Article

Airborne Laser Bathymetric Survey of Qatar's Coastal Waters

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The Land Information Centre (LIC) of the Ministry of Municipal Affairs & Agriculture (MMAA) is responsible for the land and hydrographic survey work in the State of Qatar. The land data is well organised in the cadastral digital data base, but hydrographic data barely exist. A few individual projects have been performed by various private companies and government agencies, but in general Qatar waters are poorly surveyed. At the beginning of 2002 a budget was provided for the bathymetric survey. Qatar waters, like the whole

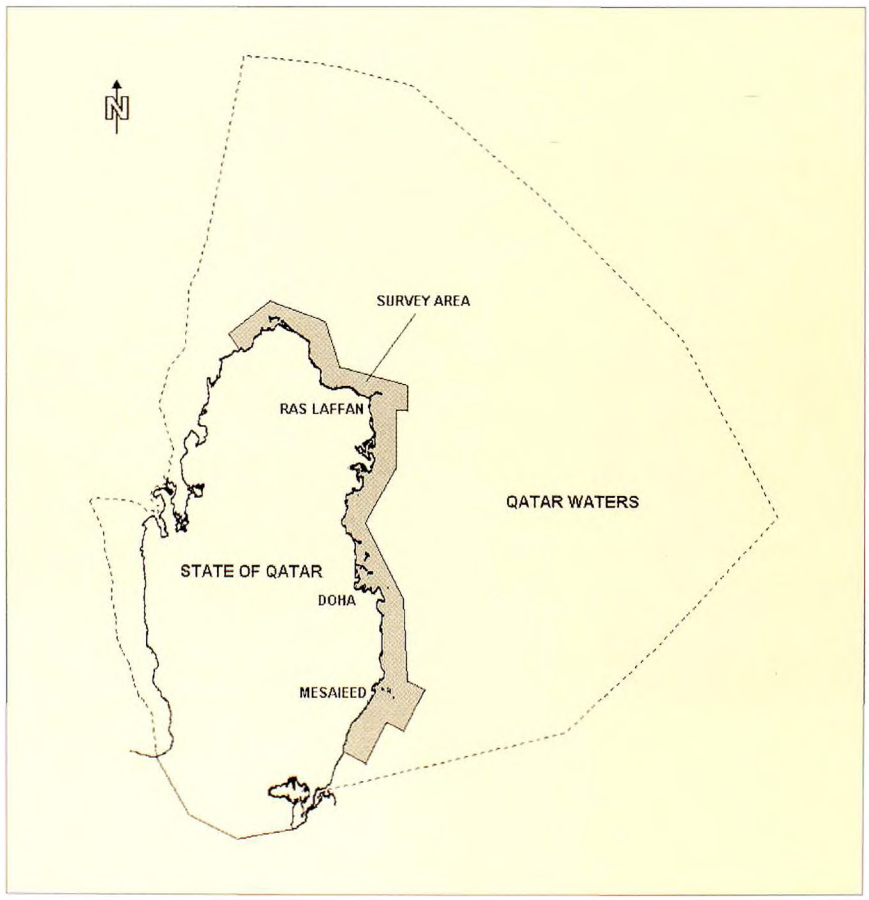

Figure 1: Survey area

Figure 2: A scene from the LADS aircraft

Persian Gulf, are shallow and clear, which are ideal for Airborne Laser Bathymetry (ALB) techniques so it was decided to use this technology.

The survey area of interest was a shallow coastal area, which provides significant efficiency advantages for ALB systems in comparison with the more conventional bathymetric survey systems. This advantage in efficiency of ALB has been demonstrated in recent years with ALB surveys having achieved Order 1 specifications of the International Hydrographic Organisation (IHO) for Hydrographic Surveys. The main objective of the project was to provide a digital hydrographic data base which will be used for the coastal management and production of the nautical charts of Qatar waters.

