Surf Zone Ground Investigation Using ROV-mounted CPT

South West Water Ltd, through its contractors M. J. Gleesons, and designers Jacobs Babtie, are extending existent, long, sea outfall at Woolacombe in Devon, UK. A ground investigation required for design and construction of the extension was carried out by cone penetrometer testing-rig (CPT) mounted on a ROV deployed from a converted landing craft.

The existing outfall terminates at mean low-water springs, so that the outlet becomes visible at extreme low water. The proposed extension will place the outlet so that it will be water-covered in all tides states. South West Water commissioned a ground investigation over the general area of the outfall extension to allow design and construction to proceed with the minimum of risk from unforeseen ground conditions. Lankelma Limited carried out the investigation to a design prepared by Jacobs Babtie. Equipment used in the investigation included a cone penetrometer testing-rig mounted on a remotely operated underwater vehicle deployed from converted landing craft.

The Situation

The existing outfall trajectory extends in a northwest-southeasterly direction across the rocks off Woolacombe, between Woolacombe Sand and Barracane Beach. The beach itself is sandy and slopes at a gradient of approximately 1:60 above MLWS. A number of possible routes were surveyed during the preliminary investigation to ensure that the best possible one for the extension could be chosen during design. The area of the extension is within the surf zone, with water depths ranging from only a few centimetres to 1.5m at low-water and becoming approximately 10m at high-water. The use of traditional, standard land or marine methods of investigation for this zone would have been problematical and costly, not only because of these variations in water depth but also because of the exposure of Woolacombe to potentially strong westerly and south-westerly winds, waves and heavy swells. It was therefore anticipated that a variety of methods, some possibly innovative, would be necessary to successfully undertake and complete the investigation.

The solid geology of the site is shown on the Bideford and Lundy Island Sheet No. 292, scale 1:50,000. It shows Morte Slates of the Upper Devonian Age, dissected by north-west/south-east-striking mineral veins occurring in the area. Dip arrows suggest that these fold steeply locally into a north-west/south-east striking syncline. The Morte Slates are generally greenish-grey slates with much quartz veining. Siltstones, fine-grained sandstone and limestone can also occur. Blown sand and beach sand occur, mantling the Morte Slates, but their thickness, extent, density and texture within the area to be investigated were unknown. Therefore the investigation was designed to determine and/or confirm the type, extent, thickness, density and strength of the soils overlying the bedrock, together with the lithology, strength and degree of weathering of bedrock plus the pattern of discontinuities within it. The elevation of the seabed within the area of the proposed extension was also required for design, and was made one of the prime aims of the investigation.

Competitive Tender

The contract for the investigation was led by competitive tendering. Each contractor was asked to price a specific Bill of Quantities, and each was encouraged to suggest alternative methodologies to provide the same or equivalent information. The proposed methodology was in three parts, each to be undertaken either concurrently or sequentially. Each contractor was free to choose type of equipment and how the work would be undertaken. The three parts were topographical surveying, probing and intrusive sampling and laboratory testing. It was decided that qualified and experienced personnel were required to undertake and supervise the investigation on a full-time basis, control the data-gathering process, ensure flexibility, provide confidence that good quality data was being gathered in an efficient manner, and maintain contact with the consultants and client.

Difficulties Onsite

It is recognised that the successful completion of ground investigations within the marine environment, especially in the nearshore zone, is difficult both in terms of the quality of data that must be obtained and management of the environment, i.e. waves, currents, depth of water and wind etc. Good management, correct equipment and suitably trained personnel are all needed for the required information to be collected with as little downtime as possible. In exposed marine environments, weather downtime for conventional geotechnical plant and equipment (drilling platforms and barges and survey vessels) can be highly variable, even under the management of experienced marine contractors. Therefore durable and versatile equipment, together with high-quality recording equipment employed by suitably trained and experienced operators are required in order to minimise demurrage yet provide the requisite data needed for design.

The Fieldwork

After initially considering performing the tests from the shore using conventional land Cone Penetrometer Testing (CPT) plant or a traditional near-shore jack-up approach, Lankelma determined that the works could only realistically be performed using a subsea-crawler or Remotely Operated Vehicle (ROV). However, no such system existed with the necessary geotechnical capability and therefore one was designed and built using off-the-shelf tried and tested equipment, especially for the Woolacombe investigation.

