Greater Dublin Drainage

Alternative Sites Assessment and Route Selection Report (Phase 4):
Final Preferred Site and Routes

Appendix 11
Hydrographic Survey

June 2013

Document control sheet P 04 F8

Client: Fingal County Council

Project: Greater Dublin Drainage Job No: 32102900

Document Title: Hydrographic Survey

	Originated by	Checked by	Reviewed by
ORIGINAL	NAME **TechWorks MARINE**	NAME **Anna Wrzosek-Duk**	NAME **Ciaran O'Keeffe**
Approved by	NAME **David Conneran**	As Project Manager I confirm that the above document(s) have been subjected to Jacobs' Check and Review procedure and that I **approve them for issue**	INITIALS DC
DATE **June 2013**		**Document status: Final**	

REVISION 1	NAME	NAME	NAME
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Greater Dublin Drainage Scheme:
Hydrographic Survey Report GEO13_GDD
Fingal County Council
TW/13/PRJ-012

15th April 2013

TechWorks Marine Limited
1, Harbour Road
Dun Laoghaire
Co. Dublin, Ireland

Draft Version V 0.8

Private and Confidential

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Document Information

Written By:	Position	Date
Ronan O'Toole	Marine Geoscientist	April 2013
Adam Partington	Marine Scientist	April 2013
John Deasy	Data Processor	April 2013

Reviewed By:	Position	Date

1. Introduction

1.1 Executive Summary

Between 6th February and 3rd March 2013, TechWorks Marine conducted a set of near-shore seabed surveys on behalf of Fingal County Council (FCC) in two areas North of Dublin. The purpose of these surveys was to investigate the seabed properties of each area and to ascertain their suitability for the optimum location of a marine outfall pipeline to serve the new WWTP of the greater Dublin area. This process involved the acquisition and analysis of high resolution bathymetry and backscatter data in order to build up an overview of the surface and shallow geology for each of the possible candidate sites. This report details bathymetric analysis carried out for the potential sites off Skerries (Site A) and Howth (Site B) Co. Dublin.

The survey results and data obtained from the investigation will be used by Jacob's Engineering team to determine the optimum location of the marine pipeline.

2. Project Overview

2.1 Survey Area Site A

Survey work was carried out on the South East coast of Skerries Islands, Co. Dublin between Ballyhavil in the north and Loughshinny to the south. The Survey area extends approximately 4km east offshore from Rockabill View and covers depths ranging from 0-20 metres LAT (lowest Astronomical Tide).

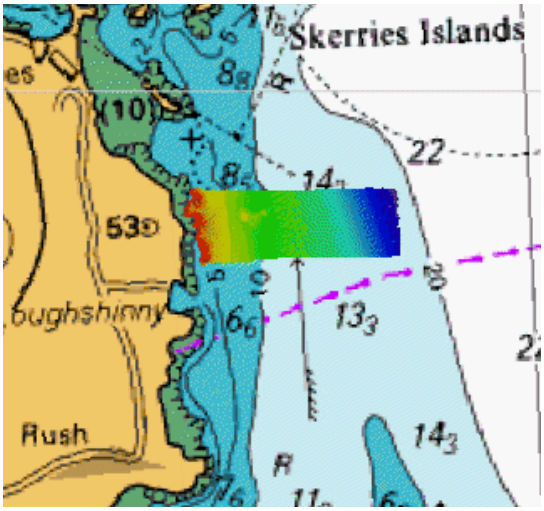

Figure 1- TechWorks Marine Project survey area Site A

2.2 Survey Area Site B

Survey work was carried out on the North coast of Ireland's Eye, Co. Dublin. The Survey area extends approximately 5km east offshore from Portmarnock Beach and covers depths ranging from 0-25 metres LAT (lowest Astronomical Tide).

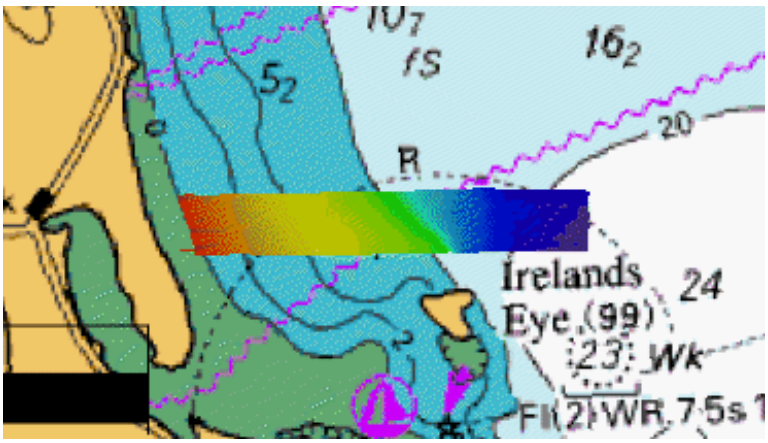

Figure 2 - TechWorks Marine Project Survey area Site B

2.3 Lat/Long coordinates

Point	Easting's	Northings	Latitude	Longitude (-ve)
Area A				
A	326171.317	258204.199	53o 33'31.585''	6o 5'48.225''
B	330431.034	258204.199	53o 33'27.841''	6o 1'56.956''
C	326171.317	257242.853	53o 33'0.508''	6o 5'49.62''
D	330431.034	257242.853	53o 32'56.765''	6o 1'58.398''
Area B				
A	323422.398	242699.988	53o 25'12.714''	6o 8'39.408''
B	330431.034	242699.988	53o 25'6.65''	6o 2'20.13''
C	323422.398	242038.541	53o 24'51.33''	6o 8'40.399''
D	330431.034	242038.541	53o 24'45.267''	6o 2'21.114''

Table 1 -Survey area boundaries

2.4 Survey Platform

Survey work for both sites was carried out by the RV Geo, which is run by the Geological Survey of Ireland for use on the INFOMAR programme.

The RV Geo is a 7.5 m RIB used to map very shallow/ intertidal water depths. She is equipped with a SEA (Systems Engineering and Analysis) Swathplus interferometric mapping system allowing for wide swath coverage in shallow water depths. Much can be inferred by examining the high resolution bathymetric data from the RV Geo. Positioning, heading and motion information is provided using an Applanix POS-MV integrated system. The RV Geo is typically crewed by a team of two individuals.

Figure 3 - GSI owned RV GEO Dun Laoghaire Marina

R.V. Geo Vessel Specifications	
Length	7.5 m
Beam (moulded)	2.5 m
Draught	1.5 m (With transducer down)
Engines	250hp Yamaha
Speed	28 knots
Fuel	200 lt Diesel
Generator	Panda 8 kVA
Max passenger and crew	4 persons
Passenger Licence	P6

Table 2 -Survey Vessel Specifications

2.5 Survey Equipment

Survey Equipment		
System	**Type**	**Comment**
Interferometer	SEA SWATH System	468 kHz
Positioning system	POS-MV 320	With PosPac PPK software
Differential GPS	Hemisphere RTCM DGPS	Coastguard broadcast
RTK GPS	Leica GPS	Shore based logging (PPP)
R/T Sound Velocity Probe	AML SVP 'smart probe'	Mounted with Swath head
Sound Velocity Probe	Castaway	Backup: AML Smartprobe

Table 3- Survey Equipment on board the R.V. Geo

2.6 Survey Team

Survey operations for GEO13_GDD were conducted by the personnel listed in Table 2

GEO13_GDD Survey Team		
Adam Partington	Marine Scientist	TechWorks Marine
Ronan O'Toole	Surveyor	GSI
John Deasy	Surveyor	Independent

Table 4 -Personnel on board the R.V. Geo

2.7 Geodetic Parameters

Geodetic Parameters	
GEO12_01 Vessel Geodetic Parameters	
Datum	ITRS89
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
Local Datum Geodetic Parameters	
Datum	ETRS89
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 29/30 (CM)	009° West or 003° West (depending on survey site)
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	Metres

2.8 Base of Operations

The base of operations for survey leg GEO13_GDD began in DunLaoghaire Harbour, Co. Dublin. From here, the R.V. Geo conducted calibration lines in the harbour before it transited north to conduct survey operations in Survey area B (Howth site - Ireland's Eye). While working in the survey area B, the R.V. Geo mapped everything in as shallow as possible depending on tide and weather conditions. During survey operations in area B, the R.V. Geo was moored in Howth Yacht club. Once survey area B was completed, the R.V. Geo Survey base of operations was moved to Malahide harbour further north. This reduced the transit time to the second area (Skerries) - Area A. The RV Geo also ran some exploratory lines into Howth and Malahide harbour channels.

2.9 Survey Statistics

For a full list of daily logs and activities. Please see the attached document (Daily logs.xls)

Category	**Percentage**	**Duration (hours:min:secs)**
Port Call	73.07852675	262:54:00
Standby	4.17882789	15:02:00
Mobilisation	1.908732916	6:52:00
Transit	5.235116979	18:50:00
Operational	14.25526986	51:17:00
Down Time Vessel	0.203845263	0:44:00

Downtime Survey	1.139680334	4:06:00
TOTAL	100	359:45:00

Table 5 - Cumulative survey statistics

Descriptor	**Events Covered**
Port Call	Vessel Alongside, usually for night hours, PR events
Operational Standby	Vessel is working but not acquiring survey data
Downtime Vessel	Operations ceased due to problem with vessel systems
Downtime Survey	Operations ceased due to problem with survey systems
Transit	Vessel is operational and travelling to destination
Mobilisation	Raising/lowering transducer heads, loading/unloading vessel

Table 6 -Breakdown of Event Descriptors

2.10 Survey Vertical Datum and VORF Model

TechWorks Marine has used the UKHO VORF (Vertical Offshore Reference Frame) sea surface model which is integral to processing data from GSI vessels. This model allows the use of 'GNSS tides' and relates all depth soundings to the WGS 84 ellipsoid. INFOMAR has gridded this model to a 1km resolution around Ireland to 15km offshore for reducing all soundings to Lowest Astronomical Tide - LAT (VORF). By utilising 'GNSS tides' there is no requirement to adjust for draft or squat.

2.11 Survey Order and Objectives

Survey work was carried out to International Hydrographic Organisation (IHO) Order 1A standard. The objective for this survey leg (GEO13_GDD) was to acquire high resolution bathymetric data and backscatter imagery for the shallow waters of two areas which are potential locations for a new marine outfall pipe.

