



## INFOMAR Survey Report: CV19\_01 Area: Celtic Sea

For:  
Marine Institute & Geological Survey Ireland

*RV Celtic Voyager*

April 2019


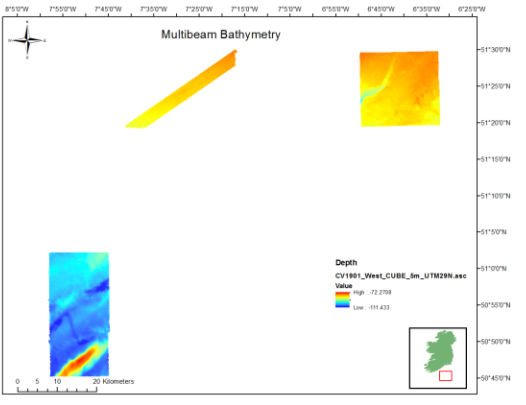
Prepared by Kevin Sheehan



Marine Institute Reference No:	Survey Report: CV19_01
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Issue	Change	Date	Description	By	Approved
1		10/12/2019	Draft	K. Sheehan	
2		03/02/2020	Final	K. Sheehan	F.Sacchetti

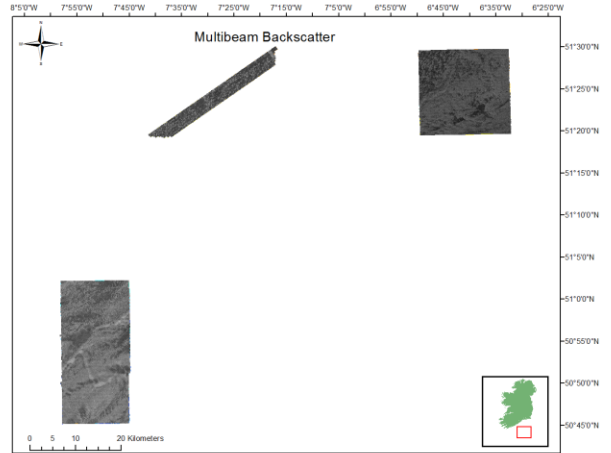
Executive Summary			
Survey Summary			
<b>Survey Vessel:</b>	RV <i>Celtic Voyager</i>	<b>Survey Leg:</b>	CV19_01
<b>Mobilisation:</b>	Cork	<b>Demobilisation:</b>	Cork
<b>Survey Areas:</b>	Celtic Sea	<b>Start Date:</b> <b>End Date:</b>	12/04/2019 29/04/2019
<b>Northeast Boundary</b>	50° 46.800N 7° 58.810W	<b>Southwest Boundary</b>	53° 47.498N 09° 45.602W
<b>UKHO Admiralty</b>	1121 (1:500,000) and 1123 (1:500,000)		
<b>Key References</b>	CV19_01 Survey Leg Report		
<b>Equipment Used</b>	EM2040 multibeam, Pinger sub-bottom profiler, EA400 single beam, SeaSpy magnetometer, AML MVP200, Valeport SVP Mini, C-Nav 3050 GNSS, Seapath 330+.		
Survey Statistics			
<b>Minimum Water Depth (VORF LAT):</b>	71 m	<b>Maximum Water Depth (VORF LAT):</b>	111 m
<b>Area Covered:</b>	996 km <sup>2</sup>	<b>Survey Line Kilometres:</b>	2639 km
<b>Approximate Operational:</b>	46%	<b>Approximate Downtime :</b>	31%
<b>Groundtruthing Stations:</b>	0	<b>Wrecks</b>	4
<b>H525 forms issues (wrecks)</b>	1	<b>H102 forms issued (shoals)</b>	0
Survey Tracklines		Bathymetry	
			

## Survey Images

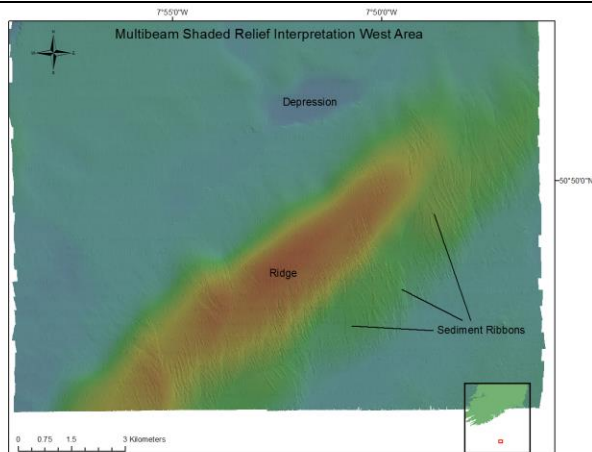
### Multibeam Shaded Relief



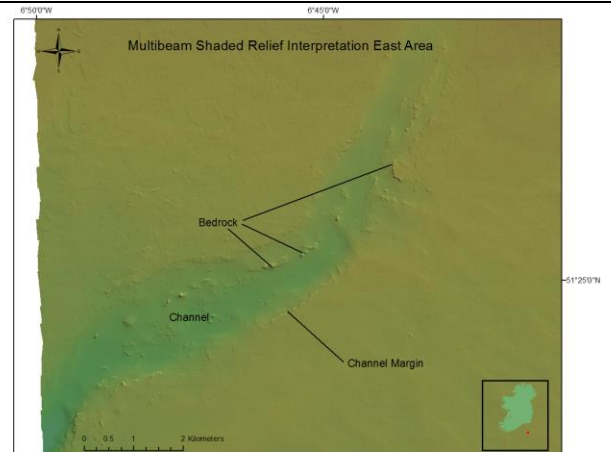
### Multibeam Backscatter



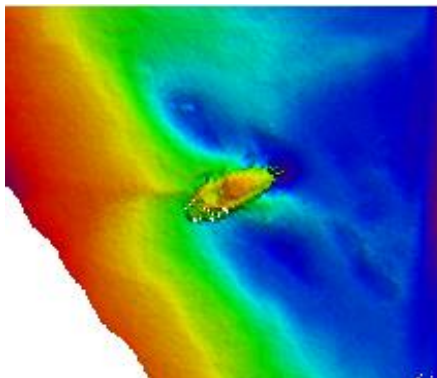
### Shaded Relief Illustrating Ridge



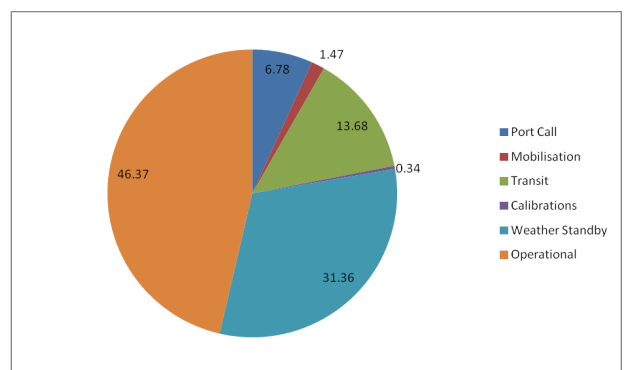
### Shaded Relief Illustrating Channel



### Wreck in Cork Harbour Channel



### Survey Statistics



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## List of Acronyms Used Within This Report

<b>Acronym</b>	<b>Full Name</b>
AML	AML Oceanographic
CUBE	Combined Uncertainty and Bathymetry Estimator
DCCAE	Department of Communications, Climate Action & Environment
DGNSS	Differential Global Navigation Satellite Systems
DPR	Daily Progress Report
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
GSI	Geological Survey Ireland
HSE	Health Safety & Environment
HVF	Hips Vessel File
IHO	International Hydrographic Organisation
INFOMAR	INtegrated Mapping FOr the Sustainable Development of Irelands MArine Resource
INSS	Irish National Seabed Survey
ITRF	International Terrestrial Reference Frame 2014 (ITRF2014)
LAT	Lowest Astronomical Tide
MVP	Moving Vessel Profiler
MBES	Multibeam Echo-Sounder
MI	Marine Institute
MRU	Motion Reference Unit
NPWS	National Parks & Wildlife Service
PPE	Personal Protective Equipment
PPS	Pulse Per Second
PPP	Precise Point Positioning
QINSy	Quality Integrated Navigation System
RTG	Real Time Gypsy
RV	Research Vessel
SBP	Sub Bottom Profiler
SBES	Singlebeam Echo Sounder
SIS	Seafloor Information System
SVP	Sound Velocity Profile
TPU	Total Propagated Uncertainty

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UKHO	UK Hydrographic Office
UTC	Coordinated Universal Time
VORF	Vertical Offshore Reference Frame
WGS	World Geodetic System

## **1. Introduction**

### **1.1 Project Overview and Objectives**

Geological Survey Ireland (GSI) and Marine Institute (MI) conducted seabed mapping between 2003 and 2005 under the auspices of the Irish National Seabed Survey (INSS) and this continued from 2006 to present day under the INtegrated mapping FOre the sustainable development of Irelands MARine Resource (INFOMAR) programme. INSS was one of the largest marine mapping programmes ever undertaken globally, with a focus on deep water mapping. INFOMAR is a joint venture between the GSI and the MI and is funded by the Irish Government through the Department of Communications, Climate Action and Environment (DCCA). (DCCA).

INFOMAR Phase 1, 2006 to 2015 focused on mapping 26 priority bays and 3 priority areas around Ireland and creating a range of integrated mapping products of the physical, chemical and biological features of the seabed in those areas. INFOMAR Phase 2, 2016 to 2026 intends to map the remainder of Ireland's entire seabed. Figure 1 shows the extent of the continental shelf mapped area under INSS and INFOMAR and the outstanding areas as of January 2019. Grey have already been mapped, blue, white and coloured hatched areas are unmapped.

As of 2018 the remaining survey area has been split at the 30 nautical mile limit (Nm). The inshore survey fleet, managed by GSI is responsible for mapping inshore of the 30Nm limit and the MI vessels are responsible for mapping the offshore. Survey areas are defined into gridded survey units known as INFOMAR Survey Units (ISUs). ISUs are all 1000 km<sup>2</sup> in size and are uniquely identifiable by a letter on the x axis and number on the y axis. Each ISU is coloured in a shade of blue which indicates the modal water depth in that ISU. Colour scales are used, to denote the three depth bands; 50 to 100m, 100 to 150m and 150m plus.

## INFOMAR SURVEY PLANNING

Reference grid for 1000km<sup>2</sup> Standard Survey Units. Covers Infomar surveyed area and survey gap areas.

Survey Units that contain survey gaps below 50m have been symbolised by most common depth value (modal).


Survey Units that contain survey gaps have also been clipped to show gap area extent.

Date: 23/01/19

### Legend

 1000km<sup>2</sup> Standard Survey Unit

 INFOMAR Surveys

 Biologically Sensitive Area

 Exclusive Economic Zone (EEZ)

 30nm from Coast

### Standard Survey Units by Modal Depth Value for Areas containing Data Gaps Outside of 30NM only

 50m to 100m

 100m to 150m

 150m Plus


### Data Gaps by Depth Below 50m

 0m to 50m

### Proposed Survey Areas 2019

 Proposed Survey Area CV Primary

 Proposed Survey Area CV Contingency

 Proposed Survey Area CE

 Proposed Survey Area GS Vessels

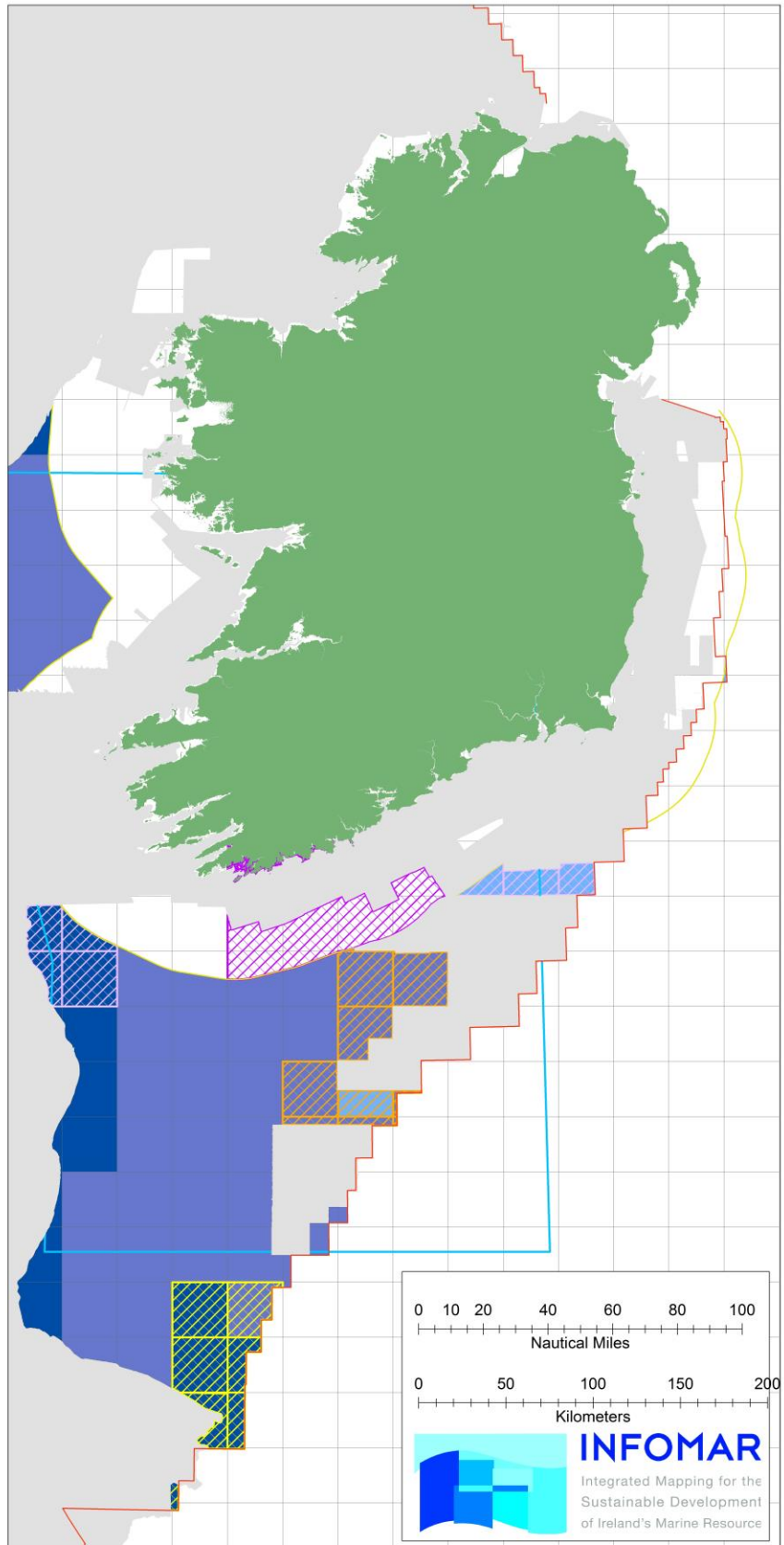


Figure 1: Survey coverage status January 2019.

MI supplied the research vessel *RV Celtic Voyager* and experienced personnel for the survey.

The scientific aims of the survey were to:

(i) Undertake a Multibeam Echo Sounder (MBES) hydrographic survey to International Hydrographic Organisation (IHO) Order 1A standard in depths less than 100 m and Order 2 in areas deeper than 100 m.

(ii) Produce bathymetry, shaded relief and backscatter mosaic products to provide depth, seabed features and seabed hardness/roughness information.

(iii) Acquire Sub Bottom Profiler (SBP) data of the shallow (up to 30 m) sub seabed to determine the existence of buried objects and ascertain the sub-seabed character.

(iv) Acquire magnetometer data to investigate the sub seabed geology and provide information on manmade seafloor debris.

(v) Map in detail and provide hydrographic wreck reports on any wrecks.

(vi) Groundtruth the acoustic data with grab samples.

## **1.2 Proposed Survey Area**

Figure 2 shows the area designated for mapping by the *RV Celtic Voyager* in 2019. The entire area is in the Celtic Sea in water depths ranging from 70 to 130 m. Predicted survey coverage for the *RV Celtic Voyager* 2019 survey season is 4169 km<sup>2</sup> based on annual survey statistics since 2016 and modal depth of ISUs to be surveyed. The primary target area, hatched in orange in figure 2 is 4640 km<sup>2</sup> as hatched boundaries were drawn along existing ISU boundaries. Approximately 10% of the area lies in the 50 to 100 m depth zone and 80% in the 100 to 150 m depth zone. Survey coverage rates for these two zones are estimated at 80 km<sup>2</sup> and 113 km<sup>2</sup> per day respectively.

A bad weather contingency area located to the north east of the primary area is hatched in pink. It is 480 km<sup>2</sup> and it resides within the 50 to 100 m depth zone.

