Figure 1. Pipeline shorepull.

Dean Campbell, Engineering Manager and Tom Seeber, Senior Engineer, Atteris Pty Ltd, explain how the pipeline shore approach for the Pluto LNG Project was completed successfully and on time.

Pluto LNG project

The Pluto gas field was discovered in the Northwest Shelf of Western Australia by Woodside in April 2005. Three months later it was announced that Pluto would be a stand-alone project. The Pluto LNG Project would go on to become not only Woodside's largest single investment, but also the largest of any Australian company at that time. Woodside set itself a target to turn this proposal into a reality in just five years.

It is estimated that the Pluto field contains 4.6 trillion ft^3 of dry, low CO_2 natural gas. The gas will be collected by five subsea wells and flow 23 km via two 20 in. diameter subsea pipelines to an offshore processing platform. A 36 in. diameter pipeline will transport the gas 180 km to an onshore LNG plant on the Burrup Peninsular near Dampier in Western Australia. The 36 in. trunkline is accompanied by a 6 in. piggy-backed pipeline that will transfer monoethyl glycol out to the platform.

Pipeline shore approach

The shore approach of the pipeline route was particularly challenging. The offshore pipeline route enters Mermaid Sound from the northwest, but 25 km before the entrance to the Sound, still 50 km from

the LNG plant, is where the subsea pipeline design becomes complicated. At this location the water depth is only about 45 m, and the annually occurring tropical storms (cyclones) have the potential to destabilise the pipeline. It is from this point to the shore that secondary stabilisation measures are required, that is, stabilisation methods over and above the self-weight of the pipeline. A cost-effective way to stabilise a subsea pipeline in sand is to bury it below the seabed, but geotechnical investigation revealed that, under a veneer of sand, rock was present for most of the route. In two locations the rock formation was protruding from the seabed for several kilometers, in the fashion of an ancient reef, meaning trenching would be uneconomical.

Mermaid Sound falls within the proposed Dampier Archipelago Marine Park, and these waters and islands are of exceptional natural beauty. The native flora and fauna, particularly the coral habitat, found in the park are unique to the area. For this reason, the design and construction footprint of the pipeline was required to be kept to an absolute minimum.

Within Mermaid Sound, the Pluto pipeline was constrained by existing infrastructure. Two live gas pipelines located to the east had to be avoided, however the real challenge lay in traversing the busy North West Shelf JV shipping channel. Nearly 300 m wide, the shipping channel was a design obstacle in itself, and the Pluto pipeline needed to be constructed without disturbing the 95 000 t LNG tankers using the channel. The shore approach design also needed to consider all the implications of shipping traffic associated with an international port, from recreational fishing boats up to bulk iron ore carriers.