2.12 Health, Safety, Environment (HSE) and Licensing

All personnel joining the vessel were given a safety induction tour. All survey personnel hold valid STCW95 marine safety training certificates and ENG11 medicals.

The R.V. Geo was equipped with all the necessary safety equipment for a P6 license including flares, extinguishers, EPIRB (emergency position-indicating radio beacons) and life buoys.

All on-deck operations were carried out by the survey crew and were performed with personnel wearing correct PPE.

The necessary licences were acquired for survey operations in both areas.

No loss time accidents occurred.

2.13 Challenges, Incidents and Troubleshooting

1. The vessel incurred 12 days of weather downtime and 1 day of standby while the vessel was lifted from the water for a structural survey

2. Minor episodes of troubleshooting were required from time to time, such as system restarts and PC timing checks.

3. The survey area was littered with lobster pots and there were several occasions where survey lines had to be adjusted to avoid prop fouling.

No other issues or troubleshooting occurred during the course of the survey.

2.14 MMO (Marine Mammal Observations)

Figure 4 - Photograph taken on 2/3//2013 of harbour seal spotted in transit to survey site A

The surveys conducted in this project abided by the National Parks and Wildlife Service's (NPWS) Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters. There was one marine mammal spotted during transit to survey Area A from Malahide harbour on the 02/03/2013 at 12:20. The harbour seal was spotted following a fishing vessel out of the marina. At the time the sonar system on the R.V. Geo was not running. As usual, once the crew arrived at the survey area a soft start was carried out in accordance with NPWS.

2.15 Soft Starts

In accordance with legislation from the NPWS, the survey team carried out 'soft starts' at the beginning of each survey day to reduce any potential impacts to marine mammals in the area.

Both crew members engaged in observations in transit to survey areas. After half an hour observational scans, the sonar was started for 20minutes in the following manner

1 min ON, 5min OFF, 1min ON 5min OFF, 1min ON, 1min OFF, 1min ON, 1min OFF, 1min ON, 1min OFF, 1min ON, 1min OFF.

This procedure was carried out during the stabilisation period for the POS MV navigation system.

3. Data Analysis

Results and conclusions from this study are based on an examination of key datasets acquired during TechWorks survey leg GEO13_GDD. These datasets and the associated software used to process them are described below.

3.1 Survey Site A – Skerries

Site "A" outlined in Figure 4 is located just south of the Skerries Islands and is bound by the green area in the image.

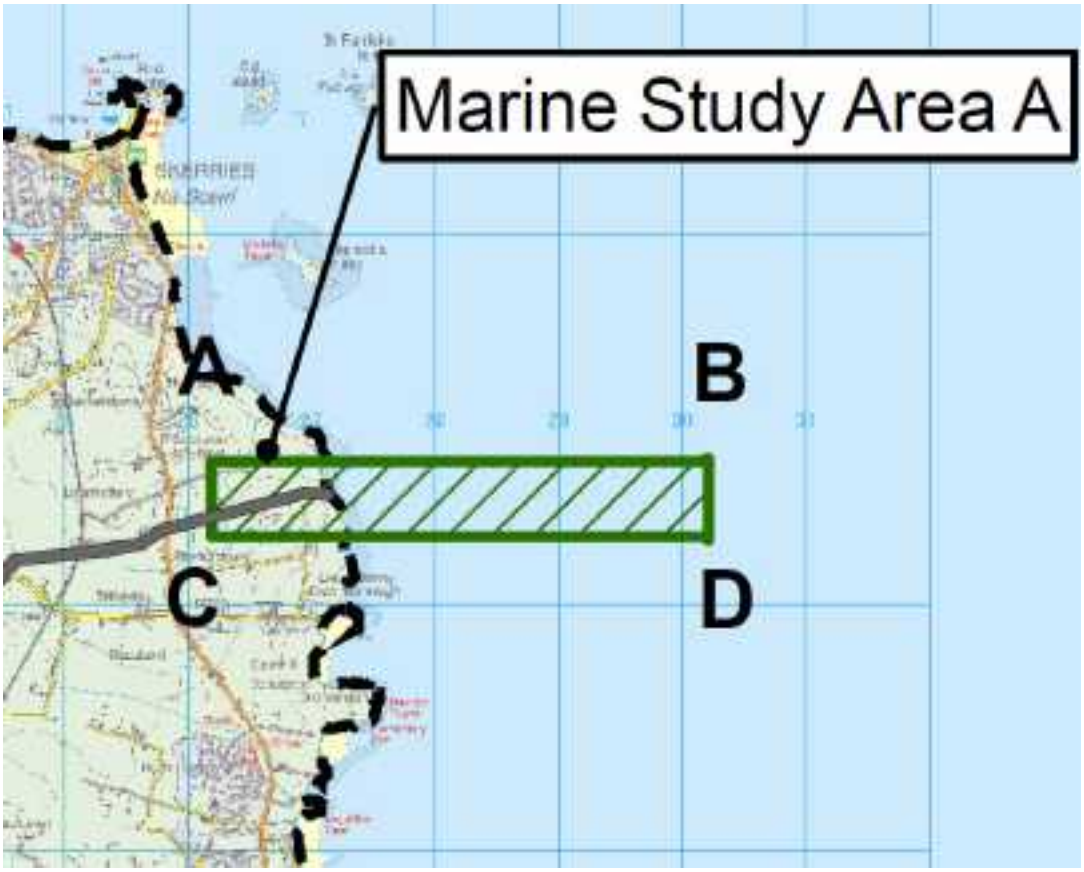

Figure 5- OSI map showing Survey Area of site A

The coast is characterised by small coves, inlets and cliffs along the extent of Site "A".

Figure 6- Google earth image of Site A survey area. The red lines represent the intended track lines of the survey vessel

Examination of Google Earth photographic imagery provides good evidence for the seabed characteristics in found in site “A”. Figure 5 reveals steeply inclined bedrock overlain in places by a sedimentary infill. The image strongly suggests that this sedimentary cover (seen here as a blue/grey colouration) is sandy in nature. This is in agreement with bathymetric results seen in Figure 7.

Figure 7- Google earth image of survey site A

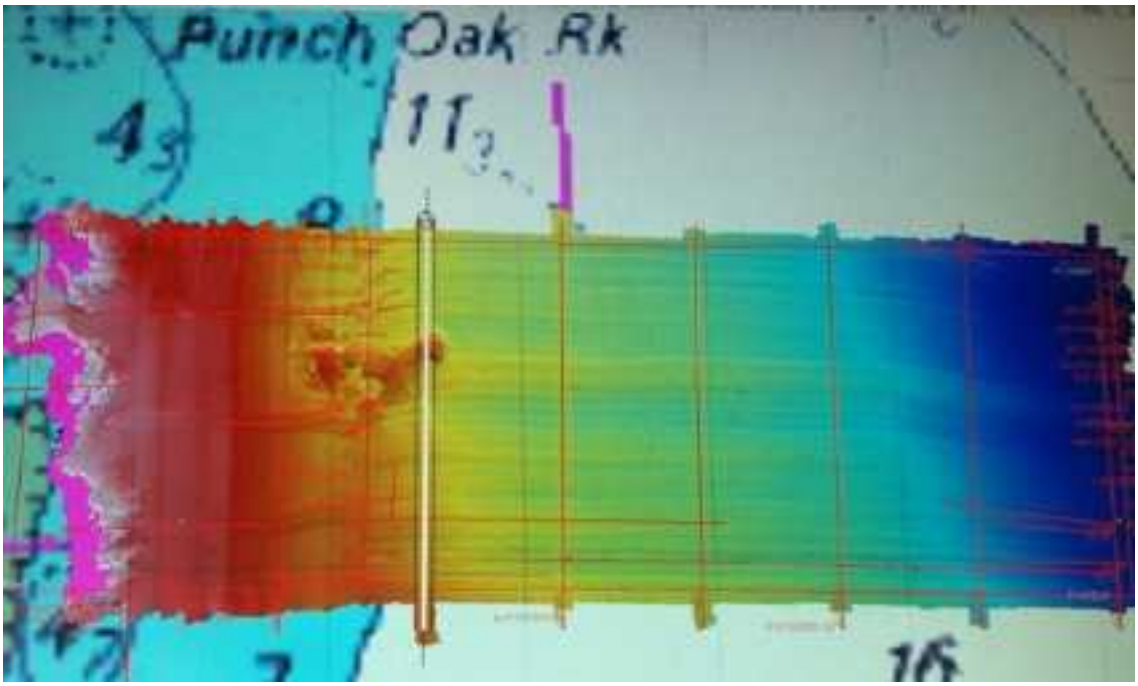

Figure 8 - Screen shot from the Swath image onboard the RV Geo showing the pre-processed Inteferometric sonar data

3.2 Survey Site B – Howth

Site "B" outlined in Figure 9 is located just north of the Howth headland and is bound by the green area in the image.

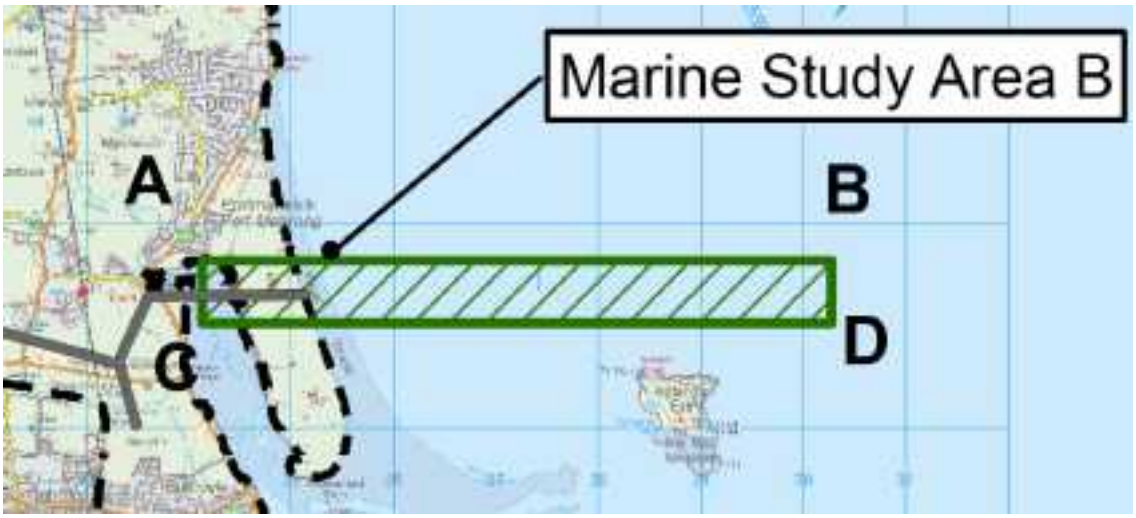

Figure 9- OSI map showing the extent of the survey area at site B

The coast is characterised by sandy beaches with a gradual sloping along the extent of Site "A".

