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1. SURVEY EQUIPMENT

The *Contractor* must provide the following survey equipment on the Site from the commencement to the completion of the dredging works:

1.1. A survey boat and survey equipment as specified below.

1.1.1. Sonar survey equipment as specified below;

a) The *Contractor* must supply the necessary survey vessel suitable for the hydrographic and multibeam swath surveys, taking into account the different water depths, winds, waves, currents and other significant site conditions that may be experienced on site. All lighting, safety features and equipment required for the safe operation and mooring of vessels must be supplied by the *Contractor* and must be approved by the relevant Maritime Safety Authority. The *Contractor* must provide for qualified personnel to operate the boat as well as the survey equipment and must keep the equipment in working and seaworthy order at all times.

b) A differential GPS system capable of a horizontal positioning accuracy of better than 250 mm at the 95% confidence level must be used for all positioning. The DGPS receiver(s) aboard the vessel must be configured such that satellites below 8 degrees above the horizon are not used in position computations. The age of pseudo-range correctors used in position computation must not exceed 20 seconds. Horizontal Dilution of Precision (HDOP) must be monitored and recorded, and should not exceed 4 nominally. Satellite geometry alone is not a sufficient statistic for determining horizontal positioning accuracy. Other variables, including satellite pseudo-range residuals, are to be used in conjunction with HDOP to estimate DGPS horizontal accuracy. A minimum of four satellites must be used to compute all positions. Horizontal and vertical offsets between the GPS antenna and transducer(s) must be observed and applied with a precision better than 0.05 m.

The following other equipment is a minimum requirement:

- Vessel motion sensor (i.e. roll, heave and pitch).
- Heading: Gyro / Fluxgate compass.
- Navigational computer for on-line navigational control during the survey.
- Digital acquisition (data logging) of all the above sensor outputs.
- Post processing, for motion correction of the vessel movements and heading. Conversion of all bathymetry data into absolute (x, y, z) files for digital maps.
- All other survey equipment to deliver the specified services.
- A high quality multibeam echosounder with a frequency of not less than 200 kHz is to be used for the survey. The multibeam sonar must have an effective beam width of no greater than 1.5 degrees in both the along-track and cross-track directions and lateral coverage of at least 30 metres for depths greater than 10 metres;

- The data logger system must have adequate electronic storage capabilities. The system must store multiple inputs (Date, Time, X, Y, Z Position, and echo sounder data) on an electronic medium, which can be transferred to a personal computer. The system must be provided with the necessary approved software to plot the positions of the recordings and draw maps, contours, cross profiles, etc. The data must be stored at 1-second intervals or less.

1.2. Other Equipment

Other equipment such LIDAR scanners and drones (as per the Drone Survey Generic Specifications) may be used, provided that they can provide data of similar quality or better.

2. SURVEY CONTROL AND SETTING OUT OF THE WORKS

2.1. General

All co-ordinates used during this contract must be to World Geodetic System 84 (WGS84).

All hydrographic survey work must be carried out and certified by a qualified hydrographic surveyor (IHO Cat A/B recognised hydrographic surveying course or equivalent). The *Contractor* must give the *Supervisor* unlimited access to the survey vessels at all times.

2.2. Technical Requirements

2.2.1. Tidal data

Regardless of whether RTK GPS is used for position fixing, independent tidal measurements for purposes of water level corrections will be required. The tide gauge must be calibrated using a local benchmark to determine the installation level to within 2 cm. Tidal records must be corrected for onsite barometric pressure changes. No tidal records are required if an approved RTK DGPS system is used.

2.2.2. Multibeam echosounder

The hydrographer must ensure that the multibeam coverage must have an overlap of at least 50% in order to check the surveyed data. Heave, roll, pitch, heading, and navigation timing error (latency) corrections must be applied to multibeam soundings to correct the effect of vessel motion caused by waves and swells (heave, roll, pitch), the error in the vessel's heading, and the time delay from the moment the position is measured until the data is received by the data collection system (navigation timing error). Heave must be observed in no coarser than 0.05 m increments. Roll and pitch must be observed in no coarser than 0.05 degree increments. Heading must be observed in no coarser than 0.1 degree increments. Navigation timing error must be observed in no coarser than 0.01 second increments.