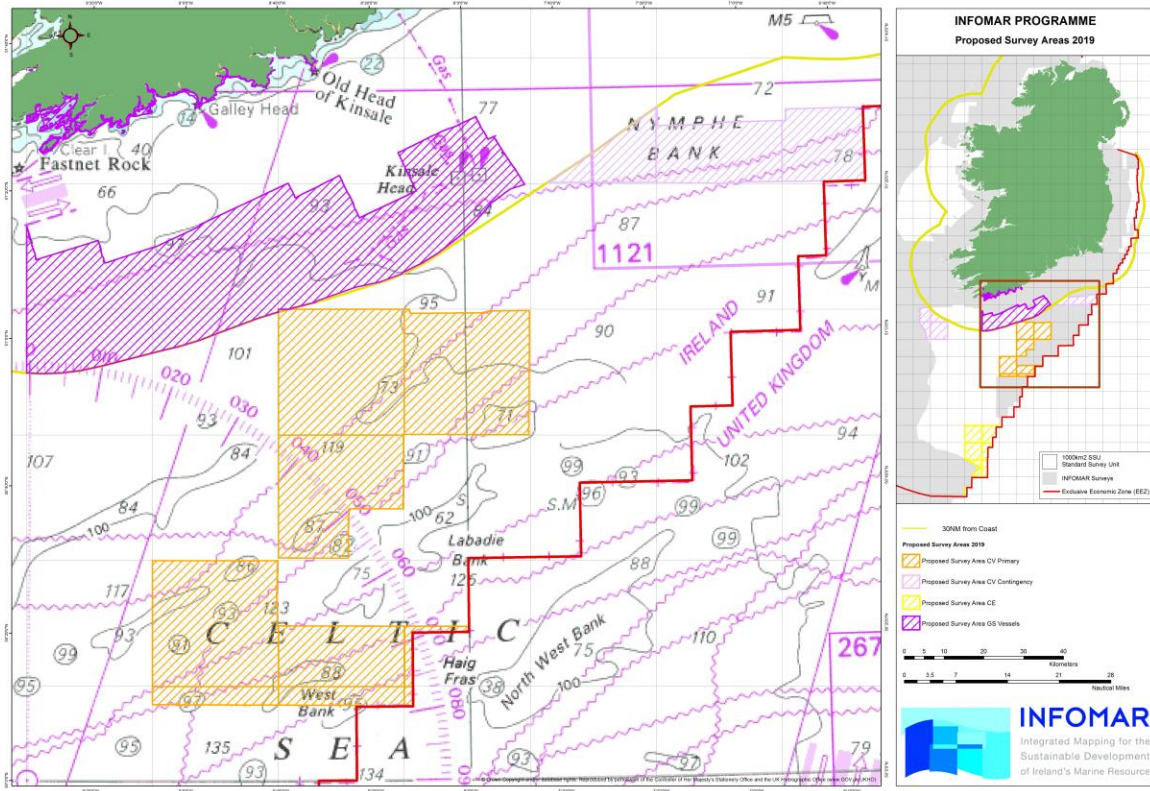


Figure 2: Proposed survey area for 2019.

## 2. Operations & Survey Setup

Mobilisation took place in Cork on 12<sup>th</sup> April. Survey acquisition took place between 16<sup>th</sup> and 29<sup>th</sup> April. Kevin Sheehan and Fabio Sacchetti of the MI acted as Party Chiefs. The survey team comprised skilled personnel from the MI and a freelance contractor.

### 2.1 Survey Tracklines

The final survey trackline plot is contained in figure 3. Mainlines were acquired on east – west and northeast – southwest reciprocal headings. Three separate survey polygons were mapped, denoted in this report as the west and east areas respectively.

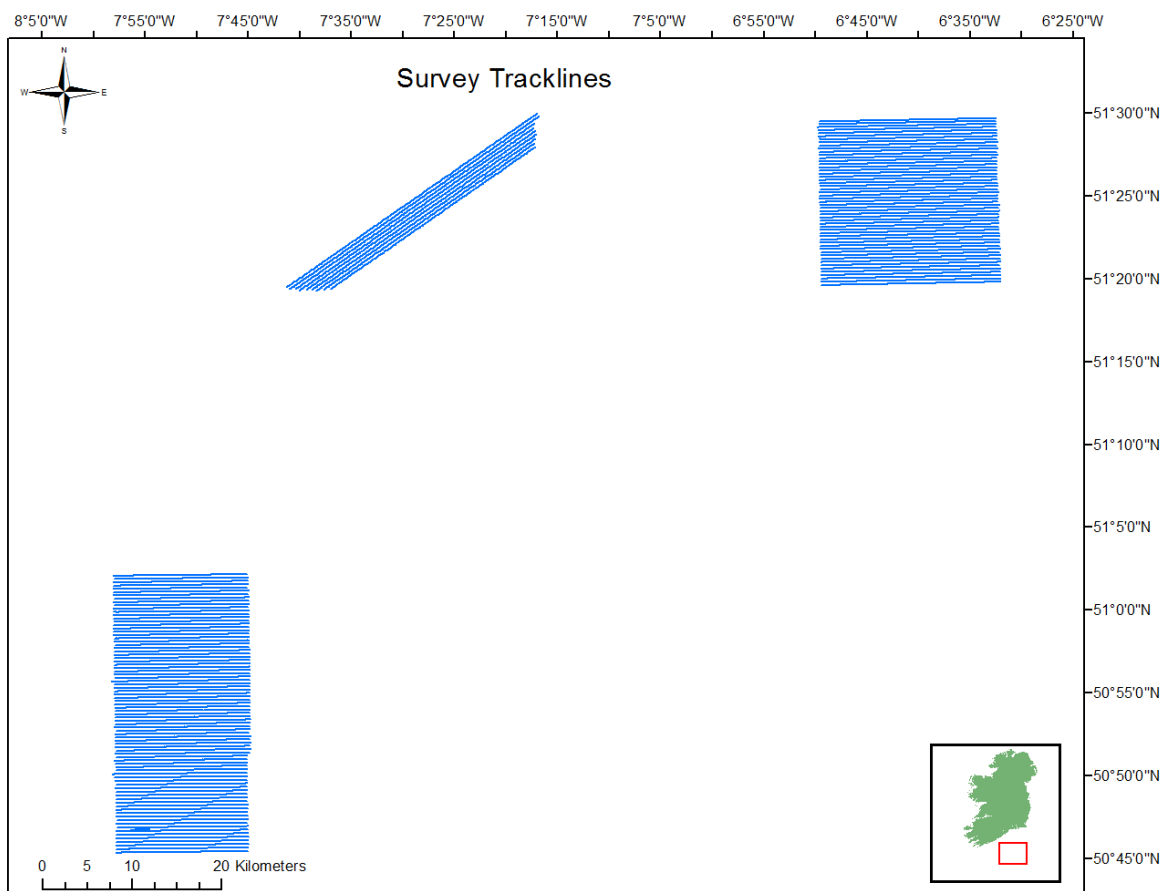


Figure 3: Survey trackline plot produced in Caris and ArcGIS software.

### 2.2 Summary of Events

A summary of the key events is presented in table 1. Times are in Coordinated Universal Time (UTC). Daily Progress Reports (DPRs) were distributed to management and INFOMAR personnel on a daily basis.

Date and time	Activity
---------------	----------

12/04/2019 07:30	Mobilised in Cork City
12/04/2019 14:00	Departed Cork for patch test site
12/04/2019 15:45	EM2040 Patch Test
12/04/2019 17:15	Weather Standby
16/04/2019 11:00	Departed Cork for survey site
16/04/2019 19:55	Commenced operations
20/04/2019 00:20	Made transit to Cork
20/04/2019 09:30	Port call Cork. Change of survey personnel.
20/04/2019 12:00	Departed Cork for survey site
20/04/2019 19:20	Commenced survey operations
24/04/2019 14:44	Weather Standby
24/04/2019 23:00	Alongside Cork
27/04/2019 22:00	Departed Cork
28/04/2018 05:12	Commenced survey operations
29/04/2018 00:39	Made Transit to Cork
29/04/2018 08:00	Alongside Cork
29/04/2018 23:59	Demobilisation complete

Table 1: Summary of survey events.

### 2.3 Survey Personnel

Survey personnel, their affiliation and role are listed in table 2.

Name	Affiliation	Role
Kevin Sheehan	MI	Party Chief /Surveyor
Fabio Sacchetti	MI	Party Chief /Surveyor
Nicola O' Brien	MI	Surveyor
David O' Sullivan	MI	Surveyor
Slava Sobolev	Contractor	Data Processor

Table 2: Survey personnel details.

### 2.4 Health, Safety and Environment (HSE)

All personnel joining the vessel were given a safety induction tour which was recorded by the Second Mate. Medical and Personal Sea Survival certifications for all personnel were checked for validity prior to departure. A muster drill was held within 24 hours of departure from port. Magnetometer and sound velocity profiler deployments were performed by vessel crew and without incident, with personnel wearing correct Personal Protective Equipment (PPE). There were no near misses or safety incidents to report.

### 2.5 Marine Mammal Observations

National Parks and Wildlife Service (NPWS) published a *Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters* in 2007. An updated

document titled “Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters” was published in January 2014. Full details of both documents are published on the NPWS website. The code and guidance are applicable to all seismic, MBES and sidescan sonar surveys in bays, inlets or estuaries and within 1500 m of the entrance of enclosed bays/inlets/estuaries. All operations were outside of the areas covered under the above guidelines. No marine mammals were observed during the course of the survey.

## 2.6 General Survey Information

A summary of key survey statistics is contained in table 3.

Total Line Length (km)	2639
Area Covered (km <sup>2</sup> )	996
Operational (%)	46
Weather Standby (%)	31
Transit (%)	14
Port Call (%)	7

Table 3: Key survey statistics.

The pie chart in figure 4 presents the cumulative statistics from the final DPR. Survey data acquisition accounts for approximately 46% of the time.

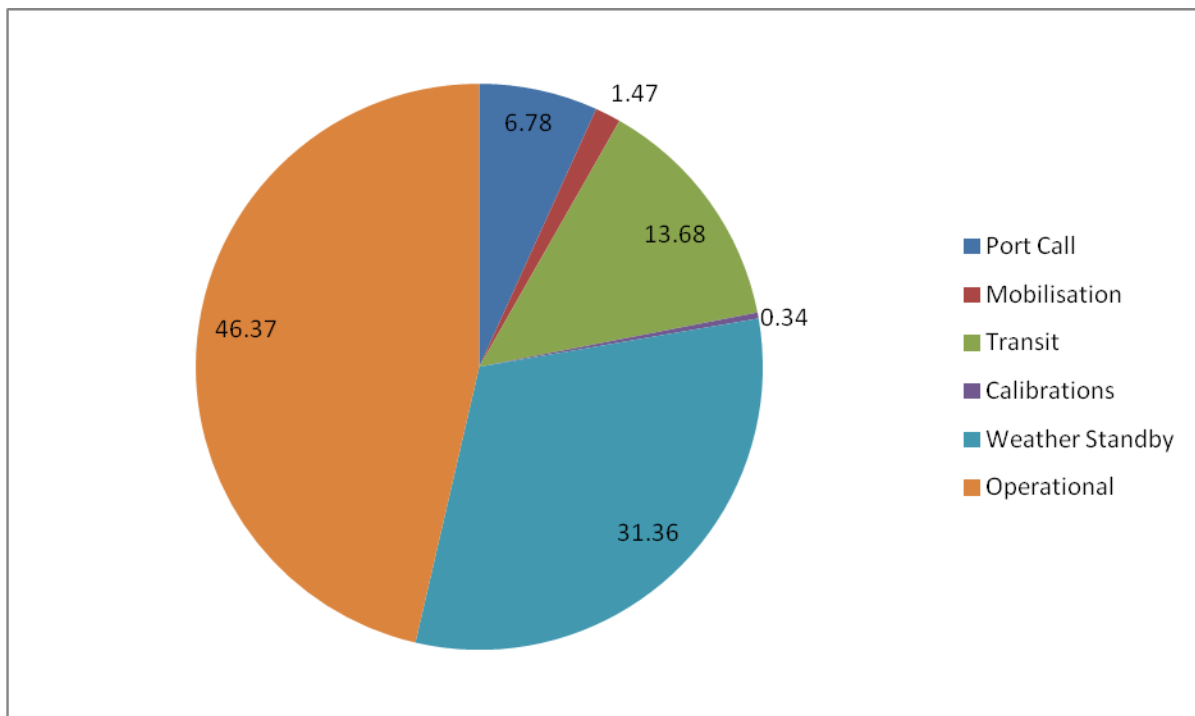


Figure 4: Survey statistics pie chart.

### 3 Survey Vessel Offsets, Equipment and Data Acquisition

The RV *Celtic Voyager* (figure 5) is a multipurpose research vessel owned by MI and managed by P&O Maritime. The vessel has wet, dry and chemical laboratories, which are permanently fitted with standard scientific equipment and can accommodate 8 scientists with a maximum endurance of 14 days. It has a hull mounted high resolution EM2040 MBES system, a Singlebeam Echo sounder (SBES), pinger source SBP and C-NAV Differential Global Navigation Satellite Systems (DGNSS) as primary navigation and a Seatex Seapath 330+ as secondary navigation and Motion Reference Unit (MRU). All necessary geophysical and DGPS positioning equipment were pre-installed, calibrated and tested prior to commencement of survey activities.



Figure 5: The RV *Celtic Voyager*.

Detailed vessel information is contained in table 4.

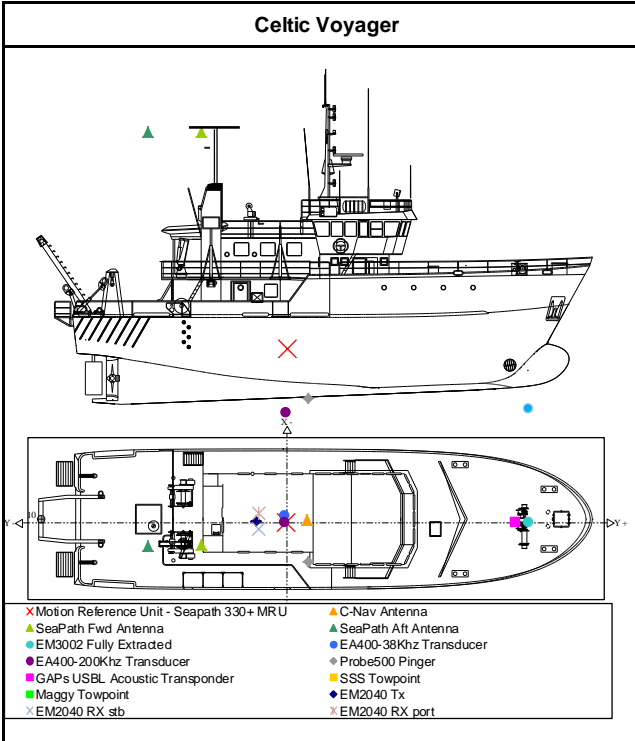
Parameter	Numeric
Length	31.4 m
Beam	8.5 m
Draught	4.0 m
Engine	1 x Baudouin 26.2 655 kW
Power Output	640 kW/1200 RPM

Speed	10 knots
Fuel	38000 Lt MGO
Generator	2 x Daewoo 1x Deutz
Max Scientists and Crew	15
Passenger Licence	P5

Table 4: RV *Celtic Voyager* vessel information.

### 3.1 Vessel Offsets

Bluepix performed an offset survey of the RV *Celtic Voyager* in August 2015 while in dry dock Killybegs. An additional offset survey was conducted by Bluepix in January 2016. Current vessel offsets are presented in table 5 below.