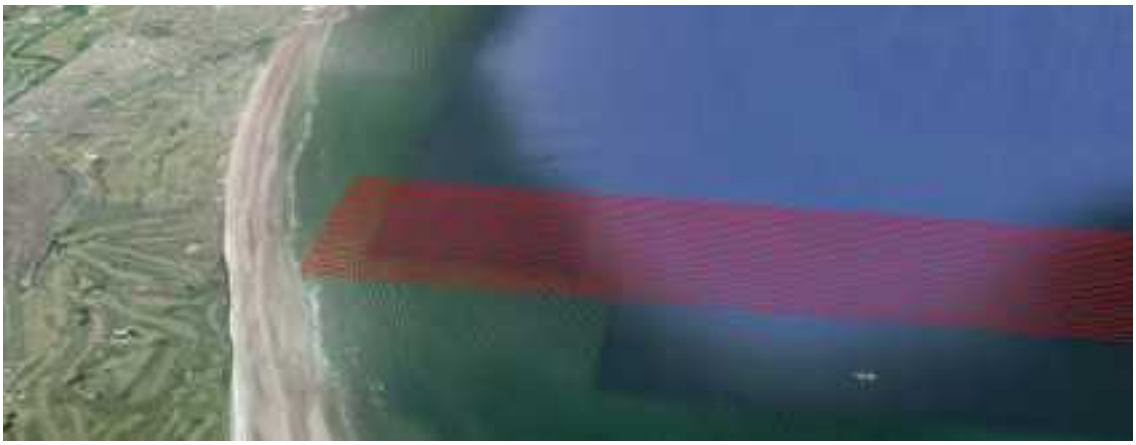

Figure 10 -Google earth image showing the survey area site B

Examination of Google Earth photographic imagery provides good evidence for the seabed characteristics in found in site "B". Figure 10 reveals the gradual sloped sandy shoreline. The image suggests that this sedimentary cover is sandy in nature. This is in agreement with interferometric results seen in Figure 11.

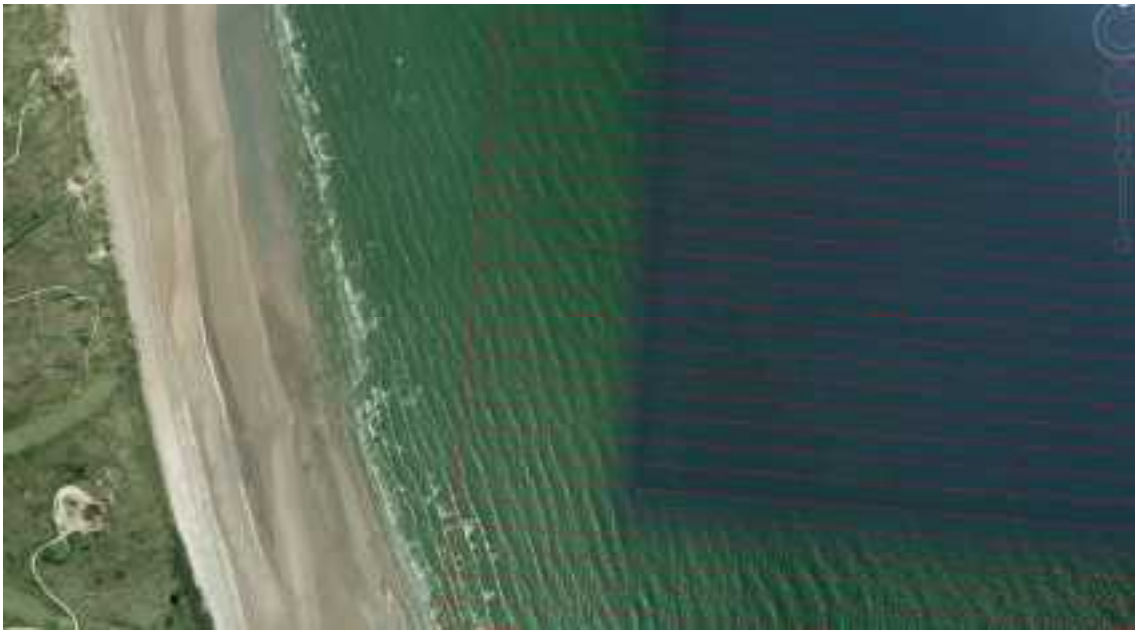

Figure 11 - Google earth image showing the survey area site B

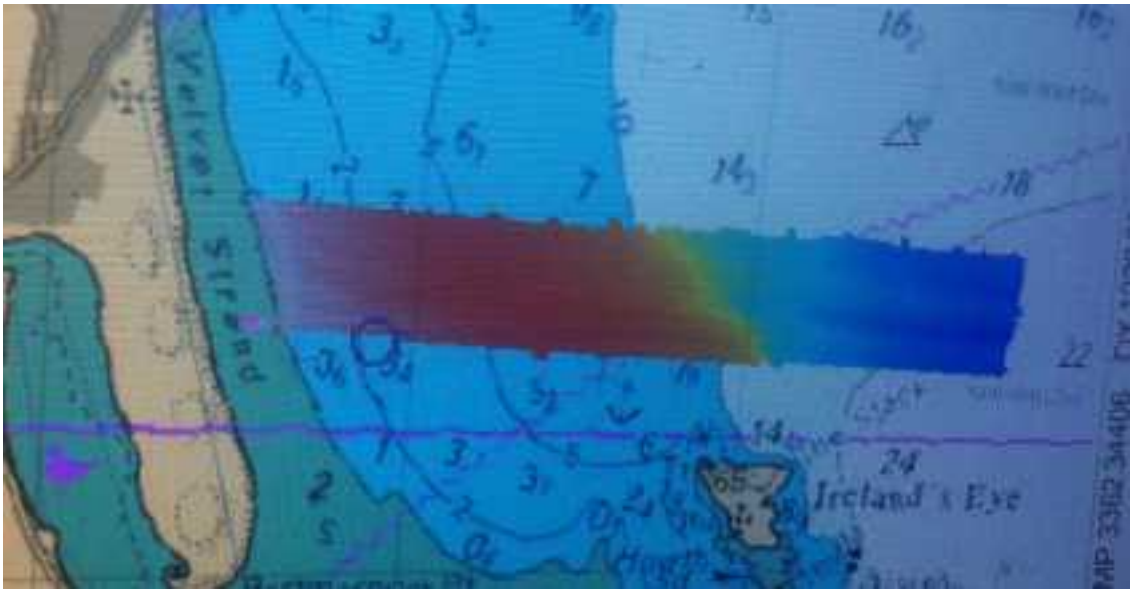

Figure 12 -Screenshot taken from onboard the RV Geo showing the Inteferometric coverage of survey area B

3.4 Sidescan sonar data

3.4.1 Site A

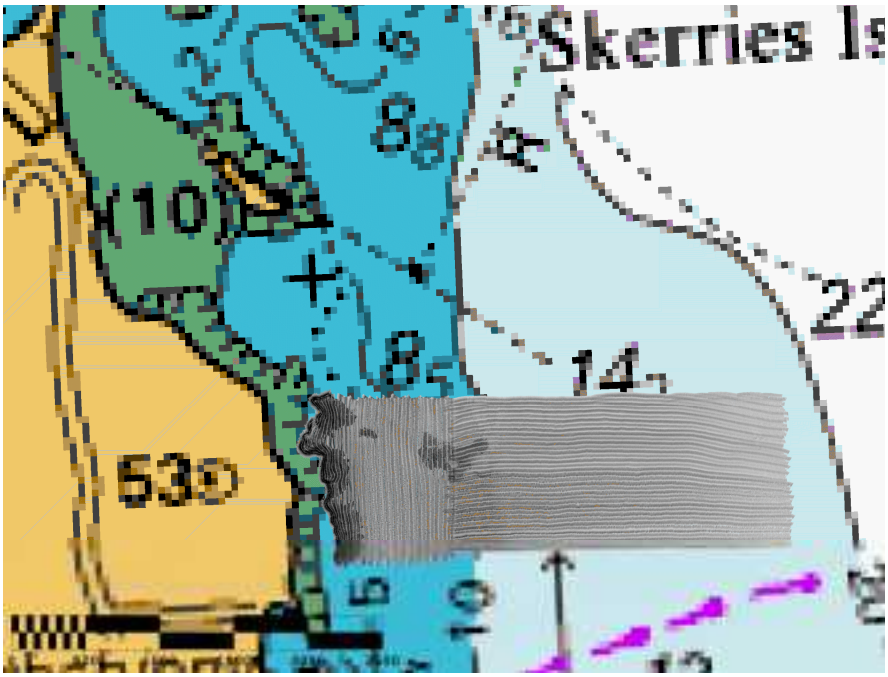

Figure 13- Processed backscatter data from survey site A

3.4.2 Site B

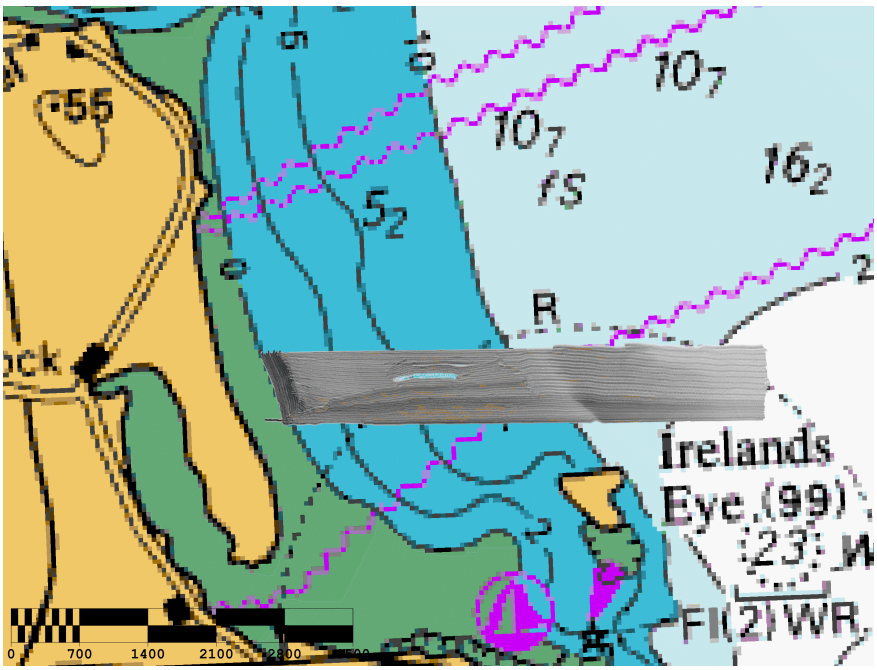

Figure 14 - Processed backscatter data from survey site B

4. Data Processing

4.1 Software

The primary data processing software packages used to process survey data are listed in Table 1.

