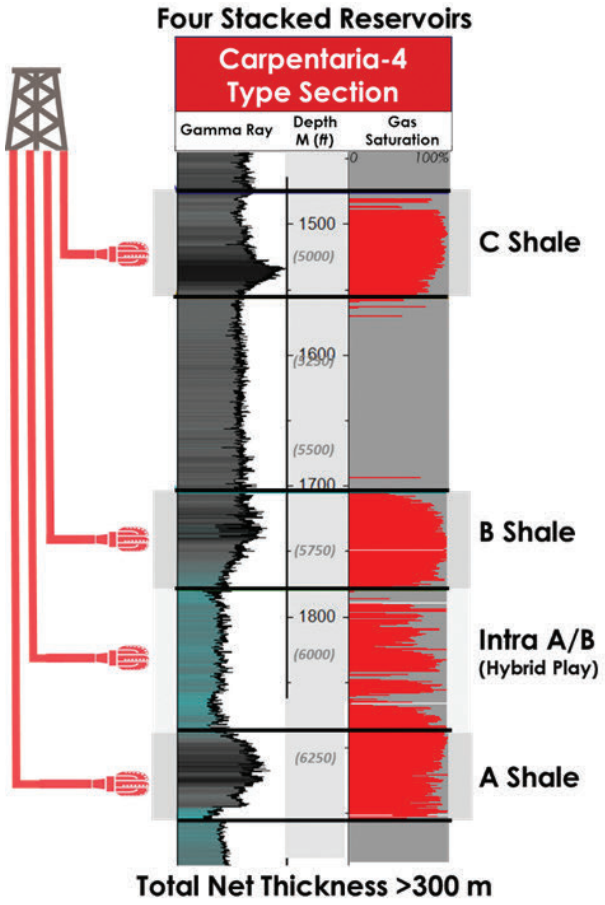

Figure 2. Lithostratigraphic column showing Amungee Member shale gas reservoirs.

Carpentaria seismic

Imperial has acquired two 2D seismic surveys within western part of EP187. The first was the six-line 231 km Broadmere seismic survey acquired in 2019. The seven-line 164 km Charlotte seismic survey was acquired in 2021 to infill the Broadmere survey. Line orientation has been broadly aligned to the principal horizontal stress direction, with the approximately north–south lines utilised to aid geosteering of horizontal wells in the pilot phase of the project . The nominal spacing of the lines is 4 km (**Figure 5**).

Carpentaria vertical drilling, hydraulic stimulation and testing

In September to October 2020, the vertical Carpentaria-1 well was drilled to 1915 m measured depth (mMD). The well proved the presence of all the Velkerri Shale reservoirs at prospective depths. The gross thicknesses of the shales were ~70 m for the C and B Shales, and ~60 m for the A Shale. The Intra A/B hybrid play had a net pay of ~50 m. The average total porosity across all reservoirs is ~7–9%. The Velkerri shales are brittle with typically 50–60% quartz. Total organic carbon (TOC) averages between 4 and

