


HYSPEC

Contract Specifications for Hydrographic Surveys Version 2.0

New Zealand Hydrographic Authority

Acceptance

Role	Name	Signed	Date
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Revision history

Date	Version	Revision	Description
June 2020	1	0	First Edition
Sept 2020	1	1	Minor change – reference section number updating
March 2021	1	2	Correction to Table 1, LINZ-1 and LINZ-2 grid resolution. 20-40m depth, 2m resolution

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Introduction

As a contracting government to the International Convention for the Safety of Life at Sea (SOLAS), New Zealand has an obligation to arrange to collect and compile hydrographic data, and to publish, disseminate and update all nautical information necessary for safe navigation (SOLAS Chapter V, Regulation 9). Land Information New Zealand (LINZ) is the New Zealand Hydrographic Authority (NZHA) and is the competent authority responsible for meeting these obligations. The information in this specification details the requirements for hydrographic surveys undertaken on behalf of LINZ and is to be used in conjunction with the relevant project-specific Contract Documents i.e. project specification and desk top study, to give comprehensive guidance for delivering the required services in its entirety.

The specification is written in a way that is sensor agnostic, acknowledging that different technologies can still achieve the desired survey outcome. However, it is written for LINZ surveys in coastal waters where total quantitative seabed coverage is necessary for safe navigation. Although technologies such as Single Beam Echo Sounders (SBES) and Side Scan Sonars (SSS) are not capable of achieving this, they are still mentioned here as they can be used on occasion.

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Related Standards and Publications

The following publications must be read in conjunction with this document. The most recent versions of the following documents at the time of contract signing apply:

1. *Standards for Hydrographic Surveys (S-44)*, International Hydrographic Organization, Monaco.
2. *Specifications for Geodetic Control of Hydrographic Surveys*. National Geodetic Office, LINZ.
3. *Manual on Hydrography (C-13)*. International Hydrographic Organization, Monaco.
4. *The Mariner's Handbook NP100*, Admiralty Publication.
5. *LINZ Source Data Specification*. New Zealand Hydrographic Authority, LINZ.
6. *Backscatter measurements by seafloor-mapping sonars: Guidelines and Recommendations*. Publication by GeoHab Backscatter Working Group.
7. *Ellipsoidally Referenced Surveying for Hydrography*– Publication No 62, International Federation of Surveyors (FIG)
8. *Standard for the Geospatial Accuracy Framework*. LINZS25005, LINZ.
9. *Standard for Tiers, Classes, and Orders of LINZ Data*, LINZS25006, LINZ.
10. *Transfer Standard for Digital Hydrographic Data (S-57)*, International Hydrographic Organization, Monaco.
11. *Specifications for Chart Content and Display Aspects of ECDIS (S-52)*, International Hydrographic Organization, Monaco.
12. *Standard for undersea feature names – NZGB60000*.
13. *INT 1 Symbols, Abbreviations and Terms used on Charts*, International Hydrographic Organization, Monaco

The following publications are recommended reading:

14. *Admiralty Manual of Hydrographic Surveying*, Volume One, NP 134 a. Admiralty. 1969
15. *Admiralty Manual of Hydrographic Surveying*, Volume Two, Chapter 2 Tides and Tidal Streams NP 134 b (2). Admiralty. 1969.
16. *NP122(2) Admiralty Tidal Handbook No.2*. Admiralty Publication. 1975.
17. *General Instructions for Hydrographic Surveyors (GIHS)*, NP 135, Seventeenth Edition, 1996. Admiralty.

Note: All LINZ publications detailed above are published at the LINZ web-site: <http://www.linz.govt.nz/> or are available from the New Zealand Hydrographic Authority (NZHA).

Terms, Abbreviations and Definitions

Terms/Abbreviations	Definitions
ADCP	Acoustic Doppler Current Profiler
AHSCP	Australasian Hydrographic Surveyors Certification Panel
ALB	Airborne Laser Bathymetry
AtoN	Aids to Navigation
BAG	Bathymetric Attributed Grid
BM	Benchmark
CD	Chart Datum
CHRT	CUBE with Hierarchical Resolution Techniques
CTD	Conductivity / Temperature / Depth
CUBE	Combined Uncertainty Bathymetry Estimator
DGNSS	Differential Global Navigation Satellite System
ENC	Electronic Navigation Chart
GDP	Geodetic Data Pack
GNSS	Global Navigation Satellite System
GSF	Generic Sensor Format
HAT	Highest Astronomical Tide
IHO	International Hydrographic Organisation
INT1	INT1 Symbols, Abbreviations and Terms used on Charts (IHO Publication)
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LINZ	Land Information New Zealand
MBES	Multibeam Echo Sounder
MHWS	Mean High Water Springs
MSL	Mean Sea Level

NZGB	New Zealand Geographic Board Ngā Pou Taunaha o Aotearoa
NZGD	New Zealand Geodetic Datum
NZHA	New Zealand Hydrographic Authority
NZNA	New Zealand Nautical Almanac (NZ204)
PA	Position Approximate
QC	Quality Control
QADP	Quality Assurance Data Pack
ROS	Report of Survey
SBES	Single Beam Echo Sounder
SD	Sounding Datum
SDB	Satellite Derived Bathymetry
SIC	Surveyor in Charge
SO	Special Order
SSS	Side Scan Sonar
SV	Sound Velocity
SVP	Sound Velocity Profile
TDP	Tidal Data Pack
THU	Total Horizontal Uncertainty
TPU	Total Propagated Uncertainty
TVU	Total Vertical Uncertainty
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
WGS-84	World Geodetic System 1984

1 Standard

1.1 Orders of survey

The table below details LINZ's standards for depths, sounding positions, feature detection, seafloor coverage and ancillary feature positions for hydrographic surveys.

Table 1: Standards for LINZ hydrographic surveys

Survey Order	LINZ-Special		LINZ-1		LINZ-2	
IHO SO Multiplier (M)	1		1.5		2	
Surface Positioning (dynamic survey platform)						
Horizontal Accuracy	+/- 0.50m or better (95%)					
Vertical Accuracy	+/- 0.10m or better (95%) if GNSS tides					
Soundings (m)						
Uncertainty of Horizontal Position of soundings	$\pm M(0.5 + 0.025 * \text{Depth})$					
Vertical Depth Uncertainty (distance from ref. surface)	$\pm M\sqrt{0.25^2 + (0.0075 * \text{Depth})^2}$					
Data Grid Resolution* (100% of all grid cells shall be populated with at least 4 soundings If using CUBE at least 5 soundings per node (***) see node capture distance requirements	<i>Depth Range (m)</i>	<i>Resolution (m)**</i>	<i>Depth Range (m)</i>	<i>Resolution (m)**</i>	<i>Depth Range (m)</i>	<i>Resolution (m)**</i>
	0 – 20	0.5	0 - 20	1	0 - 20	2
	20 – 40	1	20 - 40	2	20 - 40	4
			40 - 100	5	40 - 100	8
			100 - 200	10	100 - 200	15
			200 - 500	15	200 - 500	25
			500 - 1000	25	500 - 1000	50
		1000 - deeper	50	1000 - deeper	100	
Feature Detection ** (minimum object size)	0 - 40	1	0 - 40	2	0 - 40	4
	40 - deeper	2.5% Depth	40 - deeper	5% Depth	40 - deeper	10% Depth
Swath Coverage	200%		100%			

Ancillary Features Horizontal Uncertainty (m)	
Fixed Aids and Features Significant to Navigation	2
Drying Rocks	2
Natural Coastline	10
Mean Position of Floating Aids to Navigation	10
Topographical Features	10

*Data Grid Resolution - Sounding density has to be such that data can be gridded to these resolutions for the corresponding depth band; it defines the minimum grid size and relates to the feature detection requirements.

** Feature detection is the minimum object size the sensor can detect. Feature detection is to be proven at the mobilization phase of the project during the feature detection test. Feature detection is proven if the sensor can achieve 3 detections across track and 3 detections along track in a single pass at expected survey speeds/swath widths.

***Capture Distance – Statistical gridding approaches such as CUBE and CHRT use nodes where multiple soundings can contribute. When rendering a statistically derived surface such as CUBE/CHRT the contractor shall use the settings below for capture distance minimum and scale factor.

$$\text{capture distance minimum} = \text{surface resolution} / \sqrt{2}$$

A capture distance scale should be defined so that there isn't excessive reuse of soundings and to achieve feature detection requirements for each Order.

- (i) Capture distance scale for LINZ Special = 2.5% of depth
- (ii) Capture distance scale for LINZ-1 = 5% of depth
- (iii) Capture distance scale for LINZ-2 = 10% of depth

For surveys with depths that span several depth ranges multiple surfaces shall be used each with the correct resolution. Alternatively, if supported by the processing tools, Variable Resolution may be accepted, but approval has to be obtained from LINZ.

The resolutions can be extended for deeper depths than the ranges stated in the table if the bathymetric survey system is capable of supporting this, i.e. the data density is sufficiently high.

1.2 Total Propagated Uncertainty (TPU)

1. Uncertainty calculations are required to assess the TPU of all soundings. For each sounding these shall be split into two different uncertainty values, THU (Total Horizontal Uncertainty) for positioning uncertainty and TVU (Total Vertical Uncertainty) for depth uncertainty. For all measures of uncertainty the required confidence level is 95%.
2. Prior to the survey an assessment of the apriori TPU shall be conducted using an appropriate model such as Hare-Godin-Mayer model (or any other model which accurately accounts for the covariance of factors in the sounding equation). The model shall take into account all the individual sources of uncertainty from positioning and sounding systems. This should be done using the best available knowledge of the survey system and shall accommodate the conditions expected at the time of the survey. The contractor shall graph the two components of TPU (THU and TVU) across the whole expected depth range of the survey area. The tolerance of the relevant LINZ order shall also be plotted to prove the system/methodology is capable of theoretically meeting the specification. Graphs are to be included in the Quality Assurance Data Pack with a full list of the input parameters and assumptions made. An example of these graphs is included in the Figures below.