MARINE INSTITUTE		VESSEL OFFSET LOG			
Project: <b>INFOMAR</b>					
Client: <b>MI &amp; GSI</b>					
Project Title:					
Date Last Surveyed	10-11/01/2016 - Bluepix	Date:	11/01/2016		
<b>Celtic Voyager</b>					
					
<ul style="list-style-type: none"> <li>✗ Motion Reference Unit - Seapath 330+ MRU</li> <li>▲ SeaPath Fwd Antenna</li> <li>● EM3002 Fully Extracted</li> <li>● EA400-200Khz Transducer</li> <li>● GAP's USBL Acoustic Transponder</li> <li>● Maggy Towpoint</li> <li>✗ EM2040 RX stb</li> <li>▲ C-Nav Antenna</li> <li>▲ SeaPath Aft Antenna</li> <li>● EA400-38Khz Transducer</li> <li>◆ Probe500 Pinger</li> <li>● SSS Towpoint</li> <li>◆ EM2040 Tx</li> <li>✗ EM2040 RX port</li> </ul>					
No'	Offset Name	X	Y	Z	Reason for change
	Common Reference Point (CRP)	0.000	0.000	0.000	
1	Motion Reference Unit - Seapath 330+ MRU	0.000	0.000	0.000	
2	C-Nav Antenna	-0.114	0.965	14.396	
3	SeaPath Fwd Antenna	0.924	-3.993	13.292	
4	SeaPath Aft Antenna	0.984	-6.491	13.299	
5	EM3002 Fully Extracted	-0.078	11.190	-3.532	New Position 2015
6	EA400-38Khz Transducer	-0.343	-0.122	-3.783	
7	EA400-200Khz Transducer	-0.036	-0.115	-3.783	
8	Probe500 Pinger	1.636	0.989	-3.004	
9	GAP's USBL Acoustic Transponder	-0.077	10.633	-4.332	
10	SSS Towpoint	0.000	-13.905	1.987	
11	Maggy Towpoint	-3.835	-13.905	1.987	
12	EM2040 Tx	-0.064	-1.417	-4.863	New Position
13	EM2040 RX stb	0.279	-1.287	-4.693	New Position
14	EM2040 RX port	-0.411	-1.288	-4.696	New Position
Surveyor: Fabio Sacchetti		Checked: Kevin Sheehan		Date: 11/01/2016	

EM2040 geometry	10-11/01/2016		
	X (forward)	Y (starboard)	Z(+Down)
Pos Com1( C-Nav)	0.965	-0.114	-14.396
EM2040 TX	-1.417	-0.064	4.863
EM2040 RX Port head	-1.288	-0.411	4.696
EM2040 RX Starboard head	-1.287	0.279	4.693
Seapath aft	-6.491	0.984	-13.299
Seapath fore	-3.993	0.924	-13.292
MRU 5+	0.000	0.000	0.000

Bluepix Report 10&11/01/2016 Killybegs			
Item	Yaw	Roll	Pitch
MRU 5+	0.57	0.07	0.21
EM2040 TX	-0.05	-0.37	0.74
EM2040 RX Port	-0.83	39.68	0.67
EM2040 RX Stb	0.69	-40.28	0.73
Seapath	-1.39	N/A	N/A
EM3002	0.68	-0.47	-0.14

Positive Yaw is clockwise. Positive Roll is starboard down. Positive Pitch is fore up.

Table 5: Vessel offsets and installation angles.

### 3.2 Survey Equipment

Table 6 contains information on the survey equipment both permanently installed and available for mobilisation onboard the RV *Celtic Voyager*.

System	Type	Comment
Multibeam Echo-Sounder	Kongsberg EM2040	200, 300 & 400 kHz
Singlebeam Echo-Sounder	Kongsberg EA400	38 and 200 kHz
Sub-Bottom-Profiler	Sonar Equipment Services Pinger source	3.5 – 9 kHz
Sidescan Sonar	Edgetech 4200	100 and 500 kHz
Positioning	C-Nav DGNS	Seapath330+ as secondary
USBL	IXsea-Gaps	Sonardyne Scout as secondary
Sound Velocity Profilers	Valeport SVX2	SV & Conductivity
Moving Velocity Profiler	AML MVP200	SV
Realtime Sound Velocity	Valeport / AML	SV
Magnetometers	SEASPY	Overhauser Effect

Table 6: RV *Celtic Voyager* available survey equipment.

### 3.3 Data Acquisition

#### 3.3.1 Geodetic Parameters

Table 7 contains the geodetic parameters used for the survey.

<b>Local Datum Geodetic Parameters</b>	
Datum	ITRF2014
Spheroid	World Geodetic System 1984 (WGS-84)
Semi-Major Axis (a)	6378137.000 m
Semi-Minor Axis (b)	6356752.314 m
First Eccentricity Squared ( $e^2$ )	0.0066943800
Inverse Flattening (1/f)	298.257223563
<b>Projection Parameters</b>	
Grid Projection	Universal Transverse Mercator
Central Meridian Zone 29 (CM)	009° West
Origin Latitude (False Lat.)	00.0°
Hemisphere	North
False Easting (FE)	500000.0 m
False Northing (FN)	0.0 m
Scale Factor on CM	0.999600
Units	M

Table 7: Geodetic parameters.

#### 3.3.2 Survey Datum, GNSS Tides and VORF Model

Table 7 above details the vertical and horizontal datum applied during operations. Global Navigation Satellite Systems (GNSS) tides do not require us to account for vessel draft or vessel squat values, as recorded depths are related directly to the World Geodetic System (WGS) 84 Ellipsoid. These values were reduced to Lowest Astronomical Tide (LAT) using GNSS tidal measurements and by then applying the Vertical Offshore Reference Frame (VORF) model (LAT/WGS84 separation) as illustrated in figure 6 below.

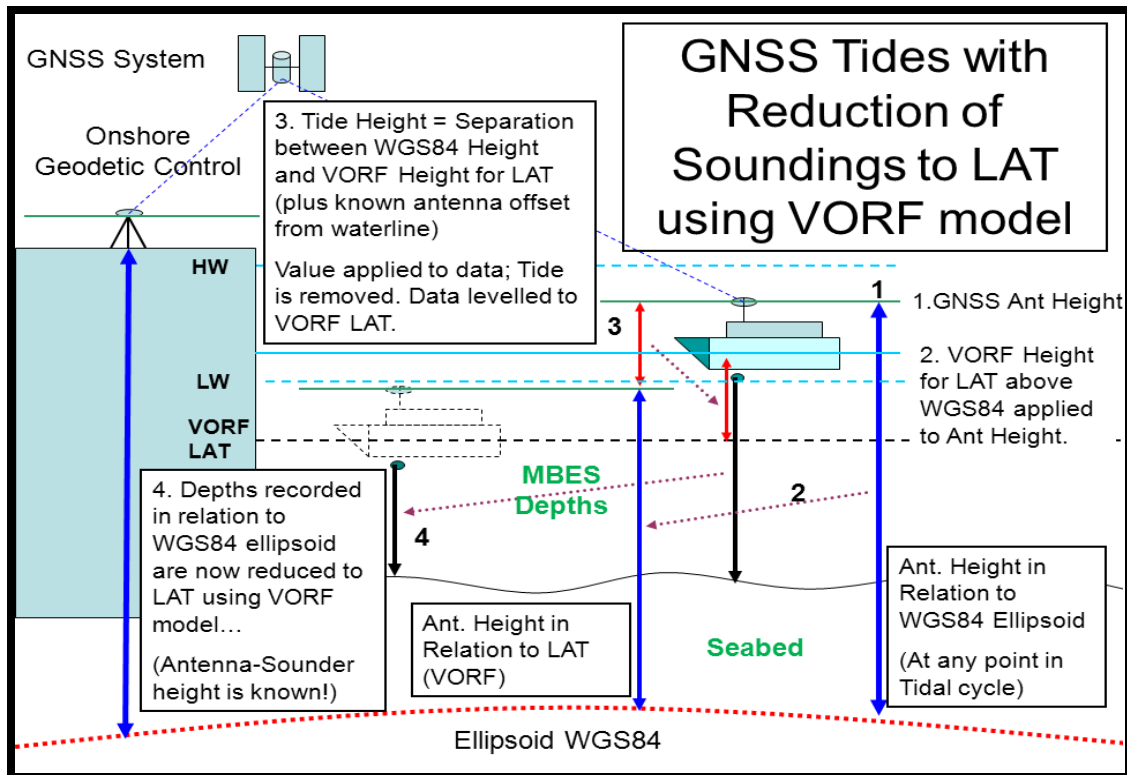


Figure 6: GNSS tides to LAT using VORF model.

### 3.3.3 Acoustic Systems

A Kongsberg EM2040 high resolution multibeam mounted on a retractable pole was used for swath acoustic acquisition. First bottom returns from the MBES produce highly accurate bathymetric data. Additionally, backscatter acquired by MBES sonars contains important information about the seafloor and its physical properties. This information provides valuable data to aid in seafloor classification and important auxiliary information for a bathymetric survey.

The configuration consists of dual RX transducer (0.7° each) and a single TX transducer (0.7°). The system operates at frequency ranges of 200, 300 or 400 kHz with 800 soundings per ping and allows coverage of up to 10 times water depth on a flat bottom. It has a maximum ping rate of 50 Hz. The 200 kHz frequency was used for this survey. Primary positioning was provided by C-Nav 3050 DGNSS. Seapath 330+ with integrated Seatex MRU5+ inertial unit provided secondary position and real time heading, heave, pitch, roll and velocity to the MBES system.

MBES data was recorded in raw.all format using Kongsberg's Seafloor Information Software (SIS). The raw.all files were continuously backed up on the vessel server. Table 8 contains MBES metadata.

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	NA
Data Files	323
Date Created	16-04-2019 to 29-04-2019
Dataset Size	75.2 GB
File Formats	.all

Table 8: MBES metadata.

Multibeam water column data (.wcd) were acquired for all survey lines. This data was stored on a separate backup disk as file sizes were large. United Kingdom Hydrographic Office (UKHO) guidelines were implemented when carrying out wreck investigations. Three survey lines along the wreck's primary axis with high overlap and one or more lines across its secondary axis to ensure full wreck coverage along both axes were acquired. The water column logging functionality in SIS was used throughout the investigation. Beam angles, survey speed, operational frequency and pulse length were configured for maximum resolution. Wrecks were reported to the UKHO using the standard UKHO "H-Forms". A total of one wreck was surveyed in detail.

A hull mounted pinger source 2x2 transducer array SBP operating at 3.5 kHz was used for sub-bottom data acquisition. The sweep time was varied appropriately with water depth to maximise ping rate and resolution. The pinger source is most effective in investigations of the top 20 or 30 m sub-seabed and where sediments are fine to medium grained. The signal does not penetrate bedrock. A Coda DA4G acted as the topside trigger and acquisition system. Raw data was recorded in native coda format along with tiff images of each survey line. Positioning data was provided from C-Nav DGNS and MRU data was fed directly from the Seapath 330+. QC was maintained by the online engineers, with reference to the digital display; with sweep time, gains, filter parameters and transmit energy adjusted as required for optimal imaging. All data were backed up to the vessel server. Table 9 contains SBP metadata.

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	NA
Data Files	298
Date Created	16-04-2019 to 29-04-2019
Dataset Size	28.2 GB
File Formats	.cod & .tiff

Table 9: SBP metadata.

### 3.3.4 Magnetometer

A Marine Magnetics Corporation SeaSPY towed Overhauser Magnetometer was used to acquire magnetic field data. The system comprises a towfish, tow cable, deck lead and transceiver interfaced to a standard Windows based PC. Acquisition parameters and QC were controlled via BOB software.

The magnetometer was towed 100 m behind the vessel at a depth of less than 5 m beneath sea surface. Magnetometer and GPS data from the towfish were input to the control PC via separate serial ports and synchronised. Initial QC was performed via real-time graphing of the magnetic field trace and by monitoring real-time GPS data. Magnetometer data were recorded in a database using BOB and output in proprietary BOB format as a .mms file. Metadata is contained in table 10.

Descriptor	Metadata
Survey lines	NA
Data Files	2
Date Created	16-04-2019 to 29-04-2019
Dataset Size	728 MB
File Formats	.mms, .txt

Table 10: Magnetometer metadata.

### 3.3.5 DGPS Systems

C-Nav DGNSS provided the primary navigation. The C-Nav 3050 is a dynamic DGNSS Precise Point Positioning (PPP) system providing accuracy of <0.1 metre horizontally and 0.2 metre vertically. It provides 66 channel tracking, including multi-constellation support for GPS, GLONASS and Galileo. C-Nav provided the primary navigation feed for the MBES, SBES, SBP and magnetometer sensors. C-Nav also provided a reliable GPS tide correction.

C-Nav has a range of QC output displays that were monitored in real-time including number of satellites in use, satellite attitude and angles, vertical accuracy, vessel speed, heading and precise position. GPS signal was always very good and the system never lost the Real Time Gypsy (RTG) solution. A hard disk connected to the C-Nav receiver provided real-time data storage.

Seapath 330+ provided the secondary navigation. Seapath and C-Nav data were monitored continuously in Quality Integrated Navigation System (QINSy) software to ensure data

integrity and comparison between the primary and secondary navigation systems remained within tolerance. Navigation data were recorded in .cnav3050 format using C-Nav software. One file per day was created. Metadata is contained in table 11.

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	All
Data Files	16
Date Created	13-04-2019 to 29-04-2019
Dataset Size	3.13 GB
File Formats	.cnav3050

Table 11: C-Nav navigation metadata.

### 3.3.6 Online Navigation

QINSy software was used for navigation acquisition and QC. QINSy performs visual and QA data-feeds from the key acquisition systems. A project template database was created containing all survey configuration parameters relevant to the project. The project template contains the datum, projections, vessel shape, administrative information, as well as vessel offsets and I/O parameters. QINSy uses a sophisticated timing routine based on the Pulse Per Second (PPS) option from the GNSS receiver. All incoming and outgoing data is accurately stamped with a UTC time label.

Survey line and groundtruthing positioning data were recorded in QINSy software in .db and .txt format. The QINSy navigation .txt file was input to the Multilog database for metadata recording of each survey system. QINSy metadata is provided in table 12.

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	NA
Data Files	619
Date Created	16-04-2019 to 29-04-2019
Dataset Size	22.6 GB
File Formats	.db & .txt

Table 12: QINSy navigation metadata.

### 3.3.7 Sound Velocity

An AML Moving Vessel Profiler (MVP) 200 was the primary instrument for acquiring sound velocity profile data. A Valeport Mini Sound Velocity Profiler (SVP) instrument was used as backup. Both instruments are equipped with sound velocity sensors that directly measure sound velocity. The dual benefit of the MVP is that the vessel did not have to slow down or stop to acquire sound velocity data and more casts were acquired to better constrain the sound velocity regime. Fresh sound profiles were input to the echosounders as required. A Valeport sound velocity sensor positioned at the transducer head provided a real time sound velocity input directly to the EM2040.

MVP deployment was controlled from the vessel Dry Lab using Rolls Royce MVP software. The probe was continually towed in the water at between 4 and 8 metres depth off the starboard aft side and deployed to within 15 metres of the seabed during casts. Sound velocity profiles in .asvp format were automatically sent to SIS where they were checked and extended for import into the echo sounders.

SVP profiles were acquired at times when the MVP was inoperable due to technical issues. Sound velocity profile data were recorded in asvp format and downloaded with DataLog X2 software. Metadata is contained in table 13.

<b>Descriptor</b>	<b>Metadata</b>
Survey lines	NA
Data Files	150
Date Created	16-04-2019 to 29-04-2019
Dataset Size	0.57 MB
File Formats	.asvp

Table 13: Sound velocity metadata.

### **3.3.8 Multilog**

A Microsoft Access database was used for logging survey metadata. Data acquisition parameters, data QC, sound velocity and daily progress report information were input and recorded. A backup of the database was made regularly. DPRs were created using this database.

## 4 Online QC, Data Processing, Results and Interpretation

The hydrographic survey was performed to International Hydrographic Organization (IHO) survey standard Order 1a for areas of 100 m depth or less and Order 2 for areas exceeding 100 m. The survey order represents the minimum standard for position, depth accuracy and feature detection achieved during data acquisition and processing. Order 1a and Order 2 requirements are presented in table 14.

	<b>Order 1a (S-44)</b>	<b>Order 2 (S-44)</b>
<b>Description of Areas</b>	Shallower than 100m, features of concern to shipping.	Areas generally deeper than 100 m where a general description of the sea floor is considered adequate.
<b>Max THU allowable (95%C)</b>	Total Horizontal Uncertainty (THU) 5m+5% of depth	Total Horizontal Uncertainty (THU) 20 m+10% of depth
<b>Max TVU allowable (95%C)</b>	Total Vertical Uncertainty (TVU) a = 0.5 metre b = 0.013 $\pm\sqrt{a^2 + (bxd)^2}$	Total Vertical Uncertainty (TVU) a = 1.0 metre b = 0.023 $\pm\sqrt{a^2 + (bxd)^2}$
<b>Full Seafloor Search</b>	Required	Not Required
<b>Feature Detection</b>	Cubic Features > 2m (Depths < 40m) 10% depth > 40m	Not Applicable
<b>Recommended Max line spacing</b>	Full Seafloor search	4 x average depth

Table 14: IHO standards for hydrographic surveys

### 4.1 MBES Online Quality Control

#### 4.1.1 Acquisition Parameters

Most of the important acquisition parameters are set in the Runtime Parameters module of SIS. Figure 7 shows an example of settings in the Sounder Main tab in Runtime Parameters. Max angle and max coverage parameters were adjusted to take account of depth, sea state, sound velocity conditions and seafloor character. Pulse type for survey mainlines and crosslines was maintained at FM and ping mode set to 200 kHz, which maximised swath width in the depths encountered. Wreck surveys were performed at Medium CW or Long CW and at 300 kHz to provide maximum resolution.