ALB Survey Specification

After the budget was granted, work started immediately with the compilation of the tender documents. Available money and required accuracy defined the total area of survey, which is approximately 2,060 square kilometres (Figure 1). The east coast of Qatar is the most developed urban area in the country and it was decided to cover the north and east coast from the coastline to approximately 9 kilometres offshore. The survey area was bounded by the coastline and 17 points related to the Qatar National Datum 95 (QND95) and WGS84. Maximum depth expected in the area was 30 metres.

Horizontal accuracy of the position of soundings, depth accuracy for reduced depths and object detection in selected areas (ports and navigational channels) were required to satisfy the IHO Order 1 standard for hydrographic survey. Tender responses were required to include a detailed description of how the horizontal and vertical positioning accuracy are to be met. It was the Contractor's responsibility to ensure that tidal data was of suitable quality to achieve IHO Order 1 so a tidal network to cover the area of survey was requested. All soundings were to be reduced to Qatar Chart Datum (QCD) using an appropriate tidal model.

One very important request to the Contractor was the request for confidentiality. The Contractor had to treat all information and data related to the project as confidential and it was specified not to publish, release or disclose any information without written permission from LIC.

Most technical specifications were typical of any bathymetric survey. Two independent positioning

systems were required, the system was to be fully checked against a benchmark area, the survey area was to be completely covered with main lines of sounding with at least 20 metres overlap, cross tie comparison lines were to be surveyed, gaps in the survey coverage were to be identified and covered with additional lines.

On the completion of survey and post-processing all data was to be rendered to the LIC. It was specified that the deliverables would be; a report of survey, fair sheets, colour-coded depth Images, two sun illuminated images and field records. All the data was to be rendered in hard/paper copy and digitally. Digital data was specified to include raw data, processed data, tidal data and digital copies of fair sheets, images and reports. The raw data was required to be delivered in format readable by the Terramodel software package or in proprietary file format together with a source code level library for reading the data. The processed data was required to be delivered in the Hydrographic Transfer Format (HTF) which is the hydrographic data archive file format used in LIC. The tidal data was required to be delivered as an ASCII text file or Excel spreadsheet. All images were required to be delivered as Tagged Image File Format (TIFF).

ALB Survey Operations

After the tendering procedure the LIC awarded the contract to the Australian company Tenix LADS Corporation (TLC). They commenced the project on 30 April 2002 and after 25 survey flights-sorties, finished data acquisition on 17 June 2002. The equipment was then demobilised and final data processing and quality control was conducted at the TLC survey depot in Adelaide, Australia.

There were no major set-backs during the survey. The weather conditions were excellent with flights being prevented by a strong dusty south wind on only two days. The maintenance of the system was well organised which ensured that the progress of the survey was not adversely affected by defects.

One very important issue arose during the survey. In relatively small countries such as Qatar, aircraft flight paths may intersect restricted areas, this occurred on the east coast where Doha International Airport is located. Therefore assistance from the LIC was needed by TLC to liaise with local authorities in order to secure flight approvals. Without the help from the LIC the data collection flight planning would have been more difficult and the deployment period substantially longer. In order