The ROV was sourced from Global Marine Systems of Portland and comprised a ROV frame, power plant and tracks, with a full complement of underwater cameras. It is operated and controlled via an armoured electro-hydraulic umbilical cable from the central control cabin on the deck of the survey boat. Lankelma mounted a Neptune CPT unit onto the ROV to enable underwater CPTs to be performed. This system, normally deployed from a floating marine plant in water depths up to 3,000m, weighs 1.5 tonnes and uses a 2cm2 or 5cm2 cone with a depth capability of up to 10m below bed level; it is controlled via an umbilical. The ROV CPT unit weighs 4.5 tonnes in air, sufficient to provide the necessary submerged reaction weight for the proposed 5m CPTs, yet light enough to overcome the hazard of potentially aerated sands. It was controlled via a joint ROV/CPT umbilical, all tied into a bundle and supported by buoys positioned

intermittently between the unit and the survey vessel.
It was initially proposed that the system be deployed from the beach at Woolacombe. However, because the fieldwork was performed during the height of the tourist season it was decided to deploy the system using a converted landing craft, thereby avoiding the beach and any possibility of the equipment posing a risk to the tourists enjoying the beach. It was also recognised that the area of the existing outfall is a Site of Special Scientific Interest and an Area of Outstanding Natural Beauty.
After mobilisation and during the first falling tide the landing craft was moved inshore until it grounded. It then lowered its front ramp and the crawler ROV was driven down onto the seabed. The landing craft then withdrew into deeper waters, leaving the ROV operational within the survey area. Whilst the ROV was designed to operate within the offshore environment in deep water depths of up to 2,000m and CPTs have been successfully completed in the North Sea for many years, this combined ROV and CPT system had never before been used successfully in this configuration, particularly in conditions similar to those at Woolacombe. Throughout the project the unit was successfully deployed within 0.5 to 1.0m waves and swell, operated in 2.0 to 2.5m waves and swell, and recovered in 1.5 to 2.0m waves and swell (via on-board hiab).

The Results
Although the presence of bedrock outcropping on the beach suggested limited thickness soil cover, nineteen cone penetrometer tests (CPT) were completed to determine and confirm soil type and depth. Each CPT was put down within 5 metres of the proposed position and its location measured to an accuracy of 0.1m using a conventional shore-based EDM Total Station with eight-metre mast, detail pole and single prism. Spot levels to Ordnance Datum Newlyn at and in between each probe location were undertaken to satisfy the topographic requirements of the investigation. CPT penetration at each location was continued until refusal within the bedrock, and recorded to the nearest 0.1m.
The data from each CPT was recorded on computer, and draft logs of all the CPTs completed during the day were prepared each evening. Each log included the actual location in National Grid co-ordinates, elevation and plots of cone resistance, sleeve friction and friction ratio with depth. A legend giving interpreted soil types was also included.
As part of the investigation Geotechnical Engineering was subcontracted by Lankelma to drill a borehole to 20.05m using a Pioneer rig in the pumping-station compound on top of the foreshore cliffs. The ground conditions comprised topsoil, underlain by very sandy very gravely silt and clay to a depth of 1.10m. The bedrock comprised very weak slate that became progressively more robust with depth, with very closely to closely spaced inclined and sub-vertical planar discontinuities. Point load tests were undertaken on some of the core samples recovered from the hole to enable design decisions to be made concerning the piles that would be required to support the outfall extension and resist lateral forces that would act upon it. The discontinuities within the rock were vertical and sub-vertical, and therefore the recovered core was unsuitable for uni-axial compressive strength testing.
The investigation was completed with the preparation of a factual report. This contained a description of the site, investigative methods and the equipment used. The results were presented as CPT and borehole logs, together with maps and plots showing the location of the site, the location of each CPT, and the location of each spot height. In addition, plots were also provided of the relative density and angle of internal friction of the soils, together with their equivalent SPT â€˜N60â€™ value.

Conclusions
The investigation was completed successfully and the following conclusions drawn:

- the subsea CPT unit was successfully mated to the ROV unit; command, control and deployment systems were also successful
- the adverse sea-state conditions encountered affected only deployment and recovery of the unit, not affect its ability to complete locations and obtain CPT data
- the survey and positioning methods (EDM Total Station) used were relatively slow in comparison to DGPS and would need to be modified for further marine works.