Max angle, sector mode, vessel speed and pulse type were adjusted to attain maximum resolution for wreck inspections. Water Column data were acquired for all survey lines and stored directly to external disk.

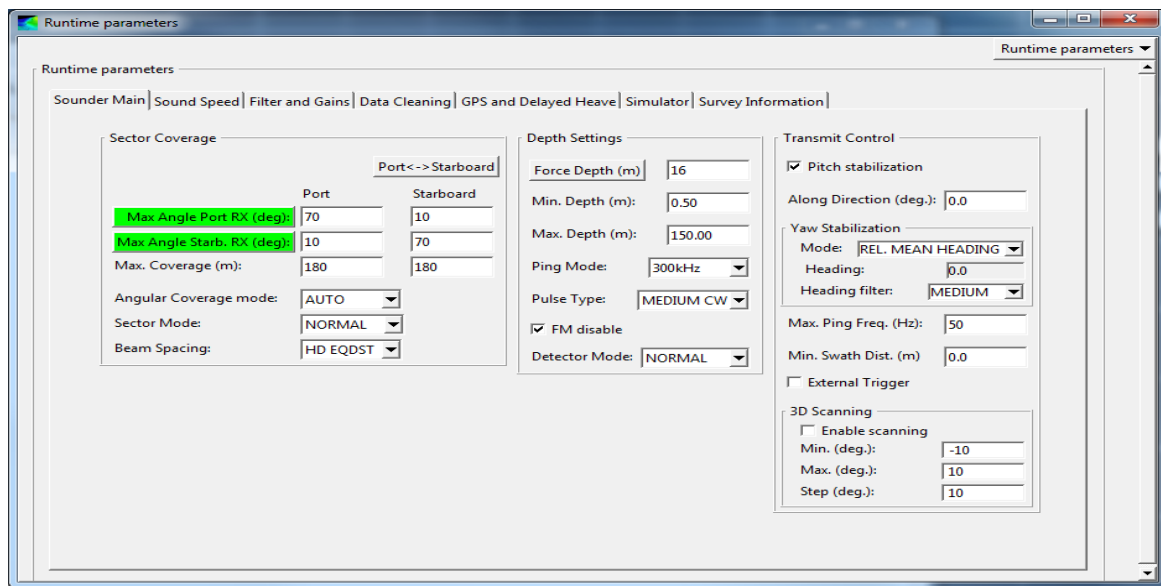


Figure 7: Runtime parameters window in SIS.

#### 4.1.2 Crossline versus Mainline Statistics

Crossline data were acquired for QC of depth soundings. A total of 4 crosslines were acquired for statistical analysis in Caris Hips. Crossline data were compared with mainline data and all crossline data indicated that the soundings exceeded the 95% certainty required for Order 1a specification.

#### 4.1.3 Feature Detection

The minimum standard for feature detection for an Order 1a survey are cubic features > 2 m in depths up to 40 m and 10% of depth beyond 40 m. Feature detection is not relevant for water depths greater than 100 m where a general description of the seafloor is deemed adequate for Order 2 survey specification. Water depths range from 71 to 111 m. The minimum sized cubic features that require detection are 7.1 m, i.e. 10% of water depth. A minimum of 9 soundings per 7.1 m bins are required in order to attain the feature detection criteria. A bin size of 7 m was selected to QC the data density and the results are shown in figure 8.

The mean number of soundings per bin was computed at 76. This easily exceeded the 9 soundings required per bin. Green indicates where 9 soundings per bin were achieved and red where the 9 soundings requirement was not attained.

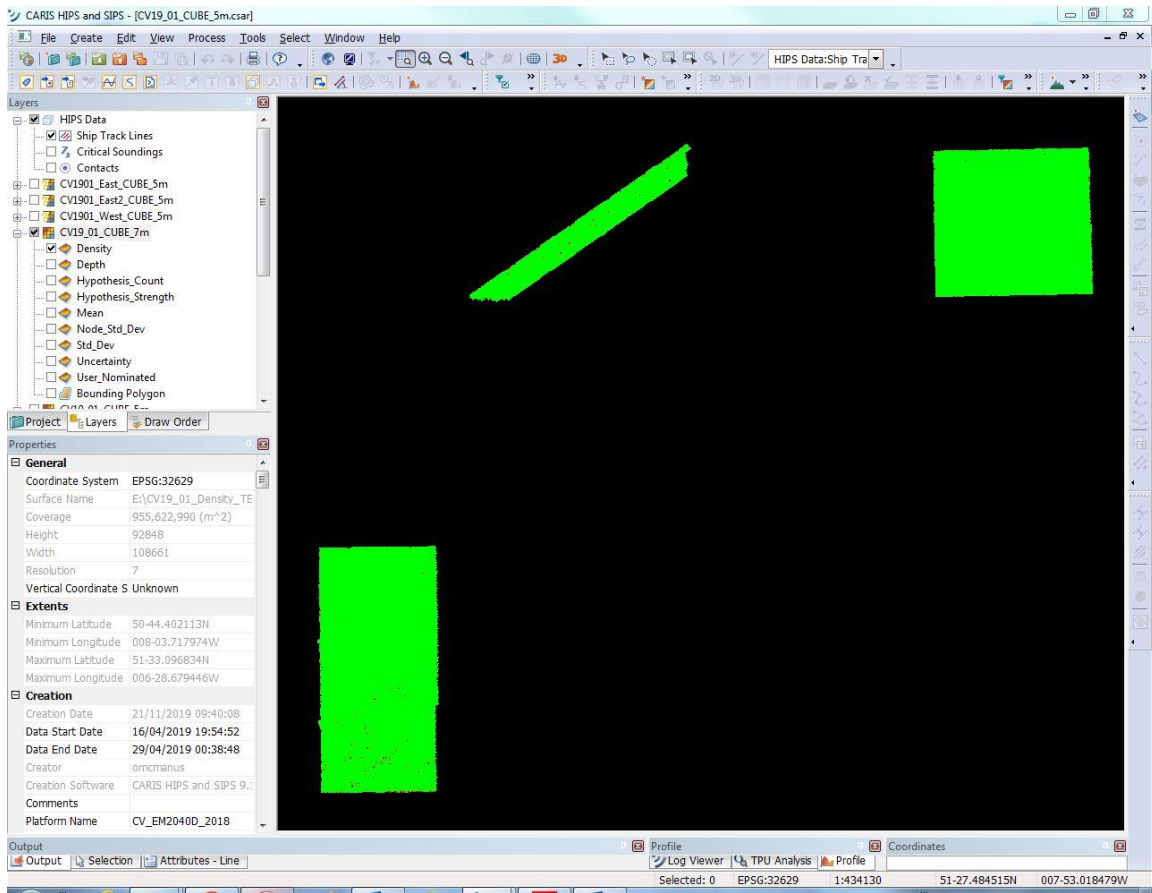


Figure 8: Sounding density traffic light plot.

Figure 9 shows the statistics associated with the data density QC.

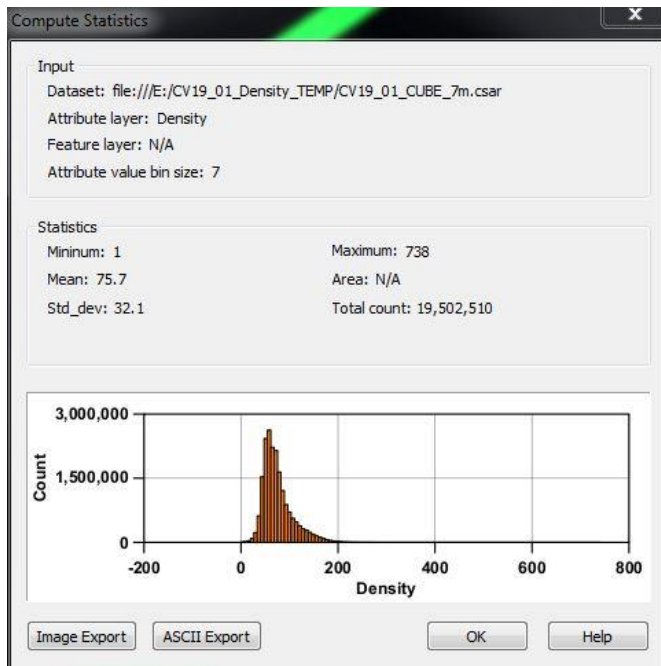


Figure 9: Sounding density statistics, north area.

#### 4.1.4 Error Budget and Uncertainty Model

Manufacturer values for positioning and sounding errors were factored into the vessel error budget. Vessel offsets were established through an onshore dimension control survey (see section 3.1). In addition; uncertainty levels over positions of soundings were improved through good sound velocity control while surveying. Calibration of the MBES through a standard patch test, combined with good online quality control, ensured that the vessel's error budget fell within IHO 1a specifications.

Table 15 below details standard deviation values applied in the calculation of the vessel's Total Propagated Uncertainty (TPU) model. TPU is an estimate of the uncertainty of any individual sounding, taking into account the uncertainty estimates of the component measurements (tide, sound speed, draft, range measurement, angle measurement, attitude, offsets etc). TPU is expressed as a separate value in horizontal and vertical planes. The uncertainty of each sensor was entered in the HIPS Vessel File (HVF) and the TPU calculated.

Heading Accuracy	0.065°
Heave	5 cm or 5 % Amplitude
Roll	0.01°
Pitch	0.01°
Pitch Stabilised	0.00°
Position Navigation	0.1 m
Timing Transducer	0.00 s
Timing Navigation	0.00 s
Timing Gyro	0.00 s
Timing Heave / Pitch / Roll	0.00 / 0.00 / 0.00 s
Sound Velocity Measured	0.001 m/s
Sound Velocity Surface	0.001 m/s
Offsets X / Y / Z	X=0.01 / Y=0.01 / Z=0.01
MRU Alignment	Gyro=0.1 / Pitch=0.1 / Roll=0.1
Vessel Speed	0.03
Vessel Loading	0.00
Vessel Draft	0.00 (Use of GPS tides)
Delta Draft	0.00

Table 15: Standard deviation values used in TPU calculation.

#### 4.1.5 Sound Velocity Control

Multibeam data processors continuously monitored the effect of sound velocity variations on the processed multibeam data. The processors advised on the frequency and geographical distribution of MVP casts based on this analysis.

Sound velocity issues were also monitored by QC of the Crosstrack window and by comparison of the sound profile versus the realtime sound velocity reading in the Numerical window of SIS. The MVP failed on 19<sup>th</sup> April and was out of commission for the remainder of the survey. A Valeport Mini SVP was used for profile acquisition from the 19<sup>th</sup> April onwards.

A profile comparison plot from 28<sup>th</sup> April is shown in figure 10. Three profiles were acquired at different locations along a survey lines to show the variation in conditions. Sound velocity in metres per second is plotted on the x axis and depth in metres on the y axis.

Profiles show a large difference between near surface sound velocities. The water column is well mixed from 3 m depth in the case of the SW profile, from 12 m depth in the Middle profile and from 8 m depth in the NE profile. Velocity increases with pressure beneath these respective depths. The near surface shows a distinct layering as seen by the rapid variation in sound speed with depth.

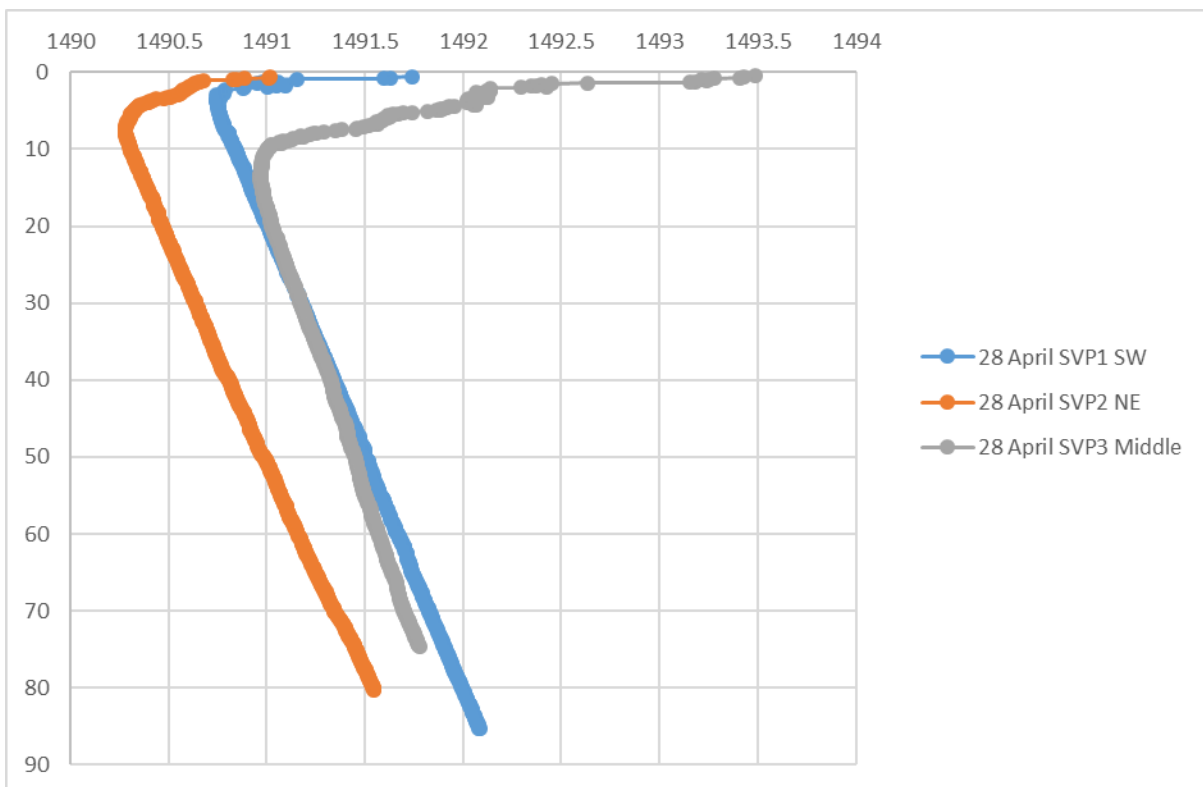


Figure 10: SVP comparison plot 28<sup>th</sup> August

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## **4.2 Post Processing Methods**

### **4.2.1 Navigation**

Navigation data was logged in standard C-Nav format. Real time positioning data quality from C-Nav was of sufficient quality to exceed IHO Order 1a standard requirements. Vertical errors on the GPS heights were low (+/- 20 cm) and provide a robust solution for computation of GPS tide.

Navigation data and in particular GPS heights were despiked and smoothed in Caris HIPS. GPS tide was computed using the separation model between International Terrestrial Reference Frame (ITRF) datum and VORF LAT.

### **4.2.2 Depth Soundings Data Processing**

Soundings were edited in Caris HIPS software against an existing chart background. Combinations of automated and manual processing procedures were applied by experienced data processors to remove systematic errors and obvious outliers. Uncertainty results were examined to ensure soundings fell within IHO specifications for Order 1a and Order 2 surveys. Processed and cleaned data were subjected to final validation by an experienced and qualified hydrographer. The following is a simplified list of steps undertaken during sounding data processing:

1. Navigation data were checked and spikes removed.
2. GPS tides were computed using the UKHO's VORF model. This reduced the MBES depth soundings to LAT. GPS tide results were then checked for quality and consistency.
3. TPU values were calculated.
4. Swath Editing was performed in CARIS to clean large "noise" spikes from the data.
5. SVP data were applied to correct for refraction errors caused by water column heterogeneity. A range of SV Algorithms were used to determine the most suitable method of applying SV corrections. (Example: nearest in distance verses nearest in time).
6. A CARIS Combined Uncertainty and Bathymetry Estimator (CUBE) base surface was then created to allow CUBE automatic filtering.
7. Final verification of sounding consistency and absence of spikes was carried out using subset editing.
8. Export of final products from Caris: Multibeam Bathymetry grids, Shaded Relief grids, and Backscatter Mosaics. XYZ and trackline grids were also output.

### 4.2.3 Backscatter Mosaic Generation

Backscatter is a function of the hardness and roughness of the seafloor. Multibeam backscatter mosaics were produced using QPS Fledermaus Geocoder Tool (FMGT), backscatter analysis software with advanced functionalities capable of providing an enhanced backscatter mosaic.

## 4.3 Survey Results and Data Interpretation

A preliminary interpretation of MBES and SBP data was used to assess bathymetry, seabed texture, seabed features, and shallow geology.

### 4.3.1 Multibeam Images

Grids and geotiff images were created in Caris Hips software of MBES bathymetry and shaded relief. Backscatter mosaics were created in FMGT. Geotiffs and grids were imported into ArcGIS and images (figures 11 to 17) output for this report.