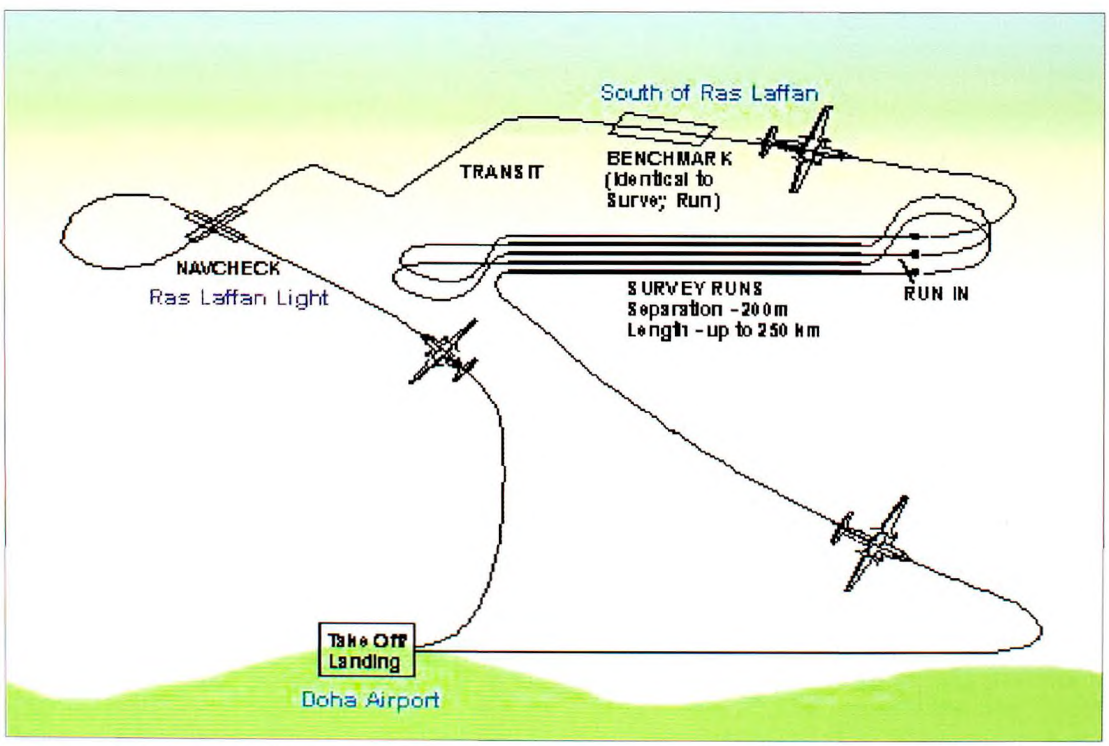

Figure 3: A typical sortie, daily survey flight

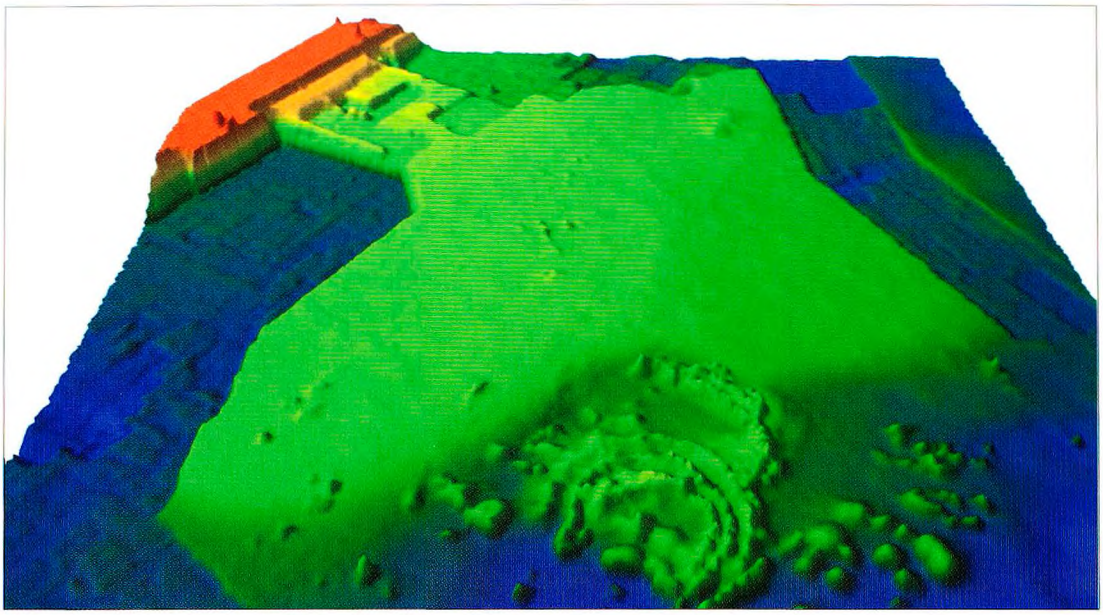

Figure 4: 3D image from ALB survey

to improve co-operation with local authorities a detailed survey plan was required from TLC before the commencement of the survey.

