www.searchmesh.net

Title:	**Recommended operating guidelines (ROG) for swath bathymetry**
Author(s):	Alan Hopkins
Document owner:	Alan Hopkins
Reviewed by:	Janine Guinan (MI) 07/09/07
Workgroup:	n/a
MESH action:	2.1
Version:	1.1
Date published:	Not Published
File name:	Swath Bathymetry ROG .doc
Language:	English
Number of pages:	20
Summary:	The document provides an overview of the different swath bathymetry systems employed for seabed mapping. Also included are details relating to survey operations and calibration tests for swath bathymetry systems.
Reference/citation:	n/a
Keywords:	Multibeam echosounder, interferometric, calibration
Bookmarks:	
Related information:	

Change history		
Version:	**Date:**	**Change:**
1	23/01/07	Initial version of document

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE

Recommended operating guidelines for swath bathymetry

1. Methodology

A swath bathymetry system is one that is used to measure the depth in a line extending outwards from the sonar transducer. Systems acquire data in a swath at right angles to the direction of motion of the transducer head. As the head moves forward, these profiles sweep out a ribbon-shaped surface of depth measurement, known as a swath (Figure 1).

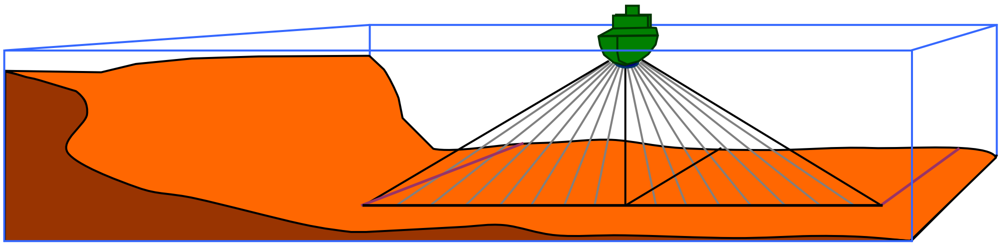


Figure 1. Swath sounder sonar system swathe.

Current swath bathymetry systems utilise two differing technologies to achieve bathymetry measurements across a 'swath' of the seafloor:

1. Beam forming (Multibeam echosounders [MBES])
2. Interferometric or phase discrimination sonars.

Both of these techniques have their merits; however, the same end results are achieved.

1.1 Multibeam echosounder systems

Multibeam echosounders (MBES) collect bathymetric soundings in a swath perpendicular to the ship track. This is done by electronically forming a series of transmit and receive beams in the transducer hardware which measure the depth to the seafloor in discrete angular increments or sectors across the swath (Hughes-Clarke *et al.* 1996). Various transmit frequencies are utilised by different MBES systems depending on the seafloor depth. For example, low frequency (12 kHz) systems can collect swath soundings at full ocean depths, many up to 10,000 m. In contrast, high frequency MBES systems (300+ kHz) are utilised for collecting swath bathymetry in depths of 20 m or less. The range of systems typically used is detailed in Table 1. For a more detailed description refer to the Review of Standards and Protocols for habitat mapping (http://www.searchmesh.net/default.aspx?page=1442).

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE

Table 1. Typical multibeam swath systems.

Company	Model	Frequency (kHz)	Max Depth Range	Swath Coverage
Reson	Error! Hyperlink reference not valid.	100 kHz	1 km	150°
Reson	SeaBat 7125	400 kHz	600 m	128°
Reson	Error! Hyperlink reference not valid.	12 kHz or 24 kHz	15 km	150°
Reson	SeaBat 8101	240 kHz	300 m	7.4 x water depth
Reson	SeaBat 8111	100 kHz	600 m	150°
Reson	SeaBat 8124	200 kHz	400 m	3.5 x water depth
Reson	SeaBat 8125	455 kHz	120 m	3.5 x water depth
Reson	SeaBat 8150	12 kHz and/or 24 kHz	12 km	5 x water depth
Reson	SeaBat 8160	50 kHz	3 km	Greater than 4 x water depth
Reson	SeaBat 9001	455 kHz	140 m	2 x to 4 x water depth
Simrad	EM 3002	300 kHz	200 m	4 x D/200 m
Simrad	EM 3002D	300 kHz	200 m	10 x D/250 m
Simrad	EM 2000-120	200 kHz	300 m	3.6 x D/300 m
Simrad	EM 2000-150	200 kHz	300 m	7.5 x D/300 m
Simrad	EM 710RD	70-100 kHz	600 m	5.5 x D/800 m
Simrad	EM 710S	70-100 kHz	1 km	5.5 x D/1900 m
Simrad	EM 710	70-100 kHz	2 km	5.5 x D/2500 m
Simrad	EM 302	30 kHz	7 km	5.5 x D/10 km
Simrad	EM 122	12 kHz	11 km	5.5 x D/35 km