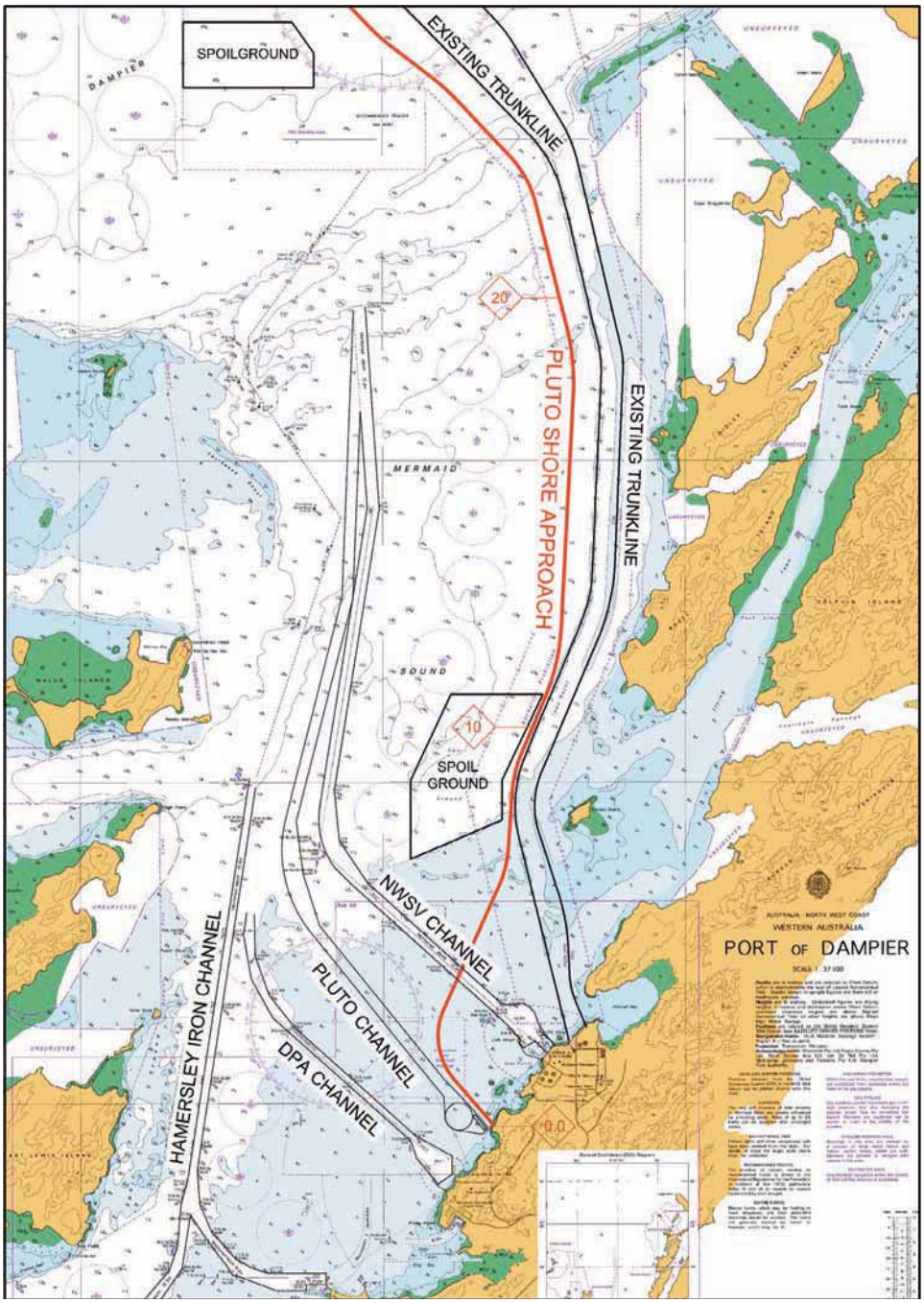

Figure 2. The shore approach route.

The shore crossing location of the Pluto Pipeline was equally congested. The new LNG plant is next door to the existing Northwest Shelf gas plant, which already has two LNG jetties and two trunkline shore crossings. The area is also home to the Dampier Port cargo wharf and materials offloading facility, and a private liquids offloading berth. In addition to these, it is a land with significant heritage value. To bring the new trunkline ashore, a location was identified on Holden Point. The shoreline was not without its challenges, characterised by strong igneous rock including basalt and granite. The Pluto export jetty is located immediately to the south of the landfall, and jetty construction activities would be ongoing for the duration of the shore crossing works. To the north, a protected heritage area restricted access to the shore crossing to a narrow corridor of only metres.

