

# HDD Success in Hong Kong

By Stephen Loneragan  
and Andrew Lukas

**H**orizontal directional drilling has made history in Hong Kong due to the size of the installations and difficulty of the borehole profiles.

Two adjacent projects have been undertaken by HDD specialist A J Lucas (Hong Kong) Ltd. Eight large diameter crossings were required to carry water mains, power cables and telecommunications from the new territories on the mainland and Lantau Island deep under the main shipping channel to the Sun Hung Kai Properties Park Island Development on Ma Wan Island.

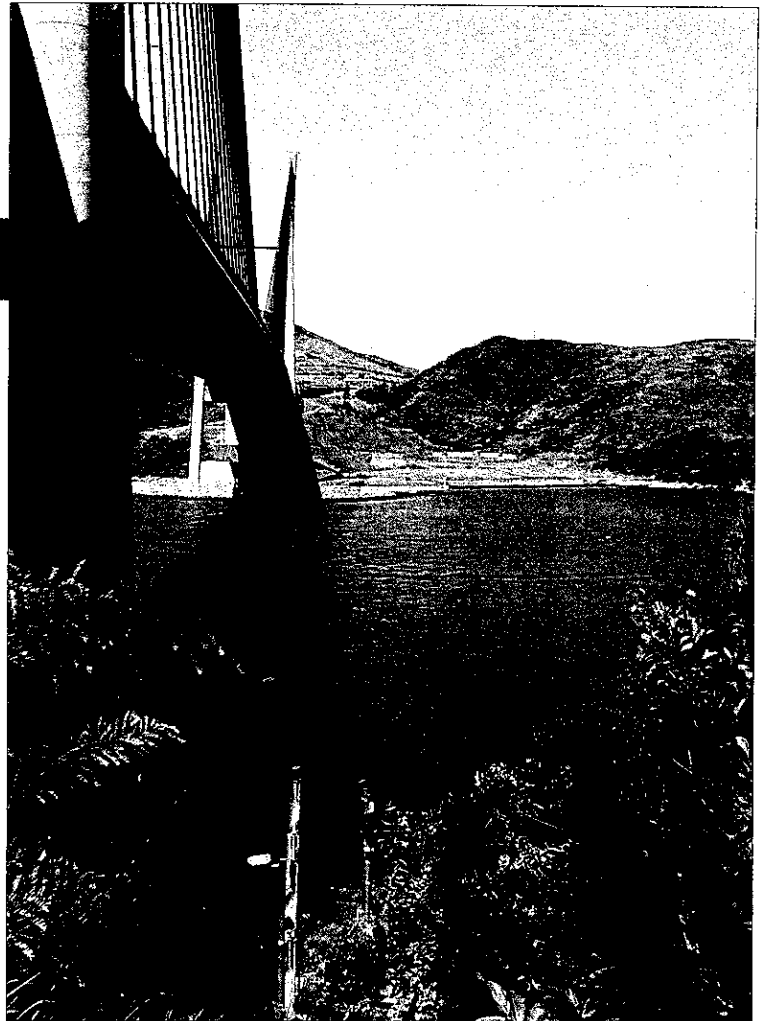
The urban setting required noise limitations, strict environmental compliance, restricted working hours and limited areas for set up. The crossings have been constructed in extremely hard rock consisting of granite and welded tuff. Geotechnical conditions made the work more difficult by the presence of parallel subvertical faults, dykes, broken ground, weathered ground — all causing lost circulation and granite boulders in landfill at entry points.

Boreholes ranged from 850 to 1,370 m long with the profile design requiring drilling to nearly 100 m below sea level and curved horizontal alignments of up to 60 degrees. The borehole diameters ranged from 584 to 820 mm. These conditions meant that the largest drilling rigs and equipment available were required. Time constraints meant that four drilling rigs were needed. Eight directionally drilled holes have been required: two for Sun Hung Kai, the developer of Ma Wan Island, and six for China Light and Power.