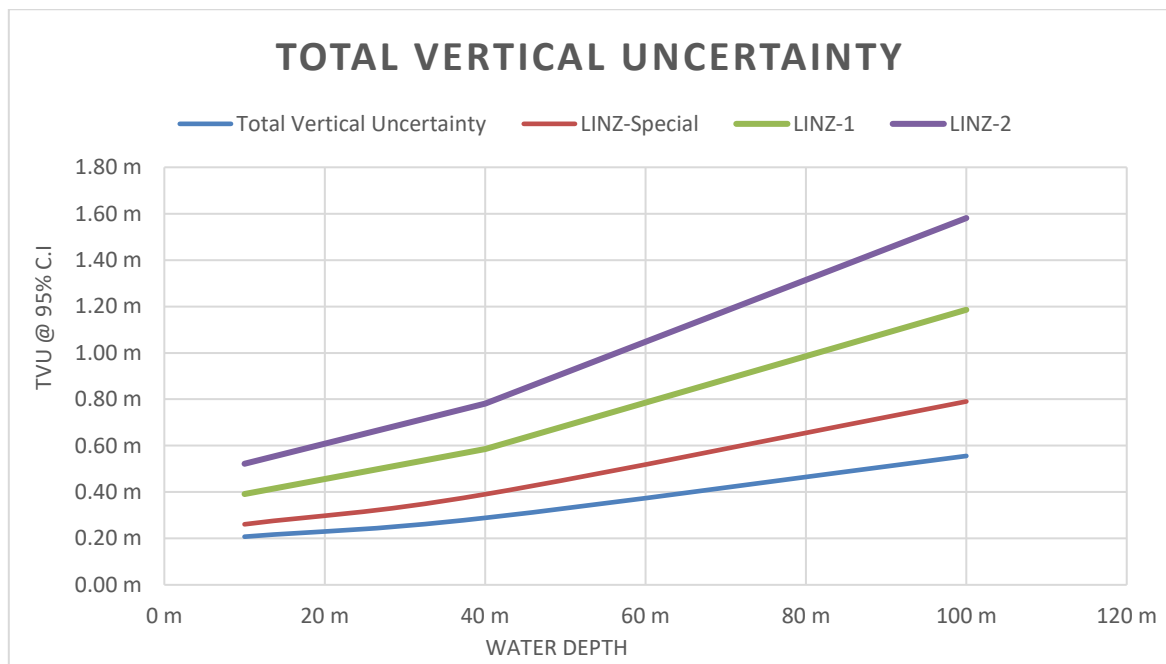


Figure 1 - TVU comparison of LINZ Orders of survey

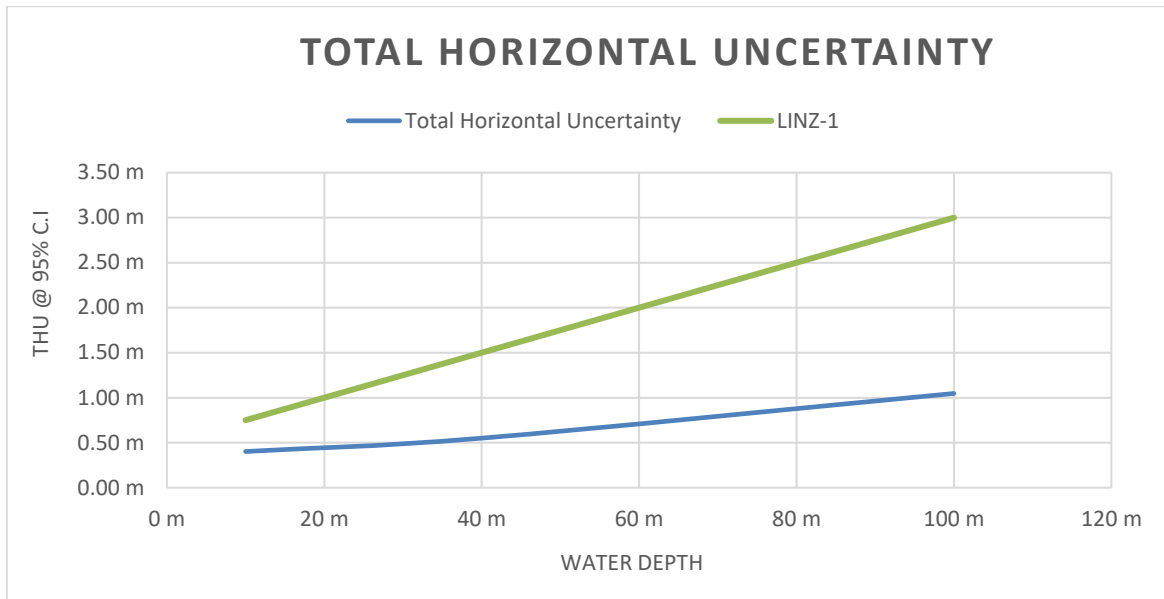


Figure 2 - THU comparison of LINZ Orders of survey

1. Where CUBE or other statistical approaches are used to render a surface a full table of the TPU values used to realise the CUBE result shall be rendered in the ROS.
2. At the completion of fieldwork a crossline comparison shall be done against the final surface to provide a definitive TVU assessment. The ROS shall detail the methods used to conduct the assessment and how a final TVU value was derived. The TVU assessment may be broken up into individual areas, this may be relevant where different sensors are used or where different tidal regimes occur. Ideally the assessment shall be done using uncleaned crosslines so as to give the best picture on the accuracy of the data.
3. If the project defined uncertainty is not met during the survey, the Contractor shall report these instances and discuss the results with LINZ before departing survey grounds. In-fills might be required.
4. The SIC shall provide a statement on the final TVU/THU of the survey. The statement shall provide a rationale for the values provided and may draw on information provided from the apriori TPU assessments. The statement shall highlight whether the survey has met the uncertainty requirements as specified.
5. Uncertainty values are a requirement in the rendered surfaces (see Section 5.5.3). The contractor shall describe the method used to populate this field. Ideally this should take into account the final TVU values from crossline comparisons and should be spatially appropriate. Where CUBE or other statistical gridding algorithms are used to derive a final surface it may not be relevant to render the horizontal uncertainty layer as the THU will be a function of the gridding approach taken. In cases where this is the case the absence of this layer shall be mentioned in the ROS.
6. The uncertainty of the tide correction, from single station or co-tidal model is to be estimated. The uncertainty value used shall be reasoned in the ROS.

1.2.1 Coverage

1. Line overlap must be sufficient to meet the requirements of Table 1 and should ensure there are no data gaps between the usable portions of the swaths.
2. Data with gaps between the geometrically usable portions of the swaths will be rejected.
3. The spatial distribution of geometrically usable points is expected to be relatively uniform and free from clustering, in order to ensure consistent data densities throughout the project area and meet the requirements in Table 1. It is recognised that with some acquisition systems some clustering may occur due to the effects of pitch/roll.
4. The Contractor must ensure that the data accurately reflects the condition of the seafloor at the time of the survey and adjust operations if required. Any deviations from the specifications must be clearly explained in the ROS and discussed with LINZ as they occur.

1.2.2 Swath to Swath Overlap

For these Standards the swath width used to define any coverage is to be that part of the swath which meets the uncertainty standards (see Table 1)

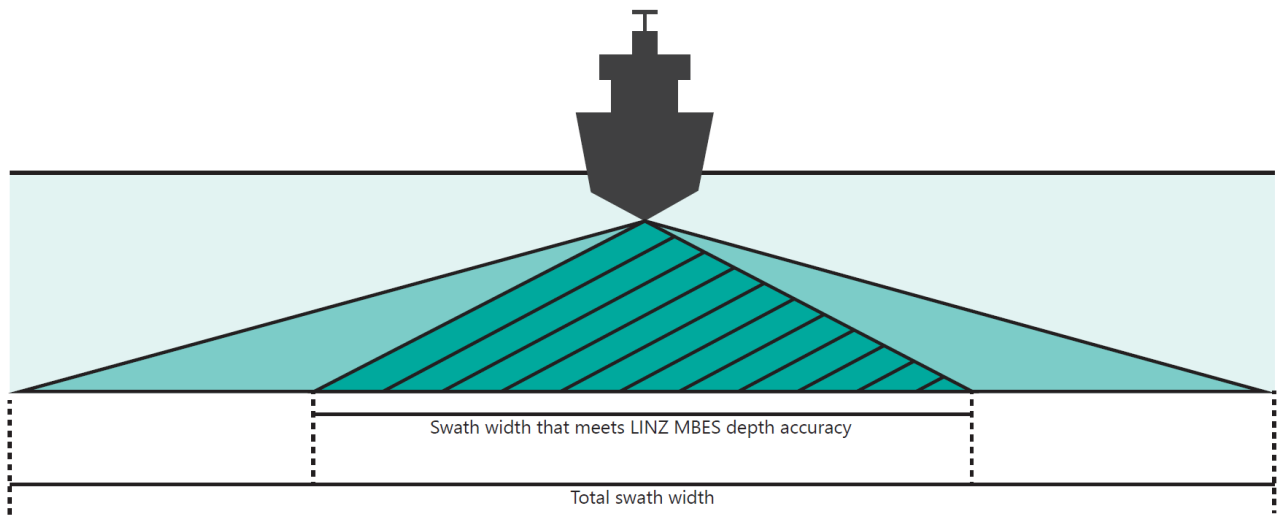


Figure 3 - Swath width that achieves TPU

2 General Principles

2.1 Personnel

2.1.1 Surveyor-in-Charge (SIC)

1. The SIC and any nominated alternative(s) must be qualified and competent and are to be approved by LINZ prior to commencement of the project. Such approval will involve a review of the individual's hydrographic surveying experience, qualifications and references.
2. As a minimum, any nominated SIC is to have successfully completed an FIG-IHO-ICA IBSC Category A recognised programme and/or an FIG-IHO-ICA IBSC recognised certification scheme (such as the AHSCP Level 1 Certification) with a specialism in Nautical Charting.
3. A proven track record of at least five years recent field experience as SIC, supported by evidence and references, is required which demonstrates that they are capable of meeting the requirements of a hydrographic survey for nautical charting purposes.
4. To assist with building capacity and capability, the contractor may consider a mentoring programme whereby a SIC who does not fully meet the above proven track record is supported by a SIC who does fully meet the requirement.
5. Additionally the SIC is to have completed professional training in the principles and operation of the primary survey sensor. An example of such training is the course run by the UNB-OMG / UNH-CCOM for MBES as a primary sensor. The SIC must also provide evidence of at least two years recent field experience with MBES.
6. A SIC is responsible for, and must be involved in, all aspects of the work required for the survey including planning, preparation, conduct, rendering and approval.
7. A SIC must take the lead role in the mobilisation, calibration and performance check of the integrated survey system and be present during all critical sounding operations and readily available for acquisition, processing and delivery of data.
8. A SIC may not be replaced or substituted without the prior written approval of LINZ.
9. A SIC is to validate all data and document the quality control that has been undertaken.

2.1.2 Project Team

1. The survey team shall include qualified and competent personnel with relevant and adequate experience of surveying and data processing for nautical charting purposes. The team should include personnel who have successfully completed an FIG-IHO-ICA IBSC Category B recognised course and/or an FIG-IHO-ICA IBSC recognised certification scheme (such as the AHSCP Level 2 Certification).
2. The Project Manager shall have relevant and adequate experience of managing commensurate projects.

2.2 Project Planning

The hydrographic survey shall be progressed in a systematic manner to ensure coverage of all areas specified is complete in all respects.

2.3 Verification of Charts and Publications

1. During the execution of the contract every opportunity should be taken to verify the adequacy or otherwise of existing published charts and documents of those areas in which the survey is being carried out.
2. When examining the detail on a published chart, attention should be paid to whether land features are visible from seaward (or even whether they still exist), to the prominence or otherwise of objects described as 'conspicuous' and to whether major changes have taken place in built-up areas.

3 Geodetics and Tides

3.1 Horizontal Datum

1. The horizontal reference system for all positions will be WGS84.
2. Realisation and coordinate epoch is required, preferably to the nearest day (incl. Metadata).

3.1.1 Geodetic Control Points

1. Where existing geodetic control points of Order 5 NZGD2000, or better, are available and suitable, these should be used for shore-based base stations and reference marks.
2. Lower order marks, or newly established stations, may be used provided they meet the requirements set out in *Specifications for Geodetic Control of Hydrographic Surveys* (see Related Standards and publications).

3.2 Vertical Datum

1. All depths will be referenced to Chart Datum (CD) or Sounding Datum (SD) for Coastal Areas (<15km away from a fixed tide station) requiring the use of Tidal Stations for direct tide measurements.
2. Offshore Areas (≥ 15 km away from a fixed tide station) will be referenced to the Ellipsoid using GNSS tides.
3. Ellipsoid referenced surveying in Coastal Areas is allowed. However this shall be discussed with and approved by LINZ.
4. If the depth reference is based on GNSS heights, the Contractor shall provide a detailed description of the Methodology, e.g. vessel derived water line, separation model.
5. Any ellipsoid referenced surveying must include the vertical datum and realisation used.

3.2.1 Tides

3.2.1.1 Sounding Datum and Chart Datum

1. SD is a low-water plane to which soundings are reduced and above which drying heights are referred on hydrographic survey records.
2. CD is the level to which soundings are reduced on the published chart and to which tidal heights are referred in the NZ Nautical Almanac NZ 204 (NZNA). CD may, or may not, be the same as SD.

3. Care must be exercised when comparing surveyed depths with the chart. All references to the datum used during the survey should bear the wording "Sounding Datum".
4. The suitability of the SD is to be checked by inspecting the coastline and drying heights on a day when the tide falls close to datum. Comments on this check are to be made in the rendered reports.

3.2.1.2 Establishing Sounding Datum

1. Existing CD(s) within the survey area shall be recovered, if possible, from associated BMs and checked for reliability. If any existing datum cannot be recovered, SD shall be established afresh.
2. On an open coast, SD will be determined by the most appropriate method, such as, transfer of SD from an appropriate reference tidal station using the range ratio method or by harmonic analysis.
3. Whenever a tidal station is established for longer than one spring/neap cycle, any datum transfer should be checked at or near at least one subsequent spring tide.
2. If, during the course of a survey, the datum is found to be unsuitable for any reason, LINZ shall be informed without delay. Any adjustments made to the datum during a survey are to be fully documented in the ROS.
3. In an estuary, or narrow bay, datum everywhere should be the low water level of a tide which falls to CD at the main port, or tidal station, as advised by LINZ. Care is necessary in the transfer of datum from one part of the estuary to another as the actual tidal characteristics will vary from place to place. In addition, meteorological effects (e.g. persistent winds causing the water to pile up) can affect one shore more than another.

3.2.1.3 Tide Stations

1. Tide stations are to be established to obtain observations for each of the tidal regimes which may occur within the survey area to ensure that an accurate tidal model can be constructed.
2. Each tide station will comprise:
 - two sea level sensors capable of recording averaged sea level height and time,
 - a barometer if non-vented underwater pressure sensors are deployed,
 - a tide pole or GNSS buoy, and either
 - a minimum of three geodetic marks close to the tide station, or
 - determination of the ellipsoidal height of the sensor (with LINZ approval)
3. Both sea level sensors are to record data, one is to be used as the primary sensor, the second as a backup in case the primary sensor fails.

3.2.1.4 Tide Station Geodetic Marks

1. Existing suitable survey marks may be designated as tide station geodetic marks, otherwise new marks will need to be established; in either case the minimum number of marks (3) must be achieved.
2. All tide station geodetic marks are to meet, and be surveyed in accordance with, the *Specifications for Geodetic Control of Hydrographic Surveys*.
2. The vertical relationships between the geodetic marks and the tide pole (or GNSS base station when used in association with the GNSS tide buoy calibration methodology) shall be recorded to the nearest mm and must meet the requirements of Section 4 of the *Specifications for Geodetic Control of Hydrographic Surveys*.
3. Levelling is to include all locatable bench marks from any previous tidal observations at the location, regardless of whether or not they meet the criteria for tide station geodetic marks.

