Our Case Number: ABP-312131-21

An Bord Pleanála

Catherine McMahon
69 St Anne's Square
Portmarnock
Co. Dublin

Date: 03 October 2022

Re: Greater Dublin Drainage Project consisting of a new wastewater treatment plant, sludge hub centre, orbital sewer, outfall pipeline and regional biosolids storage facility
Townlands of Clonshagh, Dubber and Newtown, County Fingal and Dublin City

Dear Sir / Madam,

An Bord Pleanála has received your submission in relation to the above mentioned proposed development and will take it into consideration in its determination of the matter.

The Board will revert to you in due course in respect of this matter.

Please be advised that copies of all submissions / observations received in relation to the application will be made available for public inspection at the offices of Fingal County Council and at the offices of An Bord Pleanála when they have been processed by the Board.

More detailed information in relation to strategic infrastructure development can be viewed on the Board's website: www.pleanala.ie.

If you have any queries in the meantime please contact the undersigned officer of the Board. Please quote the above mentioned An Bord Pleanála reference number in any correspondence or telephone contact with the Board.

Yours faithfully,

Eimear Reilly
Executive Officer
Direct Line: 01-8737184

PA09

Teil	**Tel**	(01) 858 8100
Glao Áitiúil	**LoCall**	1890 275 175
Facs	**Fax**	(01) 872 2684
Láithreán Gréasáin	**Website**	www.pleanala.ie
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64 Sráid Maoilbhríde
Baile Átha Cliath 1
D01 V902

64 Marlborough Street
Dublin 1
D01 V902

Our Case Number: ABP-312131-21

An Bord Pleaná

AN BORD PLEANÁLA
LDG-
ABP- 312131-22
30 SEP 2022
Fee: € Type:
Time: 15:03 By: hand

Catherine McMahon
69 St Anne's Square
Portmarnock
Co. Dublin

Date: 29 August 2022

Re: Greater Dublin Drainage Project consisting of a new wastewater treatment plant, sludge hub centre, orbital sewer, outfall pipeline and regional biosolids storage facility
Townlands of Clonshagh, Dubber and Newtown, County Fingal and Dublin City

Dear Sir / Madam,

I have been asked by An Bord Pleanála to refer to the above-mentioned case.

Please find enclosed a copy of further information requested by the Board, which is being forwarded t you for information purposes only. Any response received from Irish Water shall be circulated to all parties for comment in due course.

If you have any queries in relation to the matter please contact the undersigned officer of the Board.

Please quote the above-mentioned An Bord Pleanála reference number in any correspondence or telephone contact with the Board.

Yours faithfully,

pp. K. McGettigan
Eimear Reilly
Executive Officer
Direct Line: 01-8737184

PA12

Our Case Number: ABP-312131-21

An Bord Pleanála

Betty Ennis and others
97 St Anne's Square
Portmarnock
Co. Dublin

Date: 29 August 2022

Re: Greater Dublin Drainage Project consisting of a new wastewater treatment plant, sludge hub centre, orbital sewer, outfall pipeline and regional biosolids storage facility
Townlands of Clonshagh, Dubber and Newtown, County Fingal and Dublin City

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64 Marlboro

Our Case Number: ABP-312131-21

An Bord Pleaná

Velvet Strand Concerned Sea Swimmers & Beach Users
C/O 69 St. Annes Square
Portmarnock
Co. Dublin

Date: 29 August 2022

Re: Greater Dublin Drainage Project consisting of a new wastewater treatment plant, sludge hub centre, orbital sewer, outfall pipeline and regional biosolids storage facility
Townlands of Clonshagh, Dubber and Newtown, County Fingal and Dublin City

Dear Sir / Madam,

I have been asked by An Bord Pleanála to refer to the above-mentioned case.

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Please quote the above-mentioned An Bord Pleanála reference number in any correspondence or telephone contact with the Board.

Yours faithfully,

Eimear Reilly
Executive Officer
Direct Line: 01-8737184

PA12

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GDDP. Re 312131-21

This is the submission from Catherine McMahon of 69 St. Anne's Square, Portmarnock.
I am representing myself, the Velvet Strand Concerned Sea Swimmers and Beach Users and Betty Ennis and others. Letters of 29th August from ABP

We wish to bring to the attention of ABP that the Foreshore Licence application for the GDD Project was lodged in April 2020 following a pre application process.

https://www.gov.ie/en/foreshore-notice/3b16d-irish-water-greater-dublin-drainage-outfall/?referrer=http://www.gov.ie/en/publication/90f07-irish-water-greater-dublin-drainage-outfall/

The NIS submitted as part of this application has been updated since the planning application was lodged. We attached one report as an example to highlight the differences between the planning application NIS and the Foreshore Licence application NIS. We do this as in our opinion the NIS and EiAR submitted as part of the planning application are now out of date. We have been invited to make further observations, if we wish, on the planning application now with new case number 312131-21, but are in doubt as to which version of the NIS and EIAR to comment on.
We ask that the board or newly appointed Inspector compare the attached Quiet Oceans reports - Modeling Dredging Noise Offshore Dublin Report (Version 02) submitted at planning stage, and the Modeling Dredging and Piling Noise Offshore Dublin Report (Version 04) submitted at Foreshore Licence stage. We have highlighted areas where the reports differ. App. 1 App. 2
We also attach a copy of the updated Mitigation Measures summary that was submitted as part of the Foreshore Licence application and mitigation measure BM9 refers to secondary treatment only. Yet this is after Irish Water, out of an abundance of caution, introduced UV treatment on the first day of the oral hearing. We have attached a link to the Foreshore Licence application and ask that the board consider the whole application and not just what we have attached. App. 3.
We also raise issues around the dye and drogue surveys and the resulting modelling and have attached tow Aquafact reports dated 2012 and 2015. (I ran out of time to print fresh versions of these and have submitted my own copies). We also include the drawing showing the location. App. 4.+5 App. 6.

Appendix A9.1 Underwater Noise Assessment and Modelling
EIAR
Volume 3 Part B of 6

Techworks Marine Ltd
Laboratori d'Applicacions Biociustiques
Quiet Oceans

We have highlighted as best we can the edits or differences between the two reports. In our opinion the original Quiet Oceans report that is part of the EIAR for the GDD planning application has been updated for the Foreshore Licence application.

Survey period August 2015
Report for GDD planning application July 2017
Report for GDD Foreshore Licence application April 2018

The following are a few of the edits or amendments. For clarity, I will call the planning application version 02A and the Foreshore Licence application 04A. I will also use the page number where possible.

02A Page 40 - No mention of piling.
04A Page 2 – states dredging and piling works and two extra version04s

02A Page 41 - No scope of works
04A page 3 – Scope of works and 600mm piling

02A page 45
04A page 6 - Top paragraph is an addition as is the Objectives and Scope of work

02A Page 54 – EMODNet number 19
04A page 13 – EMODNet number 20

02A page 56 – Extracted from 19
04A page 14 - Extracted from 20 (maps look the same)

02A page 58- 23 and 24 TSHD
04A page 16 – 24 and 25. TSHD figures different

02A page 59 – requested by customer
04A page17 – requested in the Scope of Work

02a page 63 – 0^{th} percentile
04A page 21 – 5^{th} percentile and for illustrative purposes

02A page 64 – 0^{th} percentile
04A page 22 – 5^{th} percentile (different map)

02A page 65 – 0^{th} percentile march 2017
04A page 23 – 5^{th} percentile can't make out date
02A page 66 – 0^{th} percentile March 2017
04A page 24 – 5^{th} percentile No date

02A - No 8kHz
04A - No 8kHz

Extra bibliographie in 04A
No Techworks Report overview and conclusions in 04A

Techworks Marine Ltd were contracted by Jacobs Engineering Ireland to analyse the underwater noise impact in the context of the construction of an outfall pipeline offshore.

Three Static Acoustic monitoring were deployed along the proposed GDD outfall route. A Turbidity monitoring device and a IcListen HF Hydrophone were attached to the GDD3 monitoring site.

Laboratori d'Applicacions Biociustique were engaged by TWM to access the data from the hydrophone and was then used for modelling of the underwater noise footprint by Quiet Oceans.

On page 7 of the TWM report, figure 1 shows the location of the drogue and dye release, the 3 SAM locations, GDD 1,2 and 3. The hydrophone and turbidity monitoring devices are attached to GDD3 at the end of the outfall.

The drogue and dye release points are located approximately half way along the proposed marine based outfall, to the west of the outfall point, not at the dispersal units. It was never clarified by Irish Water why this location was chosen instead of the dispersal area itself. As we are not experts in effluent dispersal, and have no means to carry out investigations ourselves, we are asking on ABP, out of an abundance of caution, to engage an independent expert to look at all marine investigation survey reports submitted, especially those that formed the dispersal and noise modelling.

We also request that the board/inspector instruct Irish Water to revisit the dye and drogue surveys, and undertake new dye and drogue investigations at the dispersal point. We have attached a summary of the mishaps that occurred during the investigations that lead us to believe the model is flawed. We have attached the copies of the Aquafact surveys that we have worked off, with notes and highlights and attached a separate sheet ca;;ed hydrographic monitoring with highlighted areas of concern. APP. 7

Page 45 (Quiet Oceans Report) 1.2 Project information. The back hoe dredger working from the inshore outwards and the Trailer Suction Hopper Dredger working from the Outfall point towards the shore. The objective of the study requested by LAB was to map the noise propagation of the dredging activity at one specific position for three frequencies, 125Hz, 1kHz and 8kHz. In our opinion the Inspector failed to address the issue of works taking place at both the inshore area and the outfall area simultaneously, and the resulting disturbance to the seabed and water column. Irish Water did not address this issue and we believe no modelling was undertaken to show to the extend of the sediment dispersal. We request that the board/ inspector instruct Irish Water to provide modelling results for this issue.

Page 53 (Quiet Ocean Report) It is essential to bear in mind that no underwater noise measurements made with hydrophones have been used to calibrate the noise maps. An active acoustic calibration measurement is STRONGLY RECOMMENDED. We believe that this was never acted upon and this is another area that needs to be addressed by the board/inspector/Irish Water.

Page 58 IV.1 Noise introduced in the marine environment from dredging. Was modelling only done for dredging at one point, 53.4169 degrees latitude and -6.075 degrees longitude? We could find no evidence of modelling results for piling noise, or piling and dredging combined. This needs to be addressed by Irish Water and we ask the board/ inspector to request this information from Irish Water. We attach photos of latitude and longitude coordinates taken from the reports and again question why these areas were chosen as we believe the results are misleading. APP 8

Page 59 IV.2 Noise introduced in the marine environment from piling of 600mm piles only using impact hammer. As the piling and dredging methods have not been determined yet, as per the Planning Application and Foreshore Licence application, we question why 600mm piles were only accessed and why only jack hammer. We believe the inspector failed to address this issue. New modelling should be requested from Irish Water, for the interface area, the subsea cable area, and the outfall dispersal area, where piling (or whatever method is decided upon), is required. The depth of each area should also be considered and reported upon. We ask the board/inspector to instruct Irish Water to submit this information.

Chapter V.1. Noise maps produced.
Modelling should be performed for the full audibility band of each species, which was not required by the customer.
Bullet point three – Three third octave bands, centred at 125Hz, 1kHz, dredging and piling, and 8kHz, only for dredging, as required by the customer. No maps for the 8kHZ are contained in the report. This needs to be clarified, and we ask the board/inspector to request this information from Irish Water.

Only 5 maps attached to report out of 21.

Report overview and conclusions drawn by Techworks Marine Ltd. (at the back of the 02 version of Quiet Oceans Report).
Location details
AIS data not available
Equipment and methodology
No map produced for piling at 8kHz.
Only noises picked up were mooring noises and environmental.
Report only shows propagation characteristics of the area in the range of frequencies that were measured and can be expected from dredging not piling.
Due to the range of the recording device, it is also only possible to state that no cetaceans were present vocalising under 8kHZ within range of the recorder, though this does not mean no cetaceans were present. We ask that the board/inspector request clarification on this. Were they present vocalising over 8kHz? Again, we are not experts on cetaceans and we are relying on the competent authority to act on our behalf. We ask that an independent expert is brought in to look at the reports related to cetaceans. We have attached a response from IWDG to questions we raised. As the land-based survey was only carried out from Howth and not Irelands Eye, we raised this with the IWDG. We believe the results of this land-based survey is not reflective of how many harbour porpoise were actually present on those days, as Ireland's Eye was blocking the view. Areas of concern are highlighted on attached sheet showing there wer only 5 days where the results seemed to be ok over the timescale of the boat based surveys. App 9.

Trusting that you can follow what we submitted. We could have done with more time and feel it is unfair that we have to make our submissions before Irish Water. We trust that we will have a chance to further comment when Irish Water revert to you with their information. We do however, raise the question after reading the letter addressed to Kevin McSherry of Irish Water, the use of the word further in the first sentence. This gives the impression that Irish Water has already made contact with the board or that the board have contacted Irish Water. There is no evidence of this on the public file. If it is the case that something was submitted, we should be allowed to comment on it.

We attach copies of the drawings from what we believe to be the Inspectors copy of Volume 5 Part A and B. This were photocopied in ABP. There are handwritten notes that show queries were being raised but we don't think they were addressed. In particular Figure 9.6 - why is there a very low/no sediment at tunnel interface location? This backs up a question we raised earlier in this submission. Why was it not addressed? This drawing is of the maximum suspended sediment plume concentration arising from dredging over the duration of the dredging works for the proposed outfall pipeline route. Not for piling and dredging. App. 10 4. in 7or

Figure 9.5 – Inshore shellfish grounds along Fingal coast. The inspector didn't really get the extent of these areas. This drawing does not show the classified area for razor clam fishing to the south of the designated shellfish area.

Figure 8.12 Quality of bathing waters – What's the influence on pattern of water quality?

Figure 8.11 Ecological Status - HA 09 Unassigned. Mayne river waters unassigned.

We ask that the board take note of the questions the inspector raised that do not appear to be answered.

We wish to request an oral hearing on 312131-21.

Trusting this to be in order.

Catherine McMahon
30th September 2022

Catherine McMahon

02 - GDD Planning App Version.

Modeling Dredging Noise Offshore Dublin

Brief Technical Report

APP. 1

Identification du document	
Réference du document	QO.20170329.01.RAP.001.02A
Donneur d'ordre	TechWorks Marine
Client	Laboratori d'Aplicacions Bioacústiques
Contract number	NA

PROJET	DOC	CHRONO	VER	IND	CLIENT	ACRO	DATE	TYPE	CLASS
QO.20170329.01	RAP	001	02	A	LAB	GDD	29.03.2017	PROD	DR

Quiet oceans

Ocean Noise Forecasting Monitoring & Mitigation

Document history					
Version	Ind.	Authorship	Date	Released	Description
02	**A**	T. Folegot	26.07.2017	28.07.2017	Add piling scenario and important disclaimer
01	**A**	T. Folegot	29.03.2017	30.03.2017	Initial version

Citation

T. Folegot (2017), Modeling Dredging Noise Offshore Dublin, Brief Technical Report, Quiet-Oceans, QO.20170329.01.RAP.001.02A

Piling not mentioned

Ocean Noise Forecasting
Monitoring & Mitigation

65, place Nicolas Copernic – 29280 Plouzané – France
www.quiet-oceans.com
contact@quiet-oceans.com
RCS BREST RCS BREST 524 673 803

Table of content

Terms and definitions

This section defines the technical terms used in the report.

1/3rd-octave frequency band

A frequency band with one third of an octave bandwidth. One octave is a doubling of frequency, whereas one third of an octave is a frequency ratio of 21/3 ≈ 1.26 between the highest and the lowest.

Bandwidth

The frequency range within which a recording system is sensitive. The frequency range (in Hertz) is obtained by subtracting the lower from the upper cut-off frequency.

Broadband level

The sound pressure level obtained over a wide frequency range with defined bandwidth.

Center frequency

The geometric mean of the lower and upper cut-off frequencies. Please note that the intensities should be averaged before converted into decibels.

Sound

The term "sound" is used to refer to the acoustic energy radiated from a vibrating object, with no particular reference for its function or potential effect. "Sounds" include both meaningful signals and "noise" (defined below), which may have either no particular impact or may have a range of adverse effects.

Noise

Noise is in direct contrast to signals, but always depending on the receiver and the context. What one receiver considers noise may be a signal to another receiver and even for the same receiver can the exact same sound be either signal or noise, depending on context.

"Noise" can be used in a more restrictive sense where adverse effects of sound are specifically described or when referring to specific technical distinctions such as "masking noise" or "ambient noise".

Ambient noise

That part of the total noise background observed with a non-directional hydrophone, which is not due to the hydrophone and its manner of mounting (self-noise), or to some identifiable localized source of noise.

Environmental background noise not of direct interest during a measurement or observation; may be from sources near and far, distributed and discrete, but excludes sounds produced by measurement equipment, such as cable flutter.

For a specified signal, all sound in the absence of that signal except that resulting from the deployment, operation or recovery of the recording equipment and its associated platform.

Natural ambient noise

Ambient noise in the absence of any contribution from anthropogenic sources.

Continuous sound

Imprecise term meaning a sound for which the mean square sound pressure is approximately independent of averaging time.

A sound with no clear definable beginning or end with no bandwidth restrictions and a large time bandwidth product when the frequency range is broadband. Continuous sounds have finite power, but may have infinite or at least undefined energy.

Sound pressure

The difference between instantaneous total pressure and pressure that would exist in the absence of sound. Instantaneous pressure at time t. p(t) in [Pa]

Reference pressure

1 µPa in underwater acoustics. p_0 in [Pa]

Sound exposure

The integral of the square of the sound pressure over a stated time interval or event.

E in [µPa²s], $E = \int_0^T p(t)^2\, dt$, with T being the time period of the event of interest.

Sound Pressure Level

SPL in [dB re 1 µPa]

$$SPL = 10 \cdot log_{10} \frac{1/_T \int_0^T p(t)^2 dt}{p_0^2} = 10 \cdot log_{10} \left(\frac{p_{rms}}{p_0}\right)^2 = 20 \cdot log_{10} \left(\frac{p_{rms}}{p_0}\right)$$

with T = integration time.

Sound Exposure Level

SEL in [dB re 1 µPa²s]

$$SEL = 10 \cdot log_{10} \left(\frac{E}{p_0^2\, T_0}\right) = SPL + 10 log_{10}(T)$$

With reference time $T_0 = 1$ s

With T being the time period of the event of interest in seconds.

Percentile level

A percentile corresponds to the proportion of time and space for which the noise exceeds a given level. This concept is widespread even in everyday life. For example, the average income of the top 10% of income earners or the "income threshold corresponding to the 90th or to the 95th percentile", i.e. the income earned by the poorest individual among the top 10% or top 5% richest individuals. Meanwhile, the 50th percentile corresponds to the median salary. For underwater noise, the percentile, or exceedance level, is meant to describe the noise level occurring at least.

In the context of underwater noise, it is defined as the level L_N that is exceeded for N percent of the time interval considered. For example, L_1 is the level that is exceeded 1% of the time. This is accomplished by (1) ordering all measured levels in the time interval numerically in descending order and (2) and picking the value 1% of the rows below the top of this ordered list. Both steps can be done together in Matlab with the quantile or prctile function (available in the Statistics Toolbox).

The L_1 is a measure for the maximum level. It is a more robust estimate than taking just the maximum observed level, since the latter may be an outlier caused by a single event, such as rattling of the anchoring system or other types of self-noise. Accordingly, L99 and L95 are used to describe the minimum level. L_{50} is the median level.

Chapitre I. Context and objectives

I.1. Context

Techworks Marine has asked the Laboratori d'Aplicacions Bioacústiques for the assessment of the underwater noise impact in the context of the construction of an outfall pipeline offshore Dublin, Ireland. Quiet-Oceans has been asked to provide some modelling of the underwater noise footprint of the project.

I.2. Project information

The outfall pipeline consists of two elements, a tunnel section running from the Coast Road to approx. 500m off the beach, and a dredged section from this interface point to the final outfall point. The tunnel section will be constructed using a micro-tunnelling machine.

The dredged section will be constructed using Back Hoe Dredgers (BHD) and Trailer Suction Hopper Dredgers (TSHD) with the BHD working from the inshore outwards and the TSHD working from the Outfall point towards the inshore.

The dredging operation includes an excavation phase with material either side cast or placed in barrages for deposition a short distance away from the trench, and a backfilling phase where the excavated material will be replaced over the installed pipe.

I.3. Objectives

The objectives of the study requested by the Laboratori d'Aplicacions Bioacústiques is to map the noise propagation of the dredging activity at one specific position for three frequencies: 125Hz, 1kHz and 8kHz third octave as defined by the international standards [1] [2] for a single environmental condition.

Chapitre II. Introduction to Quonops©

Quiet-Oceans operates since 2010 the proprietary Quonops© ocean noise-monitoring and prediction system developed and owned by the company and protected by an international patent [1] . In a similar manner to weather forecasting systems, Quonops© produces an estimate of the spatio-temporal distribution of noise levels generated by human activities at sea, aggregating multiple sources, and assessing short-, mid- and long term source contributions to the global noise field (Figure 1). As demonstrated in a number of international projects, Quonops© caters for a broad range of maritime activities, including:

- maritime traffic [1] [5] ;
- oil exploration [6] ;
- underwater warfare exercises;
- offshore construction [7] ;
- fossil-fuel extraction;
- offshore wind-power construction and operations [8] ; underwater drilling and blasting operations.

Based on physical acoustic propagation models, Quonops© considers the reality of the area through input data and has been largely validated through in-situ measurements over the last 6 years.

The outputs from Quonops© are tailored to the requirements of existing and emerging national and international regulations regarding underwater noise, the conservation of habitats and marine ecosystems, and the protection of marine species [9] .

The production of statistical soundscapes effectively characterizes the spatio-temporal emergence of anthropogenic noise from the real environmental conditions of the area. The system also supports underwater noise impact assessments and assists in the formulation of optimized planning and focused mitigation of maritime industrial activities in terms of environmental compliance. Quonops© brings together relevant information and data into a noise prediction platform to deliver a series of services, such as:

the geo-referenced mapping of statistical, historical or real-time human and environmental situation of the areas of interest,

- the geo-referenced mapping of noise pollution according to given ocean-meteorological and human scenarios.

Such a tool aims to support management decisions by assessing, quantifying and prioritizing direct and indirect anthropogenic pressures on marine life, according to the emerging national and international regulations on underwater noise, especially the descriptor 11 of the European Marine Strategy Framework Directive [10] .

Quonops© is able to provide:

- real-time regional survey of shipping noise and natural noise from waves;
- historical statistical regional noise maps at a daily, weekly, quarterly and/or annual resolution;
- noise maps of single or multiple customized noise sources through a large selection of maritime activities.

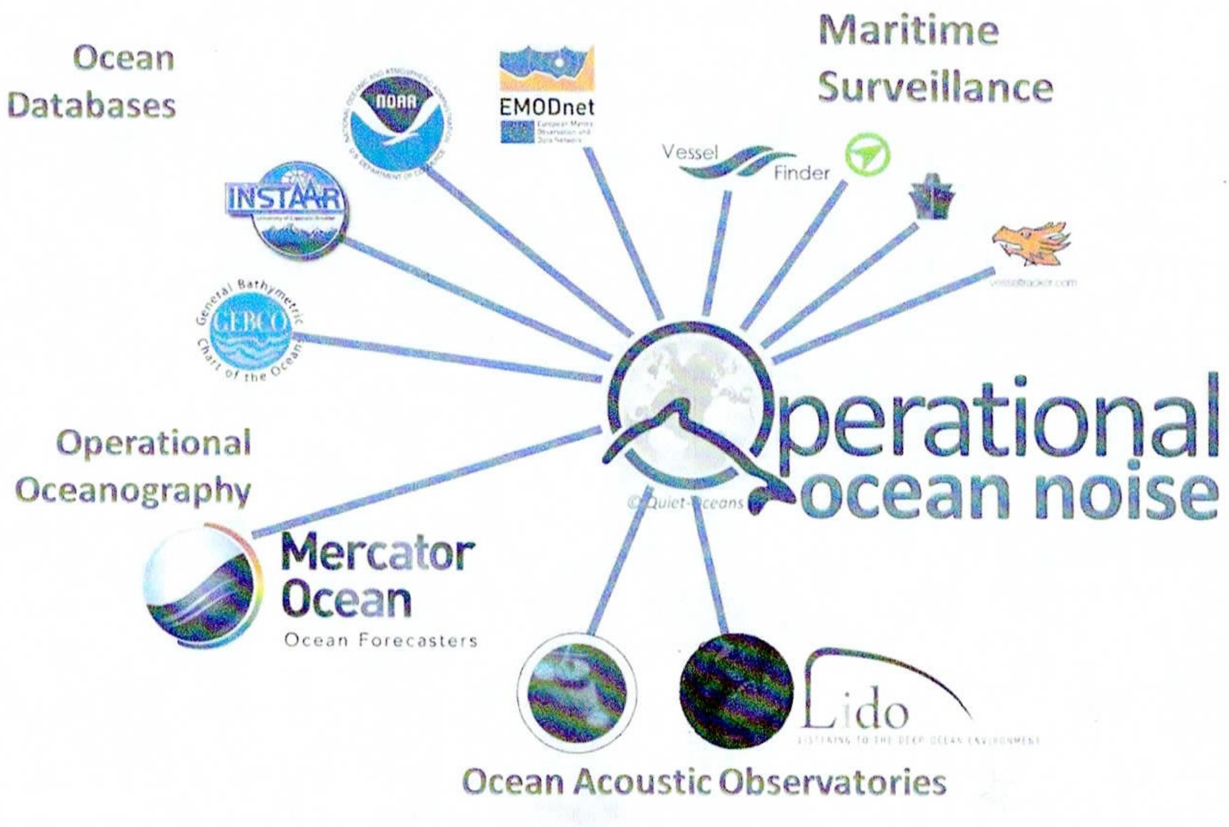


Figure 1 : Principle of Quonos©, Quiet-Oceans' underwater noise prediction and monitoring system.

Chapitre III. General principles of noise mapping

The noise received at a particular position in the marine environment depends on the characteristics of the sound source(s) and the propagation through the marine environment (Figure 2). Noise propagation and therefore noise levels are mainly determined by the following (Table 2):

- ✓ Bathymetry (underwater terrain);
- ✓ The nature of the seabed (sediment type);
- ✓ Oceanographic conditions such as temperature and salinity, currents, sea level;
- ✓ Weather conditions such as the wind (and consequently waves) and rainfall intensity.

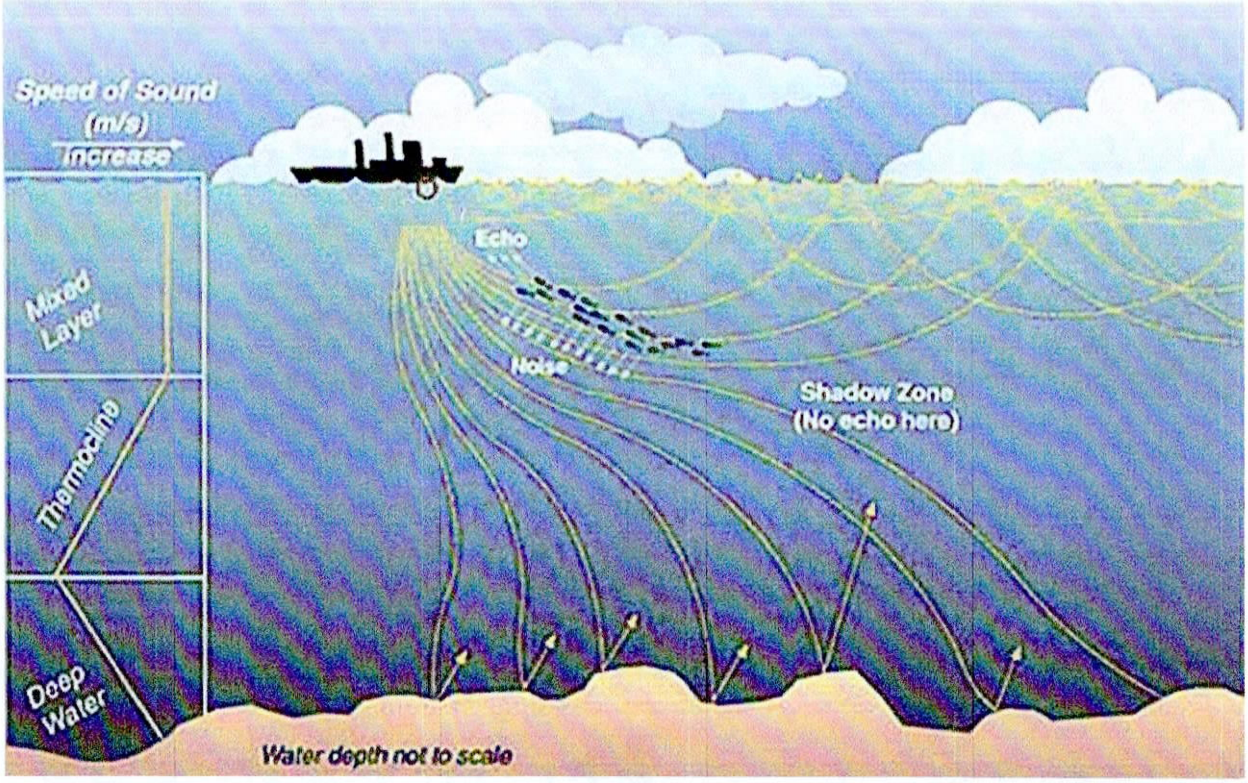


Figure 2: In the warm upper layer of the ocean, sound is refracted toward the surface. As sound waves travel deeper into colder water, they slow down and are refracted towards the seafloor, creating a shadow zone. Image courtesy of the National Academy of Sciences. Source: www.dosits.org.

III.1. Key ocean variables affecting sound propagation

Sound propagation losses increase as water depth lessens, and this is a cumulative loss effect which applies to shoaling caused by bathymetry and tidal fluctuations together. The effect is linked to the interaction of sound waves with the interfaces of the oceanic waveguide (surface and seabed). Furthermore, it should be noted that ocean waves (waves at the sea surface) tend to surge as they encounter shallower water, which increases their contribution to the ambient noise.

Propagation losses are more significant when the seabed is loose and fine-grained (i.e. silt absorbs sound waves better than gravel). However, the denser the sediment, the more reverberant it is; sound waves with significant angles of incidence on sediment are better reflected when the sediment is dense.

Wind generated ocean-surface waves propagate and absorb sound waves, an effect that increases with increasing sea-state. However, the noise generated by surging waves also increases the level of ambient noise. In other words, rough seas increase natural noise levels, but other noise sources do not carry as far as they would in calm conditions.

In shallow water, sedimentary particles are mobilized by currents and/or waves, and noise is generated when sedimentary particles collide with each other. The coarser the sediment and faster the speed of sound in the sediment, the higher the noise level.

Rainfall exerts a negligible effect on underwater sound propagation; however the sound generated by droplets falling on the sea surface does contribute to an increase in natural noise levels.

Table 1: Effect of physical properties of the ocean environment on acoustic propagation and noise generation.

	Influence noise propagation	Generate noise and contribute to ambient noise
Bathymetry	✔	✖
Bottom parameters	✔	✔
Temperature/salinity	✔	✖
Sea level	✔	✖
Currents	✖	✔
Wind/waves	✔	✔
Rain	✖	✔

✔ *indicates that the effect exists* ✖ *indicates that the effect does not exist or is marginal.*

III.2. Underwater noise modelling

Underwater modelling benefits from more than 50 years of scientific and operational development for military purposes, ranging from basic propagation modelling to more sophisticated sonar performance modelling. The military research in the field of experimental ocean acoustics has involved extensive equipment, with typically at least one ship and often an assortment of at-sea platforms equipped with sound projectors and receiving arrays. The objective of this research was to incorporate the acoustic propagation phenomena into a theoretical and numerical formalism, which gives a quantitative prediction of the sound field for arbitrary ocean environments. The progress in the field of numerical computing has largely contributed to the development of the modelling capability.

There are essentially five types of models (computer solutions to the wave equation) to describe sound propagation in the sea: spectral, normal mode, ray, and parabolic equation models, and direct finitedifference, or finite-element solutions of the full wave equation. All these models permit the ocean environment to vary with depth. Models also permit horizontal variations in the environment, i.e., slopping bottom or spatially variable oceanography [12] .

The acoustic models accurately reflect the propagation of noise in the water column in realistic oceanographic conditions by resolving the Helmholtz Equation, the State Equation:

where p is the acoustic pressure, c is the sound speed in the medium (water or sediment), t is time, t_0 the instant of emission of the signal, and r the three-dimensional position of observation and r_0 the threedimensional position of the source, assumed to be punctual.

$$\Delta p - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = \delta(t - t_0, r - r_0)$$

$$\rho c^2 = p \; \rho_0 \frac{\partial \vec{v}}{\partial t} + \vec{\nabla} p = 0$$

$$j2\pi f \rho_0 \vec{v} + \vec{\nabla} p = 0$$

III.2.1. Modelling bellow 2kHz

For frequencies bellow 2kHz, we have used state-of-the-art parabolic equation [13] [14] [15] [16] . Developed before World War II, and widely used in many areas of physics, parabolic equation methods are based on fast

Fourier transforms. It has become the most popular wave-theory technique for solving range dependent problems in ocean acoustics. It consists in a parabolic approximation of the Helmholtz equation into an elliptic wave equation. We have used the model developed by Collins et al. which is among the state-of-the-art parabolic equation implementation which especially solves the equation for elastic media, such as the marine environment.

III.2.2. Modelling above 2kHz

For frequencies above 2 kHz, we have used an energy distribution to Gaussian beams approach to limit calculation times. Used since the early 1960's, the ray modelling is based on a high frequency approximation. Ray methods are still used extensively in operational environment where speed is critical and where the environmental uncertainties pose more constraints on the accuracy. Quonops© use Bellhop [17] which is among the state-of-the-art ray tracing codes which handles Gaussian ray bundles to somewhat overcome the high frequency approximation.

Table 2: Validation of Quonops through in-situ acoustic measurements in a very large number of different marine environments and projects.

Project Name	Year	Area	Type of noise	Effort	Partners
ERATO	2011	Atlantic Ocean	Shipping and natural	6 hydrophones, 24 hours	French Hydrographic Office (France)
STRIVE	2011	Irish seas	Shipping and natural	1 hydrophone, 21 days	Environmental Protection Agency, Cork University (Ireland)
AQUO	2013-2015	Mediterranean Sea	Shipping and natural	1 hydrophone, 9 months	Laboratory of Bioacoustics Applications, Barcelona (Spain)
AQUO	2013-2015	North-sea	Shipping	Cross-models validation	TNO (Netherland), FOI (Sweden), Leiden university (Netherland)
MaRVEN	2013 - 2015	North-sea	Piling noise & Windfarm operation	2 hydrophones	DHI (Denmark), Royal Belgian Institute of Natural Sciences (Belgium), European Commission
NRL	2013-2014	Indian Ocean	Shipping and natural	2 hydrophones, 7 months	Biotope (La Réunion)
FEC-COU	2013	English Channel	Shipping and natural	4 hydrophones, 20 days	EMF, EDF, WPD (France)
SNA	2013	Atlantic Ocean	Shipping and natural	3 hydrophones, 20 days	EMF, EDF, WPD (France)
BENTHOSCOPE	2015	English Channel	Tidal device in operation	1 hydrophone, 1 day	Marine Energy France (France)
POSTE H	2013	Indian Ocean	Vibrodriving Shipping and natural	2 hydrophones	Biotope (La Réunion)
ETM	2014	Caribbean	Shipping and natural	1 hydrophone, 30 days	AKUO (France)
JETSKI	2014	Atlantic Ocean	Watercraft	1 hydrophone	Marine Protected Area (France)
PORTIER	2014 2016	Mediterranean Sea	Shipping and natural	2 hydrophones, 5 months	BYTP (France)
EMDT	2015-2016	English Channel	Shipping and natural	4 hydrophones, 12 months	ENGIE (France)
EMYN	2015-2016	Atlantic Ocean	Shipping and natural	4 hydrophones, 12 months	ENGIE (France)
GOEMONIER	2016	Atlantic Ocean	Fishing device	1 hydrophone	Marine Protected Area (France)

III.3. Calibration of the maps

It is essential to bear in mind that no underwater noise measurements made with hydrophones have been used to calibrate the noise maps. An active acoustic calibration measurement is strongly recommended.

Chapitre IV. Input data and assumptions

The data used to perform the modelling describes:

- the bathymetry of the area provided by EMODNet [19] and illustrated in Figure 3;
- the coast line of the area provided by [20] ;
- the sediment provided by EMODNet [19] ; The original sediment data has a spatial resolution of 1/40°. The EMODnet database classifies the sediments into 6 categories:
  - ✓ Boulders & bedrock;
  - ✓ Till/diamincton;
  - ✓ Coarse-grained sediment;
  - ✓ Mixed sediment; ✓ Muddy sand and sand; ✓ Mud and sandy mud.

  The geo-acoustic parameters used in the acoustic model as boundary conditions are reported in Table 4. Since the sediments being assumed to be fluid-elastic, the geo-acoustic parameters are limited to density (in ton per m3), compressional speed (m/s) and compressional attenuation (in dB/□, □ being the acoustic wavelength) as illustrated in Figure 4. Shear waves propagating in solid materials are neglected.

- the sound speed derived from temperature and salinity of the sea water provided by the Copernicus Marine Environment Monitoring Service (CMEMS) which provides regular and systematic reference information on the physical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas. The Mackenzie equation (1981) has been used to derive temperature and salinity into sound speed (Figure 5):

$$c(D,S,T) = 1448.96 + 4.591T - 5.304 \times 10^{-2}T^2 + 2.374 \times 10^{-4}T^3 + 1.340\,(S-35) + 1.630 \times 10^{-2}D + 1.675 \times 10^{-7}D^2 - 1.025 \times 10^{-2}T(S - 35) - 7.139 \times 10^{-13}TD^3$$

  In which T is the temperature in degrees Celsius, S is the salinity in parts per thousand, and D is the depth in meters. The range of validity: temperature 2 to 30 °C, salinity 25 to 40 parts per thousand, depth 0 to 8000 m.

- the sea-state or sea surface roughness provided by the Wave Watch 3 model.

The type and source of data used is summarized in Table 3. The background noise is set using the Wenz model [21] for natural noise derived from the surface roughness of the sea in the area.

Table 3 : Summary of the input data used for the modelling

Data Type	Provider	Coverage	Spatial resolution
Bathymetry	EMODNet	European seas	7.5"
Coast line	Open Street Map	World	-
Sediment	EMODNET	European seas	7.5"
Temperature	Copernicus Ocean	World	5'
Salinity	Copernicus Ocean	World	5'
Surface roughness	Wave Watch 3	World	30'

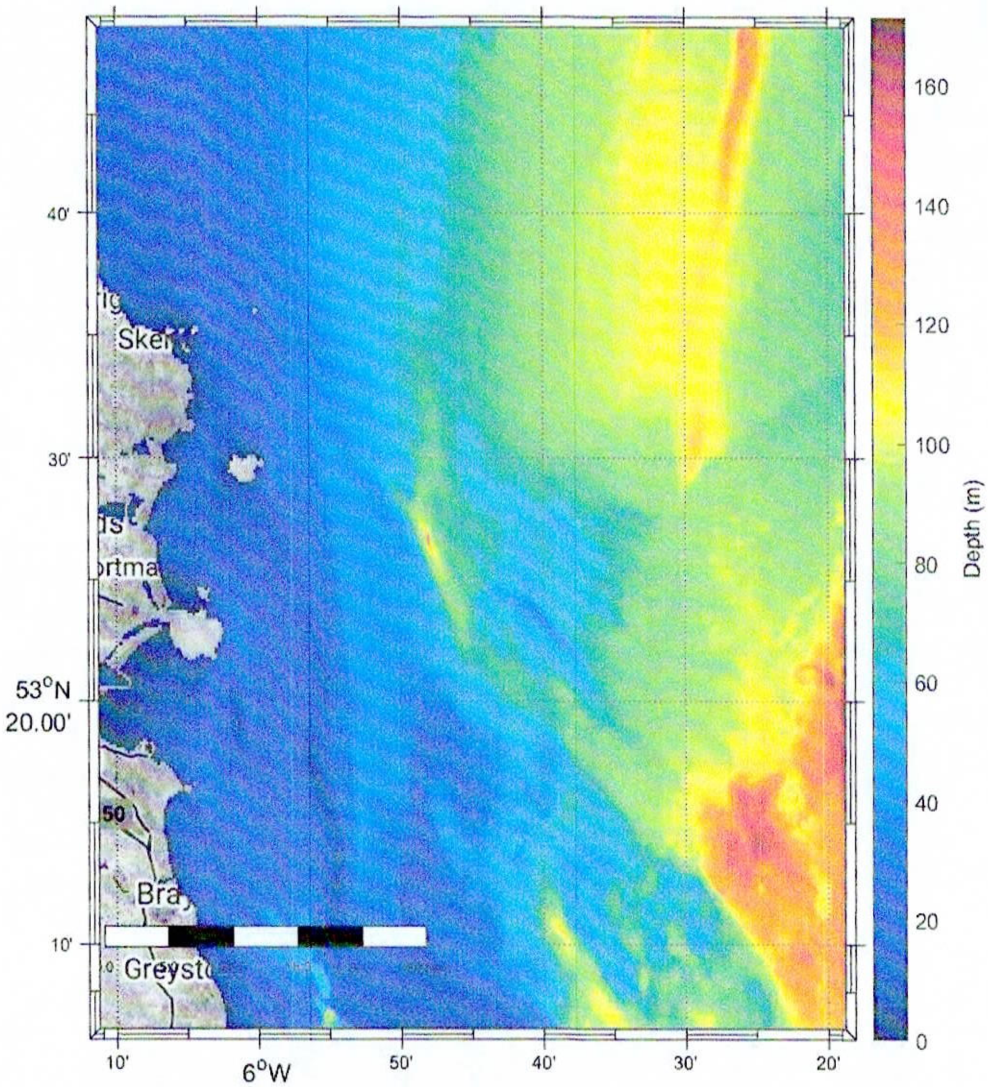


Figure 3: Bathymetric map used for modelling offshore Dublin extracted from [19]

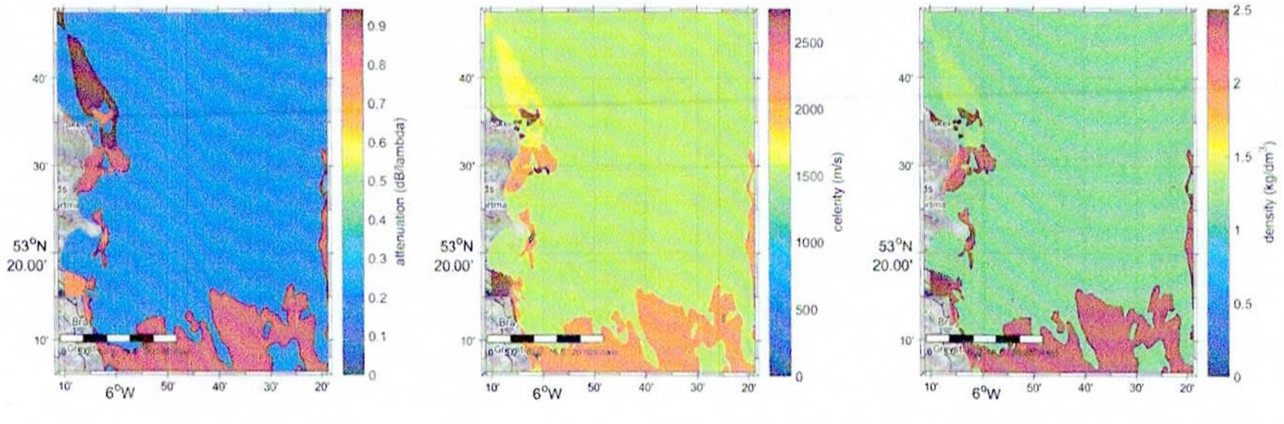


Figure 4: Distribution of values of compressional attenuation of sound (left), compressional sound speed (middle), and density (right) of the sediment provided by [19] .