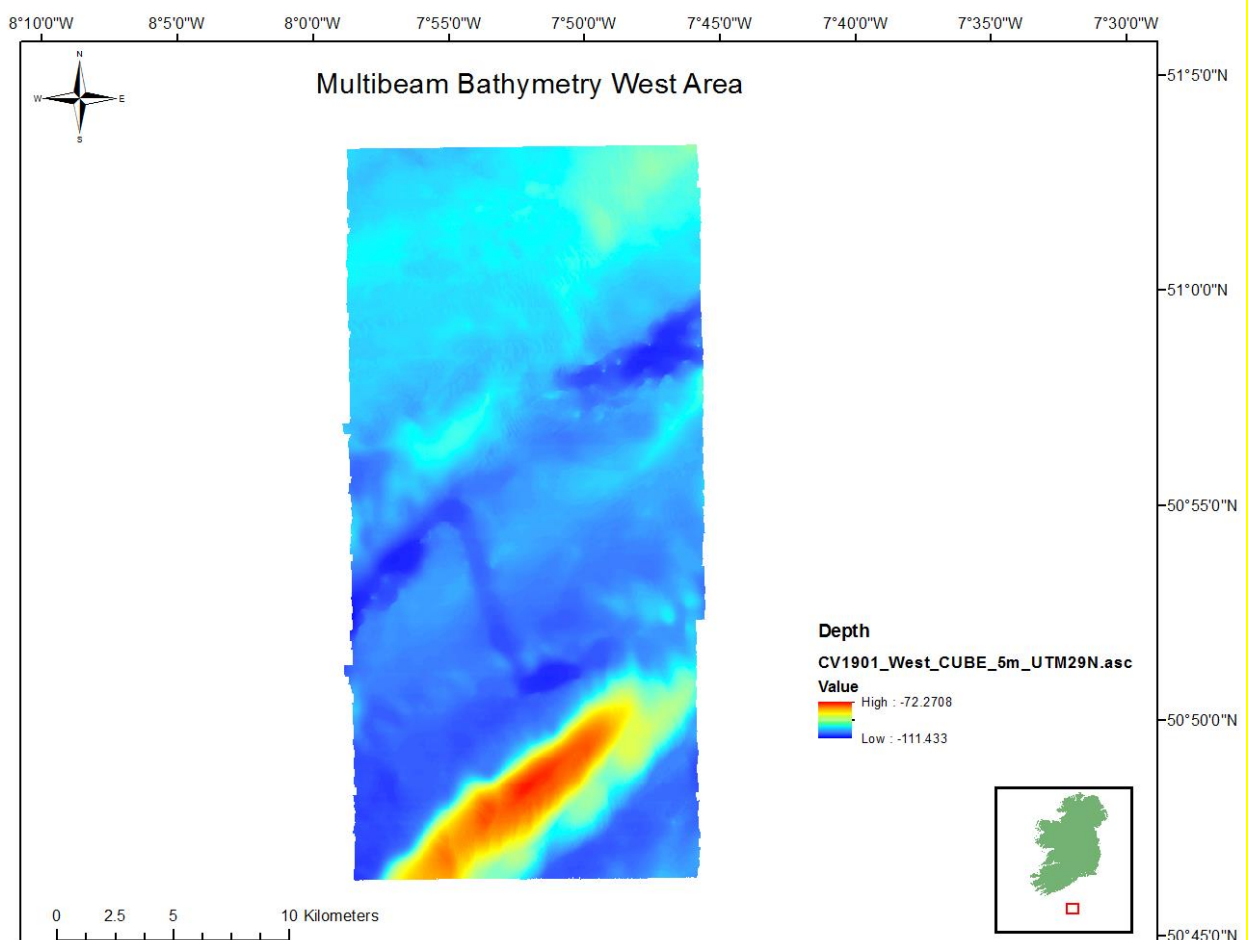


Figure 11: Multibeam bathymetry west area.

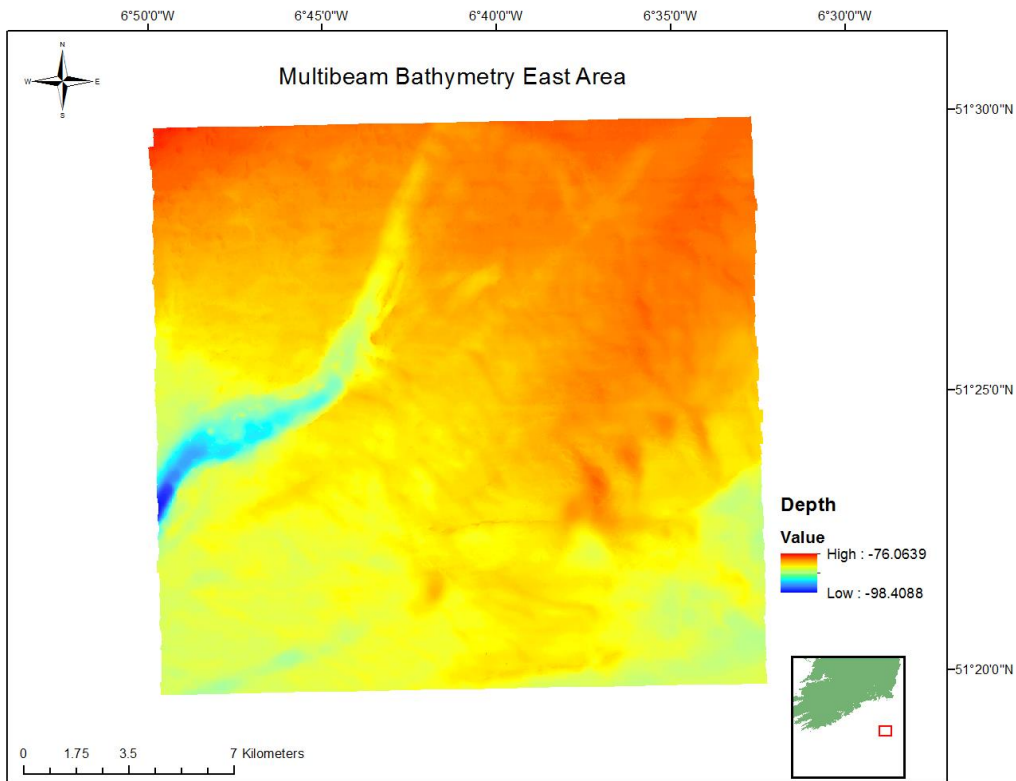


Figure 12: Multibeam bathymetry east area.

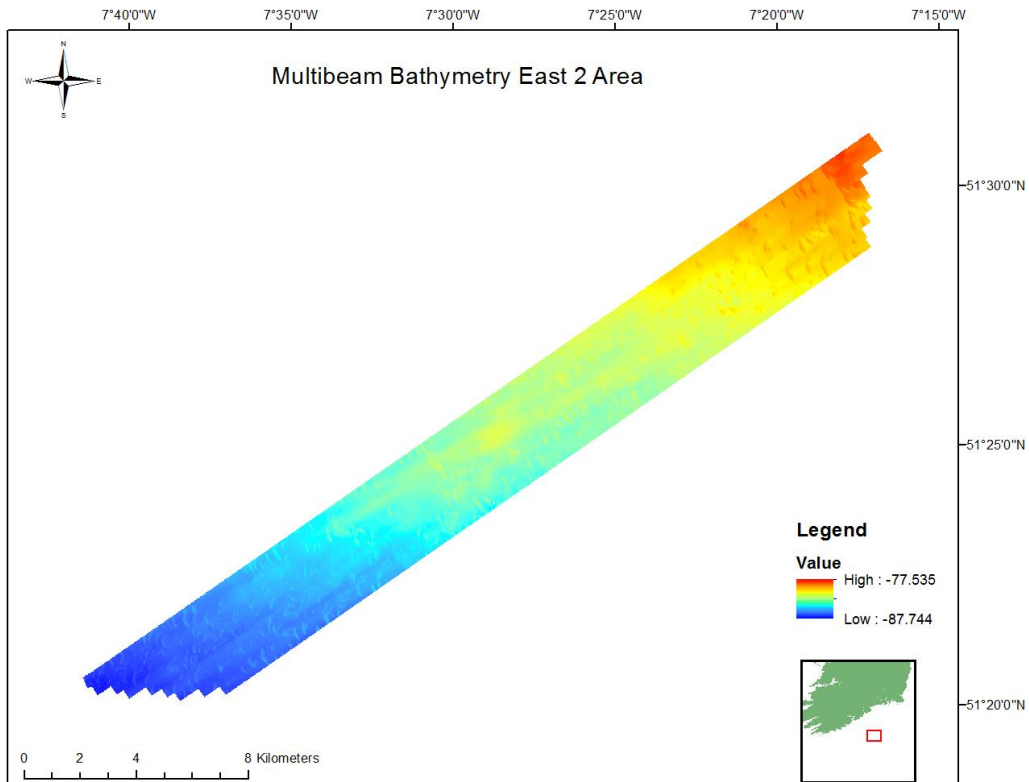


Figure 13: Multibeam bathymetry east 2 area.

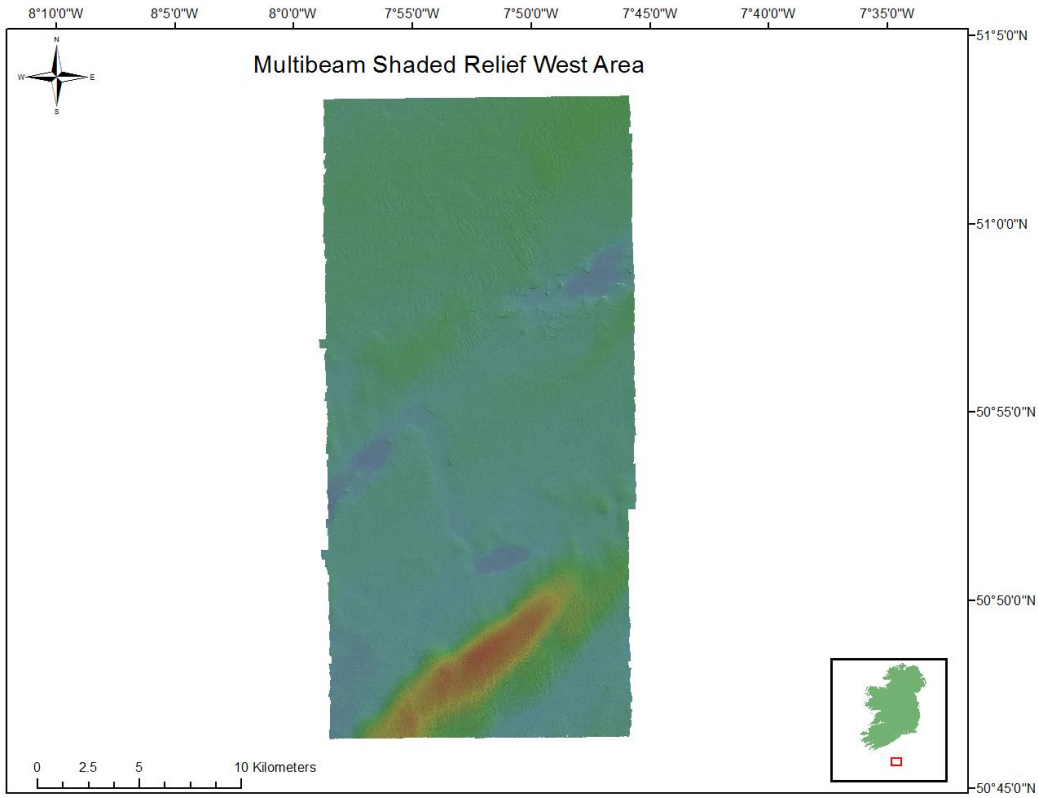


Figure 14: Multibeam shaded relief west area.

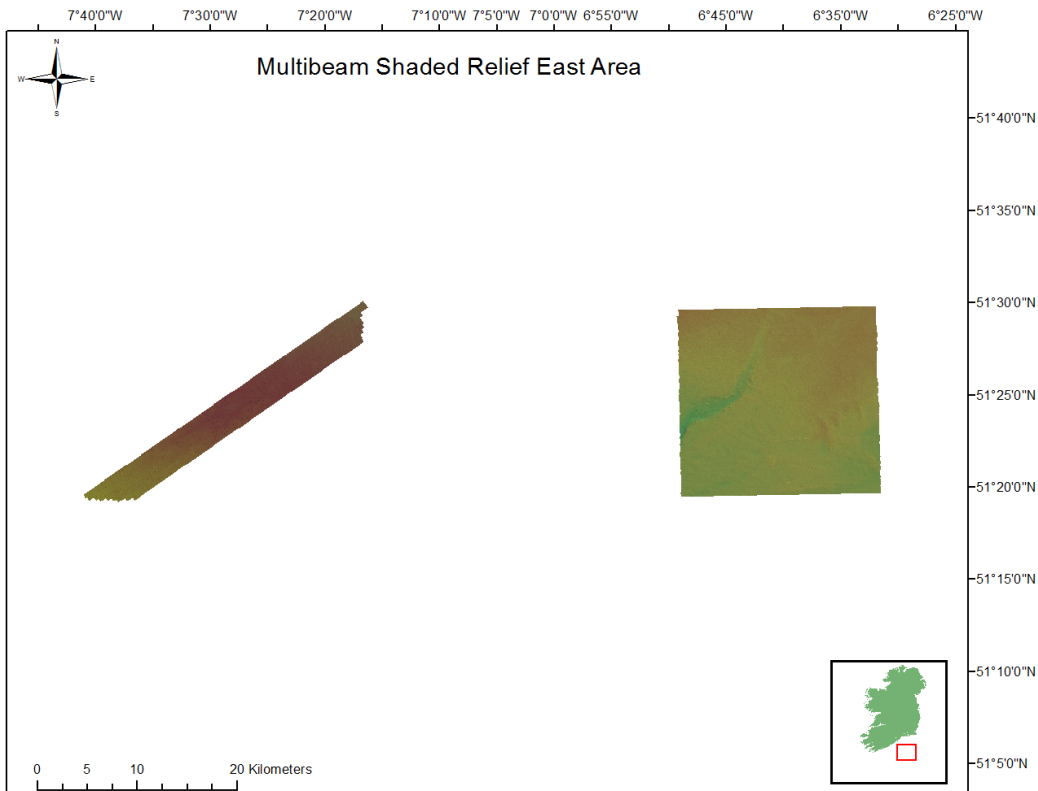


Figure 15: Multibeam shaded relief east areas combined.

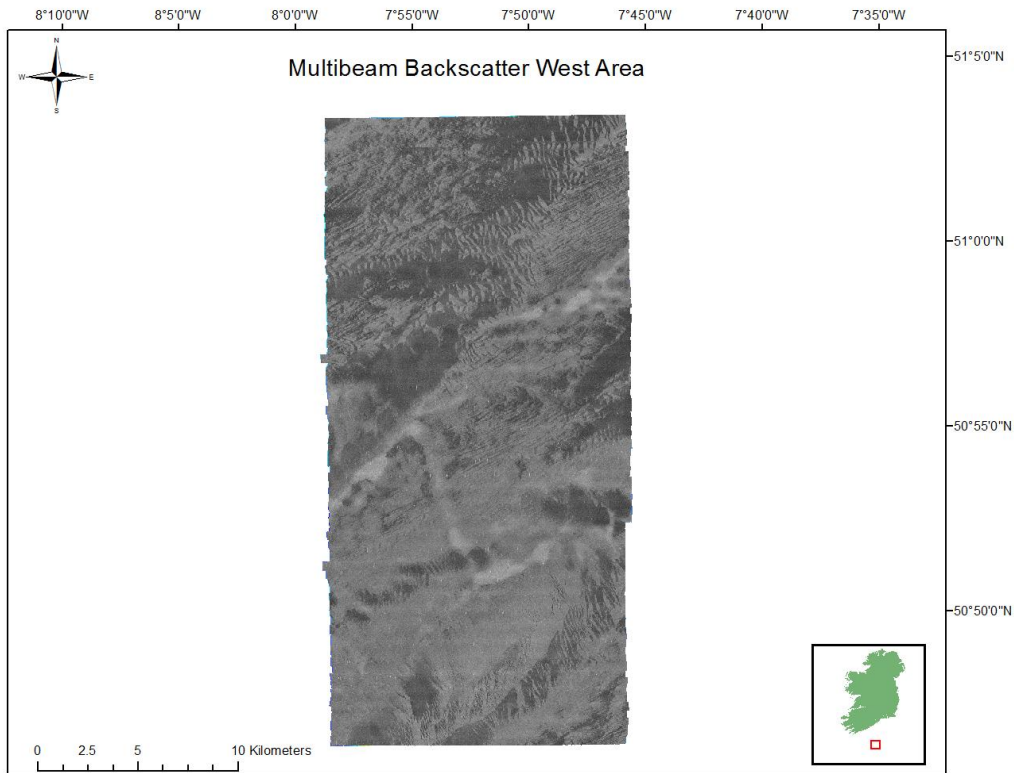


Figure 16: Multibeam backscatter mosaic west area.