3.2.1.5 Sea Level Observations

1. Sea level observations are to be recorded for 35 days or the duration of the survey, whichever is longer, with <5% interruption.
2. The following recording requirements are to be met for all sea level observations:
 2. time of sea level measurements is to be recorded to within 5 seconds of UTC,
 3. sea level height is to be measured to an accuracy not less than $\pm 0.05\%$ of the full scale of the sea level sensor. For digital sensors the recorded value is to be an average of height samples taken over a minimum of 51 seconds centred on the recorded time of reading, and
4. averaged sea level height is to be recorded at intervals not greater than 10 minutes with values synchronised "on the hour".

3.2.1.6 Calibration

1. Prior to deployment, every sensor used for sea level measurements must have a factory calibration certificate that is within the manufacturer's recommendation, or less than 3 years old.
2. Modern digital sea level sensors shall not be adjusted in the field and shall be returned to the manufacturer for repair if found to be recording erroneous data. The manufacturer's pre-deployment checks standard procedures shall be followed.
3. In-situ calibration of each sensor is to be carried out as soon after deployment as practical by making simultaneous independent observations of sea level using either a tide pole or another technology (GNSS buoy, for example) as close as possible to spring tide.
 2. Once established, checks of the tide pole and sensor are to be conducted whenever practical to ensure that the sensor/pole relationship remains valid. In the event that a sensor becomes defective and has to be replaced, then a new calibration must be conducted.

3. For sensor deployments of > 3 months' duration a repeat calibration procedure immediately prior to the dis-establishment of the tide station is recommended.
4. When an established sea level sensor (usually belonging to a local authority or port company) is used, the sensor zero versus datum value must be checked to ensure that it corresponds to the stated figure.
5. Calibrations employing a tide pole are to be conducted over a period of at least 13 hours with readings (coinciding with the sensor recording schedule) at intervals no greater than 30 minutes except during the period 30 minutes either side of high and low water when readings shall be taken every 10 minutes.
6. Calibrations using other technologies (such as a GNSS buoy) are to be conducted over a period of at least 13 hours.
7. The sensor calibration parameters are to be determined from the intercept and gradient of a straight line fitted to the sensor readings plotted against the independent sea level values.
8. When using a GNSS buoy shall reduce all observations to absolute WGS84 ellipsoidal heights

3.2.1.7 Reduction of Soundings for Tide

1. In reducing soundings, the principle to be observed is that depths are never to be shown as greater than they actually are, relative to CD (SD).
2. LINZ may specify in the survey contract the preferred method of reduction of soundings and tidal model, and surveyors are to report any problems with implementation of these instructions.
3. All interim soundings shall be reduced using either predicted or observed tides, corrected for temporary datum and then reprocessed for the correct SD once it has been confirmed. In all cases LINZ shall be consulted prior to adjustment.
4. Tidal reductions applied to soundings are to be periodically checked for validity.
5. The contractor shall, in the TDP, describe the method used to apply tidal adjustments to the data.
6. In areas where the character of the tide is unknown, tide poles or tide stations should be set up at regular intervals. A comparison of the curves from adjacent tide stations should show whether any intervening area requires an additional tide station or whether a co-tidal model could be used.
7. It is often possible to refine a co-tidal model, or guard against gross errors, by mooring the survey vessel in a convenient part of the area where the seabed is flat. Depths are then taken at regular intervals for one or more tidal cycles. From these observations, which must be taken in calm weather, and preferably near spring tide, approximate range ratios can be obtained, as well as the time differences for high and low water. The flat bottom sounding method described above should only be used as a last resort.

3.2.1.8 Tidal Streams and Currents

1. The direction and rate of tidal streams shall be observed wherever they are of navigational significance and where there is no evidence that observations have been made previously. Locations for tidal stream observations will normally be indicated in the survey contract, but SICs are to include additional stations if they observe significant stream activity elsewhere. Entrances to harbours, channels, navigable straits, anchorages and in the vicinity of wharves are the most important locations. Short term observations should not be made under abnormal weather conditions.
2. When observations are made using either a moored digital recording current meter or a vessel-mounted acoustic doppler current profiler (ADCP), the tidal stream data (rate and direction) shall be recorded for the upper-most 6 metres of the water column.
3. Moored current meters shall be deployed for a 30 day period. Measurements averaged over a period of 3 minutes shall be recorded at 15 minute intervals.
4. When using a vessel-mounted ADCP the frequency of observations should be adequate, e.g. made over 13 hour periods at both spring and neap tide, to ensure that analysis of the stream can meet the spatial resolution specified in the contract.
5. Tidal stream rate and direction measurements should be made with an uncertainty of less than ± 0.1 knot and $\pm 5^\circ$ (with respect to true north) respectively, both at 95% confidence. The positional uncertainty of moored current sensors and vessel mounted ADCP measurements shall be less than ± 20 metres and ± 2 metres respectively.
6. The operation of all equipment used for stream/current observations shall be confirmed prior to undertaking survey measurements and checked following the completion of the survey. A copy of the raw downloaded data shall be rendered in addition to the processed data.
7. When observing tidal streams, simultaneous observations of tidal height must always be obtained at the nearest convenient location.
2. In addition to measuring the tidal stream information of a less formal nature which may be of navigational significance is to be recorded and rendered, especially if it may effect low powered vessels or yachts. Data shall include the estimated maximum rates at spring tides and the directions of tidal streams assessed by the best available means. Local knowledge shall be sought where possible.
3. Stream/current information is of particular importance in narrow channels, and may vary between the centre and the sides of the passage, and with the direction of flow. Data shall be shown in the ancillary data, and is to be described in the ROS.
4. In processing tidal stream information, results shall always be related to the closest standard port and shall clearly state the recommended text and numerical values to insert in the "tidal diamond" table to be included on the chart.

3.2.1.9 Eddies and Overfalls

1. In areas of strong tidal stream, especially in the vicinity of banks, rock shelves, headlands and in narrow passages. The limits of eddies and overfalls may occur which can be of considerable significance especially to low-powered vessels or yachts.
2. The limits of these phenomena shall be fixed on both directions of the tidal stream, rendered in the ancillary data, and remarked on in the ROS.

3.2.1.10 Deliverables

1. A Tidal Data Pack is to be rendered in accordance with the requirements found in Section 5.3.
2. Sea level data is to be rendered together with relevant deployment records and logging parameters. The data is to be rendered as comma delimited text file(s) comprising, as a minimum, time and height (referenced to a defined datum) to 0.01 metre or better.
3. Tide stream data is to be rendered together with relevant deployment records and logging parameters. The data is to be rendered as comma delimited text file(s) comprising, as a minimum, time and current direction and rate to 0.1° and 0.1 knots or better respectively
2. Geodetic deliverables for the tide station geodetic marks are to be rendered in accordance with the *Specifications for Geodetic Control of Hydrographic Surveys*.

3.3 Time Datum

All observations shall be time stamped and rendered to LINZ in digital data in terms of Co-ordinated Universal Time (UTC), and descriptive text used in reporting in terms of the relevant local time (for example NZST in New Zealand coastal waters).

4 Data Acquisition

4.1 Bathymetry

1. Sounding lines shall be parallel to adjacent track-lines.
2. Track-lines shall be spaced such that the depth uncertainty standard in the outer beams for the order of survey is achieved.
3. For MBES surveys sounding lines shall be parallel to the bathymetric contours wherever possible.
4. Data acquired during turns and when following sinuous track-lines is to be logged but not to be incorporated into the final processed data-sets. However, on providing evidence that uncertainty requirements are acceptable during these manoeuvres, they may be incorporated into the final processed data-sets on the approval of LINZ.
5. The exception to this is data acquired during periods of calibration and testing. During these times all data shall be logged and processed.
6. Data acquired by the outer beams which fall outside the required uncertainty standard are to be used for reconnaissance and shall be logged but not incorporated into the final processed data sets.
7. Data filtered and/or edited as erroneous shall be flagged as rejected and included in the final processed data set (outlined in Section 5.5). Where CUBE or other statistical methods are used data may not be flagged as rejected to maintain the statistical integrity of the dataset as a whole. It is expected that large systematic noise is flagged as rejected.
8. This specification does not apply to interferometric multibeam echosounders. If such systems are proposed for the survey, Contractors must demonstrate they meet the object detection and depth uncertainty requirements and be specifically authorized by LINZ.

4.1.1 Sound Velocity (MBES)

1. Sensor minimum requirements are:

Parameter	Requirement
Sound Velocity	±0.05 m/s relative accuracy
Temperature	±0.01°C
Pressure	±0.05% range

1. Sound velocity (SV) Profile must be measured as a minimum at 6-hourly intervals. The frequency of profiles may be increased or decreased at the discretion of the SIC.
2. Determination of SV must be by an independent method other than by echo sounder. Preferably a SV digital "time of flight" sound velocity sensor and temperature sensor shall be utilized. Alternatively a CTD sensor can be used to measure SV (in some

circumstances a CTD may be preferred for processing backscatter data – see Section 4.2). If both direct SV and CTD sensors are used, the direct measurement shall be utilized for processing. The formula from *Chen and Millero* or *Del Grosso* shall be used for calculation of sound speed if using a CTD sensor

3. At the transducer head(s), the SV should be monitored in real time using direct SV measurement. SV may be re-observed when the difference between the existing SV sensor value and the observed profile value at the transducer head differ by a significant amount, as determined by the SIC. The interval between SV measurements may be relaxed at the discretion of LINZ.
4. In addition to SV, temperature and pressure shall be logged.
5. Other methods of deriving sound velocity (such as TU Delft algorithm or sound velocity inversion) may be used but these are to be discussed with LINZ during the proposal phase of each survey. For each method the contractor shall demonstrate the accuracy of the proposed method, how it meets the requirements of this section and how it impacts the overall accuracy of soundings.

4.1.2 Environmental conditions (LiDAR)

1. Where possible, LiDAR data should be collected when the following conditions are met:
 - a. Atmospheric conditions must be free of cloud, fog, heavy smoke and haze between the aircraft and ground during all collection operations.
 - b. Periods of low turbidity e.g. calm weather, low river discharge and low swell
2. The primary data product is the bathymetry with any optional products including aerial imagery having less priority in survey timing. If the optional products are included within the final project scope the weather should be taken into account, but not at the expense of the primary objectives or timeframes.

4.1.3 Calibration of Bathymetric Systems

1. The survey platform's bathymetric system shall be fitted with peripheral equipment which can provide corrections for the following:
 - Platform Offsets
 - Platform Positioning
 - Platform Heading
 - Platform Roll
 - Platform Pitch
 - Platform Heave (when applicable)
 - Platform Squat and Settlement (when applicable)

- Platform Draught (when applicable)
 - Platform Speed
 - Synchronised Timing
 - Velocity of Sound in Water (when applicable)
 - Tidal Time and Height
1. All equipment shall hold a valid calibration certificate and shall be maintained and handled according to manufacturer's recommendations.
 2. Historical records of calibration and verification results for all equipment shall be kept, including equipment serial numbers.
 3. Calibration of the survey platform, bathymetric sensor and all peripherals shall be undertaken prior to each survey project, or after any significant component change/swap of the system or associated sensors.
 4. Methodology and the uncertainty of the calibration and verification results of the integrated survey system shall be documented in the Quality Assurance Report. Reporting and data files shall contain all the required information for a third party to verify the results.
 5. Quality Control during data collection and processing shall be continuously carried out and documented, and LINZ shall have access to the data and procedures
 6. The continued validity of the survey spread shall be confirmed on a periodic basis during each survey season, or after any significant component swap-out, or suspected damage to the Bathymetric system or associated sensors. In the event a vessel or platform is mobilised in a location other than the survey area, a patch test is to be conducted on site as soon as practicable. It is recognised that it may take time to find a suitable location if local depths are unknown.
 7. Transducer draught measurement shall be carried out on a daily basis for MBES operations.
 8. The checks and calibrations of MBES system platform when underway are to be outlined. These may include:
 - Acoustic Sensor Bar Checks (when applicable)
 - Draft, Settlement and Squat (when applicable)
 9. Any modification of the survey spread during the project, including the introduction of a new survey platform shall be fully documented and reported to LINZ. New equipment shall meet the project requirements.
 10. Documentation that all requirements given in this specification have been met shall be provided to LINZ as part of the Survey Calibration, Verification and QA Report (QADP), including Methodology and records of all calibrations, parameters and checks.