CARIS HIPS and SIPS	Version: 7.1 with Hotfixes 1 to 6 (Feb 2013)
Applanix, POS PAC	Version: 6.1

Table 7 - Data Processing Software

4.2 SEA Swath Data

Inteferometric data on the survey was acquired using a SEA (Systems Engineering and Assessment Ltd.) Inteferometric SWATH System. Swath data was recorded in .sxr format through the swath system and in .xtf format using QPS QINSy software. This software was used for online quality control. A datagram from the SEA Swath software was sent to QPS QINSy software, which was used to display survey coverage and undertake survey line planning when necessary. Both the .sxr format and the .xtf format files were backed up to the portable hard drive at the end of each day and backed up to the servers in TechWorks Marine.

This data was exported from SEA Swath Processor Software and imported to CARIS 6.1 where the data was checked for consistency and accuracy. Data cleaning was undertaken to remove incorrect depth information, while tidal effects and navigation spikes were compensated for using reprocessed navigation data from POS PAC 5.4. The resulting bathymetric imagery used in this report was exported from CARIS 6.1 and visualised in ARC GIS 9.3.1

Table 8 -Sonar Data logged during GEO_GDD

Main Lines	192
Calibration Lines	7
Crosslines	21
Data Files	440
Dataset size	57.8 GB
File format	.sxr and .xtf

4.3 Sound Velocity Data

During survey operations water-column environmental data was acquired using an YSI "Castaway" CTD to provide temperature, conductivity and salinity used to calculate the speed of sound data. This instrument also incorporates an inbuilt GPS sensor allowing water column data to be analysed easily with respect to position and time. Several casts were made throughout each day's survey operations with the resultant sound velocity measurements converted into a set format for use with CARIS HIPS and SIPS processing software. A Valeport mini SV probe was used to record real time sound velocity at the sonar heads.

Sound Velocity Data Files	309		
Dataset size	2.87 MB		
File formats	Raw: .ctd	Caris: .svp	
Daily SVP Casts JD (Julian Days) – no. of casts	JD039 - 5	JD040 - 13	JD050 - 25
	JD051 - 5	JD055 - 10	JD056 - 25
	JD057 - 3	JD058 - 8	JD059 - 8
	JD060 - 20	JD061 - 16	JD062 - 11

Table 9 -Sound Velocity Data logged during survey GEO_GDD

4.4 Navigation / Attitude Data

Applanix POS- MV navigation and attitude raw data was imported to Applanix POS-PAC software. Here the data was post processed with a combination of OSI rinex data from the active station at Swords and the GNSS base station data set up for the duration of the survey at Malahide. Once the navigation / attitude data was processed, POS-PAC produced a series of output files which were then applied as corrections to the raw hydrographic data using CARIS HIPS and SIPS.

Station Name	Latitude	Longitude	Ellipsoid Height (m)
OSI Swords Active	53° 27' 32.59727" N	6° 13' 08.51778" W	94.6162
GNSS Base Station Malahide	53° 27' 23.98148" N	6° 09' 14.21487" W	62.1969

Table 10 -Locations used to generate rinex files for navigation post processing.

Table 11 - Navigation / Attitude Data

Navigation Data Processing for GEO_GDD	
POSPAC Projects	14
Dataset size	57.4 GB
File Format	.000, .001, etc. POS format
Files and Folders	GEO_GDD-NonCaris/GEO_GDD_NavReprocess

5. Data Processing Methodology

5.1 Navigation Data

1. Raw navigation/attitude data files logged by POSview software were loaded into an individual POSPAC project for survey each day.
2. Initially rinex data from the OSI active station in Swords was used to as base station data to process the vessel data. This allowed sonar data to be corrected and cleaned.
3. The processed POSPAC outputs, .sbet and .smrmsg, files were used to apply navigation/attitude and error corrections to the sonar data.
4. Rinex data from the Leica GNSS 1200 series base station set up in Malahide for the duration of the survey was used to replace OSI rinex where available. Data from Malahide was not available JD050, JD051, JD055, JD056 and JD057 as storage space on the base station was exceeded.

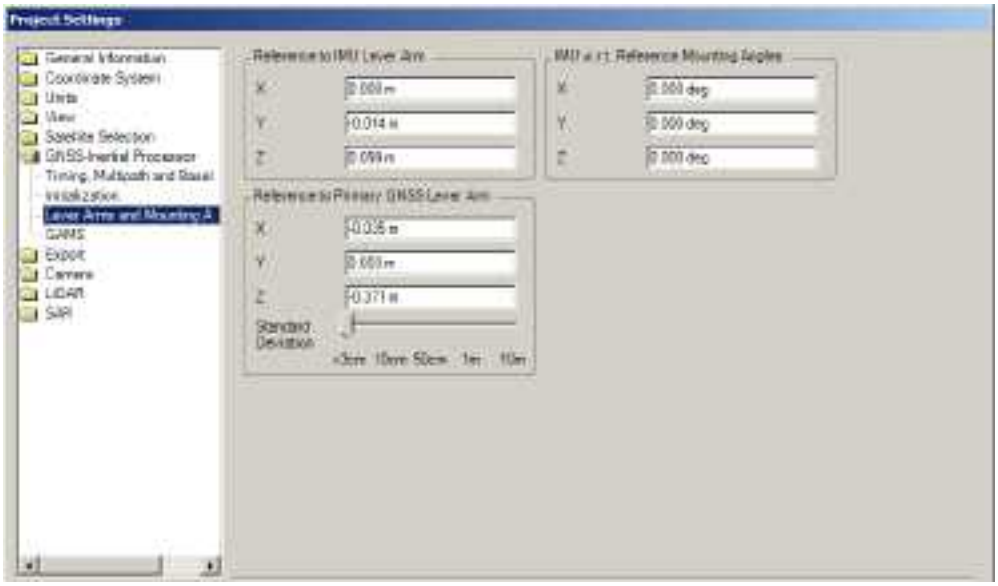

Figure 15 -Vessel offsets used in navigation processing

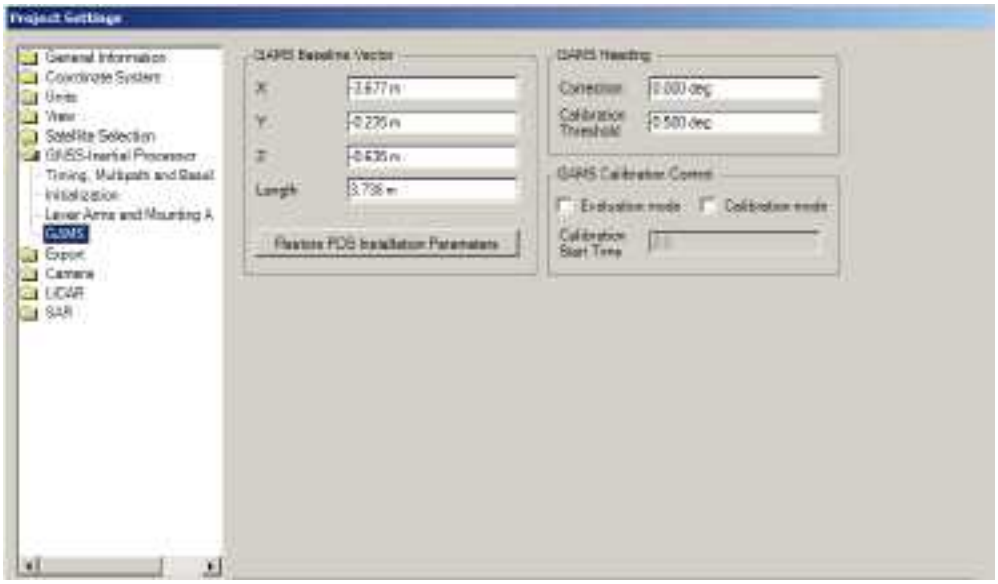

Figure 16- GAMS values and Antenna baseline length used in navigation processing

5.2 Sound Velocity Data

1. Raw data was exported from YSI castaway software in Caris format .svp format.
2. Individual casts were merged to one file for the full survey day.
3. Using Caris SVP editor these casts were quality controlled and extended to 50 m.
4. Files were saved and named e.g. JD040_ALL.svp

Note: all raw and processed files have been submitted with final report

5.3 Sonar Data

Sonar data files in .XTF format were converted and imported into CARIS HIPS and SIPS software. Once converted, survey data was then organised by specific Julian day and the following workflow commenced:

1. True Heave was derived from raw POS-MV logged data and applied to survey data.
2. Reprocessed navigation data from POS-PAC was applied to survey data.
3. Navigation error data was calculated from POS-PAC processing and applied to survey data in CARIS.
4. GPS tides were computed using the UKHO's VORF model. This reduced the MBES depth soundings to LAT. (Lowest Astronomical Tide) GPS Tide Results were then checked for quality and consistency.

