INFOMAR Survey Report: CV19_03
Area: Celtic Sea

For:
Marine Institute & Geological Survey Ireland

RV *Celtic Voyager*

July 2019

Prepared by Kevin Sheehan
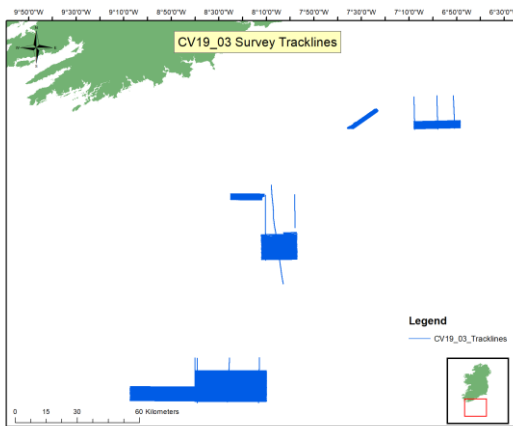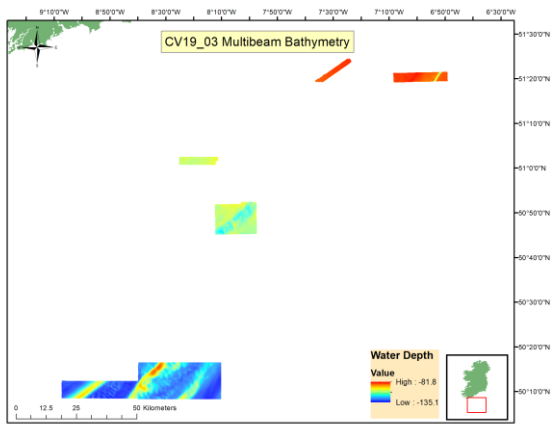
INFOMAR
Integrated Mapping for the
Sustainable Development
of Ireland's Marine Resource

Marine Institute Reference No:	Survey Report: CV19_03

		Signature	Date
Compiled by	Kevin Sheehan	*Kevin Sheehan*	28/02/2020
Checked	Fabio Sacchetti	*Fabio Sacchetti*	02/03/2020
Project Managers: Marine Institute & Geological Survey Ireland			

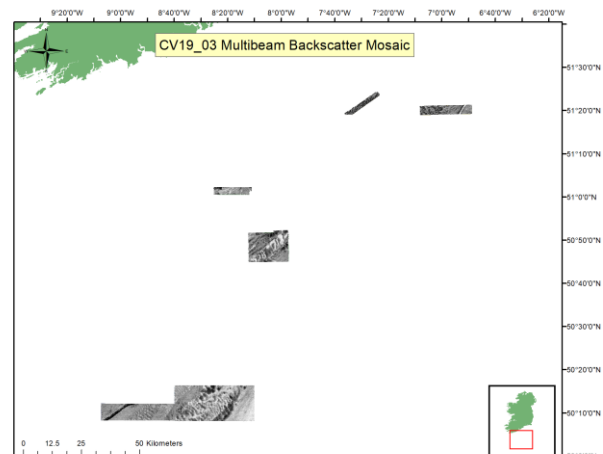| Issue	Change	Date	Description	By	Approved
1		28/02/2020	Draft	K. Sheehan	
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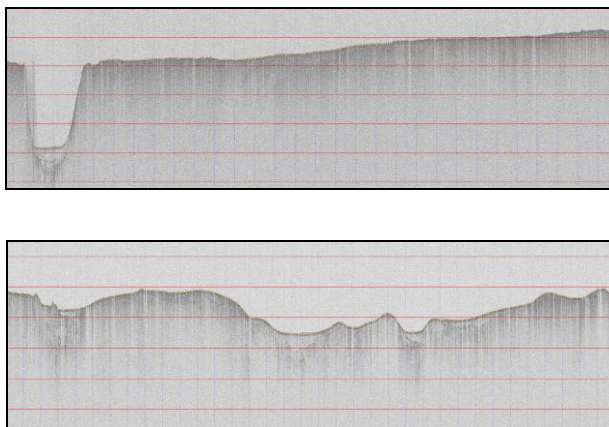| Executive Summary			
Survey Summary			
Survey Vessel:	RV *Celtic Voyager*	**Survey Leg:**	CV19_03
Mobilisation:	Cork	**Demobilisation:**	Cork
Survey Areas:	Celtic Sea	**Start Date:** **End Date:**	12/07/2019 30/07/2019
Northeast Boundary	51º 22.092N -6º 49.836W	**Southwest Boundary**	50º 10.144N -9º 07.045W
UKHO Admiralty	1121 (1:500,000) and 1123 (1:500.000)		
Key References	CV19_03 Survey Leg Report		
Equipment Used	EM2040 multibeam, Pinger sub-bottom profiler, EA400 single beam, SeaSpy magnetometer, AML MVP200, Valeport SVP Mini, C-Nav 3050 GNSS, Seapath 330+.		
Survey Statistics			
Minimum Water Depth (VORF LAT):	82 m	**Maximum Water Depth (VORF LAT):**	135 m
Area Covered:	1145 km²	**Survey Line Kilometres:**	2904 km
Approximate Operational:	50%	**Approximate Downtime :**	33%
Groundtruthing Stations:	9	**Wrecks**	1
H525 forms issues (wrecks)	1	**H102 forms issued (shoals)**	0
Survey Tracklines		**Bathymetry**	

Survey Images	
Multibeam Shaded Relief	**Multibeam Backscatter**
Sub Bottom Profiler Lines 223 & 276	**Shaded Relief Illustrating Ridge**
Wreck Number 1	**Survey Statistics**
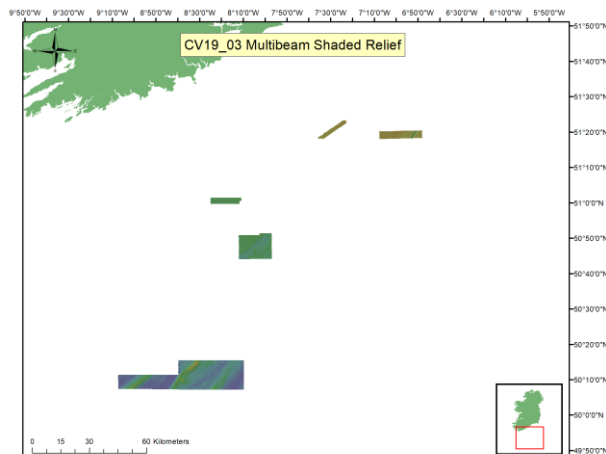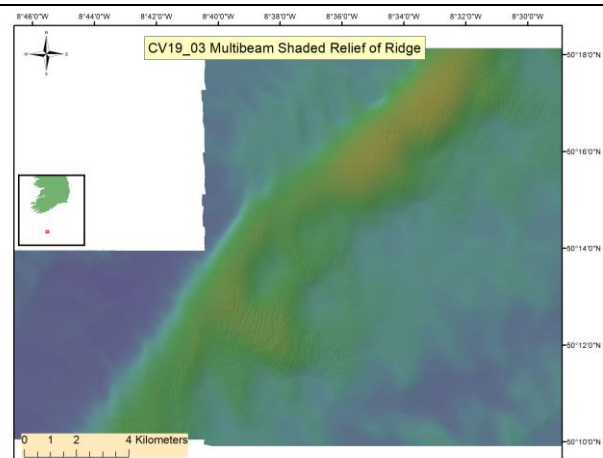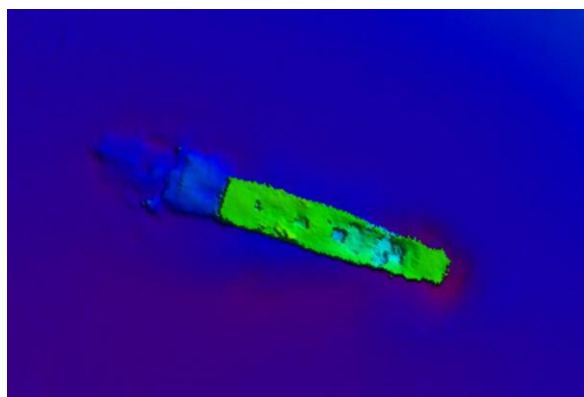
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List of Acronyms Used Within This Report

Acronym	Full Name
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
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 FOr 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 (DCCAE).

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 (Nm) limit. 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^2 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.
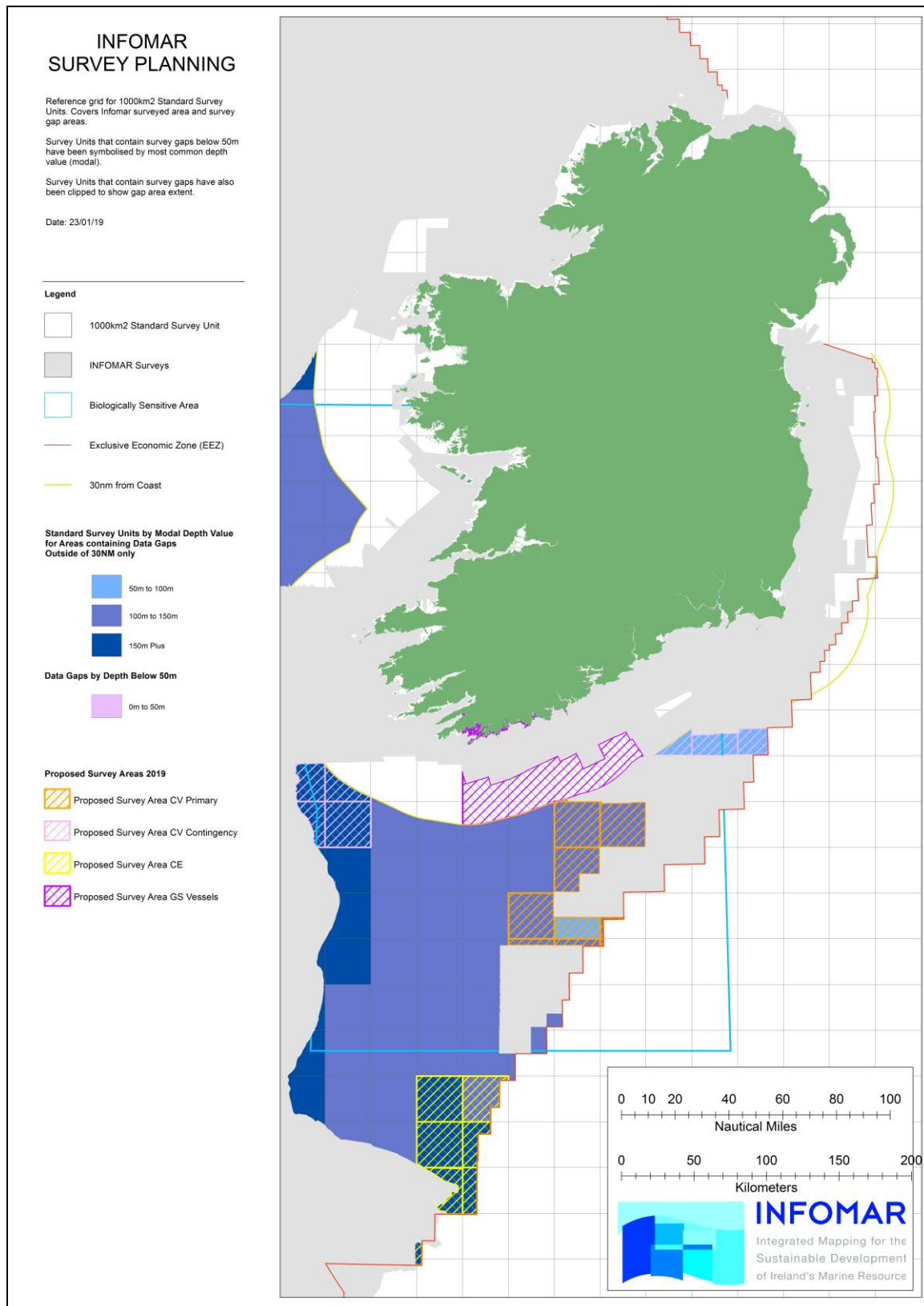
Figure 1: Survey coverage status January 2019.

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^2 based on annual survey statistics since 2016 and modal depth of ISUs to be surveyed. The primary target area, hatched in orange is 4640 km^2 as hatched boundaries were drawn along existing ISU boundaries. Approximately 10% of the area lies in the 50 to 100 m depth zone and 90% in the 100 to 150 m depth zone. Survey coverage rates for these two zones are estimated at 80 km^2 and 113 km^2 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^2 and it resides within the 50 to 100 m depth zone.
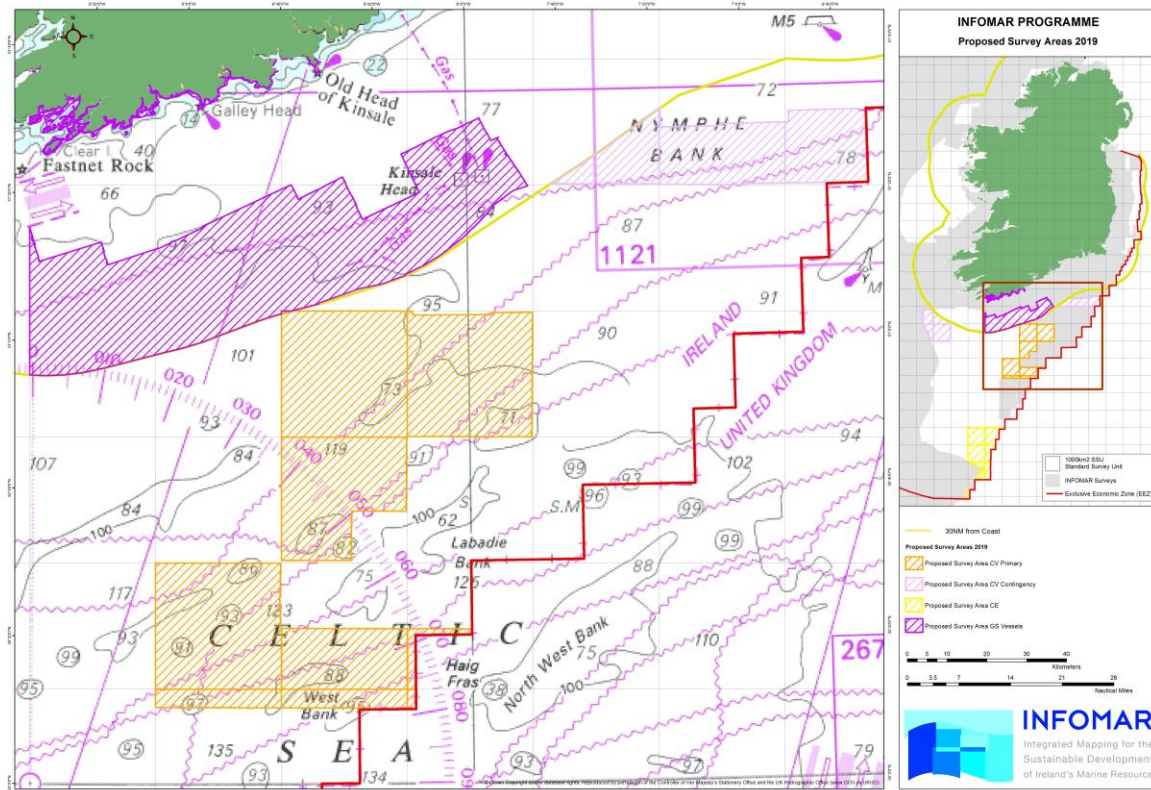
Figure 2: Proposed survey area for 2019.