Figure 17: Multibeam backscatter mosaic east areas combined.

### 4.3.2 Shallow Geology Analysis

Data quality and penetration varied depending on prevailing sea state, survey direction and sub-bottom hardness. Survey speed (4-9 knots) was dictated by the ability of the MBES to meet its data density and data quality requirement. This is faster than the optimal maximum speed of 4 knots for sub bottom data integrity. Sea state varied significantly during the survey and in general the seabed is hard apart from channels and sand ribbons. This combination resulted in limited sub bottom penetration and sub-surface horizon delineation.

Tiff images and coda format seismic files were recorded for all SBP lines. Profile lines 059, 165 and 268 are selected for discussion here. Their geographical locations are shown in figures 18 and 19 where the profile extents have been overlain on shaded relief data. Profile 059 was acquired on a westerly heading in the eastern area. Profiles 165 and 268 were acquired on easterly headings in the western survey area.

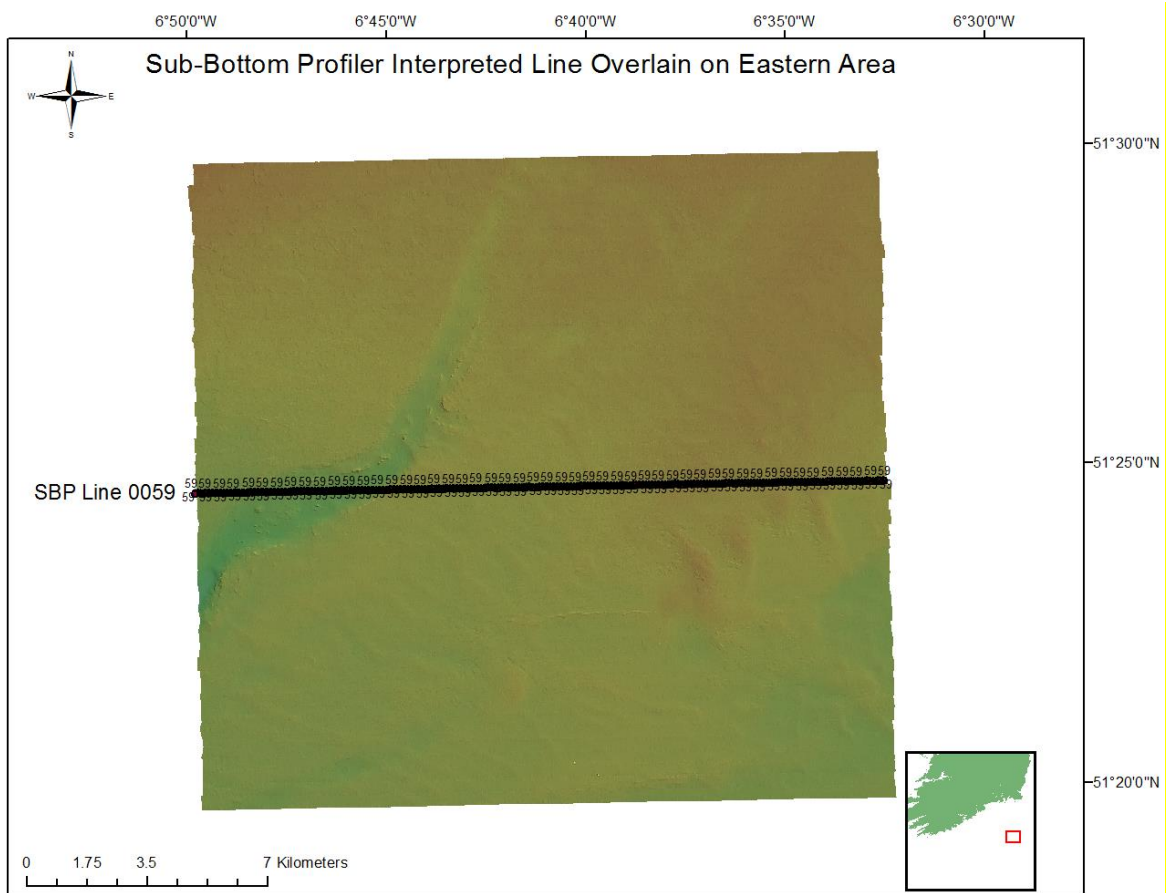


Figure 18: Sub bottom profile line 0059 overlain on shaded relief data.

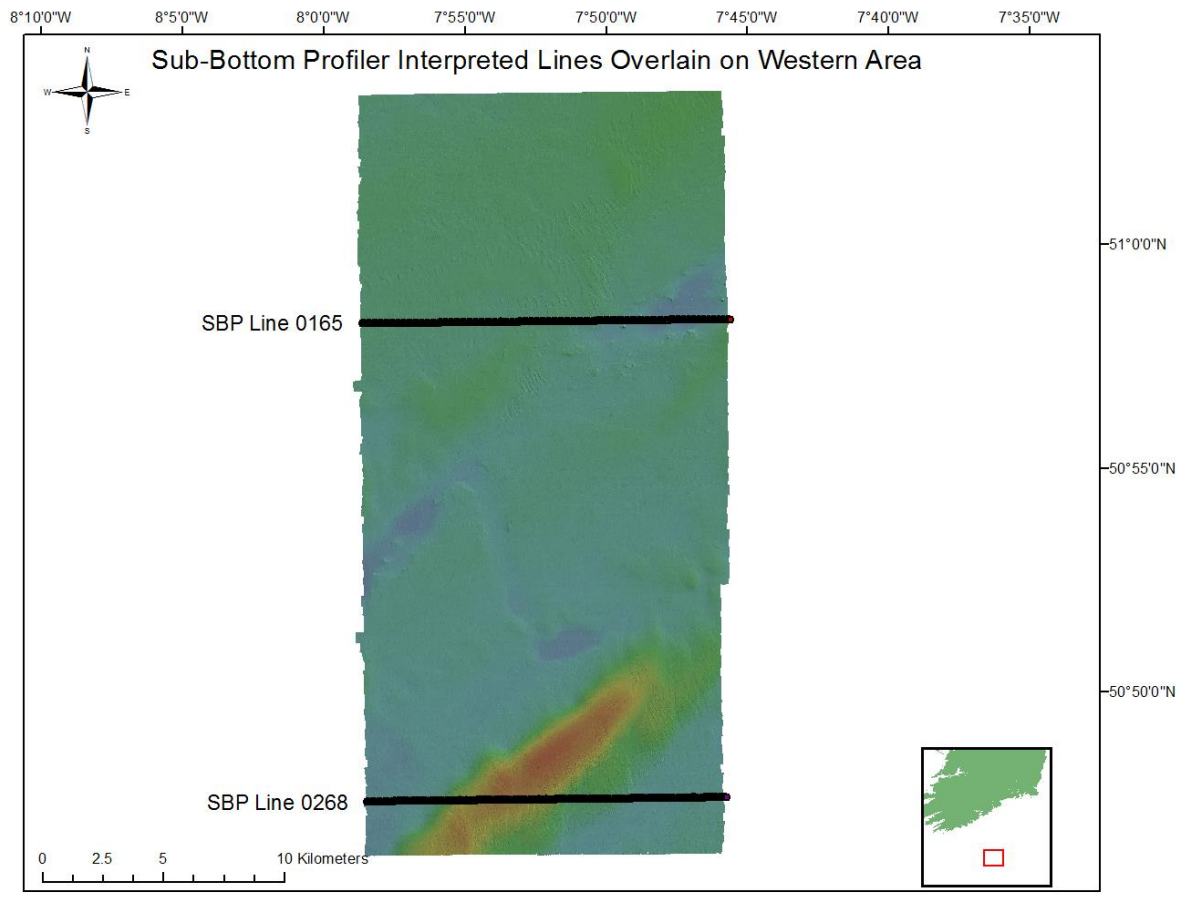


Figure 19: Sub bottom profile lines 0165 and 0268 overlain on shaded relief data.

Interpreted sub bottom profiler tiff images of survey lines 059, 165 and 268 are shown in figures 20, 21 and 22 respectively. A bandpass filter with low cut 2.2 kHz and high cut 4.7 kHz was applied in processing, along with a suitable gain. Heave compensation is applied to the images displayed. Horizontal scale lines are at 10 metre intervals for all sub bottom images below.

Profile 059 (figure 20), acquired on the eastern block is 20 km in length. The profile is dominated by hard ground with the result that signal penetration is limited. The eastern part of the profile shows a few sporadic discontinuous reflectors. A recently deposited soft sedimentary unit forms the topmost unit over most of the profile. It unconformably overlies the unit containing sporadic discontinuous reflectors. Bedrock forms the base unit in the west. A number of dipping reflectors are evident. The bedrock is unconformably overlain by sediments which are infilling a channel. These sediments are up to approximately 3 m in thickness. Bedrock outcrops at one location on the western end.

Profile 165 in figure 21 is acquired on an easterly heading in the west data block. The profile is 15.3 km in length. The base unit is bedrock throughout the profile. The top of the bedrock unit is clearly visible in the east, where it is hummocky in character. Further west dipping reflectors are sporadic. The bedrock is unconformably overlain by soft sediments in the east. This soft sedimentary unit varies in thickness up to a maximum of approximately 13 m. This unit is overlain by a thin sedimentary unit of recent sediments. It is up to 3 m in thickness and pinches out against the underlying unit. Bedrock outcrops at one location. Further west these top two units are not present. The near surface sediments are a mix of sand ribbons which laterally transition to lag deposits. Sand ribbons are less than 1 m thick and approximately 50 m in width. Lag sediments between the ribbons are also approximately 50 m in width. The top of the bedrock unit cannot be seen over the western part of the profile.

Profile 268 in figure 22 is 15 km in length and acquired from west to east in the west survey block. Signal penetration is poor along the entire profile due to the acoustic properties of the substrate sediments. The profile is dominated by a ridge at the western end. A reflector is evident at the west side of the ridge and also on the east side. This reflector is not traceable beneath the ridge crest. Sediment thickness above this reflector ranges from over 10 m west of the ridge to about 5 m east of the ridge. The reflector is dipping west of the crest but appears sub-horizontal east of the ridge.

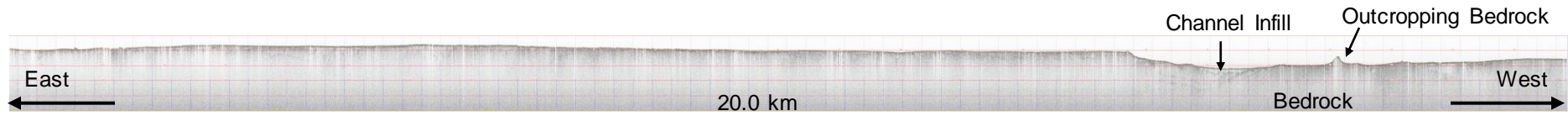


Figure 20: Sub bottom profile interpreted image, line 0059.

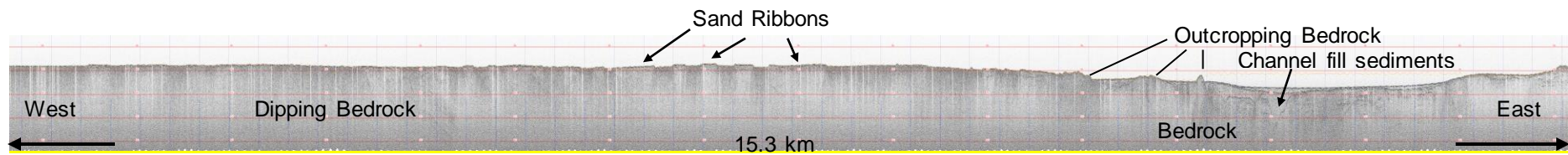


Figure 21: Sub bottom profile interpreted image, line 0165.

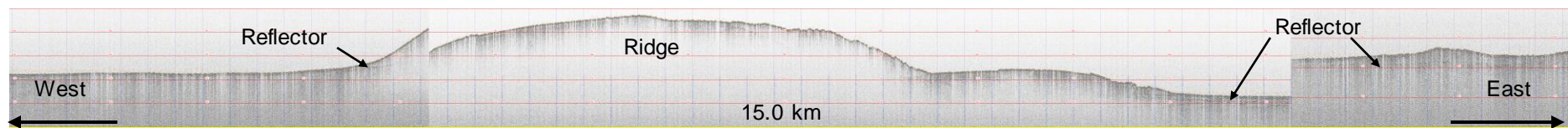


Figure 22: Sub bottom profile interpreted image, line 0268.

### 4.3.3 Bathymetry

Figure 23 shows the colour coded multibeam bathymetry image for the west area. Water depth varies from 72 to 111 m. Depth contours are generally aligned along a northeast – southwest trend. A large ridge in the south is the most prominent bathymetric feature. It is approximately 30 m in amplitude, 3 km in width and over 10 km in length.

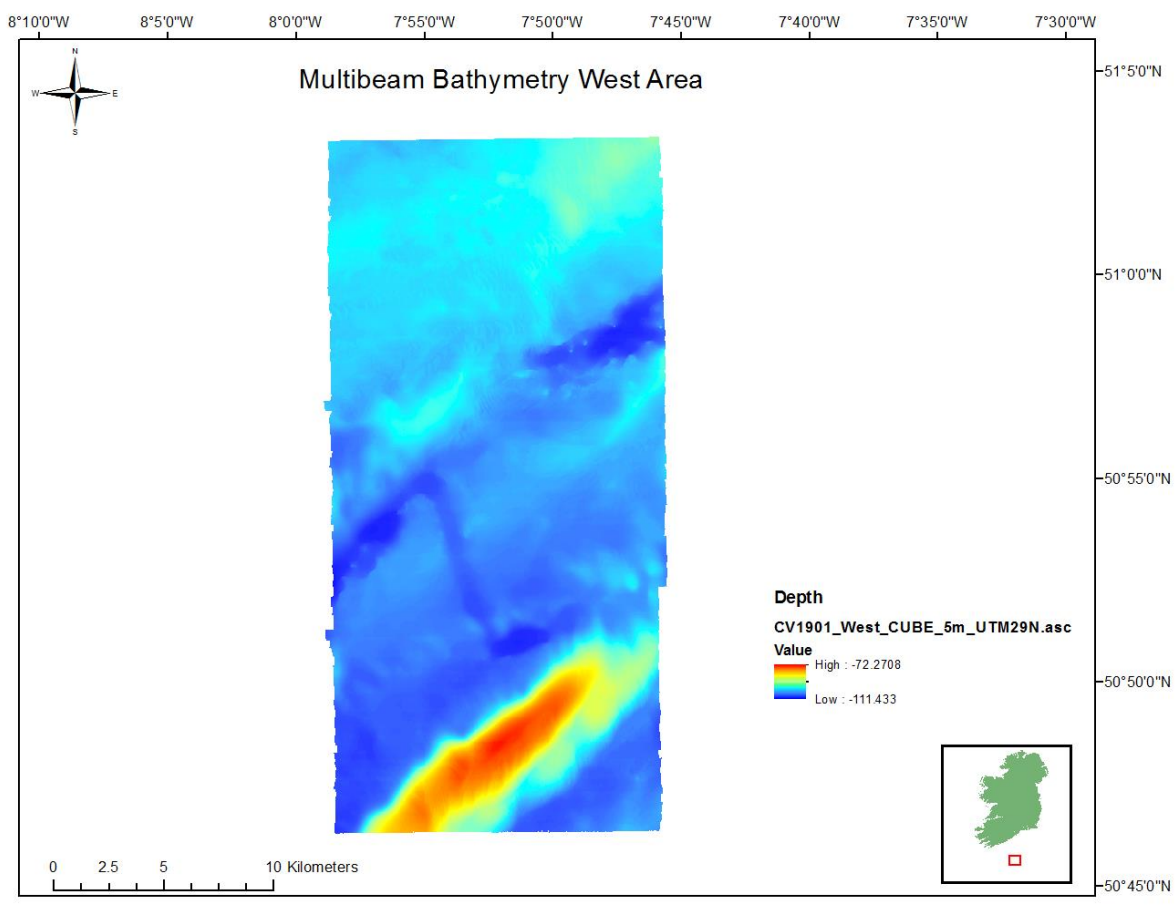


Figure 23: Multibeam bathymetry image west area.

Figure 24 shows the colour coded multibeam bathymetry image for the east area. Water depth varies from 76 to 98 m. Water depth generally increases from north to south. A sinuous channel cuts through the northwest of the area. It is up to 2 km in width and 15 m deep.