Table 4: Bottom characteristics used for modelling.

Sediment Name	Density		Compressional Speed		Compressional Attenuation	
	Ton/m3		m/s		dB/lambda	
	Mean	Uncertainty	Mean	Uncertainty	Mean	Uncertainty
Boulders & bedrock	2,50	0,08	3 820	23	0,75	0,04
Till/diamincton	2,50	0,08	2 750	23	0,75	0,04
Coarse-grained sediment	2,37	0,10	2 122	315	0,88	0,07
Mixed sediment	2,03	0,26	1 855	79	0,89	0,01
Muddy sand and sand	1,53	0,22	1708	70	0,91	0,06
Mud and sandy mud	1,16	0,03	1517	32	0,37	0,41

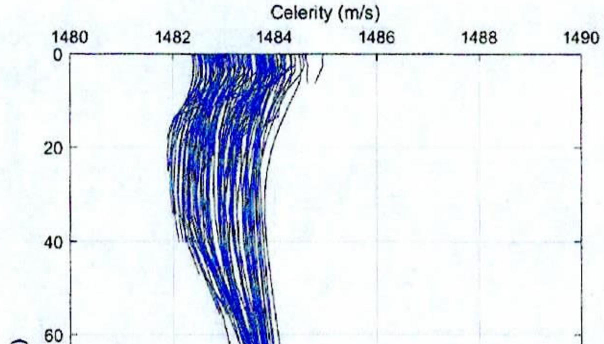


Figure 5: Sound speed profiles in the area the 17th of March 2017 provided by CMEMS.

IV.1. Noise introduced in the marine environment from dredging

We will consider as sources a Trailing Suction Hopper Dredger (TSHD) (see illustration Figure 6).

The location for modelling is at 53.4169° latitude and -6.075° longitude, offshore Dublin, which correspond to the far end of the dredging track length (about 4 km offshore). The physical geometry of the sound source is modelled as two points of generation: 50% of the generated energy is at 6m depth to describe the noise from the vessel, and 50% of the energy is located close to the bottom to describe the noise generated by the suction pipe.

The activity selected for the modelling is the flattening and removal of rocks. The wideband source level is derived from [23] and [24] and set at 178 dB ref 1µPa in the 50Hz to 89 kHz). Detailed source levels for the frequencies modelled are reported in Table 5.

Table 5 : Source levels used for modelling the dredging activities

Source level dB ref1µPa²@1m	Sound Pressure Level in the 125Hz 1/3 octave	Sound Pressure Level in the 1kHz 1/3 octave	Sound Pressure Level in the 8kHz 1/3 octave
TSHD	190.5 dB ref1µPa²@1m	188.5 dB ref1µPa²@1m	187.2

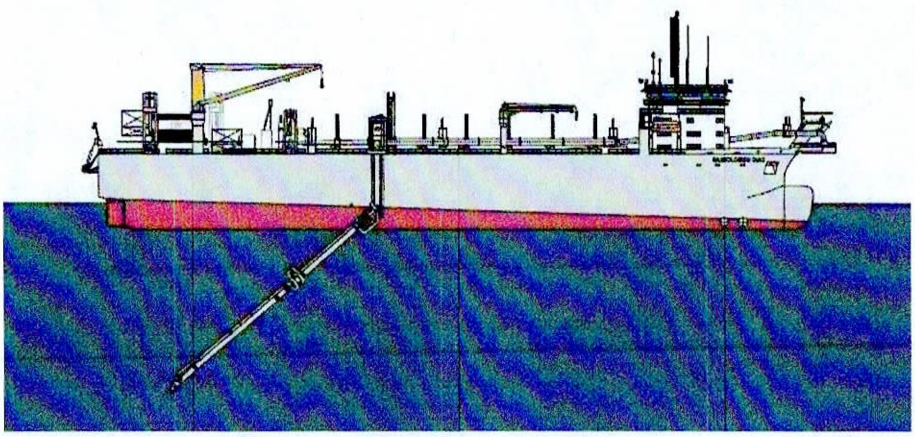


Figure 6 : Illustratio of a Trailing Suction Hopper Dredger (TSHD)) (vessel name: Bartolomeu Dias) Source : Jan De Nul

IV.2. Noise introduced in the marine environment from piling

We will consider as sources the piling of 600mm piles using an impact hammer (see illustration).

The location for modelling the piling is at 53.42466° latitude and -6.098955° longitude, offshore Dublin. During a piing phase, the sounds generated are impulsive. In order to translate the potential impacts more accurately, the scientific community (NOAA, 2016) now agrees to quantify the level as Sound Exposure Level (SEL), expressed in dB 1µPa².s). The sound exposure energy corresponds to the acoustic energy received at a point, integrated over a given frequency band and over the significant duration of the sound pulse (Ti). In this study, Ti is chosen to be 100ms, according to the literature (De Jong, et al., 2008), for example.

Earlier modeling and measurement research programs have shown that the level of sound exposure in water increases logarithmically as a function of the diameter of the pile, which makes it possible to extrapolate with confidence measurements reported in the literature. The source levels used in the modeling study are derived from measurement taken at the Q7 and OWEZ construction projects (De Jong et al., 2008), Beatrice (Talisman Energy et al., 2004) and Horns Rev II (ITAP, 2008).

The piling source is modelled using an ensemble of four punctual sources. 40% f the total energy is at the bottom end of the pile, while 60% of the energy is equally distributed along the pile. Detailed source levels for the frequencies modelled are reported in Table 6.

Table 6 : Source levels used for modelling the piling activities

Source level dB ref1µPa²@1m	Sound Pressure Level in the 125Hz 1/3 octave	Sound Pressure Level in the 1kHz 1/3 octave	Sound Pressure Level in the 8kHz 1/3 octave
600mm diameter pile driving Per stroke	186 dB ref1µPa²@1m	172 dB ref1µPa²@1m	Not modelled as requested by customer

Chapitre V. Noise maps produced

V.1. Important disclaimers

Maps have been produced at 125Hz, 1kHz and 8kHz third-octaves. Therefore, the levels obtained **cannot** be directly compared to cetaceans' nor seals' PTS or TTS thresholds, since the thresholds are valid for the total energy contained in the audibility band of the species (NOAA, 2016), which is much larger than a third-octave band. To be able to compare and estimate a risk area, modelling should be performed for the full audibility band of each species, which has not been required by the costumer. For example, the source level in the auditory band of seals for a single-stroke piling of a 600mm diameter pile is 178 dB ref1µPa²@1m, while the source level in the 1kHz third-octave band is only 172 dB ref1µPa²@1m, which makes a significant difference.

The maps are purely modelling maps using the best known description of the environment. Usually, an acoustic calibration measurement is needed to ground truth the maps and reduce uncertainties.

V.2. Summary of maps produced

For each scenario (dredging and piling), a total of 21 maps have been produced and delivered in a NetCdf Format. The noise maps correspond to:

- ✓ March 2017 environmental context;
- ✓ The full water column;
- ✓ Three third-octave bands, centred at 125 Hz, 1kHz and 8 kHz (only for dredging) as required by the costumer;
- ✓ Seven percentiles, 0th (maximum), 10th, 25th, 50th, 75th, 90th and 100th (minimum) percentiles to characterise the variability of the sound field with depth;
- ✓ Three depth ranges (Surface to -15m, 30m to the bottom, and the full water column).

V.3. Delivery

Quiet-Oceans has delivered noise ambient maps in NetCDF format version 4. Files format respect principals rules of NetCdf Climate and Forecast (CF) Metadata Conventions release 1 [22] .The NetCdf provided is described by :

- ✓ global attributes : attributes used for context, history or versioning file ;
- ✓ dimensions : scalar data that describes dimensions for the variables contained in file ;
- ✓ variables : vectors or matrix that describes the data.

The following sections detail the content of the delivered data.

Why these dates ?

V.3.1. File name

Files are named as follow: Dredging_DublinNorth_20170330.nc for the dredging scenario and Piling_600mm_DublinNorth_20170728.nc for the piling scenario.

V.3.2. Dimensions

The dimensions of the variables contained in the delivered Netcdf are detailed in Table 7.

Table 7: Summary of the dimensions of the variables contained in the delivered Netcdf files.

Group	Name	Value	Statut (Mandatory, Optionnal)
AcousticData	Lat	number of latitudes, configuration dependent	M
	Lon	number of longitudes, configuration dependent	M
	frequency	number of frequency	O
	percentile	number of percentiles, configuration dependent	M
	Layer	Number of immersion layers	M
	maxLayerNameLen	Max length of layer names	M

V.3.3. Variables

A variable can be associated with attributes. When CF conventions describes it, standard attributes are mentioned:

- ✓ standard_name : name for variable according to CF conventions
- ✓ long_name : description for variable according to CF conventions
- ✓ units : : units according to UD Units Unidata dictionnary
- ✓ valid_min : minimal value for data validation
- ✓ valid_max : maximal value for data validation

For geographic reference, SPL is linked to a coordinate reference system (CRS) which defines all the parameters attached to a mapping projection :

- ✓ grid_mapping_name : naming of projection as defined in conventions
(Appendix F. Grid Mappings). In our case, latitute_longitude is equivalent to geodesic projection in which coordinates positions are latitude and longitude,

- ✓ epsg_code : EPSG code (4326) for correspondant geodesic projection with WGS84 ellipsoid
- ✓ longitude_of_prime_meridian : longitude of prime meridian in geodesic projection
- ✓ semi_major_axis : half the major axis of the ellipsoid linked to the projection
- ✓ inverse_flattening : 1/flattening of the ellipsoid linked to the projection

Table 8: Description of the variables of the Netcdf delivered.

Name	Dimensions	Datatype	Statut (Mandatory/ Optionnal)	Attributes	Description
layer	Layer	int8	M	Standard_name Layer Layer Long_name layer_bnds bounds layer_names layer_names	Immersion field.
Name	Dimensions	Datatype	Statut (Mandatory/ Optionnal)	Attributes	Description
layer_names	Layer, maxLayerName Len	char	M		Immersion identification (Ex : High, Low, Full).
layer_bnds	layer, nv	int	M	unit m positive down	Immersion bounds
frequency	frequency	int	O	Standard_name frequency long_name Central band frequency units Hz order_convention IEC 61260 : 1995"; order_octave 3.0	
percentile	percentile	int8	M	Standard_name percentile Long_name percentile comment QO definition : The value above which a given percentage of observations in a group of observations fall unit Percent	
Lon	Lon	double	M	Standard_name longitude longitude Long_name None comment unit degrees_east	

lat	Lat	double	M	Standard_name latitude latitude Long_name None comment unit degrees_north	
energy	layer, frequency percentile, lon, lat	single	O		

crs		Single	M	grid_mapping_name latitude_lo ngitude
				epsg_code EPSG:4326
				longitude_of_prime_meridian 0.0; // double
				semi_major_axis 6378137.0;
				// double
				inverse_flattening
				563; // double 298.257223	

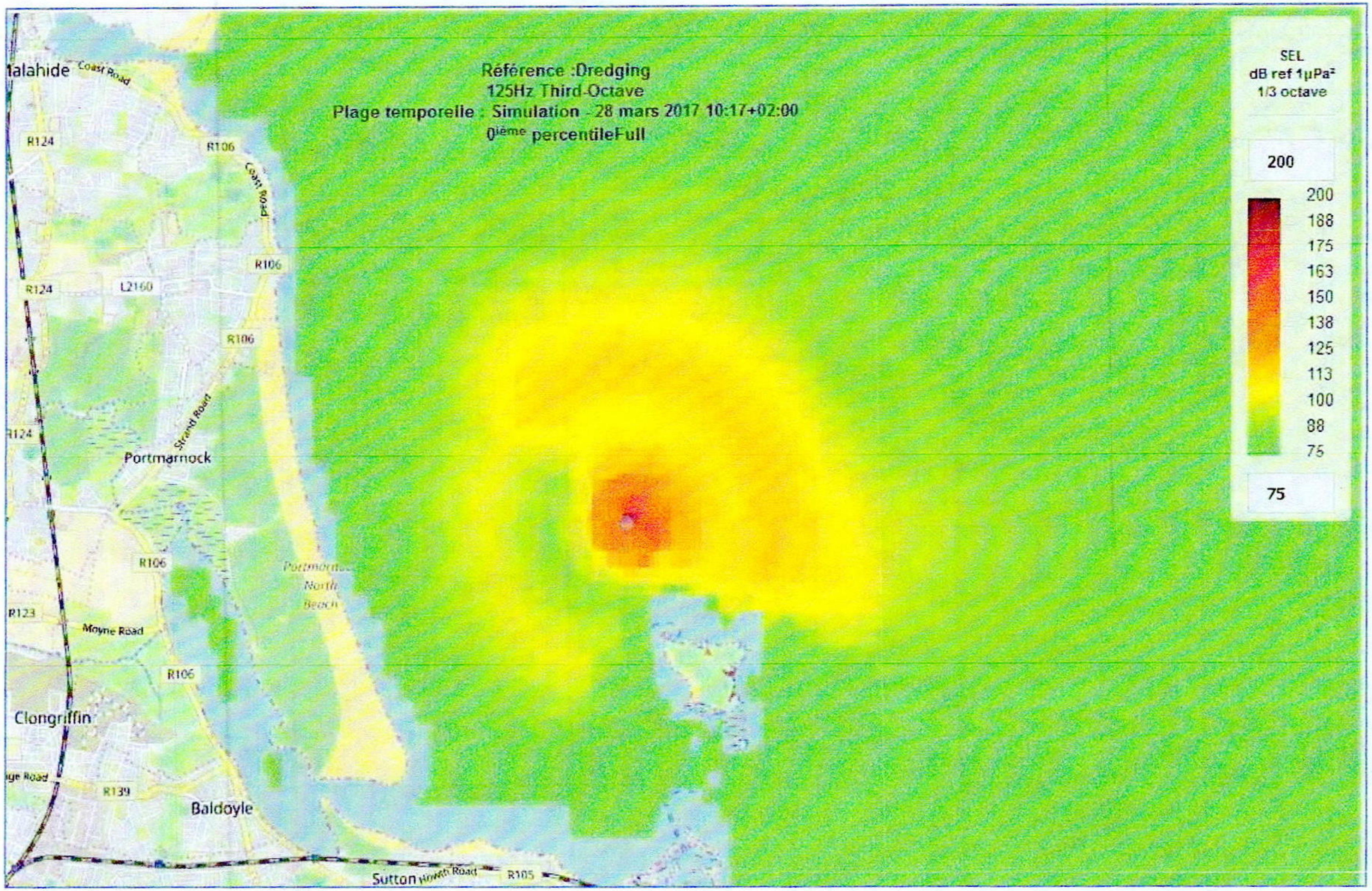
V.4. Selection of noise maps

This section gives a non-exhaustive overview of the noise maps for dredging. The maps reported hereafter are the 0th percentile (maximum levels) for the full water column for the 125 Hz, 1kHz and 8 kHz third-octave bands.

V.5. Dredging noise maps

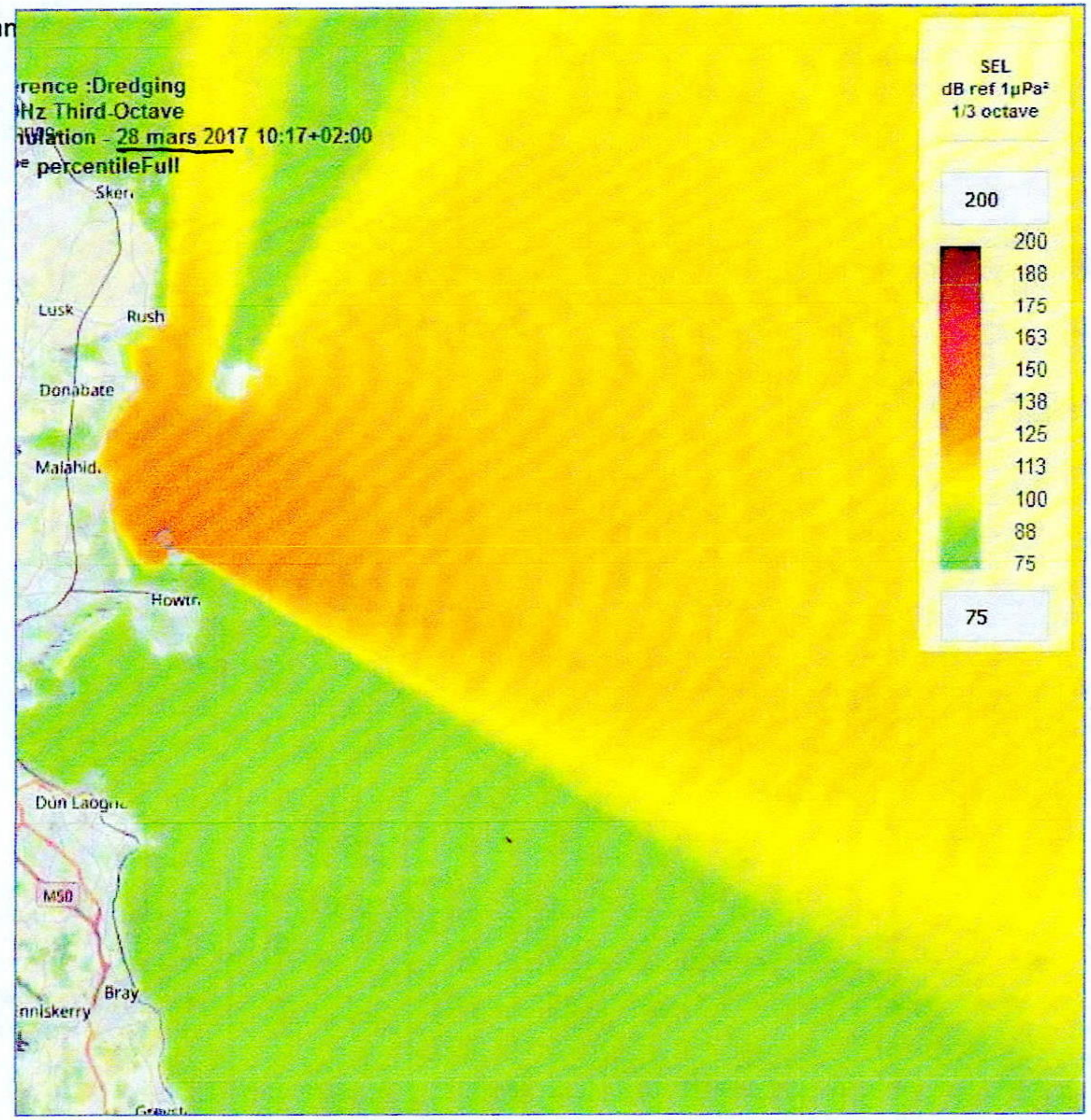
0th
Q1

Maximum levels at 125 Hz 1/3 octave band



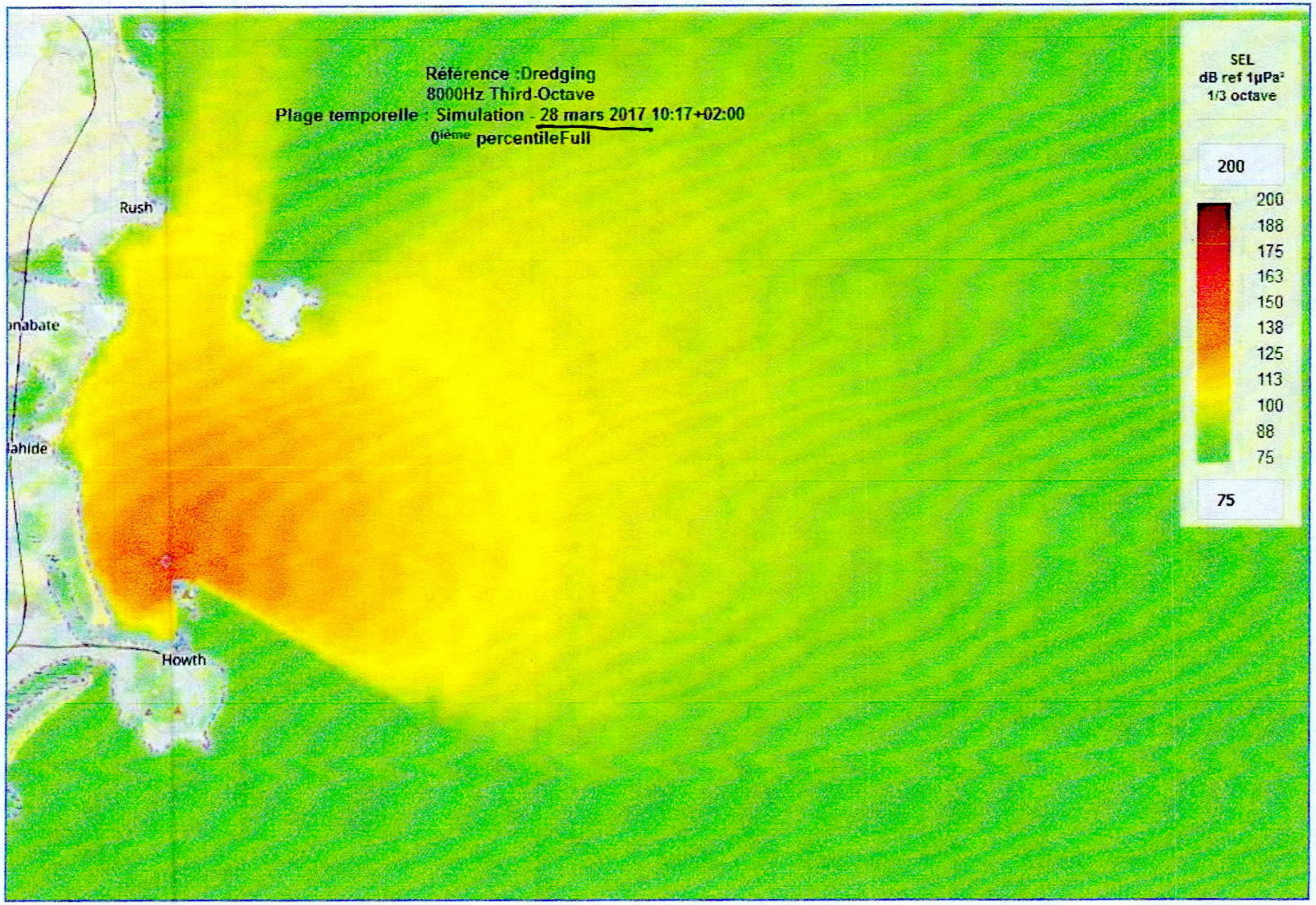
Maximum levels at 1kHz 1/3 octave ban

0% percentile



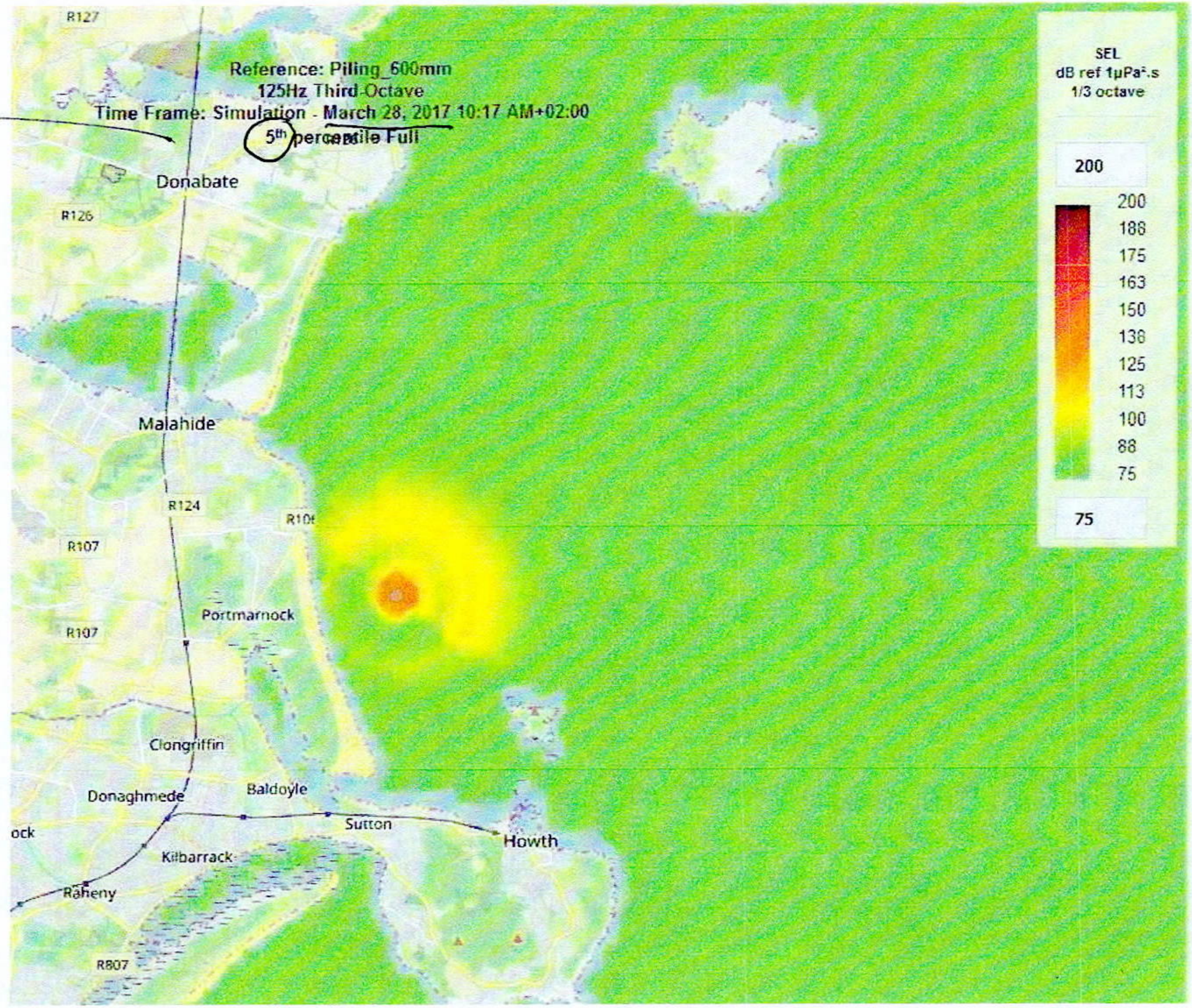
0/15

Maximum levels at 8kHz 1/3 octave band



V.6. Piling noise maps

5th



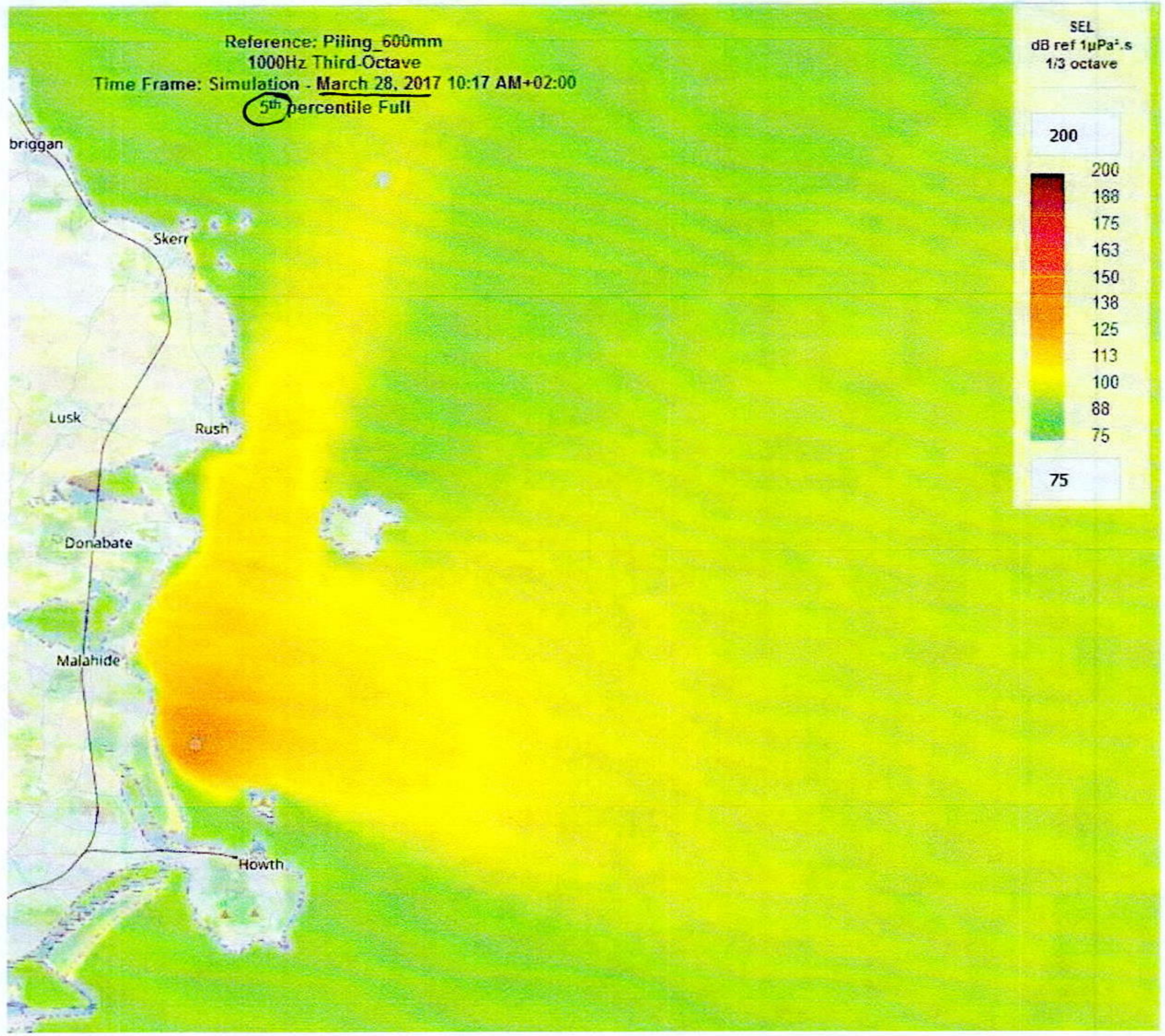
0th Percentile

5th ?

Piling 600mm diameter Maximum 1sec SEL levels at 125 Hz 1/3 octave band

Why located here?

Maximum 1sec SEL levels at 1kHz 1/3 octave band



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Report overview and conclusions

The following sections are the comments and conclusions drawn by TechWorks Marine in review of the reports above.

Location details

The report utilises data from The European Marine Observation and Data Network (*EMODnet*) as the source for the bathymetry. This data was utilised in the models and the sediment types were also gained from this model. The anthropogenic activity in the area was demonstrated from the overview of AIS data. However the AIS data from the specific location during the deployment period was unfortunately not available. *?*

Equipment and methodology

A single icListen recorder was deployed on a line below a buoy near Ireland's Eye at 53°24.901'N 006°2.978'W. It was operating continuously from July 30 to September 1. The recording duty cycle was configured with 15 minutes on and 50 minutes off. The hydrophone sensitivity taken from the stored wav files was -168 dB re 1 V/ µPa. The data was sampled at 16 kHz in 24 bits; the quantization was between +-3V. No gain was used. *1–31 Aug.*

not for piling

The data collected was then used to produce maps at 125Hz, 1kHz and 8kHz third-octaves. The Marine Strategy Framework Directive (MSFD) standardises the use of third octave bands.

Recordings and soundscape

As the description of an area as being noisy or quiet can quickly become contentious depending on the parameters being measured it is not possible to definitively categorise this area in this way from the results of the report.

However, while the data in the report only represents a month long 'snapshot' of the area the only noises picked up by the recorder were mooring noises and environmental. While further recordings and modelling would allow for modelling during different seasons, greater assessment of marine mammal presence, MSFD sound level indicators etc. the report shows the propagation characteristics of the area in the range of frequencies that were measured and can be expected from dredging. *What about piling?*

Thought the location cannot be called "quiet". The levels were not different than what could be expected at a location like this.

The bathymetry of the location is fairly flat and shallow towards the coast and demonstrates quick absorption. Looking at the radiation of noise into the deeper water the modelling shows that low frequencies are absorbed quickly and close to the source. Higher frequencies propagate out, but with source levels close to 190 dB the received level drops below 160 dB within a kilometre.

This noise level can have an effect on marine mammals at a range of 1km. It would therefore be recommended that dredging or pile driving does not commence if marine mammals are sighted within this distance. The use of a marine mammal observer (MMO) on board is also recommended.

However, it is also worth noting that the recordings collected did not contain any cetacean vocalisations. This may be due to several factors. The depth of the recording area was quite shallow which reduced the effective detection range. Therefore, we can only specifically state that no cetaceans were present for that month inside the detection zone. Additionally, due to the range of the recording device it is also only possible to state that no cetaceans were present that were vocalising under 8 kHz within range of the recorder; though this does not mean no cetaceans were present.

04 Foreshore licence
app. version.
Update ?

Modeling Dredging & Piling Noise Offshore Dublin

Brief Technical Report

APP. 2

Identification	
Document reference	QO.20170329.01.RAP.001.04A
Beneficiary	TechWorks Marine
Customer	Laboratori d'Aplicacions Bioacústiques
Contract number	N/A

PROJET	DOC	CHRONO	VER	IND	CLIENT	ACRO	DATE	TYPE	CLASS
QO.20170329.01	RAP	001	04	A	LAB	GDD	29.03.2017	PROD	DR

Quiet oceans

Ocean Noise Forecasting Monitoring & Mitigation

Document history					
Version	Ind.	Authorship	Date	Released	Description
04	**A**	T. Folegot	20.04.2018	20.04.2018	Integration of LAB comments
03	**A**	T. Folegot	16.03.2018	16.03.2018	Integration of beneficiary comments –Correction of Dedging source level correction
02	**A**	T. Folegot	26.07.2017	28.07.2017	Add piling scenario and important disclaimer
01	**A**	T. Folegot	29.03.2017	30.03.2017	Initial version

Citation

T. Folegot (2017), Modeling Dredging & Piling Noise Offshore Dublin, Brief Technical Report, Quiet-Oceans, QO.20170329.01.RAP.001.04A

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Table of content

Terms and definitions

This section defines the technical terms used in the report.

1/3rd-octave frequency band

A frequency band with one third of an octave bandwidth. One octave is a doubling of frequency, whereas one third of an octave is a frequency ratio of 21/3 ≈ 1.26 between the highest and the lowest. [1] [2]

Bandwidth

The frequency range within which a recording system is sensitive. The frequency range (in Hertz) is obtained by subtracting the lower from the upper cut-off frequency.

Broadband level

The sound pressure level obtained over a wide frequency range with defined bandwidth.

Center frequency

The geometric mean of the lower and upper cut-off frequencies. Please note that the intensities should be averaged before converted into decibels.

Sound

The term "sound" is used to refer to the acoustic energy radiated from a vibrating object, with no particular reference for its function or potential effect. "Sounds" include both meaningful signals and "noise" (defined below), which may have either no particular impact or may have a range of adverse effects.

Noise

Noise is in direct contrast to signals, but always depending on the receiver and the context. What one receiver considers noise may be a signal to another receiver and even for the same receiver can the exact same sound be either signal or noise, depending on context.

"Noise" can be used in a more restrictive sense where adverse effects of sound are specifically described or when referring to specific technical distinctions such as "masking noise" or "ambient noise".

Ambient noise

That part of the total noise background observed with a non-directional hydrophone, which is not due to the hydrophone and its manner of mounting (self-noise), or to some identifiable localized source of noise.

Environmental background noise not of direct interest during a measurement or observation; may be from sources near and far, distributed and discrete, but excludes sounds produced by measurement equipment, such as cable flutter.

For a specified signal, all sound in the absence of that signal except that resulting from the deployment, operation or recovery of the recording equipment and its associated platform.

Natural ambient noise

Ambient noise in the absence of any contribution from anthropogenic sources.

Continuous sound

Imprecise term meaning a sound for which the mean square sound pressure is approximately independent of averaging time.

A sound with no clear definable beginning or end with no bandwidth restrictions and a large time bandwidth product when the frequency range is broadband. Continuous sounds have finite power, but may have infinite or at least undefined energy.

Sound pressure

The difference between instantaneous total pressure and pressure that would exist in the absence of sound. Instantaneous pressure at time t.

p(t) in [Pa]

Reference pressure

1 µPa in underwater acoustics. p_0 in [Pa]

Sound exposure

The integral of the square of the sound pressure over a stated time interval or event.

E in [µPa²s], $E = \int_0^T p(t)^2\, dt$, with T being the time period of the event of interest.

Sound Pressure Level

SPL in [dB re 1 µPa]

$$SPL = 10 \cdot log_{10} \frac{1/T \int_0^T p(t)^2 dt}{p_0^2} = 10 \cdot log_{10} \left(\frac{p_{rms}}{p_0}\right)^2 = 20 \cdot log_{10} \left(\frac{p_{rms}}{p_0}\right)$$

with T = integration time.

Sound Exposure Level

SEL in [dB re 1 µPa²s]

$$SEL = 10 \cdot log_{10} \left(\frac{E}{p_0^2\, T_0}\right) = SPL + 10 log_{10}(T)$$

With reference time T_0 = 1 s

With T being the time period of the event of interest in seconds.

Percentile level

A percentile corresponds to the proportion of time and space for which the noise exceeds a given level. This concept is widespread even in everyday life. For example, the average income of the top 10% of income earners or the "income threshold corresponding to the 90th or to the 95th percentile", i.e. the income earned by the poorest individual among the top 10% or top 5% richest individuals. Meanwhile, the 50th percentile corresponds to the median salary. For underwater noise, the percentile, or exceedance level, is meant to describe the noise level occurring at least.

In the context of underwater noise, it is defined as the level L_N that is exceeded for N percent of the time interval considered. For example, L_1 is the level that is exceeded 1% of the time. This is accomplished by (1) ordering all measured levels in the time interval numerically in descending order and (2) and picking the value 1% of the rows below the top of this ordered list. Both steps can be done together in Matlab with the quantile or prctile function (available in the Statistics Toolbox).

The L_1 is a measure for the maximum level. It is a more robust estimate than taking just the maximum observed level, since the latter may be an outlier caused by a single event, such as rattling of the anchoring system or other types of self-noise. Accordingly, L99 and L95 are used to describe the minimum level. L_{50} is the median level.

Chapitre I. Context and objectives

I.1. Context

As part of a data processing contract Techworks Marine has asked the Laboratori d'Aplicacions Bioacústiques to include noise level maps for pile driving and dredging operations. Quiet-Oceans has been asked to provide the propagation modelling for a few selected frequencies of interest.

I.2. Project information

The outfall pipeline consists of two elements, a tunnel section running from the Coast Road to approx. 500m off the beach, and a dredged section from this interface point to the final outfall point. The tunnel section will be constructed using a micro-tunnelling machine.

The dredged section will be constructed using Back Hoe Dredgers (BHD) and Trailer Suction Hopper Dredgers (TSHD) with the BHD working from the inshore outwards and the TSHD working from the Outfall point towards the inshore.

