LMR Drilling UK Ltd.

"The Impossible Drill ?"

Macduff Outfall, Berrymuir Quarry, Scotland

Horizontal Directional Drilling (HDD) Contractor, LMR Drilling UK Ltd., have recently completed the installation of an outfall pipe from Berrymuir Quarry, near Banff in Scotland, into the Moray Firth. This challenging Sub-Contract was completed on programme, within budget and to the satisfaction of all concerned.

The Main Contractor on the project was Bechtel Morrison JV, having been contracted by the North of Scotland Water Authority to construct a new sewage treatment plant within the disused quarry. An essential part of this plant was the outfall pipeline into the Moray Firth. This was to be constructed with 355 mm dia. SDR 13.6 MDPE pipe. The sensitivity of the marine ecology of the Moray Firth, the hardness of the rock, the topography and the rugged coastline precluded installation by conventional trenched methods. Despite the reservations of the Consultant Engineers, who were sceptical about the use of HDD, LMR convinced the Main Contractor that they had the engineering experience and know how to complete the installation with minimal engineering risk and environmental impact. The Sub-Contract for the outfall construction was awarded to Van Oord ACZ, Marine Contractors working for Bechtel Morrison JV along this section of coastline. LMR Drilling were awarded the Sub-Contract for the drilling operations.

Installation of Casing Pipe

Prior to LMR commencing drilling operations, a 20" OD casing pipe was installed down to the bedrock. By excavating a 3 m wide x 20 m long trench from the entry point towards the sea. This deepened away from the entry point, allowing the casing to be lowered into position and aligned with the drill line and the 19° entry angle. Once in position, the lower end of the casing was covered with a cement slurry and the trench was partially backfilled. The casing pipe guaranteed drill mud returns to the entry point, reduced drag on the drill pipe through the backfilled material and ensured that the pathway to the rock hole remained open should the drill string have to be removed from the hole.

Only a limited 25 x 25 m area was available for the drilling spread within the quarry. Therefore, the water storage, mud mixing and mud recycling plant was erected outside the quarry, some 120 m from the drilling spread. Bechtel Morrison laid concrete foundations to carry two huge 90 m^3 water storage tanks prior to the arrival of the drilling equipment. These were kept topped up by tankers throughout the drilling operations.

Water Storage Tanks

Prior to mobilisation, access to the site was upgraded. Despite this, access was far from straightforward for the largest loads. Nevertheless, the 300 Tonne mobile crane off-loaded and positioned the equipment both in and outside the quarry in one working day. The equipment was interconnected over the following two days in readiness for drilling operations.

Boreholes showed that the drill would pass through both the Macduff Slate and Cullen Quartzite Formations. These rocks varied in compressive strength from 120 MPa to 393 MPa, classified as very to extremely strong. This, together with the highly abrasive mineralogy of the rocks, was a major cause of concern to the Consulting Engineers and Bechtel Morrison JV, especially for hole opening operations. LMR proposed, therefore, to alleviate these concerns

by drilling a 17½" pilot hole, far larger than had been tried before in the HDD field. This removed the necessity for hole opening operations altogether and convinced Bechtel Morrison JV of the viability of HDD.

Having decided on the method, LMR had to use all their experience to choose the best downhole equipment to form the bottom hole assembly (BHA). After careful consideration, a tri-cone roller bit with tungsten carbide inserts was chosen. In addition to the standard specification, the bit was ordered with extensive shirt tail protection and diamond enhanced inserts in order to maximise wear resistance and bit life. With these bits costing upwards of £20,000 apiece and problems with undergauge holes extremely costly to rectify, the additional expense of these features was considered 'money well spent'. The bit in turn was fitted to an 11¼" mud motor, again much larger than had been used before in the industry. The mud motor spins the bit as the drill fluid is pumped through it. This large diameter of motor was essential to maintain steering control whilst drilling, to follow the profile and to reach the correct exit position. Similarly the other components of the drill string (drill collars, non-mags and drill pipes) had to be built up to give sufficient strength and rigidity to enable the push forces from the rig to be transmitted to the bit. LMR also used a shock sub in the drill string. This acts as a shock absorber, both reducing breakdowns at the drilling rig and prolonging bit life.