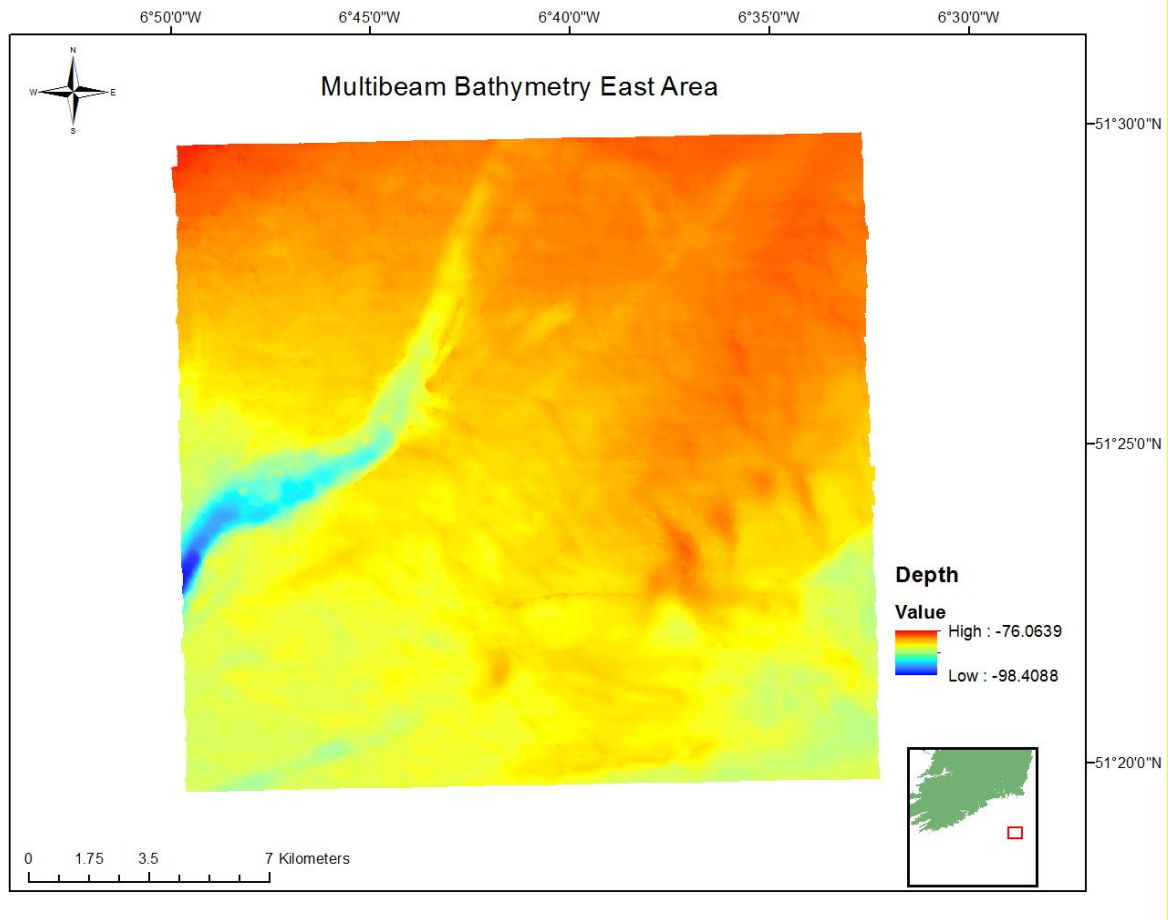


Figure 24: Multibeam bathymetry image east area.

Figure 25 shows the annotated bathymetry image for the east 2 area. It is located about 40 km to the west of the area above. Water depth ranges from 78 to 88 m. Depth generally increases from northeast to southwest. Seafloor gradient is very gentle although sand ribbons aligned along northwest - southeast trend exhibit very localised moderate gradients.

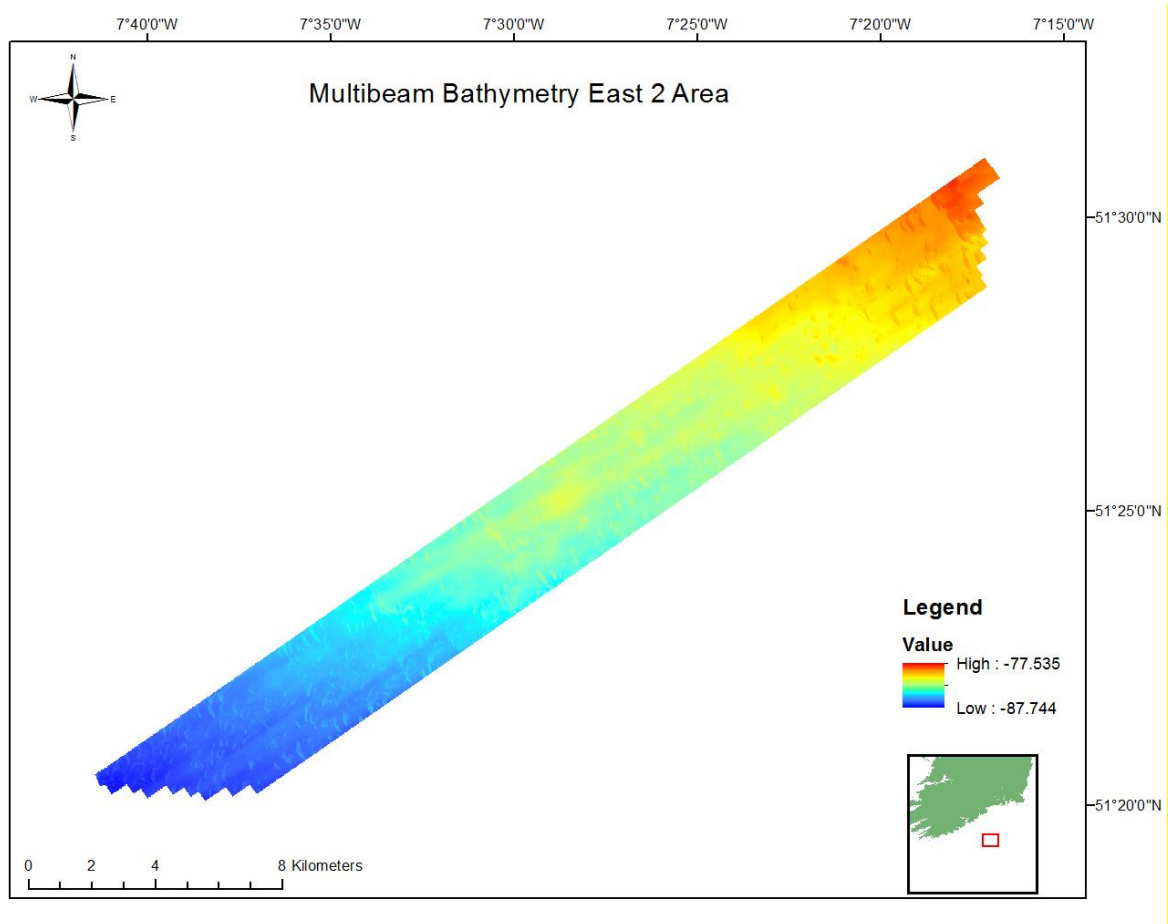


Figure 25: Multibeam bathymetry image east 2 area.

#### 4.3.4 Seabed Texture

Multibeam backscatter is the amount of acoustic energy received by the sonar after a complex interaction with the seafloor. By analysing the amplitude of the returning sound waves it is possible to extract information about bottom structure and hardness, allowing for identification of bottom types. Seabed reflectivity properties depend on the hardness and roughness of the seafloor surface. In simple terms a strong return signal indicates a hard and/or rough surface and a weak return signal indicates a soft, smooth surface.

Figure 26 shows the substrate interpreted backscatter mosaic for the west area. The convention used in this report is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. A wide variety of backscatter responses are found with intensities ranging from 8 to -49 db. Lowest backscatter intensities are located mostly in the bathymetric lows and strongly correlate with the morphology of those bathymetric lows.

Other low backscatter intensity areas correlate with sand ribbons, located mainly in the northern half of the area. Large homogeneous areas of intermediate backscatter are found in the south. High backscatter intensity areas are located throughout and are adjacent to all of the other backscatter intensity types. There is not a strong correlation between high backscatter type and bathymetry.

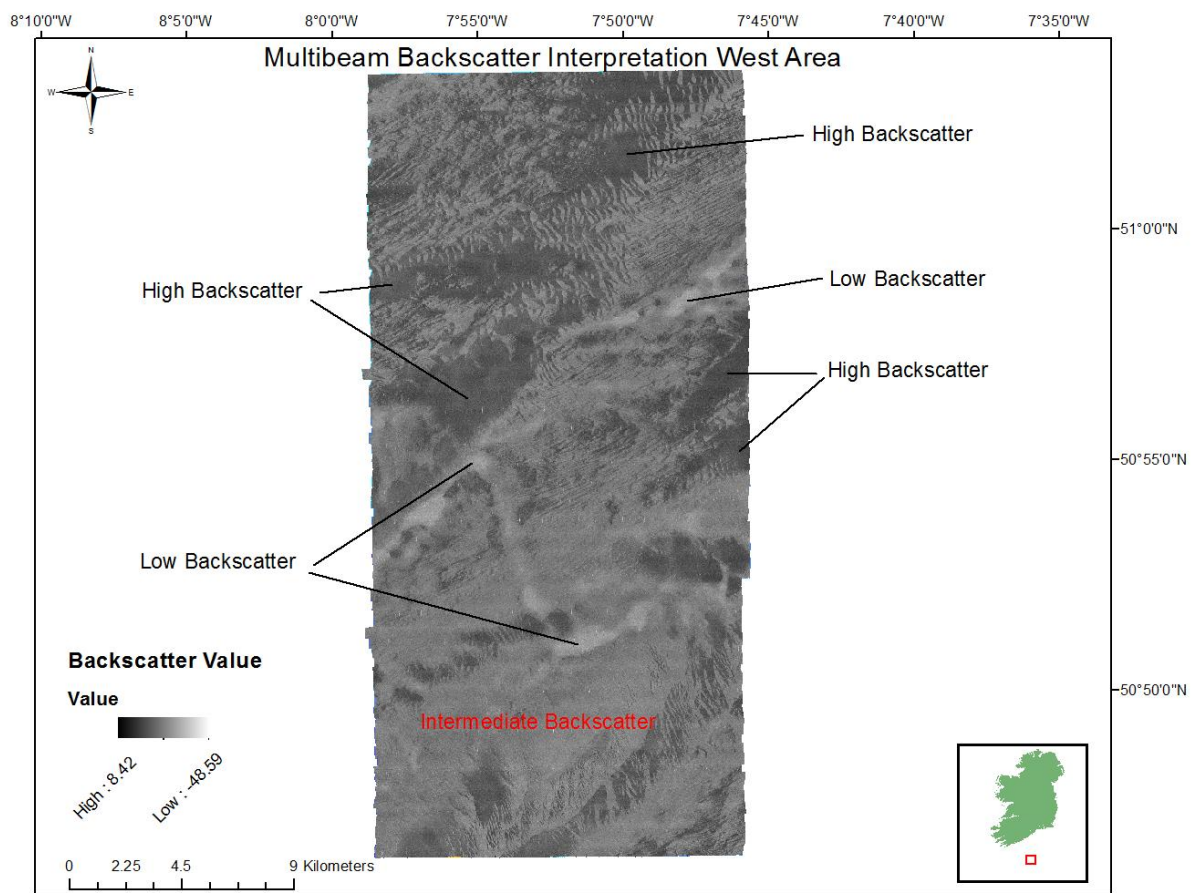


Figure 26: Interpreted multibeam backscatter, west area.

Figure 27 shows the substrate interpreted backscatter mosaic for the east area. The convention used in this image is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. Backscatter intensities range from 0 to -58 db. Intermediate backscatter intensities are the dominant type. Low backscatter intensities are rare and are restricted to parts of the channel (see bathymetry image). High backscatter intensities are found mainly in the northwest and south central parts.

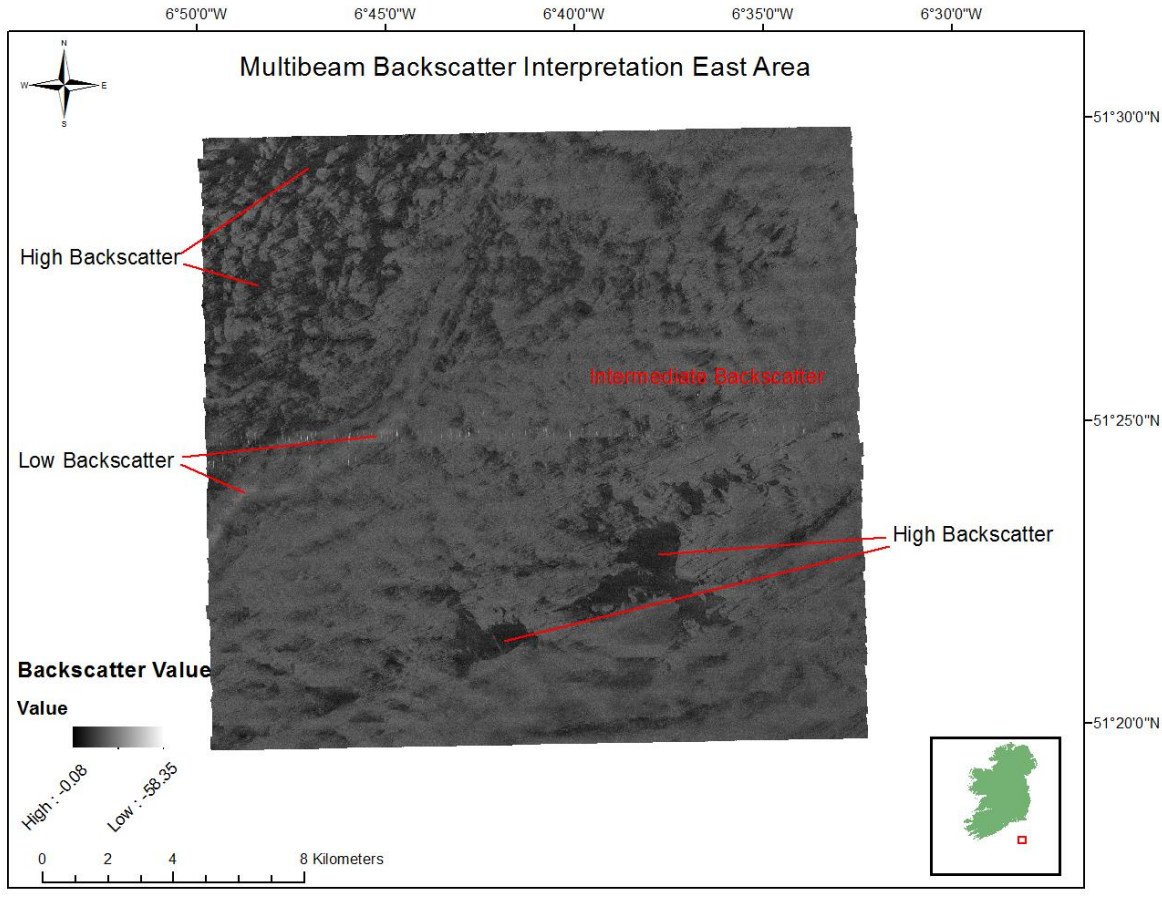


Figure 27: Interpreted multibeam backscatter, east area.

Figure 28 shows the substrate interpreted backscatter mosaic for the east 2 area. Backscatter intensities range from 4 to -47 db. The area has been categorised into high and low backscatter. There is a strong correlation between backscatter intensity and bathymetry with the low intensities associated with bathymetric highs and high intensities associated with bathymetry lows. Low intensity backscatter here is interpreted as sand ribbons.