The dredging operation includes an excavation phase with material either side cast or placed in barrages for deposition a short distance away from the trench, and a backfilling phase where the excavated material will be replaced over the installed pipe.

I.3. Objectives and Scope of Work

Quiet-Oceans expert team was not involved in the definition of the Scope Of Work (SOW).

This work is solely meant to provide an indication of the noise propagation properties in the underwater environment where the construction will take place, taking into account the sources of interest, and does not constitute a noise impact assessment. No calibrated source recordings were available to evaluate the modelling results.

When there is interest in a noise impact study the internationally agreed methodology to assess the noise risks towards the marine species consist in the following steps [3] [9] :

- Baseline broadband mapping of the existing noise;
- Broadband calculation of the exceedance level of each individual project activities above the baseline (noise footprint calculation [10]);
- Perceived levels in the bandwidth of sensitivity for the species potentially exposed to the noise of the project (high frequency cetaceans, mid frequency cetaceans, high frequency cetaceans, pinnipeds, 3 categories of fish (with/without swim bladders, with/without sensitive cells), sea turtles and larvae;
- PTS, TTS, behavioural and masking risk areas mapping based on the perceived levels for each class of species.

Since noise impact study **was not the interest mentioned in the Scope Of Work provided to Quiet-Oceans,** a few specific frequencies for propagation modelling have been requested by the Laboratori d'Aplicacions Bioacústiques:

- to map the noise propagation of the dredging activity at one specific position for three frequencies: 125Hz, 1kHz and 8kHz third-octaves for a single environmental condition corresponding to a March situation;
- to map the noise from one piling activity at one specific position for two frequencies: : 125Hz and 1kHz third-octaves for a single environmental condition corresponding to a March situation.

Therefore, this report is limited a brief technical description, briefly explaining the modelling assumptions and giving a limited number if illustrations of the noise maps produced. Raw data of the modelled maps have been delivered jointly to the report for further exploitation.

Chapitre II. Introduction to Quonops©

Quiet-Oceans operates since 2010 the proprietary Quonops© ocean noise-monitoring and prediction system developed and owned by the company and protected by an international patent [3] . In a similar manner to weather forecasting systems, Quonops© produces an estimate of the spatio-temporal distribution of noise levels generated by human activities at sea, aggregating multiple sources, and assessing short-, mid- and long term source contributions to the global noise field (Figure 1). As demonstrated in a number of international projects, Quonops© caters for a broad range of maritime activities, including:

- maritime traffic [3] [6] ;
- oil exploration [7] ;
- underwater warfare exercises;
- offshore construction [8] ;
- fossil-fuel extraction;
- offshore wind-power construction and operations [9] ;
- underwater drilling and blasting operations.

Based on physical acoustic propagation models, Quonops© considers the reality of the area through input data and has been largely validated through in-situ measurements over the last 6 years.

The outputs from Quonops© are tailored to the requirements of existing and emerging national and international regulations regarding underwater noise, the conservation of habitats and marine ecosystems, and the protection of marine species [10] .

The production of statistical soundscapes effectively characterizes the spatio-temporal emergence of anthropogenic noise from the real environmental conditions of the area. The system also supports underwater noise impact assessments and assists in the formulation of optimized planning and focused mitigation of maritime industrial activities in terms of environmental compliance. Quonops© brings together relevant information and data into a noise prediction platform to deliver a series of services, such as:

- the geo-referenced mapping of statistical, historical or real-time human and environmental situation of the areas of interest,
- the geo-referenced mapping of noise pollution according to given ocean-meteorological and human scenarios.

Such a tool aims to support management decisions by assessing, quantifying and prioritizing direct and indirect anthropogenic pressures on marine life, according to the emerging national and international regulations on underwater noise, especially the descriptor 11 of the European Marine Strategy Framework Directive [11] .

Quonops© is able to provide:

- real-time regional survey of shipping noise and natural noise from waves;
- historical statistical regional noise maps at a daily, weekly, quarterly and/or annual resolution;
- noise maps of single or multiple customized noise sources through a large selection of maritime activities.

Figure 1 : Principle of Quonos©, Quiet-Oceans' underwater noise prediction and monitoring system.

Chapitre III. General principles of noise mapping

The noise received at a particular position in the marine environment depends on the characteristics of the sound source(s) and the propagation through the marine environment (Figure 2). Noise propagation and therefore noise levels are mainly determined by the following (Table 2):

- ✓ Bathymetry (underwater terrain);
- ✓ The nature of the seabed (sediment type);
- ✓ Oceanographic conditions such as temperature and salinity, currents, sea level;
- ✓ Weather conditions such as the wind (and consequently waves) and rainfall intensity.

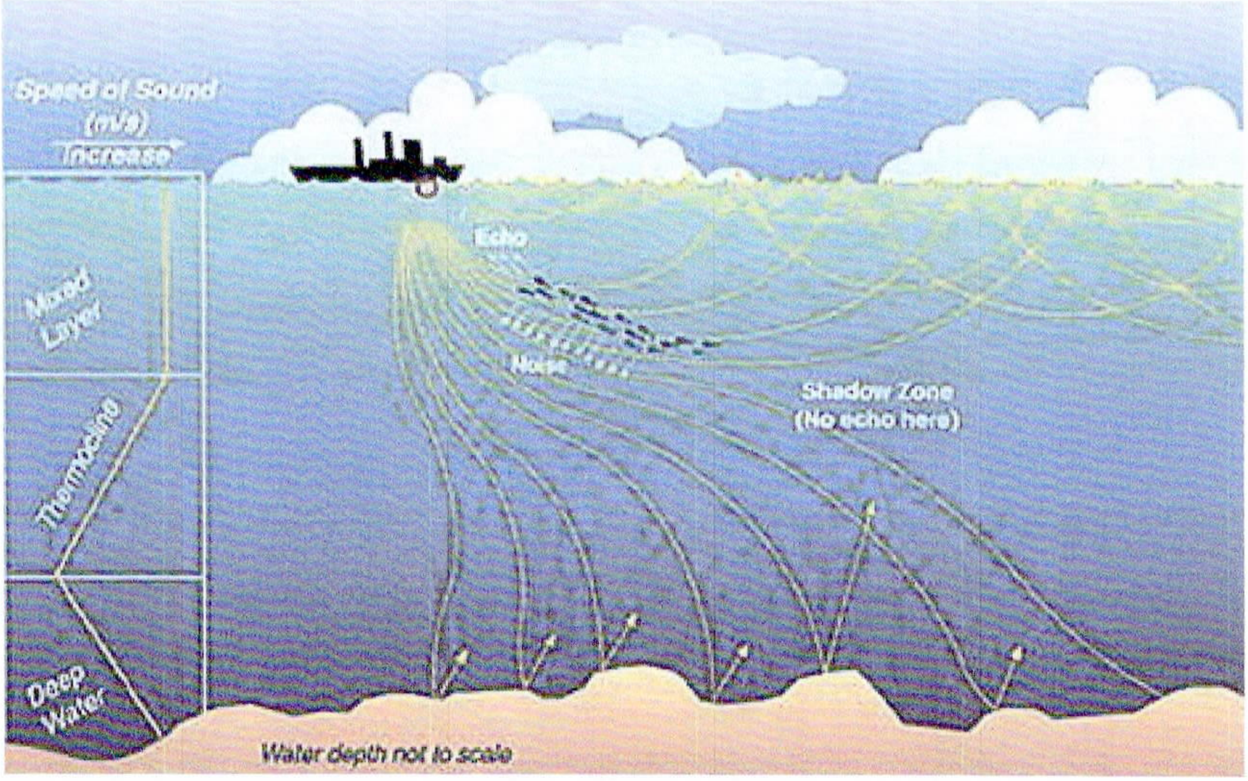


Figure 2: In the warm upper layer of the ocean, sound is refracted toward the surface. As sound waves travel deeper into colder water, they slow down and are refracted towards the seafloor, creating a shadow zone. Image courtesy of the National Academy of Sciences. Source: www.dosits.org.

III.1. Key ocean variables affecting sound propagation

Sound propagation losses increase as water depth lessens, and this is a cumulative loss effect which applies to shoaling caused by bathymetry and tidal fluctuations together. The effect is linked to the interaction of sound waves with the interfaces of the oceanic waveguide (surface and seabed). Furthermore, it should be noted that ocean waves (waves at the sea surface) tend to surge as they encounter shallower water, which increases their contribution to the ambient noise.

Propagation losses are more significant when the seabed is loose and fine-grained (i.e. silt absorbs sound waves better than gravel). However, the denser the sediment, the more reverberant it is; sound waves with significant angles of incidence on sediment are better reflected when the sediment is dense.

Wind generated ocean-surface waves propagate and absorb sound waves, an effect that increases with increasing sea-state. However, the noise generated by surging waves also increases the level of ambient noise. In other words, rough seas increase natural noise levels, but other noise sources do not carry as far as they would in calm conditions.

In shallow water, sedimentary particles are mobilized by currents and/or waves, and noise is generated when sedimentary particles collide with each other. The coarser the sediment and faster the speed of sound in the sediment, the higher the noise level.

Rainfall exerts a negligible effect on underwater sound propagation; however the sound generated by droplets falling on the sea surface does contribute to an increase in natural noise levels.

Table 1: Effect of physical properties of the ocean environment on acoustic propagation and noise generation.

	Influence noise propagation	Generate noise and contribute to ambient noise
Bathymetry	✓	✗
Bottom parameters	✓	✓
Temperature/salinity	✓	✗
Sea level	✓	✗
Currents	✗	✓
Wind/waves	✓	✓
Rain	✗	✓

✓ indicates that the effect exists   ✗ indicates that the effect does not exist or is marginal.

III.2. Underwater noise modelling

Underwater modelling benefits from more than 50 years of scientific and operational development for military purposes, ranging from basic propagation modelling to more sophisticated sonar performance modelling. The military research in the field of experimental ocean acoustics has involved extensive equipment, with typically at least one ship and often an assortment of at-sea platforms equipped with sound projectors and receiving arrays. The objective of this research was to incorporate the acoustic propagation phenomena into a theoretical and numerical formalism, which gives a quantitative prediction of the sound field for arbitrary ocean environments. The progress in the field of numerical computing has largely contributed to the development of the modelling capability.

There are essentially five types of models (computer solutions to the wave equation) to describe sound propagation in the sea: spectral, normal mode, ray, and parabolic equation models, and direct finite-difference, or finite-element solutions of the full wave equation. All these models permit the ocean environment to vary with depth. Models also permit horizontal variations in the environment, i.e., slopping bottom or spatially variable oceanography [13] .

The acoustic models accurately reflect the propagation of noise in the water column in realistic oceanographic conditions by resolving the Helmholtz Equation, the State Equation:

$$\Delta p - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = \delta(t - t_0, r - r_0)$$

$$\rho c^2 = p \quad \rho_0 \frac{\partial \vec{v}}{\partial t} + \vec{\nabla} p = 0$$

$$j2\pi f \rho_0 \vec{v} + \vec{\nabla} p = 0$$

where p is the acoustic pressure, c is the sound speed in the medium (water or sediment), t is time, t_0 the instant of emission of the signal, and r the three-dimensional position of observation and r_0 the three-dimensional position of the source, assumed to be punctual.

III.2.1. Modelling bellow 2kHz

For frequencies bellow 2kHz, we have used state-of-the-art parabolic equation [14] [15] [16] [17] . Developed before World War II, and widely used in many areas of physics, parabolic equation methods are based on fast Fourier transforms. It has become the most popular wave-theory technique for solving range dependent problems in ocean acoustics. It consists in a parabolic approximation of the Helmholtz equation into an elliptic wave equation. We have used the model developed by Collins et al. which is among the state-of-the-art parabolic equation implementation which especially solves the equation for elastic media, such as the marine environment.

III.2.2. Modelling above 2kHz

For frequencies above 2 kHz, we have used an energy distribution to Gaussian beams approach to limit calculation times. Used since the early 1960's, the ray modelling is based on a high frequency approximation. Ray methods are still used extensively in operational environment where speed is critical and where the environmental uncertainties pose more constraints on the accuracy. Quonops© use Bellhop [18] which is among the state-of-the-art ray tracing codes which handles Gaussian ray bundles to somewhat overcome the high frequency approximation.

Table 2: Validation of Quonops through in-situ acoustic measurements in a very large number of different marine environments and projects.

Project Name	Year	Area	Type of noise	Effort	Partners
ERATO	2011	Atlantic Ocean	Shipping and natural	6 hydrophones, 24 hours	French Hydrographic Office (France)
STRIVE	2011	Irish seas	Shipping and natural	1 hydrophone, 21 days	Environmental Protection Agency, Cork University (Ireland)
AQUO	2013-2015	Mediterranean Sea	Shipping and natural	1 hydrophone, 9 months	Laboratory of Bioacoustics Applications, Barcelona (Spain)
AQUO	2013-2015	North-sea	Shipping	Cross-models validation	TNO (Netherland), FOI (Sweden), Leiden university (Netherland)
MaRVEN	2013 - 2015	North-sea	Piling noise & Windfarm operation	2 hydrophones	DHI (Denmark), Royal Belgian Institute of Natural Sciences (Belgium), European Commission
NRL	2013-2014	Indian Ocean	Shipping and natural	2 hydrophones, 7 months	Biotope (La Réunion)
FEC-COU	2013	English Channel	Shipping and natural	4 hydrophones, 20 days	EMF, EDF, WPD (France)
SNA	2013	Atlantic Ocean	Shipping and natural	3 hydrophones, 20 days	EMF, EDF, WPD (France)
BENTHOSCOPE	2015	English Channel	Tidal device in operation	1 hydrophone, 1 day	Marine Energy France (France)
POSTE H	2013	Indian Ocean	Vibrodriving Shipping and natural	2 hydrophones	Biotope (La Réunion)
ETM	2014	Caribbean	Shipping and natural	1 hydrophone, 30 days	AKUO (France)
JETSKI	2014	Atlantic Ocean	Watercraft	1 hydrophone	Marine Protected Area (France)
PORTIER	2014 2016	Mediterranean Sea	Shipping and natural	2 hydrophones, 5 months	BYTP (France)
EMDT	2015-2016	English Channel	Shipping and natural	4 hydrophones, 12 months	ENGIE (France)
EMYN	2015-2016	Atlantic Ocean	Shipping and natural	4 hydrophones, 12 months	ENGIE (France)
GOEMONIER	2016	Atlantic Ocean	Fishing device	1 hydrophone	Marine Protected Area (France)

III.3. Calibration of the maps

It is essential to bear in mind that no underwater noise measurements made with hydrophones have been used to calibrate the noise maps. An active acoustic calibration measurement is strongly recommended. ?

Chapitre IV. Input data and assumptions

The data used to perform the modelling describes:

- the bathymetry of the area provided by EMODNet [20] and illustrated in Figure 3;
- the coast line of the area provided by [21] ;
- the sediment provided by EMODNet [20] ; The original sediment data has a spatial resolution of 1/40°. The EMODnet database classifies the sediments into 6 categories:
  - ✓ Boulders & bedrock;
  - ✓ Till/diamincton;
  - ✓ Coarse-grained sediment;
  - ✓ Mixed sediment;
  - ✓ Muddy sand and sand;
  - ✓ Mud and sandy mud.

  The geo-acoustic parameters used in the acoustic model as boundary conditions are reported in Table 4. Since the sediments being assumed to be fluid-elastic, the geo-acoustic parameters are limited to density (in ton per m3), compressional speed (m/s) and compressional attenuation (in dB/λ, λ being the acoustic wavelength) as illustrated in Figure 4. Shear waves propagating in solid materials are neglected. ?
- the sound speed derived from temperature and salinity of the sea water provided by the Copernicus Marine Environment Monitoring Service (CMEMS) which provides regular and systematic reference information on the physical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas. The Mackenzie equation (1981) has been used to derive temperature and salinity into sound speed (Figure 5):

$$c(D,S,T) = 1448.96 + 4.591T - 5.304 \times 10^{-2}T^2 + 2.374 \times 10^{-4}T^3 + 1.340\,(S-35) + 1.630 \times 10^{-2}D + 1.675 \times 10^{-7}D^2 - 1.025 \times 10^{-2}T(S-35) - 7.139 \times 10^{-13}TD^3$$

  In which T is the temperature in degrees Celsius, S is the salinity in parts per thousand, and D is the depth in meters. The range of validity: temperature 2 to 30 °C, salinity 25 to 40 parts per thousand, depth 0 to 8000 m.
- the sea-state or sea surface roughness provided by the Wave Watch 3 model.

The type and source of data used is summarized in Table 3. The background noise is set using the Wenz model [22] for natural noise derived from the surface roughness of the sea in the area.

Table 3 : Summary of the input data used for the modelling

Data Type	Provider	Coverage	Spatial resolution
Bathymetry	EMODNet	European seas	7.5"
Coast line	Open Street Map	World	-
Sediment	EMODNET	European seas	7.5"
Temperature	Copernicus Ocean	World	5'
Salinity	Copernicus Ocean	World	5'
Surface roughness	Wave Watch 3	World	30'

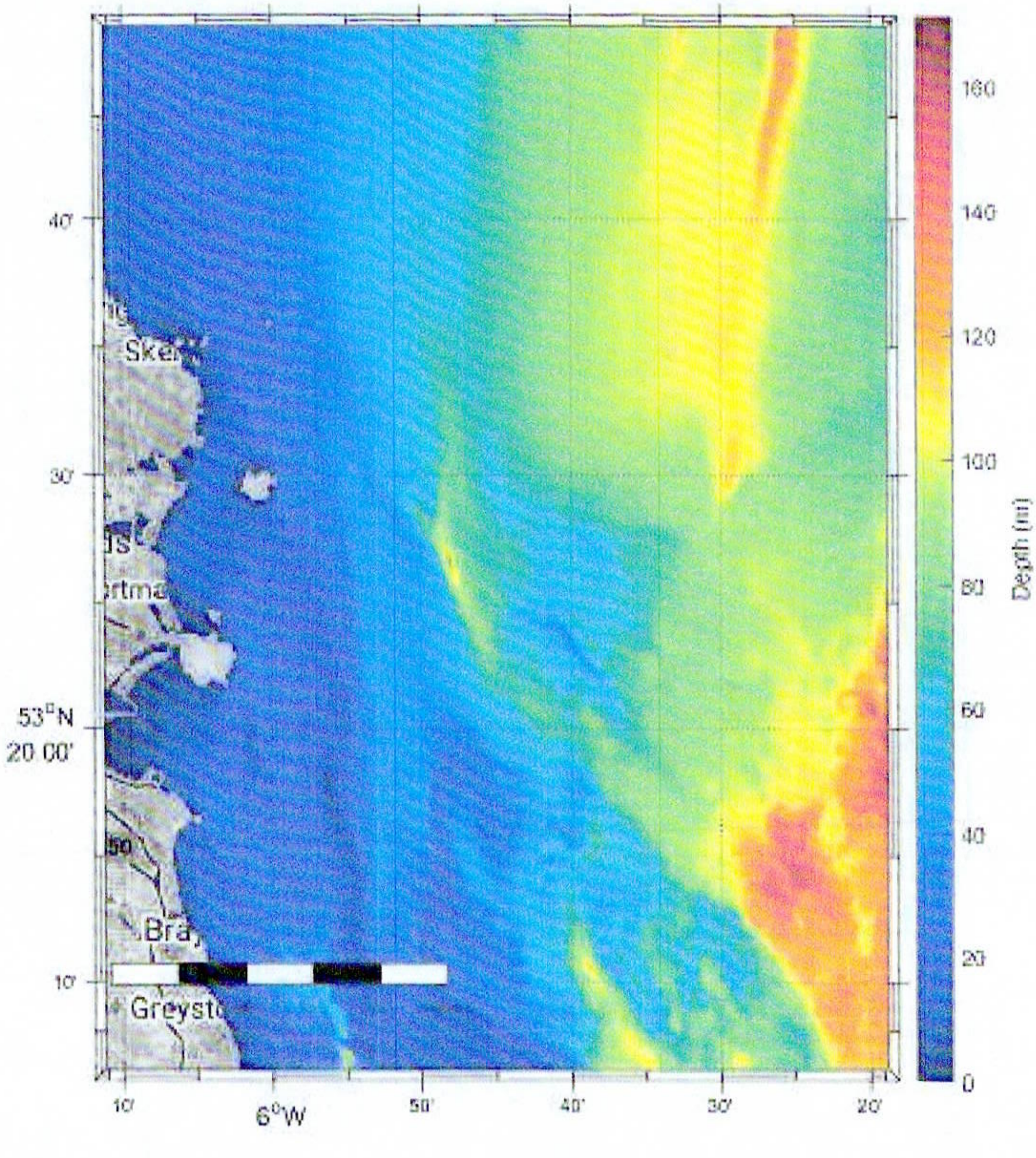


Figure 3: Bathymetric map used for modelling offshore Dublin extracted from [20]

Figure 4: Distribution of values of compressional attenuation of sound (left), compressional sound speed (middle), and density (right) of the sediment provided by [20] .

Table 4: Bottom characteristics used for modelling.

Sediment Name	Density Ton/m3		Compressional Speed m/s		Compressional Attenuation dB/lambda	
	Mean	Uncertainty	Mean	Uncertainty	Mean	Uncertainty
Boulders & bedrock	2,50	0,08	3 820	23	0,75	0,04
Till/diamincton	2,50	0,08	2 750	23	0,75	0,04
Coarse-grained sediment	2,37	0,10	2 122	315	0,88	0,07
Mixed sediment	2,03	0,26	1 855	79	0,89	0,01
Muddy sand and sand	1,53	0,22	1708	70	0,91	0,06
Mud and sandy mud	1,16	0,03	1517	32	0,37	0,41

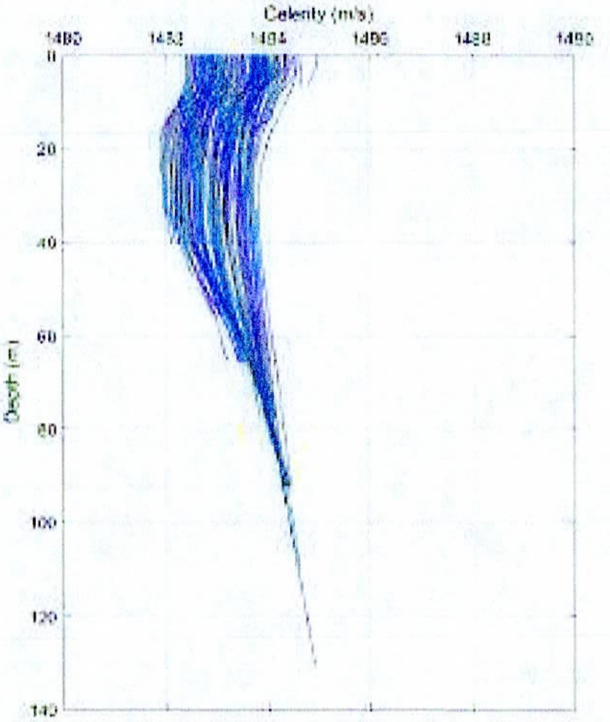


Figure 5: Sound speed profiles in the area the 17[th] of March 2017 provided by CMEMS.

IV.1. Noise introduced in the marine environment from dredging

The Scope of Work describe a dredged section using Back Hoe Dredgers (BHD) and Trailer Suction Hopper Dredgers (TSHD) with the BHD working from the inshore outwards and the TSHD working from the Outfall point towards the inshore. For modelling, the Scope of Work has requested to consider as sources a Trailing Suction Hopper Dredger (TSHD) (see illustration Figure 6).

The location for modelling is at 53.4169° latitude and -6.075° longitude, offshore Dublin, which correspond to the far end of the dredging track length (about 4 km offshore). The physical geometry of the sound source is modelled as two points of generation: 50% of the generated energy is at 6m depth to describe the noise from the vessel, and 50% of the energy is located close to the bottom to describe the noise generated by the suction pipe.

Is this correct activity ?

The activity selected for the modelling is the flattening and removal of rocks. The wideband source level is derived from [24] and [25] and estimated at 188 dB ref 1µPa in the 50Hz to 89 kHz. Detailed source levels for the frequencies modelled are reported in Table 5.

Table 5 : Source levels used for modelling the dredging activities

Source level dB ref1µPa²@1m	Sound Pressure Level in the 125Hz 1/3 octave	Sound Pressure Level in the 1kHz 1/3 octave	Sound Pressure Level in the 8kHz 1/3 octave
TSHD	175.5	173.4	172.2

Figure 6 : Illustratio of a Trailing Suction Hopper Dredger (TSHD)) (vessel name: Bartolomeu Dias)
Source : Jan De Nul

IV.2. Noise introduced in the marine environment from piling

We will consider as sources the piling of 600mm piles using an impact hammer (see illustration).

The location for modelling the piling is at 53.42466° latitude and -6.098955° longitude, offshore Dublin. During a piing phase, the sounds generated are impulsive. In order to translate the potential impacts more accurately, the scientific community (NOAA, 2016) now agrees to quantify the level as Sound Exposure Level (SEL), expressed in dB 1µPa².s). The sound exposure energy corresponds to the acoustic energy received at a point, integrated over a given frequency band and over the significant duration of the sound pulse (Ti). In this study, Ti is chosen to be 100ms, according to the literature (De Jong, et al., 2008), for example.

Earlier modeling and measurement research programs have shown that the level of sound exposure in water increases logarithmically as a function of the diameter of the pile, which makes it possible to extrapolate with confidence measurements reported in the literature. The source levels used in the modeling study are derived from measurement taken at the Q7 and OWEZ construction projects (De Jong et al., 2008), Beatrice (Talisman Energy et al., 2004) and Horns Rev II (ITAP, 2008).

The piling source is modelled using an ensemble of four punctual sources. 40% f the total energy is at the bottom end of the pile, while 60% of the energy is equally distributed along the pile. Detailed source levels for the frequencies modelled are reported in Table 6.

Table 6 : Source levels used for modelling the piling activities

Source level dB ref1µPa²@1m	Sound Pressure Level in the 125Hz 1/3 octave	Sound Pressure Level in the 1kHz 1/3 octave	Sound Pressure Level in the 8kHz 1/3 octave
600mm diameter pile driving Per stroke	186 dB ref1µPa²@1m	172 dB ref1µPa²@1m	Not modelled as requested in the Scope of Work

Chapitre V. Noise maps produced

V.1. Important disclaimers

Maps have been produced at 125Hz, 1kHz and 8kHz third-octaves (for dredging). Therefore, the levels obtained **cannot** be directly compared to cetaceans' nor seals' PTS or TTS thresholds, since the thresholds are valid for the total energy contained in the audibility band of the species (NOAA, 2016), which is much larger than a third-octave band. To be able to compare and estimate a risk area, modelling should be performed for the full audibility band of each species, which has not been required by the costumer. For example, the source level in the auditory band of seals for a single-stroke piling of a 600mm diameter pile is 178 dB ref1µPa²@1m, while the source level in the 1kHz third-octave band is only 172 dB ref1µPa²@1m, which makes a significant difference.

The maps are purely modelling maps using the best known description of the environment. Usually, an acoustic calibration measurement is needed to ground truth the maps and reduce uncertainties.

V.2. Summary of maps produced

For each scenario (dredging and piling), a total of 21 maps have been produced and delivered in a NetCdf Format. The noise maps correspond to:

- March 2017 environmental context;
- The full water column;
- Three third-octave bands, centred at 125 Hz, 1kHz and 8 kHz (only for dredging) as required by the costumer ;
- Seven percentiles, 0^{th} (maximum), 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 100^{th} (minimum) percentiles to characterise the variability of the sound field with depth;
- Three depth ranges (Surface to -15m, 30m to the bottom, and the full water column).

V.3. Delivery

Quiet-Oceans has delivered noise ambient maps in NetCDF format version 4. Files format respect principals rules of NetCdf Climate and Forecast (CF) Metadata Conventions release 1 [23] .The NetCdf provided is described by :

- global attributes : attributes used for context, history or versioning file ;
- dimensions : scalar data that describes dimensions for the variables contained in file ;
- variables : vectors or matrix that describes the data.

The following sections detail the content of the delivered data.

V.3.1. File name

Files are named as follow: Dredging_DublinNorth_20170330.nc for the dredging scenario and Piling_600mm_DublinNorth_20170728.nc for the piling scenario.

why these dates ?

V.3.2. Dimensions

The dimensions of the variables contained in the delivered Netcdf are detailed in Table 7.

Table 7: Summary of the dimensions of the variables contained in the delivered Netcdf files.

Group	Name	Value	Statut (Mandatory, Optionnal)
AcousticData	Lat	number of latitudes, configuration dependent	M
	Lon	number of longitudes, configuration dependent	M
	frequency	number of frequency	O
	percentile	number of percentiles, configuration dependent	M
	Layer	Number of immersion layers	M
	maxLayerNameLen	Max length of layer names	M

V.3.3. Variables

A variable can be associated with attributes. When CF conventions describes it, standard attributes are mentioned:

- ✓ standard_name : name for variable according to CF conventions
- ✓ long_name : description for variable according to CF conventions
- ✓ units : : units according to UD Units Unidata dictionnary
- ✓ valid_min : minimal value for data validation
- ✓ valid_max : maximal value for data validation

For geographic reference, SPL is linked to a coordinate reference system (CRS) which defines all the parameters attached to a mapping projection :

- ✓ grid_mapping_name : naming of projection as defined in conventions (Appendix F. Grid Mappings). In our case, latitute_longitude is equivalent to geodesic projection in which coordinates positions are latitude and longitude,
- ✓ epsg_code : EPSG code (4326) for correspondant geodesic projection with WGS84 ellipsoid
- ✓ longitude_of_prime_meridian : longitude of prime meridian in geodesic projection
- ✓ semi_major_axis : half the major axis of the ellipsoid linked to the projection
- ✓ inverse_flattening : 1/flattening of the ellipsoid linked to the projection

Table 8: Description of the variables of the Netcdf delivered.

Name	Dimensions	Datatype	Statut (Mandatory/ Optionnal)	Attributes		Description
layer	Layer	int8	M	Standard_name Long_name bounds layer_names	Layer Layer layer_bnds layer_names	Immersion field.

Name	Dimensions	Datatype	Statut (Mandatory/ Optionnal)	Attributes	Description
layer_names	Layer, maxLayerName Len	char	M		Immersion identification (Ex : High, Low, Full).
layer_bnds	layer, nv	int	M	unit m positive down	Immersion bounds
frequency	frequency	int	O	Standard_name frequency long_name Central band frequency units Hz order_convention IEC 61260 : 1995"; order_octave 3.0	
percentile	percentile	int8	M	Standard_name percentile Long_name percentile comment QO definition : The value above which a given percentage of observations in a group of observations fall unit Percent	
Lon	Lon	double	M	Standard_name longitude Long_name longitude comment None unit degrees_east	
lat	Lat	double	M	Standard_name latitude Long_name latitude comment None unit degrees_north	
energy	layer, frequency percentile, lon, lat	single	O		

crs		Single	M	grid_mapping_name latitude_longitude
				epsg_code EPSG:4326
				longitude_of_prime_meridian 0.0; // double
				semi_major_axis 6378137.0; // double
				inverse_flattening 298.257223563; // double	

V.4. Selection of noise maps

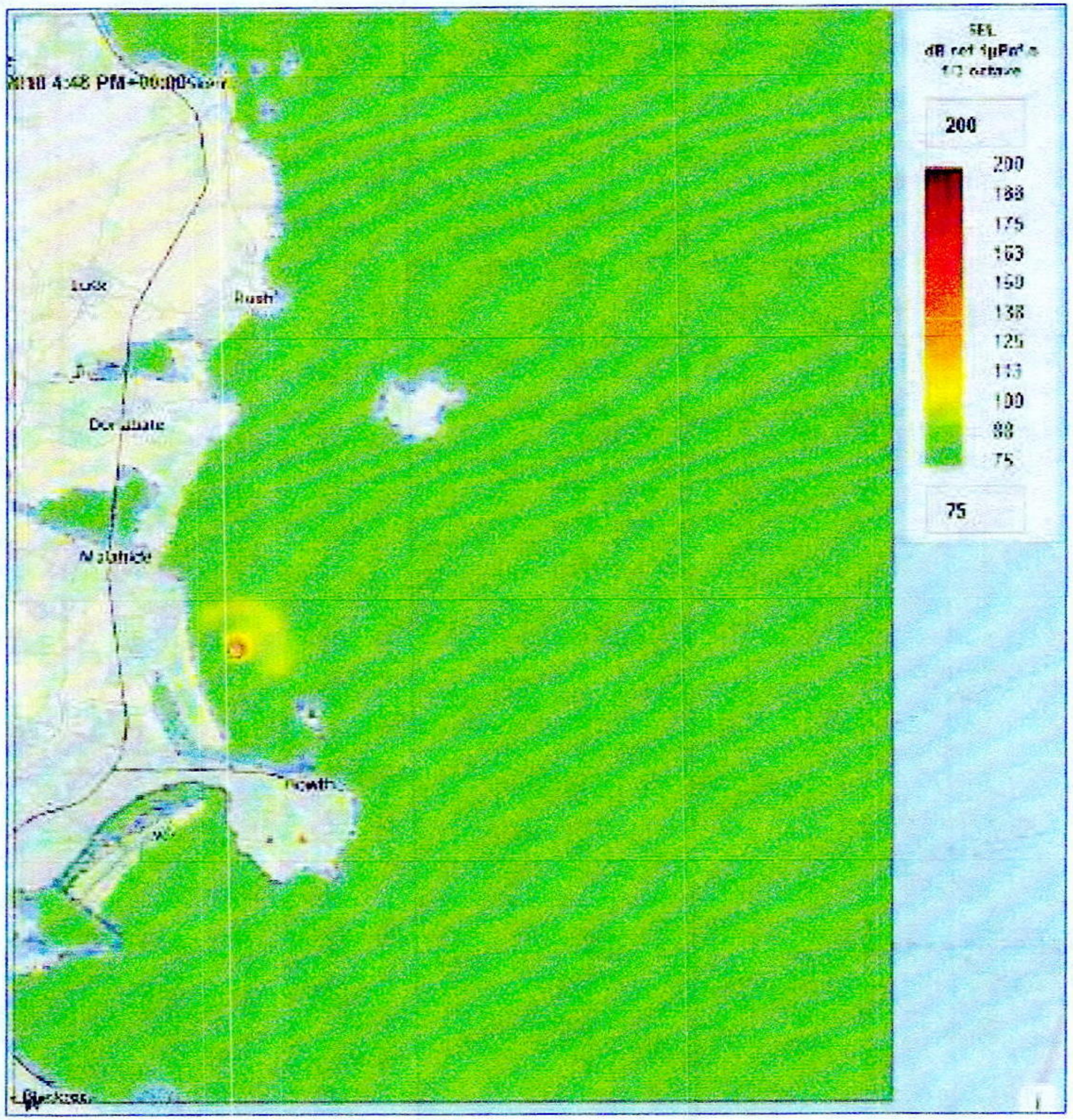
This section gives **a non-exhaustive overview** of the noise maps for dredging. The maps reported hereafter are only for illustration purposes, and shows either the maximum levels or the 5th percentile (or exceedance level) for the full water column for the 125 Hz, 1kHz and 8 kHz third-octave bands.

All raw data of modelled maps have been delivered in a Netcdf format for further exploitation by the customer.