2.   Operations & Survey Setup

Mobilisation took place in Cork on 12th July. Survey acquisition took place between 12th and 29th July. Kevin Sheehan and Oisin McManus 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. Five separate survey polygons were mapped, denoted in this report as the East (2), Central (2) and South (1) areas respectively.
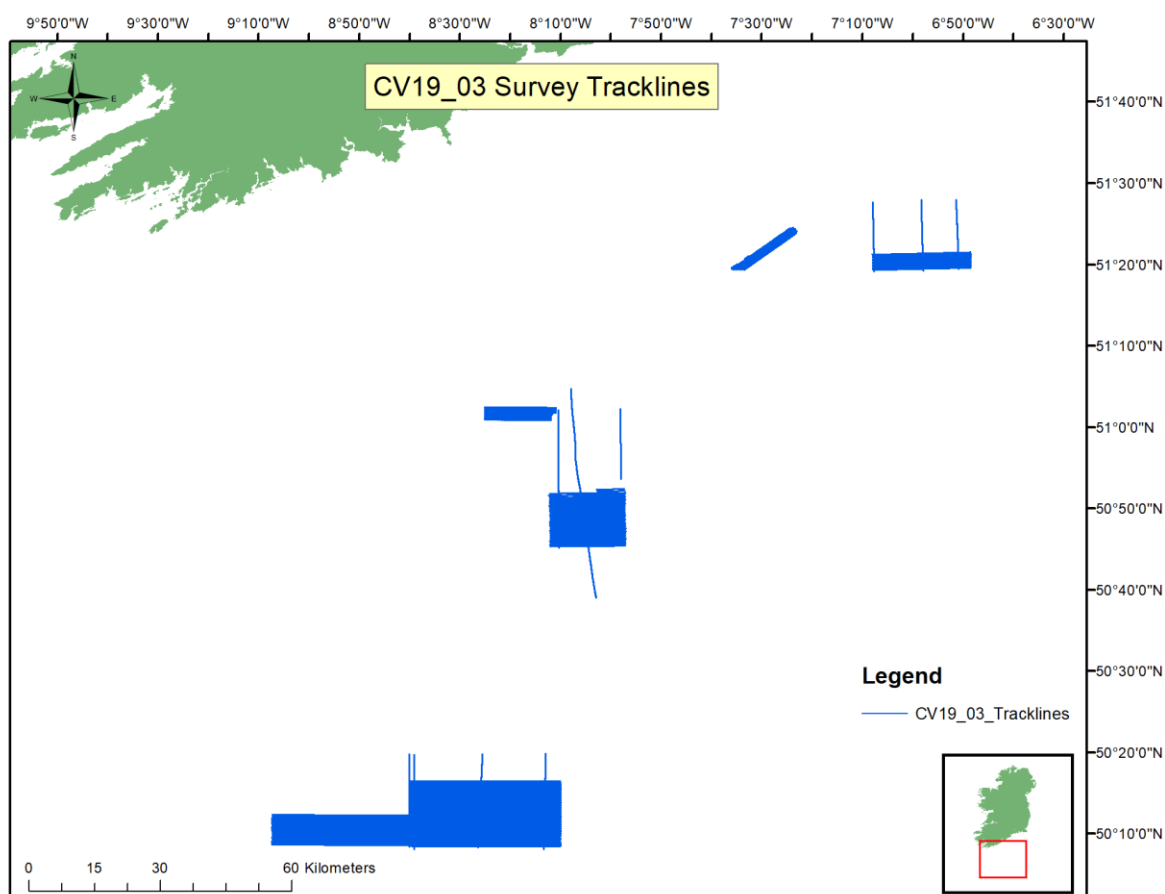
Figure 3: Survey trackline plot produced in Caris and ArcGIS software.

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

12/07/2019 08:00	Mobilised in Cork City
12/07/2019 11:15	Departed Cork
12/07/2019 23:33	Commenced operations
20/07/2019 00:27	Weather Standby. Transit to Cork. Scientific personnel change.
21/07/2019 13:00	Weather Standby. Alongside Cork
23/07/2019 05:30	Transit to site
23/07/2019 12:52	Resumed operations
24/07/2019 22:43	Weather Standby. Transit to Cork
26/07/2019 17:30	Weather Standby. Departed for survey site.
26/07/2019 03:08	Resumed operations
29/07/2019 15:33	Weather standby. Transit to Cork
30/07/2019 08:00	Demobilisation Cork
30/07/2019 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
Oisin McManus	MI	Party Chief /Surveyor
Nicola O' Brien	MI	Surveyor
Michael Arrigan	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, sound velocity profiler and grab 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)	2904
Area Covered (km^2)	1145
Operational (%)	50
Weather Standby (%)	33
Transit (%)	7
Port Call (%)	10

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 50% of the time.
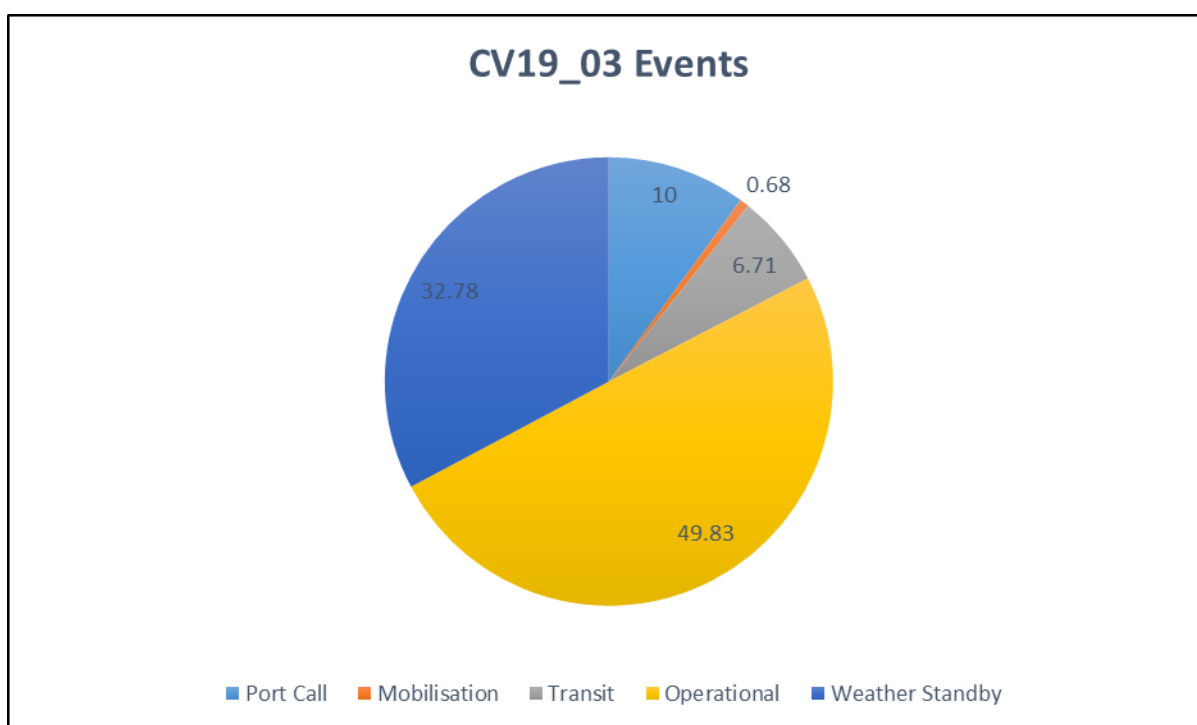
Figure 4: Survey statistics pie chart.

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

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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: **INFOMAR**
Client: **MI & GSI**
Project Title:
Date Last Surveyed **10-11/01/2016 - Bluepix**   Date: **11/01/2016**

Celtic Voyager

X Motion Reference Unit - Seapath 330+ MRU   ▲ C-Nav Antenna
▲ SeaPath Fwd Antenna   ▲ SeaPath Aft Antenna
● EM3002 Fully Extracted   ● EA400-38Khz Transducer
● EA400-200Khz Transducer   ◆ Probe500 Pinger
■ GAPs USBL Acoustic Transponder   ■ SSS Towpoint
■ Maggy Towpoint   ◆ EM2040 Tx
X EM2040 RX stb   X EM2040 RX port

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	GAPs USBL Acoustic Transponder	-0.077	10.633	-4.332	
10	SSS Tow point	0.000	-13.905	1.987	
11	Maggy Tow point	-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 (Bluepix Report 10-11/01/2016)			
Item	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
	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.

CV19_03 Installation Parameters			
Item	Yaw	Roll	Pitch
MRU 5+	-0.23	0.11	-0.09
EM2040 TX	-0.05	-0.33	0.74
EM2040 RX Port	-0.98	39.62	0.67
EM2040 RX Stb	0.69	-40.36	0.73

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 on board 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 DGNSS	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.

Local Datum Geodetic Parameters	
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
Projection Parameters	
Grid Projection	Universal Transverse Mercator
Central Meridian Zone 29 (CM)	009º 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 Word 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.
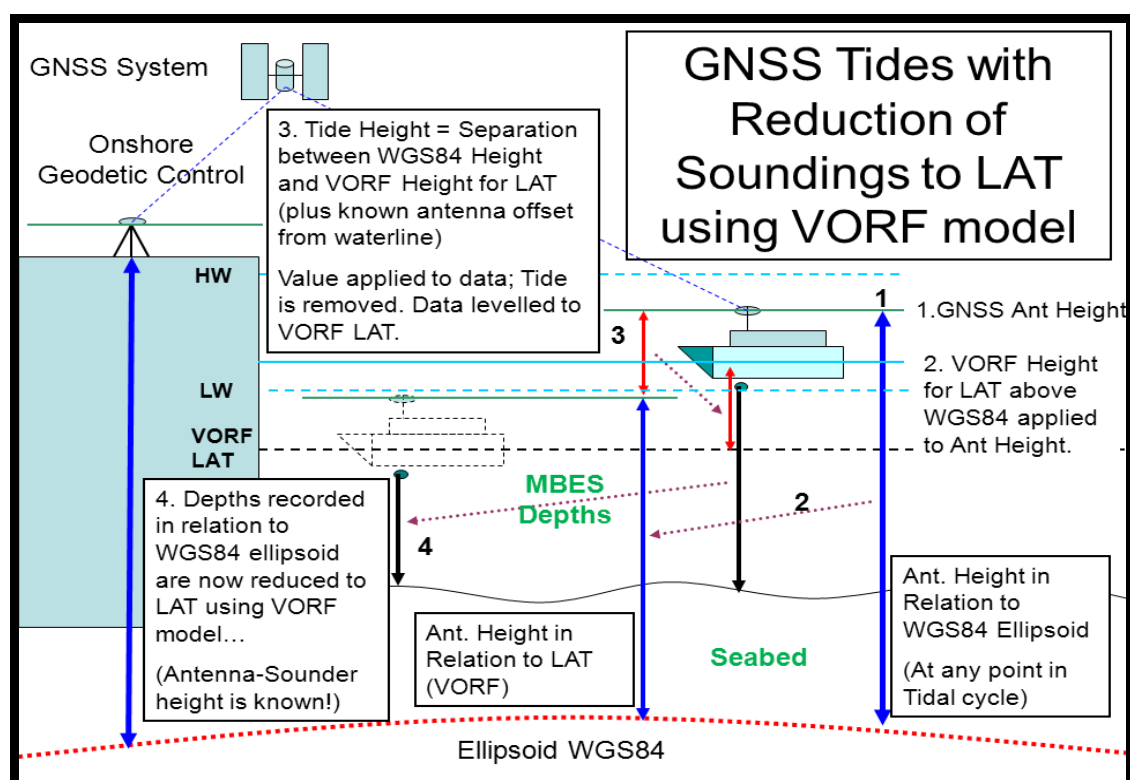
Figure 6: GNSS tides to LAT using VORF model.

3.3.3 Vessel Draft

Distances from known draft measuring points on the vessels port and starboard sides to the water line were measured by tape once ballasting was completed. Known vertical distances at port and starboard sides between these draft measuring points and the MRU (Common Reference Point for EM2040) and EA400 transducers respectively were used along with the tape measured vertical distances to calculate draft values for the EM2040 and EA400 echosounders. Port and starboard sides were averaged to get one value for each echosounder. Table 8 lists the tape measured draft figures along with the known vertical distances.

Measurement	Port Side	Starboard Side
Tape Measurement at EA400 Draft Mark (from mark to water)	3.90	4.03
Vertical distance between Starboard Side draft mark and EA400		7.4660
Vertical distance between Port Side draft mark and EA400	7.4580	
Vertical distance between Port Side EA400 draft mark and MRU	3.6746	
Vertical distance between Starboard Side EA400 draft mark and MRU		3.6824

Table 8: Draft measured and known vales.

Draft value for EM2040 = ((3.90 - 3.6746) + (4.03 - 3.6824))/2 = **0.286**

Draft value for EA400 = ((7.4580 - 3.90) + (7.4660 - 4.03))/2 = **3.497**

These draft values were entered in the respective software for both the EM2040 and EA400.

3.3.4 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 9 contains MBES metadata. Multibeam water column data (.wcd) were acquired throughout and stored on a separate disk to the main file server.

Descriptor	Metadata
Survey lines	NA
Data Files	338
Date Created	12-07-2019 to 29-07-2019
Dataset Size	80.8 GB
File Formats	.all

Table 9: MBES metadata.

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 CodaOctopus DA4G acted as the topside trigger and acquisition system. Raw data was recorded in native coda format through CodaOctopus GeoSurvey™ software along with tiff images of each survey line. Positioning data was provided from C-Nav DGNSS 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 10 contains SBP metadata.

Descriptor	Metadata
Survey lines	NA
Data Files	295
Date Created	12-07-2019 to 29-07-2019
Dataset Size	31.5 GB
File Formats	.cod & .tiff

Table 10: SBP metadata.

3.3.5 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 11.

Descriptor	Metadata
Survey lines	NA
Data Files	1
Date Created	12-07-2019 to 29-07-2019
Dataset Size	651 MB

File Formats	.mms

Table 11: Magnetometer metadata.

3.3.6 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 12.

Descriptor	Metadata
Survey lines	All
Data Files	18
Date Created	13-07-2019 to 30-07-2019
Dataset Size	3.77 GB
File Formats	.cnav3050

Table 12: C-Nav navigation metadata.

3.3.7 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 13.

Descriptor	Metadata
Survey lines	NA
Data Files	309
Date Created	12-07-2019 to 29-07-2019
Dataset Size	17.13 GB
File Formats	.db & .txt

Table 13: QINSy navigation metadata.

3.3.8 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 14.

Descriptor	Metadata
Survey lines	NA
Data Files	365
Date Created	12-07-2019 to 29-07-2019
Dataset Size	10.3 MB
File Formats	.asvp

Table 14: Sound velocity metadata.

3.3.9 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 15.