1.2 Interferometry systems

Interferometry is generally used to describe swath bathymetric sonar techniques that use the phase content of the sonar signal to measure the angle of a wave front returned from a sonar target. When backscattered sound energy is received back at the transducer, the angle the return ray of acoustic energy makes with the transducer is measured. The range is calculated from two-way travel time. The angle is determined by knowing the spacing between elements within the transducer, the phase difference of the incoming wave front and the wavelength (Submetrix 2000). A list of typical systems is given in Table 2, while for a more detailed description refer to the Review of Standards and Protocols for habitat mapping.

This project has received European Regional Development Funding through the INTERREG III B Community Initiative
nwe eno INTERREG IIIB NORTH WEST EUROPE

Table 2. Typical Interferometric systems.

Company	Model	Frequency (kHz)	Max Depth Range	Swath Coverage
GeoAcouctics	GeoSwath+	125 kHz	200 m	12 x depth
GeoAcouctics	GeoSwath+	250 kHz	100 m	12 x depth
GeoAcouctics	GeoSwathROV	500 kHz	50 m	12 x depth
SRD Ltd	MINI 240	240 kHz	200 m	120°
SRD Ltd	240 ATR	240 kHz	200 m	120°
SRD Ltd	80 ATR	80 kHz	1 km	120°
SRD Ltd	240 ATRC	240 kHz	200 m	360°

In general, Interferometry systems have a slower ping rate than MBES systems and thus they are primarily used in shallow-water operations. Along-line density of data in Interferometry systems is restricted by vessel speed, while cross-line data is only restricted by the quality of the data and processor; thus small targets can be readily observed. Multibeam echosounders have higher ping rates and so along-line density is less restricted by speed, whereas cross-line density can vary depending on the number of fixed or variable beams available.

Most MBES systems can collect acoustic backscatter information and produce digital side-scan-like imagery simultaneously with the swath acquisition. A side-scan system, operated as per the manufacturer's guidelines, will function satisfactorily. The choice of whether to utilise this function is dependent on the type of survey and the client requirements.

Interferometry systems, by the nature of their operation, produce superior digital side-scan imagery; in some cases as good as standard towed side-scan sonar. The operating frequency of these systems is 100 kHz, 250 kHz and 500 kHz, which is comparable to all available towed side-scan sonar systems. The only major difference in the final data results from the slower ping rate, which reduces the number of scan lines in the final data set. This makes these systems more suitable for shallow-water habitat surveys.

2. Equipment

Both swath bathymetry systems comprise a transducer(s), a transceiver(s) and a computer-processing system which integrates and controls all of the separate components. Additionally, a position and orientation sensor(s) are required, together with a data storage system.

This project has received European Regional Development Funding through the INTERREG III B Community Initiative
nwe eno INTERREG IIIB NORTH WEST EUROPE

The transducer unit may be hull mounted, pole mounted or ROV mounted. For surveys requiring high data density, such as Pipeline surveys, dual heads can be installed at predefined inclinations.

The vessel should be of suitable size for the survey area. For shallow-water surveys, a vessel with shallow draft, adequate cover for electronic equipment and a suitable power source is ideal. For deeper-water surveys, a hull-mounted system should be used, as pole-mounted techniques tend to suffer from vibration and damage.

When using vessels of opportunity, the transducer assembly should be installed as near as practicable to the centre line of the vessel and level about the roll axis. It should also be aligned with the centre line of the survey platform. Where this is not feasible, transducer assemblies are commonly mounted over the side/bow of vessels. It is vital that the transducer is aligned as above and tied into the vessel's 3D geometry using either land survey techniques or measured offsets, as appropriate to circumstances. Care must be taken to ensure that return signals are not masked from the transducer owing to vessel roll. The performance of transducers mounted too far forward or aft can seriously affect outer-beam performance. It has been found that over-the-side/bow mounts can also suffer from vibration caused by unsupported lengths of tubing and by tensioning lines and vortex shedding. Where used and if practically possible, the pole mount should be deployable/recoverable offshore, ensuring that after each deployment the pole returns to exactly the same location, thus avoiding repeating the patch test calibration. See Figure 2 for an example of a key-locked system. It is important that over-the-side mounts are first checked at survey speeds before operations begin and that sufficient time is allowed to rectify any problems.

Figure 2. Example of a keyed pole mount.

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE

3. System operations

3.1 Pre-survey Planning

The swath system utilised for the survey will be determined by operational requirements relating to water depth, size of survey and survey requirements. The basic concept of the system is to acquire swath data over an area of the seabed. Variations in vessel/ROV speed, flying height and sounder update rate will permit different survey plans to be undertaken. These settings have implications for the subsequent use of the data and the products that can be derived from it; e.g. Digital Terrain Model resolution and habitat maps.