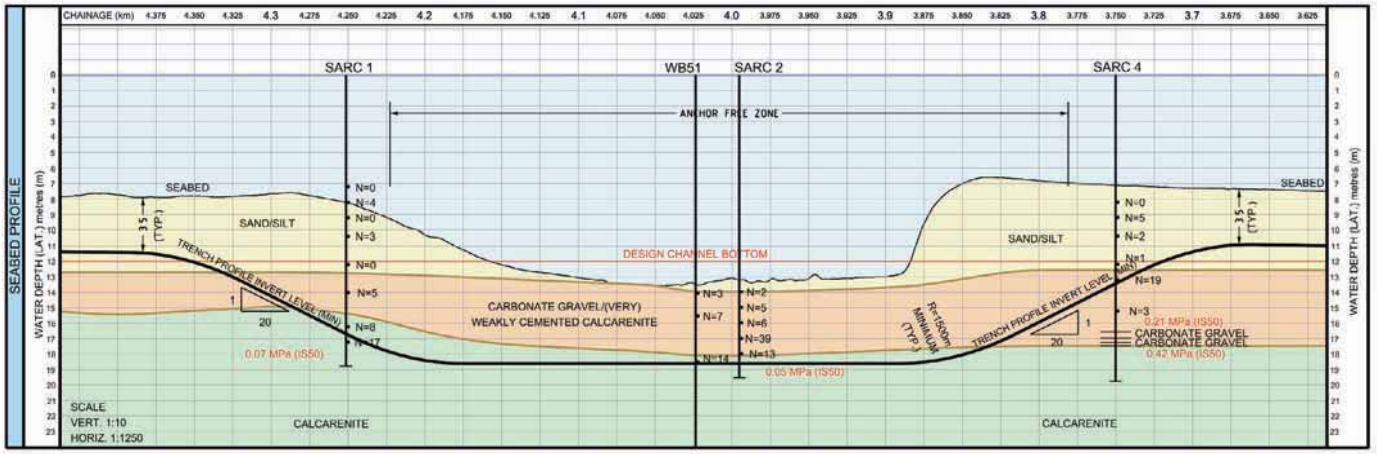

Figure 3. A section of the shipping channel crossing.

Design process

The shore approach design included:

- Pipeline routing design.
- Detailed geotechnical assessment of the pipeline route seabed and shore crossing.
- Definition of shallow water hydrodynamic loading conditions.
- Nearshore accidental impact design for the trunkline system.
- Secondary stabilisation design for the trunkline system.

Despite all the obstacles, a pipeline route was designed to come ashore within the Pluto LNG park, navigate the existing infrastructure, and avoiding the port's dredged material dumping ground.

A critical component of subsea pipeline design is having a comprehensive understanding of the seabed material and the meteorological ocean conditions. The next step for the Pluto pipeline design was to gather detailed information along the pipeline route for both. A core sampling campaign was executed and used to calibrate data from seismic reflection and refraction surveys. High definition multibeam bathymetry surveys were conducted to map the seabed. All this information was presented on precise pipeline alignment drawings so that the stabilisation methods, and related construction implications, could be determined.

Wave and current data collected in Mermaid Sound over decades was analysed to accurately determine the hydrodynamic loading parameters for the shore approach. Particular attention was paid to the shore crossing where wave loading can be severe during extreme weather events. Shipping movement data from all the port users was collated to determine external impacts the pipeline may be subject to, from anchors dragging over the pipeline to ships grounding on it. Accidental impact loads and frequencies were defined along the proposed route.

A range of secondary stabilisation methods were assessed for the changing conditions along the pipeline route. Combinations of trenching and rock dumping were compared to find the most cost effective solution. Impact protection requirements were incorporated in shallow water areas, and clear-water regulations had to be observed. The final design was the optimum balance of achieving the design requirements in the most efficient and sustainable manner.

The outcome

Construction of the Pluto pipeline shore approach began early in 2007, and was successfully completed in May 2010.

Atteris Pty Ltd became involved within months of the Pluto gas field being discovered, and employed a team of up to eight pipeline engineers and designers on the Pluto LNG project throughout pre-FEED, FEED, detailed design and follow-on engineering, between 2005 and 2010. Atteris also provided engineers to assist Woodside with the construction management phase of the project. After five years, 41 km of trench, 400 000 t of quarry rock, and 2 500 000 m^3 of trench backfill sand, the Pluto pipeline is safely stabilised against tropical cyclones and protected from accidental external impacts; a world class asset. The Pluto pipeline shore approach was constructed on time, within budget, and with a commendable safety record, however it could not have happened without excellence in design.

Woodside and Atteris developed the following design innovations:

- Significant optimisation of the trench depth as part of the secondary stabilisation design; during FEED, a trench depth of 3 m was needed to satisfy the pipeline stability functional requirements; this depth was successfully reduced to 2 m by applying innovative design practices, and allowing the very cost-effective pre-trenching scope to increase in lieu of expensive rock dumping.
- Use of sand backfill instead of rock dump to achieve adequate pipeline protection by simply increasing trench depth where possible, resulting in a further significant reduction of the quarry rock volume to be produced and placed.
- Efficient scaled model testing methods were used to optimise the rock berm designs for stability and protection. WP