	Order 1a (S-44)	Order 2 (S-44)
Description of Areas	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.
Max THU allowable (95%C)	Total Horizontal Uncertainty (THU) 5m+5% of depth	Total Horizontal Uncertainty (THU) 20 m+10% of depth
Max TVU allowable (95%C)	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 $\pm\sqrt{a^2 + (bxd)^2}$
Full Seafloor Search	Required	Not Required
Feature Detection	Cubic Features > 2m (Depths < 40m) 10% depth > 40m	Not Applicable
Recommended Max line spacing	Full Seafloor search	4 x average depth

Table 15: 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.
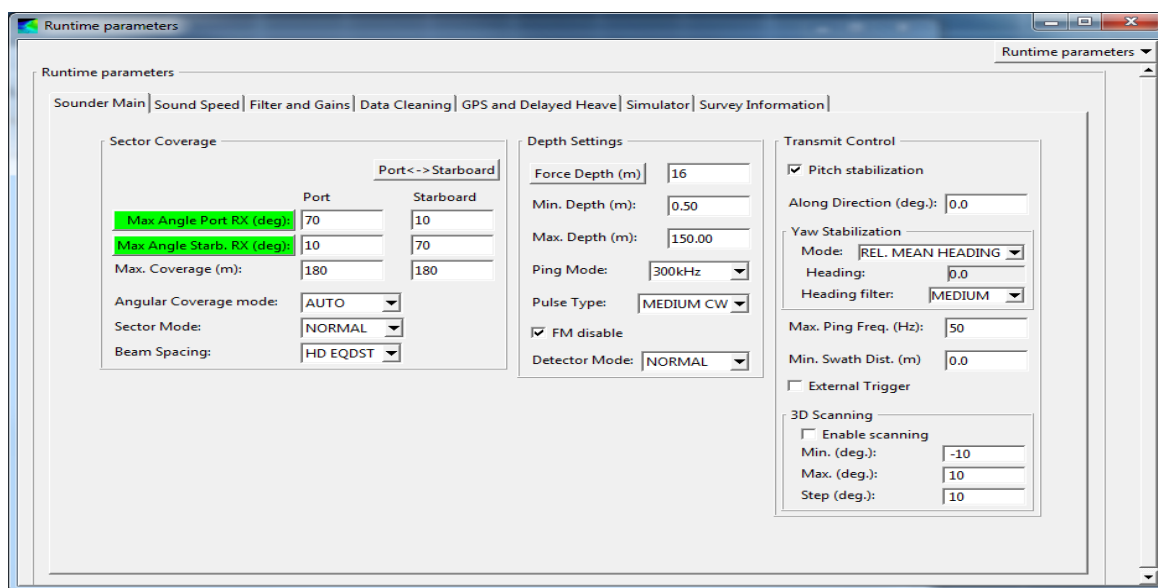
Figure 7: Runtime parameters window in SIS.

4.1.2 Crossline versus Mainline Statistics

Crossline data were acquired for QC of depth soundings. A total of 23 crosslines were acquired for statistical analysis in Caris Hips. Crossline data were compared with mainline data from both CV19_03 and the adjacent CV19_02 survey polygons. All crossline data indicated that the soundings exceeded the 95% certainty required for Order 1a specification. Results from the statistical analyses are presented in table 16. Crossline data from CV19_03 compared with mainline data from CV19_02 are in bold.

Line	Beam No.	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)
116	1-800	411,200	0.518	1.054	-0.067	0.148	99.99	100
118	1-800	6,747,801	15.071	17.532	0.071	0.286	99.67	99.78
120	1-800	3,820,572	14.013	12.084	-0.035	0.276	99.58	99.73
121	1-800	3,536,627	11.034	12.926	-0.102	0.277	99.62	99.76
172	1-800	2,840,901	0.796	1.057	-0.014	0.144	99.99	100
173	1-800	5,571,440	1.070	1.005	-0.004	0.165	99.97	100
174	1-800	2,173,108	0.831	0.897	-0.038	0.148	100	100
176	1-800	760,216	0.781	0.568	0.154	0.142	100	100
221	**1-800**	**1,939,154**	**2.207**	**3.610**	**0.079**	**0.132**	**99.78**	**99.96**
223	1-800	532,678	2.116	4.395	0.005	0.176	99.24	99.86
223	**1-800**	**5,183,646**	**1.388**	**0.829**	**0.219**	**0.111**	**99.99**	**100**
224	**1-800**	**1,488,539**	**0.837**	**0.319**	**0.251**	**0.121**	**99.90**	**100**

225	1-800	5,720,039	0.850	0.461	0.176	0.106	99.99	100
226	**1-800**	**1,382,529**	**0.821**	**0.339**	**0.141**	**0.096**	**99.99**	**100**
226	1-800	2,285,531	0.790	0.578	0.121	0.120	99.99	100
227	**1-800**	**4,068,728**	**0.729**	**0.704**	**0.005**	**0.117**	**100**	**100**
227	1-800	1,958,794	0.718	0.512	0.141	0.110	100	100
228	**1-800**	**2,050,806**	**0.526**	**0.740**	**-0.060**	**0.112**	**99.99**	**100**
305	1-800	1,842,557	0.711	0.730	0.019	0.128	100	100
306	1-800	2,109,869	0.607	0.721	-0.074	0.113	100	100
307	1-800	2,131,760	0.670	0.644	-0.072	0.109	100	100
308	**1-800**	**1,410,363**	**0.697**	**0.673**	**0.066**	**0.111**	**100**	**100**
308	1-800	377,738	0.672	0.664	-0.003	0.116	100	100
311	**1-800**	**5,033,568**	**0.687**	**0.796**	**-0.124**	**0.123**	**100**	**100**
312	**1-800**	**3,068,368**	**0.721**	**0.631**	**-0.043**	**0.114**	**100**	**100**
325	**1-800**	**4,966,439**	**0.912**	**1.107**	**0.049**	**0.128**	**100**	**100**
326	**1-800**	**3,155,668**	**0.708**	**0.626**	**0.047**	**0.131**	**100**	**100**

Table 16: Multibeam crossline statistics.

Figure 8 shows the survey line patterns for survey legs CV19_02 in red and CV19_03 in blue.
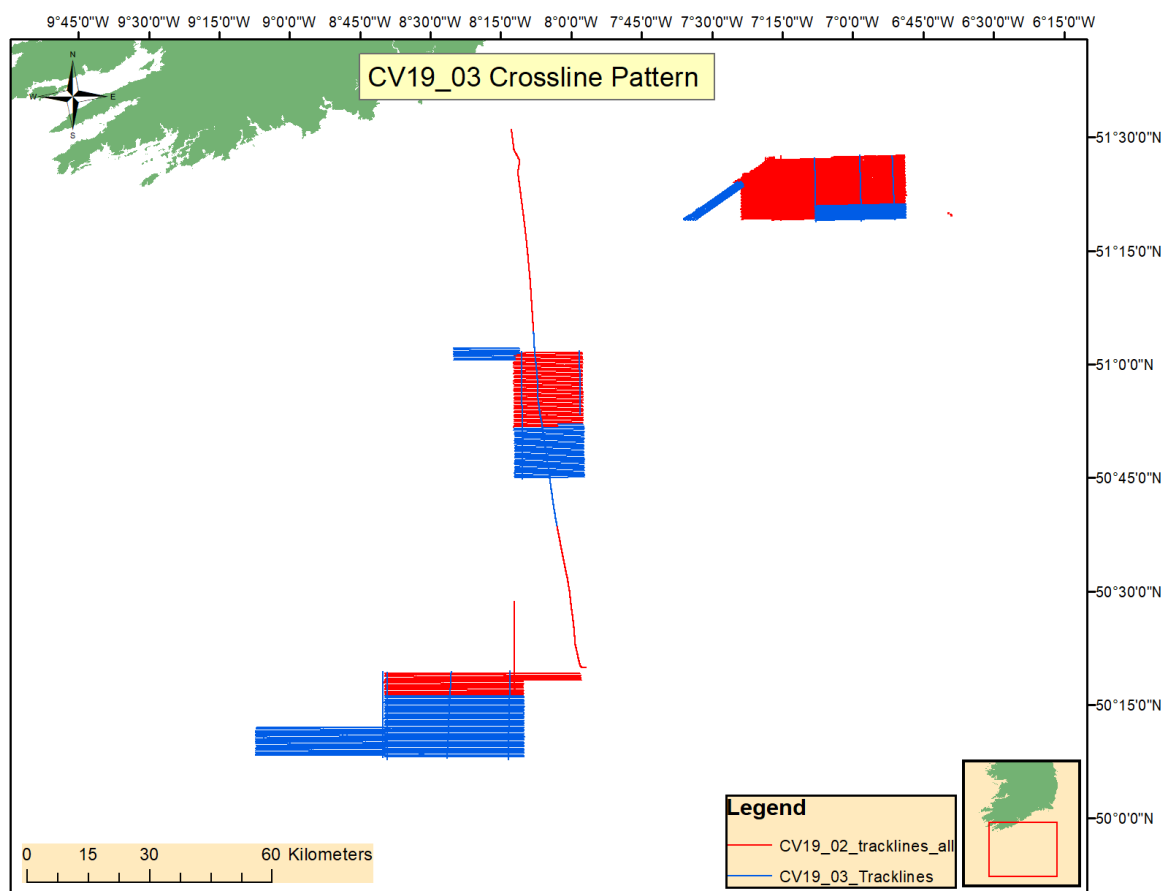
Figure 8: Crossline pattern and CV19_02 Tracklines.

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 82 to 110 m in the East area. The minimum sized cubic features that require detection are 8.2 m, i.e. 10% of water depth. A minimum of 9 soundings per 7.6 m bins are required in order to attain the feature detection criteria. A bin size of 8.2 m was selected to QC the data density and the results are shown in figure 9.

The mean number of soundings per bin was computed at 82. 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.
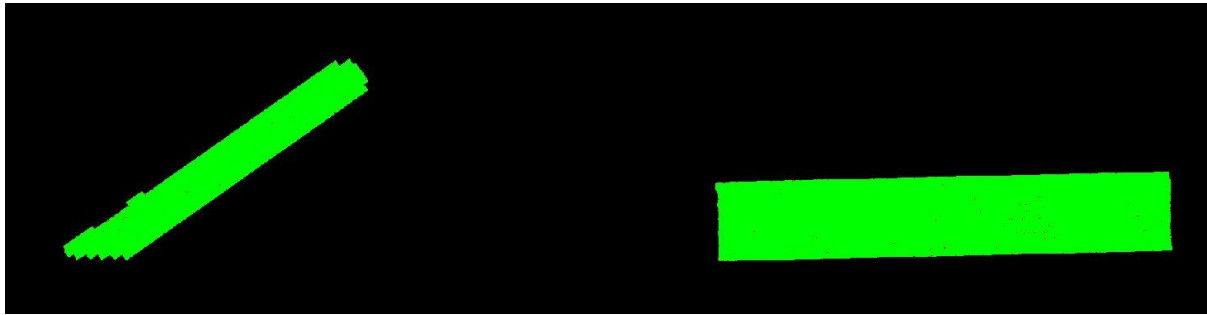
Figure 9: Sounding density traffic light plot, East area.

Water depths range from 100 to 119 m in the Central area. The minimum sized cubic features that require detection are 10 m, i.e. 10% of water depth. A minimum of 9 soundings per 10 m bins are required in order to attain the feature detection criteria. A bin size of 10 m was selected to QC the data density and the results are shown in figure 10.

The mean number of soundings per bin was computed at 84. 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. The vast majority of the dataset exceeds 9 soundings per bin. Water depths greater than 100 m fall into Order 2 IHO category where feature detection is not applicable.

Figure 10: Sounding density statistics, Central area.

Water depths range from 82 to 135 m in the South area. The minimum sized cubic features that require detection are 8.2 m, i.e. 10% of water depth. A minimum of 9 soundings per 8.2 m bins are required in order to attain the feature detection criteria. A bin size of 8.2 m was selected to QC the data density and the results are shown in figure 11.

The mean number of soundings per bin was computed at 106. This easily exceeded the 9 soundings required per bin. Green indicates where 9 soundings per bin were achieved, i.e. everywhere.
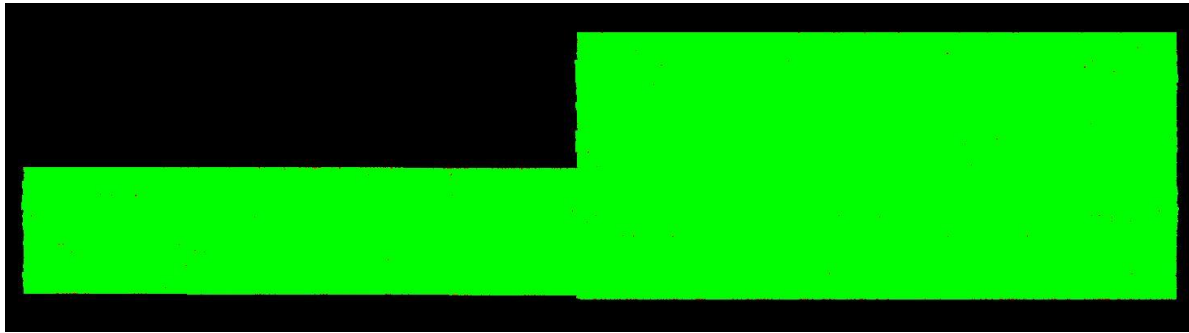
Figure 11: Sounding density traffic light plot, South area.

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 17 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	0.065º
Heave	5 cm or 5 % Amplitude
Roll	0.01º
Pitch	0.01º
Pitch Stabilised	0.00º
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 17: 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.

A composite MVP plot is shown in figure 12. Sound velocity in metres per second is plotted on the x-axes and depth in metres on the y-axes. It indicates that the top 10 to 12 m of the water column is well mixed as sound velocity is relatively stable. A thermocline is evident from those depths down to between 30 to 44 m depth. The sound speed increases below the thermocline as pressure increases. A profile comparison was done at one location by taking three profiles at different times in the same day. These profiles are highlighted in blue in the image below. All three profiles show close similarity at depths less than 12 m and depths greater than 48 m but show considerable variation in the intervening depth range. This variation indicates the requirement for frequent profile acquisition, even at the same locations.
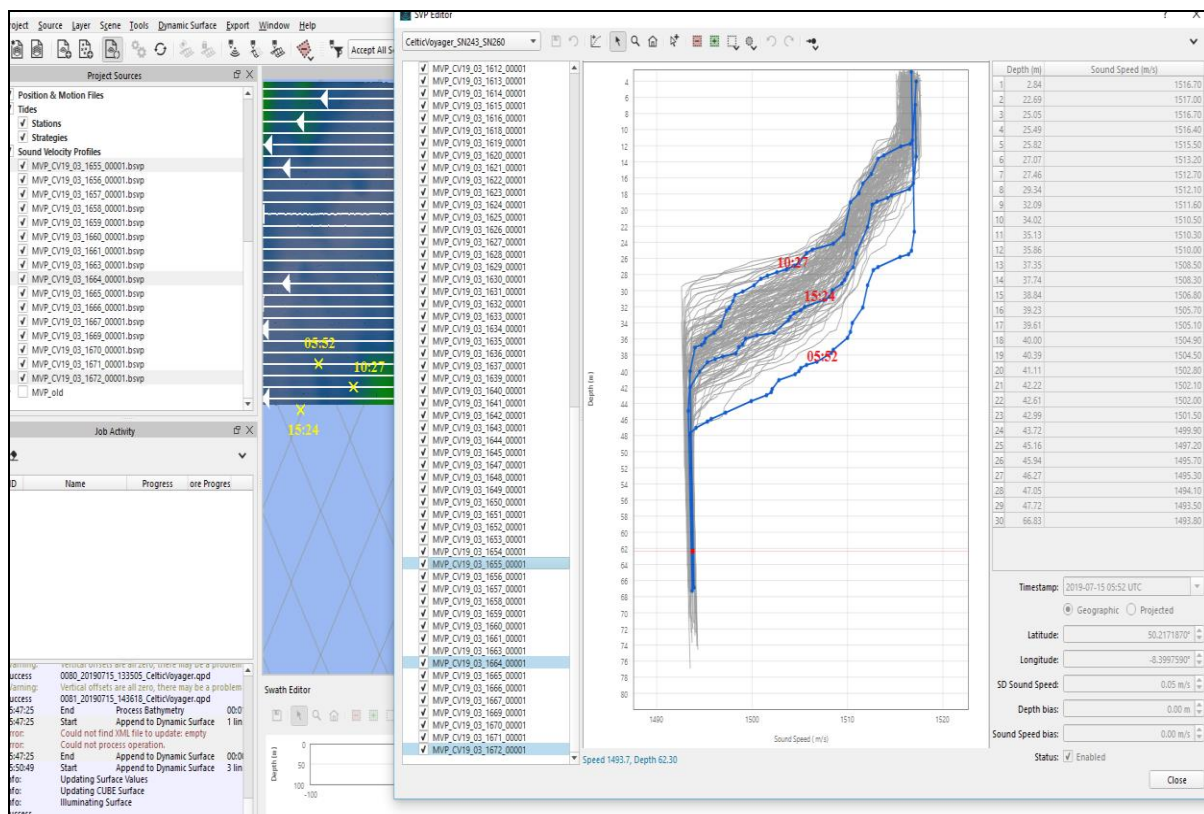
Figure 12: MVP composite plot.