5. SVP (Sound Velocity Profile) Data was then 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. At this point the day's survey data was merged in CARIS and TPU (Total Propagated Uncertainty) values were calculated. A log-file of TPU results was created automatically and was stored within the CARIS project structure.
7. Swath editing (data cleaning) was carried out in CARIS HIPS and SIPS to clean large "noise" spikes from the data. A CARIS base surface was then created to guide subset editing.
8. Refraction edits were performed to correct errors in the dataset for refraction errors caused by water column heterogeneity
9. A 2 m CUBE (Combined Uncertainty Bathymetric Estimate) surface was generated in CARIS using the shallow water setting shown below.

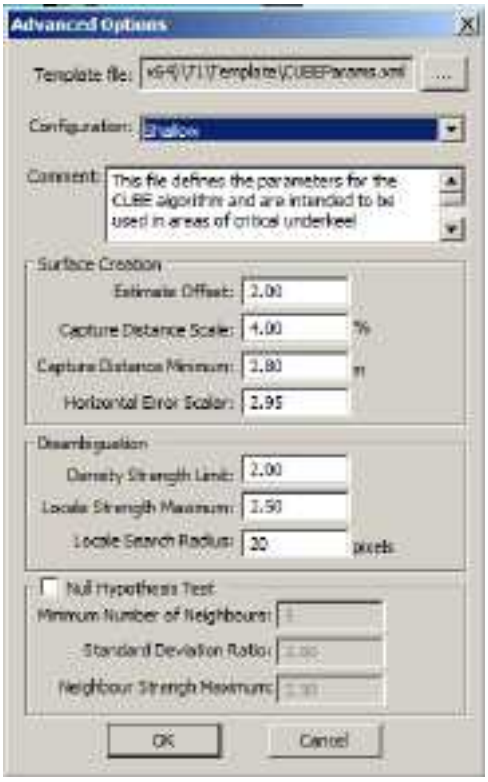

Figure 17 -Adjusting the shallow water settings in CARIS

10. The southern survey area and area east of the rock outcrops on the northern area were deemed to be suitable to run a surface cleaning filter on to remove erroneous soundings and improve the CUBE hypothesis for the surface due to the relatively flat sandy nature of the area. Settings used by the surface filter shown below.

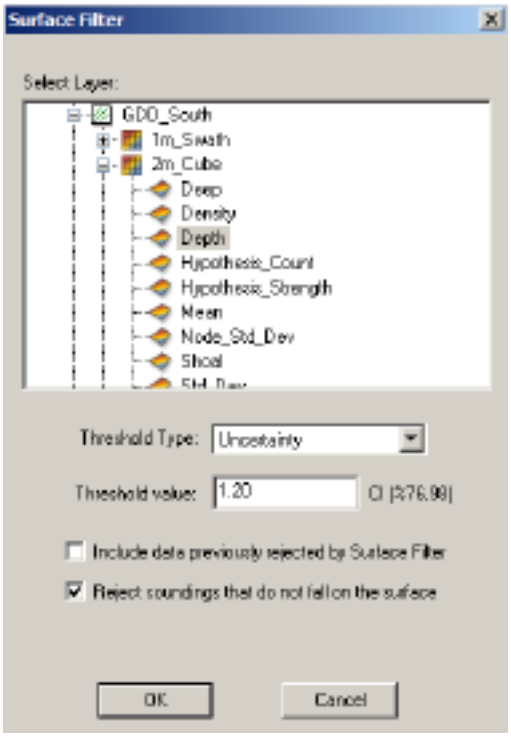

Figure 18 - Running the Surface filter function in Caris software

11. The results were examined for accuracy.
12. The areas around the rock outcrops in the northern area were not suitable for surface filtering as too much good data was rejected by the cleaning process. In this situation the area was cleaned of erroneous soundings using the subset editor tool in Caris.
13. Soundings were reduced to Malin Ordnance Datum using values from OS Grid Inquest to generate boundary points for northern and southern survey areas giving the separation from ellipsoid height to orthometric height.

5.4 Backscatter Mosaics

Backscatter is the measure of the returning acoustic energy to the sonar head after interaction with the seabed. The resulting measurements can be indicative of the seabed type as sonar returns behave differently depending on the ground type on the seafloor, e.g. rock gives a strong return whereas mud will return a weaker signal. This is represented in the greyscale backscatter mosaic as dark areas (strong return) and lighter areas (weaker return).

1. Amplitude data in both DB and Byte format were exported from Caris using the HIPS to ASCII export function. This gave two files with Easting, Northing and Amplitude figures for both the northern and southern survey areas. These were exported in the UTM29N projection.

2. Using the DMAGIC program in Fledermaus these ungridded files were gridded to a resolution of 25cm. The resulting dataset was exported in arc grid format.

3. Using ArcGIS 10 these grids were converted to rasters and the image was fine tuned to improve the visual appearance making interpretation easier.

4. The final images were exported as georeferenced tiff images at 300 and 600 dpi using ITM projection.

5.5 Reference to Malin Ordnance Datum

Vertical measurements on board the R.V. GEO all are referenced from height above a referenced ellipsoid height. The depth data was requested referenced to Malin Head OD or orthometric heights. To perform this conversion, the Ordnance Survey Grid Inquest was used to calculate a separation value between the reference ellipsoid and the geoid in the survey area. This allowed depths to be referenced to orthometric height, choosing Malin Head OD as the datum.

1. Latitude and longitude co-ordinates of the limits of each survey area were exported from Caris.
2. These values were inserted into the OS Grid Inquest and converted. A model file of the Latitude, Longitude and separation between ellipsoid and orthometric height for north and south survey areas was created to input into Caris (.xyz format) under the Process > Compute GPS tide menu.
3. After processing, the sonar data was referenced to Malin OD.

Northern Area

Node	Lat (DD)	Long (DD)	Ellipsoid to Orthometric Separation (m)
NW	53.561367	-6.083292	56.02
NE	53.559967	-6.026522	55.97
SE	53.545272	-6.027553	55.96
SW	53.546669	-6.084303	56.02

Table 12 - Values from Ordnance Survey Grid Inquest software

Southern Area

Node	Lat (DD)	Long (DD)	Ellipsoid to Orthometric Separation (m)
NW	53.424983	-6.125181	56.04
NE	53.42215	-6.021558	55.92
SE	53.405136	-6.022744	55.90
SW	53.407675	-6.126303	56.02

5.6 Tide gauges

The tide gauges installed in Skerries and Howth harbour were collected after the survey work was completed. The pressure tide gauges were set up to take readings every 30 seconds. The data which was downloaded from the tide gauges was processed in SeaBird Plot 39 software. The measurements were then averaged every 10minutes and the depth values were adjusted to the control point from the RTK surveys to give a value corrected to Malin Head datum. The tidal curve from the gauge is compared with the vessel's GPS computed tidal curve for the same tidal period in order to verify the VORF model.

For full details on the tide gauge deployments please see accompanying document. Bathymetric Survey GDDS - Geodetic control.docx

6. Quality Control

6.1 QC Procedures

Quality Control (QC) is carried out during survey operations using a combination of techniques including vessel handling, online acquisition quality checks and post-acquisition quality checks (processing). A broad overview of the QC procedures employed during survey leg GEO13_GDD is discussed below.

6.2 Operational QC Procedures

During survey operations, interferometric data quality was enhanced by maintaining outer beam angles of not greater than 68 degrees for each transducer head. Close attention was paid to sea state and weather conditions. Survey grounds were examined for sheltered areas to suit changing conditions. High swath overlap and correct survey speeds (5-6 knots) ensured good data quality and safe operation of the vessel within shallow areas. A strong focus on acquiring plenty of sound velocity profiles during each day's data acquisition allowed the onboard data processor to easily correct for refraction errors. POS-MV navigation data was logged statically for a minimum of 20 minutes prior to departure, then continuously throughout the day and for 20 minutes after arrival to port on completion of each day's survey operations. (In the event of a POS-MV failure and system restart; data would be logged for 20 minutes before resuming survey operations). Cross lines were run at the required 20 times mainline spacing.

6.3 Online QC Procedures

Data quality was monitored during acquisition by the online surveyor. Navigation data was monitored for accuracy, timing errors and satellite geometry using Applanix POS-MV software. Interferometric data was monitored for data quality using their standard acquisition software readings. QPS QINSy software provided an additional real-time check as most of the acquisition systems are interfaced with this software.

6.4 Post Data Acquisition QC Procedures

Navigation Data was checked for quality by the onboard data processor. Applanix POSPAC software was used to evaluate the POS-MV data for consistency and errors. Interferometric data was checked for quality using CARIS HIPS and SIPS software, in attitude editor and subset editor. Survey statistics and error/uncertainty values were examined in the software to ensure IHO standards were maintained.

6.5 Crossline Quality Control

Crosslines were run at the required 20 times mainline spacing. These were processed independently of the main lines and not used to generate the bathymetric dataset.

1. Crosslines were processed in Caris using the same method as mainlines.
2. Where ping range was not manually reduced at data collection stage, the data was filtered by an angle of 65 degrees either side of the nadir.
3. QC checks were run between crosslines and 2m_CUBE base surface for north and south survey areas.
4. QC reports for north and south survey areas were generated with each area achieving the specified survey standard.