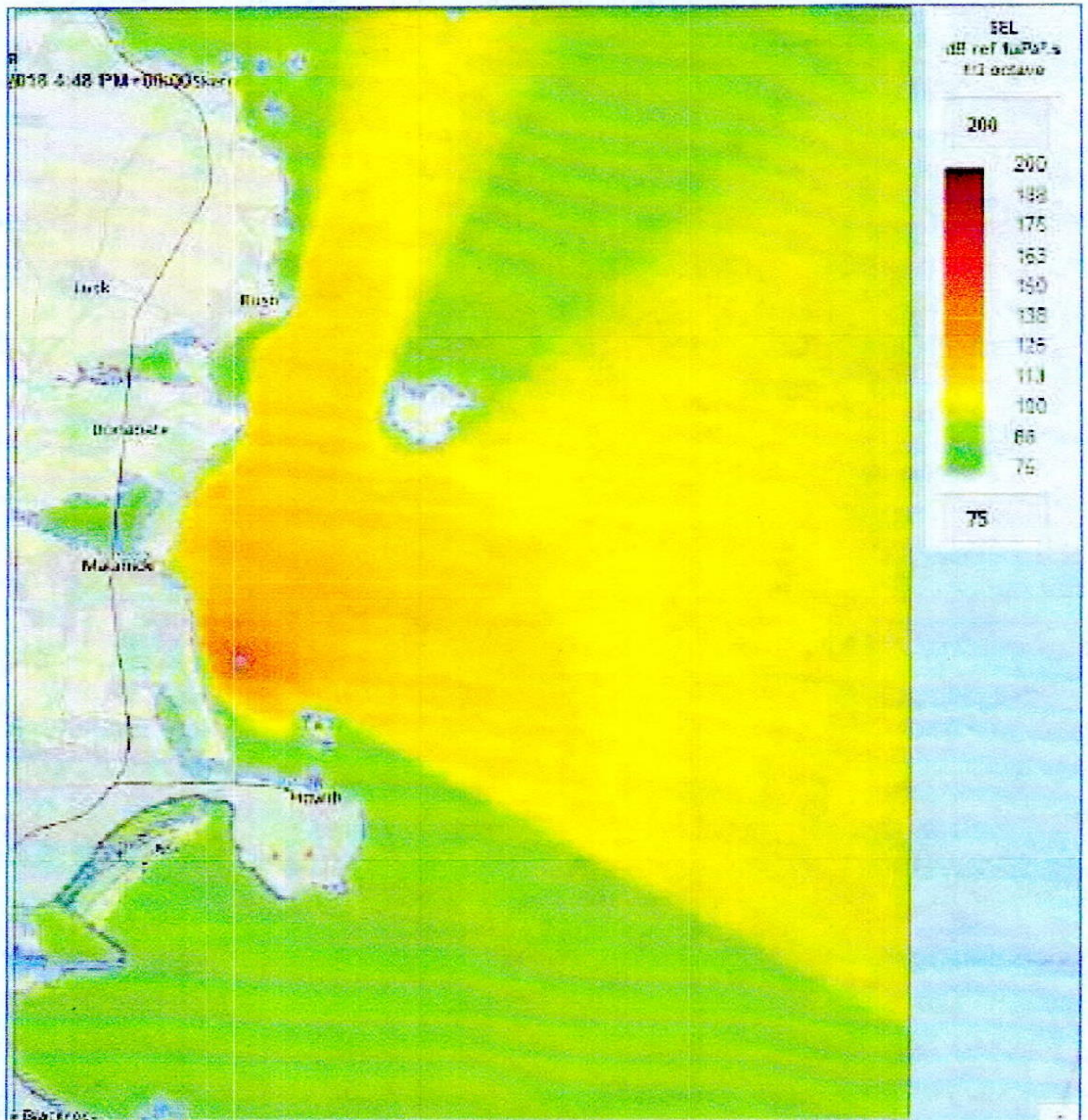
V.5. Noise maps of dredging

Max levels 5th percentile
02A – 0th "

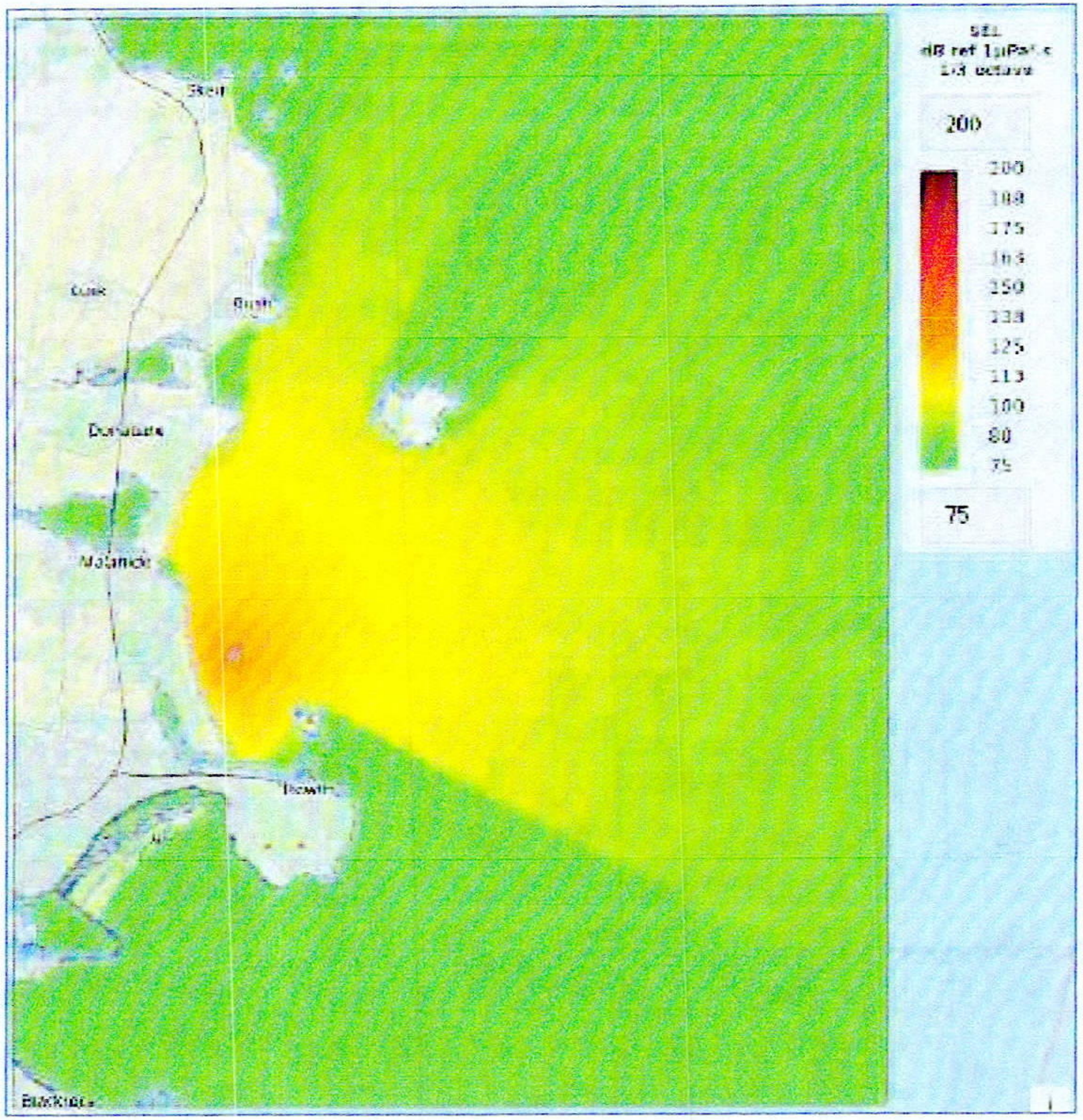
5th percentile levels at 125 Hz 1/3 octave band



5th percentile levels at 1kHz 1/3 octave band

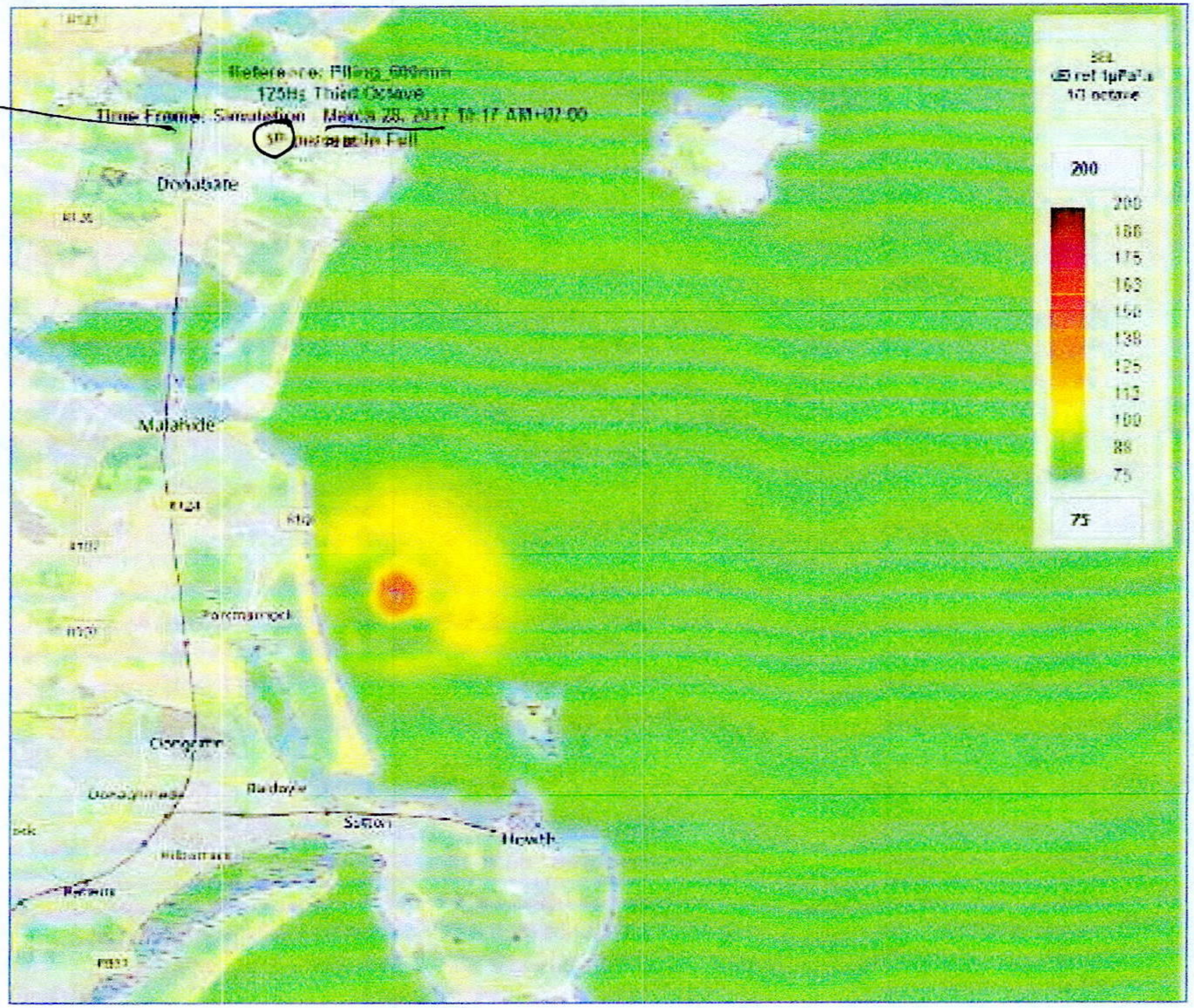


5th percentile levels at 8kHz 1/3 octave band



V.6. Noise maps of piling a 600mm pile

5th

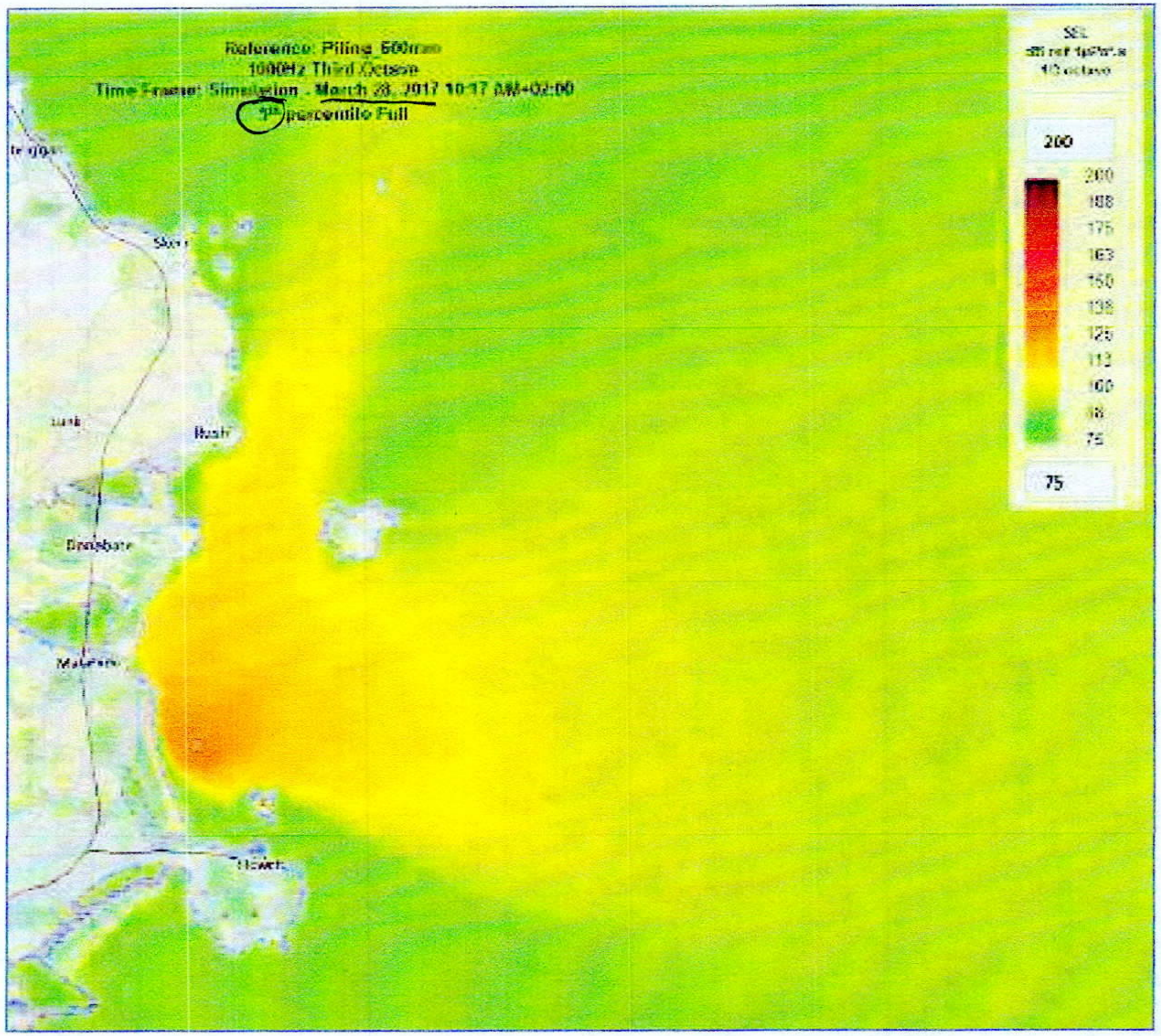


Piling 600mm diameter
Maximum 1sec SEL levels
at 125 Hz 1/3 octave band

Maximum = 0th
Should this be 5th

Why located here?

Maximum 1sec SEL levels at 1kHz 1/3 octave band



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JACOBS TOBIN

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Greater Dublin Drainage Project

Irish Water

Appendix 8

Summary of Mitigation Measures Specific to the Marine Environment

February 2020

MA.11 21.2.6. Proposed outfall pipeline route. from compound 10

In this updated version
• BM9 - Treatment is to secondary stage no mention of UV.

APP. 3

Contents

1. Summary of Mitigation Measures Relevant to the Marine Environment

1.1 Introduction

The purpose of this Report is to collate the mitigation measures identified in Chapter 24 of the Environmental Impact Assessment Report (EIAR) that are considered necessary to protect the marine environment prior to the commencement of and during the Construction Phase and/or during the Operational Phase of the Greater Dublin Drainage Project (hereafter referred to as the Proposed Project).

The outline design of the Proposed Project has been progressed taking account of environmental constraints and considerations that have been identified. This has enabled the avoidance of potential environmental impacts.

1.2 General Mitigation Requirements

Table 1.1: General Mitigation Measures

Mitigation No.	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
G1	• The mitigation strategy outlined in this Report will be incorporated by the appointed contractor(s) into the future design proposals for the proposed Project. The strategy will be incorporated into the overall Construction Environmental Management Plan (CEMP), by the appointed contractor(s) and approved by Irish Water.	Construction Phase

1.3 Population and Human Health: Population

Table 1.2: Population and Human Health: Population Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
P2	6.8.1	All Proposed Project elements	• Safe working practices, in accordance with the relevant legislation, will be in place during the Construction Phase to protect workers and visitors accessing the construction sites.	Construction Phase
P13	6.8.1	Proposed outfall pipeline route (marine section)	• A Fisheries Liaison Officer will be appointed to ensure all fishermen receive timely notifications of any restrictions/exclusion zones in place during the Construction Phase of the proposed outfall pipeline route (marine section).	Construction Phase
P14	6.8.1	Proposed outfall pipeline route (marine section)	• Notifications of the timing and duration of offshore works, and any safety advisory zones in place, will be publicised in popular marine and fisheries publications such as the Marine Times and the Irish Skipper.	Construction Phase
P15	6.8.1	All elements of the Proposed Project	• A Community Liaison Officer (CLO) shall be employed during the Construction Phase of the Proposed Project: • The role of the CLO will be to maintain an open, transparent and positive relationship with members of the public, groups and organisations affected by the works; • The CLO will work closely with Irish Water and the appointed contractor(s) to ensure that all efforts to address public concerns are made, and to ensure that information on the nature and duration of all works is provided; and • The CLO will also act as a contact point for sporting clubs and community facilities in the area.	Construction Phase
P16	6.8.1	Proposed outfall pipeline route (marine section)	• Advance notice will be given to the public in advance of the marine offshore works commencing and in advance of any major planned disruptions of walkways or car parks.	Construction Phase
P17	6.8.1	Proposed outfall pipeline route (marine section)	• Timelines and positioning of marine offshore working structures will avoid potential impacts on the scheduling of regattas and race events organised by Howth Yacht Club and the Irish Sailing Association (ISA). Howth Yacht Club and the ISA will be consulted as part of the scheduling/timing of proposed offshore works to minimise all inconvenience. The CLO will act as the contact point between these groups, Irish Water and the appointed contractor(s).	Construction Phase
P21	6.8.2	Proposed outfall pipeline route (marine section)	• Notifications of the timing and duration of any maintenance works required to be carried out on the proposed outfall pipeline route (marine section) during the Operational Phase will be publicised in popular marine and fisheries publications such as the Marine Times and the Irish Skipper.	Operational Phase
P22	6.8.2	Proposed outfall pipeline route (marine section)	• Advance notification of the timing and duration of any maintenance works required to be carried out on the proposed outfall pipeline route (marine section) during the Operational Phase will be provided to sailing and recreational clubs operating in the area, including, for example, Howth Yacht Club and the ISA.	Operational Phase

1.4 Population and Human Health: Human Health

Table 1.3: Population and Human Health: Human Health Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
HH1	7.8	All elements of the Proposed Project	• The Proposed Project will be designed and constructed to best industry standards and practices. The Proposed Project aims to reduce health risks to employees, local residents and the community it will serve.	Construction Phase/ Operational Phase
HH2	7.8	All elements of the Proposed Project	• During the Construction Phase and Operational Phase, comprehensive mitigation measures will be implemented in order to minimise/prevent the potential for human health impacts caused by the Proposed Project. Mitigation measures are outlined in detail within each of the following tables for the below relevant chapters in Volume 3 Part A of the EIAR: • Chapter 8 Marine Water Quality, Table 1.4; • Chapter 13 Traffic and Transport, **Error! Reference source not found.**; • Chapter 14 Air Quality, Odour and Climate, Table 1.8; • Chapter 15 Noise and Vibration, Table 1.9; • Chapter 17 Hydrology and Hydrogeology, Table 1.11; and • Chapter 18 Soils and Geology, Table 1.12.	Construction Phase/ Operational Phase
HH4	7.8	All elements of the Proposed Project	Noise • Please refer to Table 1.9 and Section 15.7 of Chapter 15 Noise and Vibration in Volume 3 Part A of the EIAR for a comprehensive description of proposed mitigation measures to reduce impacts to sensitive receptors which are related to noise. • The main mitigation measure to be undertaken is the preparation of a Noise and Vibration Management Plan (NVMP) by the appointed contractor(s) prior to the commencement of any site works. The NVMP will be developed as part of the overall CEMP developed by the appointed contractor(s) and will be approved by Irish Water. The NVMP will detail how the appointed contractor(s) will comply with the noise criteria set out in the EIAR and will deal specifically with construction activities in a strategic manner to remove or reduce significant noise and vibration impacts associated with the Construction Phase. The NVMP will detail the provision and installation of localised acoustic screens and the best practice noise measures that the appointed contractor(s) will adhere to for construction activities and the noise and vibration monitoring programme that the appointed contractor(s) will undertake during the construction works. • The construction works will be managed through the use of construction noise limits which the appointed contractor(s) will work within. Best practice control measures, including choice of plant, scheduling of works on-site, provision of temporary acoustic screening, on-site noise monitoring and other measures, will be employed in order to ensure noise limits are not exceeded. Best practice noise management procedures for the control of noise and vibration from construction activities as presented in BS 5228 (British Standards Institution 2014) will be followed. Such measures to be adhered to will include the following: • Good on-site work practices; • Selection of quiet plant;	Construction Phase/ Operational Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			• Acoustic screens and barriers; • Noise control; • Communications with the community; • Monitoring; and • Noise auditing.	
HH6	7.8	All elements of the Proposed Project	Marine Water Quality • Please refer to Table 1.4 and Section 8.5 of Chapter 8 Marine Water Quality in Volume 3 Part A of the EIAR for the mitigation measures with respect to marine water quality impacts. The following is an overview of the mitigation measures. • Disposal of dredged material will only take place on local flooding tides to ensure suspended sediments are not transported to sensitive receptors around Ireland's Eye. The timing of the flood tide will be confirmed with reference to Howth Harbour tide gauge. • Turbidity and suspended sediment concentrations of the receiving waters will be monitored during the course of the dredging operations. • Suspended sediment concentrations will have to monitored during the course of the operations as part of the Construction Environmental Management Plan as the consenting authority will more than likely issue conditions on any dredging licence stipulating a suspended sediment limit, beyond which mitigation measures have to be implemented. • The dredging operation will be modified to reduce water column dispersion and/or spread of material along the bottom. An operational modification to clamshell dredging will be considered, if water column concentrations of dredged material are exceeded for proposed hopper dredge discharge.	Construction Phase
HH7	7.8	All elements of the Proposed Project	Hydrology and Hydrogeology • All hydrology and hydrogeology mitigation measures are detailed in Table 1.11. The mitigation described in Section 17.5 of Chapter 17 Hydrology and Hydrogeology in Volume 3 Part A of the EIAR is embedded in the design, and the potential impact as designed was assessed. Additional mitigation measures are described in Section 17.7 of the same chapter. The Proposed Project will be designed in accordance with the report entitled *The Planning System and Flood Risk Management: Guidelines for Planning Authorities* (Office of Public Works 2009) and the Flood Risk Assessment carried out for the Proposed Project. (Appendix A17.1). With these safeguards, it is considered that the proposed WwTP and the proposed Abbotstown pumping station will not be vulnerable to flooding. Climate change has been considered under the Fingal East Meath (FEM) Flood Risk Assessment Management Study (FRAMS) Project (Halcrow Barry Consultants 2011) and the River Tolka Flooding Study (M.C. O'Sullivan & Co. 2003). • The surface water drainage design of the proposed WwTP and the proposed Abbotstown pumping station sites and access roads will incorporate Sustainable Drainage System principles, with attenuation systems in place to limit discharges from the site to the greenfield-site flow rate. Consequently, there will be no impact on the nearby water courses. • Mitigation measures for the management of hydrology and hydrogeology impacts include, but are not	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			limited to: • All temporary construction compounds, storage areas and launch pits (for trenchless techniques) will be located within Flood Zone C – low risk; • Immediate removal/disposal of surplus material off-site will be implemented; • Drainage within soil bunds will be provided to reduce the influence upon the surface runoff pathways of flood water; • Direct discharge of surface water from any temporary impervious area to the nearby watercourse without proper attenuation will be avoided; • Temporary attenuation ponds will be provided if the stream to which surface water from the construction area is discharged has limited capacity; • The shafts/construction fronts for any trenchless techniques will be located beyond the floodplain of the summer peak flood of an appropriate return period (i.e. 1 in 20 years). (For 10% risk over a two-year construction period, the required return interval for construction period flood is approximately 20 years, as per Flood and Reservoir Safety (Institute of Civil Engineers UK 2015)); • The surface water runoff at the construction sites will be managed to prevent flow of silt-laden surface water flowing into adjoining surface watercourses. To achieve this, the appointed contractor(s) must comply with the CIRIA publication Control of water pollution from linear construction projects. Technical Guidance (C648) (CIRIA 2006); • For the construction on any watercourse crossings, a detailed Pollution Control Plan (PCP), Sediment and Erosion Control Plan (SECP), Emergency Response Plan (ERP) and Method Statements (MS) will be drafted and will have regard to relevant pollution prevention guidelines. All works in or adjacent to watercourses will comply with the EPA, Inland Fisheries Ireland and OPW requirements; • Direct disposal of water from excavations and from temporary groundwater dewatering to the nearby watercourse will not be allowed, as these could both impact on water quality of the watercourse and increase flood risk. Any discharge of such water, after proper treating/de-silting will be discussed and agreed with the landowner, and if necessary, discharge consent will be acquired from the concerned authority (EPA, Inland Fisheries Ireland, etc.) prior to the commencement of work; • On-site fuel storage and refuelling of plant and vehicles will be undertaken on impermeable and bunded areas and away from any rivers or other watercourses; and • The appointed contractor(s) will inspect and monitor the water quality of surface waters near any works, particularly in relation to increased silt levels. This monitoring process will form part of the Construction Environmental Management Plan for the Construction Phase. • Further mitigation measures are detailed in Section 17.6 of Chapter 17 Hydrology and Hydrogeology, in Volume 3 Part A of the EIAR.	
HH8	7.8	All elements of the Proposed Project	Soils and Geology • With respect to managing and mitigating against impacts from ground contamination, the following mitigation measures are required. For more details, please refer to Table 1.12 and Section 18.7 of Chapter 18 Soils and Geology in Volume 3 Part A of the EIAR.	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			• Excavations in made ground will be monitored by an appropriately qualified person to ensure that, should any hotspots of contamination be encountered, they are identified, segregated and disposed of appropriately. Any identified hotspots shall be segregated and stored in an area where there is no possibility of runoff generation or infiltration to ground or surface water drainage. Care will be taken to ensure that the hotspot does not cross-contaminate clean soils elsewhere along the alignment. • Potential soil and water pollution will be minimised by the implementation of good construction practices. Such practices will include adequate bunding for oil containers, wheel washers and dust suppression on site roads, and regular plant maintenance. The Construction Industry Research and Information Association (CIRIA) provides guidance on the control and management of water pollution from construction sites in their publication Control of Water Pollution from Construction Sites: Guidance for Consultants and Contractors (Masters-Williams et al. 2001), and this shall be reflected in the CEMP. A contingency plan for pollution emergencies will also be developed by the appointed contractor(s) prior to work and regularly updated, which would identify the actions to be taken in the event of a pollution incident. The CIRIA document recommends that a contingency plan for pollution emergencies will address the following: • Containment measures; • Emergency discharge routes; • List of appropriate equipment and clean-up materials; • Maintenance schedule for equipment; • Details of trained staff, location, and provision for 24-hour cover; • Details of staff responsibilities; • Notification procedures to inform the relevant environmental protection authority; • Audit and review schedule; • Telephone numbers of statutory water undertakers and local water company; and • List of specialist pollution clean-up companies and their telephone numbers.	

1.5 Marine Water Quality

Table 1.4: Marine Water Quality Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
WQ1	8.5.1	Proposed outfall pipeline route (marine section) dredged section	• Disposal of dredged material will only take place on local flooding tides to ensure suspended sediments are not transported to sensitive receptors around Ireland's Eye. The timing of the flood tide will be confirmed with reference to Howth Harbour tide gauge.	Construction Phase
WQ2	8.5.1	Proposed outfall pipeline route (marine section) dredged section	• Turbidity and suspended sediment concentrations of the receiving waters will be monitored during the course of the dredging operations.	Construction Phase
WQ3	8.5.1	Proposed outfall pipeline route (marine section) dredged section	• Suspended sediment concentrations will have to monitored during the course of the operations as part of the CEMP as the consenting authority will more than likely issue conditions on any dredging licence stipulating a suspended sediment limit, beyond which mitigation measures have to be implemented. • The dredging operation will be modified to reduce water column dispersion and/or spread of material along the bottom. An operational modification to clamshell dredging will be considered, if water column concentrations of dredged material are exceeded for proposed hopper dredge discharge.	Construction Phase

1.6 Biodiversity (Marine)

Table 1.5: Biodiversity (Marine) Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
BM1	9.7.1	Proposed outfall pipeline route (marine section)	• The use of trenchless construction methods beneath the Baldoyle Estuary SAC will minimise the impact to the marine ecology in the sensitive inshore areas during construction, although there is a minor risk of an air or bentonite breakout. On completion of the tunnel, the remainder of the planned surface construction is based on dredging in the offshore location. • Additional mitigation will be required to minimise the impacts of noise and suspended sediments in order to prevent negative interaction with sensitive receptors in the area (in particular the cetaceans and the pinnipeds). • This mitigation is also included in the Outline CEMP, which will form part of the contract documents. Irish Water will be responsible for ensuring all mitigation measures are implemented and complied with by the contractor(s).	Construction Phase
BM2	9.7.1	Proposed outfall pipeline route (marine section)	Microtunnelling Beneath Baldoyle Estuary- Leakage of Pollutants • No discharges to estuary under any circumstances. • Managed operations with bunded storage areas and sediment settlement areas. • CEMP including Surface Water Management Plan.	Construction Phase
BM3	9.7.1	Proposed outfall pipeline route (marine section)	Microtunnelling Beneath Baldoyle Estuary- Air Breakout to Surface • Pressures will be managed	Construction Phase
BM4	9.7.1	Proposed outfall pipeline route (marine section)	Microtunnelling Beneath Baldoyle Estuary- Bentonite Breakout • Volumes and pressures of bentonite used will be managed. • The control and management of pressures during the microtunnelling processes will be undertaken to prevent air and bentonite breakouts. However, in the unlikely event of a bentonite breakout occurring, which results in a saltmarsh area high up on the foreshore being covered, intervention will be required. Intervention will involve washing the vegetation using a seawater pump and spray. Typically, this would be carried out during a high water period where washings can disperse out of the estuary naturally. Sites will only be accessed by foot (without the use of plant). Should bentonite breakout in a saltmarsh area lower down on the shoreline in areas routinely covered by seawater, this will be left to disperse naturally over the tidal cycle. • All bentonite usage will be monitored through materials balance calculations, pressure monitoring in the lines and above ground visual assessment of the works to ensure that, should a breakout occur, the volume is minimised. In the event of a bentonite breakout, the site will be monitored for chemistry and macroinvertebrate communities to ensure no residual impacts. This may include both benthic and water quality measurements.	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
BM5	9.7.1	Proposed outfall pipeline route (marine section)	Dredging Activity – Suspended Sediments • Dredging discharges from the hopper will be restricted to flooding tides only. • Plume will be monitored during dredging operations. • Disturbance of intertidal and subtidal habitats will be minimised so as to reduce the creation of suspended solids within the marine and estuarine habitats. The tunnelling compound spanning either side of the Baldoyle Estuary will be subject to surface water management as part of the CEMP to prevent all runoff into the watercourses and the estuary. • The potential for an accidental release of bentonite will be minimised by closely monitoring its use during all works. • Dredging works in the shallow areas will be carried out using a backhoe dredger with the spoil side cast at the seabed to minimise the lifting of the bucket through the water column. This will reduce losses of suspended sediments from this material and preserve the sediment composition as much as possible at bed level. Dredging carried out close to the Ireland's Eye SAC will be carried out on neap tides where possible. Monitoring of turbidity will be carried out during peak dredging activity, and operations will be restricted to flooding tides if a plume is detected >50mg/l Total Suspended Solids (TSS) above background on the northern coastline of Ireland's Eye. • The turbidity will be monitored using a buoy-mounted turbidity meter with telemetering back to the dredger to monitor potential impacts from dredging activity. As the reef is only prone to sedimentation during slack water periods, a slightly elevated level of TSS up to 40mg/l (the natural standard deviation for the year) above a daily background will be permitted off the northern coastline of Ireland's Eye. If this level increases above this threshold as a result of dredging activity, then the discharge of material will be temporarily halted to allow the resulting plume to disperse. This is particularly important 30 minutes before and after slack water where increased suspended sediments can settle within the SAC.	Construction Phase
BM6	9.7.1	Proposed outfall pipeline route (marine section)	Dredging Activity – Noise and Vibration • Detailed mitigation plan will be required and seasonal considerations. • Passive acoustic monitoring will be carried out and marine mammal observers (MMOs) will be employed to establish safe zone. • Noise and vibration from the microtunnelling and dredging operations during the construction of the proposed outfall pipeline route (marine section) (including the proposed marine diffuser) will be minimised by selecting the most appropriate equipment, dependent upon ground conditions and noise signatures. The specifications of piling systems for caisson deployments for the construction of the proposed marine diffuser, the interface connection with the microtunnelling or the fibre optic cable crossing will be assessed for likely noise outputs to assess noise impacts when working within the Rockabill to Dalkey Island SAC. • Mitigation will be undertaken during piling and dredging works to ensure the are no noise impacts to marine mammals (including harbour porpoises) near the works. This will include MMOs using a high frequency hydrophone system to establish an operational safe zone around the site. This will prevent the commencement of operations in the event that sensitive receptors (pinnipeds and cetaceans) are observed within this perimeter. The following mitigation measures will also be implemented: ◦ Following appropriate guidelines from the regulatory authorities, the NPWS (2014), the following	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			measures are proposed to remove the risk of direct injury to marine mammals in the area of operations: A trained and experienced MMO will be put in place during piling, dredging and pipeline laying. The MMO will scan the surrounding area to ensure no marine mammals are in a pre-determined exclusion zone in the 30-minute period prior to operations. It is proposed that this exclusion zone is 500m for dredging activities and 1,000m for piling activities. No works will take place should mammals be recorded in the exclusion zone. • Noise-producing activities will only commence in daylight hours where effective visual monitoring, as performed and determined by the MMO, has been achieved. Where effective visual monitoring is not possible, the sound-producing activities will be postponed until effective visual monitoring is possible. Visual mitigation for marine mammals (in particular harbour porpoise) will only be effective during daylight hours and if the sea state is 2-3 or less (Beaufort scale) or less. • For piling activities, where the output peak sound pressure level (in water) exceeds 170dB, a ramp-up procedure must be employed following the pre-start monitoring. Underwater acoustic energy output will commence from a lower energy start-up and thereafter be allowed to gradually build up to the necessary maximum output over a period of 20 to 40 minutes. • Once operations have begun, operations will cease temporarily if a cetacean or seal is observed swimming in the immediate (<50m) area of piling and dredging and work can be resumed once the animal(s) have moved away. • Any approach by marine mammals into the immediate (<50m) works area should be reported to the NPWS. • If there is a break in piling activity for a period greater than 30 minutes, then all pre-activity monitoring measures and ramp-up will recommence as for start-up. • Once normal operations commence (including appropriate ramp-up procedures), there is no requirement to halt or discontinue the activity at night-time, nor if weather or visibility conditions deteriorate, nor if marine mammals occur within a radial distance of the sound source that is 500m for dredging works, and 1,000m for piling activities. • The MMO will keep a record of the monitoring using 'MMO form location and effort (coastal works)' available from the NPWS and submit to the NPWS on completion of the works, as described in the NPWS guidance (2014). • In order to reliably quantify the zone of responsiveness associated with the proposed programme of piling activities associated with the interface pit or cable crossing, a vessel-deployed hydrophone will be used to confirm the sound source level of the operation. Additionally, passive acoustic monitoring will be used to provide additional support to the identification of harbour porpoises or other cetaceans within the survey area. The effective range of the passive acoustic monitoring system will be dictated by the frequency, with the ultra-high frequency used by porpoises likely to be limited to within 500m of the passive acoustic monitoring system.	
BM7	9.7.1	Proposed outfall pipeline route (marine section)	Dredging Activity – Pollution • Implementation of CEMP. This includes strict adherence to MARPOL guidelines, auditing of CEMP, bunded storage areas for fuels and control of compound drainage, etc.	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			• No discharge or disposal of waste to sea under any circumstances. • A detailed CEMP will be established prior to construction (see Outline CEMP). This will follow best practice for the storage, handling and disposal of hazardous/non-hazardous materials to prevent chemical pollution. All fuels or chemicals kept on the construction site will be stored in protected containers, and all refuelling and maintenance will be carried out in bunded containment areas. Refuelling and maintenance in areas draining directly to water habitats will be avoided where possible. Oil interceptors will also be installed in appropriate locations. Equipment will be regularly maintained and leaks repaired immediately. Accidental spillages will be contained and cleaned up immediately. Remediation measures will be carried out in the unlikely event of pollution of the marine environment.	
BM8	9.7.1	Proposed outfall pipeline route (marine section) marine diffuser	Installation of Proposed Marine Diffuser • The duration of dredging operations will be minimised. • Acoustic output levels and carry out marine mammal observations.	Construction Phase
BM9	9.7.2	Proposed outfall pipeline route (marine section)	• The Sustainable Drainage Systems in place at the proposed WwTP and Abbotstown pumping station will need to be maintained to ensure proper functioning during the operation of the Proposed Project. • Output to be secondary treated with strict targets for suspended sediment and DIN level outputs	Operational Phase

1.7 Biodiversity (Marine Ornithology)

Table 1.6: Biodiversity (Marine Ornithology) Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
BMO1	10.9.1	Proposed temporary construction compounds no. 9 and no. 10 at Baldoyle	Estuarine Ornithology • Hoarding will be installed at both proposed temporary construction compounds for the duration of Construction Phase. • A 2.4m high hoarding will be used for the duration of the construction works at both microtunnelling compounds (proposed temporary construction compounds no. 9 and 10). Compound construction will not proceed without the installation of hoarding around the entire perimeter of each compound and any associated access track. The deployment of this hoarding will mean that works within the microtunnelling compounds will occur out of sight of birds in the Baldoyle Bay SPA, meaning that disturbance impacts on birds are reduced to a very low level (Cutts et al. 2013). Ikuta and Blumstein (2003) found that protective barriers allow birds to behave as they would in an undisturbed environment. To avoid disturbance to wintering birds, the hoarding will only be erected and uninstalled between April and August under supervision by a professional ecologist.	Construction Phase
BMO2	10.9.2	Proposed outfall pipeline route (marine section) interface between microtunnelled section and subsea section	Marine Ornithology • Adherence to Vessel Management Plan (VMP) (see Appendix A10.2 in Volume 3 Part B of the EIAR), including withdrawing from area in event of large-scale auk movement towards vessels	Construction Phase
BMO3	10.9.2	Proposed outfall pipeline route (marine section) subsea section	Marine Ornithology • Adherence to VMP (see Appendix A10.2), including withdrawing from area in event of large-scale auk movement towards vessels • Adjustment to temporal restriction of marine construction activities from March to October, to April to October	Construction Phase
BMO4	10.9.2	Proposed outfall pipeline route (marine section) marine diffuser	Marine Ornithology • Adherence to VMP (see Appendix A10.2), including use of bird observer during July and August and withdrawing from area in event of large-scale auk movement towards vessels • Adjustment to temporal restriction of marine construction activities from March to October, to April to October	Construction Phase
BMO5	10.9.2	Proposed outfall pipeline route (marine section) marine diffuser	Marine Ornithology • It should be noted that the VMP has been prepared by the Proposed Project ornithologist. • Due to the potential presence of large numbers of birds with very high ecological value and also the sensitivity of breeding seabirds within and near the Ireland's Eye SPA, it will be necessary to put in place a VMP (see Appendix A10.2 in Volume 3 Part B of the EIAR). The VMP will have two key functions. • The first is to ensure that the Ireland's Eye SPA boundary is not unnecessarily approached or crossed by	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			construction vessels working on the proposed marine diffuser and subsea section of the proposed outfall pipeline route (marine section) at any time during the Construction Phase. This will also increase the certainty that the impact significance on the breeding colony itself during construction will be Negligible. Every vessel used on the Proposed Project will have a copy of the VMP and the crews will be acquainted with the boundary of Ireland's Eye SPA and the ornithological importance of these waters. • The second is to ensure the protection of rafting auks leaving the Ireland's Eye colony in July to mid-August. These birds are flightless, and thus particularly susceptible to disturbance by vessels. Whilst such rafts tend to immediately leave the area to moult in locations far from the shore, unfavourable winds can result in them being unable to control the direction in which they are travelling when leaving their colony. A bird observer (present either on the island or a vessel) will keep watch in July to mid-August only, noting wind direction and monitoring whether any auks that may be on the water are drifting out towards the proposed marine diffuser. • In the event of a sighting of rafting auks between Ireland's Eye and the proposed marine diffuser construction area, vessels on-site will be informed. All vessels will be obliged to immediately report the sightings to the other Proposed Project vessels with exact position of sighting, and reduce speed to less than 10 knots if within 1km of the reported sighting. Vessels should thereafter avoid coming closer than 1km to any rafting auks, and keep extra lookout for rafting auks. This may result in vessels having to temporarily leave the work area until rafting auks are no longer present. If this does occur, it is not expected that such birds would persist in the area.	

1.8 Biodiversity (Terrestrial and Freshwater Aquatic)

Table 1.7: Biodiversity (Terrestrial and Freshwater Aquatic) Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
TFA24	11.14.1	All elements of the Proposed Project	Pollution with Other Substances • Where the construction works are close to a watercourse, and at all watercourse crossings, the following best practice guidelines, adapted from Chilibeck et al. (1992), NRA (2005b) and Murphy (2004), shall be followed: ◦ Fuels, lubricants and hydraulic fluids for equipment used on the construction site should be carefully handled to avoid spillage, properly secured against unauthorised access or vandalism, and provided with spill containment according to Best Practice Guidelines BPGCS005 – Oil Storage Guidelines (Enterprise Ireland); ◦ Best Practice Guidelines BPGCS005 – Oil Storage Guidelines (Enterprise Ireland); ◦ Fuelling and lubrication of equipment shall not be carried out on-site within 20m of any watercourse or drainage ditch; ◦ Any spillage of fuels, lubricants or hydraulic oils shall be immediately contained and a pollution control kit used. The contaminated soil shall be removed from the site and properly disposed of; ◦ In the event of any spillage of fuels, lubricants or hydraulic oils, the ECoW will be notified immediately; ◦ Oil booms and oil soakage pads shall be kept on-site to deal with any accidental spillage, and replenished immediately once used; ◦ Waste oils and hydraulic fluids shall be collected in leak-proof containers and removed from the site for disposal or recycling; ◦ All pumps using fuel or containing oil shall be locally and securely bunded and shall not be located within 20m of a watercourse or drainage ditch; and ◦ Prior to any in-stream works, the appointed contractor(s) will ensure that all construction equipment is mechanically sound to avoid leaks of oil, fuel, hydraulic fluids and grease.	Construction Phase
TFA29	11.14.1	All elements of the Proposed Project	Environmental Incidents and Accidents • An emergency operating plan shall be established to deal with incidents or accidents during construction that may give rise to pollution within any watercourse. This shall include means of containment in the event of accidental spillage of hydrocarbons or other pollutants (including, for example, oil booms and soakage pads); • Throughout all stages of the Construction Phase of the Proposed Project, the appointed contractor(s) shall ensure that good housekeeping is maintained at all times and that all site personnel are made aware of the importance of the freshwater environments and the requirement to avoid pollution of all types; • All hazardous materials on-site will be stored within secondary containment designed to retain at least 110% of the storage contents; • Temporary bunds for oil/diesel storage tanks will be used on the site during the Construction Phase of the Proposed Project, as appropriate; • Safe handling of all potentially hazardous materials will be emphasised to all construction personnel employed	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			during the Construction Phase of the Proposed Project, and an ERP shall be in place in case of accidental spillage; • Raw or uncured waste concrete will be disposed of by removal from the site; • Any spillage of fuels, lubricants or hydraulic oils will be immediately contained and the contaminated soil removed from the site and properly disposed of; and • There shall be no discharge of un-attenuated water to the adjacent marine environment.	