Profiles from the Central area (Figure 13) show a well-mixed water column above approximately 10 metres depth, then a thermocline down to approximately 45 metres depth where sound velocity rapidly decreases. Sound velocity then increases with pressure beneath 45 metres. There is considerable variation between profiles within the thermocline zone, which requires regular monitoring and fresh profile acquisition.
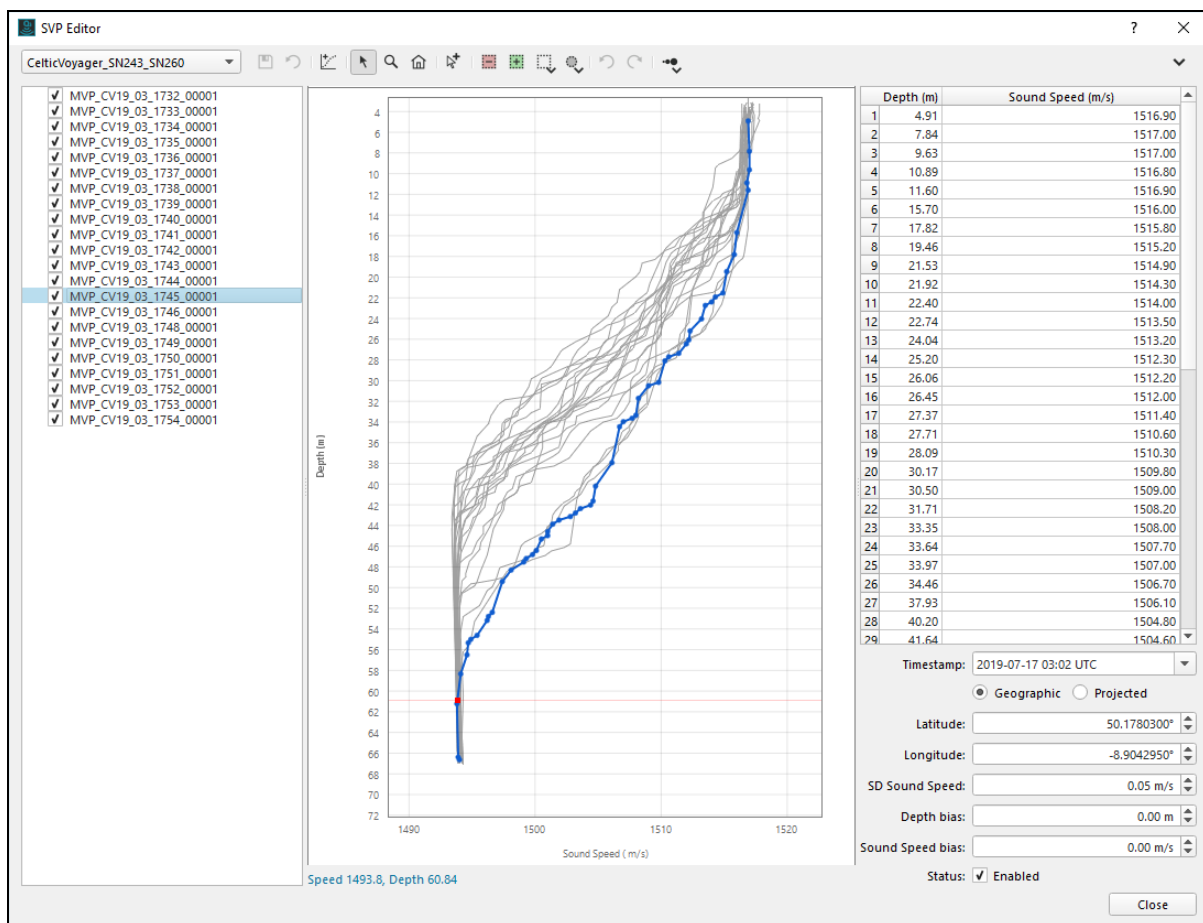
Figure 13: MVP composite plot for central area.

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 Teledyne Caris HIPS & SIPS™ software of MBES bathymetry and shaded relief. Backscatter mosaics were created in QPS FMGT™. Geotiffs and grids were imported into ArcGIS™ and images (figures 14 to 22) output for this report.
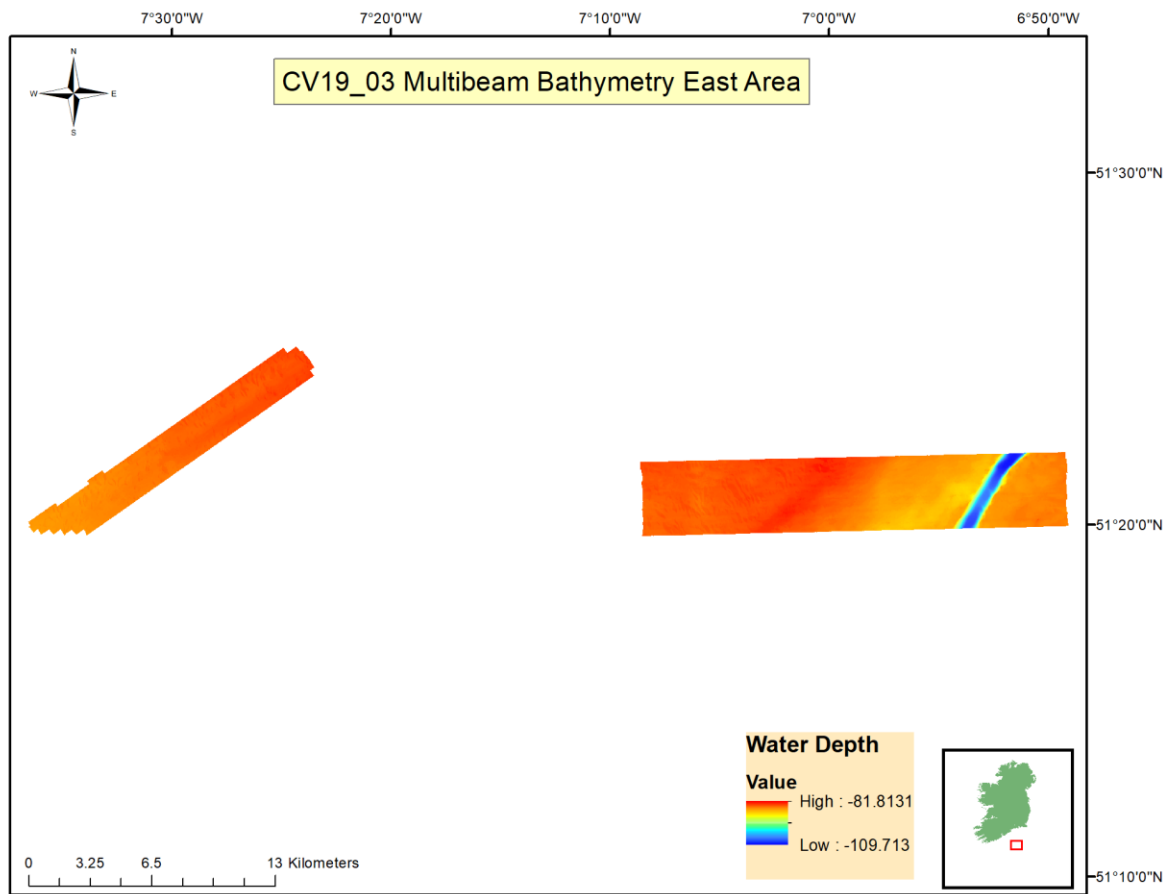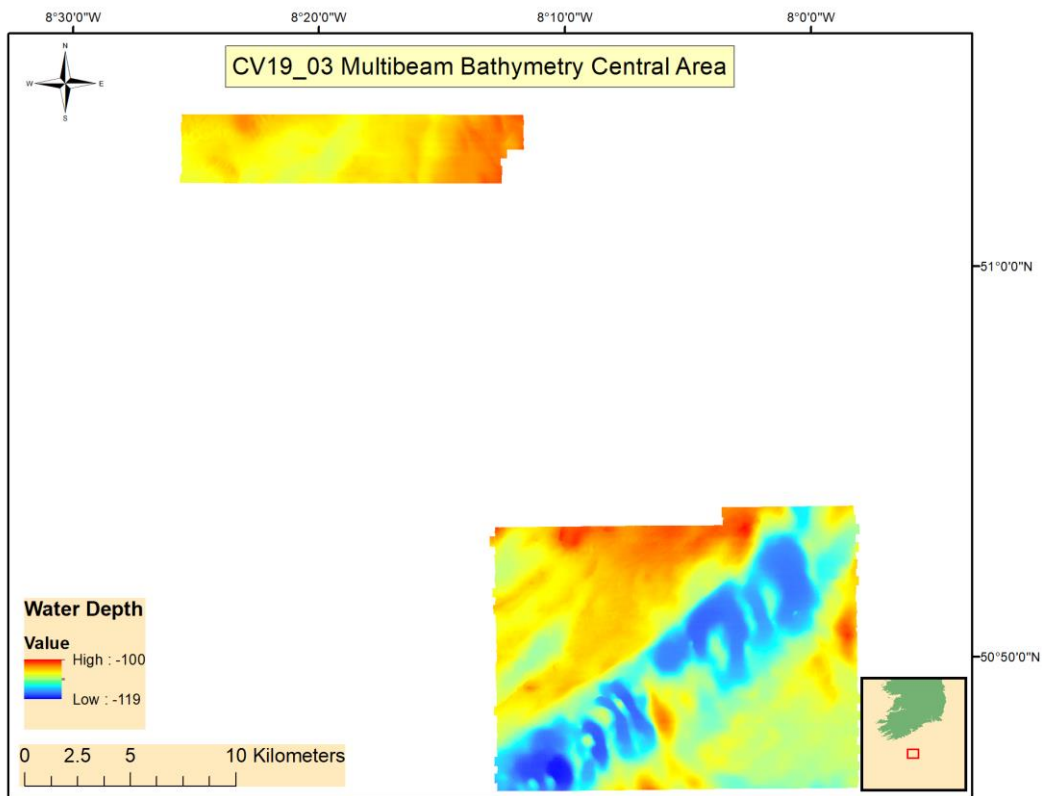
Figure 14: Multibeam bathymetry east area.

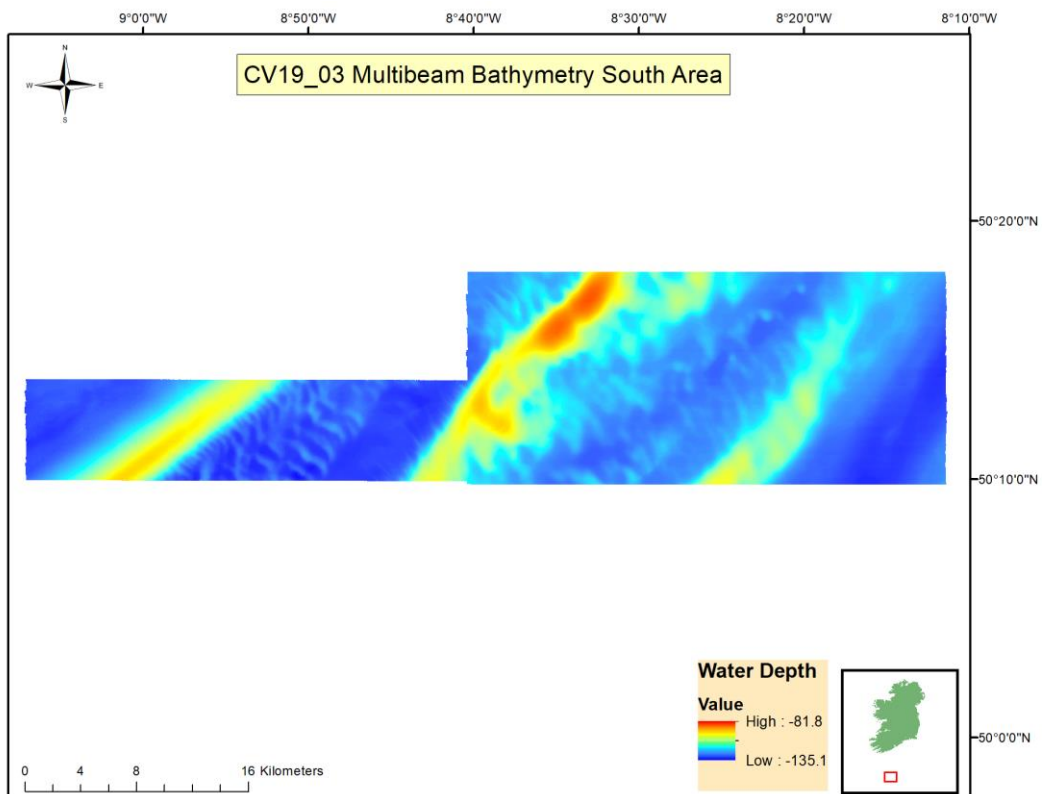Figure 15: Multibeam bathymetry central area.

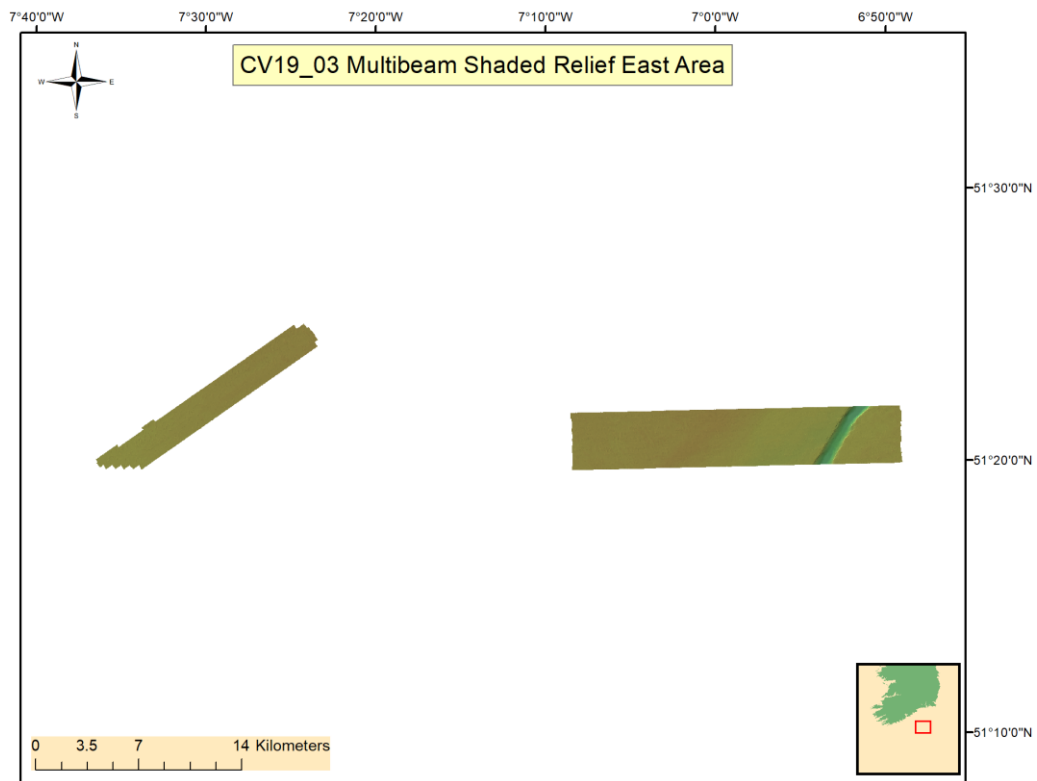Figure 16: Multibeam bathymetry south area.