2.2.3. Multibeam sonar calibration (patch test)

Prior to commencing the survey operation, the hydrographer must conduct a system accuracy test to quantify the accuracy, precision, and alignment of the multibeam system. Testing must include determination of residual biases in roll, pitch, heading, and navigation timing error. These values will be used to correct the initial alignment and to calibrate the multibeam system. System accuracy testing should be conducted in an area similar in bottom profile and composition to the survey area, and during relatively calm seas to limit excessive motions and ensure suitable bottom detection. The order in which these biases are determined may affect the accurate calibration of the multibeam system. The hydrographer should determine the biases in the following order: navigation timing error, roll, pitch, and heading (yaw).

2.2.4. Sound velocity profile

To ensure that the overall depth measurement accuracy criteria are met, velocity of sound observations should be taken with sufficient frequency, density, and accuracy. The accuracy with which the speed of sound correction can be determined is a complex function of the accuracy with which salinity, temperature, and depth, or alternately, sound speed and depth, can be measured. The sound speed profile in the survey areas must be measured and monitored at sufficient frequency and to an appropriate depth to assure that the bathymetric data provided meets the required depth accuracy specification. The sound speed profile should be determined with a calibrated system capable of measuring the speed of sound with errors no greater than 2 m/sec (at the 95% confidence level). A calibrated sound speed measuring system capable of measuring the sound-speed profile to at least 95% of the deepest anticipated depth in the survey area must be available, though collection of sound speed data to 95% of the full depth of the survey area will only be required before and after the completion of the surveys. Velocity of sound correctors must be applied to soundings to compensate for the fact that echosounders may only display depths based on an assumed sound velocity profile while the true velocity may vary in time and space.

2.2.5. Error budget analysis for depths

The accuracy of measured depths in the hydrographic survey applies to the systematic measurement of general water depths and to the least depths determined over any obstructions. The total sounding error in a measured depth at the 95 percent confidence level, after systematic and system specific errors have been removed, must not exceed ± 100 mm (Z co-ordinate) and the Total Horizontal Uncertainty (THU) 250mm horizontal (X and Y co-ordinates). The maximum allowable error in measured depth includes all inaccuracies due to residual systematic and system specific instrument errors; the velocity of sound in water; static vessel draft; dynamic vessel draft; heave, roll, and pitch; and any other sources of error in the actual measurement process. The hydrographer must document in the Descriptive Report the methods used to minimize the errors associated with the determination of depth (corrections to echo soundings).

2.3. Deliverables and data presentation

The *Contractor* must submit a survey quality control plan to the *Supervisor.* A survey report must be submitted to the *Supervisor* on completion of all in and out surveys. It must give a clear account of how

the survey was carried out, the results achieved, the difficulties encountered and the shortcomings. Emphasis should be placed on the analysis of achieved accuracies.

The *Contractor* upon completion of the survey must produce the following:

i. Shoal-biased (or median biased) high-resolution multi-beam colour bathymetric image map of the areas, inserted geographically referenced into a DXF or DWG file, contoured at 0.5m intervals.

ii. Two hard copies of the bathymetric image map and electronic copies (pdf) are required.

iii. Track Chart of all survey lines in DXF or DWG format.

iv. ASCII data files of all the points recorded.

v. ASCII data files reduced to give one point per square meter (mean of all points in a m^2).

vi. All details with regards to the co-ordinate transformation and calibration procedures and results.

vii. A report detailing the findings and all details with regards to the survey. This is to include: Survey personnel, date, time, area, conditions, survey vessel, positioning system, equipment used, software used, accuracies achieved and the respective confidence levels, etc.