4.1.3.1 Surface Positioning System

1. The survey contractor is to provide evidence of positioning confidence checks.
2. Whenever DGNSS or other positioning systems are used (e.g. RTK) for control of positioning for a survey, they must be verified against a reference position which is more accurately known, or by comparison with a more accurate system before sounding commences. The vector quantity (bearing and distance) of the offset from the more accurate positioning system shall be noted and shall not exceed the values contained in the error budget analysis.

4.1.3.2 Field Verification

1. Contractors shall document that the survey system operates within specification through a verification survey, including feature detection checks.
2. A new verification survey is required after any modification or reconfiguration of the survey spread, e.g. replace a sensor due to damage.
3. If the verification survey determines discrepancies (e.g. during periodic checks), additional calibration of the system is required.

Survey Verification

The verifications of the survey system shall take place immediately after the mobilisation and after all sensors are calibrated. The survey system verifications can take place away from the survey area as it is advantageous to carry out these verifications in a known area close to where the mobilisation takes place. The various verifications are listed in the section below.

Reference Surface

1. A verification area or reference surface shall be surveyed prior to the main survey. This area shall be an existing well-surveyed area with an already established independent reference surface.
2. If a reference surface doesn't exist, one shall be created using MBES in water depths sufficient to detect any systematic errors in the survey system and representative of the survey area depths, for shallow water systems this should ideally be around 30-40m. The surface shall be created through a grid of parallel and perpendicular survey lines with at least 150% overlap.
3. MBES data shall be corrected for sound velocity, tides, vessel draught and motion and the outer beams of the swath removed to ensure a high confidence reference surface is produced. Predicted tides may be applied to soundings in the absence of observed tides provided all reference surface lines are acquired within a short time frame. A DTM shall be created from the cleaned data using an average gridding algorithm, with a cell size no larger than the average footprint of the inner beams.

4. For an MBES system, a series of verification lines shall be run as follows inside the reference surface comprised of two lines where the vessel manoeuvres as experienced during normal sounding operations close to the shoreline (see Figure 4).

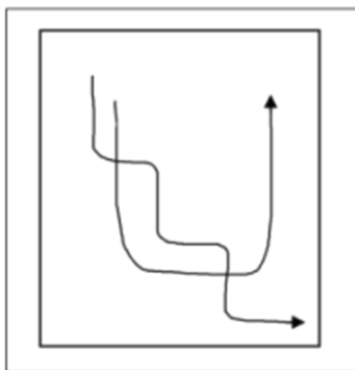


Figure 4- Verification lines on reference surface

5. Data from the verification survey shall be processed, and the accepted soundings will be compared to the existing reference surface. Each beam depth from the processed verification lines shall be compared against the reference surface and statistics computed. Statistics are to include: beam number, mean, maximum and minimum differences and standard deviation.

6. Seabed features in overlapping areas will be used to check the horizontal accuracy.

7. All data from the verification survey shall be delivered prior to the start of the main survey. The data will be checked as early as possible, preferably before the main survey starts. Commencing a survey prior to LINZ's endorsement of the verification survey is at the contractors own risk.

Feature Detection Check

This is required to assess the feature detection capability of the system, in particular, the ability to detect features of the minimum size required by the order of the survey (see Table 1). Ideally the feature used in the check should have its dimensions known so as to accurately verify whether the size of feature can be detected. Lines shall be planned around the feature so that detection can be proven in all sectors of the swath (nadir and outer beams) at the expected survey line spacing.

Data shall be processed with only accepted soundings used. On each line the number of across track and along track detections shall be noted and mentioned in the mobilisation report.

Horizontal Accuracy Check/Box In

The horizontal accuracy check may be undertaken as part of the target detection check mentioned in the section above. The horizontal accuracy check tests the systems capability to accurately resolve a feature on the seabed.

Four (4) box-in lines on opposite headings shall be conducted to assess the three dimensional position of a clearly defined small and easily detectable feature on the seabed. The feature shall appear in the outer beams on port and starboard respectively, and on opposite headings. See Figure below.

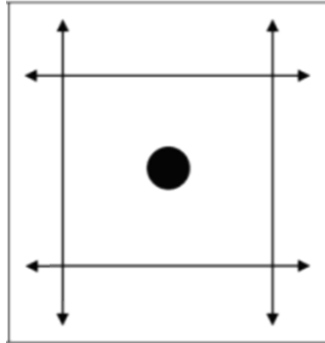


Figure 5 - Verification lines for feature detection

Data shall be processed with only accepted soundings used. An assessment of the respective geometric centres of the feature from lines on opposing headings shall be made to ascertain whether the system is capable of meeting the horizontal accuracy of the survey. The results should be tabulated and noted in the Quality Assurance Report. For horizontal accuracies refer to the standards in Table 1.

Seafloor Backscatter Check (MBES)

The ability to acquire quality seafloor backscatter data shall be verified. An understanding of the range of seabed types and backscatter responses shall be obtained and system settings derived and applied to minimise changes in settings affecting backscatter responses during the survey.

A backscatter check shall also be undertaken at the survey area as seabed types may be different to the area of mobilisation. The backscatter check shall be completed upon arrival at the survey area so that any data acquired will have the correct settings applied in acquisition.

A reference area should be flat, level, and of a homogeneous seafloor type so processing assumptions, such as projected beam footprint estimates, will minimally bias the results. The area should also be deep enough to be in the far field of the echosounder for a consistent beam pattern. Ideally a depth of 20-30m shall be used for shallow water MBES systems. The backscatter check shall as a minimum comprise of:

- Log three parallel lines (dual head MBES) or two reciprocal lines over the reference area for each setting mode to be utilised for the survey.
- Capture the parameters of these setting modes in the Quality Assurance Data Pack and the Report of Survey

- Monitor the backscatter waterfall/intensity in real time during the logging of the lines for any hardware failure/missing channels.
- Store all logged lines in their native format within the project folder structure
- Repeat the process (logging reciprocal lines) over the same reference area to check for any walk/degradation of performance of the system

A seabed sample (see Section 4.4) shall be obtained over the backscatter check/reference area to enable the interpretation of backscatter records.

Acoustic Noise Interference Test (MBES)

This test must demonstrate that the level of vessel noise at all combinations of propeller revolutions and pitches expected during the survey does not interfere significantly with the MBES system. The test must also demonstrate that acoustic noise from other vessel sensors expected to be in use during the survey does not interfere with the MBES system (i.e. vessel sounder).

4.1.4 Crosslines

1. The regular system of sounding lines shall be supplemented by a series of crosslines for verifying and evaluating the accuracy and reliability of surveyed soundings and positions, and determine issues across the survey areas, e.g. tidal and datum.
2. Crosslines shall be run at angles of 60° to 90° to the main scheme sounding lines.
3. Crosslines shall have good temporal and geographic distribution. The amount of crosslines acquired is at the discretion of the SIC. In deciding on the number crosslines the SIC shall determine an interval that will enable the statistical computation of vertical uncertainty across the whole survey area or areas. Crosslines shall cover most depth areas so as to ensure adequate representation of the nature of the survey area in the statistics.
4. Crosslines shall be acquired and processed to the same accuracy and data quality standards as required for main scheme lines, and shall not be included in the grids that are submitted as the final bathymetric product of the survey. Crosslines should be left uncleaned so any statistical comparison provides a true representation of the survey systems performance.
5. A statistical comparison between main lines and crossline swath shall be undertaken to ensure that the uncertainty requirements of the order of the survey are met. At least 95% of depth values from the two data sets shall differ by no more than the maximum allowable TVU for the depth of the comparison area. The mean difference for each crossline comparison, at the 95% confidence limit, will provide the TVU. When comparing many crosslines, the contractor may choose to apply any statistical approach as long as it is properly reasoned. A summary of the statistics and definitive statements about the results shall be included in the RoS.
6. Any deviations from this standard shall be investigated, and the source of error identified and corrected. If unexplained or excessive discrepancies persist, additional crosslines shall be re-acquired to assist in resolution of the issue.

7. Raw and Processed Data sets of sounding line crossings may be required to be delivered at intervals throughout the survey for ongoing LINZ validation.

4.1.5 Reduction of Soundings

1. In reducing soundings, the principle to be observed is that depths are never to be shown greater than they actually are, relative to sounding datum.
2. All soundings shall be reduced for tidal heights unless otherwise stated; see Section 3.2.
3. Squat, settlement, pitch, roll, yaw and heave shall be recorded as appropriate to the platform type and soundings corrected accordingly.
4. All soundings shall be corrected for vessel draught and variation in sound velocity (vessel mounted acoustic sensors only).

4.1.6 Examination of Seabed Features

4.1.6.1 Significant Bathymetric Features

1. Significant bathymetric features are seabed features which the SIC wants to bring to the attention of LINZ; these include but are not limited to:
 - Shoals dangerous to navigation
 - Isolated rocks
 - Wrecks
 - Obstructions
2. Consideration should be given to:
 - Traffic
 - Channels
 - Potential anchorages
 - Trawling activities
 - Surrounding water depth
 - Controlling depths near recommended tracks
 - Potential future uses within the area and of the survey data
3. Each feature is to be given a unique identifying number in the format 'SBF-XX'. This number should appear in INFORM of the S-57 file as well as in the Report of Survey.
4. Consideration should be given to the planned charting scale as indicated by LINZ at the outset of the survey. SBFs should be selected at a scale of half of the indicated chart scale i.e. indicated chart scale 1:25,000, SBF selection should be based on 1:12,500.

4.1.6.2 Wreck and Seabed Feature Investigations

1. For navigationally significant wrecks, obstructions or other dangerous features which have not been located and examined during previous surveys, and especially where the depth may be critical to navigation in the vicinity, the feature shall be examined in detail.
2. A minimum of one survey line centred over the feature/wreck along its centre line, two parallel lines either side and a cross line shall be carried out. MBES Water Column Data (WCD) shall be logged for further analysis.
3. WCD data shall be analysed in an appropriate software package and compared with other features present in the water column. The software package shall have the ability to pick fully georeferenced depths from the WCD for inclusion in the final sounding data.
4. If deemed necessary, wire-sweep or diver shall also be used to allow the SIC to make a firm statement as to whether the least depth has been found, and to document the reason for any differences.
5. Provide a detailed description of the methods used (e.g. WCD, diving, wire sweeping) to investigate dangerous features, wrecks and obstructions. Comment on any problems encountered with obtaining the least depths.
6. A separate deliverable of the navigationally significant wreck/feature showing position, extent and least depth shall be produced in accordance with Section 0.
7. Searches for charted wrecks on the edge of the survey area must be extended to a radius of 2.5nm.

4.1.6.3 Uncharted Features

1. Newly discovered features which may be dangerous to navigation, and charted features which are found to be significantly changed, shall be reported without delay by Hydrographic Note available through the [LINZ website](#).
2. Findings shall be included in the deliverables. All Hydrographic Notes submitted throughout the course of the survey are to be included in the final report of survey.

4.1.6.4 Disproving Searches

1. Best endeavours must be exercised when disproving charted wrecks, reported obstructions or other dangerous features which have been located in previous surveys.
2. Objects whose positions have been previously established, but which cannot be found during the survey, need a very detailed investigation to disprove them. Such searches are to include full MBES ensonification with water column data to be logged. SSS may also be considered.
3. Consideration should be given to the technology used to position seabed features in previous surveys. When searching for such a feature the SIC shall search a radius 3x the estimated positional accuracy of the feature. This is particularly the case where a feature is denoted by PA or "position approximate" on the charts. The positional accuracy of the

feature will depend on its current CATZOC rating. The contractor shall liaise with LINZ to arrive at an appropriate positional uncertainty from which to base the search.

4.2 Seafloor Reflectance

4.2.1 MBES System (seafloor backscatter)

4.2.1.1 Hydrographic Surveys

1. For all hydrographic surveys, high resolution, geo-referenced seafloor backscatter shall be logged and rendered as a survey deliverable. It is expected that if good bathymetric data is collected the backscatter should be of acceptable to good quality, but this should not be to the detriment of good bathymetric data. As the method by which the backscatter intensity is derived is system specific, documentation of the method used shall be outlined in the ROS.
2. Backscatter data shall be rendered in both proprietary raw and processed formats and shall include all real-time acquisition parameters required to conduct post processing, such as backscatter intensity, source level, pulse length, etc.
3. Further information on backscatter deliverables can be found in Section 5.5.