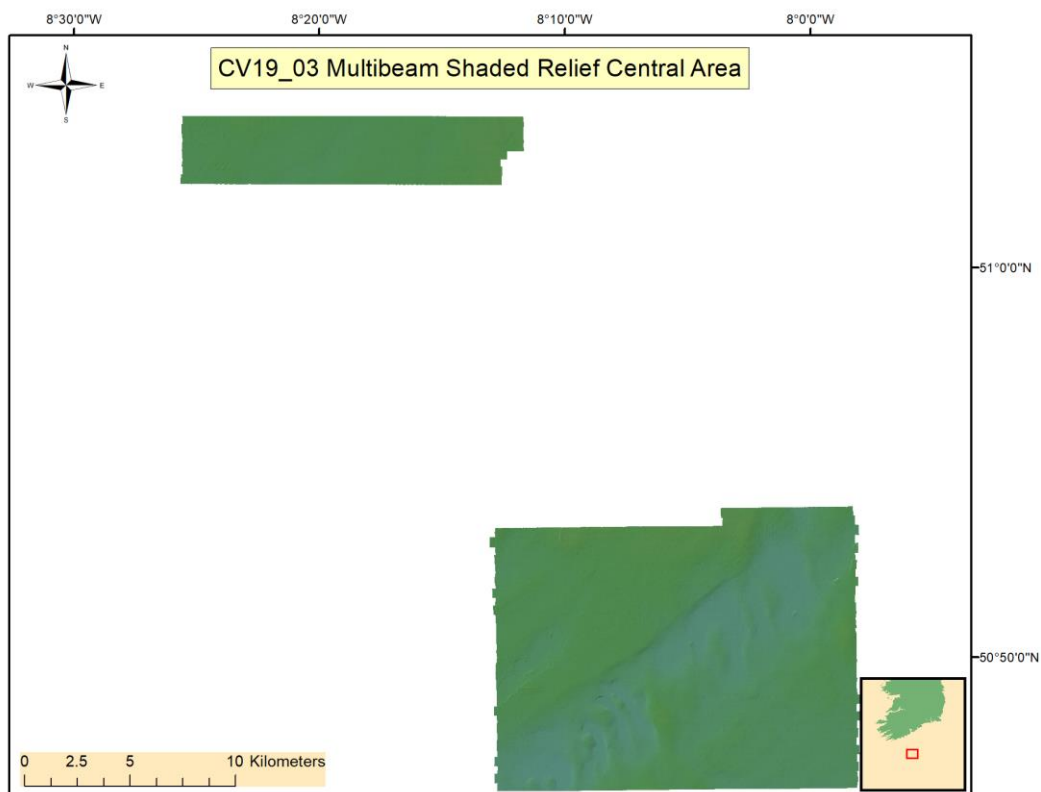Figure 17: Multibeam shaded relief east area.

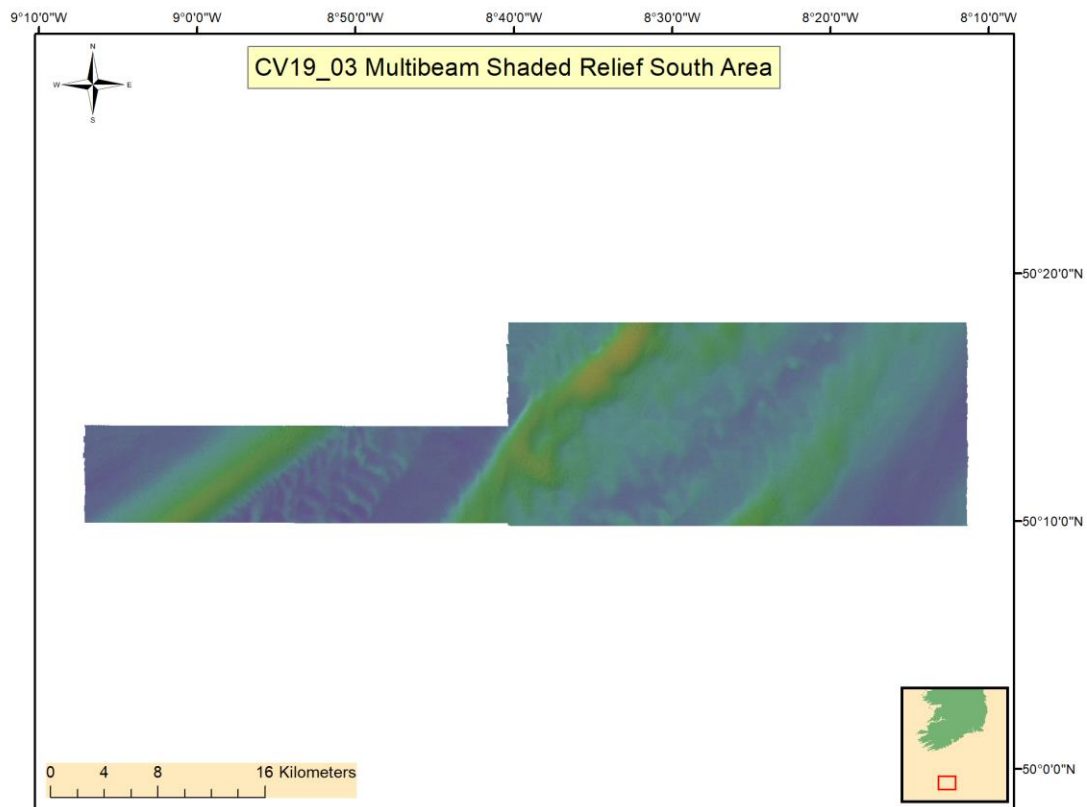Figure 18: Multibeam shaded relief central area.

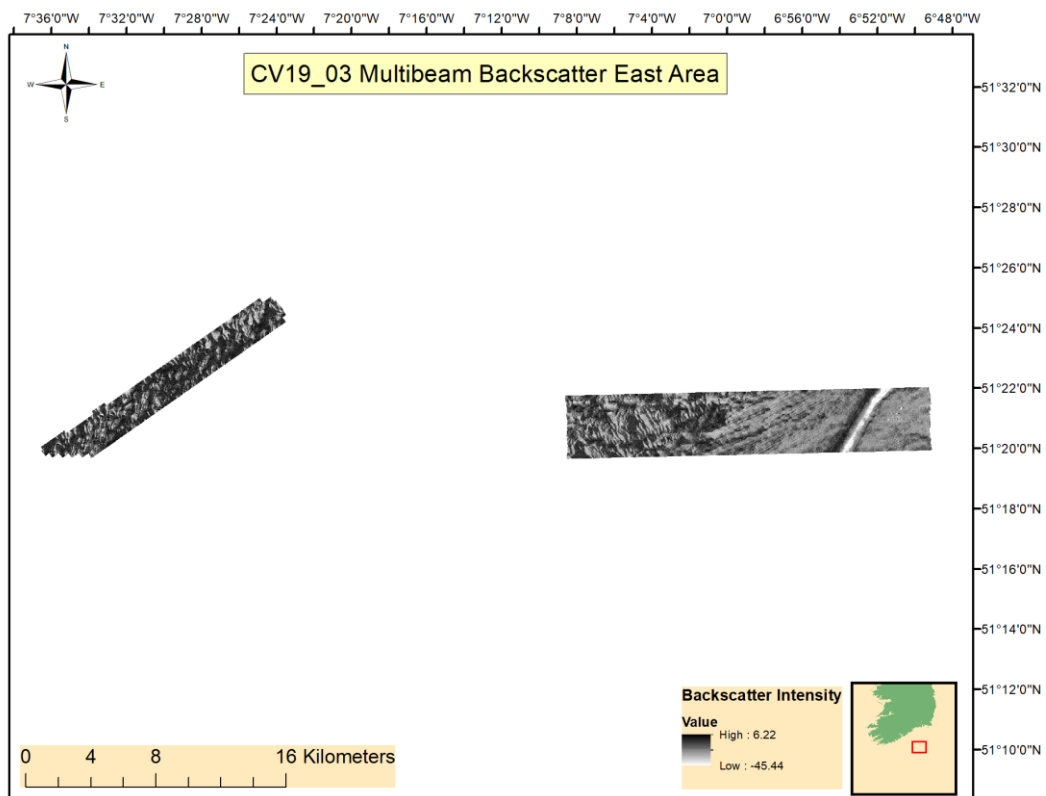Figure 19: Multibeam shaded relief south area.
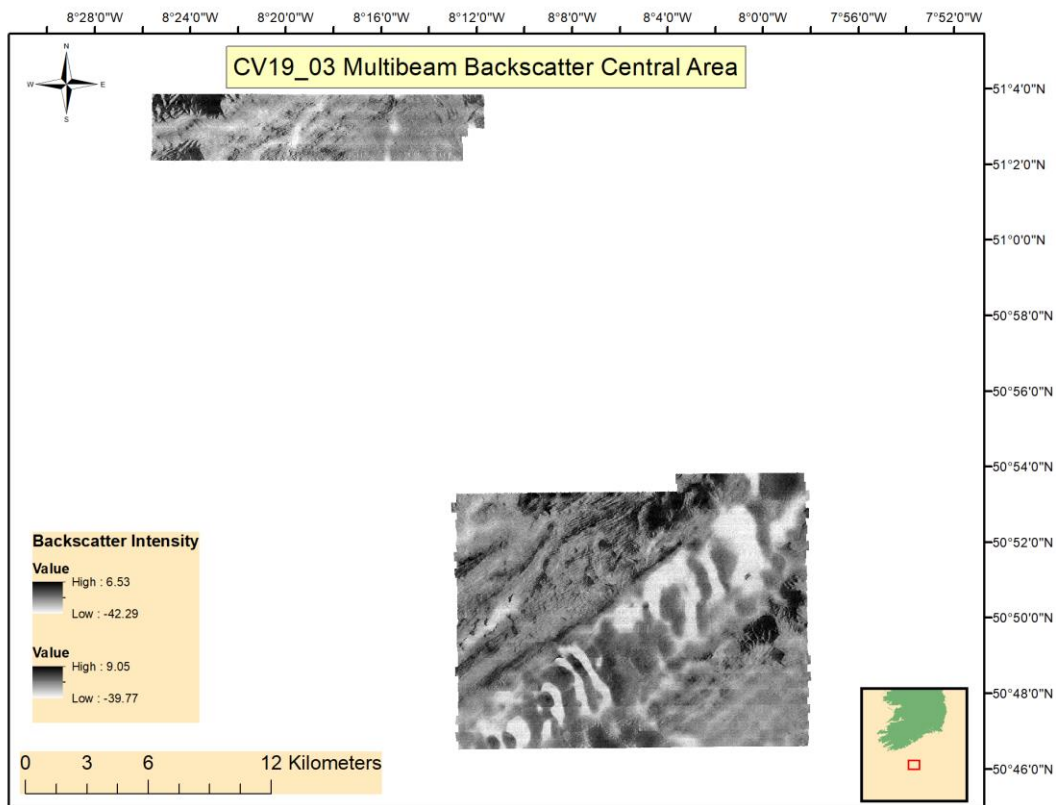

Figure 20: Multibeam backscatter mosaic east area.

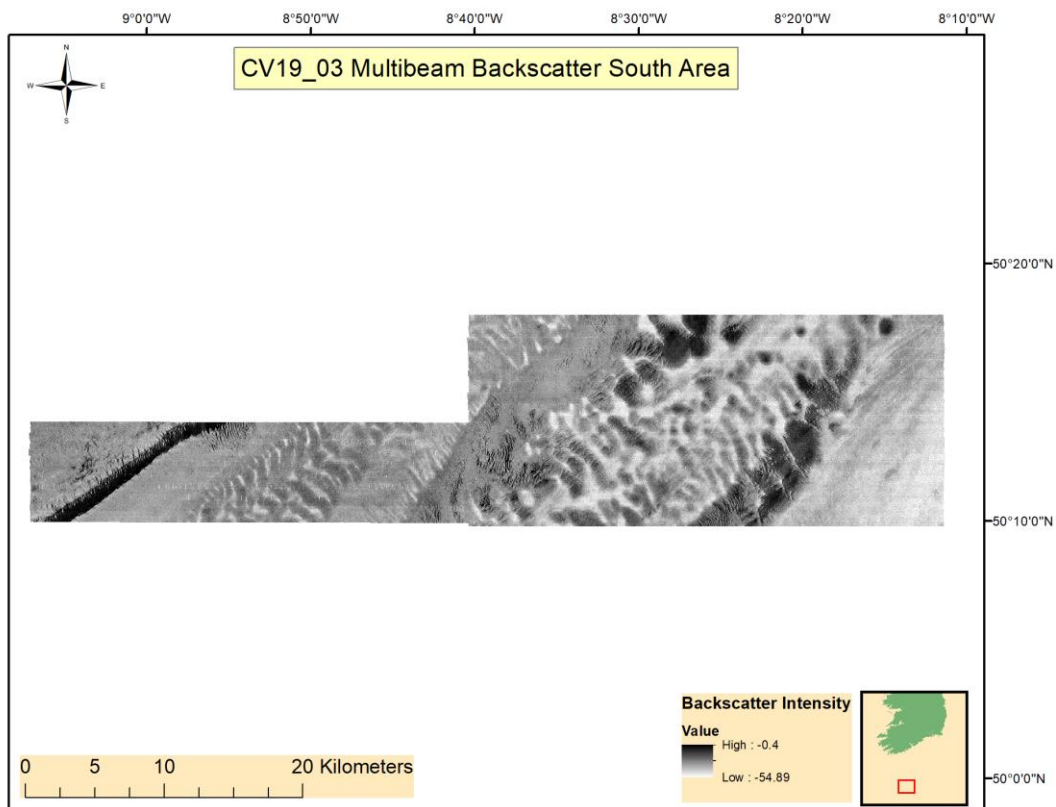Figure 21: Multibeam backscatter mosaic central area.

Figure 22: Multibeam backscatter mosaic south area.