Data collection during survey flights was from heights of 1600 feet (~490 m) at a ground speed of 175 knots. The main lines were surveyed using a 5x5 metre laser spot spacing across a swath width of 240 metres at 200 metres line spacing. In addition to the main line soundings several significant navigation channels were surveyed using a 3x3 metre sounding density at 80 metre line spacing and 100 metre swath width. Real time posi-

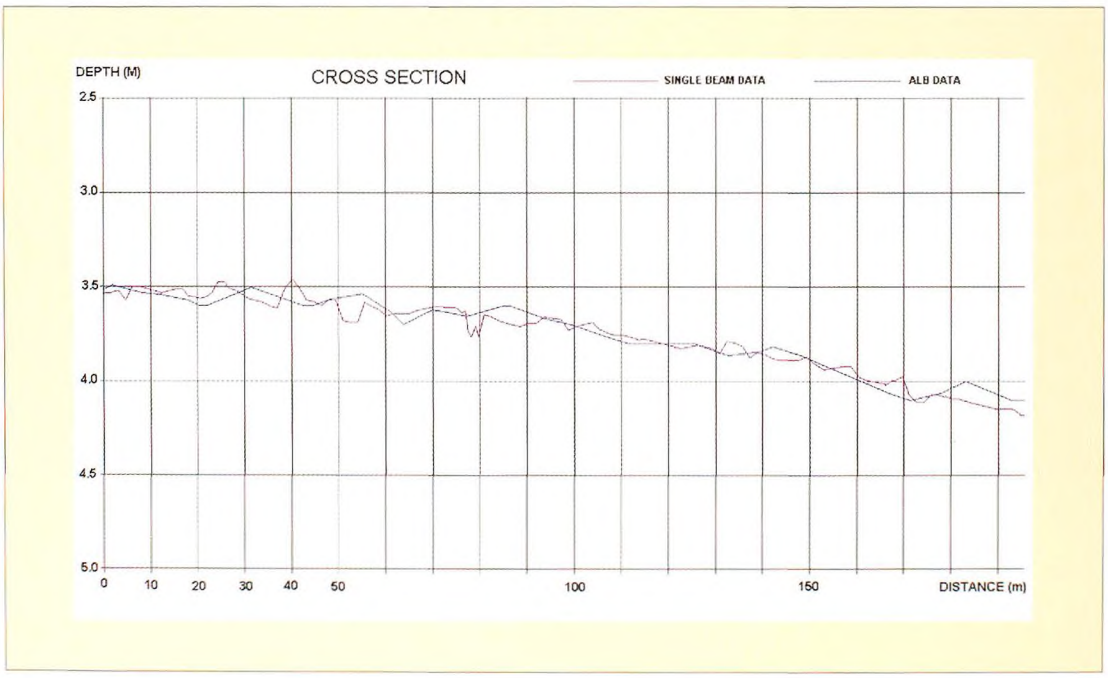

Figure 5: Cross section comparison

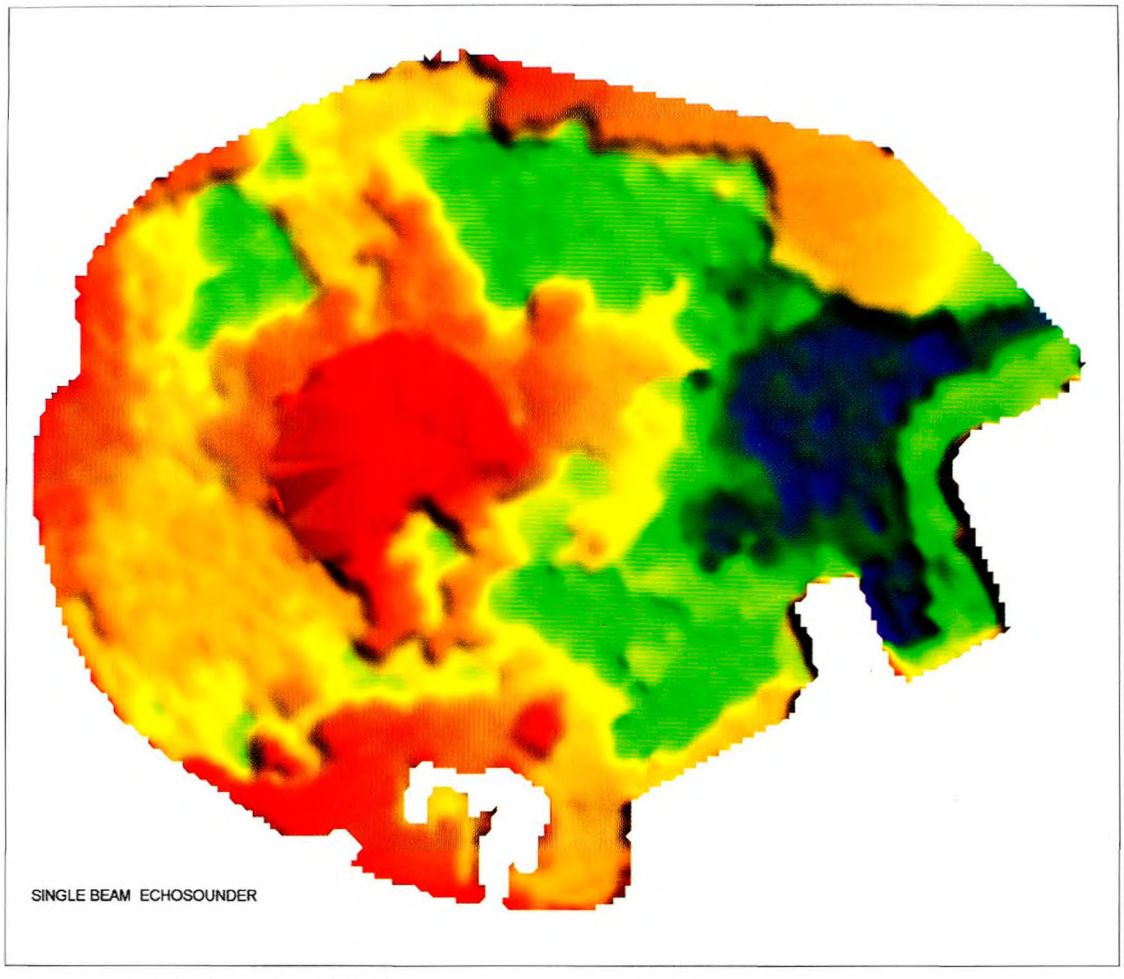

Figure 6: Image from single beam survey

tions were determined using a GPS receiver with third party WADGPS corrections provided from a reference station in Bahrain. In addition a local GPS base station was established by TLC to provide a KGPS solution for aircraft position (GPS data logged at the base station and on the aircraft simultaneously). The position systems employed were subject to various checks prior to, during and following data gathering; a static position check at the Doha Airport, daily navigation checks over the light at Ras Laffan and dynamic position calibration during the flights. The depth soundings were checked against a benchmark area and using cross tie comparisons. Four automatic tide gauges were deployed and connected to the Qatar National Height Datum. Three gauges were deployed on the east coast and one on the north coast. These gauges were left in situ at the end of the survey in order to gather additional data.

Processing of Data

A major part of data processing and quality control was conducted in Adelaide, however a significant section of the data was also processed in Doha. During the data collection phase of the survey, at the end of each sortie, the raw sounding data recorded on the aircraft were automatically processed during the night to produce depth and position. Next morning the surveyors would conduct validation of the sounding data to determine its quality and if necessary prepare a plan of flight lines that required reflying. The processing facility was established close to the airport at a temporary office. A computer network with various peripheral units and specialised software packages were set up in the office. Initial validation of the sounding data was closely monitored by the LIC staff. A few charts and colour images were produced from

interim data during the validation process, which indicated the very high quality of the data.