4.2.1.2 Science Surveys

When conducting surveys for science purposes, in addition to the requirements in the previous section the following requirements shall apply:

1. The contractor shall avoid multibeam receiver acoustic saturation of the backscatter data to ensure that systemic variations to backscatter intensity are kept to a minimum. Changes in settings such as gain, pulse length, frequency or any other system changes shall be kept to a minimum during data acquisition to prevent artefacts in the resulting backscatter product. It is recognized that some modern MBES systems account for these variations in settings, the contractor shall understand the capabilities of the system in use and account for this in their acquisition workflows.
2. Any depth or noise filters applied shall not have a detrimental effect on the backscatter data quality, nor cause irretrievable loss of data. The use of automatic acquisition settings shall be avoided as these cause problems for backscatter data processing and interpretation.
3. The overlapping area should be increased to compensate for the high variability of individual backscatter intensities.
4. Profiles of absorption coefficient shall be calculated from measured CTD profiles for correction of transmission loss in the water column. The profiles shall be calculated and applied without significant delay. Online adjustments during logging shall not be made. The formula from Francois and Garrison¹ shall be used for absorption coefficient

¹ Francois R. E., Garrison G. R., "Sound absorption based on ocean measurements: Part I: Pure water and magnesium sulfate contributions", Journal of the Acoustical Society of America, 72(3), 896-907, 1982.

calculation. All CTD profiles and the calculated absorption coefficients are to be rendered with the survey deliverables in accordance with Section 5.5.

5. Further guidance for best-practice methodology for the acquisition of seafloor backscatter data can be found in the reference document *Backscatter measurements by seafloor-mapping sonars: Guidelines and Recommendations, GeoHab Backscatter Working Group*.

6. Additional seabed sampling may be required to assist in the interpretation of side scan sonar or MBES seafloor backscatter data. The scope of this shall be confirmed with LINZ at the outset of the project and communicated in the project specific specifications.

4.2.2 SSS - Side Scan Sonars (backscatter)

SSS data shall be rendered (e.g. in the proprietary format of the system utilised, XTF, etc) and all real-time acquisition parameters shall be included with the digital logged data, such as intensity, source level, etc

4.2.3 LiDAR Systems (intensity)

1. Intensity of seafloor reflectance values is required for each discrete return.
2. A description of the adjustments that have been applied to intensity information shall be provided, e.g. intensity correction, intensity normalization.
3. True or absolute reflectance is not required.

4.3 Water Column backscatter

1. Water column backscatter shall be collected throughout the survey.
2. Water column backscatter may be logged in its proprietary formats and shall be rendered with the raw dataset

4.4 Seabed Sampling

1. Seabed sampling to describe the nature of the seabed shall be obtained in the following situations:
 - a) in all charted and likely anchorages;
 - b) on all banks, navigationally significant shoals and seamounts, particularly where these are likely to be unstable, and in the channels between them;
 - c) if required to assist in the interpretation of side-scan sonar records or MBES seafloor backscatter records, and
 - d) at the discretion of the SIC.
4. Samples shall be obtained by diver, grab, dredge or drop camera.
5. In sensitive marine areas bottom type may be determined with seabed photographs by means of a drop camera or equivalent subsea camera system.

6. Sampling interval and any particular samples obtained from interesting features shall be mentioned. Quote the number of samples retained (if any).
7. All samples taken shall be recorded, photographed and reported in the ROS. The position, heading and COG (Course Over Ground) of the vessel when the sample is taken shall be recorded along with the time of sample and nature of sample. The method of sampling used shall be described and any problems with the equipment or the recovery of seabed samples should be mentioned.
8. Sample types are to be classified in accordance with the types shown in INT1 Section J, Nature of the Seabed (see related publication list at beginning of document).
9. The project specifications may require samples to be retained. In such an event LINZ will provide guidance on the retention of samples.

4.5 Coastlining / Low Water Inspection

1. The coastline is the line reached by Mean High Water Springs (MHWS) tides, and care is necessary in order to locate the line accurately in places where the tidal range is large.
2. LINZ will provide a coastline dataset based on the largest scale chart of the survey area. LINZ contracts may call for spot checks to verify the supplied coastline dataset. Any changes to the coastline shall be noted in the ROS and rendered with the Ancillary Information (see Section 5).
3. The surveyor shall observe the coastline and record the details including the coastline type e.g. rocky, beach, cliff. Any significant differences to the provided coastline are to be noted. Significant differences are where the coastline differs greater than 1mm at the indicated chart scale and/or when the coastline type is different to that rendered on the most recent charts.
4. Where no coastline is available, the coastline shall be captured achieving the accuracy tolerances in Table 1. An overview of the methods used and an assessment of the expected accuracy of the coastline topology is to be rendered in the report of survey.
5. Whenever a surveyor is examining the coastline, the nature of the foreshore and position of the drying line, where this can be determined, shall be recorded.
6. The Contractor shall adequately delineate the drying line of the mainland, islands and all drying features. Adequate delineation is considered accurate to 1mm of the largest chart scale, (current or planned).

4.5.1 Conspicuous Objects and Landmarks

1. Conspicuous objects are natural or artificial features that stand out, are easily identifiable and plainly visible in varying light conditions over a large area of sea (except in narrow approach channels).

2. Any method may be used to position these objects as long as it is in line with the accuracy tolerances of Table 1. The contractor may elect to position objects using aerial imagery sources (if available and of sufficient temporal/spatial accuracy).
3. The positions of all objects which may be of use to the mariner shall be fixed, shown in the ancillary data (S-57) and documented in written reports.
4. When classifying objects within a survey area, the surveyor must ensure that their judgement is not affected by familiarity with the region. The objects shall be obvious to those navigating in the area.
5. Photographs shall be taken to support reports and comments on conspicuous objects and landmarks. All photographs shall be clearly labelled.
6. The Contractor shall list all objects currently charted as conspicuous by name and position, with comment on whether the description is still appropriate, together with objects considered conspicuous but not formerly charted as such.

4.5.2 Heights of Objects and Landmarks

1. All newly co-ordinated objects and all established objects for which heights are not known shall have their heights determined and recorded. The heights of all prominent features within a survey area, whether natural or man-made, shall be observed and calculated. The heights shall be given as metres above MHWS, or if MHWS is not known, as heights above MSL.
2. The drying height of all offshore rocks and islets shall be determined, recorded and documented. The height of drying rocks shall be given as height above Sounding Datum. Where there are many offshore rocks then the seaward-most rocks are to be heighted as these will be of more use to the mariner.
3. Any clearance under bridges, wires or power cables shall be determined as height above Highest Astronomical Tide (HAT).
4. The method of height observation is to be documented in the ROS.

4.5.3 Topography

The topography shown on the most recent largest scale chart shall also be checked in the field, to update detail which is not normally shown on maps and which may not be visible on air photographs, paying particular attention to coastal detail such as beacons, flagstaffs, groynes, harbour development etc.

4.5.4 Low water Inspection

1. Frequent visual observations of the foreshore shall be made at low water to ensure proper delineation of the drying line and ensure navigational dangers are properly identified.

2. When safe to do so, efforts shall be made to height and observe drying rocks and isolated dangers at low water.

4.6 Secchi Disk Observations

1. Secchi Disk observations shall be performed when called for in the contract. Unless otherwise specified in the contract, observations are to be taken at 10km intervals in depths of 20-30m.
2. The extinction depth on the down-cast, the up-cast and the mean shall be rendered in the ROS together with the position of the cast. The apparent colour of the disc (e.g. Blue/green) shall also be stated and referenced to the Forel-Ule scale.

4.7 Coastal and Harbour Facilities

1. Brief details, including dimensions, of ramps, slipways and those beaches free of obstructions and suitable for beaching boats, shall be included in the rendered data.
2. The following information (as a minimum) is to be obtained for jetties, wharves, marinas and ramps:
 - dimensions;
 - orientation;
 - depth alongside,
 - particular berthing or mooring arrangements (e.g. dolphins);
3. Where there is intensive recreational interest in an area, further details shall be obtained from the Harbour Master, Marina Manager or other authority. Any local navigational or statutory regulations or recommendations shall also be obtained.

4.8 Fresh Water Springs

The positions of any fresh water springs are to be fixed during normal surveying operations. These are to be reported in the ROS and rendered in the S-57 dataset.

4.9 Aids to Navigation

1. The characteristics of navigational lights, whether ashore, on beacons or floating marks, are to be carefully checked in the field and compared with the S-57 dataset provided by LINZ. Any changes are to be captured in the S-57 dataset.
2. Light floats and buoys shall be fixed in both their flood and ebb positions to determine the range of movement and the limits of drift. The mean position shall be shown in the rendered data.
3. When a mark is found to be sufficiently displaced as to be a navigational hazard, it is to be reported immediately by Hydrographic Note.
4. Where differences in the details are found, local authorities should be asked whether the changes are permanent. Discrepancies are to be forwarded in the reports or

by Hydrographic Note if considered more urgent. Any lights found to be unlit or to have significantly modified characteristics are to be reported immediately to LINZ by Hydrographic Note. To avoid ambiguity, the Light List publication and the International Number of the light are always to be quoted when reference is made to a listed light.

5. Describe how AtoNs (beacons, buoys, lights and sectors) were checked and positioned. If any new AtoN has been established it shall be fully described and the method of determining its position stated.

4.10 Photographic Views

1. Photographic views (aerial and/or terrestrial) should be utilised to show navigational hazards and significant bathymetric features when awash/dry.

2. Whilst NP100 specifically describes the methods to be employed for illustrating Sailing Directions, the same techniques should be applied to the illustrations in the ROS in order to assist the cartographer in interpretation of significant features in the survey area which are not appropriate to Sailing Directions. Thus panoramic views of a coastline to illustrate cliff lines and prominent features or to illustrate that certain charted features are not visible to the mariner, should be obtained in a similar fashion and rendered with the ROS.

4.11 Naming features

1. The New Zealand Gazetteer at <https://gazetteer.linz.govt.nz/> should be checked in the first instance to see if an undersea feature is already named, and if there is an existing name it should be used.

2. If a feature is not named in the New Zealand Gazetteer, every effort should be made to find out the locally used name and its spelling from local sources (these may include local authorities and iwi). The source of where the name was obtained from should be given in the Report of Survey (ROS).

4.11.1 Naming newly identified features

1. Newly identified undersea features may be provisionally named in the survey. The ROS is to indicate which are new names and provide brief reasons for choosing them.

2. When a feature has a locally used name its origin should be summarized in the ROS. New or locally known names may be included in the deliverables but should be shown in brackets to indicate their provisional nature.

3. The contractor is responsible for ensuring that any locally used name that comes to light, or new name that is used during a hydrographic contract is forwarded as a proposal to the New Zealand Geographic Board Ngā Pou Taunaha o Aotearoa (NZGB) for its consideration. Information on proposing an undersea feature name is at:

<https://www.linz.govt.nz/regulatory/place-names/propose-place-name/proposing->

undersea-feature-name. The criteria for naming an undersea feature is in the *Standard for undersea feature names* at <https://www.linz.govt.nz/regulatory/60000>

4.12 Sailing Directions and Amendments

(Ref. NZ Pilot NP51, Pacific Islands Pilot NP61, Pacific Islands Pilot NP62 and Antarctica Pilot NP9)

1. During the course of any survey, the relevant Sailing Directions shall be carefully examined and suggested amendments shall be included in the RoS. Notes for these amendments must be kept throughout the survey, as the need for them is realised, and the revised text shall be compiled immediately after the completion of work in the field, when every essential point is still fresh in the mind.
2. Familiarity with the content of Sailing Directions will ensure that the need for additional details, such as accurate positions, is addressed before the vessel leaves the area.
3. Sailing Directions are written by the surveyor as information supplementary to the processed data, but shall also be applicable, to the existing published chart.
4. It should be borne in mind that the revisers of Sailing Directions will use the published chart when examining the surveyor's proposed text. It follows that reference objects should, whenever possible, be common both to the chart and rendered data.
5. As a general rule the Sailing Directions applicable to a survey will be covered by only a few pages in the published volume, but care must be taken to check the general information in Chapter 1 as well as any of the appendices which may be relevant to the area being surveyed or to adjacent localities.

