Shallow successes

John Lincoln, OES Companies International, provides a case history timeline of landfalls and shore approach trenching projects carried out by the company worldwide.

OES, previously Ocean Engineering Systems, started in Australia in 1982 and has become a world leader in subsea pipeline and cable trenching. The company currently has offices and bases in several continents and has worked in Asia, South America, North America, Europe and the Middle East.

The company was started in Perth, Australia, by Mr. John Lincoln, an innovative American subsea pipeline design engineer sent out to help develop Woodside Petroleum and Esso Bass Strait oil reserves using world-first techniques involving ploughing, DP vessels and bottom towed pipelines.

After an initial 10 years in Australia, during which John reinvented himself as a power, mining, oil and gas process and mechanical engineer, and finally project manager, he started two companies - Lincoln Consulting and OES, and also became international.

Prior to coming to Australia, John worked in the 1970s with several pipeline construction and engineering firms in the USA. During this time, he developed special expertise in subsea pipeline trenching systems. Having worked with Mr. Bob Norman and Mr. Frank Wade of OPI, helping develop the third generation trencher - the rolling jet machines - Mr. Lincoln also added high pressure to these systems. He found that he could outperform in speed, cost and safety the larger first generation trencher jet sled, which was the typical equipment of the day.

When the large American jet sleds failed to perform in the North Sea, John suspected it was their inefficient jet nozzle pattern, which blasted away the seabed, washing out the cohesive soils holding the trench walls up. This was only part of the problem, and the other problem, which is common to ploughs (invented as a hopeful but unsuccessful alternate to jet sleds, or any seabed

Figure 1. SBHT line at low tide.

Figure 2. SBHT line excavators assist.

Figure 3. SBHT line overboard dump.

Figure 4. OES *Buaya Besar* catamaran barge.

Figure 5. *Buaya Besar* grounded.

supported device), would not be discovered until 1999. It was then John used his first sled for Esso in Bass Strait for a flexible umbilical. Here, in deepwater using an ROV, it was witnessed that after the sled passes directly behind, the soils turn in to a liquid from the release of sled pressure. The soils then fill in the trench prior to the pipeline settlement. For the pipeline supported devices that OES normally uses, this does not happen.

Much of the earlier work of OES was remedial trenching, that is completing projects where the initial trenching system failed. This includes jet sleds, cofferdams, pre-dredging, ploughs and directional drilling. Some of these systems work fine, but only under certain conditions. Often, the OES equipment is used in conjunction with directional drilling or pre-dredging, especially in rock soil conditions.

Most of the projects also happened to be in the near shore shallow water area called 'no man's land'. Here, there is the compounded problem of 1) very shallow water and sometimes no water, 2) breaking waves that fill in a trench and also knock the equipment ground and 3) shifting loose sands that require a shallow angle of reposed (30°) and consequently large volumes of sand to be removed and placed somewhere where it will not backfill back in to trench.

A few of these projects are described below.

India SBHT, 1994 'Bengal Tiger'

One of the first shore approaches completed by OES was the ONGC SBHT 48 in. gas trunkline in India in 1994.

The method originally specified was pre-dredging, however the near shore was not allowed to be pre-dredged for environmental reasons, and, in addition, it would have backfilled prior to pipe placement anyway.

The area environment was characterised by 8 m tidal variations, 10 knot currents offshore, very hard clay and breaking surf, which was 1 m high. In addition, a 5 m deep trench was required to provide the necessary design cover of 3 m over the 1.5 m diameter pipeline.

OES quickly accepted the challenge and engineered an eight point moored spud barge capable of sitting on the bottom at low tide. The existing OES lead keel trencher for 30 in. diameter pipelines with airlifts, which had already proved successful in deepwater, was made larger with larger eductors, and now water eductors were also added for the shallow water. It was named 'Bengal Tiger'.

In addition, an overboard dump system was employed that deposited the soil about 16 m away from the sides of the trench walls, about 20 m apart. This is shown in Figures 1 - 3. With this system, OES could successfully suck about 40 m^3/minute of sand slurry and deposit it 16 m away.

One major problem not anticipated was the very hard clay that was also encountered. If known in advance today, a 1000 psi jet system would have been mobilised for the project. This would have allowed the project to be completed in days instead of weeks.