Where multiple passes are required to cover an area fully (e.g. a site survey or route survey where a single pass is insufficient to fill the scope of survey), the lines should be planned to avoid any gaps in coverage. Choice of overlap (Figure 3) is a requirement of survey type and/or client requirements and will be determined on a job-by-job basis.

Two main international standards apply when deciding on survey type, if it is not specified by the client: IHO Standards for Hydrographic Surveying (S44) and LINZ 2003 Hydrographic MVBES Survey Standards (

Table 3).

Table 3. Standards for Hydrographic Surveying (IHO Standards for Hydrographic Surveying [S44] and LINZ 2003 Hydrographic MVBES Survey Standards).

	Typical area	Horizontal location accuracy of soundings	Depth accuracy	Bottom search 100%	System capability (object detection)	Min no of acoustic hits	Max line spacing	Cross Lines
S44 Special Order	Harbours; berthing areas; and critical channels	2 m	a=0.25 m b=0.0075 See note	Compulsory	Cubic features >1 m	Not specified	N/A as 100% search required	Distance not more than 15 x line interval
S44 Order 1	Harbours; harbour approach channels and recommended tracks	5 m +5% of depth	a=0.5 m b=0.013 See note	Required in selected areas	Cubic features >2 m in depths up to 40 m	Not specified	3 x average depth or 215 m, which ever is greater	Distance not more than 15 x line spacing
S44 Order 2	Areas not described in Special Order and Order 1, or areas up to 200 m water depth	20 m + 5% of depth	a = 1.0 m b = 0.023	May be required in selected areas	Same as Order 1	Not specified	3-4 x average depth or 200 m, whichever is greater	Distance not more than 15 x line spacing
S44 Order 3	Offshore areas not described in Special Order, and Orders 1 and 2	150 m + 5% of depth	Same as Order 2	N/A	N/A	Not specified	4 x average depth	Distance not more than 15 x line spacing
LINZ Special Order	Harbours; berthing areas & critical channels	2 m	1.0 x IHO SO	200% Compulsory	Cubic features >1 m in depths up to 40 m	5 on an area of 0.3m section	Dependent on scale of finial rendered survey	No less frequent than 10 cm distance on final map
LINZ Order 1 Harbours	harbour approach channels & recommended tracks	5 m +5% of depth	1.5 x IHO SO	SBES – Selected areas. MBES Compulsory	Cubic features >2 m in depths up to 40 m	5 on an area of 0.3m section	Dependent on scale of finial rendered survey	No less frequent than 10 cm distance on final map
LINZ Order 2	Areas not described in Special Order and Order 1, or areas up to 200 m water depth	10 m + 5% of depth	2.0 x IHO SO	SBES – Selected areas. MBES Compulsory	Cubic features >4 m in depths up to 40 m	?	Dependent on scale of finial rendered survey	No less frequent than 10 cm distance on final map
LINZ Order 3	Areas not described in Special Order and Order 1, or areas up to 200 m water depth	100 m + 5% of depth	2.5 x IHO SO	SBES – Selected areas. MBES Compulsory	Cubic features >8 m in depths up to 40 m	?	Dependent on scale of finial rendered survey	No less frequent than 10 cm distance on final map

Note: a and b are factors used in the calculation of error limits for depth accuracy.

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE

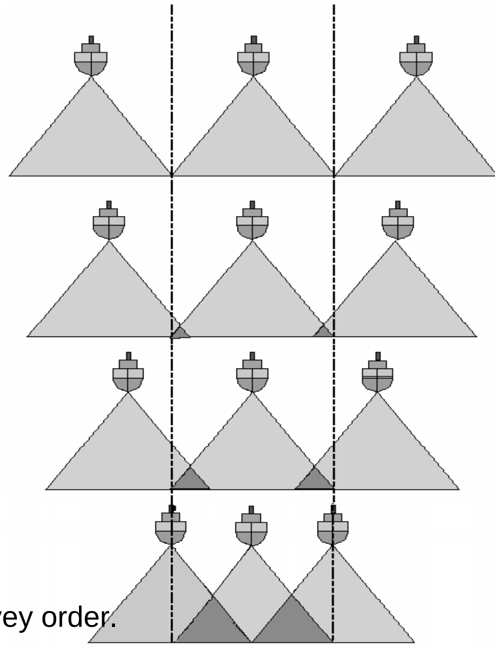


Figure 3. Swath coverage by survey order.