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 CodaOctopus™ format seismic files were recorded for all SBP lines. Profile lines 223 and 276 are selected for discussion here. Their geographical locations are shown in figures 23 & 24 where the profile extents have been overlain on shaded relief data. Profile 223 was acquired in the east area and profile 276 in the central area.
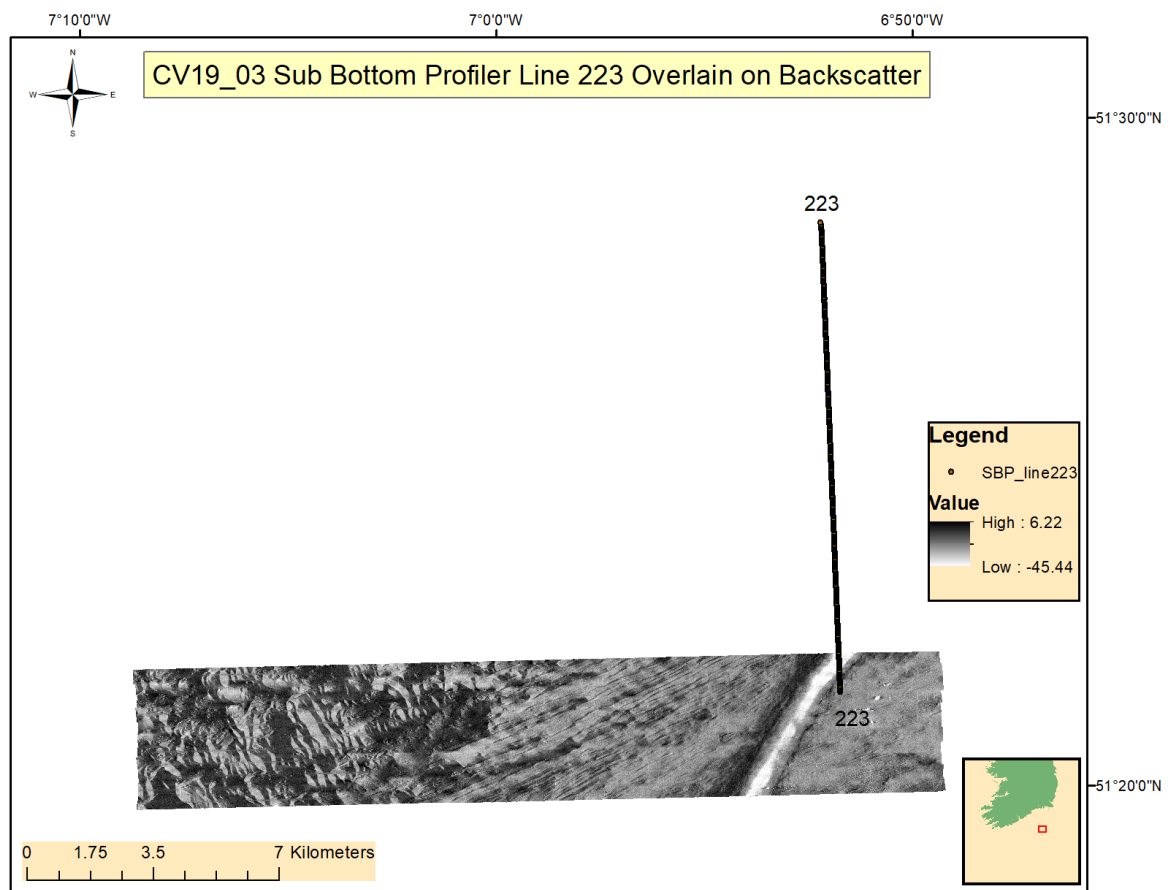

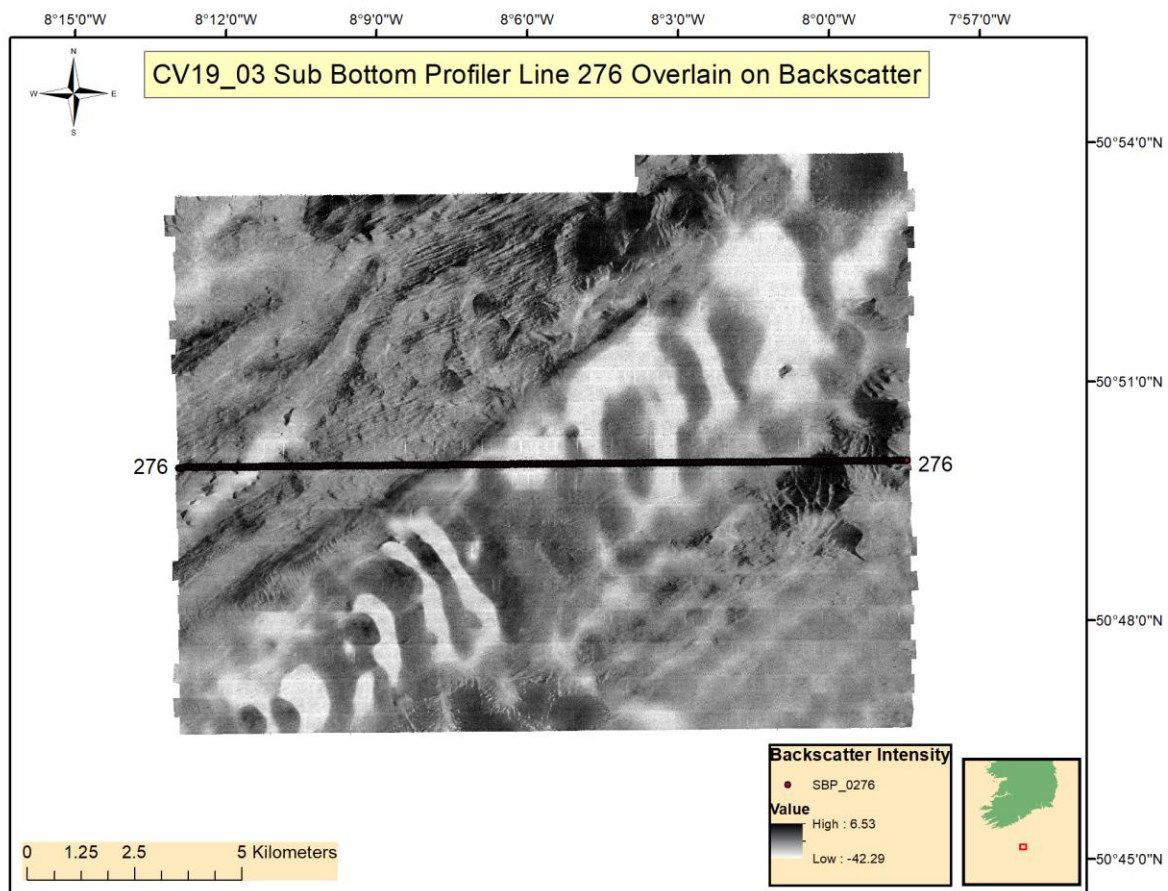Figure 23: Sub bottom profile line 223 overlain on backscatter data.

Figure 24: Sub bottom profile lines 276 overlain on backscatter data.

Interpreted sub bottom profiler tiff images of profile lines 223 and 276 are shown in figures 25 and 26 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 223 in figure 25 is 13.0 km in length. The profile was acquired from south to north. It was acquired as a crossline for QC of the previous survey leg and as such much of the profile lies outside of the CV19_03 multibeam coverage. Hard ground dominates with the result that signal penetration is limited. A thick sedimentary unit annotated as Unit 2 in the image below dominates the profile. Its base is not seen. Unit 2 has no internal reflectors. It is unconformably overlain by Unit 1 at the base of a large channel.

The most prominent feature of the profile is a large U-shaped channel (mentioned above) at its southern end. The channel narrows from its top to its base. Unconsolidated sediments

(Unit 1) up to 8 m in thickness are found at the base of the channel. Unit 1 is largely transparent. The channel is approximately 30 m in relief from rim to base. Water column noise at the southern side of the channel was correlated with a gap in MBES data and is interpreted as a fish shoal.

Profile 276 in figure 26 is 17.0 km in length. It is located in the central area. Unit 2 is the base unit throughout the profile extent. It is characterised by an absence of internal reflectors. The top of Unit 2 is marked by an unconformity; Horizon 1. Horizon 1 is most evident underneath topographic lows in the bathymetry. An unconsolidated sedimentary unit, annotated as Unit 1 overlies Unit 2. Unit 1 is best preserved beneath topographic lows in the seabed. It has a variable thickness up to a maximum of approximately 5 m.
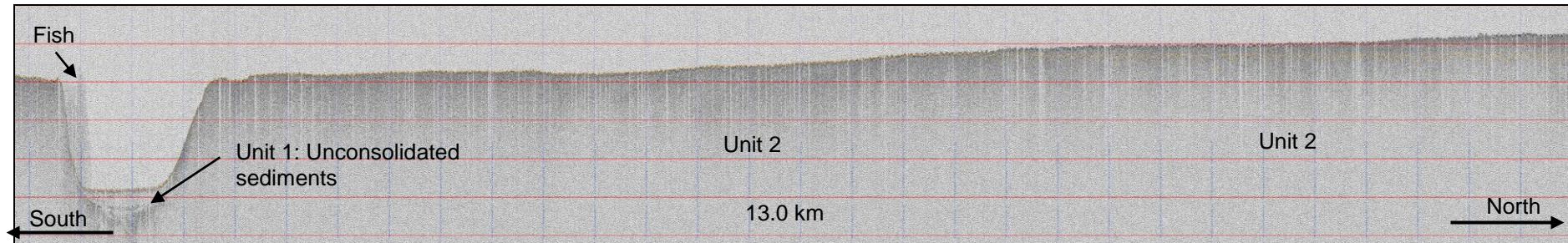
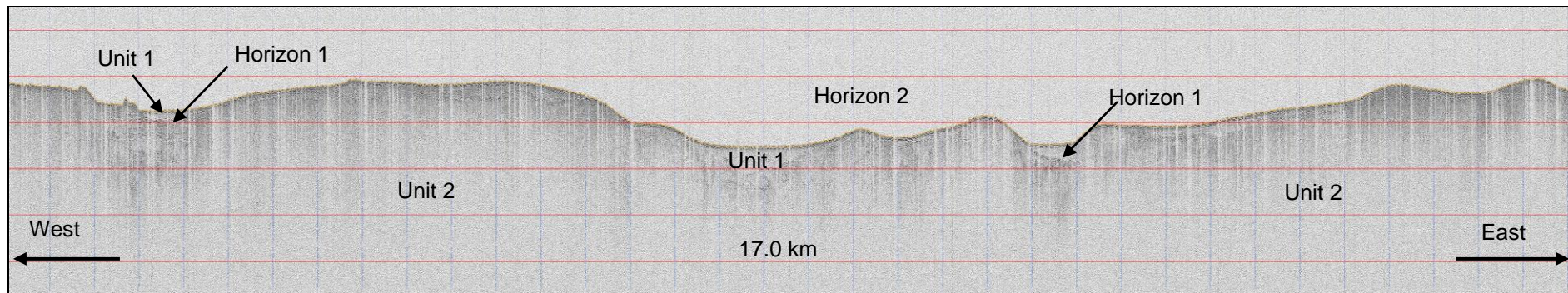Figure 25: Sub bottom profile interpreted image, line 223.

Figure 26: Sub bottom profile interpreted image, line 276.

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4.3.3 Bathymetry

Figure 27 shows the colour coded multibeam bathymetry image for the east area. Water depth varies from 82 to 110 m. Greatest depths are located in the east where a channel feature is present. Very gentle seafloor gradients are common apart from the channel margins where moderate gradients are found.
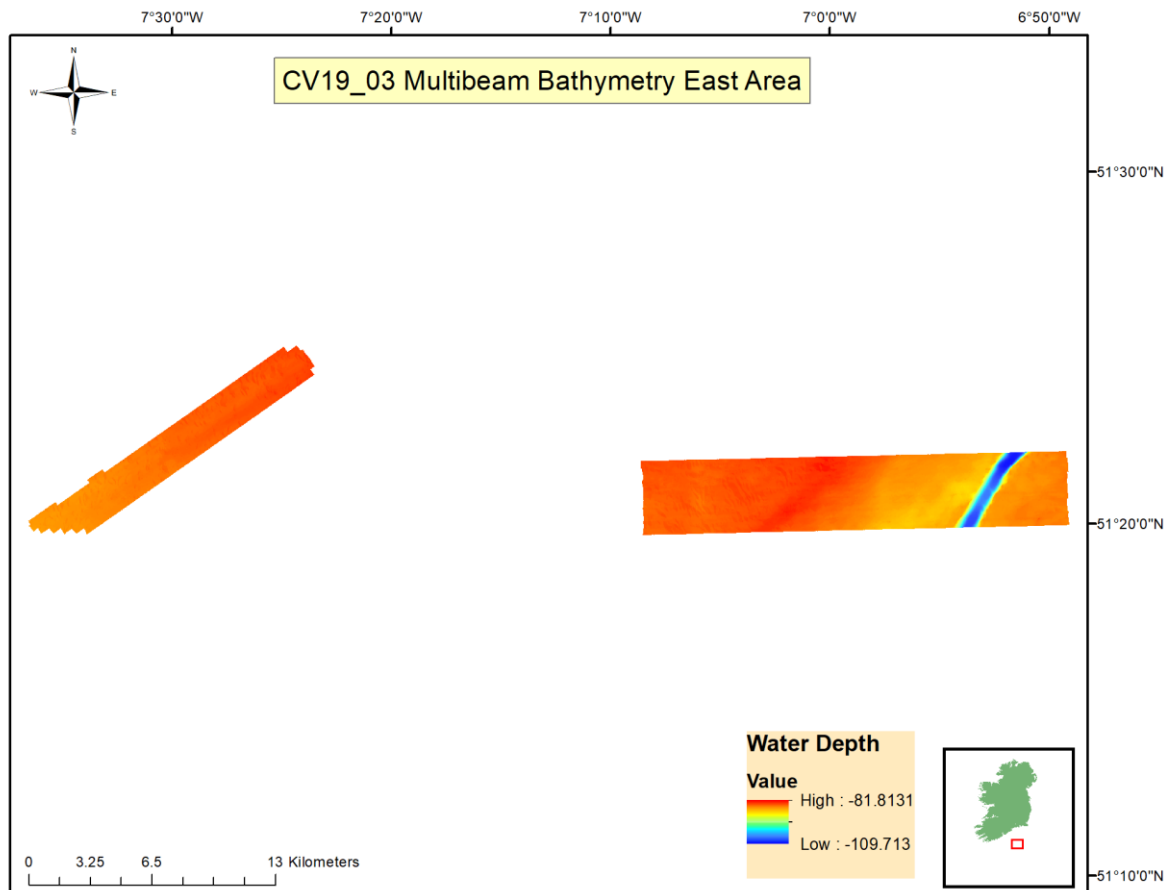

Figure 27: Multibeam bathymetry image east area.

Figure 28 shows the colour coded multibeam bathymetry image for the central area. Water depth varies from 100 to 119 m. The northern subset is shallower than the southern one. Depth contours in the southern subset are orientated NE-SW with a secondary NW-SE foot print. A gentle seafloor gradient is found throughout.
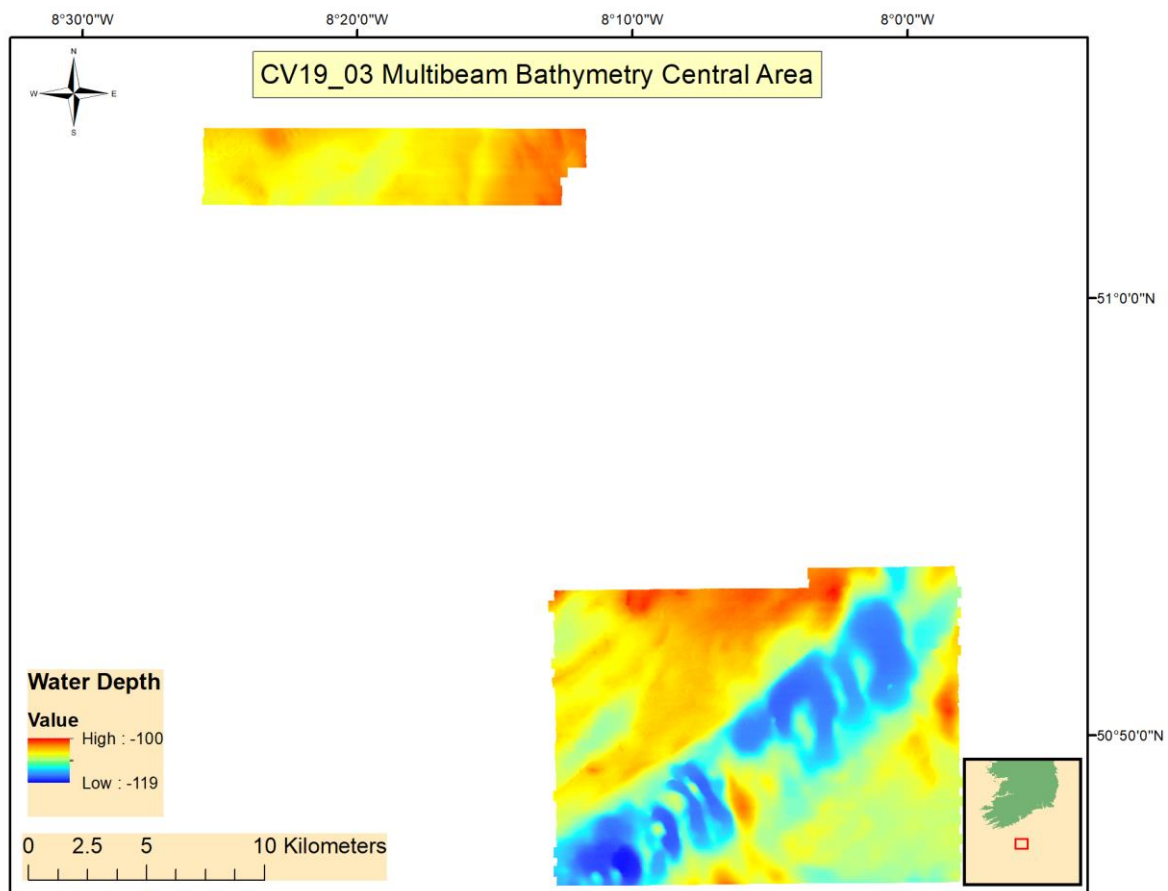
Figure 28: Multibeam bathymetry image central area.