Aramco Jizan marine terminal, 1995 ‘Arabian Leopard’

The next shore crossing project was in Saudi Arabia, which had a new unique set of constraints that included that westerners were not legally allowed to be there. The crew had armed guards to make sure that if they left the barge, they did not leave their hotel rooms.

Eight pipelines were trenched including four shore approaches, two 24 in. and two 12 in.

The marine spread provided by the Middle East contractor was not to OES specification. It could not pull OES equipment positioned on the side of the vessel as planned and required a major procedure modification. The soils offshore were 50% large shells, not soft clay as specified. With lot of hard work and some equipment changes on site, the offshore pipelines were all trenched, but it took an extra pass or two with the low pressure 200 psi and ‘shelly’ soils.

For the shore approach work, OES had to trench about 700 m each way from the overcrowded supply vessel, which served as a fixed winch platform and accommodation for the personnel.

The tidal variations were not great so the marine spread could only get within 700 m of the beach.

The company used its new very successful lead keel machine concept renamed ‘Arabian Leopard’, which rolls on top of the pipeline with water eductors, but this time it had to operate remotely from the marine spread and so placed its jet pump on a small 7 x 7 m shallow draft pontoon barge. The machine rolled on the pipeline and the pump was placed on the pontoon barge. The system was ‘see-sawed’ back and forth by a winch on the beach and another on the marine spread. If the wave climate was severe or else the soils very hard, this system would not have worked.

Shallow water catamaran barge systems, 1997 - 2009 *Buaya Besar / Granade Jacare*

The next shore-crossing project in 1997 was in Malaysia and involved the design and construction of a catamaran trenching barge.

This system offered the ability of a very shallow draft catamaran barge that could sit on either side of the pipeline at low tide (Figures 4 and 5). This had the following advantages: 1) One could easily lift the machine for adjustments 2) one could sit over the pipeline at low tide and 3) it only requires a small marine spread. In fact, often no lateral anchors were required and only one anchor was used. Plus, a soft strap was connected to the pipeline ahead and the rolling trencher became the second anchor. This was called the MPRTS (minimum pipeline risk trenching system).

In 2002, OES built a new catamaran barge called the *Buaya Besar* (the big crocodile) in Indonesia and the *Granade Jacare* (the big alligator) in Brazil.

These barges, including the MPRTS system, were used successfully by Petrobras for four pipelines in 2002 using the ‘White Jaguar’ and for four pipelines for Total

Figure 6. Roncador dune excavation.

Figure 7. Roncador surf trenching.

Figure 8. Ultra shallow water trencher.

for Tunnu 8 using the ‘Arabian Leopard’. This system was also used for the Total Nubi River in 2003 and four live gas pipelines for Hess Indonesia in 2008.

This system could handle larger waves (1.5 m) than the pontoon method and could work faster as it could fit larger jet pumps. It was limited to minimum water depths of 1.4 m and the maximum water depth was about 10 m.

Roncador heavy surf shore crossing, 2001

In 2001, OES was asked by Petrobras if it was possible to post-trench the Roncador 24 in. diameter shore crossing

Figure 9. Ultra shallow water pontoon barge.

Figure 10. Completed HDD lines.

pipeline. Petrobras did not think it was possible because of the rough seas, and all the American and European contractors they had contacted had declined. They all insisted a new directional drill shore approach with subsea tie-in would be required; but this would delay the project and add US$ 20 million to the cost.

The area was characterised by very rough breaking waves, 4 m at times, and quickly moving loose sands. In addition, the project was in Brazil and it was not easy to find a reliable marine spread contractor that would brave these conditions with their marine spread.

The previous year, OES had completed all the offshore Roncador pipelines off a DP vessel, for which OES also invented the procedure in 1992.

OES had planned to trench in the calm Summer weather season around December, but by the time Petrobras could issue a contract, three months later, and the shipping company Mersk found the missing OES containers, the project did not start until June, which is Winter in the southern hemisphere.

OES proceeded, hoping for calm water, which never came. John Lincoln had already written-off the project in his mind as his first project failure.

Plans were made to work off the *Superpesa II* barge moored 100 m offshore just outside the breakers and 'see-saw' the OES equipment to shore and back.

Special survey techniques were invented that involved using a large marked staff, which was attached to the trenching machine and hence the level of the machine and that of the pipeline could be determined by land-based surveyors.