Beam Angle	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
-65 - -60	204,043	0.99	0.412	-0.03	0.062	99.823	99.995	99.995	100
-60 - -55	195,538	0.939	0.407	-0.025	0.045	99.978	99.996	99.996	100
-55 - -50	181,877	0.327	0.5	-0.02	0.045	99.979	100	100	100
-50 - -45	225,665	0.362	0.405	-0.003	0.051	99.976	100	100	100
-45 - -40	247,680	0.422	0.417	0.009	0.054	99.963	100	100	100
-40 - -35	292,704	0.349	0.442	0.012	0.06	99.981	100	100	100
-35 - -30	314,714	0.333	0.6	0.019	0.06	99.997	100	100	100
-30 - -25	275,713	0.431	0.39	0.019	0.061	99.97	100	100	100
-25 - -20	237,897	0.382	0.347	0.012	0.061	99.987	100	100	100
-20 - -15	196,953	0.427	0.315	-0.001	0.062	99.97	100	100	100
-15 - -10	145,755	0.378	0.328	-0.013	0.059	99.955	100	100	100

-10 - -5	75,914	0.265	0.313	-0.029	0.056	99.992	100	100	100
-5 - 0	24,980	0.329	0.302	-0.055	0.056	99.98	100	100	100
0.0 - 5.0	23,754	0.508	0.307	-0.064	0.059	99.962	100	100	100
5.0 - 10.0	68,404	0.595	0.365	-0.039	0.06	99.937	99.999	99.999	100
10.0 - 15.0	132,474	0.535	0.391	-0.025	0.061	99.94	100	100	100
15.0 - 20.0	184,612	0.511	0.327	-0.013	0.062	99.953	100	100	100
20.0 - 25.0	230,500	0.415	0.306	-0.007	0.061	99.988	100	100	100
25.0 - 30.0	271,464	0.369	0.348	-0.003	0.062	99.993	100	100	100
30.0 - 35.0	312,489	0.465	0.361	-0.001	0.062	99.944	100	100	100
35.0 - 40.0	304,539	0.634	0.371	-0.006	0.061	99.927	99.996	99.996	100
40.0 - 45.0	252,776	0.607	0.31	-0.01	0.053	99.962	99.999	99.999	100
45.0 - 50.0	221,192	0.358	0.318	-0.017	0.05	99.996	100	100	100
50.0 - 55.0	202,136	0.321	0.541	-0.026	0.047	99.973	100	100	100
55.0 - 60.0	201,209	0.323	0.424	-0.032	0.044	99.978	100	100	100
60.0 - 65.0	191,657	0.355	0.406	-0.026	0.068	99.781	100	100	100

Table 13 - Results of crossline QC for southern survey area.

Beam Angle	Count	Max (+)	Min (-)	Mean	Std Dev	Special Order (%)	Order 1a (%)	Order 1b (%)	Order 2 (%)
-65 - -60	177,042	1.585	2.078	0	0.146	94.853	98.564	98.564	99.85
-60 - -55	274,205	1.487	1.536	-0.012	0.104	97.706	99.25	99.25	99.951
-55 - -50	360,232	1.356	1.413	-0.007	0.093	98.449	99.383	99.383	99.979
-50 - -45	358,028	1.182	1.511	0	0.085	98.679	99.501	99.501	99.98
-45 - -40	348,106	1.151	1.47	0.008	0.085	98.731	99.507	99.507	99.967
-40 - -35	308,886	1.193	1.479	0.008	0.083	98.81	99.609	99.609	99.978
-35 - -30	290,058	1.109	1.21	0.015	0.08	99.031	99.691	99.691	99.985
-30 - -25	278,528	1.112	1.456	0.018	0.08	99.229	99.727	99.727	99.989
-25 - -20	240,650	1.2	1.517	0.013	0.08	99.273	99.687	99.687	99.972
-20 - -15	195,516	1.096	1.545	-0.005	0.083	99.27	99.645	99.645	99.945
-15 - -10	142,706	1.086	1.601	-0.018	0.082	99.163	99.641	99.641	99.94
-10 - -5	79,011	1.064	1.478	-0.035	0.081	99.127	99.595	99.595	99.939
-5 - 0	31,442	0.898	1.539	-0.064	0.076	99.186	99.612	99.612	99.971
0.0 - 5.0	22,974	0.876	1.323	-0.067	0.075	99.112	99.743	99.743	99.961
5.0 - 10.0	62,895	1.039	1.976	-0.04	0.081	98.96	99.603	99.603	99.963
10.0 - 15.0	126,762	1.178	1.657	-0.029	0.081	99.114	99.695	99.695	99.952
15.0 - 20.0	178,901	1.227	1.944	-0.017	0.082	99.145	99.734	99.734	99.96
20.0 - 25.0	230,032	1.09	2.363	-0.015	0.086	99.039	99.67	99.67	99.96
25.0 - 30.0	272,150	1.235	2.221	-	0.09	98.837	99.584	99.584	99.935

				0.011					
30.0 - 35.0	300,610	1.302	1.994	-0.009	0.094	98.626	99.454	99.454	99.922
35.0 - 40.0	315,023	1.341	1.842	-0.02	0.1	98.198	99.284	99.284	99.902
40.0 - 45.0	345,621	2.04	1.888	-0.025	0.104	98.065	99.12	99.12	99.865
45.0 - 50.0	355,699	1.962	1.9	-0.033	0.103	98.066	99.125	99.125	99.875
50.0 - 55.0	388,939	1.078	2.061	-0.034	0.103	98.113	99.173	99.173	99.884
55.0 - 60.0	314,882	1.092	1.831	-0.044	0.118	96.677	98.848	98.848	99.892
60.0 - 65.0	187,098	1.244	1.456	-0.016	0.169	92.593	97.74	97.74	99.753

Table 14- Results of crossline QC for northern survey area.

6.6 Dimension Control Survey

A dimension control survey was carried out on the vessel to determine the offsets between the central reference point (designated the MRU on the RV GEO) and the sonar transducer heads and GPS antenna. The resulting offset measurements are detailed below in Table 8.

	X	**Y**	**Z**
STBD Transducer centre	0.092080496	-0.126042747	-1.960718485
Aft GPS (front of)	-0.214974088	-2.722987527	0.905078847
Fwd GPS (front of)	0.003212503	0.087304528	0.364065062
PORT TxRx Centre	-0.049828157	-0.110714977	-1.961908607
MRU	0	0	0

Table 15 -Offsets from dimension control survey.

Note sign convention may change depending on the specific requirements of the software.

7. Calibration

7.2 Swath System

A full set of calibration lines were run in Dun Laoghaire on 08/02/2013 for the R.V. GEO interferometric swath system before the survey operations were commenced. These values provided to the processor were assessed using CARIS HIPS and SIPS software. The results were found to be in good agreement with values used during the previous INFOMAR survey season and contained in the existing vessel file.

Figure 19 - Calibration lines run in DunLaoghaire at the start of survey operations

7.2.1 Latency

Timing issues on the RV GEO are eliminated with the use of 1PPS timing trigger from the POS MV system.

7.2.2 Pitch

Examination of the calibration lines and mainline data during processing showed no evidence of pitch artefacts in the data and so values for pitch remained unchanged.

7.2.3 Roll

Examination of the calibration lines and mainline data during processing showed evidence of very slight pitch artefacts in the data. Roll adjustments were made as follows and the vessel file was edited to reflect these changes;

Port Roll Calibration = -0.20

Starboard Roll calibration = 0.00

7.2.4 Yaw

Examination of the calibration lines and mainline data during processing showed no evidence of yaw artefacts in the data and so values for yaw remained unchanged.

7.2.5 Draught

As the vessel MRU and sonar heads are coupled and based on satellite observations changes in the vessels draught do not affect the sounding solution.

7.3 GAMS Calibration

A full GAMS (GPS Azimuth Measurement System) Calibration of the Applanix POS-MV system onboard the R.V. GEO was performed during vessel mobilisation. This automated procedure for calibrating the vessel's heading readings was undertaken and results and accuracies met all requirements for the survey. Attitude, heading, position, velocity and heave results were monitored continuously during all subsequent operations by the online surveyor for fluctuations and any deviation from established accuracy thresholds for the R.V. GEO's Applanix POS-MV system. (Max: 0.05 degrees HDG) (Max: 1.0m horizontal and 0.5m vertical-) POS-MV System accuracy was monitored in this manner throughout survey GEO13_02 and found to be satisfactory. These online quality checks were validated by the survey's data processor during post-processing of navigation data.

7.4 Sound Velocity Sensors

Real-time sound velocity (R/T-SV) readings at the MBES transducers are provided using a Valeport Mini SV probe. This data is input directly to the sonar acquisition software Swathplus. The sensor is calibrated periodically by Valeport and sound velocity readings at the transducer heads are verified using the vessel's sound velocity measurement devices.

The YSI CASTAWAY CTD device was also quality controlled using data from an AML CTD device and the results were examined and deemed satisfactory.

8. Results

8.1 Shaded Relief Images

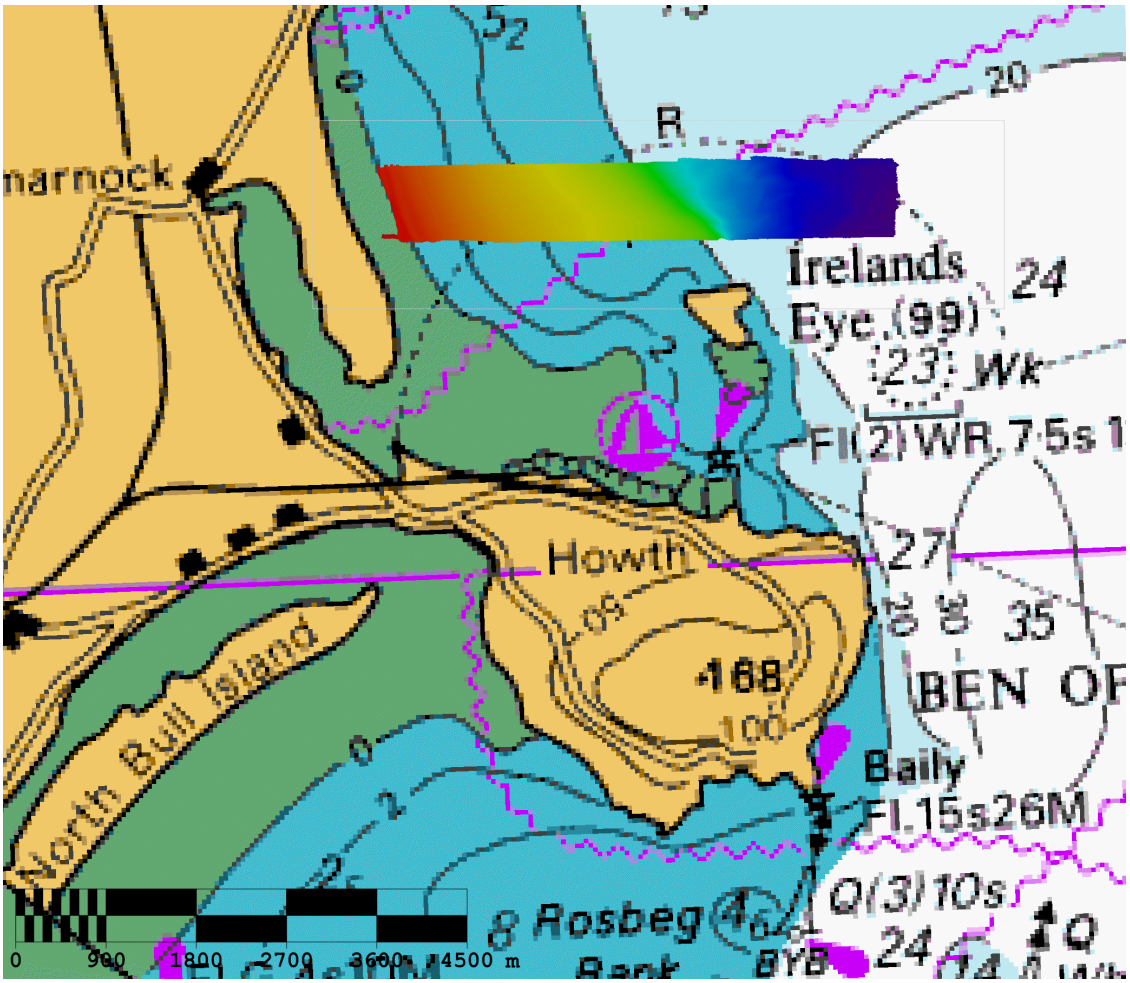

Figure 20 -Overview of southern area north of Howth Head.