The final data validation and quality control was started immediately after the data collection had been completed and the equipment demobilised. The TLC survey depot in Adelaide, Australia, was visited by LIC staff in order to check the data handling and post processing procedures, in particular, data management and security of the data. LIC was satisfied that the data was processed in a separate locked room with only authorised personnel able to enter. The computer network used for processing was also physically separated from the common TLC network. LIC was convinced that TLC implemented proper measures to protect LIC data. After the automatic data processing, completed in Doha, subsequent phases in the quality control procedure are final validation of the data, checking, visualisation and approval of the data. KGPS positions and tides were applied during the process. All soundings were reduced to Qatar Chart Datum using a complex tidal model consisting of eight tide stations in nine tidal areas. All soundings were hydrographically reviewed and flagged 'accepted' if they were valid or 'rejected' if they were not valid. All soundings are stored in HTF format. A shoal bias, 8 metre clash radius, thinned data set has been derived and used for fair sheets and colour-coded image production. The sheets were plotted on polyester film, size A0 and scale 1:20,000. The title block and other details related to the fair sheets were designed during the visit of the LIC team to Adelaide.

A number of software packages were used during these procedures, some of them developed in-house by TLC and some of them commercial software packages such as Terramodel by Trimble. All decisions during the validation, checking and approval of the data were logged in appropriate forms. The procedures used were certified as conforming to ISO-9001 Quality Assurance standards, which was a requirement of the tender specification. The final approval of all the data was performed by the TLC Survey Manager, who is accredited as an IHO Cat A Hydrographic Surveyor.

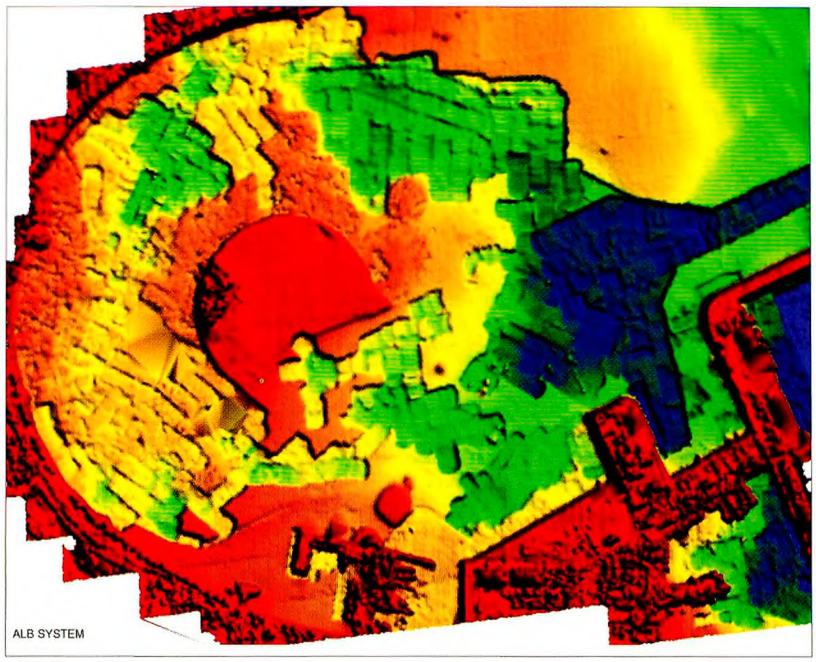

Figure 7: Image from ALB survey

Rendering of Data

LIC owns the data and records gathered or produced after post-processing. TLC was requested to deliver all the data, including all field records, sketches, notes, video tapes, raw data, processed data and all backups and copies. Raw data, ground system backup and final save databases were delivered on Digital Linear Tapes (DLT). GPS data was delivered on ZIP disks and final digital data was delivered on CDROM.