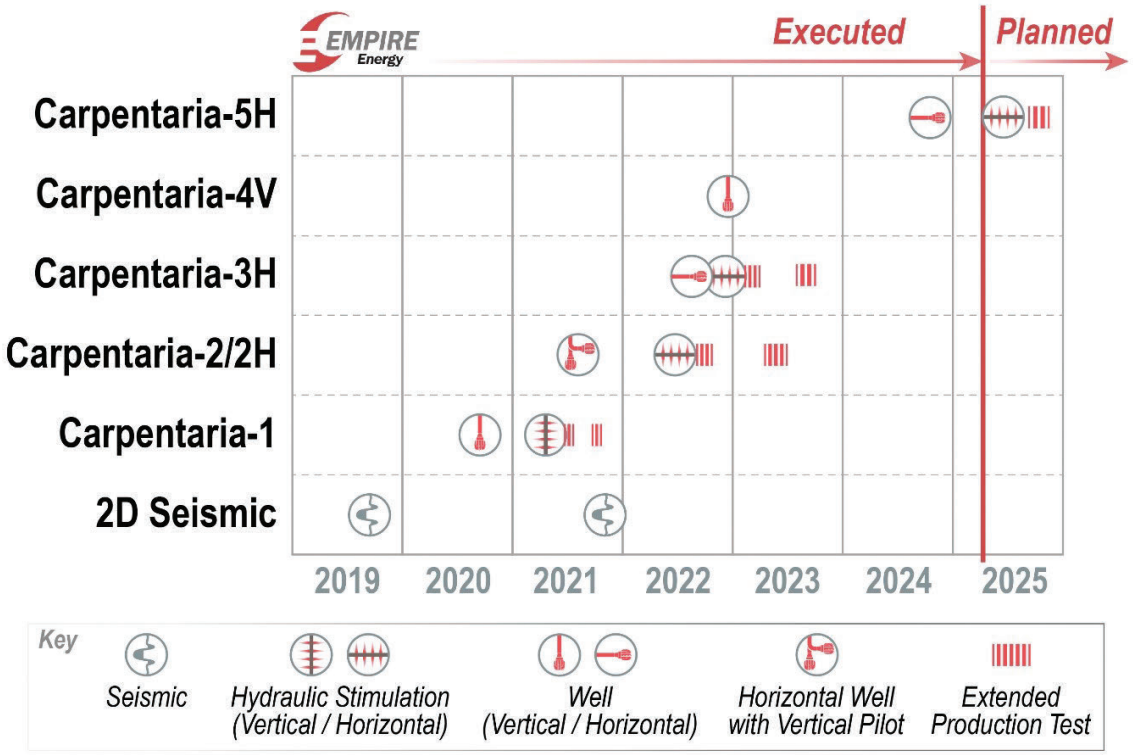

Figure 3. Timeline of activities.

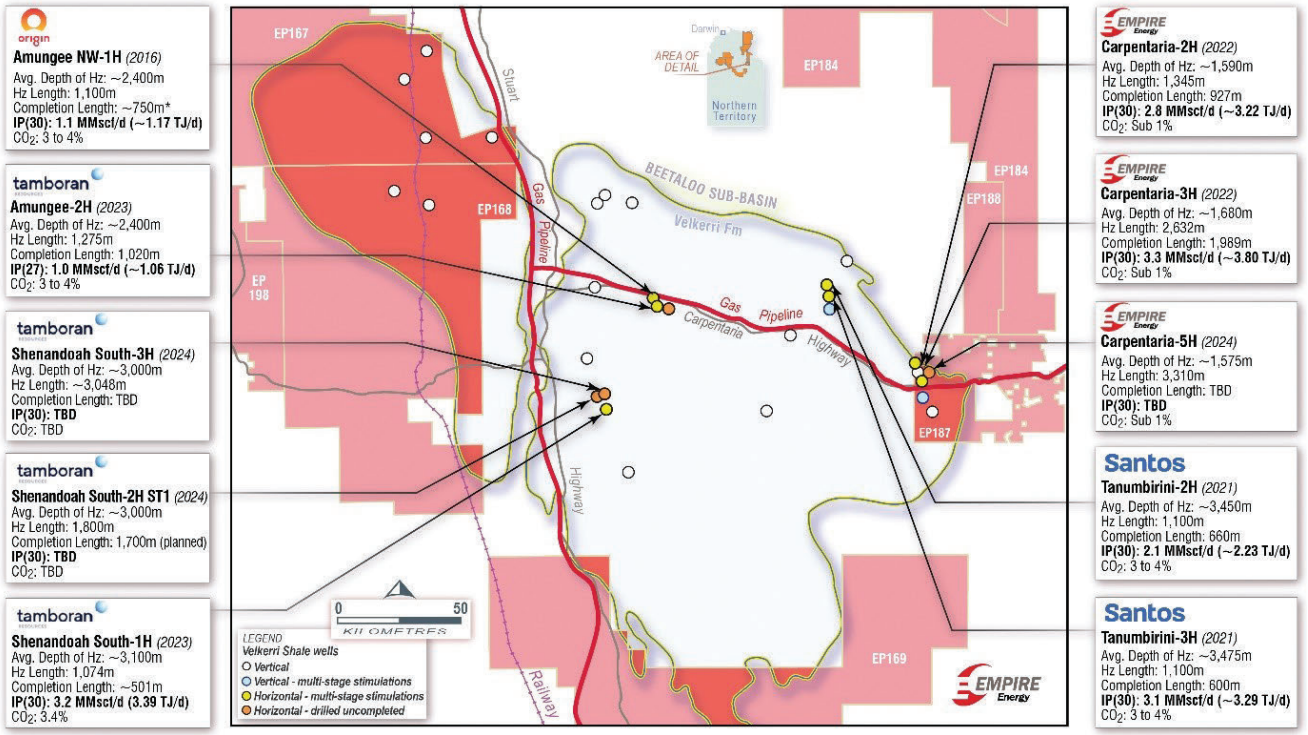

Figure 4. Summary information for lateral wells in the B Shale.