1.9 Air Quality and Odour

Table 1.8: Air Quality and Odour Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
AQ2	14.8	All elements of the Proposed Project	• The Construction Phase of the Proposed Project will be carefully managed and a Dust Management Plan will be formulated to ensure that construction activities are managed to minimise dust emissions associated with construction activities. In order to mitigate against air quality effects at receptors during the Construction Phase, Best Practice Measures will be adopted. These measures will include techniques such as those outlined in the IAQM's (2014a) Guidance on the Assessment of Dust from Demolition and Construction. • The appointed contractor(s) will be required to produce an Air Quality and Dust Management Plan as part of their CEMP, including Best Practice Measures to control dust and, in particular, measures to prevent dust nuisance. The principal objective of the Air Quality and Dust Management Plan will be to ensure that dust emissions do not cause significant nuisance at receptors near the Proposed Project. The Air Quality and Dust Management Plan will include measures such as enclosure of material stockpiles, hard surfacing of heavily used areas, and covering of vehicles carrying spoil. Measures specific to maintaining AQS are presented in the following sections.	Construction Phase

1.10 Noise and Vibration

Table 1.9: Noise and Vibration Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
NV1	15.7.1	All elements of the Proposed Project	Noise and Vibration Management Plan • Prior to the commencement of any works, the appointed contractor(s) will prepare an NVMP. The NVMP will be developed as part of the overall Outline Construction and Environmental Management Plan developed by the appointed contractor(s) and approved by Irish Water. • The NVMP will detail how the appointed contractor(s) will comply with the noise criteria set out in the EIAR and will deal specifically with construction activities in a strategic manner to remove or reduce significant noise and vibration impacts associated with the Construction Phase works. • The NVMP will detail the provision and installation of localised acoustic screens, the best practice noise measures that the appointed contractor(s) will be required to adhere to for construction activities and the noise and vibration monitoring programme that the appointed contractor(s) will be required to undertake during the construction works. • The NVMP will specifically address the following required mitigation measures as discussed in the report above.	Construction Phase
NV3	15.7.1	Proposed orbital sewer route, outfall pipeline route (land based section and marine section)	Microtunnelling Works • A site hoarding of 2.4m height will be erected around the boundary of all proposed temporary construction compounds before the main noise generating works commence. • Localised acoustic screens of 2.4m height shall be used within the proposed temporary construction compound for the TBM works at Clonshaugh Road, opposite St. Michael's House and at the R124 Road. The stationary noise generating plant shall be positioned in the proposed temporary construction compound as far away as possible from the nearest NSRs (R19, R21 and R31). The screens will be placed adjacent to the stationary noise generating plant on the dwelling house side of the works. • The appointed contractor(s) shall prepare a detailed MS regarding the likely groundborne noise and vibration levels that will be generated as a result of the microtunnelling works once the specific details of the proposed plant items and construction methodologies are known. • The appointed contractor(s), in liaison with Irish Water, shall determine an agreeable mitigation approach with the residents at the Cappagh Road cottage (R8), the house on Clonshaugh Road (R19) and the house on Golf Links Road (R35) once the detailed construction methodology and phasing is determined and the MSs are available. This may include measures such as stopping works at night-time or providing for temporary re-housing for the residents during works. • The occupiers of these properties shall also receive prior warning, written and verbal, of the microtunnelling activities proposed by the appointed contractor(s). • A structural integrity survey of the house at the Golf Links Road (R35) shall be completed before and after microtunnelling works are completed and will be shared with the property owner. The survey shall be completed by a certified structural engineer, and tell-tale crack monitors shall be used on any building faults identified during the initial survey. Vibration monitoring shall also be carried out at the house while microtunnelling works	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			are within a minimum of 30m of the property boundaries. • The Educate Together National School (R29) on the R107 Malahide Road shall receive prior warning, written and verbal, of the microtunnelling activities proposed and the potential impacts that the occupiers of the building may experience. The appointed contractor(s) shall investigate if the microtunnelling works can be completed during the holiday term when there are no occupants of the school building.	
NV7	15.7.1	All elements of the Proposed Project	Selection of Quiet Plant • In accordance with best practicable means, plant and activities to be employed on the Proposed Project will be reviewed to ensure that they are the quietest available for the required purpose.	Construction Phase

NV9	15.7.1	All elements of the Proposed Project	Noise Control
			• Noise reducing technologies, such as attenuators or enclosures, shall be used where practicable:
			  • Ensure that noise control measures are maintained as per the manufacturers requirements;
			  • Minimise the number of vehicles/heavy plant on the Proposed Project sites at any one time;
			  • Maintain vehicles in good order and employ the principles of preventive maintenance;
			  • Ensure that noisy vehicles are parked as far as possible from noise sensitive areas;
			  • Ensure that drivers are aware of the potential for noise to cause annoyance/disturbance to local residents and they shall show due regard to this, particularly when entering and leaving the Proposed Project (e.g. no unnecessary horn blowing); and
			  • Consider the use of alternative varieties of reversing alarm with reduced noise output, such as ambient noise sensing alarms with variable volume or directional modulated alarms – these must be evaluated on a case-by-case basis and regard must be had to any health and safety issues that may arise.
				Construction Phase

NV10	15.7.1	All elements of the Proposed Project	Communications • A dedicated contact shall be appointed by the appointed contractor(s), in agreement with Irish Water, for all communications in relation to noise and vibration for the duration of the Proposed Project construction works and any queries, complaints or other formal correspondence regarding noise and vibration. • The appointed contractor(s) shall ensure good communication and engagement with local residents and stakeholders and will notify them before the commencement of any works forecast to generate appreciable levels of noise or vibration, explaining the nature and duration of the works. • Any complaints relating to Construction Phase noise and vibration for the Proposed Project from local residents or other stakeholders shall be recorded, immediately addressed and notified to Irish Water. A record of how the complaint was addressed, the follow-up actions and outcome shall be maintained.	Construction Phase
NV11	15.7.1	All elements of the Proposed Project	Monitoring • Continuous unattended noise and vibration monitoring shall be carried out at the sensitive receptor locations including Connolly Hospital and the Golf Links Road house during the TBM construction works and any other works with the potential to impact these locations. The number of monitoring units required at each location shall be agreed by the appointed contractor(s) with Irish Water. The monitoring equipment shall be set up to show a live display of the measurement levels and also provide remote access to the real-time data. The system shall allow a text message or email alert for exceedance of any limit values or threshold values.	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			• The unattended noise and vibration monitoring shall be supported by attended measurements completed on a regular basis. The attended noise measurements shall be completed at least monthly and weekly for the most sensitive works. • Noise monitoring shall be carried out for LAeq, LA90 and LAmax noise parameters over 15-minute and 1-hour measurement intervals. • Vibration monitoring shall be carried out for the vibration parameter PPV in mm/sec over 1-hour measurement intervals. • On-site noise and vibration monitoring during the actual works will be a key part in the mitigation programme for the proposed works. As discussed above, monitoring of the noise and vibration levels at NSR locations for comparison with the limits during the different construction works will be critical, and the live measurement results will be used by the appointed Construction Manager to assist the scheduling of works to ensure that the noise and vibration emissions from the various works are kept within the limits.	
NV12	15.7.1	All elements of the Proposed Project	Noise Audits • Noise audits shall be carried out by a suitably qualified auditor, appointed by Irish Water in advance, at routine intervals to ensure that the mitigation measures discussed above are being correctly implemented at the various construction sites, including operating hours, use of local screens, siting of plant items, scheduling of works, communications with stakeholders and noise control measures.	Construction Phase

1.11 Archaeological, Architectural and Cultural Heritage

Table 1.10: Archaeological, Architectural and Cultural Heritage Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
AC3	16.6.1	Proposed outfall pipeline route (marine section) dredged section.	Recorded Shipwrecks • All dredging will be monitored by a specialist underwater archaeologist under licence to the NMS of the DoCHG. Should any archaeological remains be identified, further mitigation, such as preservation by record, will be required.	Construction Phase

1.12 Hydrology and Hydrogeology

Table 1.11: Hydrology and Hydrogeology Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
HY4	17.5.4	Proposed outfall pipeline route (marine section)	• Microtunnelling techniques will be used for the proposed outfall pipeline route (marine section) from the open fields immediately west of the R106 Coast Road to approximately 600m offshore, terminating below mean low water level. The microtunnelled section will be of 1.8m to 2.0m internal diameter, constructed at depths ranging between 15m and 20m below ground level (in the bedrock) using a microtunnelling machine, with pipe sections installed as the tunnelling machine progresses. • An embedded mitigation by avoidance approach has been adopted in the tunnel design and route to eliminate any potential impacts on the Baldoyle Estuary SAC and the golf club irrigation wells on the Portmarnock Peninsula. The proposed outfall pipeline route (marine section) will be constructed in a manner that will remove the pathway between the hazard and the receptor. The proposed outfall pipeline route (marine section) will be tunnelled in bedrock beneath Baldoyle Estuary and Portmarnock Peninsula and will emerge below the low tide level on the eastern side of the Peninsula. The stiff boulder clay in the overburden will act as a barrier between the groundwater in the rock and in the shallow groundwater in the dune sands from which the irrigation wells abstract. • This methodology will ensure that the tunnelled section of the proposed outfall pipeline route (marine section) will have no hydraulic connection with the groundwater from the irrigation wells abstract. • The tunnel section will require drive/receptor shafts onshore, in the open field immediately west of the R106 Coast Road and in the open space adjacent to the public car park off the Golf Links Road, immediately north of Portmarnock Golf Club. • The tunnelled pipeline will be grouted to eliminate the possibility of a preferential flow path in the annulus outside the pipe.	Construction Phase
HY17	17.7.3	All elements of the Proposed Project	• All potential harmful substances will be stored in accordance with the manufacturer's guidelines regarding safe and secure buildings/compounds.	Construction Phase
HY18	17.7.3	All elements of the Proposed Project	• The appointed contractor(s) will ensure that adequate means to absorb or contain any spillages of these chemicals are available at all times.	Construction Phase
HY19	17.7.3	Proposed outfall pipeline route (marine section) microtunnelled section	• The excavation of the tunnel drive/receptor shaft at the FCC public car park in Portmarnock will extend to about 20m in depth and will go through the shallow aquifer. This shaft will be excavated using piling techniques which will hydraulically seal off the shaft from the water bearing sands/gravels and will not involve any dewatering or pumping which could interfere with the existing groundwater flow regime and the irrigation wells' performance.	Construction Phase
HY21	17.7.4	Proposed outfall pipeline route (marine section) microtunnelled	• The tunnelled section of the proposed outfall pipeline route (marine section) will be grouted to eliminate the possibility of a preferential flow path in the annulus outside the pipe.	Operational Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
		section		

1.13 Soils and Geology

Table 1.12: Soils and Geology Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
SG1	18.7.2	All elements of the Proposed Project	• SOIL CONST 1 – Regulatory Compliance: The adopted construction techniques will comply with the requirements of statutory bodies (BCARS/Health Service Executive Inspections/Irish Water inspections and compliance with Employers Requirements), and construction will be completed in accordance with the CEMP.	Construction Phase
SG6	18.7.2	All elements of the Proposed Project	• SOIL CONST 6 – Material Reuse: All excavated material will, where possible, be reused as construction fill. The appointed contractor(s) will ensure acceptability of the material for reuse for the Proposed Project with appropriate handling, processing and segregation of the material. This material would have to be shown to be suitable for such use and subject to appropriate control and testing according to the Earthworks Specification(s). These excavated soil materials will be stockpiled using an appropriate method to minimise the impacts of weathering. Care will be taken in reworking this material to minimise dust generation, groundwater infiltration and generation of runoff. Any surplus suitable material excavated that is not required elsewhere for the Proposed Project shall be used for other projects where possible.	Construction Phase
SG11	18.7.2	Proposed outfall pipeline route (marine section) dredged section	• SOIL CONST 11 – Dredging Works: Best practice guidelines such as those outlined in BS6349-5 .- Maritime works – Part 5: Code of practice for dredging and land reclamation (2016) will be adhered to as a minimum for any dredging exercises to be carried out. Measures to minimise disruption to the seabed and mobilisation of sediments will be applied. Seabed conditions to be taken into account when selecting the method of dredging.	Construction Phase

1.14 Agronomy

Table 1.13: Agronomy Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
AG2	19.6	Proposed orbital sewer route, NFS diversion sewer and outfall pipeline route (marine section)	• The temporary loss of land by means of the proposed 20m wayleave along the proposed orbital sewer route, NFS diversion sewer and outfall pipeline route (land based section) will be mitigated by compensation to the landowner.	Construction Phase

1.15 Waste

Table 1.14: Waste Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
W1	20.6	All elements of the Proposed Project	• Any waste generated from the Proposed Project will be managed in accordance with the principles of the waste hierarchy as outlined in the current version of the European Communities (Waste Directive) Regulations 2011 (S.I. No. 126 of 2011), i.e. prevention, preparing for reuse, recycling, other recoveries and disposal. The preferable outcome from an environmental, transportation and resource efficiency perspective is to maximise the reuse of material generated from the Proposed Project.	Construction Phase/ Operational Phase
W2	20.6.1	All elements of the Proposed Project	Waste Management Plan • Contract Documents shall include provisions which set out how waste is to be controlled and managed during the course of the Proposed Project. • The appointed contractor(s) will be required to prepare a Waste Management Plan (WMP) for the Proposed Project as part of their contractual responsibilities. At the Construction Phase, a Construction and Demolition waste manager shall be appointed to implement the WMP and to educate all colleagues and site staff about alternatives to conventional construction waste disposal. • The WMP shall adopt the measures indicated in the Contract Document and set out to minimise waste, manage materials on-site effectively, prioritise reuse and recycling on-site and make sub-contractors responsible for procurement of materials. It will comply with all relevant aspects of the EIAR and shall also take cognisance of the final CEMP and all current local and national waste management legislative obligations. • Where waste generation cannot be avoided, implementation of the WMP will maximise the quantity and quality of waste delivered for recycling and reuse and allow it to move up in the waste hierarchy away from the option of landfill disposal, reducing its environmental impact. • Potential for reuse of appropriate excavation material as fill on-site around the proposed pipeline routes or in landscaping works will be considered, subject to appropriate testing to ensure the material is suitable for its proposed end use. Where excavated material is not suitable for reuse, the appointed contractor(s) will aim to send material for recovery or recycling as far as reasonably practicable. • Training and copies of the WMP will be made available to all relevant personnel on-site. All site personnel will be instructed about the objectives of the WMP and informed of the responsibilities which fall upon them as a consequence of its provisions.	Construction Phase
W10	20.6.1	Proposed outfall pipeline route (marine section)	• The proposed outfall pipeline route (marine section) is divided into two main sections. The first section will involve a tunnel from the western side of the Baldoyle Estuary to a point offshore of Velvet Strand. From this point, the tunnel will connect to a pipeline that will be laid by subsea pipe laying methods to a point approximately 1km north-east of Ireland's Eye. Subsea pipe laying methods generate a significantly lower volume of excess material when compared to the option of tunnelling the full length of the proposed outfall pipeline route (marine section). This is due to the fact that there will be no waste material arising during the construction of the subsea pipeline section of the proposed outfall pipeline route (marine section). This construction methodology reduces the amount of excess material generated and, subsequently, the volume of traffic generated during the Construction Phase of the Proposed Project. The methodologies considered above	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			are described in more detail in the Outline CEMP.	
W11	20.6.1	Proposed outfall pipeline route (marine section)	• The tunnel spoil will be inert and could be suitable for use as an infill material or possibly an aggregate after suitable treatment (e.g. crushing, screening and washing), subject to any regulatory approval required.	Construction Phase
W12	20.6.1	Proposed outfall pipeline route (marine section) dredged section	• The material excavated during the subsea pipe laying method will be temporarily stored on the seabed along the length of the trench or in an adjacent temporary storage area. There will be monitoring of suspended solid plumes during dredging operations. Dredging works in the shallow areas will be carried out using backhoe dredging with the spoil side cast at the seabed to minimise the lifting of the bucket through the water column. This will reduce the loss of suspended sediments from the excavated material and preserve the sediment composition as much as possible at bed level. Dredging carried out close to the Ireland's Eye Special Area of Conservation will be carried out on neap tides where possible. Monitoring of turbidity will be carried out during peak dredging activity and operations. Proposed temporary construction compounds no. 9 and no. 10, which will span either side of the Baldoyle Estuary, will be subject to surface water management to prevent runoff into the watercourses and the Estuary (refer to Surface Water Management Plan). The pipe will then be floated into place and sunk into the trench, with the previously stored material replaced around and over the pipe.	Construction Phase
W13	20.6.1	All elements of the Proposed Project	Disposal • For material that cannot be reused, the disposal options will depend on whether the spoil is regarded as hazardous, non-hazardous or inert. Non-hazardous and hazardous wastes are required to be disposed of at appropriately licensed landfills or other appropriately licensed facilities. Similarly, inert wastes must be reused, recycled or disposed of at appropriately licensed facilities. All material arising from the Proposed Project will be managed sustainably and in accordance with best practice as set out in the *EMRWMP 2015-2021* (EMWRO 2015). It is not envisaged that hazardous waste will be encountered, but any hazardous materials would be treated in accordance with the *National Hazardous Waste Management Plan 2014-2020* (EPA 2014). • If the options to reuse the material either on or off-site cannot be achieved, the excess material will be sent for recovery at a facility with a waste authorisation in place. Disposal of the excess material generated will only be considered when all other options to reuse or recover the material have been exhausted. Any material that is transported off-site for recovery will be done so by a haulier holding a valid waste collection permit. The traffic impact assessment carried out in Chapter 13 Traffic and Transport in Volume 3 Part A assumes the disposal of all material.	Construction Phase
W15	20.6.2	All elements of the Proposed Project	• On the basis that it cannot be reused or recycled, excess material shall be disposed of in accordance with Section 20.6.1 of Chapter 20 Waste in Volume 3 Part A of the EIAR. Screening material and grit shall be disposed of at appropriately licensed facilities.	Operational Phase

1.16 Material Assets

Table 1.15: Material Assets Mitigation Measures

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
MA7	21.2.6	Proposed outfall pipeline route (marine section)	Communications Infrastructure • A required crossing of the proposed outfall pipeline route (marine section) with the Hibernia Atlantic Ltd. Dublin to Southport submarine cable has been identified as illustrated in **Error! Reference source not found.**. • Discussions with Hibernia Atlantic Ltd. indicate that there is no requirement for planned maintenance to this cable. Currently, only maintenance to repair damage to the cable is expected to be carried out, if necessary. It was advised that there are significant cost implications if the cable is out of service as the company must lease capacity from other providers to provide a service to their customers. • Hibernia Atlantic Ltd. have indicated that the risks shall be mitigated by providing an engineering solution to protect the subsea cable during the construction of the proposed outfall pipeline route (marine section). • The exact nature of the crossing will be subject to detailed design and approval by Hibernia Atlantic Ltd. prior to the start of construction. However, the outline technical proposal and principles which shall be adhered to for the crossing are detailed below. • The cable location shall be confirmed by the appointed contractor(s) with assistance from the asset owner (Hibernia Atlantic Ltd) by means of inducing a detectable frequency and experienced divers using a probe. The appointed contractor(s) will uncover and mark the cable to mitigate the risk of accidental damage. • In order to construct the section of the proposed outfall pipeline route (marine section) that will have to cross the subsea cable, the subsea cable shall be protected by means of a cable protection system, at which point it will be supported to allow the excavation beneath the cable and installation of the proposed outfall pipeline route (marine section) beneath the cable. Further information on this crossing method is included in the Outline CEMP. • The exact details of this technical proposal are subject to site investigation, detailed design and agreement with the asset owner (Hibernia Atlantic Ltd). It is also likely that Hibernia Atlantic Ltd. will have some supervisory presence during the works adjacent to the subsea cable.	Construction Phase
MA11	21.2.6	Proposed outfall pipeline route (marine section)	Baldoyle Bay and Portmarnock Beach • The proposed outfall pipeline route (marine section) will be tunnelled from a launch compound (proposed temporary construction compound no. 10) east of Baldoyle Bay to a reception shaft (proposed temporary construction compound no. 9) on the west of Baldoyle Bay. The proposed outfall pipeline route (marine section) will also be tunnelled to a subsea interface east of Portmarnock Beach. The implementation of trenchless techniques mitigates the impact the proposed outfall pipeline route (marine section) would otherwise have on these assets. The Proposed Project team undertook extensive consultation and detailed consideration of the proposed outfall pipeline route (marine section) to ensure that the impact on Portmarnock Golf Club and public amenities were minimised. Following discussions with Portmarnock Golf Club, the proposed outfall pipeline route (marine section) was located in a manner which will minimise intrusion on the golf course. The appointed contractor(s) shall be required to continue to liaise with Portmarnock Golf Club before and during construction works. The public amenities, such as the existing car park and public walkway to the beach, have been	Construction Phase

Mitigation No.	EIAR Section Reference	Location	Description of Mitigation Measure / Environmental Commitments	Stage of Impact i.e. Construction Phase / Operational Phase
			considered through the design process also. The majority of the carpark will be kept operational through the Construction Phase and the walkway to the beach will remain open.	

MA12	21.3.5	All elements of the Proposed Project	• Consideration will be given to the sustainable sourcing of all materials. Materials arising from the excavation of the open cut and trenchless methods will be reused where possible. This, and the methodologies chosen at design stage, will result in a decrease in the amount of imported material, in turn reducing the impact of traffic on the surrounding roads and resulting in less demand on non-renewable sources such as quarries.
			• Bentonite used for the tunnelling process will be recycled within a closed system during tunnelling, thereby minimising the quantity required.
			• Other mitigation measures which will be employed in relation to raw materials are outlined below:
			  • Design will be optimised to minimise the requirements for raw materials;
			  • Materials will be reused where possible (such as excavated rock);
			  • Raw materials will be sourced locally where possible; and
			  • Raw materials will be managed in accordance with the Outline CEMP for construction.
				Construction Phase

AQUAFACT

Drogue and Dye Studies off North County Dublin

July August 2012

Report to

Fingal County Council

APP 4

Produced by

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Table of Contents

neap

Spring.

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1. Introduction

Fingal County Council (FCC) have commissioned Engineering Consultants to undertake the outline design and to secure planning permission for a Regional Wastewater Treatment Plant (WwTP) to serve the Greater Dublin Area. As part of the works required for this project, AQUAFACT International Services Ltd., in association with TechWorks Marine Ltd., were contracted to undertake a marine (tide and current) survey to aid in the determination of the optimum location for the outfall pipeline and diffuser, which forms part of the transfer pipeline from the new WwTP. The need for the scheme arises from the broadening gap between developing load in the Greater Dublin Area (GDA), and the maximum load which can be delivered to, and treated at the existing treatment plants in the catchment, primarily at Ringsend WwTP. AQUAFACT International services Ltd. were responsible for drogue and dye studies at the selected locations.

Initial 3D hydrographic modelling has commenced in order to determine the preferred locations for the marine outfall. Results of the marine (tide and current) survey will be used to augment and confirm the modelling and assumptions made to date. These locations are within the marine study areas identified on Drawing No. 32102900/MAR/001 as supplied by the consultant engineers and reproduced here as Figure 1.1. The map also details shellfish waters and statutory environmental designations that will be avoided in the locating of the marine outfall location.

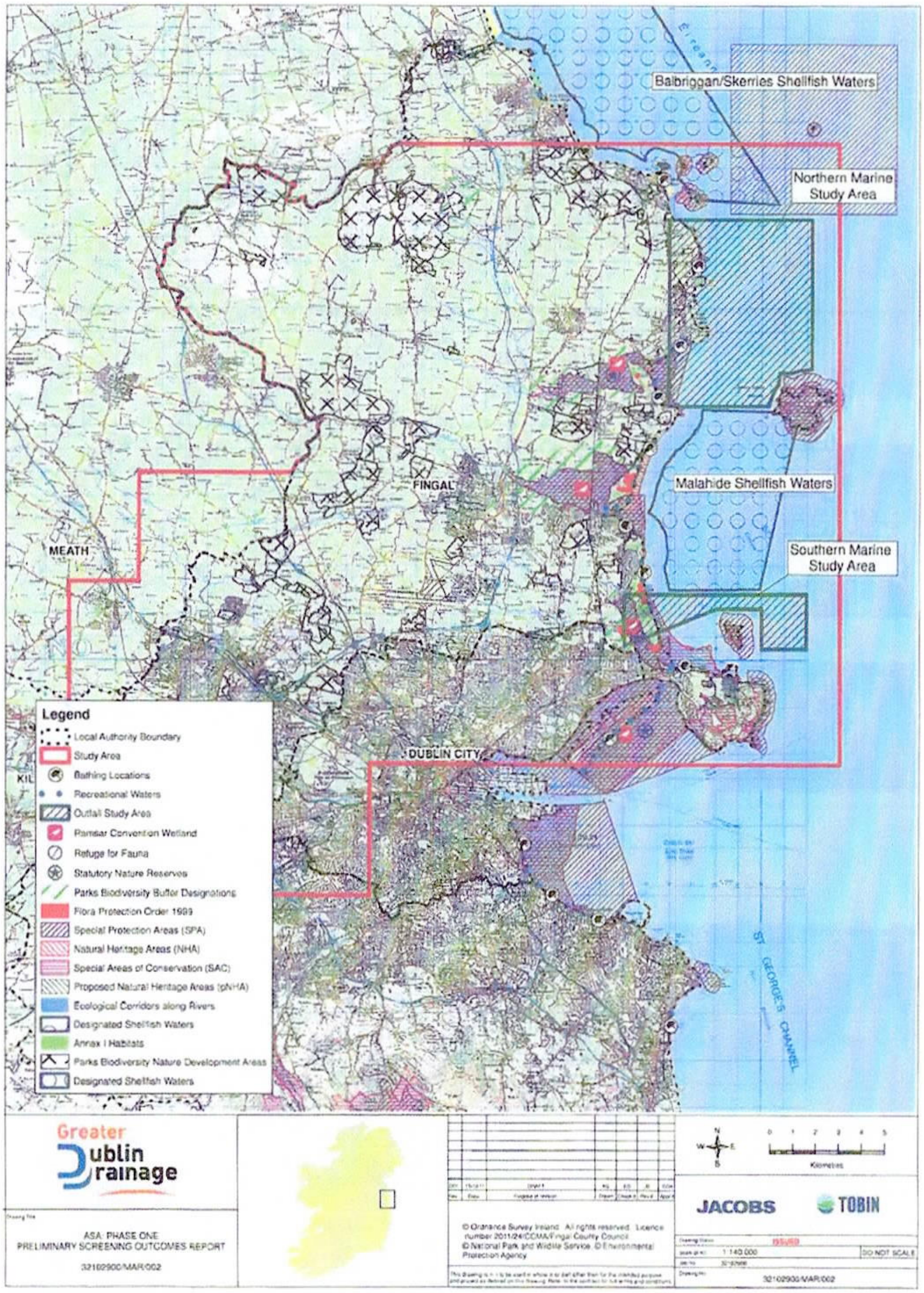


Figure 1-1 Location of the Marine Study Area Off North County Dublin.

2. Methodology

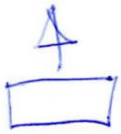
2.1. Introduction

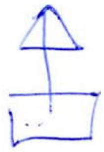
Prior to the commencement of the drogue and dye surveys, current profilers were deployed by TechWorks Marine Ltd. at three locations within the study area. The location of each of these profilers was marked by a surface buoy and the most northerly buoy (Site A) and southerly buoy (Site C) were used as markers for the release of the drogues and dye during both neap and spring tide conditions. The neap surveys occurred on 26th July (Site C) and 27th July (Site A) while the spring surveys did not take place until the 18th (Site C) and 19th (Site A) of September, weather conditions proving unsuitable on the previous spring period. Wind speed and direction were recorded regularly during the surveys by means of a hand held anemometer and compass to account for any wind-induced influences, which may have been exerted on the drogues and dye.

2.2. Dye Study

Rhodamine WT, a dye designed specifically for water tracing studies, was the chosen tracer for this study. Prior to release, the dye was diluted with methanol and distilled water to adjust its density close to that of the receiving water so that the dye dispersed through the water column. The resulting mixture was treated as a 100% concentrated tracer. A sample of this concentrate was diluted with ambient seawater to 100µg/l and used as a standard to calibrate a direct reading fluorimeter. Once calibrated, all subsequent measurements with the fluorimeter were related to the original 100% tracer released into the water.

Five litres of dye were released into the receiving waters approximately one hour after predicted high and low water at both locations during a neap tide while 10 litres of dye were released during the spring periods to allow longer account for possible increased dispersion during these periods i.e. 8 dye releases. Following release, the position and edges of the dye patch were recorded by DGPS fitted on the survey boat. When the dye patch was sufficiently dispersed to allow in-situ measurements with the fluorimeter, transects were steered through the patch at regular intervals with the fluorimeter continuously recording dye concentrations at approximately 1 m below the water surface. During the neap surveys individual transects were recorded along the main axis of the plume followed by a number of secondary transects across the short axis, each transect recorded separately. Similar transect patterns were followed during the spring tide but the fluorimeter was left recording

(A) 

 (C)

	N	S	N	S.
Dye	5 litres	10	5 L	10
	High/Low		High + Low.	
	Transects ~~broken~~ broken	continuous	Transects / Broken	continuous.
Drogue	3	3	3	3.

1 Drogue

Lost on
Spring survey
from A or C

between transects to give one long data set rather than a number of smaller sets.

Transects continued through the dye patch at regular intervals until either background levels were recorded throughout the general area of the patch or it was not possible to continue as the dye dispersed into areas which were not accessible to the operators (e.g. commercial shipping lanes) or conditions were not suitable due to inclement weather.

which was it?

2.3. *Drogue Study*

Current tracking drogues, designed to track currents at sub-surface, mid-water and off-bottom, were released into the water body at the same locations on the same dates as the dye study. The tracks of the drogues were recorded every minute by means of a small GPS, which was attached to the drogue pole. Each of the drogues was allowed to travel for approximately one hour before it was recovered and redeployed at the relevant current profile location. This was repeated for a complete tidal cycle at both locations during both the neap and spring tidal conditions.

3 drogues

In addition to the three hourly deployed drogues, a single sub-surface drogue was deployed with the dye to help relocate the dye patch when the dye dispersed below visual detection levels. This was particularly important following redeployment of the three hourly drogues which became more distant from the dye plume as the survey progressed. This drogue was also fitted with a small GPS that recorded positions every minute although this was lost during the spring survey when run over by a passing boat.

lost info.

Run over site C?

single GPS x 8 releases = 32 reports ?

3. Results

3.1. *Introduction*

All data recorded during the drogue and dye surveys are included as Excel files and accompany this report.

3.2. *Neap Tide*

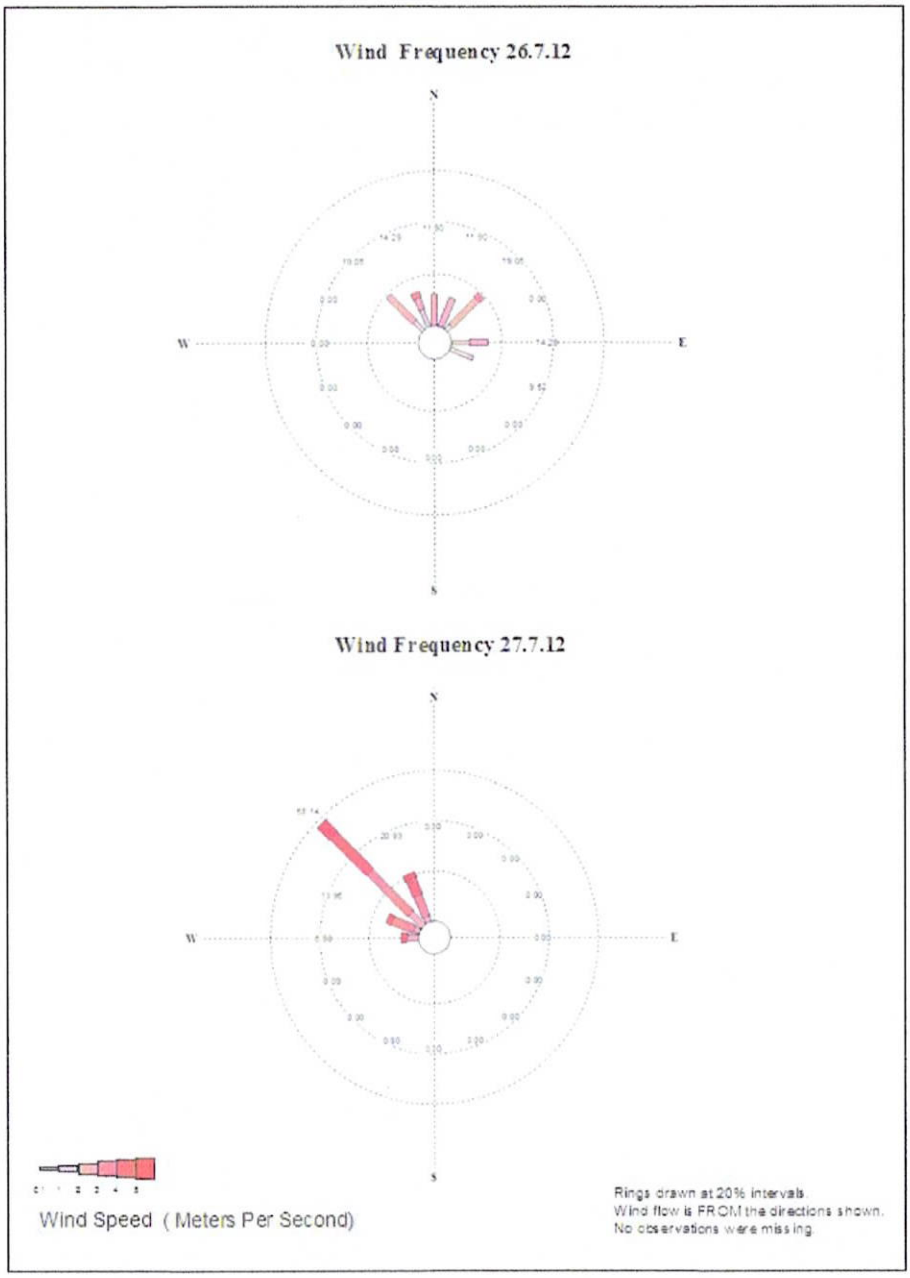
The neap tide surveys occurred on the 26th and 27th July 2012. Weather forecasts indicated a light to moderate north westerly breeze for both days. Tidal forecasts for Howth are presented in Table 3.1.

Day	Date	Time	Height(m)
Thu	26/7/12	0506	3.78
		1112	0.89
		1744	3.56
		2339	1.09
Fri	27/7/12	0609	3.60
		1217	1.02
		1852	3.54

Table 3-1 Tide Forecast, Howth

3.2.1. Wind Records

Wind records recorded during the neap tide surveys are included as Excel file "JN1156 Wind Speed Neap and Spring" and a summary of these results presented as wind roses in Figure 3.1. In general the forecasts were correct with a light northerly breeze with a mean speed of 2.3 ms^{-1} (8.1 kmh^{-1}) predominating during the survey on the 26th July. Wind speeds were slightly stronger on the 27th with a mean speed of 3.9 ms^{-1} (14.0 kmh^{-1}) recorded over the day from the northwest.



Portmarnock

Skerries

Figure 3-1 Wind frequency distribution experienced off North Count Dublin during the neap surveys.

3.2.2. Drogue Survey

Drogue track data recorded during the neap tide surveys at Site A and C are detailed in Excel files accompanying this report. A brief summary of this data is included in Tables 3-2 to 3-7 and the tracks of the drogues presented in Figures 3-2 to 3-7.

3.2.2.1. Site C

In general, the three drogues followed similar paths on both the ebb and flood tide along a northeast-southwest axis (see Figures 3-2 to 3-4). The maximum speed recorded by the three drogues occurred during the flood tide where the surface drogue recorded a mean speed of 0.88 ms^{-1} having travelled a total distance of just over 3 km during its 58 minute float time. There was little progress of the drogues during the last hour of the study on the turn of the tide.

3.2.2.2. Site A

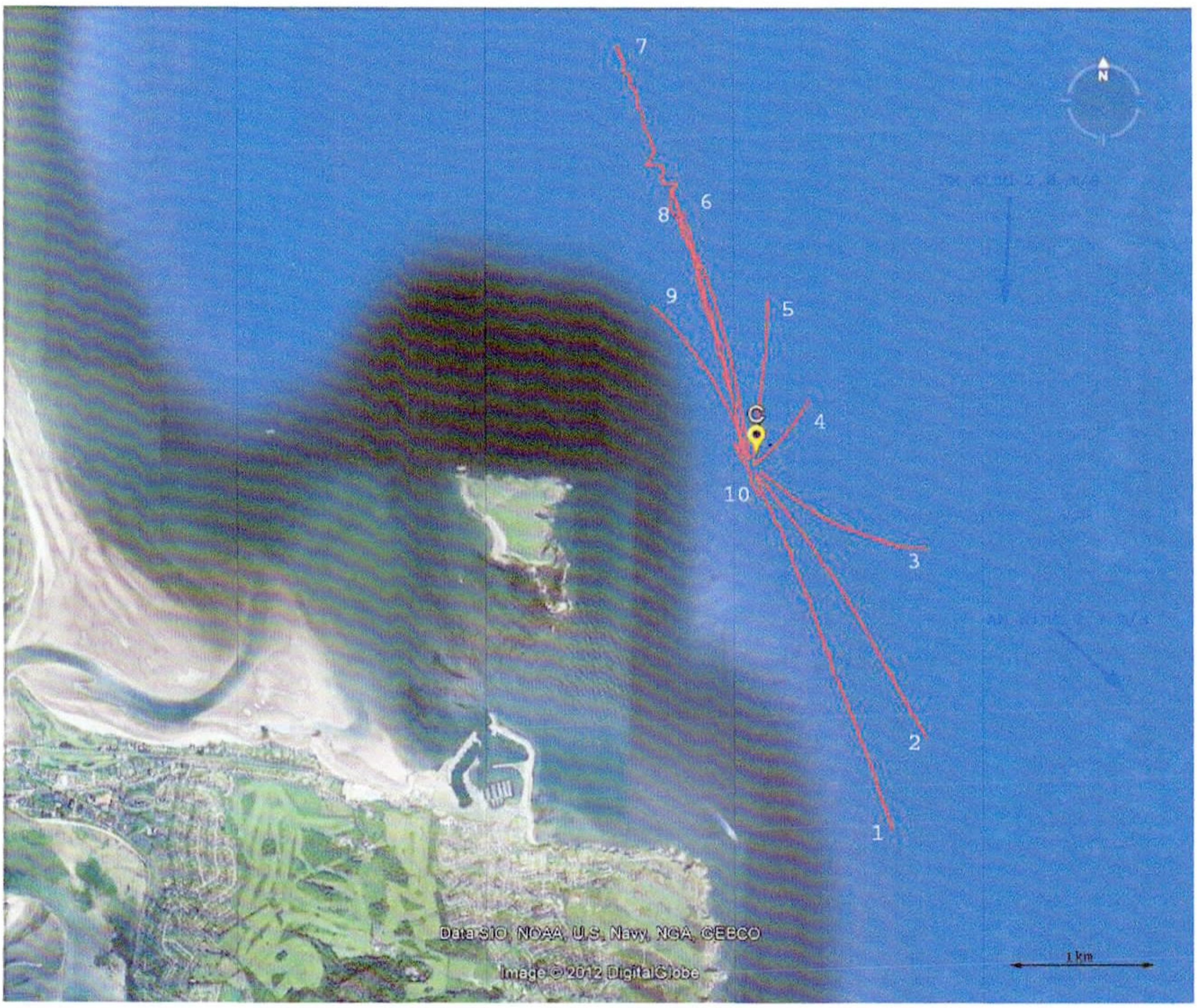
The three drogues followed paths along a north-south axis. The sub-surface drogue showed some variation to this during the second quarter of the flooding tide where it moved in a northwest to west direction against the prevailing wind. Maximum speeds were recorded during the ebb tide where the sub-surface drogue recorded a mean speed of 0.65 ms^{-1} having travelled a total distance of just over 2 km during its 54 minute float time.

Drogue Number	Release Time	Drift Time (min)	Total Distance(m)	Mean Speed (ms^{-1})	Course (deg)
1	06:59:05	61	2545	0.70	150
2	08:11:12	56	2093	0.62	150
3	09:17:24	73	1280	0.29	300
4	10:33:33	38	584	0.26	40
5	11:18:38	39	1080	0.46	360
6	12:04:57	53	1926	0.61	360
7	13:07:35	58	3064	0.88	360
8	14:15:13	49	1762	0.60	360
9	15:12:55	58	1179	0.34	360
10	16:15:11	73	652	0.15	180

why drift times not 1 hour?

why 11 drogues for Skerries?

Table 3-2 Sub-surface drogue, 26/7/2012



P

Figure 3-2 Neap sub-surface drogue tracks, 26/7/2012

deployed with the dye?