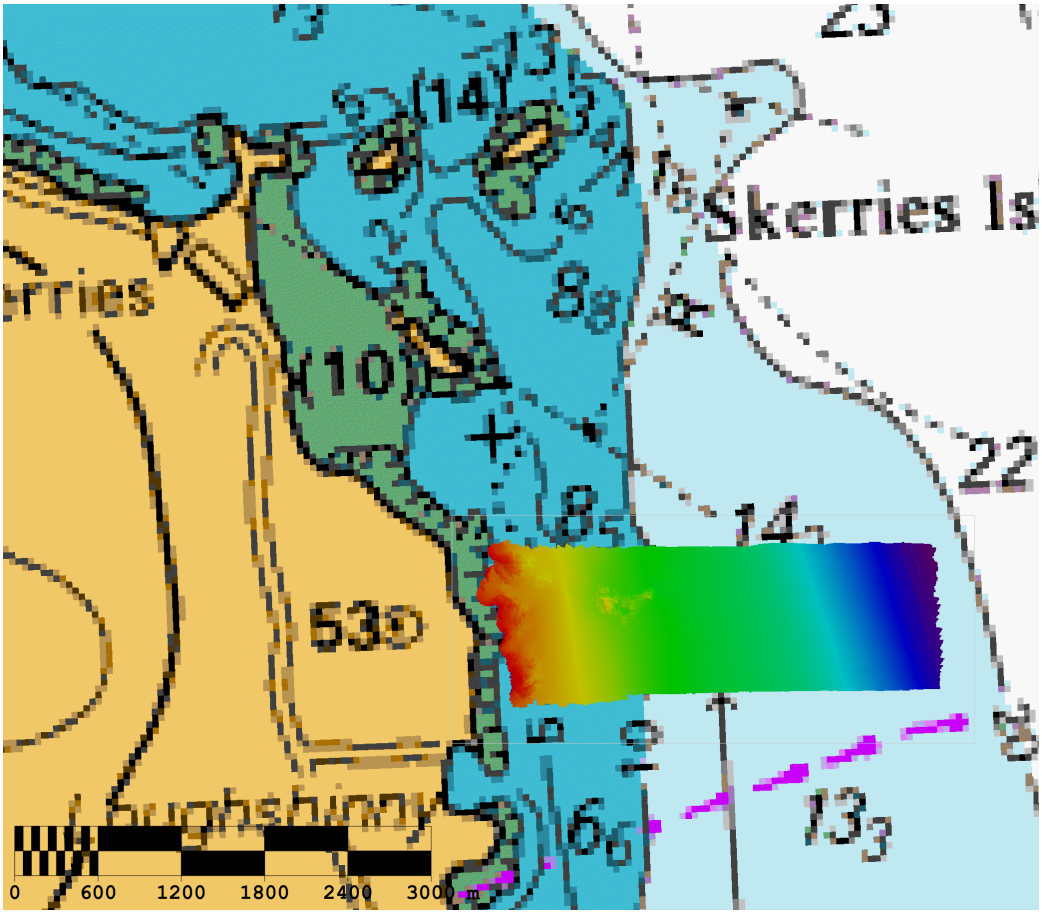

Figure 21- Overview of northern area south of Skerries Islands.

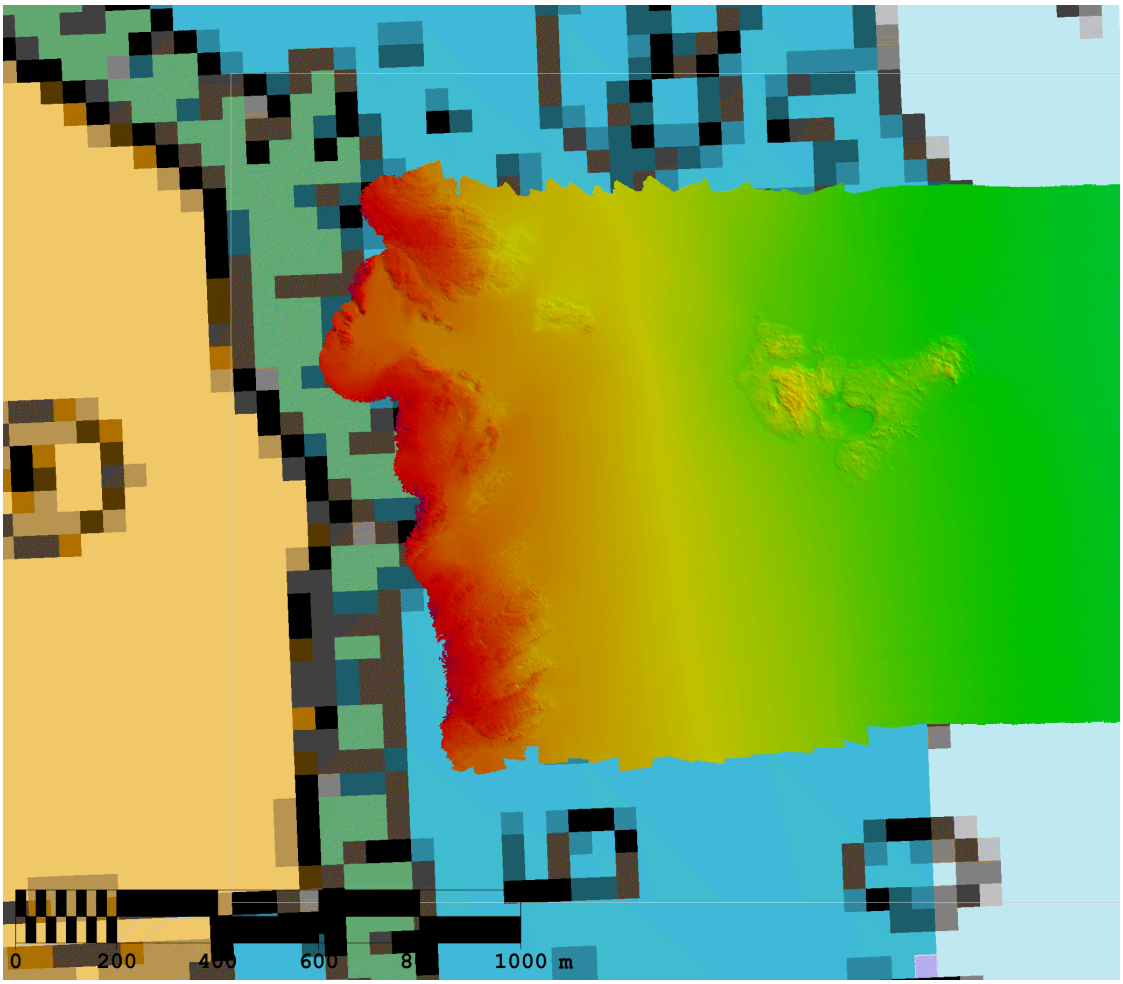

Figure 22- Detail of rock outcrops off Lough Shinny in the northern survey area.

8.2 Backscatter Mosaics

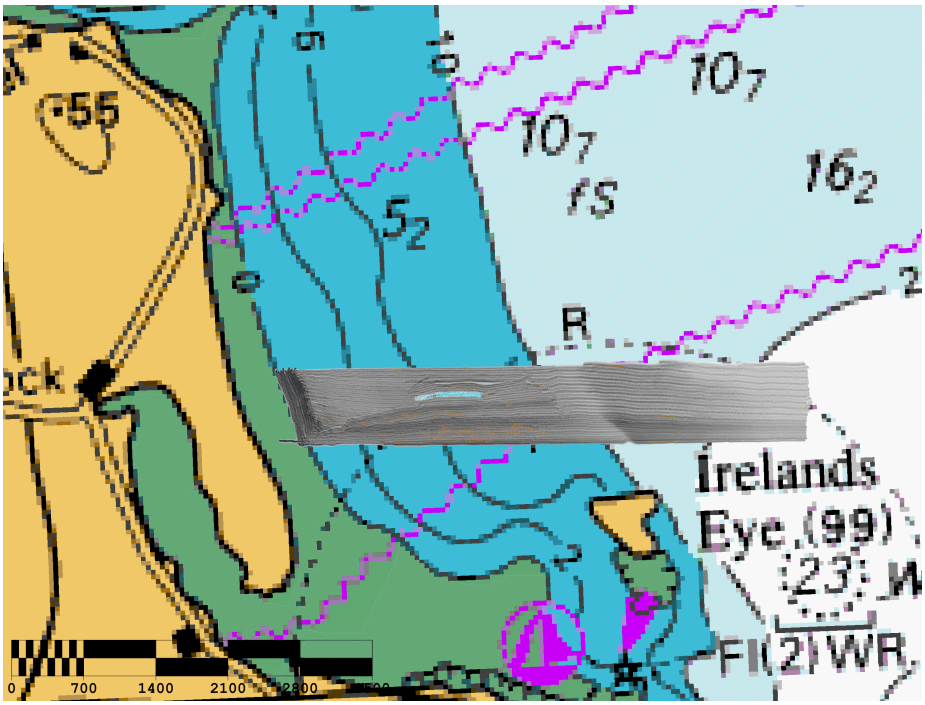

Figure 23- Overview of backscatter mosaic for southern area north of Howth Head.