Top	100% coverage (Order 3-4)	= No overlap
Mid Top	125% coverage (Order 2)	= 25% overlap
Mid Bottom	150% coverage (Order 1)	= 50% overlap
Bottom	200% coverage (Special)	= 100% overlap

Once the type of survey has been confirmed, the method related to data acquisition needs to be addressed. Two methods of acquisition can be used:

1. Survey grid: a survey sail-line plan is pre-defined and the line spacing is designed to achieve the required data density;
2. Coverage: the vessel sails the next pass so as to achieve the correct data density.

While both systems are acceptable and have their advantages/disadvantages, great care needs to be taken when choosing the method to be employed.
For example:

1. For a sloping bathymetric seabed survey, 'sailing for coverage' would be the most suitable option, as using a pre-defined sail-line pattern would involve deriving sail lines with the line spacing decreasing as the depth shallows;
2. For habitat surveys on a flat seabed, a survey grid could be used to ensure that the required overlap is theoretically achieved.

For habitat surveys these standards can be reduced, providing the final data set is not to be used for bathymetric charting. In wide area habitat surveys, overlaps between swaths can be reduced to a minimum, thus ensuring maximum data collection is achieved.

3.2 Error reductions

With improved resolution and coverage comes the need for much greater control and calibration to ensure that the sounding is recorded from the correct position on the seafloor (geopositioning). Geopositioning is accomplished by using a high-accuracy differential global positioning system (DGPS), heave-pitch-roll (HPR) sensor and a gyrocompass. In addition, the time synchronisation for all these components is critical. For most systems, GPS 1PPS timing is used, but as a minimum 'NMEA ZDA' could be used if 1PPS is unavailable. For this reason, the system accuracy is comprised not only of the swath bathymetry accuracy, but also of the various components that make up the total system. This overall quality control assessment must be performed in the field because empirical data are necessary for validation.

Several sources of errors and biases exist in multibeam surveying that are not found in single beam surveying.:

- *Static offsets of the sensors* are the distances between the sensors and the reference point of the vessel or the positioning antenna. These should be derived prior to operations using the procedure of the company at the time;
- *Transducer draft* is the depth of the transducer head below the waterline of the vessel. The vessels draft should be derived using pressure sensors on the hull; however, draft readings in conjunction with draft models can be used. Any alterations to the vessel's draft must be logged and entered into the system;
- *Time delay between the positioning system, sonar measurement and HPR sensor* is the delay or latency that must be accurately known and compensated for in the processing of the data;
- *Sound velocity measurement* is the velocity of sound in the water column that must be accurately known so the correct depth can be measured. Sound velocity profiles should be taken prior to commencement of any surveys and consideration made to repeating these at intervals during the survey should any significant changes in water column parameters be expected owing to temporal or spatial changes;
- *Vessel Sensors C-O* are critical for corrections to the vessel's roll pitch and heading. These should be derived prior to operations using the procedure of the company at the time;
- *Tidal corrections* are critical for adjusting the recorded depths to the correct datum. Ideally, numerous tide gauges will be deployed in the survey area or a highly accurate DGPS system (e.g. RTK, Starfix HP) can be used to determine tidal corrections. For habitat surveys these corrections can be derived using standard prediction methods or tidal methods.

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE

These parameters must be measured and entered in the swath bathymetry system and/or the navigation system. It is assumed that the software used in the processing will accommodate these inputs and that the correct sign is used when entering the offsets and corrections. An independent check of all entered parameters **must be undertaken** prior to the start of any operations.

3.3 Standard swath equipment calibrations

Prior to processing any swath bathymetry data, the system should be fully calibrated and the results of the calibration determined. This procedure is commonly known as the patch test.

Calibration of the swath bathymetry system involves establishing the relationship between the motion reference unit (MRU), the gyro and the swath transducer(s). In addition, the timing relationship between the navigation computer and the swath bathymetry data is also required. Through the patch test the following errors are determined:

- Position time delay (latency)
- Pitch offset
- Roll offset
- Heading offset.

The following equipment and facilities are required for the field calibration:

- An accurate positioning of the transducer head(s) via DGPS or USBL (Ultra Short Base Line)
- A calibrated USBL system for ROV operations
- A calibrated water temperature/salinity probe or velocity meter
- A calibrated gyro compass or GPS heading sensor
- A calibrated echosounder
- A calibrated motion sensor
- A suitable area of seabed or a seabed object on which to perform the calibration.

Latency

This is the delay between the time of the position system and the time of the swath system. It is assumed that the positioning system is delayed; hence this number should be positive in the order not above 0.5 seconds. If your system is 1 pps proof, then no latency is possible.