4.12.1 Amendments to Sailing Directions

1. The surveyor should always be prepared to be more expansive in the text than is likely to be necessary for the published book. The Navigation Specialist will then be able to get a fuller picture of the area and will be able to condense or revise the proposed amendments with more authority.
2. Surveyors should write amendments to the Sailing Directions in their own words whilst adhering to the following principles:
 - a. Treat the area in strict geographical sequence following the general direction of the published book unless this is obviously very illogical or inconvenient. In general, deal with matter in the order in which it will be sighted or used by a mariner arriving from seaward or taking passage along the coast.
 - b. Sailing Directions are intended as a brief for the stranger arriving at a place for the first time. Set out in words a methodical description of the area step by step. Emphasis should be placed on describing waterways rather than coasts, eliminating information from the text which is not directly relevant and which can be obtained from the published chart. Remarks should start with a general description of the area,

covering topography and landmarks, together with any other information of a general nature, such as tidal streams, affecting the entire area. Thereafter it should be broken down into sections, e.g. 10 to 30 miles, depending on the amount of information available, with the larger ports being treated as individual sections. Particular attention should be paid to information which is difficult or impossible to show in other records.

c. When amending an existing text it is important to realise that the Navigation Specialist needs to know the detail of the new information and that which has changed as well as that which is no longer correct and should be deleted. Additions shall be denoted by the use of *blue italics* and deletions shall be denoted by the use of ~~red strikethrough~~.

d. Important navigational marks are to be fully described in the Sailing Directions. Leading lines, recommended tracks, and measured distances are also to be fully described, and should include appropriate pilotage advice.

e. Whenever possible, any structure specifically mentioned in Sailing Directions should be illustrated by photographs (see Section 5.5.8) and general views. These are especially valuable in the approaches to ports, and along recommended leading lines.

f. Directions for channels, approaches and entrances to harbours should always be given just as an embarked pilot would advise a mariner when approaching for the first time. Such directions should have been used in practice, or obtained from local pilotage sources, and not merely written up from an inspection of the survey after leaving the area.

g. Ports and harbours must be fully described as an aide memoir. To avoid unnecessarily long descriptions of large ports it will often suffice if copies of port brochures and regulations are obtained and forwarded with the Sailing Directions. Attention is also drawn to Section 4.7.

h. Where applicable, details of several shoals in a given locality may be indicated by a general statement referring the reader to the chart, e.g. "Within 1.5 miles NNE of Cape Best a number of shoals exist, the positions of which can best be seen on the chart". It is most important that ambiguous and vague statements be avoided, e.g. "Another shoal lies a little further to the west".

i. Tidal streams, overfalls, and currents in the area should be described. There is no need to produce tidal stream tables that would result from observations and shown on some charts, but a semi-tabular layout is often possible and preferable to lengthy sentences in the text.

j. Metric units are to be used for depths, heights and distances on land, whilst distances at sea are to be given in nautical miles and decimals. Cables are not to be used.

k. Positions should be quoted to two decimal places e.g. 41°17'.20S., 174°46'.53E, (DD MM.MM).

4.12.2 Amendments to Other Publications

The following publications are also to be checked for any errors or omissions during the course of the survey. Proposed amendments are to be included in the ROS:

[New Zealand Nautical Almanac NZ 204,](#)

- i. [New Zealand Light List,](#)
- ii. [Annual notices to mariners ANTM.](#)

4.13 Other Survey Sensors and Platforms

4.13.1 Single Beam Echo Sounder (SBES)

For detailed requirements please refer to Single_Beam Echo Sounder specification, Annex A.

1. SBES is generally not to be used for LINZ-Special surveys. If SBES is to be used in LINZ-Special surveys then the circumstances of its use shall be approved by LINZ.
2. SBES shall be used in conjunction with SSS (see Section 4.13.2) for full bottom coverage, except when used for ground truthing in support of other full bottom coverage survey methodologies, e.g. SDB.
3. SBES must produce a digital record that is capable of being processed in an automated system.
4. SBES is to operate at frequencies capable of determining the first bottom return in depths less than 40m.
5. SBES is to continuously track the bottom in steeply shelving areas. Any issues tracking the bottom in steep areas are to be mentioned in the ROS highlighting the specific areas where there are issues.
6. Where the SBES has multiple frequencies then the highest frequency is to be operated and logged in depths less than 40m.
7. For calibration of SBES system and detailed requirements please refer to Single Beam Echo Sounder specification.

4.13.2 Side Scan Sonar (SSS)

1. The requirement to conduct a SSS search will be advised in the contract document.
2. SSS searches are to ensure a full bottom search of the survey area is achieved. Survey lines are to be spaced to ensure that the seabed directly under the transducer, and at least 50m beyond it, is ensonified by the adjacent sweeps. Where practical, adjacent lines are to be run in opposite directions.
3. Prior to commencing a SSS search, and regularly during its execution, confidence checks are to be made using known features. These confidence checks must be documented in the Quality Assurance Report (see Section 5.3).
4. Sonar searches must be conducted at speeds at which all features of the order of the survey and greater in cross-section should produce a meaningful 'return'.

5. The optimum height at which to keep the fish above the seabed is equivalent to 10% of the range scale in use, i.e. using the 150m range scale the fish should be flown 15m above the seabed.
6. Further guidance on the use of SSS to detect features can be found in Chapter 4, Section 2.3, C-13 Manual on Hydrography (see Reference Documents).

4.13.3 Satellite Derived Bathymetry (SDB)

1. Use of Satellite Derived bathymetry (SDB) may be permitted. The contractor shall demonstrate how it will be utilised, whether it will meet the required standard of survey and/or how it will add value to the final product. An overview of the methods used and a full assessment of the errors associated with the technique shall form part of this demonstration.
2. For detailed requirements please refer to Satellite Derived Bathymetry specification, Annex B.

4.13.4 Airborne Laser Bathymetry (ALB)

1. Use of ALB is permitted. The contractor shall outline how the ALB system will meet the requirements in Table 1. In particular how the system meets the feature detection requirements. The expectation is that the contractor will demonstrate the feature detection ability of the system at the outset of the survey. One approach to this is to check over an existing sub surface shoal at the outset of the survey and repeat at regular intervals during the survey. Least depths and positions of the feature shall be determined on each pass and reported on.

5 Deliverables

All digital data obtained during the course of the survey is to be rendered. This includes raw and processed datasets.

5.1 File naming

File naming for all deliverables will adhere to the following convention:

- Filenames will contain a series of elements that give information about the file contents
- These elements will be separated by an underscore
- Elements will only contain letters and numbers
- Filenames should not contain spaces
- Filename will finish with the conventional extensions (.jpg, .tif etc)
- Use NA (not applicable) to represent a null value for mandatory elements
- Abbreviations can be used for block reference/platform name/geographic locale as long as they are meaningful and unique.

5.1.1 Survey Lines

1. The required survey file naming convention is described in the table below.

Table 2 Survey line naming convention

Elements	Description
Block reference	The survey block/subarea name i.e. A
Date	Survey date (Year, month, date)
Time	hour, minute, second
Platform name	Name of platform (abbreviated to ...)
Line Type	Mainline = 'M' Crossline = 'X' Calibration lines = 'C' Infill = 'I'
Survey session number	Is the sequential survey session number

Example: A_20180407_075102_Aurora_M_1342

2. All these are assigned automatically by the acquisition software. The survey line numbers used must be continuous/sequential and must not be reset during the survey.
3. Any deviation from this naming convention shall be approved by LINZ prior to the dataset being rendered.

5.1.2 Surfaces

For all gridded surfaces, following simplified naming convention should be used:

Table 3: Surface naming convention

Element	Description
HSnumber	The Hydrographic Specification survey title for the survey i.e. HS60
Sounding source	MB = multi beam BL = Bathymetric Lidar TL = Terrestrial Laser Scanner SB = single beam CB = combined surface from multiple sensors
Geographic Locale	Free text name of the area e.g "Mercury Bay". For larger areas it may be necessary to refine this further eg "Mercury Bay North".
Bin size	Grid resolution in metres for raster data and XYZ 05 = 0.5m, 1 = 1.0m, 5 = 5.0m, variable resolution = VR
Surface type	cu = CUBE sd = Shoal Depth True Position
Horizontal datum	Projection applied to grid, e.g. NZGD2000, WGS84, WGS84UTM01S, ITRF2008
Vertical Datum	Vertical datum of gridded data PredLAT = Predicted LAT ObsLAT = Observed LAT MSL = Mean Sea Level Ellip = Ellipsoid

Example: HS60_MB_MercuryBay_05_sd_UTM60S_ObsLAT.csar

5.1.3 Ancillary information (Point, Line, Area)

For ancillary files (in S-57 format), following simplified naming convention should be used:

Table 4: Ancillary files naming convention

Element	Description
HSnumber	The Hydrographic Specification survey title for the survey i.e. HS60
Geographic Locale	Free text name of the area e.g "Mercury Bay". For larger areas it may be necessary to refine this further eg "Mercury Bay North".

Example: HS60_MercuryBay.000

5.1.4 Miscellaneous

Any products specified should follow the naming convention in the table below unless specified otherwise.

Table 5: Miscellaneous files naming convention

Element	Description
HSnumber	The Hydrographic Specification survey title for the survey i.e. HS60
Geographic Locale	Free text name of the area e.g "Mercury Bay". For larger areas it may be necessary to refine this further eg "Mercury Bay North".
ID (if applicable)	Identifier like a block number
Date (if applicable)	Survey date (Year, month, date)
Time (if applicable)	hour, minute, second
Product	PCL – Classified Point Cloud SVP – Sound Velocity Profile IMG - Aerial Imagery
Horizontal datum	Projection applied to grid, e.g. NZGD2000, WGS84, WGS84UTM01S, ITRF2008

Example: HS60_Mercury Bay BlockA_PCL_WGS84.csar

5.2 Folder structure

Deliverables shall follow the appropriate data directory structure as described in the table below. If a folder is intentionally left empty, place a Readme.txt file in the folder stating as such.

Table 6: Folder structure

Folder name	Content
1 Raw	All raw data recorded in self-explanatory folders (i.e. Raw sonar files, SVP, motion data, CTD data, GNSS data)
2 Calibration	HIPS or Qimera project folder including all relevant calibration data (i.e patch test files, reference surface, backscatter calibration lines)
3 Processed	HIPS or Qimera project folder including all products (i.e. survey lines, bathymetry grid, mosaics, ancillary information, charts, imagery)
4 Reports	All reports specified (i.e. weekly report, incident report)
5 TDP	As specified
6 GDP	As specified in <i>Specifications for Geodetic Control of Hydrographic Surveys</i> .
7 QADP	Signed calibration records Checklists Log sheets Field records
8 Imagery	Photographs linked to ancillary information i.e. views, aids to navigation Aerial imagery collected during survey




5.3 Reporting

1. **Quality Assurance Report** – is a live document which captures information on the mobilisation and calibration of the sensors. It is intended to be a single source of information on the sensor setup and checks. Results of all sensor calibrations and checks from mobilisation to demobilisation are entered into the document as the project progresses. The first revision of the Quality Assurance Report is to be rendered to LINZ 14 days after the mobilisation has been completed.
2. **Weekly Report** – is used primarily for tracking project progress, particularly in the data acquisition phase. The report should include any incidents, equipment issues or

weather downtime. The requirement to report weekly may be relaxed in agreement with LINZ. Considerations include work in remote areas with limited communications or where the project enters the processing and reporting phase.

2. **Monthly Finance Report** – is to aid in the financial reporting requirements of LINZ. The report shall contain a breakdown of the costs of the project and align with the invoice for the month. It should also highlight the current progress which is being billed, as well as projected future costs.
3. **Report of Survey (ROS)** – details the operations and the findings of the survey.
4. **Tidal Data Pack (TDP)** – details the establishment, calibration and operation of each tide station and describes how SD was determined. An interim TDP may be rendered to LINZ for review after calibration and geodetic (levelling) activities have been completed.
5. **Geodetic Report** – includes all geodetic work undertaken during the tides and geodetics phase of the survey. The interim geodetic report may be rendered to LINZ for review after the geodetic work has been completed
6. Table 2 provides templates for the various reports. These are to be used as a guide to the content of the reports and may be incorporated into corporate templates as long as they follow the same outline.

Table 7: Overview of required reports and templates

Title	Template
Quality Assurance Report	 Quality Assurance Report template v1.0.c
Weekly Report	No template available
Monthly Finance Report	No template available
Report of Survey (ROS)	 Report of Survey (ROS) template v1.0.c
Tidal Data Pack (TDP)	 Tidal Data Pack (TDP) template v1.0.c
Geodetic Report	No template available (as per Specifications for Geodetic Control of Hydrographic Surveys. New Zealand Geodetic Office, LINZ. September 2018)

5.4 Metadata

1. Metadata for each survey area and sensor type within each area should be provided in CSV format using the following table. Each bathymetric surface shall have its own line entry in the spreadsheet. Surfaces created from multiple platforms or technologies shall be indicated by entering multiple attribute values within the spreadsheet, i.e. 'TECSOU' = 'found by multi-beam, found by laser'.



Metadata v1.0.xlsx

Table 8: Survey metadata

Item	Attribute	Attribute values
Survey Authority	SURATH	Text
Date Start	SURSTA	Datum
Date End	SUREND	Datum
Position Accuracy	POSACC	Number
Sounding Accuracy	SOUACC	Number
Gridded surface resolution	grdres	Number
Gridded Surface Method	grdmtd	SDTP/CUBE (or statistical equivalent)
Bathymetric Sensor frequency	mbesfr	Text
Bathymetric Sensor model	mbesmo	Text
Survey Information	surinfo	Text
Horizontal Datum	HORDAT	List (S57)
Technique of sounding measurement	TECSOU	List (S57)
Platform Name(s)	planam	Text
Line spacing	linesp	Text
Render scale	rensca	Number
Technique of position	tecpos	Text
Technique of seafloor reflectance	tecpsc	0 - Not collected

		1 - Side Scan Sonar, 2 - MBES seafloor, 3 - MBES water column, 4 - other
Seafloor reflectance processed	bscprs	1 - Yes, No
Sonar System used	sosuse	Yes, No
Calibration line available	callav	Yes, No
Full Sea coverage achieved	fscach	True False
Category of temporal variation	tmpvar	Extreme event Likely to change and significant.. Likely to change but ... Unlikely to change unassessed
Features detected	feadet	True False
Least depth of detected features measured	ldodfm	True False
Significant features detected	Sfedet	True False
Size of features detected	sizfea	Text

5.5 Acquisition Data and Products

The table below gives an overview of required deliverables and the respective file format. A detailed description of each item can be found in the following sections. Unless otherwise stated all depths and heights are to be rendered to two decimal places except for raw data.