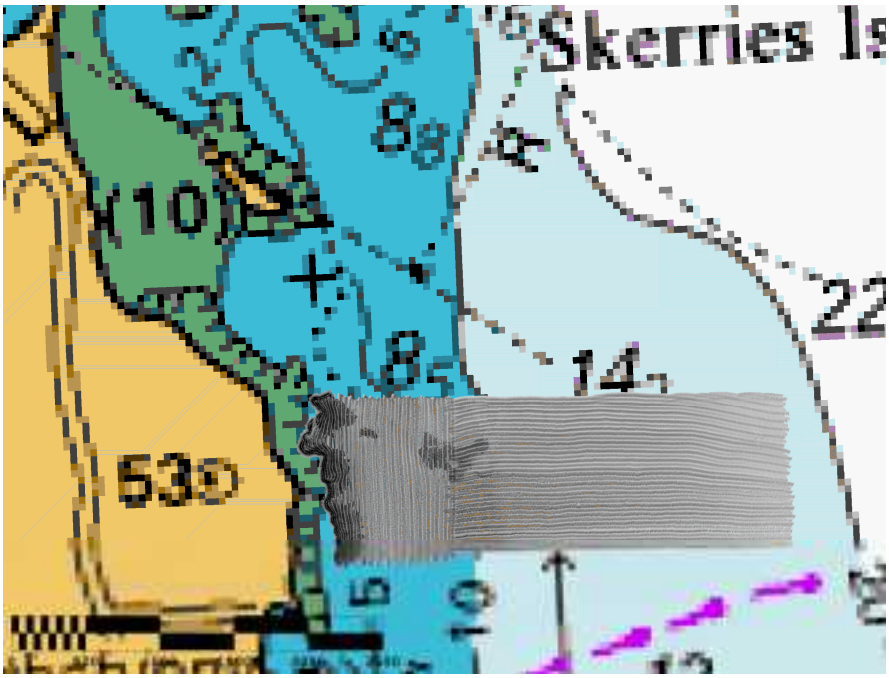

Figure 24- Overview of backscatter mosaic for northern area south of Skerries Island.

8.3 Survey Lines

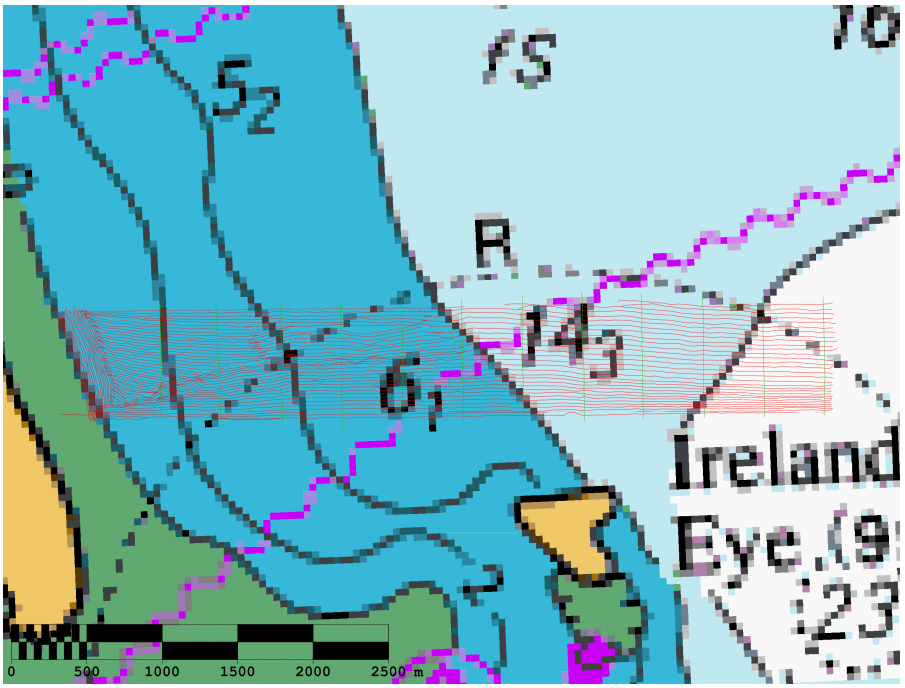

Figure 25- Overview of survey lines for southern area north of Howth Head. Mainlines in red. Crosslines in green

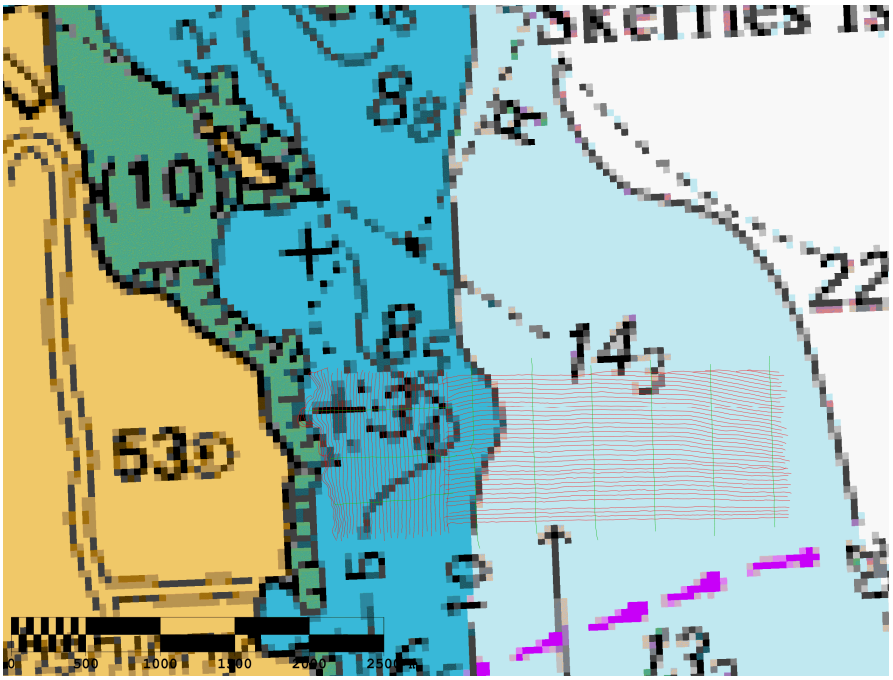

Figure 26- Overview of survey lines for northern area south of Skerries Island. Mainlines in red. Crosslines in green

8.4 Daily Processing Reports

Table 16 - Final Data Processing applied to Survey Data by Julian Day

Data Processing JD 039 (08/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	9 (2 Mainlines and 7 Calibration lines)
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	5
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 2 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 040 (09/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	16
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	13 mainlines
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 2 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Noise on 0004 and 0005 and Refraction over all

Data Processing JD 050 (19/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	29 (22 mainlines and 7 crosslines)
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	24
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Noise on 0004 and 0005 and Refraction over all

Data Processing JD 051 (20/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	4 mainlines
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	5
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 055 (24/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	18 mainlines
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	10
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Noisy data due to weather and Refraction over all

Data Processing JD 056 (25/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	53 lines (48 mainlines and 5 crosslines)
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	25
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 057 (26/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	3 mainlines
Navigation Reprocessing	OSI rinex
SVP Instrument	YSI Castaway
# SVPs for JD	3
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 058 (27/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	4 mainlines
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	8
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 059 (28/02/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	6 mainlines
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	8
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Time
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 060 (01/03/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	30 mainlines
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	20
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 061 (02/03/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	28 lines (25 mainlines and 3 crosslines)
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	16
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Refraction over all

Data Processing JD 062 (03/03/2013)	
Data Processor (initials)	JD
CARIS Version	7.1
POS PAC Version	6.1
# Lines Converted to CARIS	20 lines (14 mainlines and 6 crosslines)
Navigation Reprocessing	GNSS base station rinex
SVP Instrument	YSI Castaway
# SVPs for JD	11
True Heave Loaded	Yes
Navigation Loaded	Yes
Error / RMS Data Loaded	Yes
GPS Tide Computed	Yes
SVP Corrections Applied	Yes
SVP Algorithm	Nearest in Distance within 4 hours
Data Merged	Yes
Data Added to Base Surface	Yes
Data Cleaned	Swath Editing, CUBE, Surface Filter, Subset Editing
Data Quality / Issues	Good

8.5 Data Processing Outputs

The following outputs were produced by the data processor. All data was collected in WGS1984 UTM29N projection. All data is by default provided in UTM29N. The data was requested in Irish Transverse Mercator (ITM) projection so all geotiffs and esri grids were reprojected using ArcGIS 10. In some cases grids were generated in Latitude and Longitude (decimal degrees) to ensure accuracy.

- Shaded relief images are saved as geotiffs, ITM projection, 2m cells size, 24bit, 0 to 30 m depth range, rainbow colour scale, sun illuminated from 45 degrees and 315 degrees.
- Backscatter images are saved as geotiffs, ITM projection, 25cm cell size, 8 bit, greyscale.
- ArcGIS/ESRI grids are saved in esri grid format, 2m and 5m grid resolution, ITM projection for both North and South areas.
- Trackline shapefiles are in ArcGIS .shp format, ITM projection
- Crossline QC reports are shown above and were generated for both north and south survey areas using crosslines from the relevant areas.
- Fledermaus files are saved in UTM29N projection and SD files can be viewed by installing the Iview 4d software provided and following the 'how to' provided in the Fledermaus Data folder.
- Sounding data is in Latitude and Longitude (Decimal Degrees), Depth, Amplitude (db) and Beam and are saved by individual line.

Data Processed Outputs

Output	**Created By**	**Date**
XYZ soundings	John Deasy	20/03/2013
Average Grid (ASCII)	John Deasy	20/03/2013
Fledermaus Grid (From SD files)	John Deasy	20/03/2013
ARC-GIS/ESRI Grid	John Deasy	20/03/2013
Tracklines	John Deasy	20/03/2013

CARIS Export Geo-tiff Shaded Relief NE CARIS Export Geo-tiff Shaded Relief NW	John Deasy John Deasy	20/03/2013 20/03/2013
CARIS Export Geo-tiff Backscatter	John Deasy	20/03/2013
Crossline QC Reports	John Deasy	20/03/2013

Table 17 -Data Processing outputs