Run two lines in the same direction over the same ground target/slope but at different speeds. If there is a latency problem, the soundings from the faster line will appear astern of the soundings from the slower line. Only the soundings acquired beneath the transducer should be used to exclude roll and heading errors. The soundings should be viewed in a fore and aft profile;

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE

as the lines are run in the same direction, any fore and aft offset of the soundings owing to pitch error is common to both lines and therefore self-cancelling.

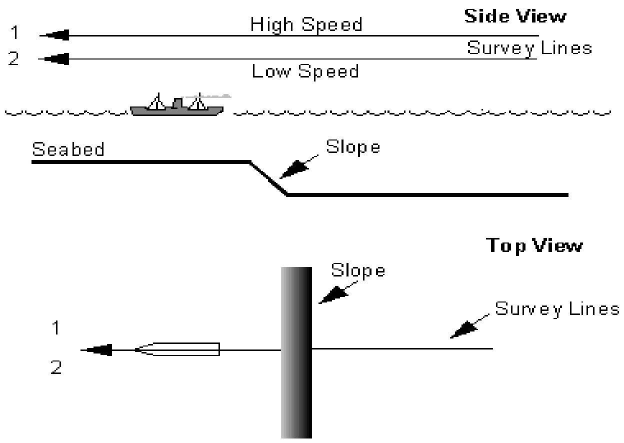


Figure 4. Testing for latency.

Pitch bias test

This is the angle between the horizontal reference of the motion sensor and the reference frame of the swath system. The test is necessary because systems cannot be mounted with total accuracy.

For pitch bias, run two lines over the same ground on a sloping seabed at the same speed but in reciprocal directions (Figure 5). Only the soundings beneath the transducer should be used, for the same reason as for the latency evaluation. Using the fore and aft profile, see if there is a miss-tie in the soundings and, if so, apply a pitch correction to bring the seabed profiles into fore and aft alignment.

This project has received European Regional Development Funding through the INTERREG III B Community Initiative
nwe eno INTERREG IIIB NORTH WEST EUROPE

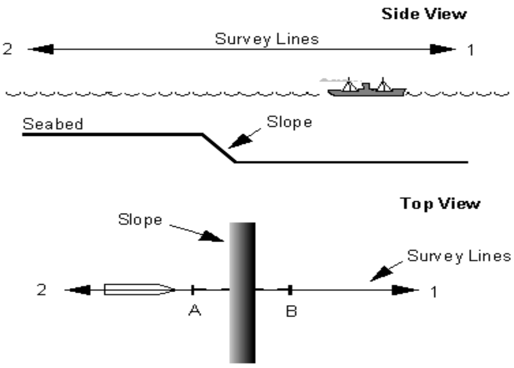


Figure 5. Testing for pitch bias.

Roll bias test

This is the angle between the horizontal reference of the motion sensor and the reference frame of the swath system. Again, this test is needed because the systems cannot be mounted with total accuracy.

The test requires a flat area of seabed rather than the change of gradient needed for the previous two tests. Run two parallel lines in opposite directions spaced half the swathe width apart (Figure 6). Using a cross-track profile, examine the soundings between the two tracks. If there is a residual roll bias, the soundings from one line will slope across track and the sounding from the reciprocal line will slope the opposite way. Enter a roll correction into the calibration software to bring the two cross profiles into coincidence.

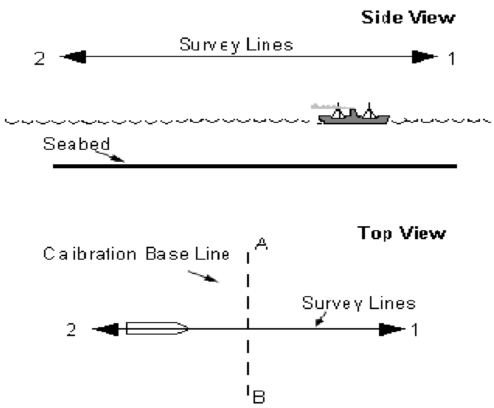


Figure 6. Testing for roll bias.

Yaw offset test

This is the angle between the gyro reference and the swath system reference frame. Once again, this test is necessary due to the fact that we cannot mount the system with total accuracy.

Run two parallel lines either side of a clearly defined object (shoal, pipeline). The lines should be spaced about half the swathe width apart (Figure 7). Construct a profile between the two calibration lines, including the defined object, at 45° to the direction of travel. Apply heading corrections to see if these bring the soundings on the defined point into better alignment. This procedure can also be done using a colour-coded plan display rather than a profile.