Table 9: Overview of required deliverable formats

Required Deliverables	Format
Aerial imagery	ECW or GeoTIFF (LZW compression is preferred)
Aerial Imagery Index	GIS polygon file (e.g. shp)
Ancillary information	S-57 (all mandatory fields populated)
Bathymetric surface (BASE)	CSAR and HDF5 (e.g. BAG) CSAR (Depth, Density, STDev, Uncertainty) BAG (Elevation, Uncertainty, <i>Digital Signature*</i>)
Calibration and check lines	CARIS HIPS & SIPS project, Qimera project or GSF (MBES) and LAS (LiDAR) + ASCII CSV (correction values)
CTD Profiles	ASCII CSV, including date/time/lat/long
Flight trajectories (tracks)	GIS vector file (e.g. shp)
Geodetic	Refer Section 6.2 <i>Specifications for Geodetic Control of Hydrographic Surveys</i>
Marine Laser Scanner Point Data	LAS
Photographs	JPEG
Processed bathymetry (all pings)	CARIS HIPS & SIPS project, Qimera project or GSF (MBES) and LAS (LiDAR) + ASCII CSV (correction values and sound velocity profiles)
Raw files	proprietary
Seafloor reflectance (unprocessed)	XTF (unless otherwise specified)
Seafloor reflectance (processed)	GeoTIFF (LZW compression is preferred)
Tidal streams	ASCII CSV
Sea level data	ASCII CSV
Water column reflectance (processed)	ASCII CSV (XYZ) file of features (e.g. wreck)

5.5.1 Aerial imagery

1. The aerial photography shall be metric digital and coincident with the survey data.
2. The aerial photography shall be corrected using a georeferenced solution although the rectification process may not necessarily follow a complete orthorectification process workflow.
2. For all aerial imagery products (SDB/LiDAR), index files shall be provided that show the extents of each image/tile. These shall be delivered in shapefile format and have the attribute field associated to the delivered file name.
3. The collection of aerial photography will be secondary to the collection of LiDAR data. Whilst the atmospheric conditions shall take into account the quality of the aerial photography it shall not do so at the expense of LiDAR capture.
4. The LiDAR aerial photography should be supplied as 1x1km tiles for the extent of the data acquired. Annex B provides specifications for SDB imagery.
5. A resolution shall be better than 25cm.
6. The spectral range of the imagery shall be rendered with the maximum number of bands supported by the photographic equipment.
7. Colour balancing and colour matching between frames is expected.
8. Contrast and brightness of each image shall be adjusted to minimise the colour variation between photos and photo runs. Colour balance across the whole mosaic shall be optimised to allow quality colour discrimination whilst still providing the best possible tonal match across the image.

5.5.2 Ancillary Information

1. Ancillary information covers all information and data collected in the field which can be reflected on a chart.
2. The following information is to be depicted as a minimum:
 - Coastline with surveyed topographic detail (which is the line of MHWS)
 - Conspicuous objects
 - Coverage of side scan sonar if applicable
 - Eddies and overfalls
 - Fixed and floating aids to navigation, light characteristics and sectors
 - Leading lines or recommended tracks (including true bearing of leading lines)
 - Limits of sounding datums used
 - Nature of the bottom, including seabed sample locations
 - Obstructions and identification number
 - Recommended alternatives to unsuitable leading lines or recommended tracks
 - Rocks

- Significant Bathymetric Features and identification number
 - Significant charted differences and identification number
 - Spoil grounds, dredged areas and sand-wave areas
 - Cables and pipelines
 - Tidal streams and currents
 - Wrecks and identification number
3. The sounding detail within the survey area as shown on the ENC published by LINZ is to be critically examined and any significant differences reported. In particular a comment is required for any charted dangers that were not discovered during the survey, or where the least depth found over a danger during the survey is deeper than charted.
 4. Describe the condition and distinguishing characteristics of all items mentioned.
 5. Uncharted features – Describe all new features not addressed and describe the condition and distinguishing characteristics of all items mentioned
 6. Indicate as an attribute which sensor was used for collecting the Objects (e.g. MBES, Laser scan). Also, the attribute values “new” and “change” are to be used for describing objects.

5.5.3 Bathymetric Surface

1. The final surface is the result of a combination of data sources, algorithmic treatment and manual inspection, used to derive the best representation of the seafloor depth at the prescribed survey order, as judged and endorsed by the Surveyor-in-Charge.
2. The grid resolution is defined by the specified standard.
3. In the event that a shoal biased regular grid is rendered, it shall contain metadata layers indicating the reduced position, THU and TVU of the shoal sounding that contributed to the height of the grid node. The methodology used to remove or designate soundings when preparing a shoal biased dataset must be systematically applied and fully described in the report of survey. The contractor may use CUBE (or other statistical gridding approaches) with approval from LINZ. In such circumstances, the contractor shall demonstrate in their proposal how they intend to control, verify and/or intervene in the performance of the gridding algorithm to ensure that the resulting surface is, in the professional opinion of the SIC, an appropriate description of the seafloor for the purpose of nautical charting. Irrespective of the surface generation method, a layer reflecting the shoal, mean and deep values of the data shall also be provided, along with a layer indicating data density, standard deviation and where applicable, computed uncertainty (in the case of CUBE and similar uncertainty-based algorithms). The contractor shall demonstrate that the uncertainty and standard deviation at each surface node are internally consistent and validated with empirical quality indicators, such as crossline comparison. Any inconsistency shall be described and explained by the contractor in the report of survey.

4. Where CUBE or other statistical algorithm processing is proposed, parameters shall be described in detail together with examples illustrating how ambiguities have been resolved. If a CUBE surface is to be used the Contractor shall ensure that the acquired data meets the data density requirements to effectively and accurately represent the seabed at the agreed grid resolution.
5. The SIC shall ensure that all data has been correctly processed and that appropriate designated soundings have been selected.
6. The SIC has the responsibility to review the surface and ensure that it truly reflects the conditions in the survey area. Data shall be reviewed including selecting designated soundings which override the gridded surface and force the model to recognize the shoal sounding. This is especially important in the case of small diameter objects, depending on the resolution of the gridded surface, where it is unlikely that the surface will capture the absolute least depth, e.g. small rocks.
7. For CSAR surface deliverables the following attributes/layers shall be included:
 - position and depth
 - 95% statistical uncertainty estimation for position (if applicable)
 - 95% statistical uncertainty estimate for depth
 - Density: number of soundings that contribute to a grid cell/node
 - Standard Deviation of the soundings that contributed to the grid cell/node
 - Shoalest sounding from the set that contribute to a grid cell/node
 - Deepest sounding from the set that contribute to a grid cell/node
 - Mean of the set of soundings that contribute to a grid cell/node

If using CUBE, the following additional attributes/layers shall be included:

- Hypothesis count
- Hypothesis strength
- User nominated (or custom hypotheses)

8. For BAG surface deliverables the following attributes/layers shall be included:

- Elevation – depth (BAG are used for topographic datasets as well)
- Uncertainty – 95% statistical uncertainty estimate for depth.
- Digital Signature of SIC

If using CUBE, the following additional attributes/layers shall be included:

- Hypothesis count
- Hypothesis strength
- User nominated (or custom hypotheses)

5.5.4 Calibration and check lines

1. Data collected and used during LINZ mob visit is to be delivered as a project in either CARIS HIPS & SIPS or QPS Qimera. Non CARIS or QPS users may submit the processed point cloud (soundings) in GSF format.
2. The project should contain the following as a minimum:
 - Processed reference surface
 - Patch Test data files with intended angular offset values applied. Where GSF files are rendered, angular offsets shall be set to zero and outliers removed.
 - Reference surface manoeuvring lines with angular offsets applied.
 - Box-in lines with angular offsets applied, and computed statistical reliability of both the horizontal position and depth measured for the feature
 - SVP, predicted tides, delayed heave for lines over reference surface
3. For the draft and final deliverables any additional calibration lines and check lines are to be included in the project.
4. Cross lines are to be provided uncleaned but with all correction values applied.

5.5.5 Flight trajectories (tracks)

1. All flight trajectories used for the capture of the delivered LiDAR data.
2. The shapefile tables must include the date of capture, local start time, local end time and which reference station was used for each trajectory

5.5.6 Photographs

1. All photographs are to be provided in JPEG format.

5.5.7 Processed bathymetry

1. The raw data with corrections for vessel motion, position, tide, draught, and sound velocity applied. All soundings are to be included in the dataset. Any soundings filtered or edited as erroneous are to be flagged as 'rejected', but not deleted from the dataset.
2. All data is to be delivered in a CARIS HIPS & SIPS or QPS Qimera project. Non CARIS or QPS users may submit the processed point cloud (soundings) in GSF format.
3. The project may contain the following datasets:
 - Processed bathymetry data (soundings and surfaces)
 - Classified point cloud (LiDAR)
 - Navigation
 - Swath and beam number (MBES)
 - Position and depth
 - 95% statistical uncertainty estimation for position
 - 95% statistical uncertainty estimate for depth
 - Motion

- Seafloor reflectance
- Sound velocity profile (MBES)
- Tide
- True heave
- Vessel configuration file
- Water column reflectance
- Waveform packet data (LiDAR)

5.5.8 Multimedia

1. Digital images should be used to illustrate many aspects of surveying data, e.g. BMs, leading lines, views for Sailing Directions, navigational aids etc.; this includes aerial imagery collected in the field as well. All digital images should have a suitable resolution to assist in further identification of features. Images should be at least 300dpi and taken with a camera capable of 4 megapixels. Any images should be suitably focussed so that the object of interest is sharp in detail.

2. In the case of photographic views for Sailing Directions, the following additional information is to be supplied:

- Date and time (UTC)
- Position of the camera in latitude and longitude (+/-0.1 mile)
- Bearing and distance of a prominent charted feature (to within +/-0.5° and +/-0.1 mile, respectively if possible, especially if a leading line or similar view is being illustrated)
- Other features, charted or uncharted, identified as described below
- Height of camera above sea level
- Type of camera

3. Where it is desired to draw attention to a particular feature on an image it may be accurately marked on a duplicate of that image

5.5.9 Raw files

100% of all data collected, no corrections applied but gross errors removed.

5.5.10 Seafloor reflectance

1. Backscatter data shall be provided as a mosaic in high resolution GeoTIFF format, the finest resolution applicable to the backscatter data collected within the mosaic area. If a survey area is too large to create one contiguous mosaic, then an individual mosaic for each block should be created.

2. The backscatter mosaic should be a representation of the backscatter intensity across the survey area. Any artefacts (e.g. nadir striping, poor data) and backscatter changes within homogeneous areas should be corrected for. The resolution of the backscatter mosaic shall be the best achievable.

5.5.11 Water column reflectance

Any reflectance collected from the water column should be provided.

Annex A: Single Beam Echo Sounder Operations

Single Beam Echo Sounder Uncertainty Requirements

1. Three orders of survey (LINZ-Special, LINZ-1 and LINZ-2) are used by LINZ to identify the uncertainty criteria whenever use of a SBES is specified. It should be noted that SBES will not meet the full bottom search and target detection requirements of the various standards of survey.
2. The maximum allowable depth uncertainty for LINZ SBES surveys is stated as a function of multiples of 1.0, 1.5, and 2.0 times the IHO Special Order depth uncertainty for reduced depths. The maximum allowable uncertainties associated with each order are detailed in HYSPEC, Section 1.
3. The contractor may choose to model apriori uncertainty using the following approach. When the individual standard uncertainty of the various elements determining the uncertainty of a sounding have been assessed, they are to be combined into the total standard uncertainty (z) of a sounding by the basic combination of uncertainties formula. The co-variance between the elements is considered to be nil. When assessing the uncertainty of SBES data, the below method may be used where the individual elements are summed. It is important to note that the method below assumes the co-variance between all individual elements to be zero.

$$z^2 = a^2 + b^2 +$$

where:

z is the total standard uncertainty,

a and b etc. are the standard uncertainties of individual elements.