Figure 29 shows the colour coded bathymetry image for the south area. Water depth ranges from 82 to 135 m. Water depth correlates with ridge features, orientated NE-SW and with secondary smaller- scale bathymetric features which run NW-SE. Seafloor gradient is gentle although some localised moderate gradients are found associated with ridges.
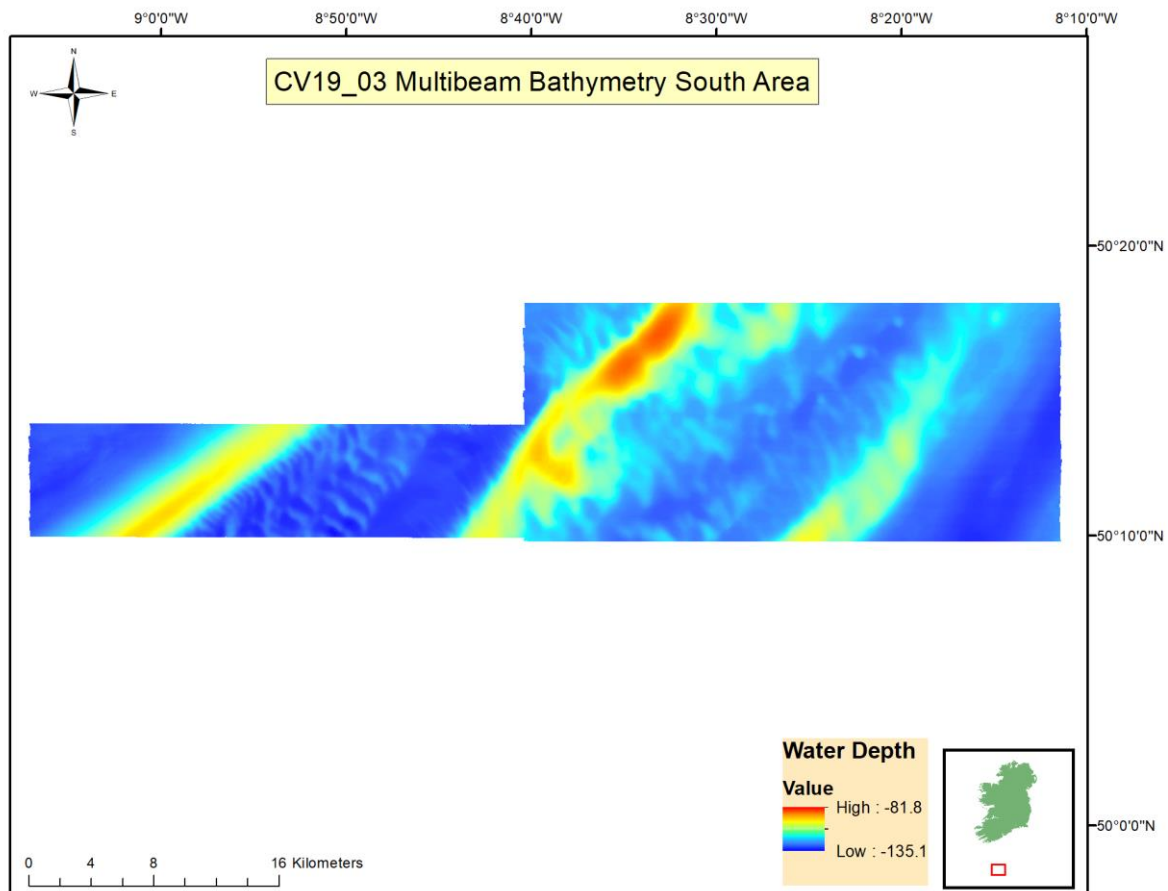
Figure 29: Multibeam bathymetry image south area.

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 and/or smooth surface.

Backscatter intensity values vary from 6 to -45 db in the east, 9 to -21 db in the central area and 0 to -55 db in the south. The backscatter images in section 4.3.1 show that a wide variety of backscatter responses are present, indicating a diversity of substrate types. A couple of backscatter images have been output from the overall dataset to illustrate particularly features and these are discussed here.

Figure 30 shows backscatter data from a subset of the south area. The convention used in this report is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. An area of high backscatter stretches from the NE to the SW of this image. This area is between 1 and 1.5 km in width. It's eastern boundary is better defined that its western one. The western side of this high backscatter area contains many small ribbons of softer/lower backscatter intensity sediments. These ribbons are orientated along N-S axes. The high backscatter area is to the NW of a large ridge crest, observed on the bathymetry data. This juxtaposition of high backscatter substrates parallel to and to the NW of large-scale ridges is found elsewhere in this part of the Celtic Sea.
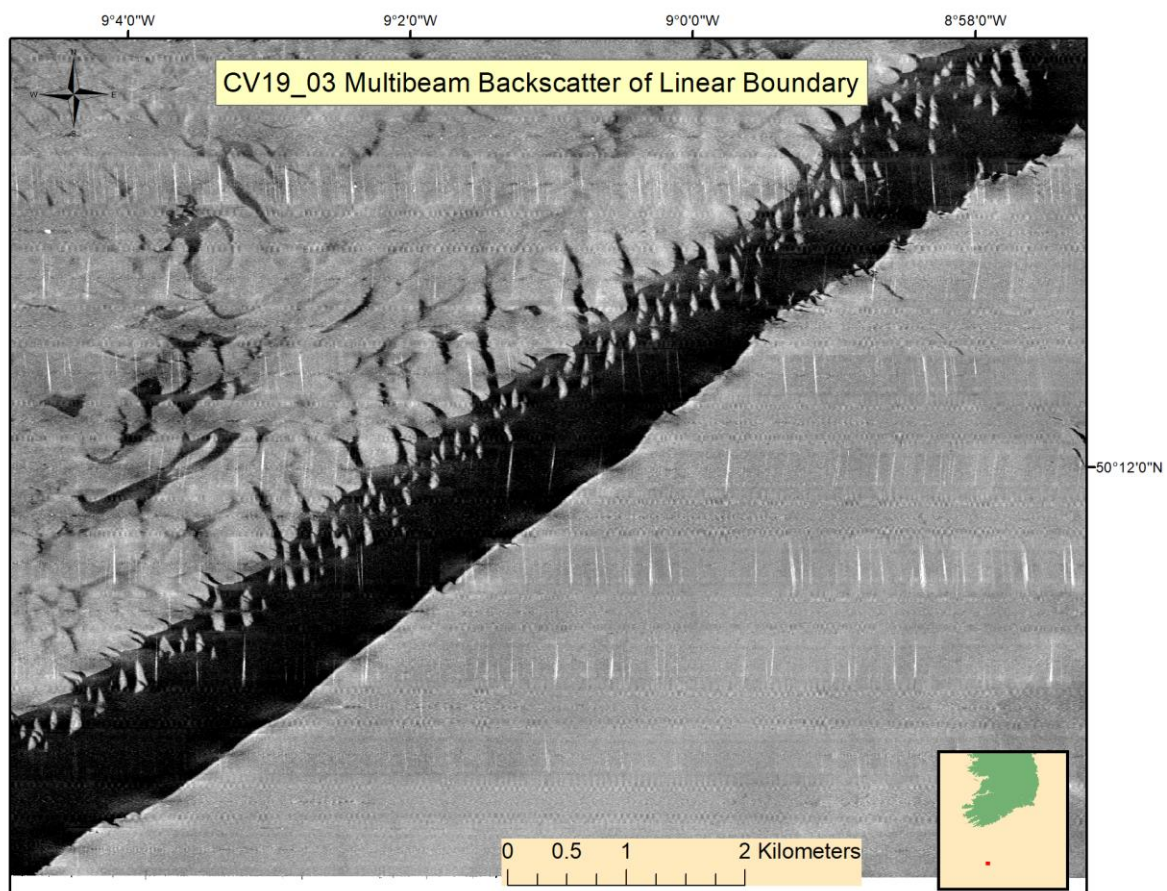

Figure 30: Backscatter data illustrating linear feature from the south area.

Figure 31 shows a subset of backscatter mosaic data for the south area. The convention used in this image is that dark coloured areas represent relatively higher backscatter intensity than light coloured areas. An area of relatively very low backscatter intensity is found at the eastern side of this image. It correlates with the channel seen in the bathymetry data. Groundtruthing samples acquired in this channel on previous surveys indicate sediments with a high percentage of mud. Elsewhere in the image below the substrate is

dominated by a NE-SW orientated fabric with relatively low intensity substrate interspersed with slivers of relatively high intensity backscatter.
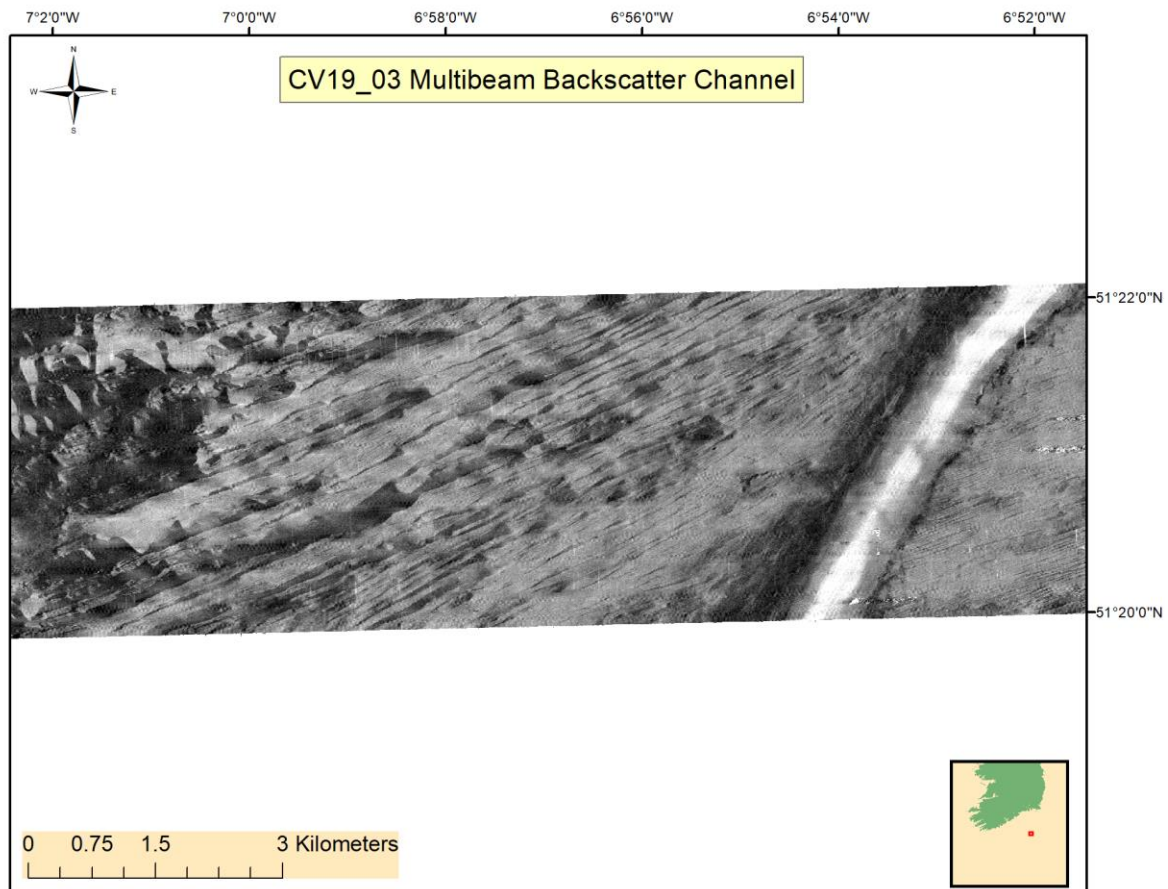

Figure 31: Multibeam backscatter data, east area.

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 35º angle over the depth colour coded multibeam bathymetry dataset. Images presented in this report are illuminated from a northwest azimuth.

Figure 32 is a shaded relief image of part of the east area illustrating a channel feature. This is part of a much larger channel which was mapped previously on other INFOMAR surveys. Relief between the surrounding plateau and channel floor is approximately 20 m. The channel is approximately 1 km wide at the section shown here.
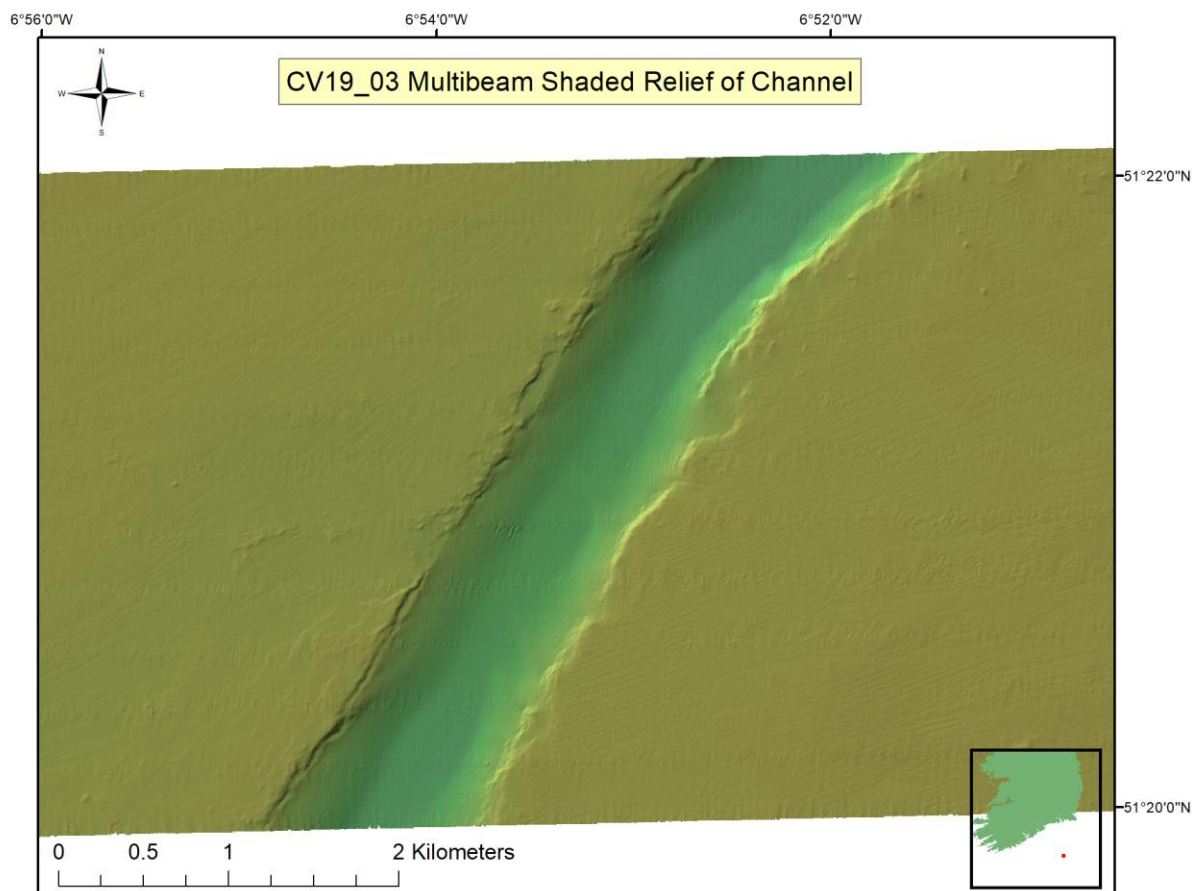
Figure 32: Multibeam shaded relief illustrating channel feature in east area.