5% with a strong correlation to total porosity, indicative of organic porosity. Such characteristics compare favourably with working US shale plays such as the Marcellus Shale.

A four-stage hydraulic stimulation campaign was undertaken in the Carpentaria-1 well in June 2021, one stage targeting each reservoir. Water and hydrocarbon tracers were applied during stimulation and sampled during flowback. Subsequent analysis indicated that all units were flowing gas, but the B Shale was contributing the most.

Technical achievements for Carpentaria-1 were:

- gas discovery
- proved extension of Beetaloo Sub-basin shale-gas play into EP187
- confirmed stacked play in the Amungee Member with four viable reservoirs.

Carpentaria horizontal drilling, hydraulic stimulation and testing

In November 2021, the vertical Carpentaria-2 and horizontal Carpentaria-2H wellbores were drilled ~10 km north and ~200 m vertically down dip of the Carpentaria-1 location (**Figure 5**). The vertical wellbore was drilled through the entire Velkerri shale sequence (**Figure 2**) proving lateral consistency of reservoir characteristics and thicknesses. After plugging back the vertical wellbore, the horizontal section was drilled 100% in the B Shale to a length of 1345 m with an average depth of ~1590 m below ground.

Commencing June 2022, the Carpentaria-2H wellbore was hydraulically stimulated. A range of different fluid systems were trialled to assess the optimal system for future development wells, and to provide risk mitigation. This was because with a single-well program there was a low tolerance of risk and the remote location meant, in case of failure, it

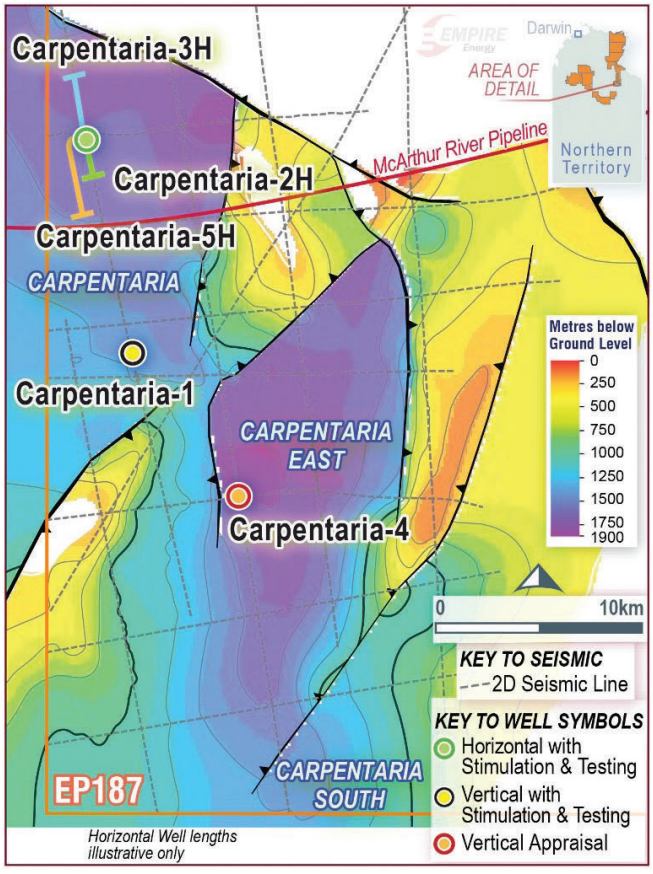

Figure 5. EP187 contoured map of depth to B Shale.

would not be possible to pivot to a different fluid system mid-operations. The primary differences between the fluid systems were the viscosity and proppant carrying capacity: the slickwater was the least viscous and had the lowest proppant carrying capacity, and the crosslink was the most viscous. Although slickwater is the preferred fluid in US shale plays,

it does carry a higher risk of not achieving breakdown and of screen-out. Screen-out can occur when sand obstructs the perforations preventing further fracture propagation and sand placement. Slickwater stimulation fluids may have significant positive implications for cost reductions and production in future development scenarios as the slickwater contains fewer chemicals and is the lowest cost system. All fluid systems were successfully placed with a total of ~6 million pounds of proppant placed without screen-out. Empire pumped 21 stages, having originally planned to pump up to 26 stages (**Table 1**). The program was reduced by 5 stages in the vicinity of a previously mapped geological fault as a conservative risk mitigation on the standalone program.