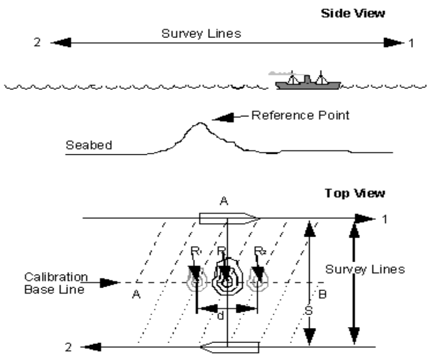


Figure 7. Testing for yaw roll bias.

4. Operations at sea

All the swath equipment for the project should be operated in accordance with these guidelines and the manufacturer's installation and operation manuals. A trained operator will operate/configure the system with an independent person checking that all the parameters entered are correct. The online surveyors must log and inform the processors of all changes to the swath bathymetry system setup.

4.1 Testing

Prior to leaving harbour, the swath system and all external sensors will be tested. If possible the transducer will be lowered and the transmitter enabled. A spot check between the single beam echosounder and the swath system should be undertaken to confirm the integrity of the two systems.

In addition, a series of calibration tests should be undertaken to check equipment settings and interfacing; this is particularly relevant for non-dedicated systems. These checks may include the following:

- Motion sensor calibration
- Positioning system calibration
- Compass calibration
- Velocity profile
- Accurate draft readings
- Accurate tide corrections (can be predicted for habitat surveys)
- Acoustic underwater positioning system calibration
- Navigation system check and calibration
- Swath sonar checks (survey a known point or object in opposite directions).

4.2 System deployment

For hull-mounted transducers that are fixed, no deployment is required. However, for hull-mounted drop transducers the bridge will need to be informed prior to lowering to ensure that there is sufficient water and that the speed is acceptable.

For over the side/bow deployments the following must be undertaken:

- All personnel involved must wear **personal protective equipment**
- The vessel is stationary
- Ensure the transducer is not damaged
- The pole is correctly locked into the survey position
- All stays are connected and tightened.

4.3 Surveying

Data acquisition using swath bathymetry systems follows standard procedures based on the operating criteria outlined by the manufacturer. Data are normally recorded through the manufacturer's own software or through third party software such as Fugro-Starfix Qinsy. The surveyor will control the vessel speed and movement to ensure that the correct data coverage is achieved during each survey pass. Where possible, alterations in the vessel's position will be controlled via the vessel autopilot system. When online, the surveyor should only adjust system parameters when required. System vital parameters will be locked by the software when online to avoid accidental data corruption.

Draft checks, velocity profiles and any parameter alterations **must be** clearly logged and forwarded to the data processor. Bathymetric and/or backscatter and/or snippets[1] data will be recorded as required by the client. For habitat

[1] Snippets data is an upgraded backscatter which uses the bathymetric data to remove water column noise.

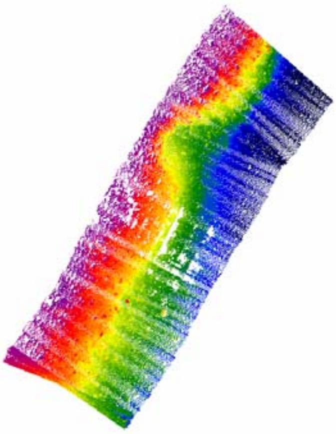
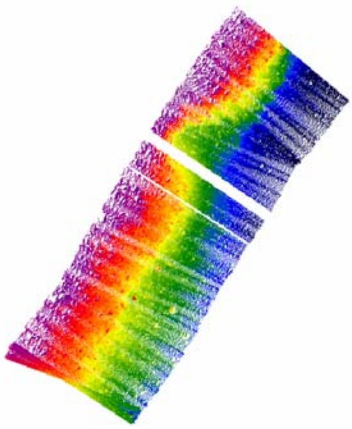
surveys, as a minimum bathymetric and backscatter will be recorded, along with snippets data if available or required . As a result of the vast amount of data being recorded, the operator must ensure that sufficient space is available on the hard disk before the commencement of any survey line.

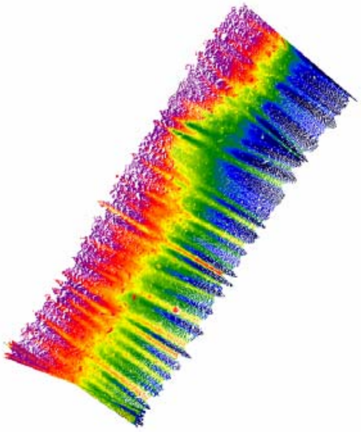
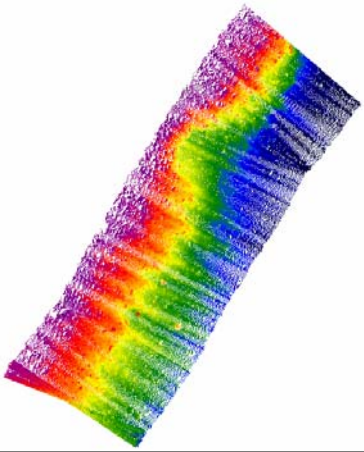
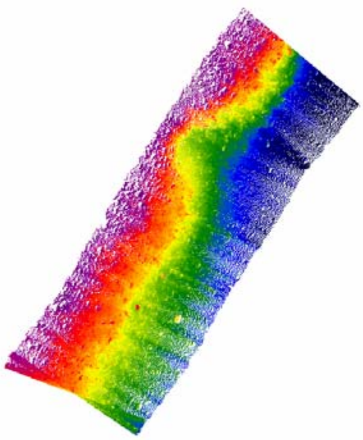
To avoid substantial data loss, frequent backups **must be** undertaken on a remote machine at suitable periods when the primary machine is not online.