124 million soundings were gathered and processed during the ALB survey from which 120 millions were valid. The total area of the survey was divided into nine sub-areas; sub-area A to sub-area I. Data collection was performed by sub-areas so the final HTF files are specific to appropriate sub-areas. The total size of the nine HTF files is over 12 Giga Byte. A total of 19 fair sheets and 19 tinned surface plots (colour coded depth images) were produced and rendered to the LIC. The sheets were compiled and plotted from the Terramodel software package on a scale of 1:20,000

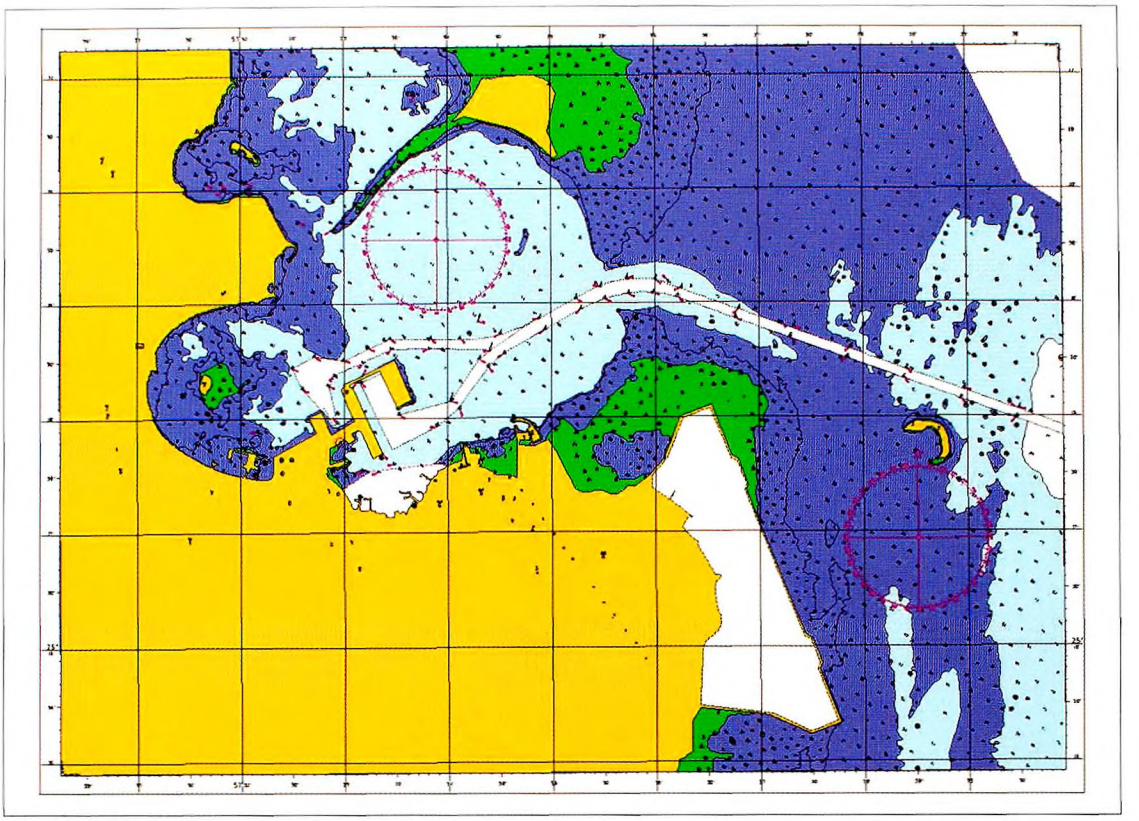

Figure 8: Pilot chart Port of Doha

on A0 polyester film. Terramodel project files and two ASCII files with 8 metre thinned data were delivered with the digital data on CDROM. One ASCII file contains soundings related to the QND95 and the second ASCII file contains sounding related to the WGS84 datum. For every sheet an appropriate geo-referenced TIFF image was produced from the Terramodel Visualiser Lite software package for 3D visualisation. The average image size is 40 MB. All sheets were exported to the Auto-CAD Drawing Exchange Format (DXF) from Terra-model. Digital copies of the report of survey and applied tides were delivered in PDF file format on CDROM.