Much to everybody's amazement, the pipeline went down to the 3 m cover depth in only four passes or two pulls to the beach. This was accomplished without a trench, as the trench was constantly filled-in by the heavy surf. What was achieved was then the world's first trenching by liquefaction. Even the trenching machine was completely covered in sand on the last two passes. It liquefied the seabed enough to move forward and allow the pipeline to sink in the liquefied soil, probably made easier in the rough sea conditions. This project is depicted in Figures 6 and 7.

Hess Indonesia - 2008 'Tiger Prawn III' ultra-shallow trenching

In 2008, OES designed and built its '*Tiger Prawn III*' - an ultra-shallow water trencher. This is a jet sled that can float and be pulled-in and operate in very shallow water about 500 mm deep. Associated with this system is a shallow draft pontoon barge that also draws about 500 mm. This equipment is depicted in Figures 8 and 9.

This was used for one out of five pipelines, which was the world's first 'live gas pipeline trenching' in very shallow water - 600 mm to 1000 mm at high tide and tidal flat above water at low tide.

This system, although it worked for very shallow water, has the following disadvantages and so is only used where no other better alternative exists:

- Not good for waves larger than 0.7 m.
- Not good in sand or for very deep trenches as sled may interfere with trench slope.
- Leaves vertical undulation or an uneven trench as jet nozzles have a downward component.
- Has a problem, as with all seabed supporting devices, as its stability and that of trench depends upon soil sled interaction.
- Not good for hard soils as has only limited power - can be placed on small pontoon barge.

Directional drilling and pipeline stress reduction 2002 - 2010 'Tasmanian Tiger'

OES has directionally drilled seven 450 mm diameter shore crossings for 300 mm HDPE liners followed by 150 mm power cable insertion, and also post-trenched directionally drilled pipeline shore crossings by others to remove the excessive residual bending stress.

Often, severe environment shore crossing pipelines are directionally drilled as an alternative to open cut. The drilled process avoids opening up the beach to excavation, which at first seems like a great environmental advantage, particularly in not damaging dune grass, but the disadvantages of the deadly caustic bentonite drill mud often are more environmentally destructive. Figures 10, 11 and 12 show OES directional drilling actions.

Directional drilling was not originally intended for subsea pipelines. It was first tried in the 1970s to cross the Houston ship channel, which was like a river crossing. For river crossings you can enter at a steep angle and pop out at a steep angle in the dry, and easily weld on bends to change direction. For an offshore pipeline, you do not have the advantage of being able to weld a bend subsea to change direction.

You need to either:

1. Drill a shallow angle, which has the risks of much loss of drill fluid washout from the thin cover of soil above.
2. Drill a steep angle and then get OES to dig a deep hole say 6 m deep using its lead keel trenchers and trench out the residual bending stress.
3. Drill in to a pre-dredged hole and altered seabed and then take the risk that the waves and swell do not cause backfill before you finish the drilling.

The larger diameter and the longer the pipeline, the less likely the drilling will be a success.

Drilling in sand is fraught with wash or frac-out problems during drilling, whereby the drill fluid is lost, especially when exiting the hole, causing holes to be restarted at times. Sometimes collapse of the holes during the pull-in of the pipelines will require the starting of a new hole and loss or abandonment of the pipe that was in the ground.

For hard clay soil or soft rock, especially for flexible cable where flexible HDPE liners can easily be pulled and in calm seas, directional drilling appears to work provided you can drill in to a pre-dredged hole.

Turbidity free cable and umbilical trenching 2010 'Tiger Prawn V' machine

OES has invented liquefaction sleds for trenching subsea cables and flowline umbilicals where environmentally sensitive conditions prevail. These systems employ a sled, as you cannot usually roll on a flexible line with normal OES equipment.

The sled shroud contains the jets and also guides the flexible line down to the desired burial depth, holding back the soils in the process until the proper depth is achieved. These systems have the added advantage that no significant trench is left; the flexible is lowered by liquefying the soil and hence no turbidity in the surrounding sea as a result.

OES also developed the innovative cable liquefaction sled 'Tiger Prawn V', which can jet down a single cable 3 m in a single pass (Figure 13). **WP**

Figure 11. HDD rig.

Figure 12. OES 'Tasmanian Tiger'.

Figure 13. OES Tiger Prawn V.