Table 10: Example of a Table of Total Propagated Uncertainty

Source of Error	At 200m	At 100m	At 50m
Draught Setting	0.1	0.1	0.1
Variation of Draught	0.05	0.05	0.05
Velocity of Sound	0.27	0.13	0.07
Spatial Variation in SV	0.13	0.07	0.03
Temporal Variation in SV	0.13	0.07	0.03
Application of Measured SV	0.13	0.07	0.03

Depth Measurement (Inst. Acc)	0.1	0.1	0.1
Heave	0.05	0.05	0.05
Settlement and Squat	0.1	0.1	0.1
Roll and Pitch	0.7	0.35	0.17
Tidal Readings	0.06	0.06	0.06
Co-tidal Corrections	0.79	0.79	0.79
Tide Corrections	0.01	0.01	0.01
Total Propagated Uncertainty	1.16	0.94	0.84

Single Beam Echo Sounding Equipment

1. If two systems are used, the preferred system is to be nominated "Primary".
2. The system must produce a digital record that is capable of being processed in an automated system.
3. The system is to operate at frequencies capable of determining the first bottom return in depths less than 40m.
4. The system is to continuously track the bottom in steeply shelving areas. Re-runs may be required in the opposite direction if bottom tracking is lost.
5. Where the system has multiple frequencies then the highest frequency is to be operated and logged in depths less than 40m.

Calibration of Single Beam Echo Sounding Equipment

1. Echo sounders must be calibrated precisely and adjusted for draught setting, index error and sound velocity. Allowance must be made for vessel squat.
2. Index error and draught setting (TX) are to be determined from a shallow bar check and corrected for by adjusting the draught control on the echo sounder recorder. This method ensures that the echogram record can be directly related to the digital record when checking and validating data.
 - a. The spacing of the marks on the bar lowering lines should allow for the appropriate mark to be placed on the sea surface when bar-checking, and not at the deck-edge.
 - b. The shallow bar check should be carried out at the start and finish of SBES operations.
 - c. Between bar checks the echo sounder draught setting should be adjusted for known changes in the draught of the vessel. These changes can be determined

- by waterline measurements to a particular offset on the vessel and verified at the bar-check.
- d. When a bar-check is not possible due to sea state, etc., the transmission line should be set at the depth of the transducers below the waterline or determined by another method.
 3. For surveys in depths below 30m, the SV as determined by probe is to be verified during the mobilisation by deep bar-check.
 4. Where an echo sounder has multiple frequencies, each frequency is to be calibrated independently in order to allow for the different response times of the transducers. When such echo sounders are used, the depths logged in digital form are to be those arising from the highest frequency used, to ensure that the highest resolution is maintained.
 5. Vessel squat effects from minimum speed to survey speed, and over a range of water depths, are to be determined from carefully controlled trials. Squat is to be applied to all measured depths where the effect exceeds 0.05m.
 6. The lengths of bar-check lines may change significantly due to wear, stretch, temperature and the effects of corrosion due to the ingress of salt water. Except where the bar is the same length as the beam of the craft at the position of the echo sounder transducers, the bar check lines will not hang vertically in the water, and allowance for this must be made when they are constructed to ensure that the markings on the lines are such that the bar will be lowered to the correct depth below the sea surface.
 7. The lengths and markings of bar-check lines must be verified at mobilisation and demobilisation.

Speed Whilst Sounding

1. When determining the speed at which to conduct sounding the surveyor must consider the depth of water being sounded and the pulse repetition rate of the echo sounder. High speed combined with a slow pulse repetition rate may lead to small but significant features being missed, particularly in shallow water. The surveyor is to adjust the ping rate and speed to achieve beam overlap in successive soundings.
2. A general formula for calculating the depth at which five pulses should insonify a feature of given size at different speeds is:

$$D = \frac{(S \times 1852/3600 \times 5/\text{pr}) - t}{2 \tan (\phi/2)}$$

Where:

D = least depth of detection (metres below transducers)

S = speed in knots

t = along track dimension of features to be detected (metres)

ϕ = echo sounder's beam width (fore and aft) in degrees.

pr = pulse repetition rate (pulses per second (Hz))

3. As a normal rule, the echo sounder should be operated in the shallowest range scale possible and at the highest frequency possible (and therefore the highest pulse repetition rate). In very shallow water, or on a steeply sloping seabed or coral atoll, it may still be necessary to reduce speed.

Direction of Single Beam Echo Sounder Sounding Lines

1. When sounding is not being undertaken concurrently with a SSS sweep, the lines should generally be run approximately at right angles to the trend of depth contours if these have been established, or at right angles to the coast when working near the shore.
2. In the vicinity of jetties or wharves, lines are to be run parallel to the line of the berths to indicate where shoal depths may extend from them.
3. Additional lines of soundings are to be run along the line of recommended routes and leading lines identified on the survey ground.
4. In many cases, where an anchorage exists in a coastal survey, it may be desirable to differentiate it from the surrounding work by running additional lines of soundings. Any indentation of the coast which may afford an anchorage in times of stress, or any headland which vessels will pass close to on normal passage, must receive special attention.
5. When working in areas where the existence of sand waves is known or suspected, sounding lines should be run at right angles to the line of the crests to avoid the possibility of missing the crest-lines should soundings be run parallel to, or along, the troughs.

Single Beam Echo Sounder Cross-Lines

1. Cross-lines are to be run at angles of 60° to 90° to the main track-lines.
2. Cross-lines are to be run at intervals no greater than 20 times the line interval of the main track-lines.
3. Cross-lines should also be run whenever the SIC is not satisfied that the normal sounding has revealed all significant features, as well as in sand wave fields, near headlands, in bays and along channels and recommended routes.
4. A statistical comparison of raw data between the main survey track and the cross-line is to be undertaken to ensure that the uncertainty requirements of the order of the survey are met. A summary of the statistics and definitive statement about the results are to be included in the ROS.
5. Whenever cross-lines reveal a discrepancy in depth exceeding twice the sounding uncertainty specified in the contract, the discrepancy is to be investigated, resolved if practicable, explained and detailed in the weekly progress report.

Examinations with Single Beam Echo Sounder

1. Some shoals found during sounding or inter-lining will require detailed examination to determine the least depth. Unless specified in the contract for the elimination of doubtful data, the decision to conduct an examination lies with the SIC. Consideration must be given to the position and probable least depth of the shoal, the seabed topography and the draught of vessels operating in the area.
2. During examinations, the vessels speed must be sufficiently slow to ensure that all pinnacles are located.
3. Line spacing during examinations must be determined by considering the footprint of the sounder's beam and the probable extent of the shoal. At times it may be necessary to run lines as little as 5m apart.
4. The surveyor should have available a predicted tidal curve so that the least depth can be recognised when found. The surveyor should keep a tally of the least depth and its position on each line so that the approximate shape of the shoal can be established.
5. When the least depth has been found a hand lead-line is to be dropped on it to confirm the depth and obtain a bottom sample where possible. If a diver is available the lead can be held on the shoalest point, and a bottom sample and description of the shoal can be obtained. In many cases the only positive means of establishing the least depth over a rock pinnacle or wreck is by use of a wire drift sweep or by divers.
6. Where diving or wire-sweep is not possible, the least depth is to be obtained by saturation sounding. The required line spacing is to be calculated from the echo sounder beam width and general depths in the area, allowing an overlap of at least 25% between lines of sounding.

Annex B: Satellite Derived Bathymetry Specification

Imagery

- avoid capture during periods of heavy smoke haze
- calm seas and clear water
- avoid capture during periods of high turbidity
- Recording geometries should avoid sunglint and sunglitter effects on the water surface
- avoid capture during periods of high cloud/fog cover, more than 10% cloud cover over the marine area of interest is unacceptable. The marine area of interest extending from the high waterline to the SDB extinction depth (15-20m contour)
- avoid capture during times of flooding. Capture should be done at times of base flow in areas with floodplains and wet lands
- There is no tidal restriction on data acquisition. Consideration shall be given to the state of the tide and its effect on turbidity.
- Strong wave activities with whitecaps shall be avoided

Orthorectification - Basic level satellite imagery is usually referred to the WGS84 ellipsoid. Unless fully orthorectified, imagery acquired off-nadir will demonstrate increasing horizontal positional errors with increasing elevation – and in offshore areas with increasing depth – away from the reference surface. To mitigate this error, imagery should be appropriately geo-processed to refer to a geoid equipotential surface before deriving bathymetry. Higher levels of imagery such as Level OR2A of image processing may remove the need to correct for this.

Positioning

1. The horizontal accuracy of all depths and positions shall be 5m circular error at the 90% confidence level without ground control. If ground control is used then the allowable horizontal error is 2m or one pixel width.
2. Horizontal ground control is required during processing to improve the positional accuracy. If MBES and LIDAR data is available then this should be used to improve and assess the accuracy of the imagery and calculated bathymetry
3. Positions of depth points are to be horizontally corrected to account for view-angle geometry and refraction effects.

Bathymetry

1. Extinction Depth – the contractor shall carefully select an extinction depth. This is the depth where bathymetry can no longer be derived (optically deep) or where the uncertainty in the derived bathymetry becomes too unreliable. The extinction depth will depend on the quality of the input imagery. An explanation of the selected extinction depth shall be included in the ROS.
2. SDB depths are a measure of observed path length from surface to seabed, as such off-nadir satellite imagery will be subject to errors combining diagonal view angle and refraction through the water surface. Both factors will need to be accounted for to derive the correct depth. The contractor shall describe how this correction was made in the ROS.
3. Where possible SDB shall be assisted by ground truthing. Existing bathymetric datasets shall be used in the processing and quality control of SDB data where they are available. The underlying uncertainty in the “ground truth” datasets shall be considered when these datasets are used.
4. The contractor shall provide an assessment of the horizontal and vertical accuracy of the derived depths. A full explanation of how these derived accuracies are to be included in the ROS.
5. Vertical uncertainty values are to be provided for each depth measurement. The contractor shall outline the approach taken to calculate uncertainty values in the ROS
6. The density of the depth data shall be the same resolution as the input image (accounting for minor differences due to refraction and diagonal view angle)
7. Coverage - Full seabed coverage should be achieved from the low waterline to the extinction depth (ie the optically shallow area). This may be limited in areas of cloud cover or vessels/onstructions where there are expected to be gaps in the data
8. Data cleaning - All systematic errors and obvious outliers shall be removed from the delivered dataset. This includes:
 - areas where false depths are automatically derived from clouds/vessels in the image
 - false depths over dry land
 - false depths in deep water beyond the extinction depth
 - areas of localised turbidity
9. Depths shall not be interpolated to fill holes in the dataset
10. Data Processing - Data processing of SDB shall include but not be limited to the following steps:
 - Data import & conversion, quality inspection, radiometric calibration
 - Land-Water masking
 - Aerosol retrieval, atmospheric & water surface correction
 - Correction for adjacency effect

- Optical properties analysis
- Retrieval of water constituent concentrations
- Coupled retrieval of in water optical properties (IOPs), atmosphere and depth
- Analysis of main sea bottom albedo types
- Creation of vertical and horizontal uncertainty information. Apply the client-provided and/or available in-situ data for validation purposes.
- Adjustment of water depth to the required vertical datum.

11. Full details of the processing involved in each step shall be included in the ROS. The contractor shall provide any intermediary datasets from each stage of the process if required.

12. Accuracy Requirements – at the time of writing it is likely that SDB vertical uncertainty will exceed all of the LINZ orders contained in section 1.1. More SDB centric accuracy requirements are outlined below:

Vertical Uncertainty

1. $\leq \pm 0.5\text{m} \pm 10\%$ depth 90% confidence interval where in situ measurements are provided
2. $\leq \pm 1\text{m} \pm 15\%$ depth. 90% confidence interval where no calibration exists

Horizontal Uncertainty

1. $\leq \pm 2\text{m}$ or within one pixel value. In case Ground Control Points
2. $\pm 5\text{m CE90}$ (in case of no ground control points)

Tides

All depths are to be reduced to sounding datum. The contractor shall outline the method used for tide reduction and outline the uncertainty involved in the reduction. All methods are to be outlined in the ROS.

SDB Deliverables

1. All original satellite data is to be rendered in the deliverables, this includes:
 - Raw images
 - satellite orientation
 - Rational Polynomial Coefficients (RPC) files
 - Ephemeris data
 - All imagery is to be provided in georeferenced GeoTIFFs. As mentioned earlier in HYSPEC 2.0 the imagery must be accompanied by an index shapefile showing the extents of each image.

2. Bathymetric Point Cloud deliverables - Two sets of derived bathymetry products are to be delivered, these include:
 - One set to represent the vertical water depth at time of image acquisition
 - One set depicting depths reduced to chart datum using tide data or separation model
3. Bathymetric point clouds are to be cleaned, ungridded and provided in ASCII XYZ format.
4. Bathymetry Gridded - 32bit floating point GeoTIFF or BAG. Grid resolution is dependant on the resolution of the imagery.
5. In conjunction to the bathymetric information the associated uncertainty of each derived point is to be provided as an extra attribute for each depth. This is also to be included in an ASCII XYZ format. This is point data therefore there is no requirement to return uncertainty for the gridded dataset.