Figure 33 is a shaded relief image illustrating areas of outcropping bedrock in the south area. These outcrops also show up clearly on the backscatter data as high intensity returns. Three discrete outcrops are evident, each several hundred metres across in scale.

INFOMAR
Integrated Mapping for the
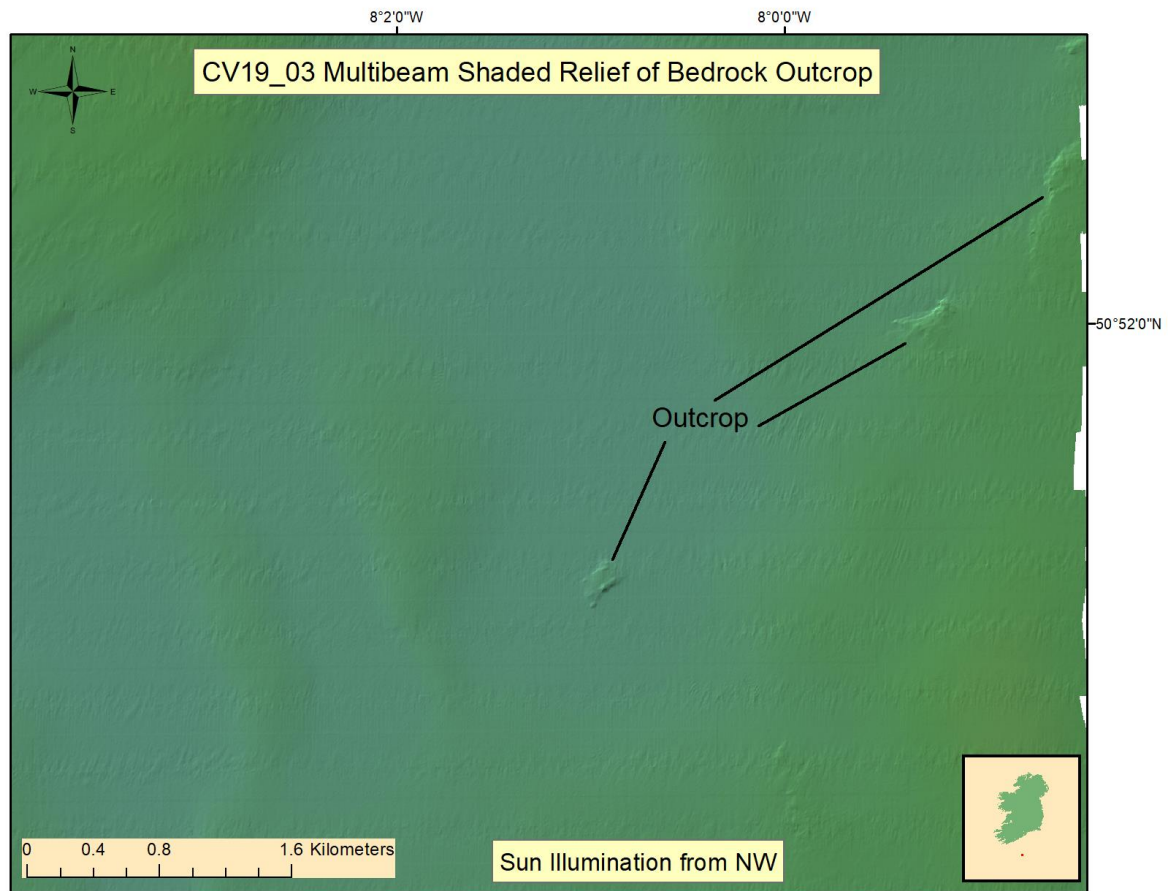Sustainable Development
of Ireland's Marine Resource

Figure 33: Multibeam shaded relief illustrating bedrock outcrops in south area.

Figure 34 is a shaded relief image illustrating a ridge and associated features in the south area. The ridge is orientated along a NE-SW orientated axes as is the case with the major ridges in the region. Water depths associated with the ridge have been discussed in the bathymetry section above. Its width varies considerably, from 2 km to almost 5 km. Seabed gradient is highest at the western side of the feature. Strong currents flowing over the ridge crest has scoured the seabed creating a series of braided channels.
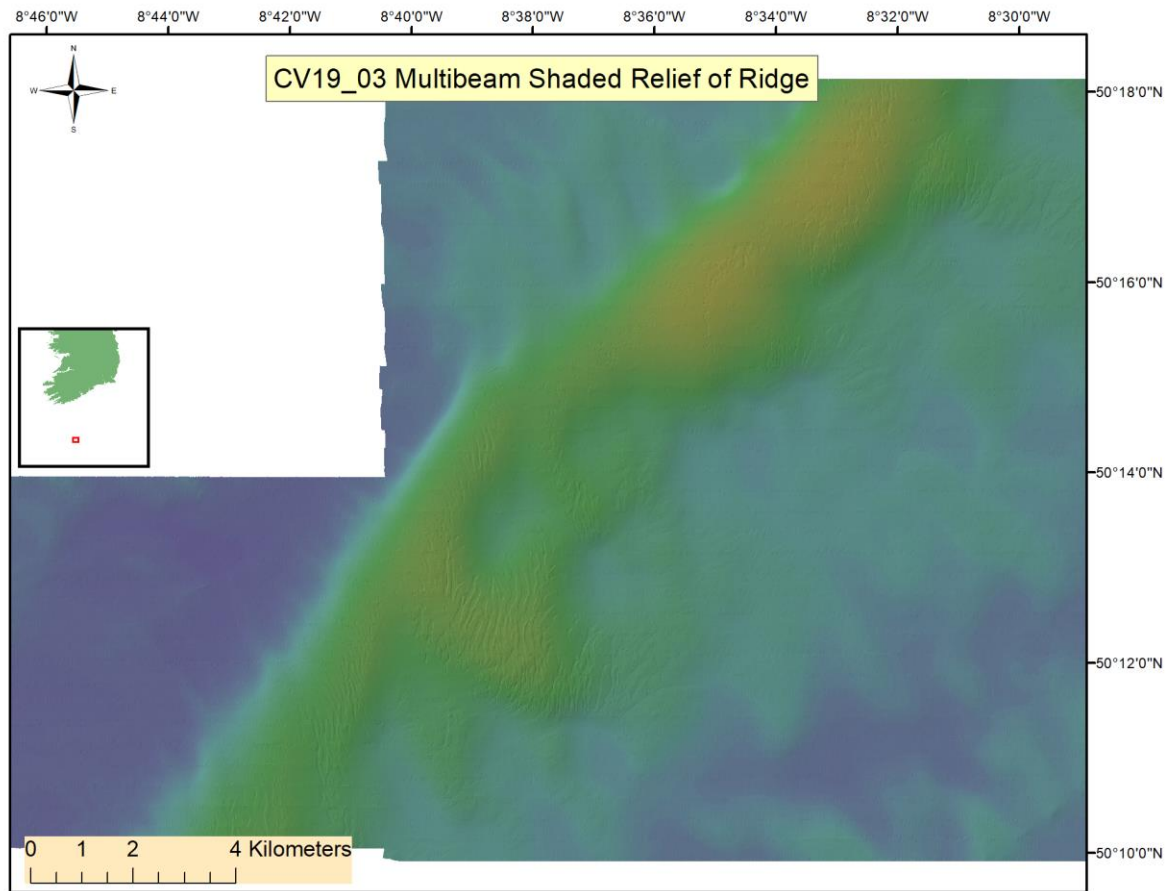
Figure 34: Multibeam shaded relief illustrating ridge & associated features in south area.

4.4   Groundtruthing

Groundtruthing was undertaken using a Shipek Grab. Nine stations were acquired with the data listed in table 18. All samples will be sent for particle size analysis in a specialised laboratory. The results will be used in the creation of substrate maps.

Station	Latitude	Longitude	Sample
035	51.05214	-8.20426	Sandy mud
036	51.04474	-8.20928	Sand
037	51.05237	-8.14599	Sandy gravel
038	51.04507	-8.1163	Sandy mud
039	51.04507	-8.01291	Sand
040	51.00941	-8.09755	Sand
041	51.00507	-8.09011	Sand
042	50.99385	-8.05101	Muddy sandy gravel
043	50.9685	-8.17717	Muddy sand

Table 18: Groundtruthing metadata.

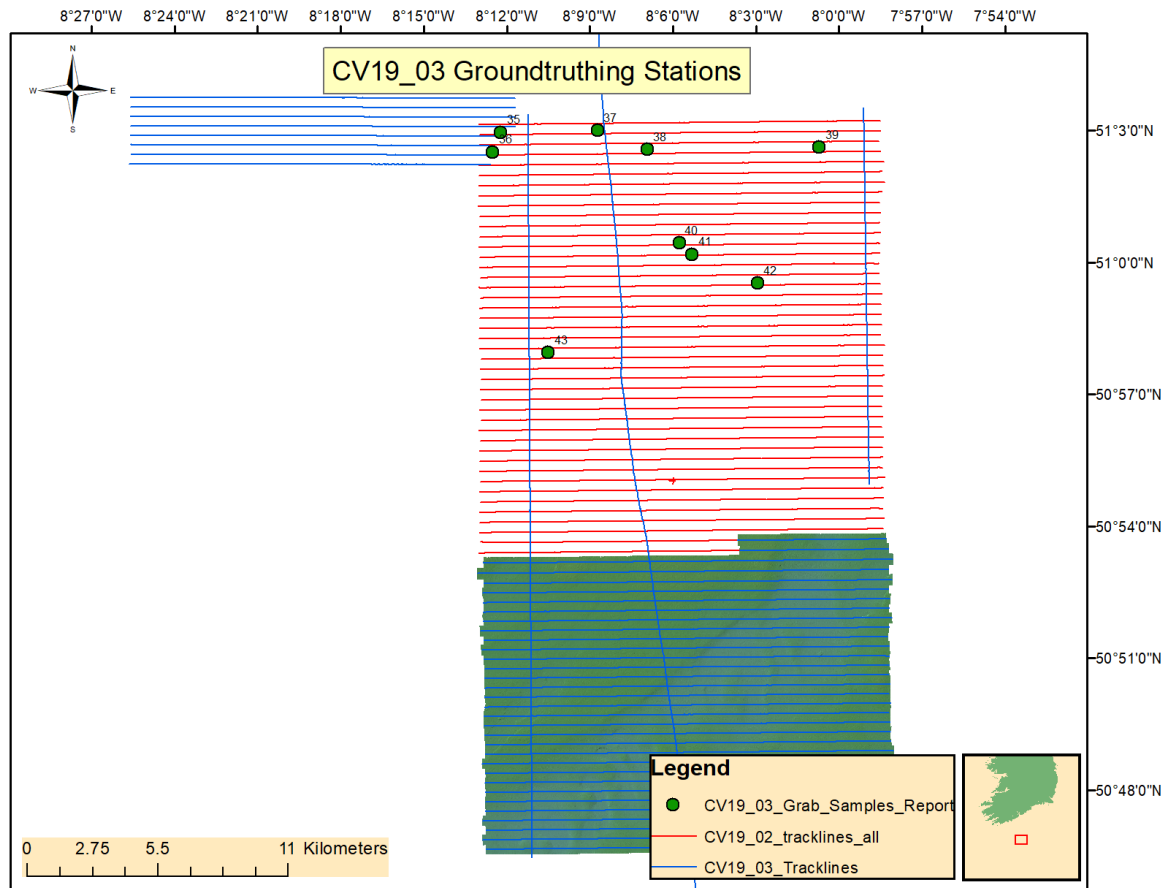Figure 35 shows the groundtruthing stations plotted over survey tracklines.

Figure 35: Grab stations locations in relation to survey track lines.

4.5   Wrecks

A total of one wreck were mapped in detail. It was previously uncharted. A H525 form was filled out and sent to UKHO. Table 19 provides the wreck metadata for this wreck.

Number	Wreck DB No	Latitude	Longitude
1	NA	50º 10.3722 N	-008º 50.7074 W

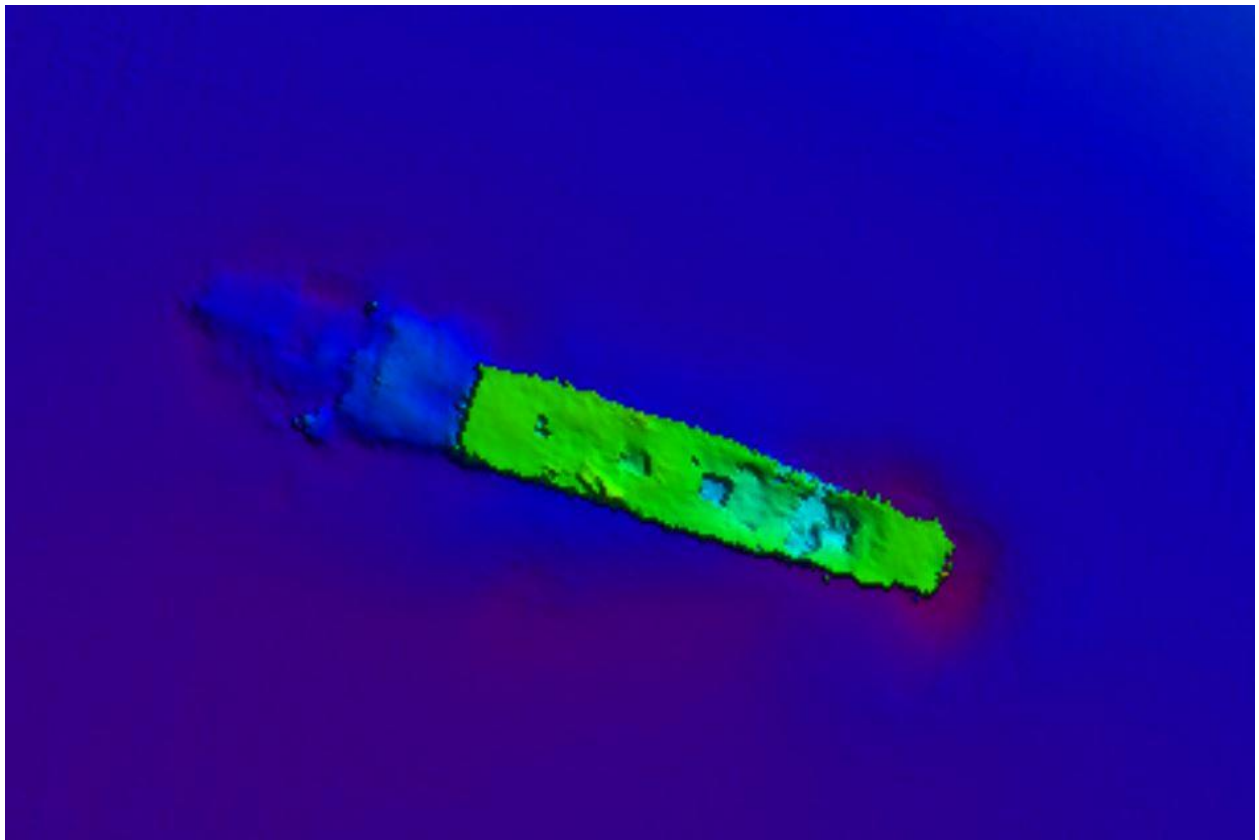Table 19: Wreck investigation metadata.

Figure 36 shows a multibeam image of the mapped wreck.

Figure 36: Multibeam bathymetry image of wreck 1.