Drogue Number	Release Time	Drift Time (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	06:59:00	63	2418	0.64	160
2	08:11:15	58	2000	0.57	150
3	09:16:35	67	815	0.20	110-360
4	10:34:25	38	473	0.21	300
5	11:18:08	40	1012	0.42	320
6	12:05:07	53	1950	0.61	340
7	13:06:48	60	2634	0.73	330
8	14:14:34	52	1760	0.56	350
9	15:12:04	58	1170	0.35	230
10	16:15:48	72	210	0.05	-

Table 3-3 Mid-water drogue, 26/7/2012

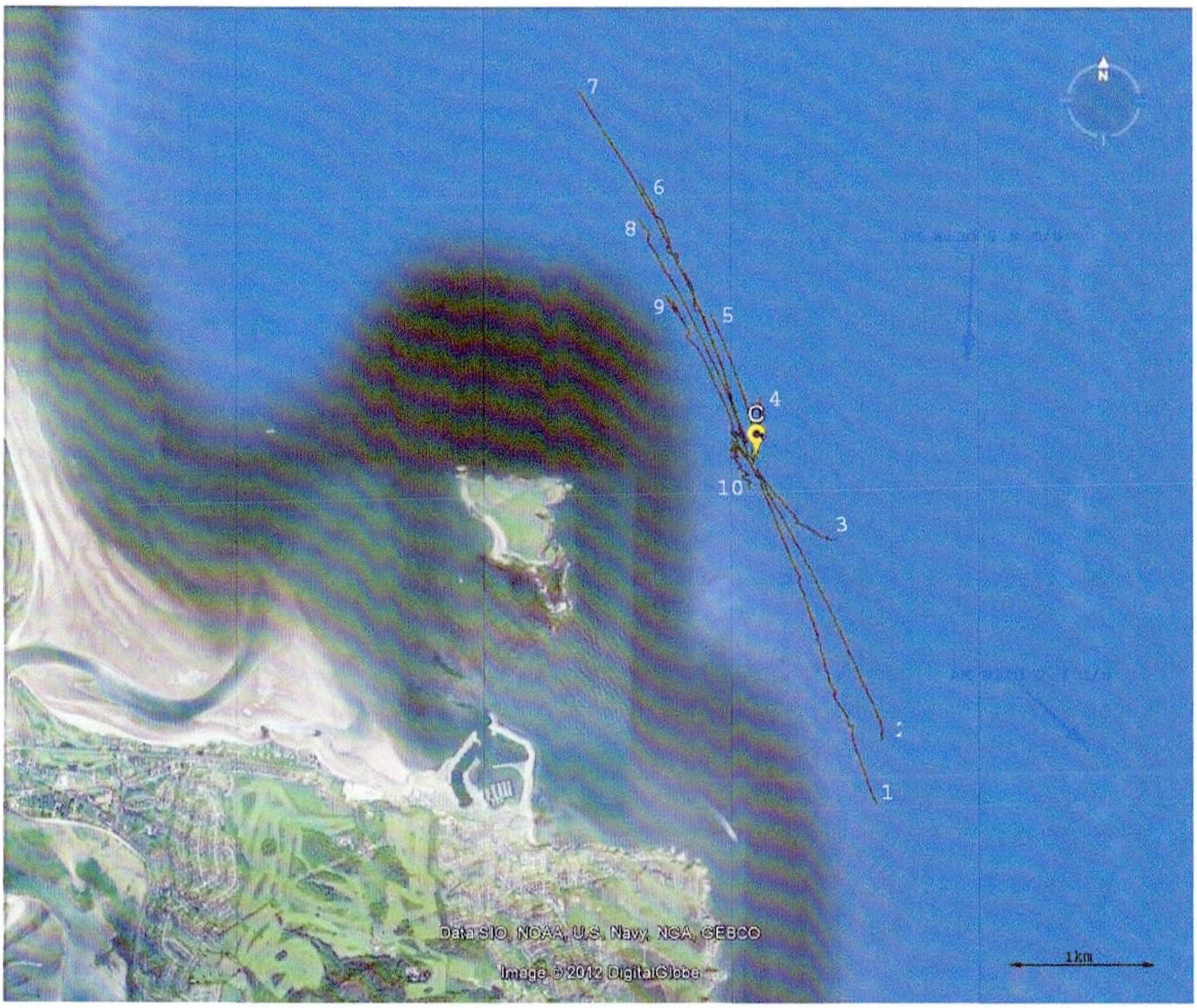


Figure 3-3 Neap mid-water drogue tracks, 26/7/2012

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	06:59:35	63	2210	0.58	150
2	08:10:21	61	1691	0.46	180
3	09:16:16	69	633	0.15	170
4	10:34:00	39	208	0.09	330
5	11:17:39	43	411	0.16	330
6	12:04:26	56	1841	0.55	330
7	13:06:33	62	2465	0.66	330
8	14:13:48	54	1741	0.54	330
9	15:11:41	60	1196	0.33	300
10	16:15:23	69	401	0.10	160

Table 3-4 Off-bottom drogue, 26/7/2012

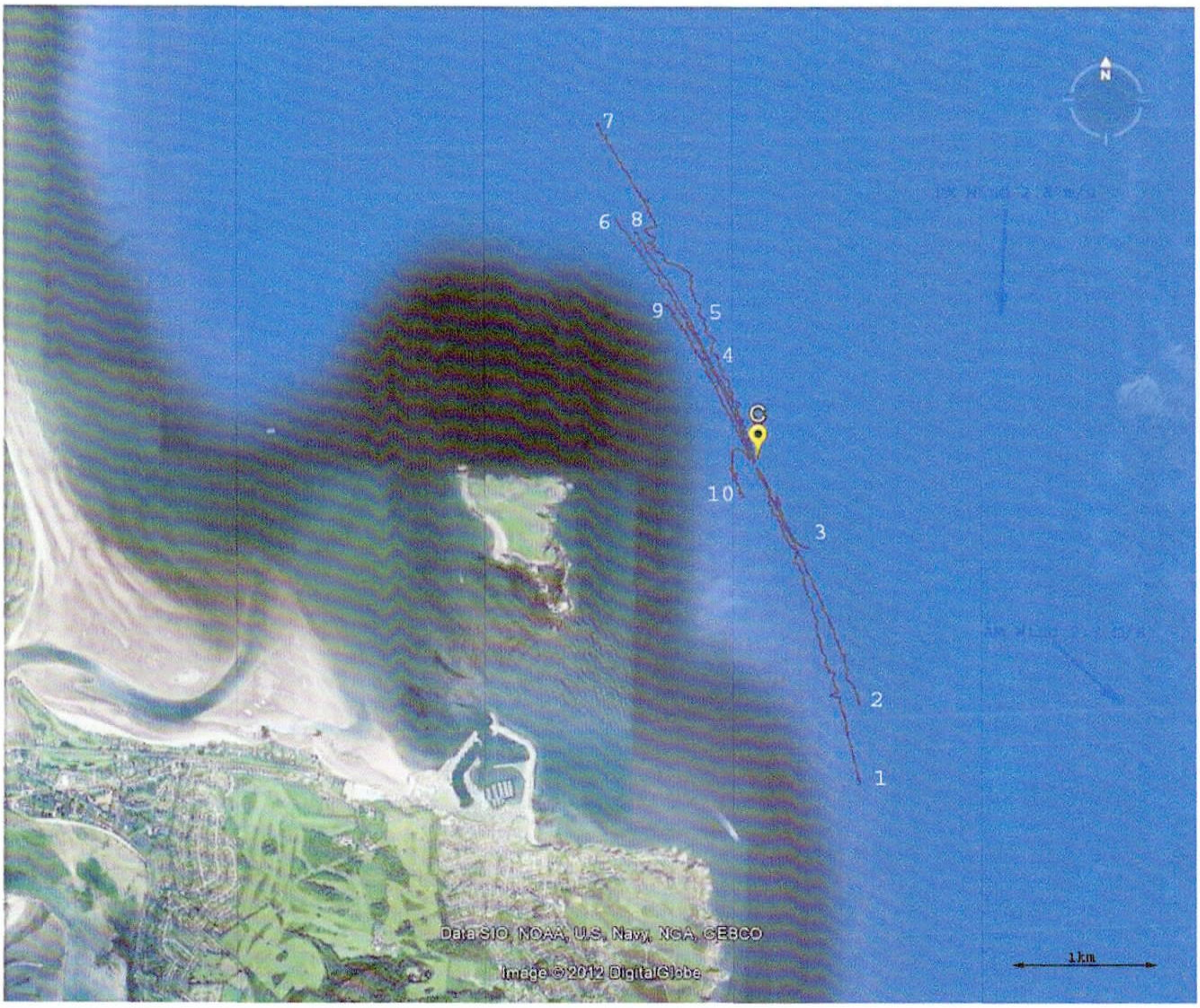


Figure 3-4 Neap off-bottom drogue tracks, 26/7/2012

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:05:04	52	2011	0.64	170
2	08:05:48	54	2122	0.65	180
3	09:08:24	56	1367	0.41	165
4	10:14:36	51	611	0.20	300
5	11:11:51	54	811	0.25	300
6	12:14:33	47	1266	0.45	360
7	13:06:22	49	1514	0.51	360
8	14:04:21	55	1406	0.43	300
9	15:05:03	78	819	0.18	200
10	16:21:03	44	523	0.20	220
11	17:07:59	14	162	0.19	200

Table 3-5 Sub-surface drogue, 27/7/2012

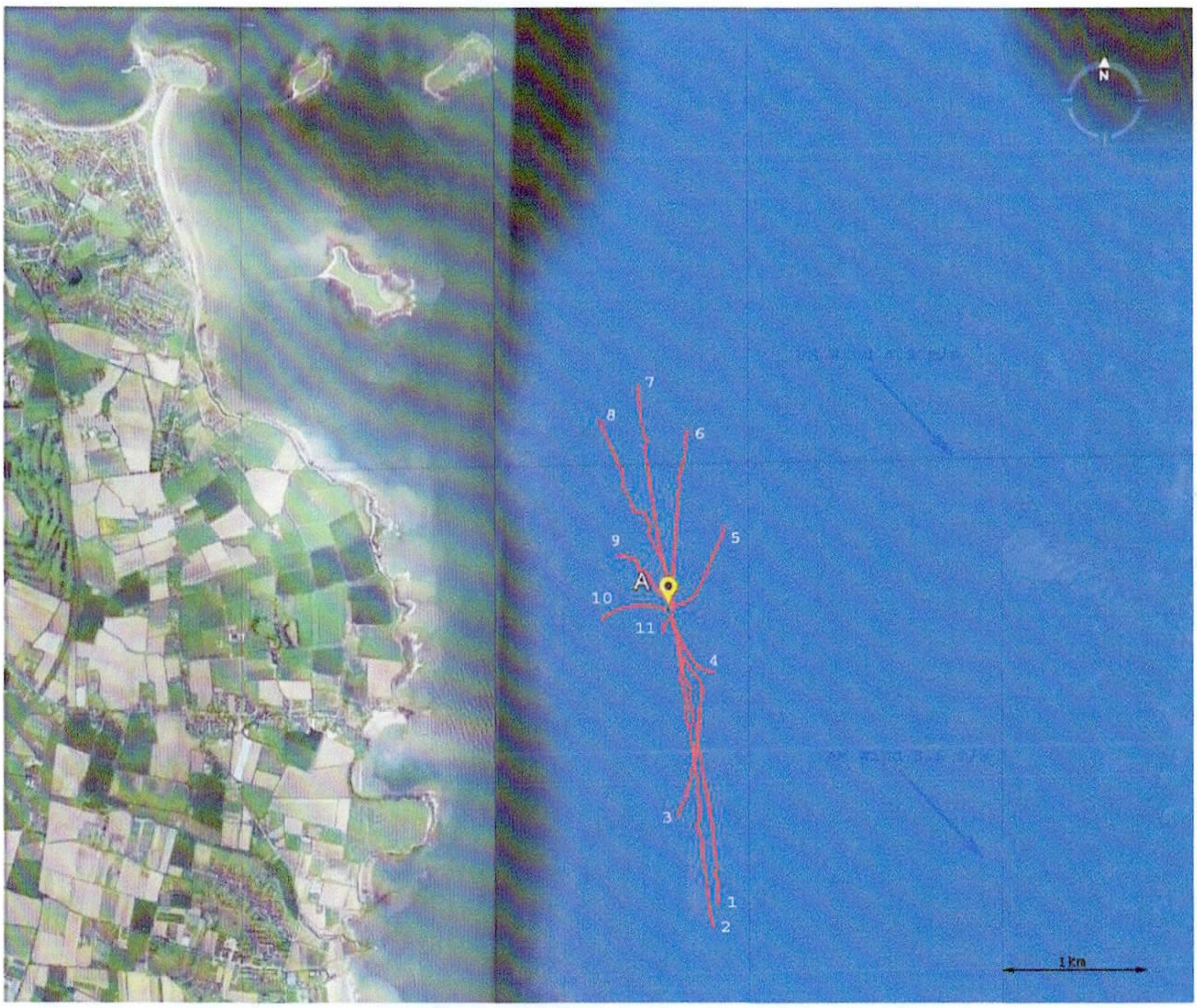


Figure 3-5 Neap sub-surface drogue tracks, 27/7/2012

11 drog. 11 hours? From 7am - 5pm

- ?

S

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:06:24	52	1651	0.53	160
2	08:05:24	56	1560	0.46	170
3	09:07:45	61	882	0.24	180
4	10:13:39	56	100	0.03	350
5	11:11:09	57	788	0.23	340
6	12:13:43	46	1101	0.40	350
7	13:06:25	48	1465	0.51	360
8	14:04:30	53	1362	0.43	350
9	15:06:28	68	849	0.21	360
10	16:21:24	41	132	0.05	200
11	17:08:52	15	133	0.05	300

Table 3-6 Mid-water drogue, 27/7/2012

Figure 3-6 Neap mid-water drogue tracks, 27/7/2012

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:08:22	52	1490	0.48	180
2	08:05:03	58	1470	0.42	180
3	09:06:56	60	961	0.27	180
4	10:14:07	54	203	0.06	200
5	11:11:30	56	764	0.23	330
6	12:13:11	45	785	0.29	340
7	13:06:44	50	1214	0.40	330
8	14:03:02	56	1106	0.33	340
9	15:05:02	68	887	0.22	190
10	16:21:53	43	101	0.04	200
11	17:08:05	14	99	0.12	200

Table 3-7 Off-bottom drogue, 27/7/2012

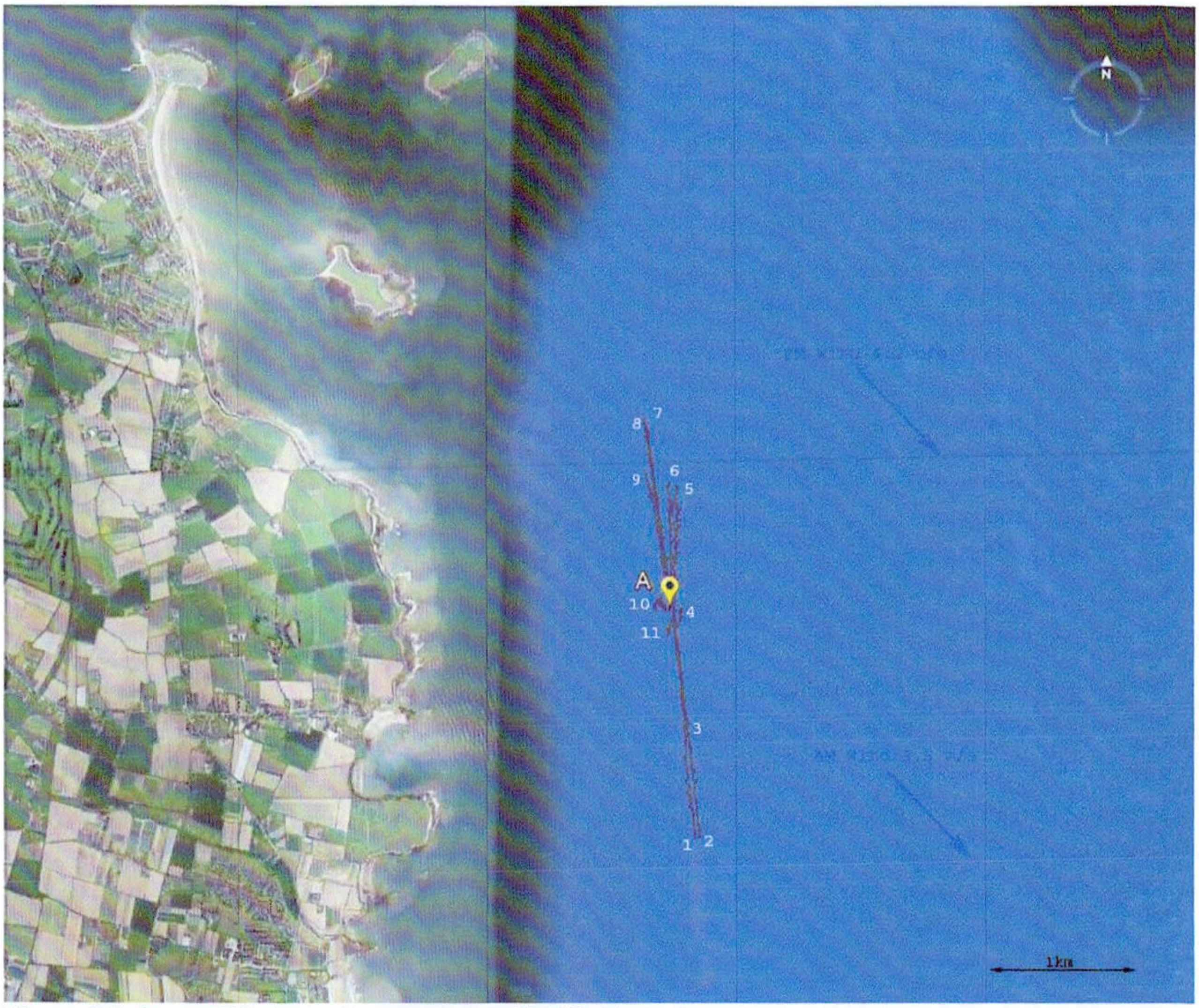


Figure 3-7 Neap off-bottom drogue tracks, 27/7/2012

3.2.3. Dye Survey

Data recorded during the dye releases during the neap tide surveys at Site A and C are detailed in Excel files accompanying this report. Data include dye release times, the progress of the dye plume over time as plume perimeter coordinates and dye concentrations with position coordinates along transects through the dye plume. In addition, the coordinates of the sub-surface drogue released to accompany the dye plume are also included as an Excel file.

Representative diagrams of the progress of the plumes as they progress over the survey periods are presented below. Initially the position and size of the plumes were recorded by recording the visible perimeter of the plumes and later by recording dye concentrations along transects through the plumes. However, it must be remembered that the dye plume is constantly moving and the start and end position of the perimeter is slightly out of sync and the position of dye concentrations along one transect is not directly related to the position of concentrations along a second transect taken across the same plume shortly after the first.

3.2.3.1. Site C

Dye Drogue

The path taken by the sub-surface drogue that was released with the dye at Site C during the neap survey is presented in Figure 3.8. Recorded wind speeds were relatively light during the survey and had had little influence on the drogue.

During the ebb tide, the drogue travelled a total distance of 5.2 km south southeast from the release point to end up off the southern end of Howth Head after a four hour drift. There was little movement of the drogue in the last hour of its deployment.

During the flood tide, the drogue travelled a total distance of 7.5 km north-northwest of the release point to end up just south of the western side of Lambay Island. There was little movement of the drogue in the last hour of its deployment.

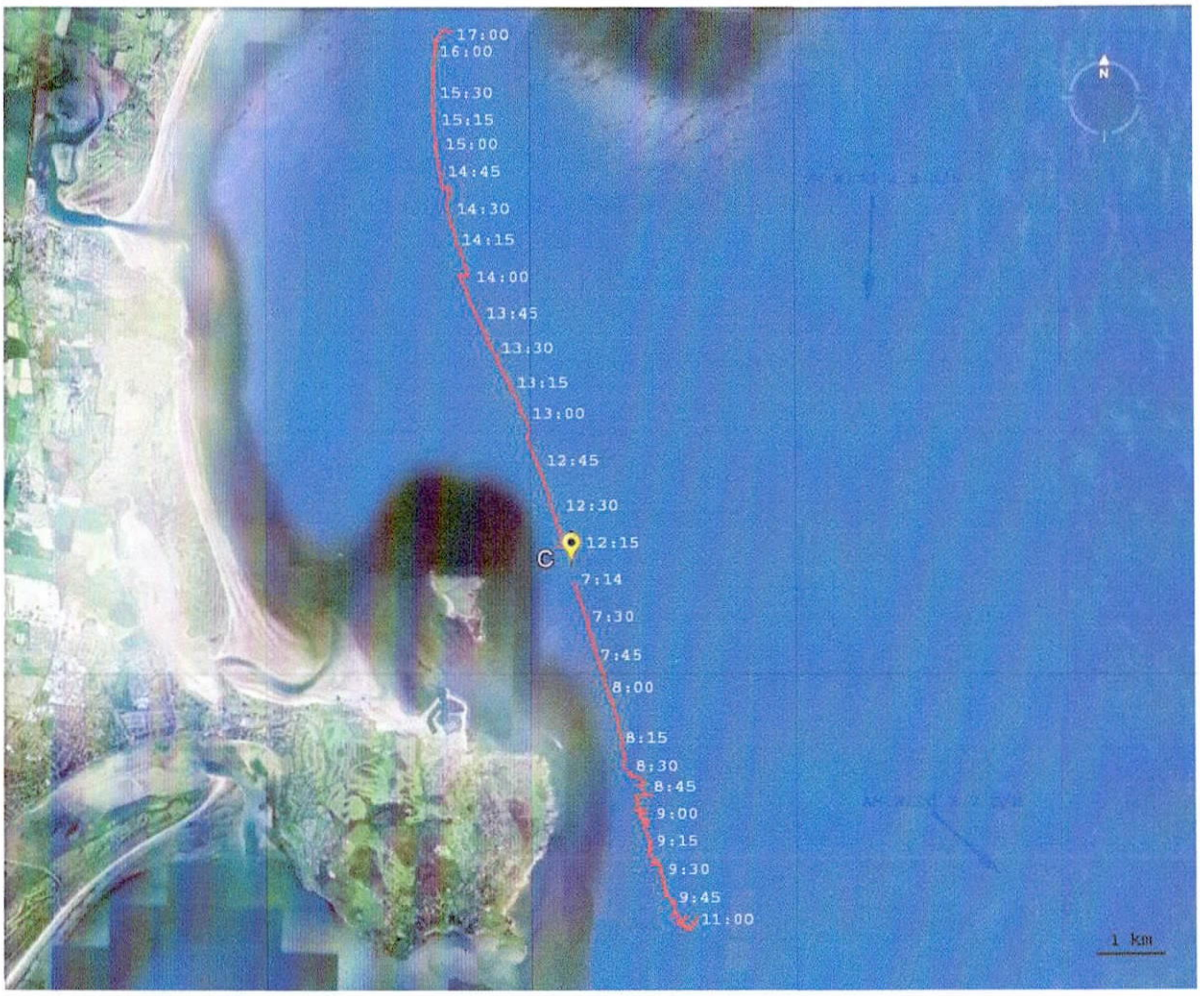


Figure 3-8 Path taken by the sub-surface drogue released with the dye at Site C during a neap tide on 26-7-2012.

Ebb Dye Plume

The flow direction and dilution rate of the dye released at 7:00 on 26th July is visually portrayed in Figure 3-9. In order to visualise the dye concentrations recorded along the transects, the scale of the concentrations have been enlarged i.e. the area of sea in which dye was recorded is not to scale with the land mass.

In the first hour following release, the dye plume continued in a southerly direction and expanded slowly with time in a relatively even fashion. By 8:30 the dye plume was formed into an oval shape, the longer axis in north-south line, with dye concentrations recorded along three transects through the plume indicating highest concentrations (*circa.* 120 µg/l) towards the leading edge. Dye flow and dispersion continued in this fashion over the next three hours with concentrations progressively decreasing to background levels by 11:00.

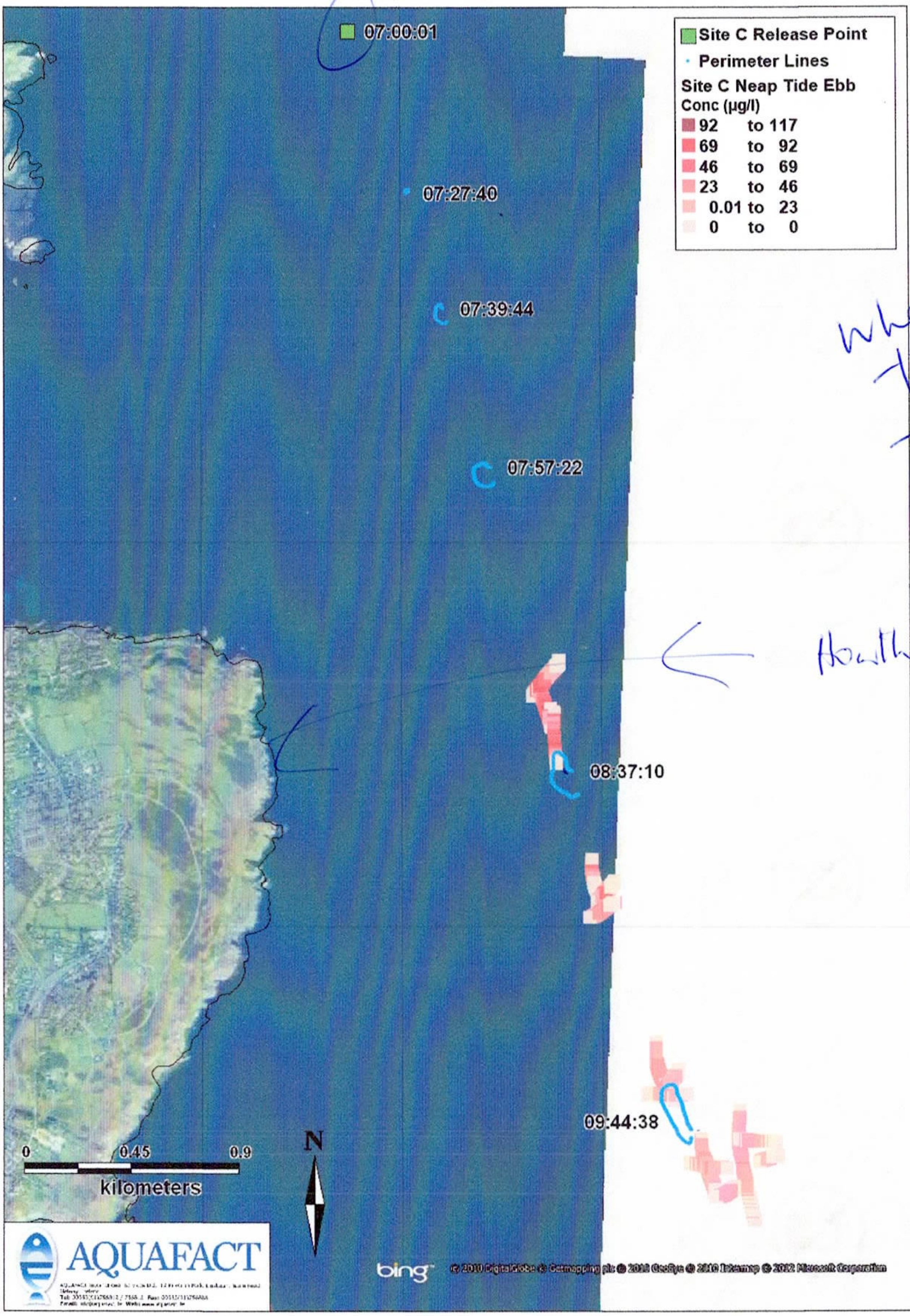


Figure 3-9 Neap ebb dye flow and dispersion, Site C, 26th July 2012

Neap

Flood Dye Plume

The flow direction and dilution rate of the dye released at 12:10 on 26th July is visually portrayed in Figure 3-10. In order to visualise the dye concentrations recorded along the transects, the scale of the concentrations have been enlarged.

In the first hour following release, the dye plume continued in a northerly direction and expanded slowly with time (Plate 3-1). Dye concentrations were recorded along the first transect across the plume at 12:44 with maximum concentrations (*circa.* 2800 µg/l) recorded towards the centre of the patch. As the dye plume progressed it formed into an elongated streak the long transect along an east-west axis. The dye continued in this fashion over the next four hours with concentrations progressively decreasing to background levels by 16:45.

Plate 3-1 Dye plume photographed 12:30 on the flood tide, Site C, 26th July 2012. (note Lambay Island in background)

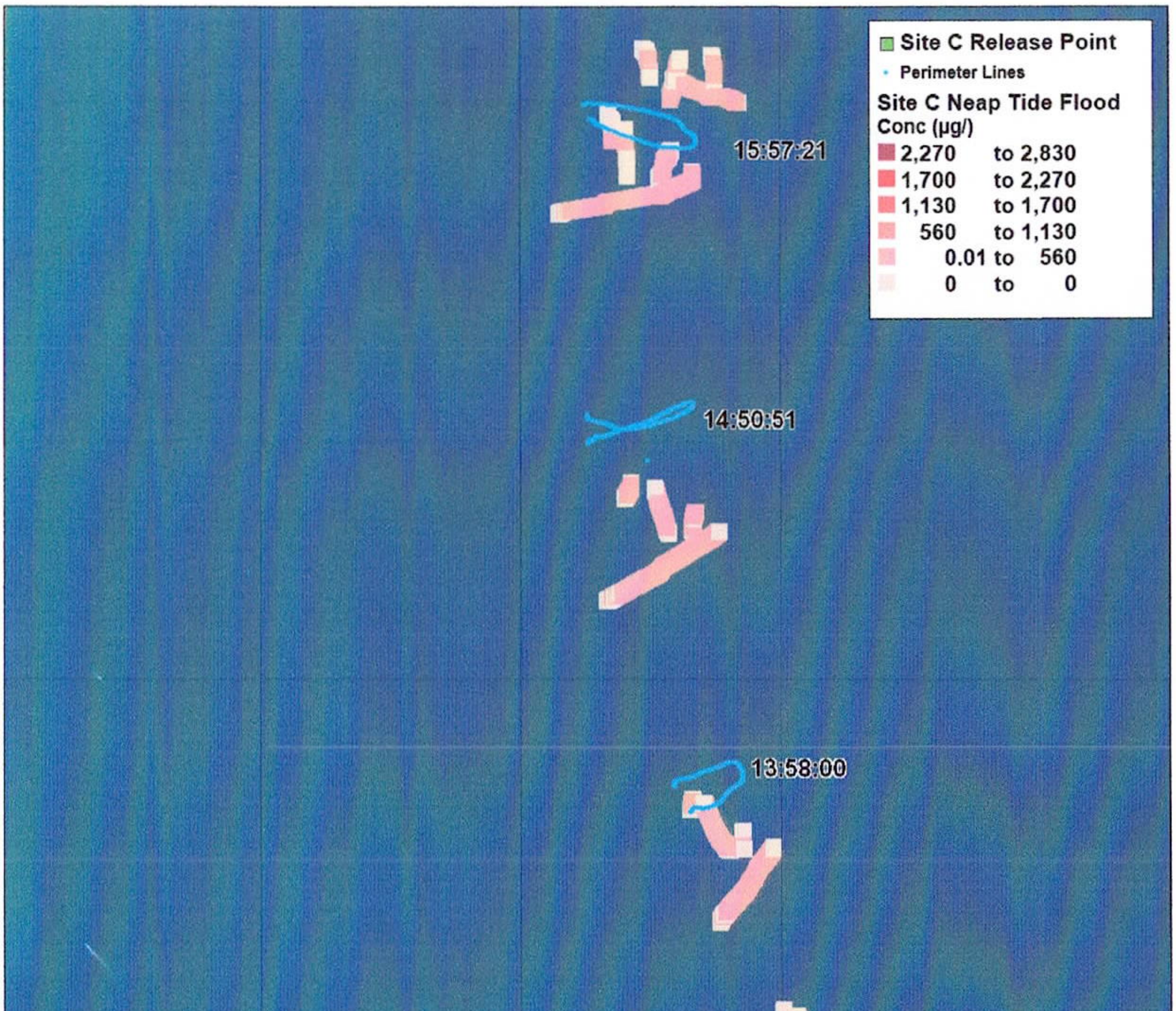


Figure 3-10 Neap flood dye flow and dispersion, Site C, 26th July 2012

3.2.3.2. Site A

Dye Drogue

The path taken by the sub-surface drogue that was released with the dye at Site A during the neap survey is presented in Figure 3.11.

During the ebb tide, the drogue travelled a total distance of 7.1 km south from the release point to end up just west of of Lambay Island. Wind speed was not a major influence in its progress.

During the flood tide, the drogue travelled a total distance of 5.9 km north-northwest of the release point to end up northeast of Skerries. Due to the prevailing northwest wind that became more influential once the dye and drogue passed the relative shelter of Skerries Head, the survey was terminated at this point as sea conditions deteriorated (Plate 3.2).

sea conditions

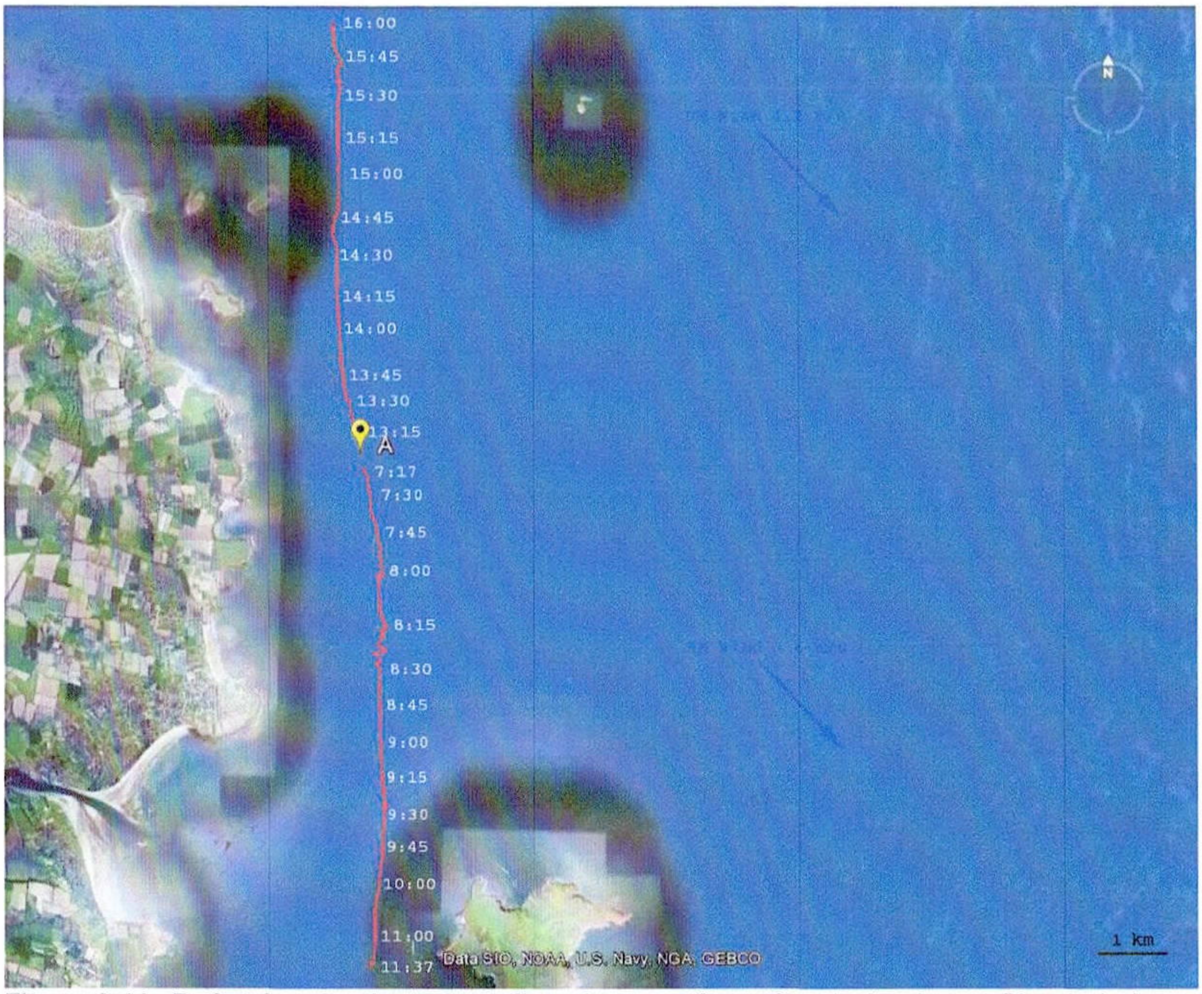


Figure 3-11 Path taken by the sub-surface drogue released with the dye at Site A during a neap tide on 27-7-2012.

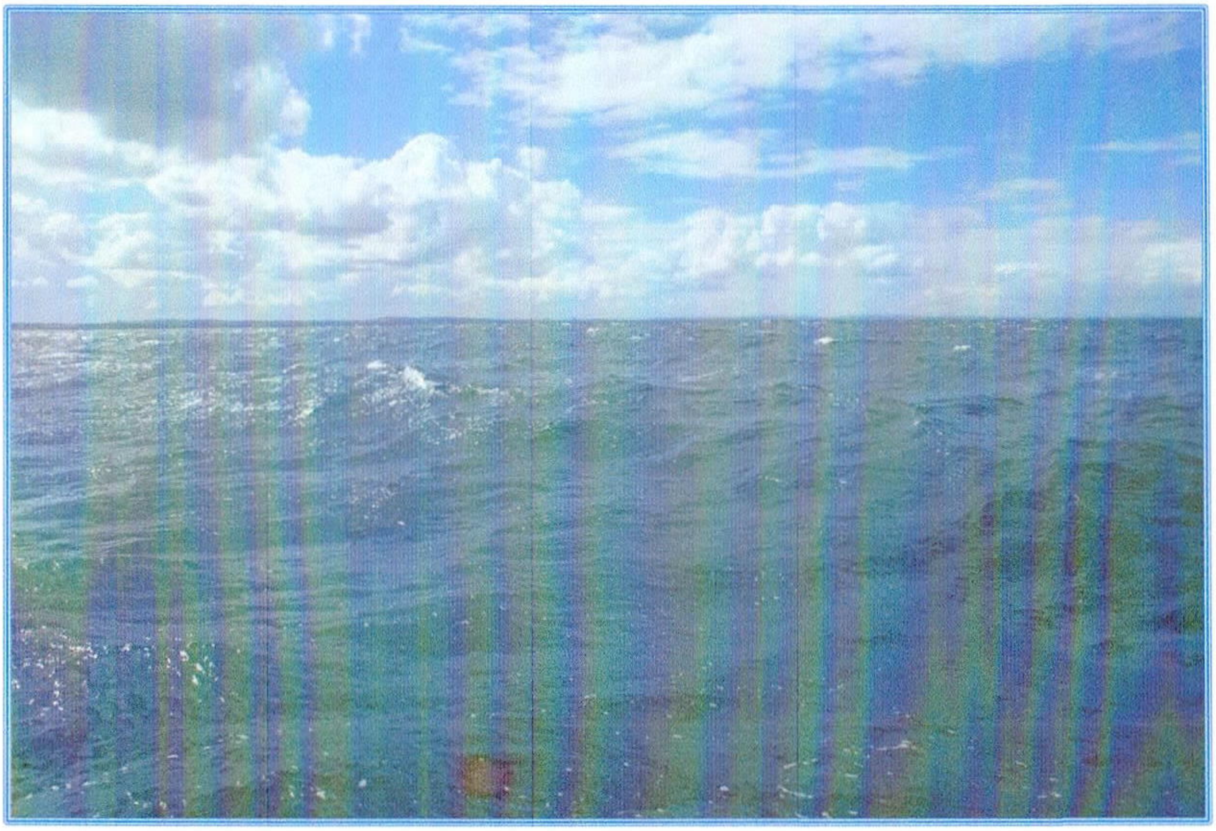


Plate 3-2 Sea conditions north of Skerries, 16:00 27th July 2012.

Ebb Dye Plume

The flow direction and dilution rate of the dye released at 7:15 on 27th July is visually portrayed in Figure 3-12. In order to visualise the dye concentrations recorded along the transects, the scale of the concentrations have been enlarged.

In the first hour following release, the dye plume continued in a southerly direction and expanded slowly with time in a relatively even fashion. The first transects were taken across the patch at 7:50 with highest concentrations (*circa.* 1495 µg/l) recorded towards the leading edge of the plume. Dye flow and dispersion continued in this fashion over the next three hours with concentrations decreasing rapidly to background levels by 9:25. Although the dye plume was no longer detectable after this time, the drogue released with the dye was left in the water and its path tracked to determine the total distance the dye would have travelled on this tide (see dye drogue description above).

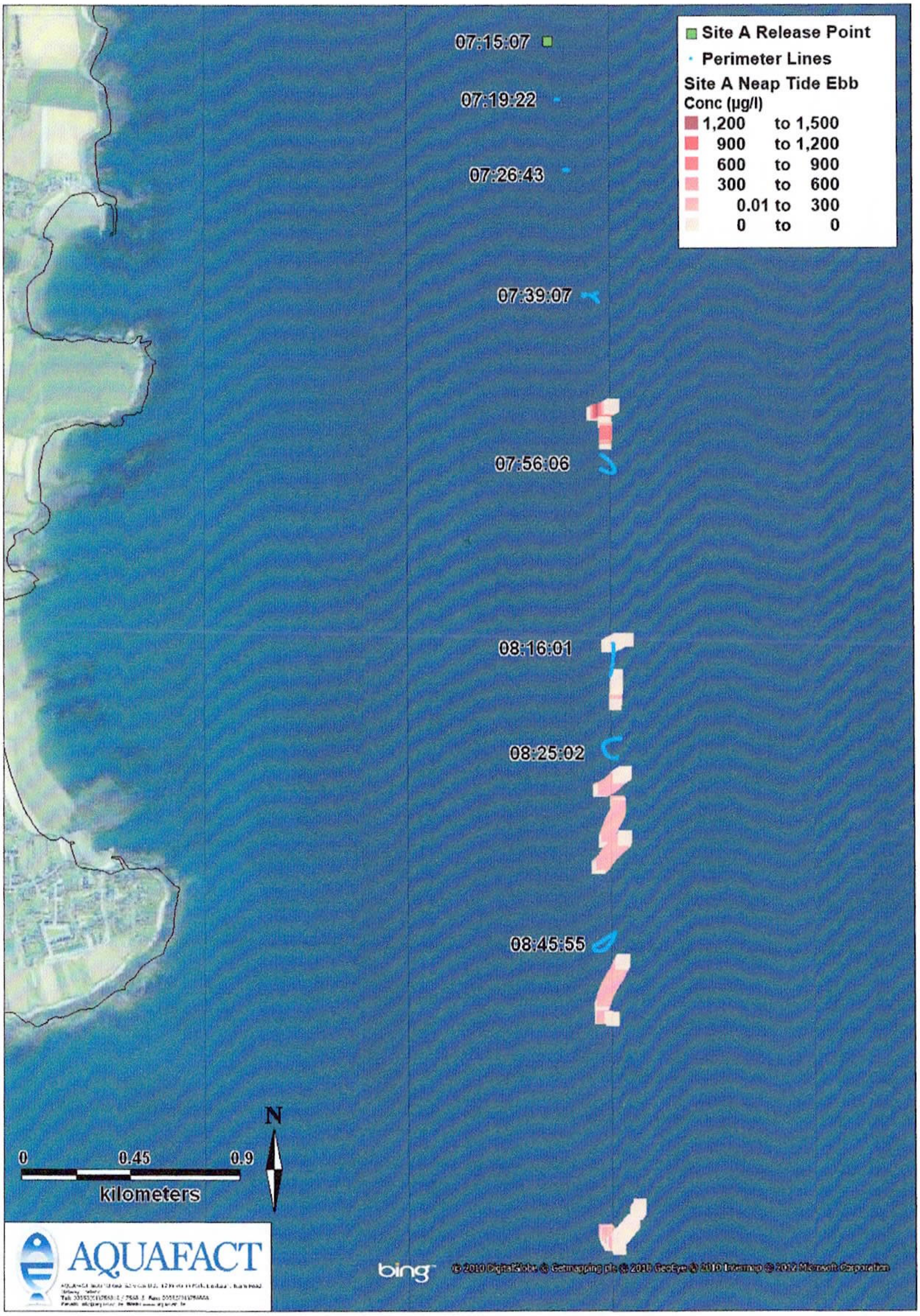


Figure 3-12 Neap ebb dye flow and dispersion, Site A, 27th July 2012

Flood Dye Plume

The flow direction and dilution rate of the dye released at 13:10 on 27th July is visually portrayed in Figure 3-13. In order to visualise the dye concentrations recorded along the transects, the scale of the concentrations have been enlarged.