The projects were culturally diverse with crewmembers from Hong Kong, Australia, New Zealand, Germany, Canada, United States, United Kingdom, Ireland and Nepal working together toward a successful completion. Among the companies that provided equipment/technology on this project were: BICO Drilling Tools, Baker Hughes Inteq, DrillTec, Baroid IDP, M-I Drilling Fluids, Scientific Drilling International, Transco Mfg., INROCK Drilling, Smith International, NUMA, PIHA and Prime Horizontal.

The directional drilling for the crossing of the Ma Wan Channel and Kap Shui Mun Channel dealt with extremely variable conditions ranging from very hard, competent rock to fault zones comprising of clay gouge and zones of highly fractured and decomposed rock.

Four directional drilling rigs were used: Lucas-manufactured Hercules Rig, Lucas' American Augers DD-660 and



The directional drilling for the crossing of the Ma Wan Channel and Kap Shui Mun Channel (shown here) dealt with extremely variable conditions ranging from very hard, competent rock to fault zones comprising of clay gouge and zones of highly fractured and decomposed rock.

two Elletari rigs — one of 400-tonne capacity, and one of 260-tonne capacity. Mud pumps used were Gardner Denver PZ-8 models and Halliburton HT-400 pumps; Derrick Equipment provided mud-processing units that had dual double deck vibrating screens and hydrocyclone desanders/desilters.

## Four Sites

There were four site locations involved in this project.

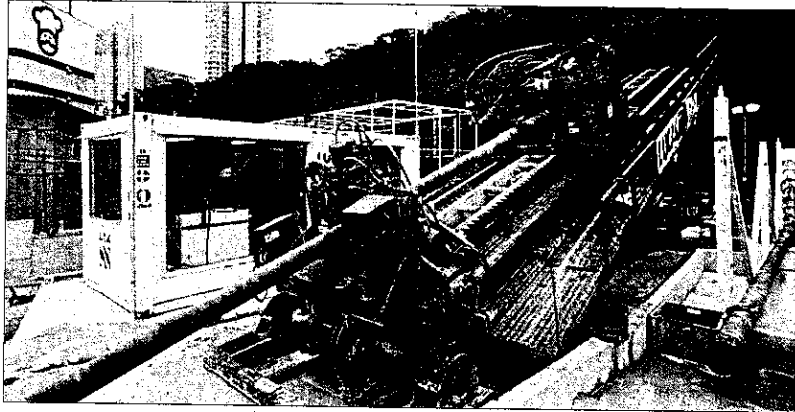
The first site was in a 3-m deep pit at Sham Tseng at the car park for the Ma Wan Ferry Wharf. Hole No. 1 and Hole No. 2 were drilled from this location with the rig in the pit. The power pack, mud pumps and mud processing units were positioned outside the pit. Being only 19 m wide, the site was restricted. Casing pipe, 1,397-mm in diameter, was driven under the adjacent road down to rock. A large Vermeer hammer mole was successfully used to drive the casing through the overburden, preventing any settlement of Castle Peak Road.

The drilling rig was needed to seat the casing pipe into the rock. The bottom of the casing was then grouted to prevent drilling fluids. Working hours were restricted; it was only possible to work 16 hours per day.

The second site was at the opposite end of Sham Tseng. This site was less restricted in space and an excellent set up was achieved. A concrete sump was constructed with concrete pads for the rotating machinery. At one stage, two maxi drilling rigs were working side-by-side, which was a rare site indeed. Hole No. 3 and Hole No. 4 were drilled from this site. Casing pipe, 750 mm in diameter, was installed through the overburden to rock. This casing was installed using the drilling rig.

The third site, while remote from major buildings, was within earshot of the Ma Wan village across the Kap Shui Mun channel. The equipment required less soundproofing and work continued at 24 hours per day.

The fourth site was set up on Ma Wan Island. This was restricted for space but there have been no noise constraints. This site was used for only a short while, during reaming operations for the first two holes.