Table 1. Carpentaria-2H fluid systems.

Fluid system	Number of stages
Slickwater	7
High viscosity friction reducer (HVFR)	2
Hybrid (Slickwater-Crosslink)	4
Crosslink	8
Total	21

Technical achievements of the Carpentaria-2H stimulation project were:

- successfully drilled within target interval
- stimulated an effective horizontal length of 927 m
- achieved average proppant intensity of ~2050 lb/ft
- stimulated the greatest number of stages in a single well in the Beetaloo to that time
- placed 97% of the designed proppant volume into the stimulated stages
- successfully placed multiple slickwater stages without screening-out – first time that a Beetaloo operator has done this
- achieved technical learning during the stimulation program, resulting in increased operational efficiencies, including 2 stages stimulated per day in the final 4 days of the program, which will have cost reduction benefits in future stimulation programs.

Shortly after stimulation, the well was put on cleanup and extended production testing, confirming high calorific gas with less than 1% CO_2. After an initial 51 days of testing, the well was put on buildup and soak for five months to align with Carpentaria-3H drilling operations from the same pad. Soaking is the process of shutting-in a well to allow the injected fluids to imbibe into the shale to facilitate gas production. During flowback operations, samples were collected and gas and water tracers that had been added during hydraulic stimulation were analysed. Tracer data indicated all stages were contributing with no clear advantage of any one frac fluid over another, given the limited duration of the testing and other factors. The intention was for tracer data to form the basis of the Carpentaria-3H fluid system design. However, tracer data limitations and the requirement of long lead procurement during the early Carpentaria-2H flowback resulted in a hybrid slickwater and crosslink design for Carpentaria 3H, which allowed greater flexibility during execution.

In October to November 2022, the horizontal Carpentaria-3H well was drilled from the same pad as Carpentaria-2H but in the opposite direction (**Figures 5** and **6**). The 2632 m horizontal section encountered greater structural complexity than the Carpentaria-2H wellbore. Although fault throws were less than the thickness of the reservoir, the well path undulated to stay in zone, and had departures from the B Shale target accounting for ~10% of the stimulated wellbore length.

In the same drilling campaign as the Carpentaria-3H well, the vertical Carpentaria-4 well was drilled in the southern area of the permit to establish the presence and continuity of the shale-gas reservoirs in a syncline to the east of the earlier drilling locations (**Figure 5**).

Carpentaria-3H was stimulated from December 2022 to January 2023. Forty stages were successfully placed without screen-out, with a total proppant volume of ~12 million pounds, double that used for Carpentaria-2H (**Table 2**). At the time, it was the largest pumped hydraulic stimulation in Australia. Immediately following cleanup, the well was put on extended production test for 27 days prior to a period of buildup and soaking for a period of five months.