Drill Bit Comparison

Drilling progressed smoothly, with an average rate of penetration (ROP) of 10 m an hour. Both steering of the drill and the ROP vindicated LMR's confidence in the method used. Once within 30 m of the punch out position on the seabed, the entire string was pulled from the hole and run back in to minimise the risk of cuttings remaining in the hole. This was an essential operation, flushing a further 2 m^3 of cuttings from the bore. Calculations of the volume of cuttings removed from the hole indicated that 90 – 100% of the drilled material had been flushed from the hole following this operation.

Following tripping back in to the bottom of the hole, the last 30 m of the hole was drilled. 20 m from the exit point circulation of the drilling fluid to the rig ceased and, in order to minimise the environmental impact, sea water was then pumped downhole instead of drilling mud. The flow through the drill string, some 3,000 litres/minute (lpm), was essential to power the mud motor. This was augmented by pumping directly into the casing pipe, giving a total flow through the hole of 5-7,000 lpm. This flow rate was maintained through to punch out.

At this point marine assistance was required. Van Oord ACZ mobilised a barge from Buckie, 20 km West of the outfall to the location. The barge was equipped with a large excavator, capable of reaching the seabed, and a diving team for marine operations. With spud legs and thrusters, the barge could maintain its position offshore, although this was dependent on the sea state.

On punch out conditions were ideal and the barge was positioned some 20 m offshore from the proposed exit point. Divers entered the water to locate the drill string and to identify the exit point. The bucket of the excavator was fitted with a global positioning system and this could then measure the position of the exit point. This was found to be 60 cm away from the specified line which was well within the required tolerance.

Marine Equipment Preparing for Pipe Pull

With the accuracy of the punch out confirmed, preparation for pullback could begin. LMR began pulling the drill string back towards the drilling rig until the BHA was fully removed and laid down. Several parts of the pullback assembly, such as the barrel reamer, have threaded connections. LMR, therefore, assembled these items on the drilling rig where the connections could be made up with relative ease and pushed the assembly back through the hole assembled on the drill pipes until exiting once more on the seabed.

Before the 355 mm MDPE pipe string could be installed, it was necessary for all rocks and debris to be cleared from the seabed close to the exit point. This was necessary to ensure that no rocks could be pulled into the hole thus jamming the reamer or causing damage to the MDPE pipe during the pullback operation. Individual divers were able to work for one hour at a time in the water depths (10 - 14 m). Their helmets were equipped with video cameras, allowing the operation to be monitored from the barge by LMR personnel. The clearance of the seabed was achieved by a combination of removing large pieces with the excavator, hand-sized pieces by hand and smaller detritus using an airlift. With safety being of primary concern to all parties, the sea state periodically precluded operations resulting in this operation taking several days.

Berrymuir Quarry Rig Site

The 355 mm MDPE product line had been fabricated by Van Oord ACZ some 15 km down the coast, at Gabbert Point. With weather conditions looking far from ideal for the coming days, it was decided to tow the pipe string to a more proximal location, allowing mobilisation to the site at short notice and with little delay. Several narrow slots had been cut into the pipe, allowing it to fill with water as it was towed. The pipe was anchored in the bay 2 km from the site and remained there until seabed clearance was complete and the sea state was suitable for the pullback.

With the seabed free from detritus and having closely monitored weather predictions from the Met Office, the pipe pull could be commenced. The barge sailed out of the nearby Macduff harbour to location, while a tug hooked up to the pipe and towed it into position alongside the barge. The pipe was lifted onto the barge where a swivel was attached to the pulling head on the pipe. With the swivel attached, the additional weight helped in lowering the pulling head to the seabed for the final connection to be made. This connection was then a relatively simple operation involving one shackle. By 1500 hrs all was ready to commence the pullback. High flow of water through the casing and borehole helped to keep the entrance to the hole clear as the pipe was pulled into the hole. A diver monitored this operation, with pictures relayed back to the barge.

With the first few metres of the pipe safely in the hole, seabed monitoring was no longer required and the pulling speed could be increased. Just three hours later the pullback was complete and the pipe was in its final position. The pipe continued to fill with water as it was pulled virtually neutralising its buoyancy. As a result, the maximum pull force was only 2 - 3 Tonnes. Indeed, the pipe had to be tied off to the drill rig to avoid the risk of it sliding back out of the hole!!

All told, the project had taken 38 days from arrival on site to departure. This compared to the 35 days programmed, a fine achievement for such a testing project. Environmental impact had been kept to an absolute minimum and all parties were justifiably proud of their achievements in overcoming so successfully the challenges met on the project. One important lesson for one-and-all is that, given sufficient time to plan and design, even the most challenging projects can be completed to the benefit of all parties concerned.