5. Record interpretations

5.1 Checking quality

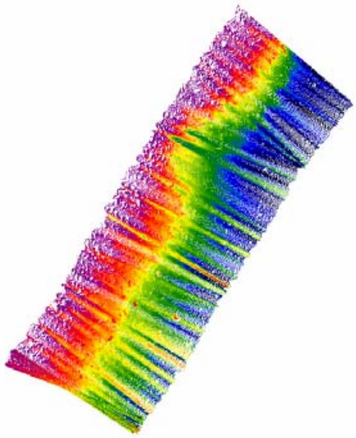
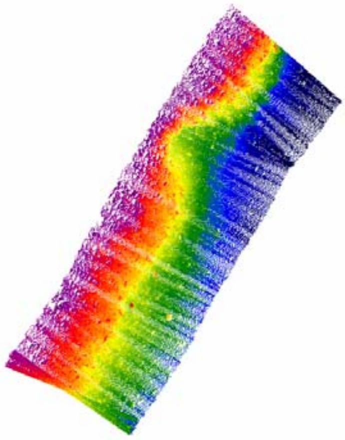
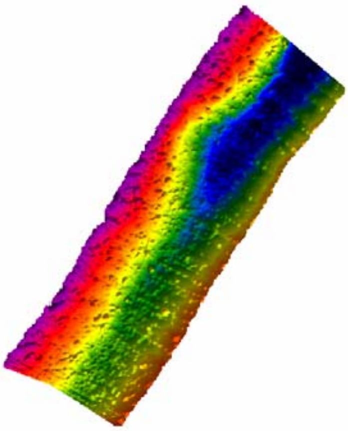
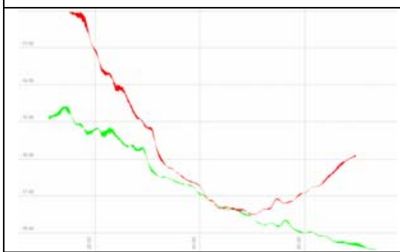
Like any other type of acoustic system, swath systems are susceptible to interference and poor data quality from a number of sources, but with experience most of these can be recognised in the data. Examples of typical errors and their causes are detailed below.

	**Survey vessel noise** Data point dropouts which reduce the data density. Operating the system in suitable weather conditions to minimise aeration below the keel will remove the noise. Note: Missing data with the swath data.
	**Loss of DGPS positioning** This is normally evident with swaths being plotted erratically or missing on the online screen. Note: Complete swaths missing from the data.

	**Raw data without heave, pitch and roll applied or timing errors** Note: The data look poor with ripple and roll artefacts visible.
	**Raw data without heave applied or timing errors** Note: A ripple artefact is evident in the data set. This can also be caused by pitch errors.
	**Raw data without pitch applied or timing errors** Note: A ripple artefact is evident in the data set. This can also be caused by heave errors.

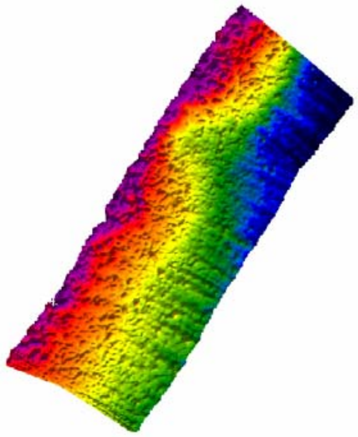
This project has received European Regional Development Funding through the INTERREG III B Community Initiative

INTERREG IIIB NORTH WEST EUROPE

	**Raw data without roll applied or timing errors** Note: A row artefact is evident in the data set.
	**Raw data with heave, pitch and roll applied** Note: The data still have what looks like artefacts; however, on closer inspection these are minor areas where the data density is reduced.
	**DTM generated with incorrect velocity of sound applied. Note the curve edges** Note: The displayed DTM would appear to show that the area surveyed is a valley. This is incorrect and should show a slight slope from right to left.
	**Cross profile highlighting the correct seabed (green) with the incorrect velocity of sound seabed (red).**

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE

	**Data with all correction applied and light illumination enabled** Note: A slight pitch artefact is still evident with the final data set but within the tolerance of the system.