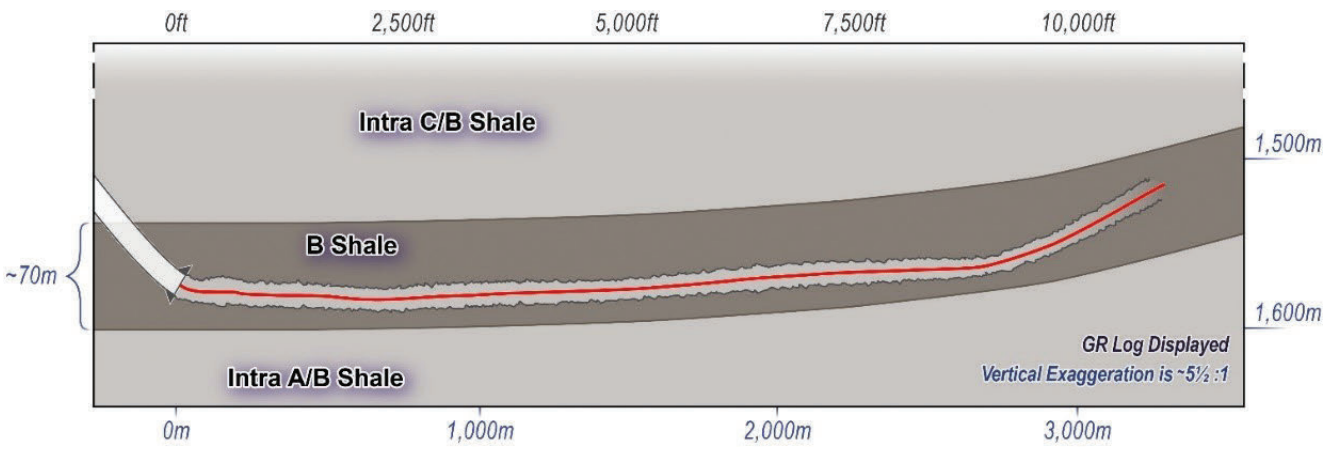

Figure 6. 3D schematic of lateral wells in EP187.

Table 2. Carpentaria-3H fluid systems.

Fluid system	Number of stages
Slickwater	3
Hybrid (Slickwater–Crosslink)	21
Crosslink	16
Total	40

Technical achievements of the Carpentaria-3H stimulation project were:

- stimulated an effective horizontal length of 1989 m
- Achieved average proppant intensity of ~1950 lb/ft
- stimulated the greatest number of stages in a single well in the Beetaloo Sub-basin to that time
- placed >98% of the designed proppant volume into the stimulated stages
- proved the suitability of low viscosity fluids repeatedly over a large number of slickwater and hybrid stages.

While Carpentaria-3H was put on soak, Carpentaria-2H extended production testing recommenced and ran for an additional 63 days. During that period an average initial production over 30 days (IP30) of 2.8 million standard cubic feet per day [MMscf/d; ~3.22 terajoules per day (TJ/d)] was achieved. Following the five-month period of shut-in and soak, Carpentaria-3H was put back on extended production test, achieving an IP30 of 3.3 MMscf/d (3.8 TJ/d). Both wells achieved an increase in productivity after a period of soak.

Coupled with Carpentaria-2H, Carpentaria-3H results showed the importance of productivity elements such as well path geometry, geosteering in zone, frac plug selection and application of recycled water use, as well as perforation and flowback techniques. Tracer analysis was somewhat ambiguous but there is evidence that the slickwater stages had higher gas production with lower flowback water volumes. This and other factors point to a desiccated shale with potentially improved gas recovery using a slickwater fluid system.

Carpentaria-5H ongoing program

In November to December 2024, the Carpentaria-5H well was drilled parallel to the Carpentaria-2H wellbore, once again targeting the B Shale. A horizontal length of 3310 m was drilled, with 100% placement in the targeted reservoir (**Figures 6, 7, 8**). At the time of writing, final planning for fracture stimulation and extended production testing of Carpentaria-5H was in progress and the stimulation will be executed in 2025.

Carpentaria-2H and Carpentaria-3H were early wells in a new basin. Aspects of those wells included proof of concept, development of basin-specific procedures, logistics, and increasing scale of operations. Although gas productivity was a driver, the primary operational focus was ensuring successful execution and, most importantly, a gas flow in single-well drilling campaigns. A cautious operational approach was required to minimise risk and many of the design elements were experimental. This may have an impact on ultimate well productivity but has provided valuable experience and knowledge for continual improvement and optimisation of future wells.

These learnings have been incorporated into the drilling, fracture stimulation, and testing design for Carpentaria-5H. The key developments in design to uplift productivity compared with the Carpentaria-2H and Carpentaria-3H wells are outlined below and illustrated in **Figure 9**:

- longer horizontal section with more stimulation stages
- improved geosteering process
- increased casing size (5½”) to allow greater stimulation pump rates (~double)
- increased hydraulic stimulation horsepower (more than double)
- slickwater fluid design on all stages
- increased fluid concentration (~double)
- proppant concentration (~25% higher)
- enhanced perforating strategy
- managed flowback.