Acceptance of the ALB Survey

The required IHO Order 1 accuracy of position and depth was achieved for the project. Based on the result of the static and dynamic position checks, daily navigation check and theoretical calculation, the achieved survey positional accuracy did not exceed 3.38 metres (95 per cent confidence limit). The survey depth sounding accuracy has been assessed theoretically and did not exceeded 0.43 metres (95 per cent confidence limit). The benchmark comparisons, cross tie line comparisons and comparison of overlapping data between adjacent survey lines was consistent with this assessment. The static position check conducted on the Doha Airport compares the WADGPS and KGPS solution with a known point on the tarmac. The absolute accuracy of the WADGPS position solution which was used in real-time to gather data, was 2.32 metres (95 per cent confidence) and the accuracy of KGPS (L1/L2 carrier phase) position which was applied to all soundings during post-processing was 0.24 metres (95 per cent confidence). Dynamic position checks conducted during each sortie showed that the mean difference between the real-time WADGPS and post-processed KGPS position was 1.20 meters. Daily navigation checks conducted over the light at Ras Laffan, which enabled the known position of the structure to be checked against the image on the downward looking video record, shows the mean offset in easting was 3.2 metres with a standard deviation of 3.4 metres and northing offset was 3.0 metres with a standard deviation of 5.2

metres. The precision of this check is limited by the pixel size from the recorded video. The depth benchmark comparison shows the average mean depth difference of all benchmarks was 0.02 metres with a standard deviation of 0.09 metres. Cross tie comparisons show the average mean depth difference for the survey was 0.01 metres with standard deviation of 0.09 metres.

In addition to the statistical checks included in the report the ALB survey was compared with a recent single beam echo sounder survey of Doha bay. The single beam survey was conducted in February 2002 which was 2 months before the ALB survey, with survey lines at 25 and 50 metres spacing from which a set of 20 metres gridded points was derived. Cross sections between three dimensional terrain models compiled from the single beam data and the ALB data have been compared. The statistical agreement between two sets of data was very good and inside the required accuracy as well as graphical agreement (Figure 5). Comparison of colour coded depth images derived from the same 3D models (Figure 6 and Figure 7) also indicates very good general agreement in depth, but the difference in details is very obvious due to the much higher data density of the ALB survey. Scours on the seabed from recent dredging activity can be clearly seen (Figure 7) in the ALB data.

As expected, excellent data quality was achieved throughout the 2,060 square kilometre survey area. Very high data quality was provided due to the combination of clear water and a highly reflective seabed which provided strong return laser waveforms. Some gaps in the seabed coverage exist due to localised high levels of turbidity and deeper water. However the gaps total less then 3 per cent of the total area of survey which is highly acceptable. In addition to the survey area two reconnaissance lines were sounded and demonstrate that other areas in Qatar are also highly suited to ALB survey.

Conclusion

The ALB survey of Qatar's coastal waters was the first major laser hydrographic survey in the Middle East and LIC is proud to have successfully conducted it. The project confirmed the well known advantages of the ALB technique compared with any other shallow water survey systems and has shown that the choice of this survey technique was correct. The achieved accuracy met the requirements for an IHO Order 1 survey and all other technical specification requirements were fulfilled. LIC received good co-operation and support from Tenix LADS Corporation during the project.

The Land Information Centre now owns a valuable hydrographic data base of Qatar's waters. A good strategy is required to use the data and in particular for producing Nautical Charts for Qatar. A pilot chart production of the Port of Doha (BA chart 3,786) was undertaken (Figure 8). The LADS data was exported into the CARIS GIS software package and used to produce the pilot chart. The experience from this test and the whole project was very positive which provides great motivation to continue with ALB surveys of Qatar waters.

Biographies

Ali Abdulla Al-Abdulla is Director of the Land Information Centre of the Ministry of Municipal Affairs & Agriculture, State of Qatar. He joined to the Ministry in 1989, became a Head of Survey Section of LIC in 1996 and has since 2001 been Director of LIC. He received the Engineer Diploma in Civil Engineering from the Miami University Florida USA in 1989.

Vladan Jankovic is Senior Hydrographic Surveyor in the Hydrographic Unit of the Land Information Centre, State of Qatar. He joined the Unit at the beginning of 2001 after 17 years working for the Yugoslav government agency for inland waterways as Hydrographic Surveyor and Head of the Hydrographic Department. He received the Engineer Diploma in Geodesy and Surveying from the Belgrade University Yugoslavia in 1983.

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