In the first hour following release, the dye plume continued in a northerly direction and expanded slowly with time in a relatively even fashion. The first transects were taken across the patch at 13:29 with highest concentrations (1652 µg/l) recorded towards the leading edge of the plume. Dye flow and dispersion continued in this fashion over the next two hours with the final transect across the plume recorded at 15:46. Although the dye plume was still detectable after this time (max 59 µg/l), sea conditions didn't allow the survey to continue (see dye drogue description above).

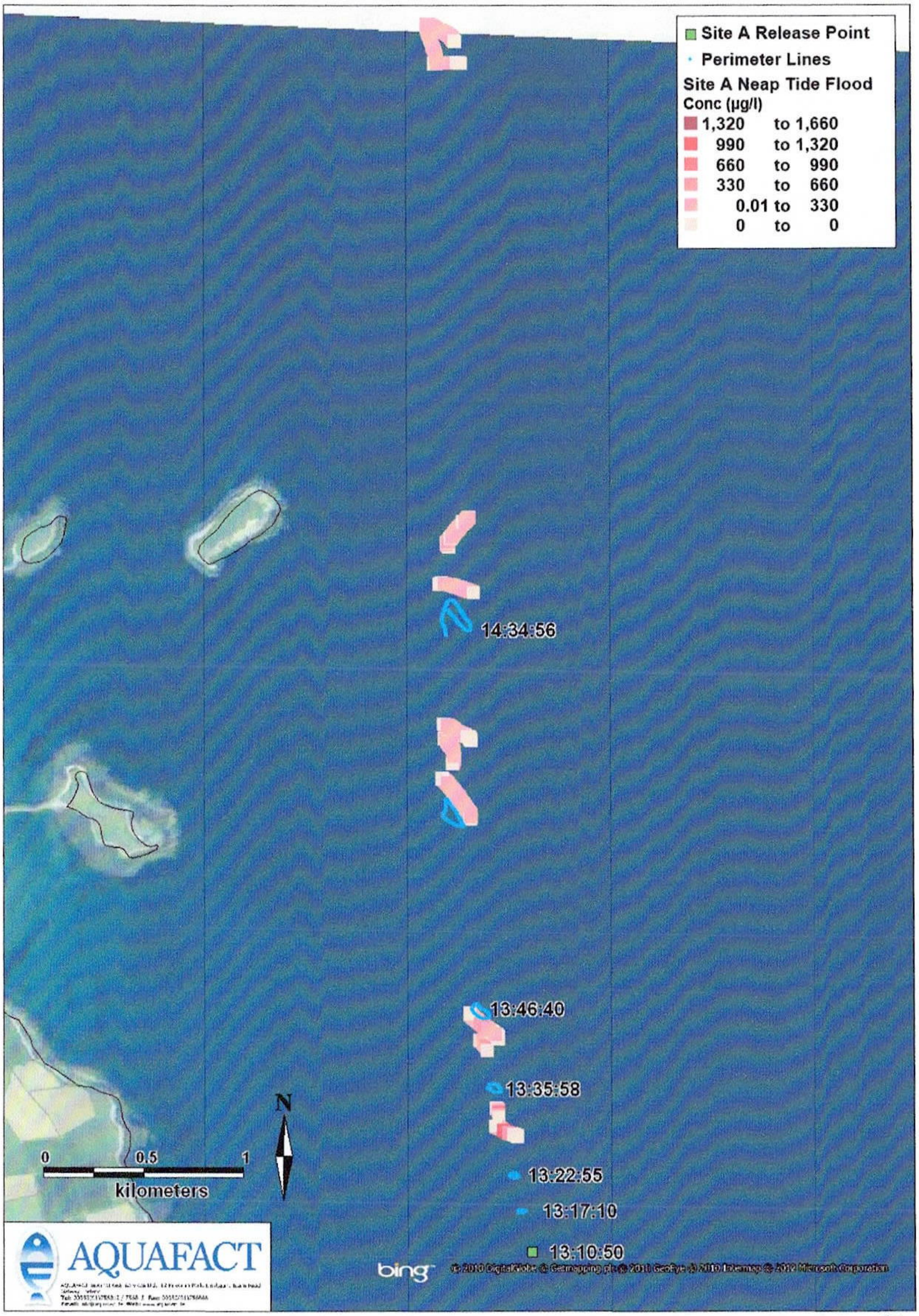


Figure 3-13 Neap flood dye flow and dispersion, Site A, 27th August 2012

July?

— September

3.3. *Spring Tide*

The spring tide surveys occurred on the 18th and 19th August 2012. Weather forecasts indicated a light to moderate south westerly breeze for both days. Tidal forecasts for Howth for these days are presented in Table 3.8.

Day	Date	Time	Height(m)
Sat	18/9/12	0023	4.31
		0619	0.31
		1249	4.02
		1829	0.41
Sun	19/9/12	0204	4.39
		0753	0.21
		1427	4.25
		2015	0.30

Table 3-8 Tide Forecast, Howth, 18th & 19th August 2012

3.3.1. Wind Records

Wind records recorded during the neap tide surveys are included as excel file "JN1156 Wind Speed Neap and Spring" and a summary of these results presented as wind roses in Figure 3.14. Wind conditions were variable over the two days with a light westerly breeze predomination for the morning of the 18th (mean speed of 3.3 ms^{-1}) that changed direction around midday to a southerly wind and increased as the afternoon progressed (mean of 4.4 ms^{-1}). Wind speeds were slightly stronger on the 19th with a mean speed of 4.2 ms^{-1} in the morning that progressively increased over the afternoon. The survey was terminated when recorded mean wind speeds were 6.5 ms^{-1} (23.4 kmh^{-1}) with gusts in excess of 7.5 ms^{-1} (27 kmh^{-1}) from a southeast direction.

Terminated

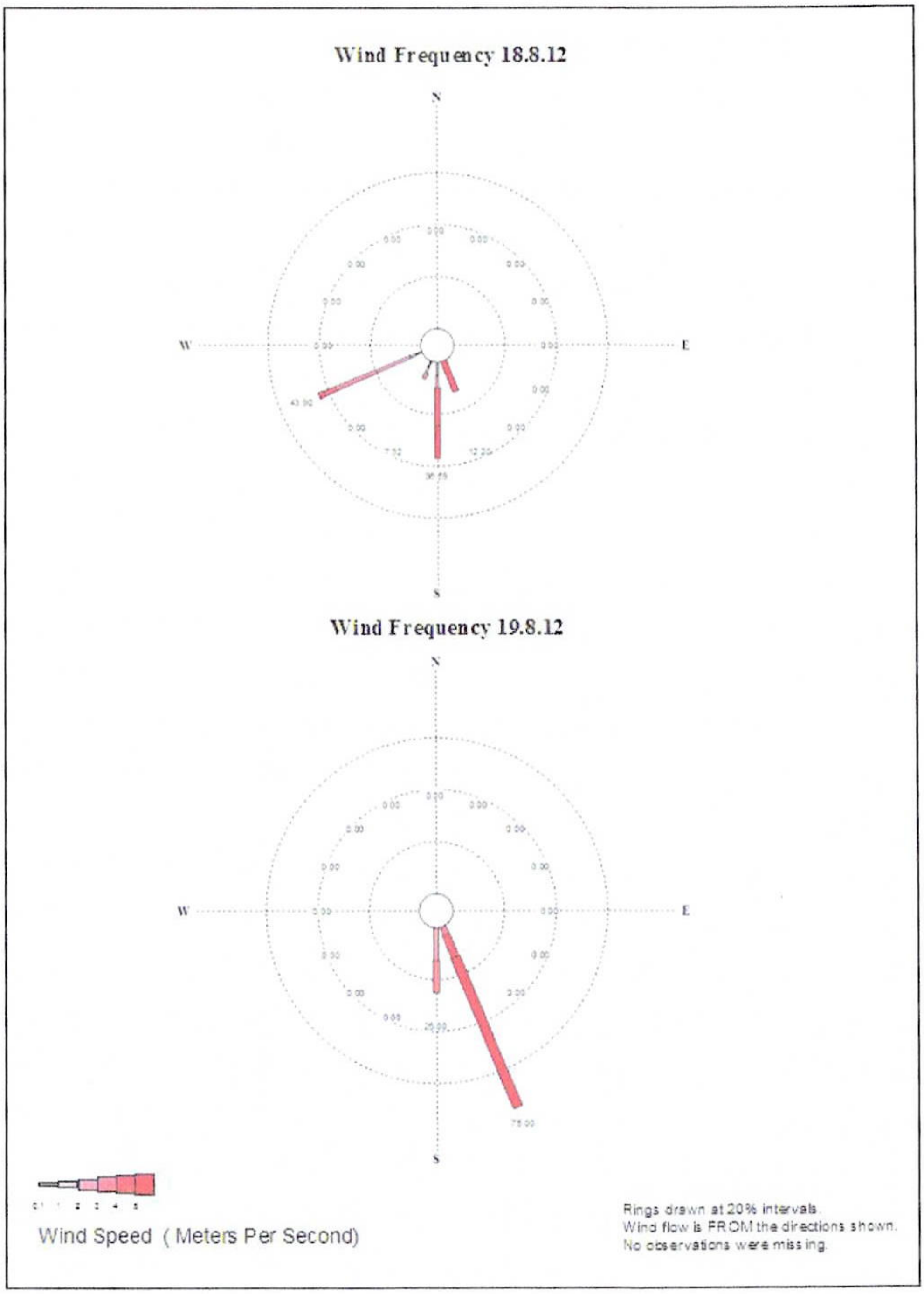


Figure 3-14 Wind frequency distribution experienced off North Count Dublin during the spring surveys.

3.3.2. Drogue Survey

Drogue track data recorded during the spring tide surveys at Site A and C are detailed in Excel files accompanying this report. A brief summary of this data is included in Tables 3-8 to 3-13 and the tracks of the drogues presented in Figures 3-8 to 3-13. Due to deteriorating weather conditions, the survey was terminated early on the 19th as wind speeds exceeded ms^{-1} with an associated increase in wave height.

3.3.2.1. Site C

The three drogues followed similar paths on both the ebb and flood tide along a northeast-southwest axis (see Figures 3-5 to 3-8). The maximum speed recorded by the three drogues occurred during the ebb tide where the surface drogue recorded a mean speed of 0.84 ms^{-1} having travelled a total distance of just under 3 km during its 55 minute float time (Table 3.8). The off-bottom drogue was dragged for a period by a passing boat during the ebb tide (Drogue release 8, Table 3-10)

3.3.2.2. Site A

The three drogues followed paths along a north-south axis. Maximum speeds were recorded during the ebb tide where the sub-surface drogue recorded a mean speed of 0.90 ms^{-1} having travelled a total distance of just under 2.5 km during its 46 minute float time.

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:16:04	41	1611	0.65	10
2	08:09:23	56	2711	0.81	330
3	09:15:30	53	2482	0.78	340
4	10:17:35	49	1352	0.46	340
5	11:15:52	52	356	0.11	180
6	12:09:31	74	1989	0.45	160
7	13:28:05	30	1374	0.76	150
8	14:06:17	55	2769	0.84	170
9	15:13:53	59	2462	0.70	160
10	16:25:53	38	936	0.41	25
11	17:12:40	26	253	0.16	10

— max speed

Table 3-9 Sub-surface drogue, 18/8/2012

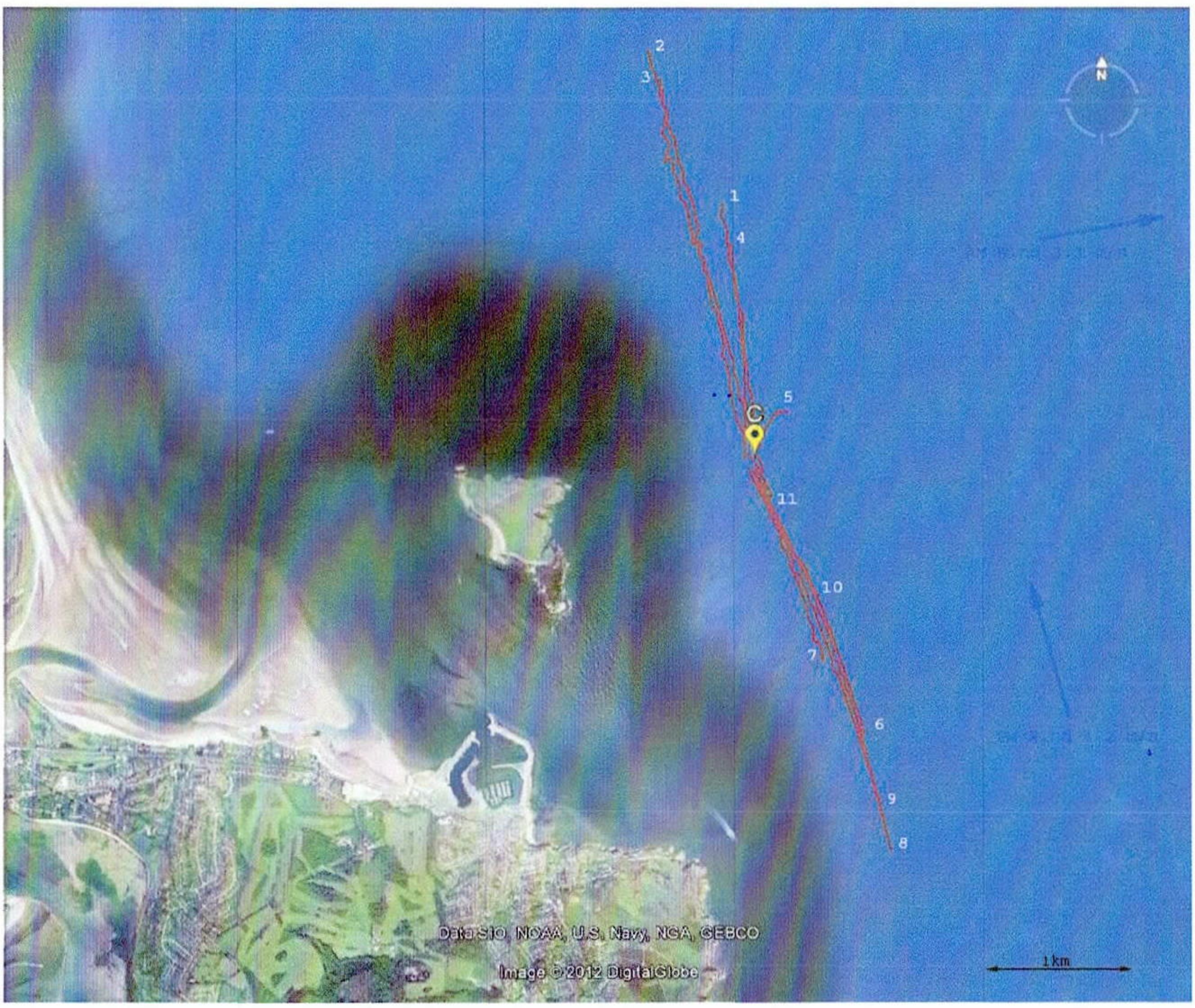


Figure 3-15 Spring sub-surface drogue tracks, 18/8/2012

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:13:58	44	1687	0.64	320
2	08:09:35	58	2679	0.77	300
3	09:15:01	50	2300	0.77	260
4	10:19:01	49	1531	0.52	350
5	11:19:55	43	295	0.11	300
6	12:10:28	71	1421	0.33	150
7	13:28:41	31	1308	0.70	170
8	14:06:10	57	2939	0.86	170
9	15:14:02	61	2822	0.77	165
10	16:24:18	43	1216	0.47	160
11	17:12:02	30	554	0.31	240

Table 3-10 Mid-water drogue, 18/8/2012

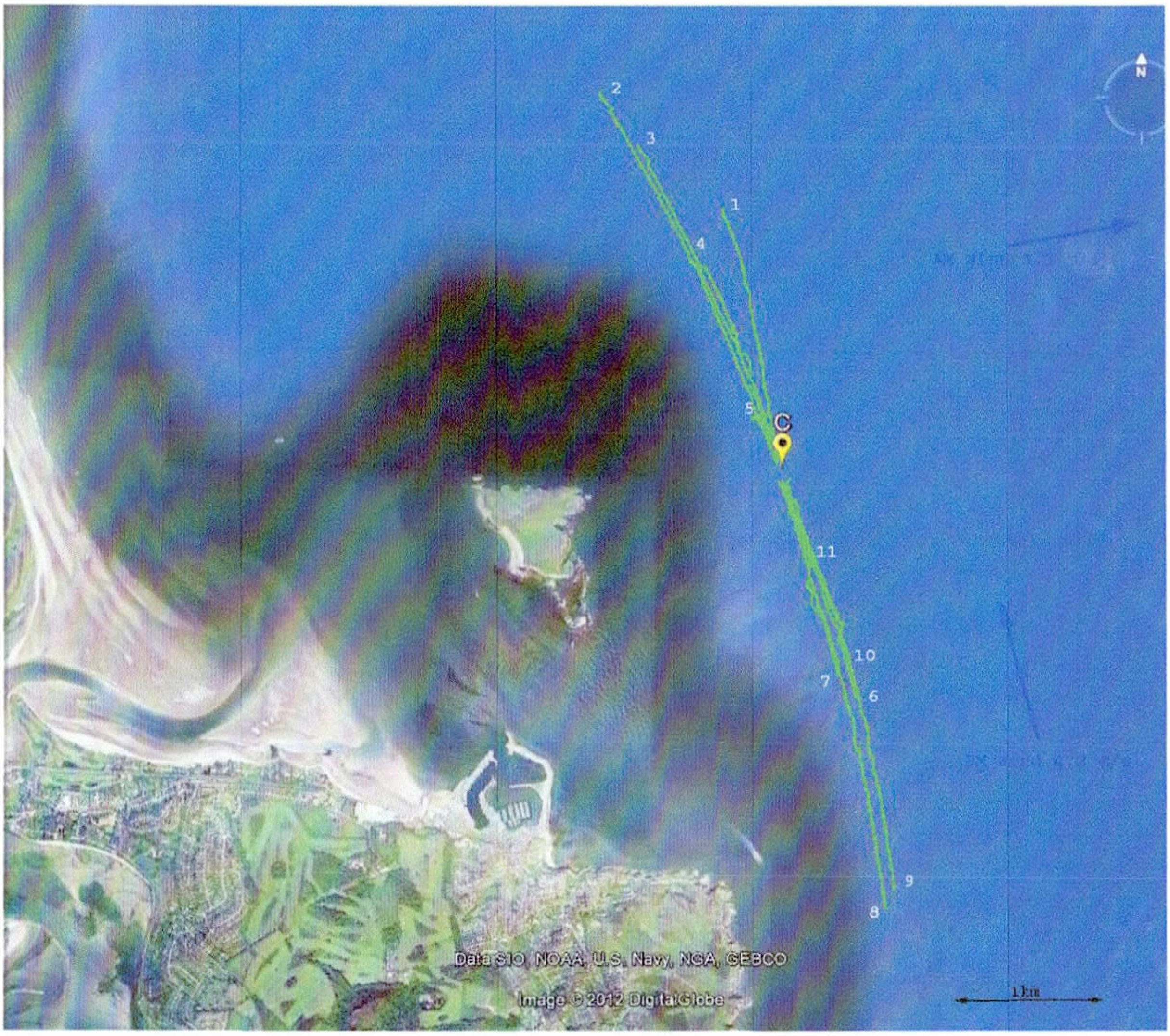


Figure 3-16 Spring mid-water drogue tracks, 18/8/2012

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:13:33	47	1449	0.51	330
2	08:08:09	59	2502	0.71	300
3	09:14:44	51	2069	0.68	330
4	10:18:36	52	1397	0.45	330
5	11:15:01	50	451	0.15	200
6	12:10:06	70	1346	0.32	180
7	13:29:09	31	1278	0.69	160
8	14:06:26	59	2724	0.77	170
9	15:13:20	60	2540	0.71	160
10	16:25:12	40	1140	0.48	170
11	17:12:18	28	321	0.19	160

This was dragged by boat, under 3 km in 55 mins

Table 3-11 Off-bottom drogue, 18/8/2012

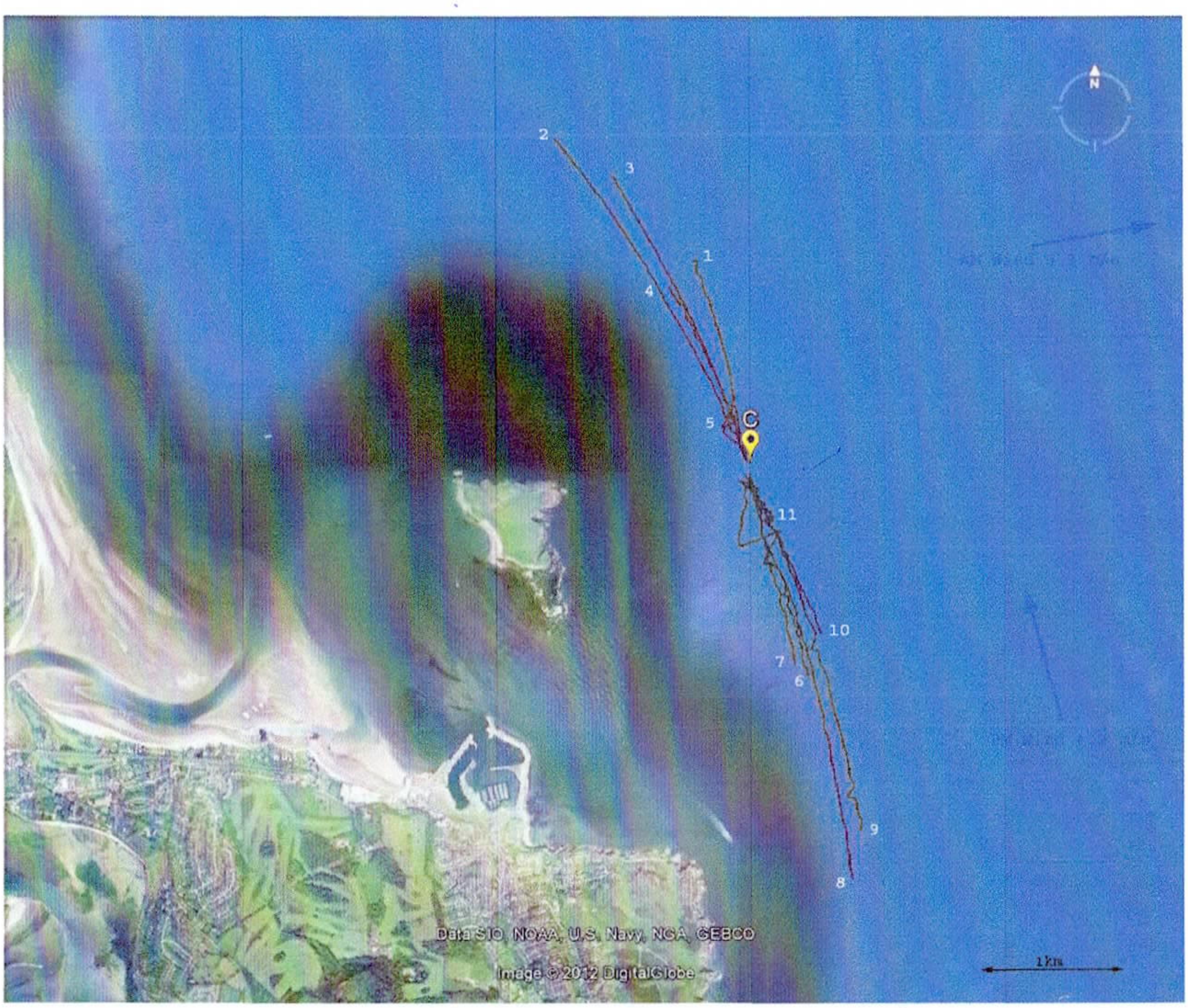


Figure 3-17 Spring off-bottom drogue tracks, 18/8/2012

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Approx. Course (deg)
1	07:20:22	40	1828	0.76	55
2	08:13:42	46	2479	0.90	65
3	09:10:35	50	2230	0.74	50
4	10:11:35	57	2053	0.60	360
5	11:17:59	40	840	0.35	360
6	12:13:37	51	210	0.07	170
7	13:13:48	41	898	0.37	170
8	14:03:05	54	1593	0.49	170
9	15:03:02	48	1349	0.47	180

Table 3-12 Sub-surface drogue, 19/8/2012

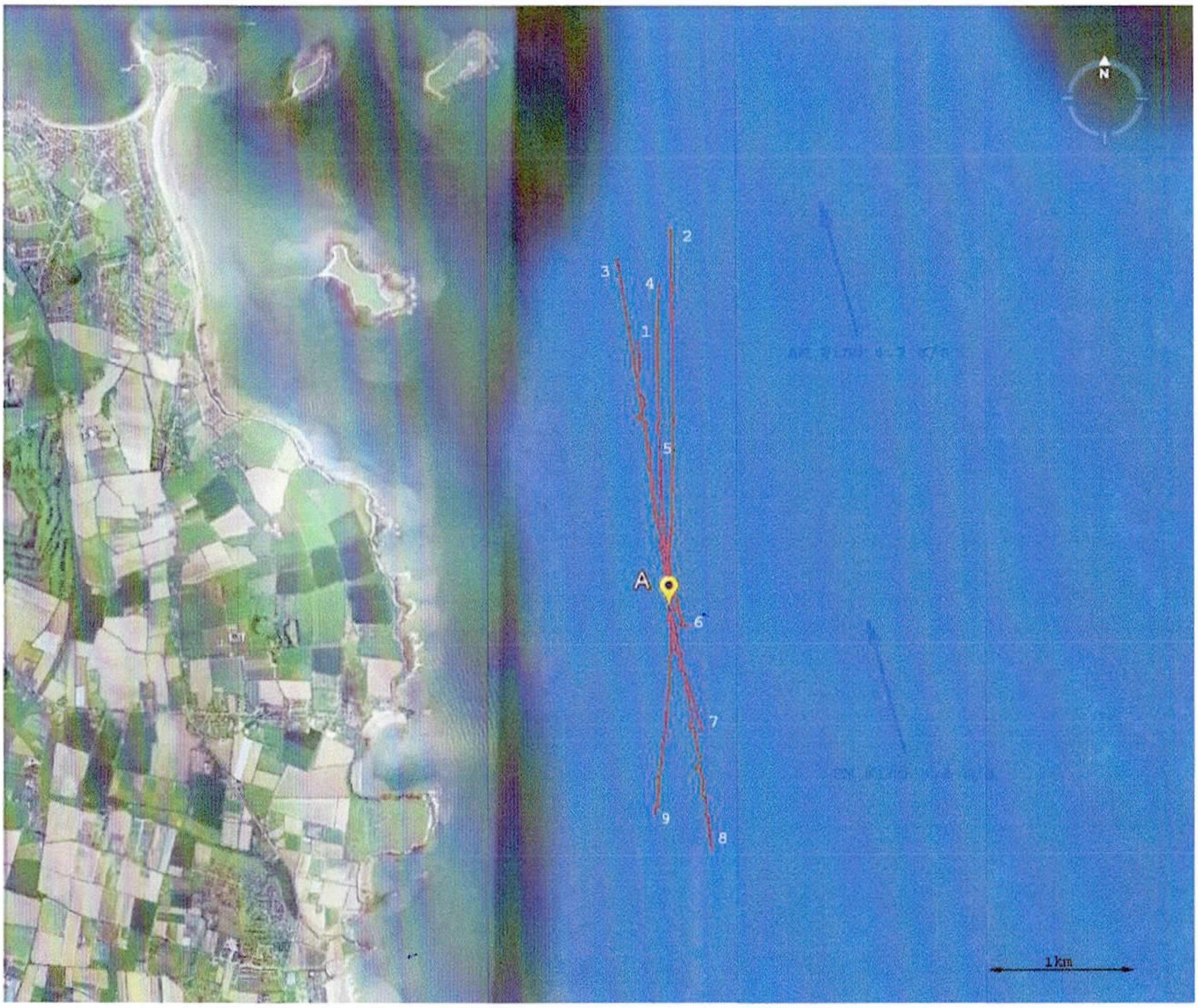


Figure 3-18 Spring sub-surface drogue tracks, 19/8/2012

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Approx. Course (deg)
1	07:19:04	42	1496	0.59	360
2	08:12:16	50	2221	0.74	360
3	09:08:41	55	2015	0.61	360
4	10:10:54	60	21675	0.47	350
5	11:17:55	51	665	0.22	360
6	12:12:25	55	498	0.15	180
7	13:12:22	44	1014	0.38	180
8	14:03:25	48	1358	0.51	180
9	15:05:00	44	1321	0.50	180

Table 3-13 Mid-water drogue, 19/8/2012

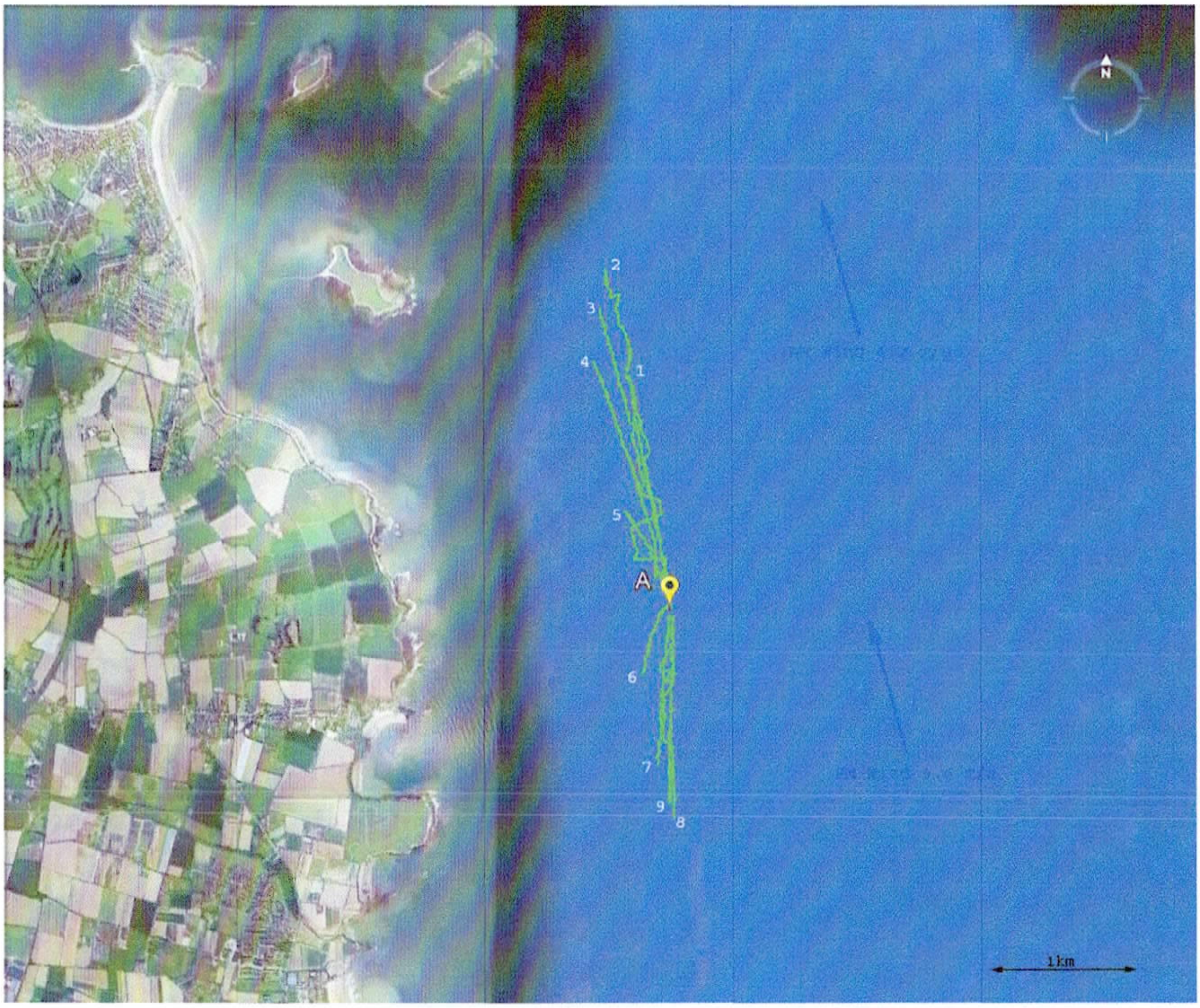


Figure 3-19 Spring mid-water drogue tracks, 19/8/2012

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Approx. Course (deg)
1	07:20:34	43	1574	0.61	360
2	08:12:05	48	2248	0.78	360
3	09:09:53	54	2021	0.62	350
4	10:10:23	55	1679	0.51	300
5	11:19:05	47	729	0.26	260
6	12:12:57	52	487	0.16	200
7	13:12:50	46	981	0.36	180
8	14:02:36	51	1399	0.46	190
9	15:04:28	44	1125	0.43	170

Table 3-14 Off-bottom drogue, 19/8/2012

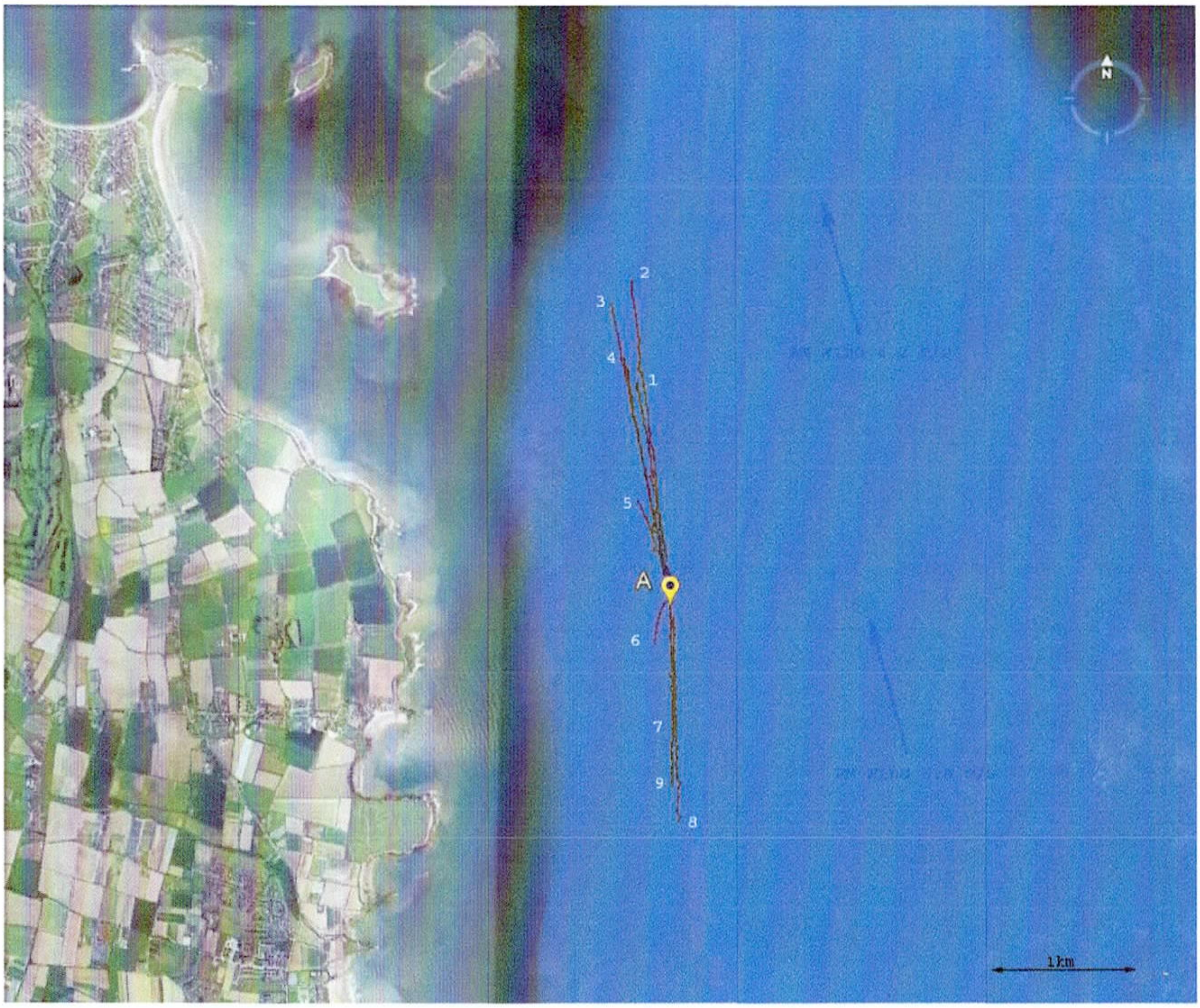


Figure 3-20 Spring off-bottom drogue tracks, 19/8/2012

3.3.3. Dye Survey

Data recorded during the dye releases during the spring tide surveys at Site A and C are detailed in Excel files accompanying this report. Data include dye release times, the progress of the dye plume over time as plume perimeter coordinates and dye concentrations with position coordinates along transects through the dye plume. In addition, the coordinates of the sub-surface drogue released to accompany the dye plume are also included as an excel file.

Representative diagrams of the progress of the plumes as they progress over the survey periods are presented below. Initially the position and size of the plumes were recorded by recording the visible perimeter of the plumes and later by recording dye concentrations along transects through the plumes. However, it must be remembered that the dye plume is constantly moving and the start and end position of the perimeter is slightly out of sync and the position of dye concentrations along one transect is not directly related to the position of concentrations along a second transect taken across the same plume shortly after the first.

3.3.3.1. Site C

Dye Drogue

During the start of the spring survey the dye drogue that was released with the dye was run over by a passing boat with the loss of the drogue and gps tracker. Consequently the 1 minute track data that was recorded during the heap survey was not available. However, a second drogue, without a gps tracker, was released with the dye and the location of this drogue recorded when possible by onboard DGPS. The path taken by this drogue at Site C during the spring survey is presented in Figure 3.21. Recorded wind speeds were relatively light during the morning (west 3.2 ms^{-1}) although increased to moderate (south 4.2 ms^{-1}) in the afternoon during the ebb tide.

During the flood tide, the drogue travelled a total distance of *circa* 6 km north from the release point to end up south west of Lambay Island after a three and a half hour drift. There was little movement of the drogue in the last hour of its deployment.

During the flood tide, the drogue travelled a total distance of just over 7.0 km south of the release point to end up southeast of Howth Head after two and a half hours. However, as the drogue and dye were drifting into the Dublin commercial shipping zone, the study had to be terminated for safety reasons as a number of ferries and commercial ships approached.

Figure 3-21 Path taken by the sub-surface drogue released with the dye at Site C during a spring tide on 18-8-2012.

Flood Dye Plume

The flow direction and dilution rate of the dye released at 8:13 on 18th August is visually portrayed in Figure 3-22. In order to visualise the dye concentrations recorded along the transects, the scale of the concentrations have been enlarged.

In the first hour following release, the dye plume continued in a northerly direction and expanded slowly with time (Plate 3-1). Dye concentrations along the first series of transects were recorded at 9:00 with a maximum concentration of 544 µg/l recorded towards the centre of the patch. As the dye plume progressed it formed into an elongated streak the long transect along an east-west axis. Dye concentrations decreased rapidly to background levels and by 10:00 no dye could be recorded in the water. The drogue associated with this plume was left in the water and its position recorded intermittently for the rest of the tide (see relevant drogue description above).