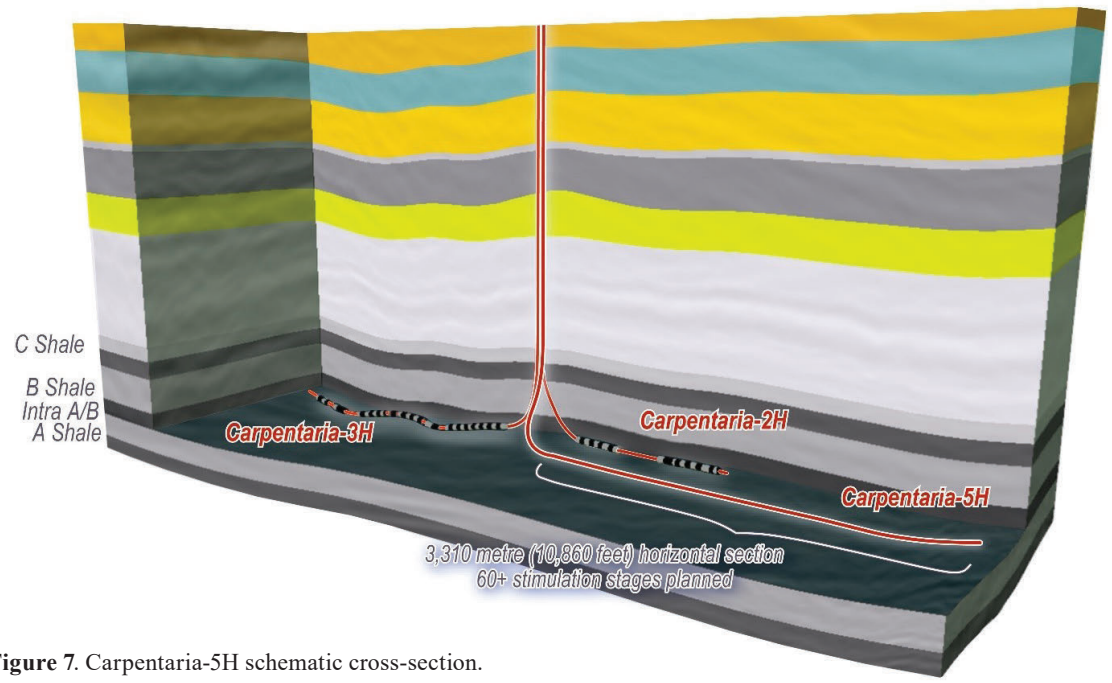

Figure 7. Carpentaria-5H schematic cross-section.

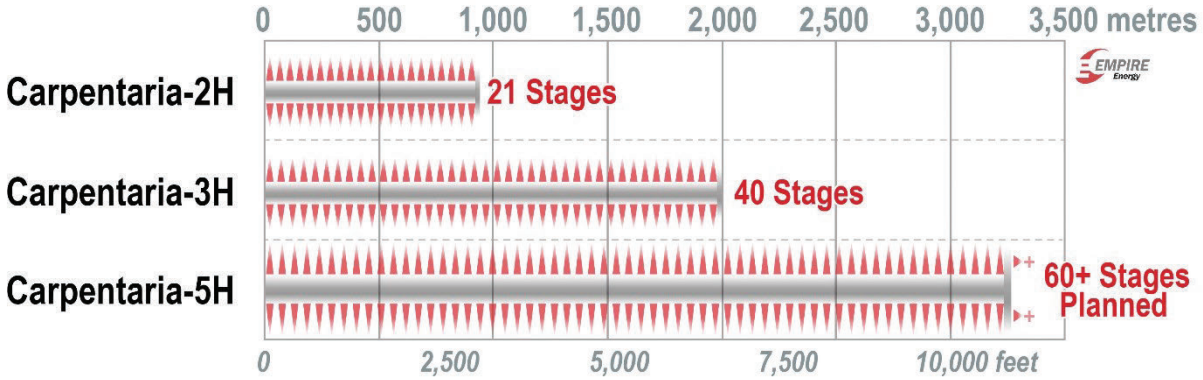

Figure 8. Incremental improvements in stimulation length through time.