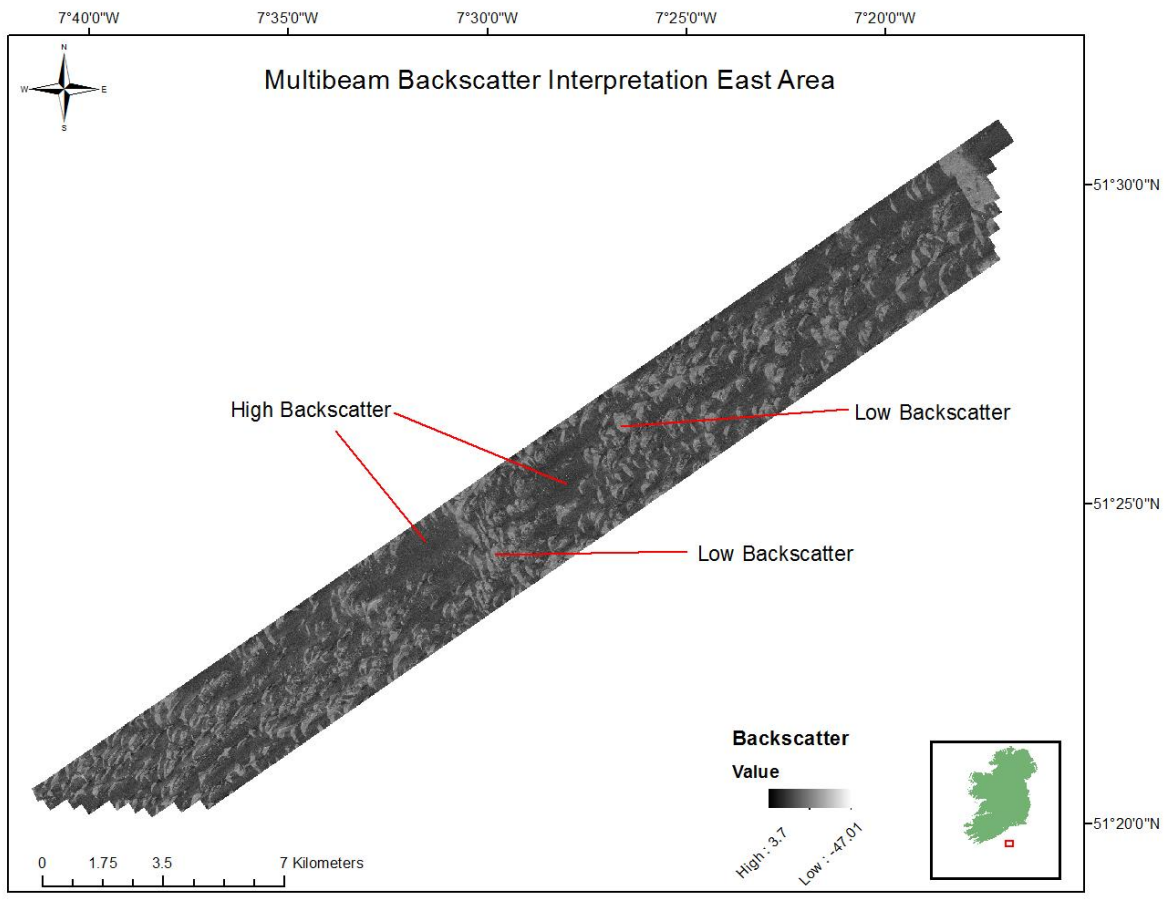


Figure 28: Interpreted multibeam backscatter, east 2 area.

#### 4.3.5 Seabed Features

Description of seabed features is based on analysis of bathymetric, shaded relief and backscatter data. It is possible to make valid inferences on seabed character and composition by correlating these datasets. Shaded relief data are used to illustrate the features discussed in this section. Shaded relief imagery is produced in Caris by shining an imaginary sun at 35° angle over the depth colour coded multibeam bathymetry dataset.

Figure 29 is a shaded relief illustrating the ridge located in the west area. It has long axis orientated on a northwest – southeast trend. Its top surface is marked by sediment ribbons which tend to be orientated at right angles to the ridge crest. The dimensions of the ridge are discussed in the bathymetry section of this report.

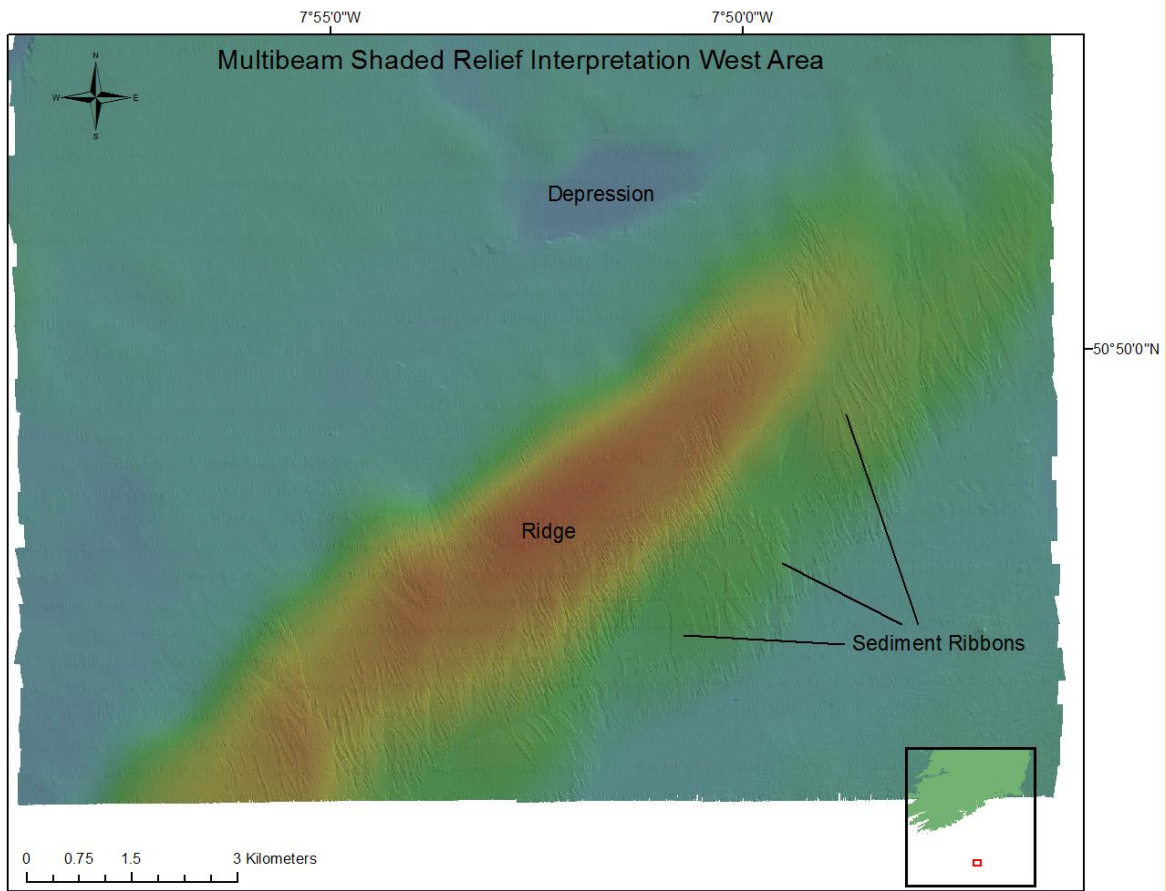


Figure 29: Multibeam shaded relief of ridge and associated features in west area.

Figure 30 is a shaded relief illustrating the channel situated in the east area. It is sinuous in character and up to 3 km in width. Outcropping bedrock is evident on both margins and within the channel itself. The channel widens and deepens to the southwest. It is the extension of a feature mapped in previous years.

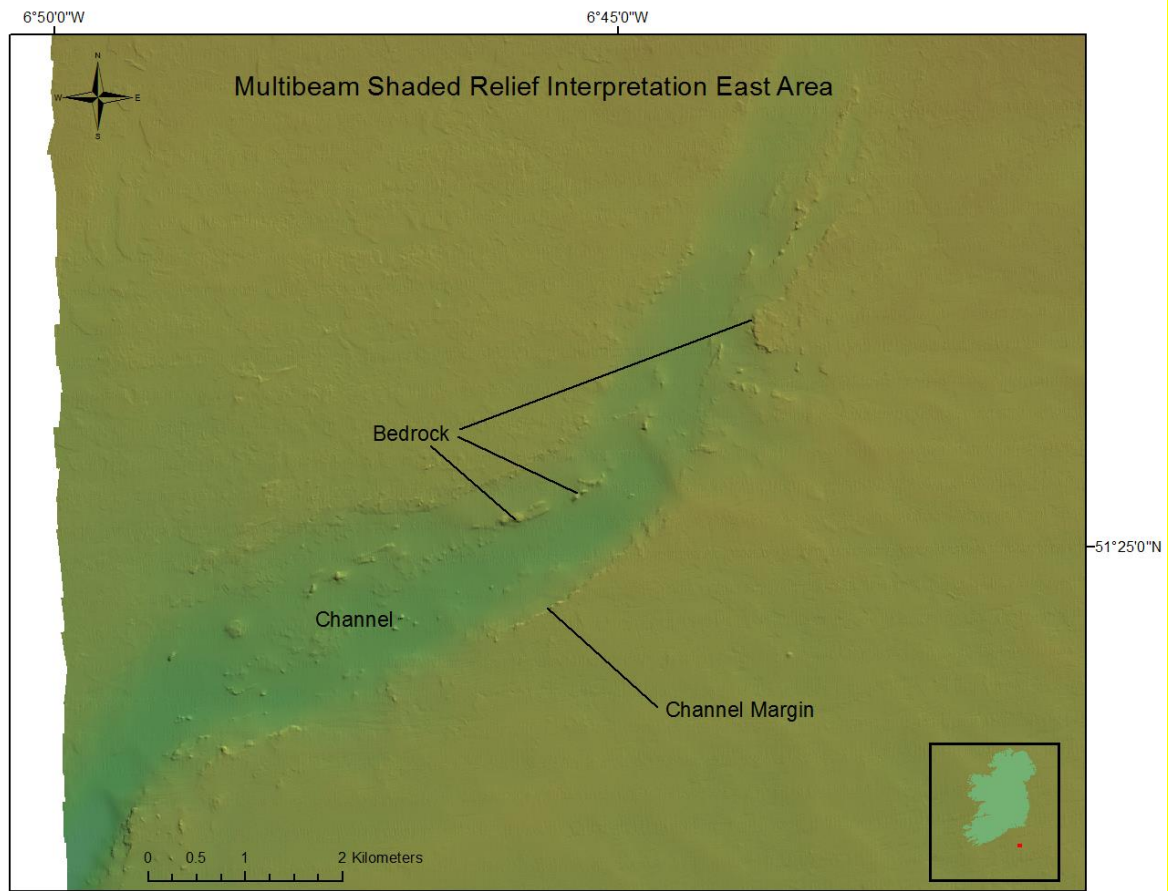


Figure 30: Multibeam shaded relief illustrating channel in east area.

Figure 31 is a shaded relief illustrating sand ribbons in the east 2 area. The ribbons have long axes orientated along northwest - southeast axes. They are less than 1 m in height and are typically less than 500 m in length and less than 200 m in width.

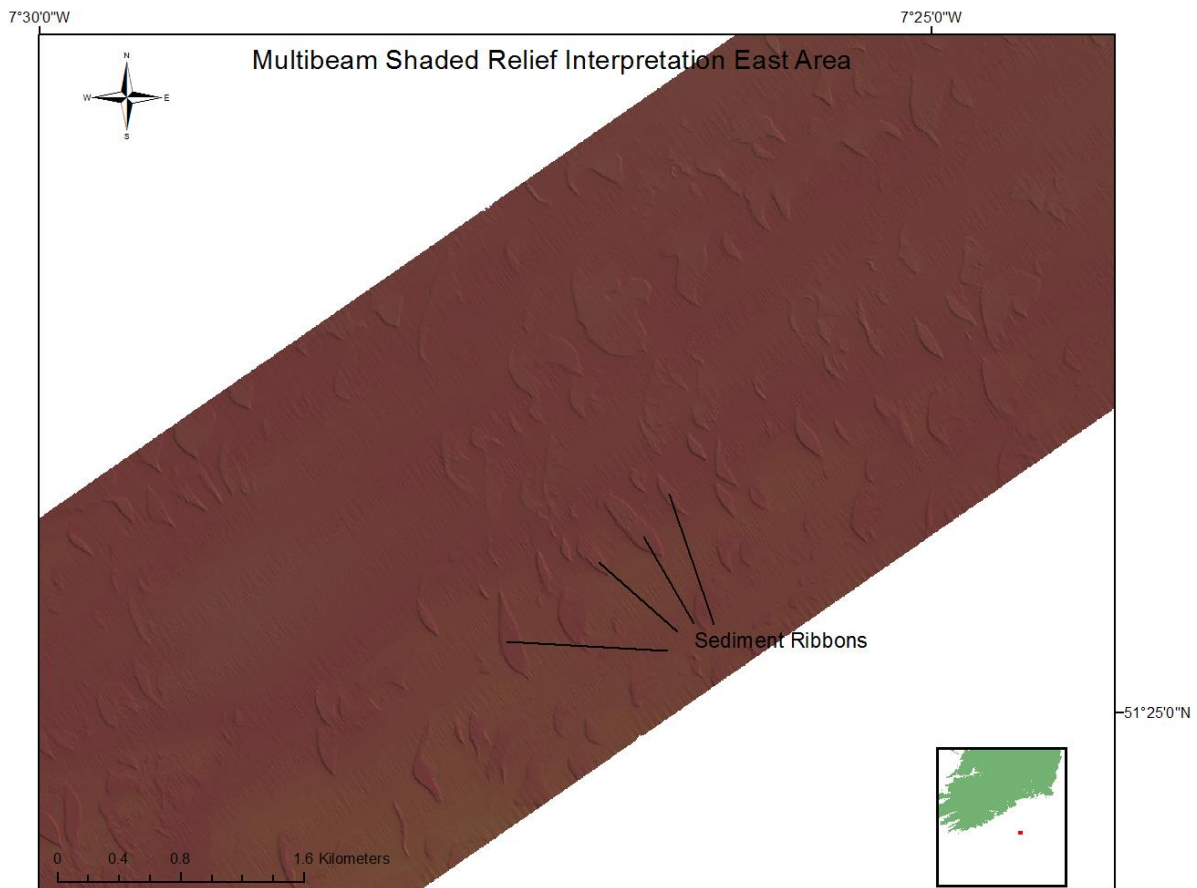


Figure 31: Multibeam shaded relief illustrating bedforms in east 2 area.

#### 4.4 Groundtruthing

Groundtruthing was not attempted during this survey due to adverse weather conditions.

#### 4.5 Wrecks

A total of four wrecks were identified from multibeam data. A detailed wreck survey was completed on one of these wrecks. This wreck was discovered during the course of a patch test in Cork Harbour. It is situated at the edge of the navigable channel, north of Roches Point. The Harbour Master was informed and a hydrographic wreck report (H525) was issued to the UKHO. Figure 32 shows the wreck.

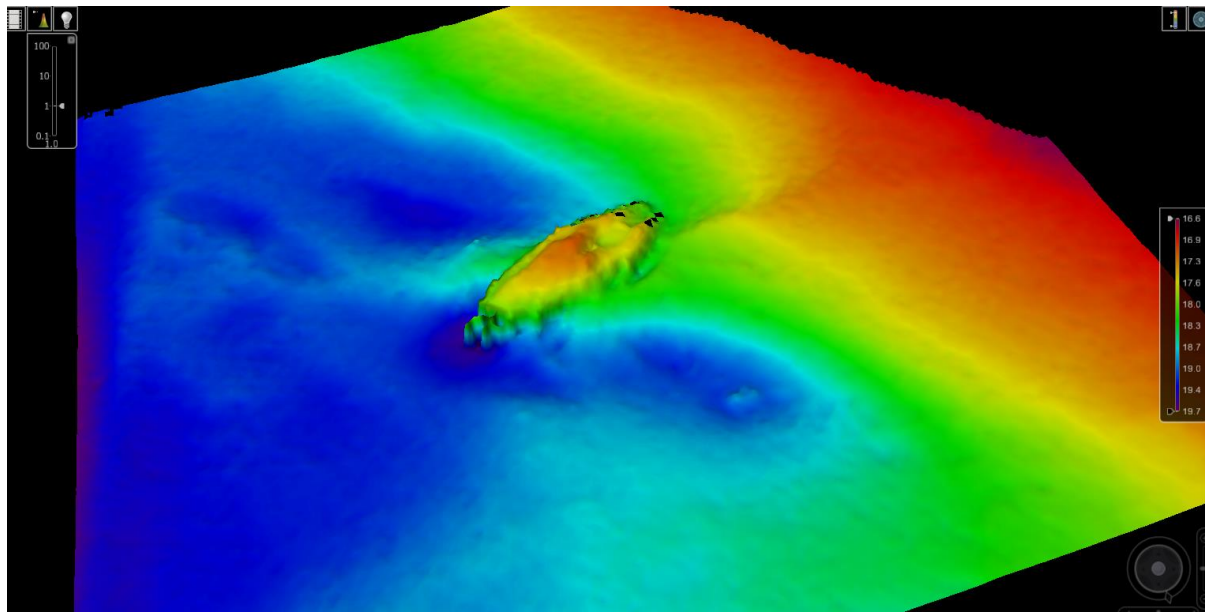


Figure 32: Mapped wreck, number 1.

Table 16 provides the wreck metadata for this wreck. Adverse weather hampered our ability to map the other wrecks in detail and this work will be done in subsequent surveys during 2019.

Number	Wreck No	Latitude	Longitude
1	NA	51° 48.845 N	-008° 16.450 W

Table 16: Wreck investigation metadata.