6. Data interpretation

6.1 Online processing quality control

To assist the surveyor, the online software quality control package will notify/display the following as a minimum:

- Flag peripheral systems error as required;
- Perform residual bias tests and other software calibration routines;
- Provide real-time output sufficient to successfully maintain the system and ensure that specifications are met;
- Log data with suitable flags to allow use/review of data rejection in processing package;
- Provide online display of coverage and data density.

In view of the high data acquisition rates and volumes involved in swath bathymetry operations, automated filtering is a prerequisite. Because of this, the online surveyors will have to configure some online acceptance or rejection parameters to ensure that erroneous or spurious signals are controlled. This optimal usage of 'de-spiking' and filtering is critical and relies on the skill and experience of the online surveyor to vary the parameters, depending on many external factors.

Caution must be observed when using filters, as sharp or uncharacteristic seabed features will be rejected or smoothed. Where possible the online surveyor should be able to flag the data within the raw file and still record them, thus allowing for later examination and possible reinstatement.

7. Data processing

During processing operations the processor should apply tidal corrections to the datum required by the client. If real-time GPS tides or tide gauges have been used, a quality control check between predicted tides should be undertaken. When using predicted tides only (e.g. during habitat surveys), expect slight miss ties between data corridors and cross lines because of prevailing weather conditions during the survey and errors in predictions.

Once one or more adjacent corridors of data have been acquired, the processor should undertake test routines to prove that the swathe system and the related sensors are correctly calibrated. One test will be to validate the pitch and roll correction by comparing the raw data sets from adjacent corridors of data and those that are perpendicular to the main line direction. This might include extracting individual sweeps from a cross line for comparison with the centre beams of a main line corridor. Errors occurring in the application of the speed of sound through the water column may be evident and can be corrected using de-smile algorithms.

Once acquisition of data is well underway, it is a straightforward task for the processor to analyse test panels. These tests should include data density statistics, area coverage expressed as number of sweeps and beams in a corridor of data, and achieved survey coverage. Should the data density set by survey/client/manufacturer's specification not be met, then the processor must inform the surveyor at the first opportunity.

As a final quality control check, Digital Terrain Models (DTMs) using light illumination can be generated and a visual inspection made to confirm that all external artefacts have been removed. Light illumination will highlight minor errors in the data set and in some cases care must be taken:

- Illuminated flat seabeds can appear to be very stripy; however, at a closer look the strips can be as small as 0.01 m;
- Extreme sloping seabeds can lead to certain contacts not being readily visible. In this case you may have to zoom into the area in question to confirm the quality of the data.

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE

8. Data reporting

Once the survey is completed or a designated area has been completed, the processor can choose the gridding algorithm and define the parameters most suitable for the data. The parameters used for the DTM will need to take into account the quality and density of the field data and the contractual requirements of the survey. Once the processor has produced an acceptable DTM, it can be exported into a standard GIS/charting package for mapping. If required, the data can also be exported into XYZ format (Easting, Northing, reduced Depth). Digital side-scan mosaics can be produced from backscatter and/or snippets data, ensuring that the maximum density of data is maintained to support subsequent habitat mapping.

References

Diaz, José Vicente Martínez. (2000) Analysis of Multibeam Sonar Data for the Characterization of Seafloor Habitats. A Report Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering.University Of New Brunswick, Canada. (http://hidrografica.tripod.com/Analysis_MB_SeafloorHabitats.pdf)

Hughes-Clarke, J.E., Mayer, L.A. & Wells, D.E. (1996) Shallow-water imaging multibeam sonars: A new tool for investigating seafloor processes in the coastal zone and on the continental shelf. *Marine Geophysical Research* Vol. 18: 607-629.

IHO Standards for Hydrographic Surveying (S.44).

LINZ 2003 Hydrographic MVBES Survey Standards.

Samual Deleu, Veronique Jegat, Jonathan White & Koen Vanstaen , Multibeam Echo Sounders.

Shallow Water Surveys using the GeoAcoustics GeoSwath. http://www.geoacoustics.com/Application%20Notes/Note_9/Note_9.htm

Submetrix (2000). Series Training Pack, 2000. Submetrix Ltd, Bath, UK.

Veronique Jegat & Jonathan White, Interferometric Sonar Systems.

This project has received European Regional Development Funding through the INTERREG III B Community Initiative

nwe eno INTERREG IIIB NORTH WEST EUROPE