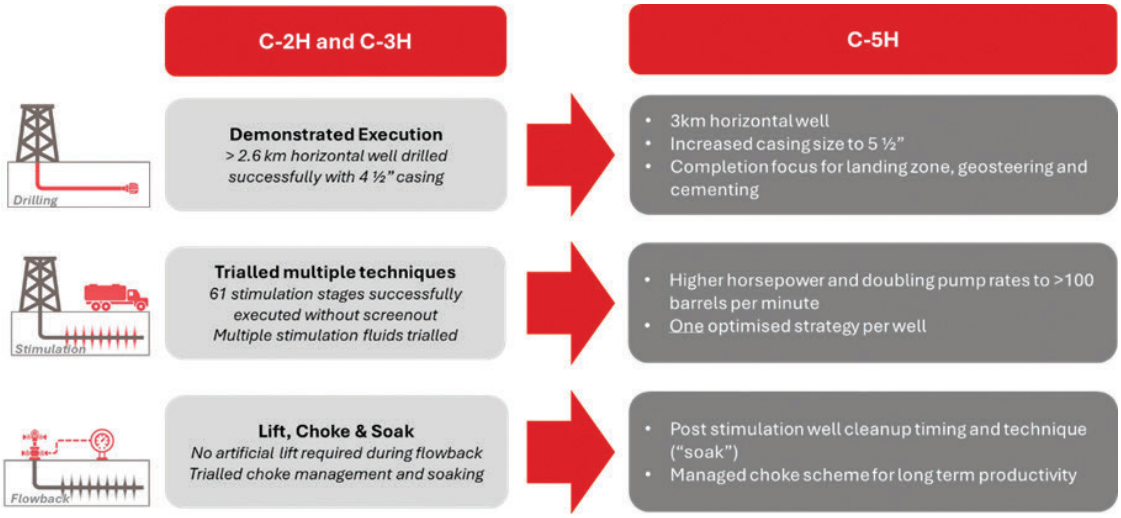

Figure 9. Implementation of lessons learned in frac design.

Carpentaria Project

The Carpentaria Gas Project (CGP) is a shale-gas appraisal-development located in EP187 in which Imperial holds a 100% working interest and operatorship. To determine the commercial viability of the CGP, Imperial is undertaking the Carpentaria Pilot Project (CPP). The CPP aims to produce gas from the existing Carpentaria-2H and Carpentaria-3H appraisal wells, the Carpentaria-5H well, and future pilot development wells.

To date, extended production testing has been conducted for a total of three to four months per well. This duration is not sufficient for long-term forecasting of productivity performance and decline. Because the Northern Territory Government is allowing the gas to be delivered into the domestic market, the CPP will be able to achieve a longer-term production test, greater than 12 months, with the purpose of generating a more robust set of type curves for forecasting production from future wells and determining the Estimated Ultimate Recovery (EUR). A longer-term CPP aim is to deliver both cash flow and additional gas resources for large-scale development.

For producing and off-take of the gas, Imperial has purchased the Carpentaria Gas Plant that has a design capacity of 42 TJ/day (~40 MMscf/day). The plant is the former Rosalind Park Gas plant acquired from AGL in 2023. It will be reassembled at the CPP for first gas after refurbishment. The acquisition of an existing gas plant has had material cost and lead time savings compared to a new-build alternative.

Gas off-take will be through the McArthur River Pipeline that runs through the centre of the Carpentaria project area parallel to the Carpentaria Highway. Currently, the pipeline transports gas from the Amadeus Pipeline west of the CPP to the McArthur River mine located ~100 km east of the Carpentaria project area. The pipeline has a current capacity of ~15 TJ/day, but this can be increased to ~25 TJ/day with bi-directional flow and additional boosting and compression.

Forward plan

Prior to first gas off-take, the Carpentaria-5H well will be stimulated and put on an extended production test. Following testing, the well will be shut-in during the construction and commissioning phase of the Carpentaria processing facility. First gas deliveries from the project are expected to be ~10–15 TJ/day. Once gas sales have commenced, ongoing drilling may grow production to ~25 TJ/day in the few years thereafter.

Current focus is on the B Shale. However, the stacked Velkerri shale sequence allows a Permian Basin style development. With the four stacked shale reservoirs, fewer well pads are required to drill more development wells, reducing surface impact and leading to improved development efficiencies and economics. Using a

conservative well spacing assumption, more than 200 drilling locations (mid-level case) have been delineated in the B Shale, with ~600 additional locations across the A, Intra A/B, and C Shales.

Currently, the EP187 Carpentaria project has 1739 Petajoules (PJ) of gas (1.5 trillion cubic feet) 2C Contingent Resources and 3542 PJ of gas (~3 trillion cubic feet) best estimate prospective resources. These volumes, coupled with the high calorific and low CO_2 gas characteristic, provides significant scope for Empire to contribute to Australia's east coast domestic gas market and LNG markets. The project also presents a significant opportunity for long-term investment, job creation, and economic growth in a remote area, with the potential to provide an economic boost to local communities and the Northern Territory.