Four directional drilling rigs were used in this project: a Lucas-manufactured Hercules Rig, Lucas' American Augers DD-660 and two Elletari rigs — one of 400-tonne capacity and one of 260-tonne capacity.

## Drilling Pilot Hole

Pilot Hole No.1 was drilled in advance to 178 mm in diameter for geological investigation purposes. This hole proved to have a considerable number of relatively short doglegs of high dogleg severity so Lucas decided to drill the remaining holes using a large stiff assembly. Lucas used a 306-mm diameter bit to drill the remaining seven holes. The bits were driven by downhole motors: 9 ½ in. diameter Black Max Motor with 7 to 8 lobes, 9 in. diameter Baker Hughes motor M1P HF 9 to 10 lobes, 9 in. diameter BICO P100 motors and 8-in. diameter BICO Kombo motors.

The reaming of the holes, particularly the 32-in. diameter of Hole No.1 and Hole No. 2, were challenging.

Lucas had witnessed major reaming problems in hard granite on another company's project elsewhere in Asia, and he believed that conventional hole-opening tools might not deliver the result required. There was also considerable concern that there would be excessive and expensive wear on the tooling by the hard granite on fast-rotating drill pipe during conventional reaming.

Therefore, it was decided to use raised-face boring technology and the type of cutters being successfully employed by tunnel boring machines in similar or identical ground conditions in other locations in Hong Kong. Using such tools, a considerably higher point loading could be developed and less rotating speed was needed.

There were problems with the reamer negotiating the doglegs present in Pilot Hole No.1. The doglegs present were considerably more severe than indicated in the tender documents such that considerably greater torque and drag developed downhole than expected from the design calculations.

The reamer also got stuck on steel "junk" in the hole. After some considerable frustrations, it was decided to open the remainder of Hole No. 1 and the other holes by forward reaming with a downhole motor. This technique had proved very successful for reaming the 17½-in. pass. Although this technique had been successfully used by Lucas in other rock holes outside of Hong Kong, it was not widely known in the HDD industry.

Subsequently, all the holes were opened using this forward reaming technique, except a clay section on Ma Wan Island that required back reaming. Forward reaming to 32 in. in diameter required careful stabilization of the downhole motor and reaming assembly.

A number of proprietary hole openers were tried. Some patented hole-openers have been developed as a result. Those

patents are now jointly held by Lucas and Transco Mfg. The best results have been achieved using hole-openers that used the Smith HDX cutters.

Hole No. 1 and Hole No. 2 required the installation of a 600 mm diameter steel casing pipe with a 450-mm diameter HDPE water main inside the casing pipe. Because of limited space at the pipe side, the pipe strings were limited to 70 m in length. The steel casing pipe was pulled into each hole first. The HDPE pipe was pulled in subsequently.

The initial difficulties of reaming the holes to 32 in. in diameter on the water mains lead Lucas to focus on making the holes for the power cables as small as possible. The key considerations were making the clearances as small as possible so that the hole would be as small as possible.

The holes were reamed to 584 mm in diameter. Into these holes, a 406-mm diameter steel casing was inserted. The casing pipe is 12.7 mm wall thickness. The HDPE power cable ducts have been bundled together using a purpose fabricated HDPE spacer ring that has been stud welded to the larger HDPE ducts. The larger HDPE pipes have been butt-welded together with fusion couplings used on the smaller diameters.

The crew was truly international: personnel came from Hong Kong, Australia, New Zealand, United States, Canada, Germany, United Kingdom, Ireland and Nepal. The professionalism of this very mixed bunch was also a considerable tribute to their character and dedication to the importance of the work. The people of Sham Tseng village are to be thanked for their tolerance and warm acceptance of this diverse crew.

Stephen Loneragan is manager of directional drilling with the AJ Lucas Group, based in Australia. Andrew Lukas is the managing director of the AJ Lucas Group Ltd.