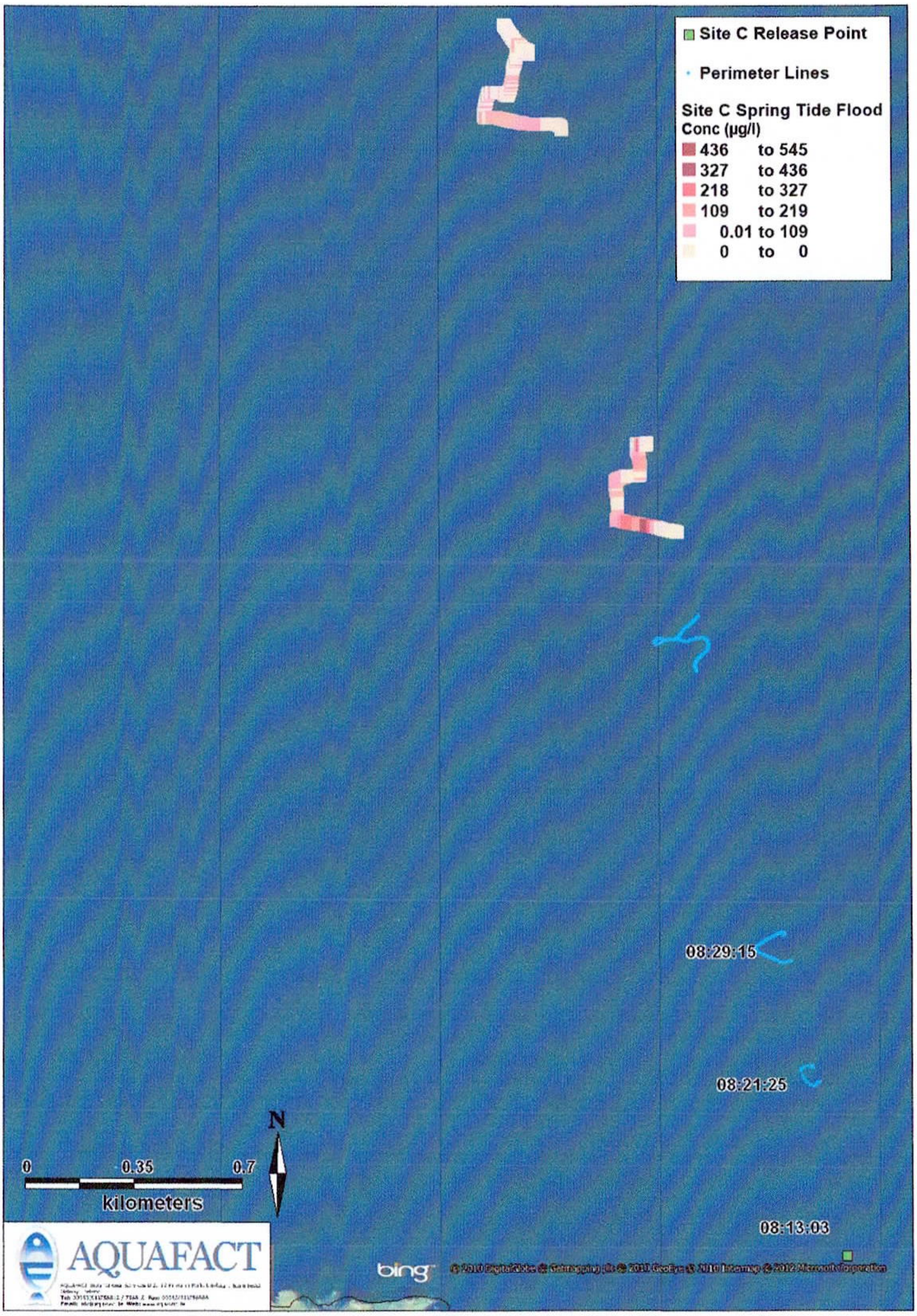


Figure 3-22 Spring flood dye flow and dispersion, Site C, 18th August 2012

Ebb Dye Plume

The flow direction and dilution rate of the dye released at 13:32 on 18th August is visually portrayed in Figure 3-23. In order to visualise the dye concentrations recorded along the transects, the scale of the concentrations have been enlarged.

In the first hour following release, the dye plume continued in a southerly direction and expanded slowly with time (Plate 3-3). Dye concentrations along the first series of transects were recorded at 14:23 with a maximum concentration of 3966 µg/l recorded towards the centre of the patch. As the dye plume progressed it formed into an elongated streak the long transect along an southwest-northeast axis. Dye concentrations decreased progressively over the study. However, although dye was readily detectable during the last transect across the plume (max concentration 744 µg/l) the study had to be terminated for safety reasons as the drogue and dye were drifting into the Dublin commercial shipping zone.

Terminated

Plate 3-3 Dye plume following release at Site C during the ebb tide, 18th August 2012

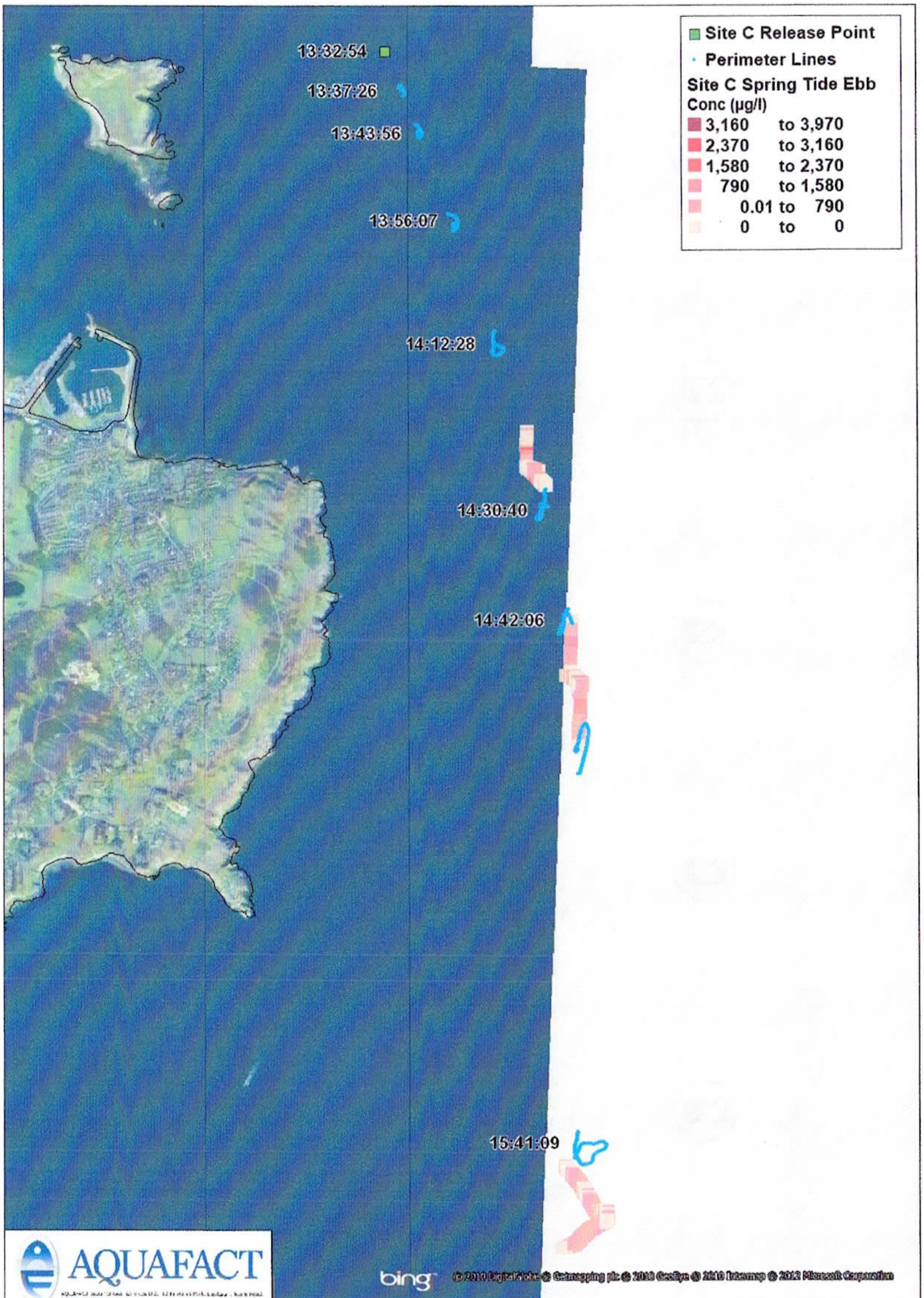


Figure 3-23 Spring ebb dye flow and dispersion, Site C, 18th August 2012

3.3.3.2. Site A

Dye Drogue

The path taken by the sub-surface drogue released with the dye at Site A during the spring survey is presented in Figure 3.24. Recorded wind speeds were moderate during the morning (southeast 4.2 ms^{-1}) and increased in the afternoon (southeast 5.8 ms^{-1}) during the ebb tide.

During the flood tide, the drogue travelled a total distance of *circa* 8.5 km north from the release point to end up northeast of Skerries by 11:00.

During the ebb tide, the drogue travelled a total distance of just over 4.2 km south of the release point after two hours. However, due to deteriorating weather conditions, the survey was terminated early on the 19th as wind speeds exceeded 7 ms^{-1} with an associated increase in wave height.

Figure 3-24 Path taken by the sub-surface drogue released with the dye at Site A during a spring tide on 19-8-2012.

Flood Dye Plume

The flow direction and dilution rate of the dye released at 8:18 on 19th August is visually portrayed in Figure 3-25. In order to visualise the dye concentrations recorded along the transects, the scale of the concentrations have been enlarged.

In the first hour following release, the dye plume continued in a southerly direction and expanded slowly with time. Dye concentrations along the first series of transects were recorded at 8:50 with a maximum concentration of 1822 µg/l recorded towards the trailing edge of the patch. Dye concentrations decreased progressively and dye couldn't be detected in the water after 10:30. The drogue released with the dye was left in the water to give an indication the distance the dye would have travelled over the flood tide.

Ebb Dye Plume

The flow direction and dilution rate of the dye released at 13:27 on 19th August is visually portrayed in Figure 3-26. In order to visualise the dye concentrations recorded along the transects, the scale of the concentrations have been enlarged.

In the first hour following release, the dye plume continued in a southerly direction and expanded slowly with time forming into an elongated streak, the main axis along a southwest-northeast line. Dye concentrations along the first series of transects were recorded at 14:20 with a maximum concentration of 511 µg/l recorded towards the middle of the patch. Dye concentrations decreased progressively over the study. However, although dye was readily detectable during the last transect across the plume (max concentration 522 µg/l) the study had to be terminated for safety reasons as weather conditions deteriorated as described above.

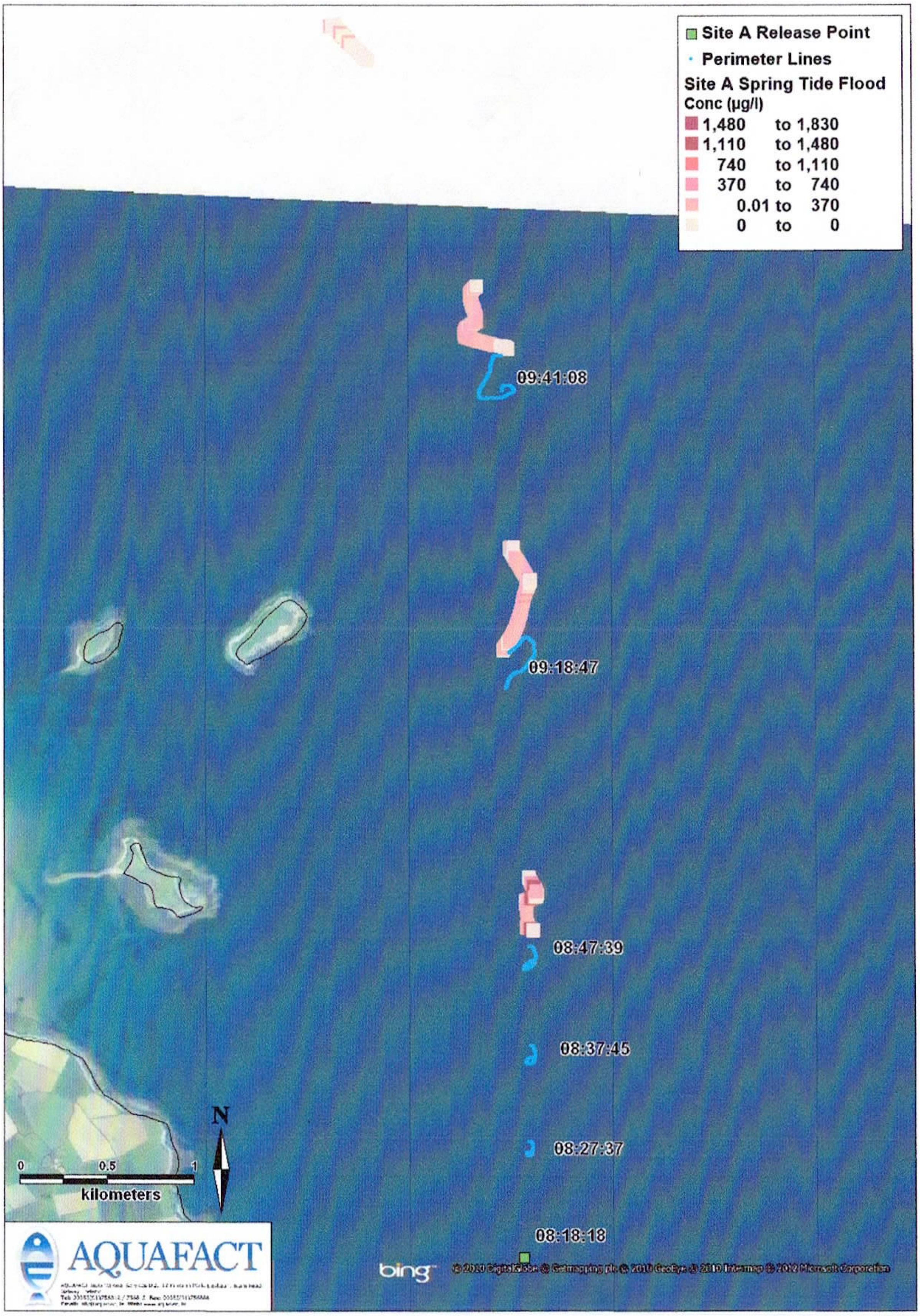


Figure 3-25 Spring flood dye flow and dispersion, Site A, 19th August 2012

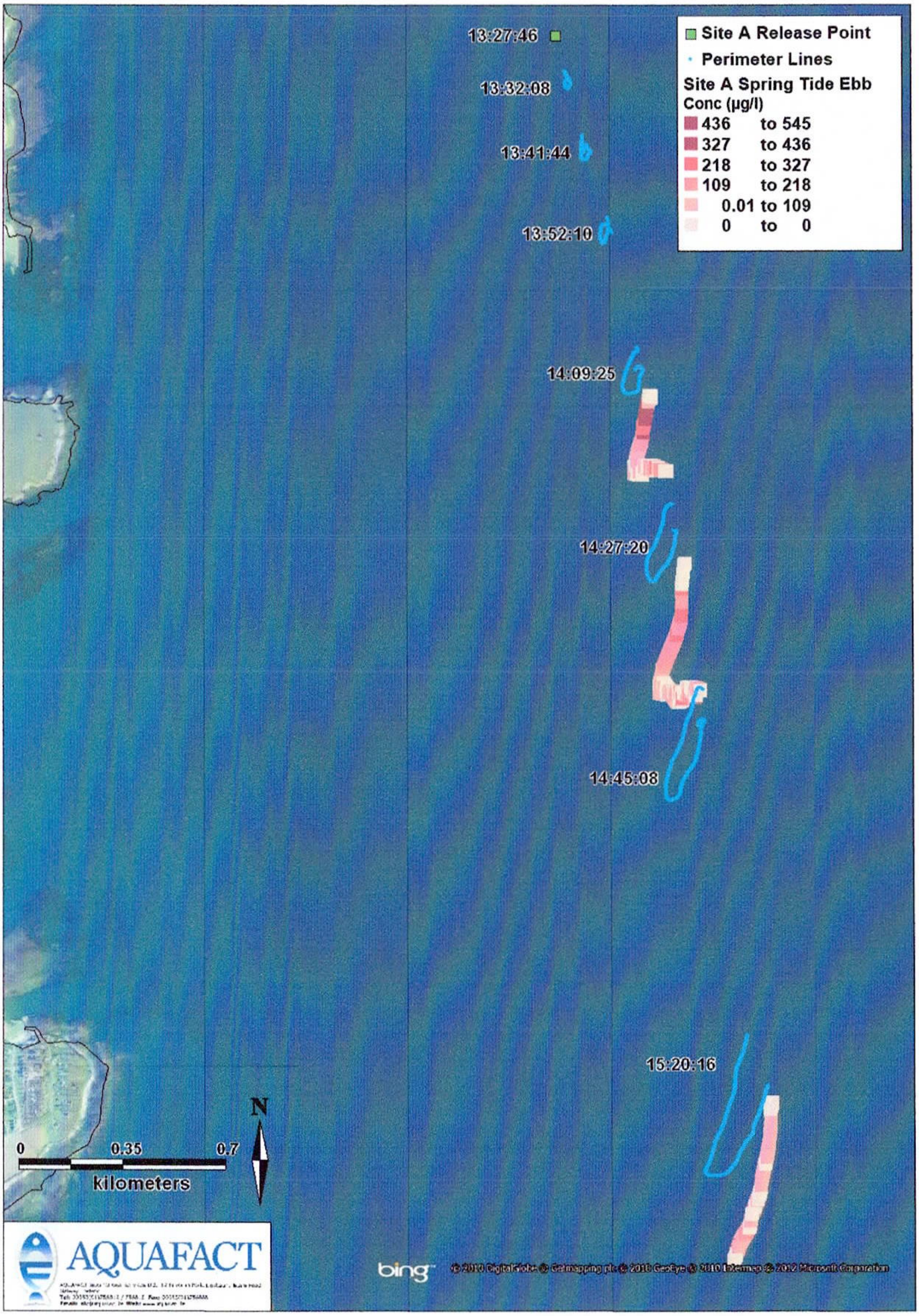


Figure 3-26 Spring ebb dye flow and dispersion, Site A, 19th August 2012

AQUAFACT

Drogue and Dye Studies off North County Dublin

April June 2015

Report to

TechWorks Marine Limited

Produced by

APP 5

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1. Introduction

AQUAFACT International Services Ltd. were contracted by TechWorks Marine Ltd. to undertake a marine (tide and current) survey in the North Dublin area in the vicinity of Irelands Eye off Howth, North County Dublin. This follows on from previous surveys carried out in 2012 (AQUAFACT, 2012) to aid in the determination of the optimum location for an outfall pipeline and diffuser, which forms part of the transfer pipeline from a Regional Wastewater Treatment Plant (WwTP) to serve the Greater Dublin Area. The need for the scheme arises from the broadening gap between developing load in the Greater Dublin Area (GDA), and the maximum load which can be delivered to, and treated at the existing treatment plants in the catchment, primarily at Ringsend WwTP. AQUAFACT International services Ltd. were responsible for drogue and dye studies at the location.

no coordinates for 2012 survey

2. Methodology

2.1. *Introduction*

The present survey consisted of dye and drogue releases at a single location (approx. 53°24' 59.6"N 6°04'39.2"W) on both a neap and spring tide. The spring survey occurred on 20th April while the neap survey did not take place until the 9th of June, weather conditions proving unsuitable on numerous spring periods prior to that. Wind speed and direction were recorded regularly during the surveys by means of a hand held anemometer and compass to account for any wind-induced influences, which may have been exerted on the drogues and dye.

2.2. *Dye Study*

Rhodamine WT, a dye designed specifically for water tracing studies, was the chosen tracer for this study. Prior to release, the dye was diluted with methanol and distilled water to adjust its density close to that of the receiving water so that the dye dispersed through the water column. The resulting mixture was treated as a 100% concentrated tracer. A sample of this concentrate was diluted with ambient seawater to 100μg/l and used as a standard to calibrate a direct reading fluorimeter. Once calibrated, all subsequent measurements with the fluorimeter were related to the original 100% tracer released into the water.

Five litres of dye were released into the receiving waters after predicted high water, mid-ebb, low water and mid-flood during both a spring and neap tide i.e. 8 dye releases. Following release, the position and edges of the dye patch were recorded by DGPS fitted on the survey boat. When the dye patch was sufficiently dispersed to allow in-situ measurements with the fluorimeter, transects were steered through the patch at regular intervals with the fluorimeter continuously recording dye concentrations at approximately 1 m below the water surface. Transects were recorded along the main axis of the plume followed by a number of secondary transects across the short axis.

Transects continued through the dye patch at regular intervals for a period of two hours after release or until either background levels were recorded throughout the general area of the patch or it was not possible to continue as the dye dispersed into areas which were not accessible to the operators (e.g. rocky shore etc.).

Rocks

2.3. *Drogue Study*

Current tracking drogues, designed to track currents at sub-surface, mid-water (3m) and off-bottom (6m), were released into the water body at the same location on the same dates as the dye study. The tracks of the drogues were recorded every minute by means of a small GPS, which was attached to the drogue pole. Each of the drogues was allowed to travel for approximately one hour before it was recovered and redeployed at the start location. This was repeated for a complete tidal cycle at both locations during both the neap and spring tidal conditions.

In addition to the hourly deployed drogues, a single sub-surface drogue was deployed with the dye to help relocate the dye patch when the dye dispersed below visual detection levels. This drogue was also fitted with a small GPS that recorded positions every minute.

Copy & paste from 2012 ?

both?

no depths given in 2012.

3. Results

3.1. *Introduction*

All data recorded during the drogue and dye surveys are included as Excel files and accompany this report.

3.2. *Spring Tide*

The spring tide survey occurred on the 20th April 2015. Weather forecasts indicated a light to moderate southerly breeze. Tidal forecasts for Howth are presented in Table 3.1.

Day	Date	Time	Height(m)
Monday	20/4/15	06:51	0.0
		13:19	4.3
		19:14	0.0

Table 3-1 Tide Forecast, Howth

3.2.1. Wind Records

Wind records recorded during the spring tide survey are presented in Table 3.2. In general the forecasts were correct with a light southerly breeze with a mean speed of 2-3 ms^{-1} (7.2-10.8 kmh^{-1}) predominating during the survey on the 20th April.

Time	Max speed (m/s)	Mean speed (m/s)	Direction (°)
09:25	3.1	2.0	130
10:30	3.2	2.8	120
11:20	3.3	2.9	120
11:45	3.9	3.1	120
13:00	4.4	3.5	120
14:23	4.9	3.2	110
15:00	3.4	2.8	120
16:05	3.2	2.7	120
18:00	1.6	1.3	90

Table 3-2 Wind data, 20th April 2015

3.2.2. Drogue Survey

Drogue track data recorded during the spring tide survey are detailed in Excel files accompanying this report along with AutoCAD drawings of the drogue paths. A brief summary of this data is included in Tables 3-3 to 3-5 and the tracks of the drogues presented in Figures 3-1 to 3-6. Due to the very low tide, it was not possible to launch the survey boat until 8:45 with the first set of drogues released just after 9:00.

low tide

In general, the three drogues followed similar paths on both the flood and ebb tide with all three moving in a south east direction (see Figures), the sub-surface drogue travelling slightly further than the other two. On the flooding tide the drogues followed a path to the west of Irelands Eye, the surface drogue recording a mean speed of 0.33 ms^{-1} at mid-flood. During the ebbing tide, the surface drogue recorded a mean speed of 0.55 ms^{-1} at mid-ebb. A significant flow ran along the north shore of Irelands Eye for a period during the ebb tide where the water became turbulent in a relatively narrow band that followed the contour of the Island. There was little progress of the drogues during the last hour of the study on the turn of the tide at low water.

The mid-water drogue experienced a significant alteration in its course during the first deployment (see Figure 3.3). It is not clear what occurred to cause this variation in its path and the observed deviation may be a result of a GPS error in the recording hardware rather than a true record of the path.

GPS

Haven't put dye out on lowest Tide.

Launched from where?
Low water not recording.

Drogue Number	Release Time	Drift Time (min)	Total Distance(m)	Mean Speed (ms^{-1})	Course (deg)
1	09:07:22	88	923	0.18	180
2	10:48:04	45	880	0.33	150
3	11:37:10	74	1038	0.31	150
4	12:56:59	66	1190	0.30	150
5	14:13:42	73	2267	0.52	120
6	15:33:18	45	1472	0.55	120
7	16:31:28	58	1246	0.36	120
8	17:40:29	53	332	0.10	120

Table 3-3 Spring Sub-surface drogue, 20/4/2015

Handwritten in the right margin (uncertain reading): Why Sits ~~3m off bottom~~ 6m. If effluent discharges at 20+m depth. why not a drogue at that level...?

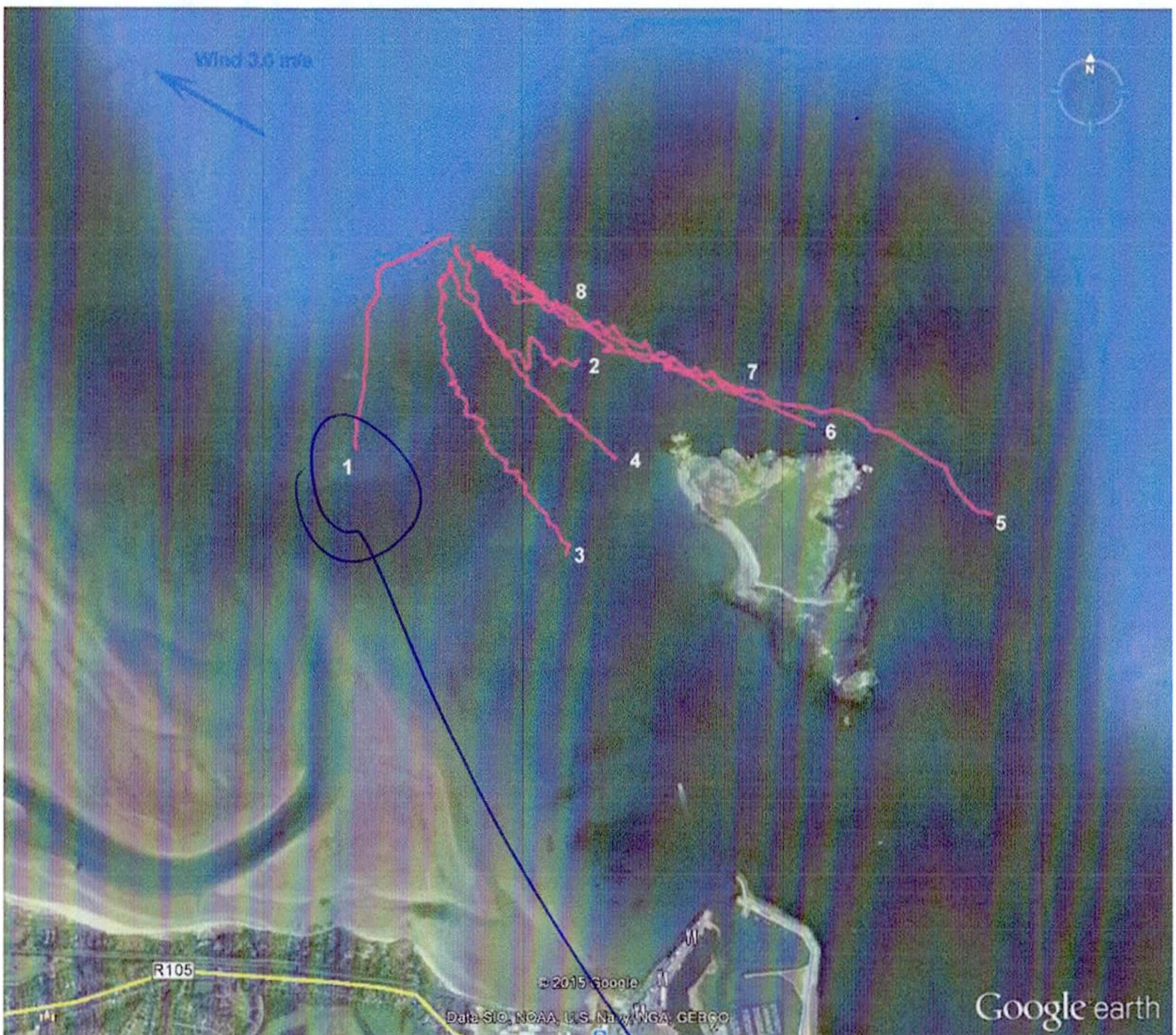


Figure 3-1 Spring sub-surface drogue tracks, 20/4/2015

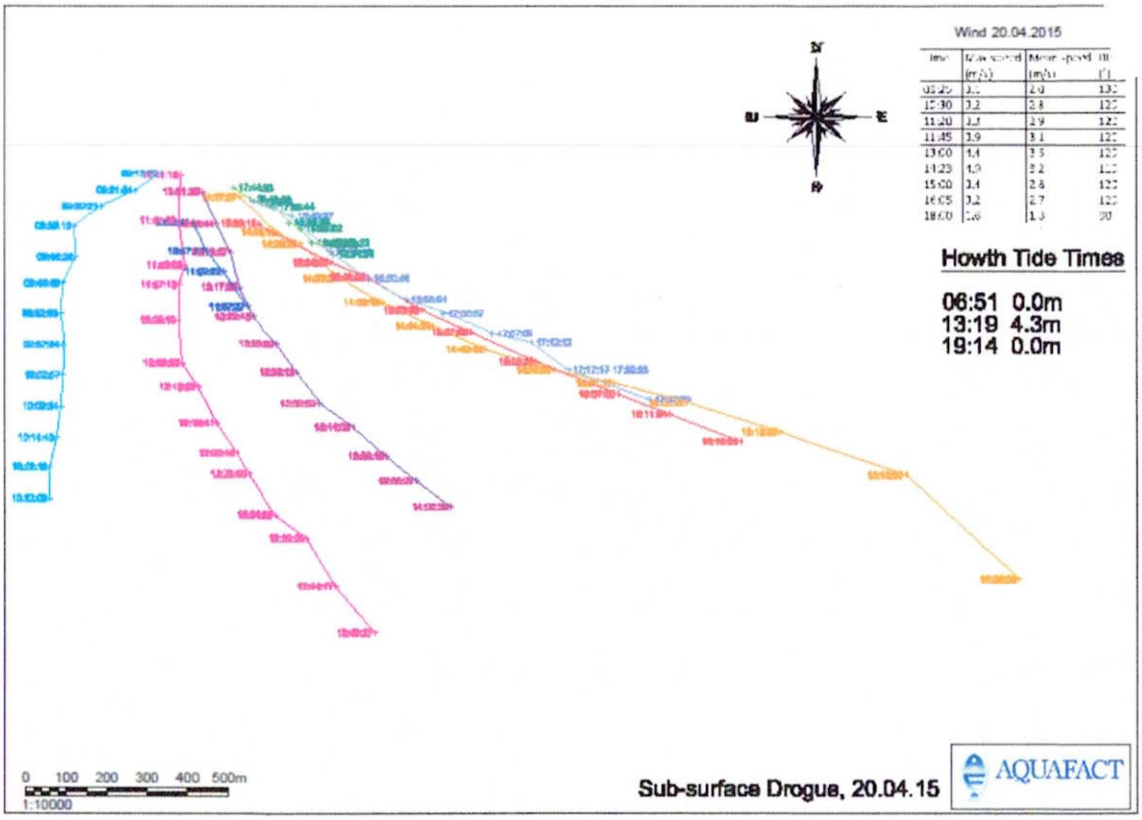


Figure 3-2 Spring sub-surface drogue tracks with time intervals, 20/4/2015

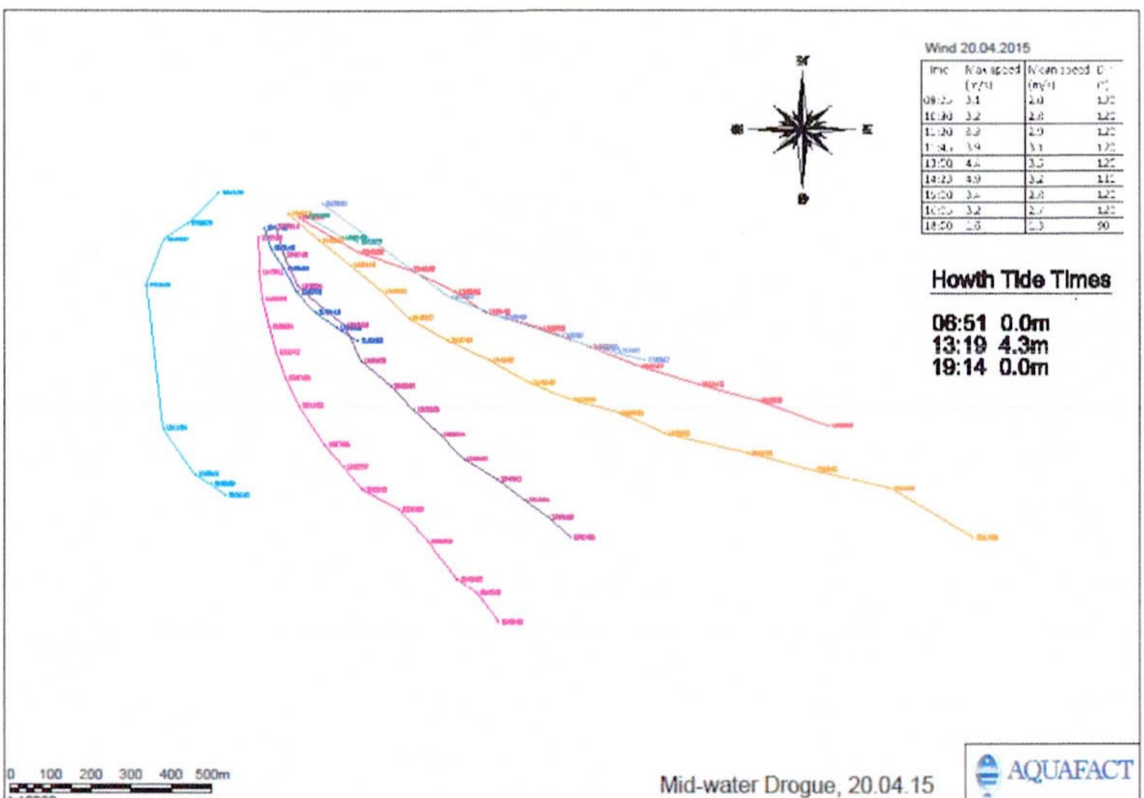


Figure 3-3 Spring mid-water drogue tracks with time intervals, 20/4/2015

3m

Drogue Number	Release Time	Drift Time (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	09:06:58	90	1000	0.19	180
2	10:43:16	31	750	0.40	140
3	11:38:31	71	1230	0.29	160
4	13:00:34	60	1220	0.34	160
5	14:13:33	81	2270	0.47	120
6	15:32:14	48	1560	0.54	120
7	16:28:33	56	1150	0.34	120
8	17:42:25	33	310	0.16	120

— GPS cr

3m

Table 3-4 Mid-water drogue, 20/4/2015

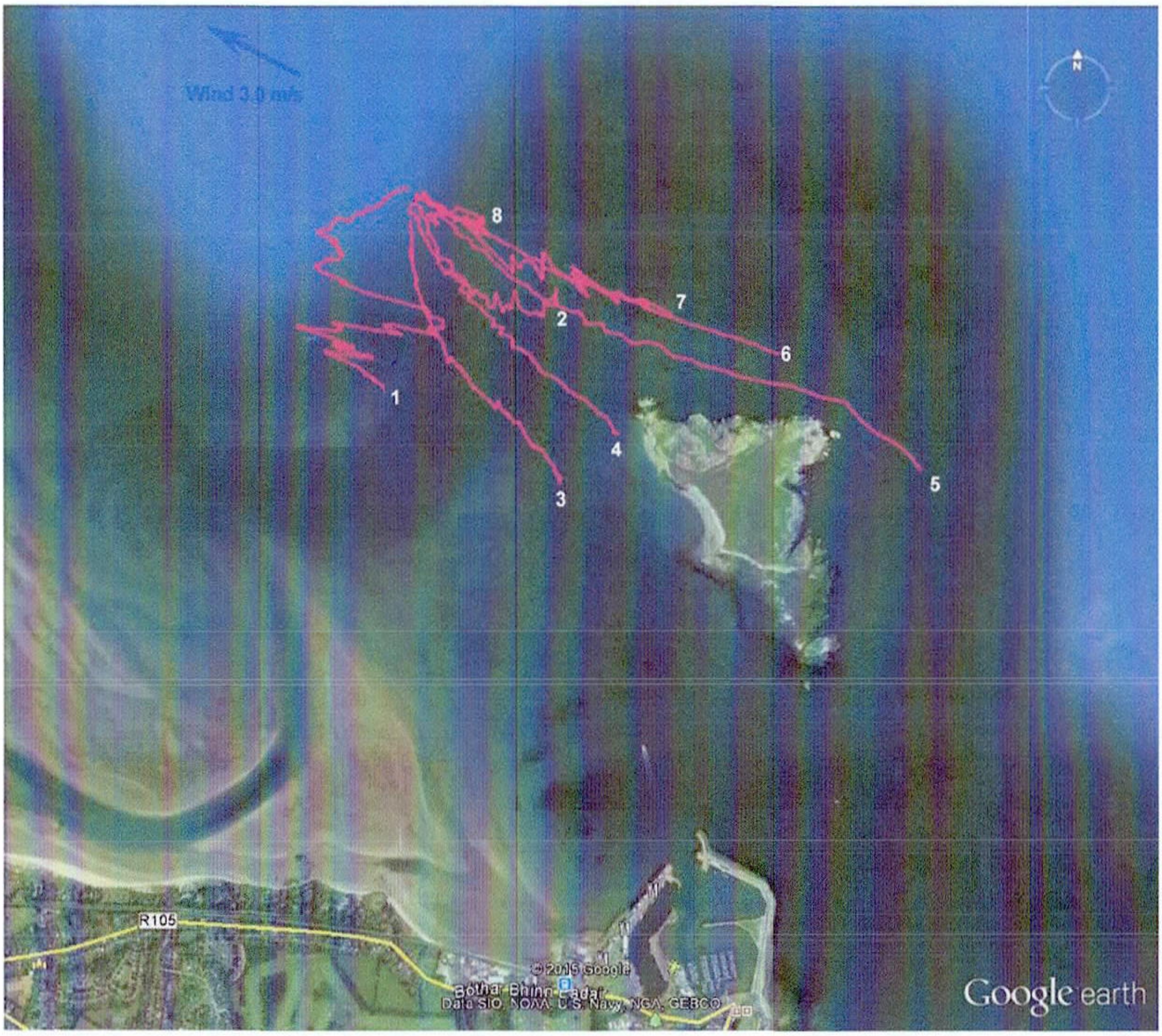


Figure 3-4 Spring mid-water drogue tracks, 20/4/2015

3m

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	09:07:22	94	950	0.17	180
2	10:44:28	45	720	0.27	130
3	11:39:29	67	1270	0.32	160
4	12:58:01	60	1200	0.33	160
5	14:12:40	71	2230	0.52	130
6	15:42:32	50	1520	0.51	120
7	16:28:02	64	990	0.26	120
8	17:38:10	44	100	0.04	120

6m

Table 3-5 Off-bottom drogue, 20/4/2015

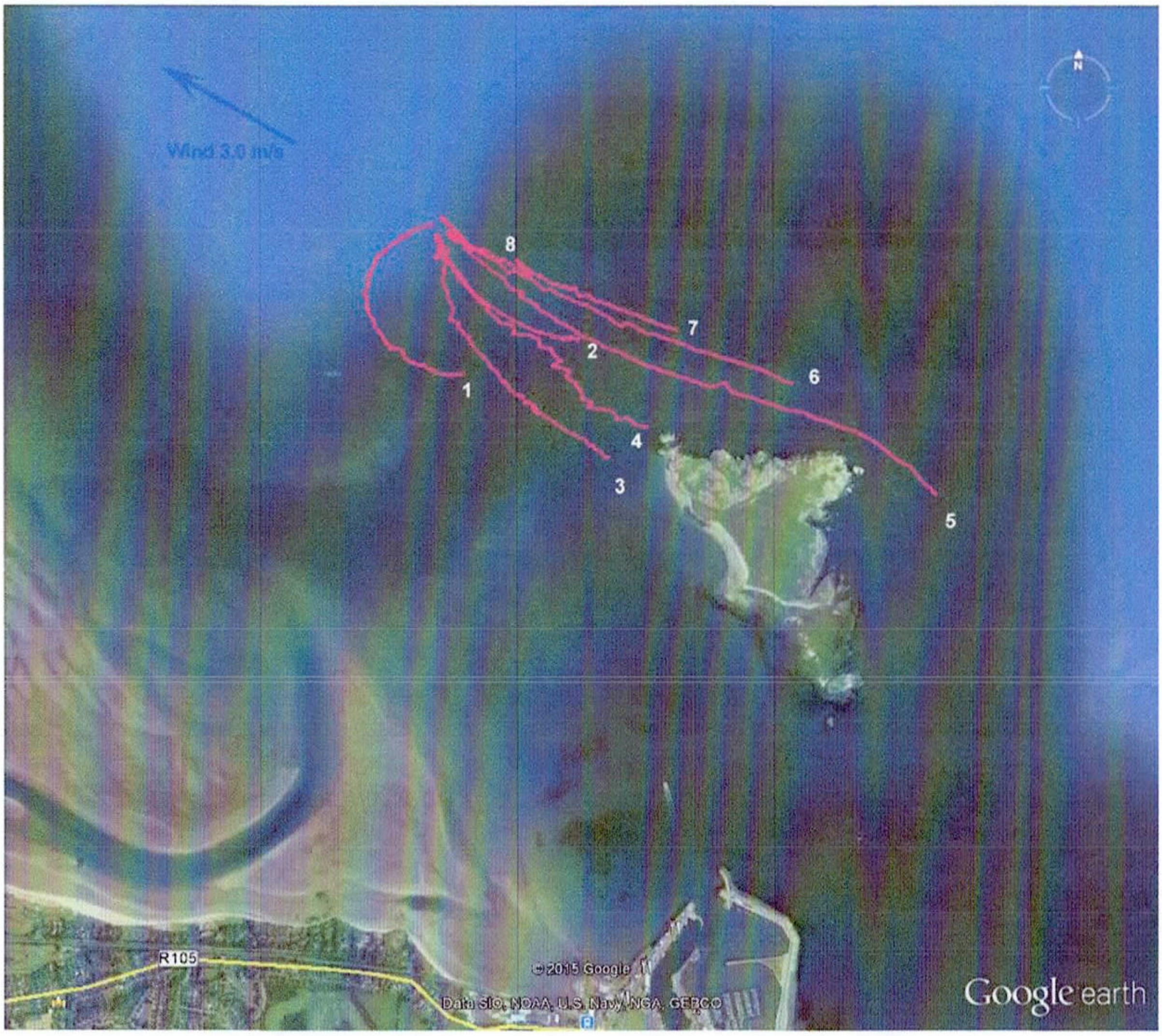
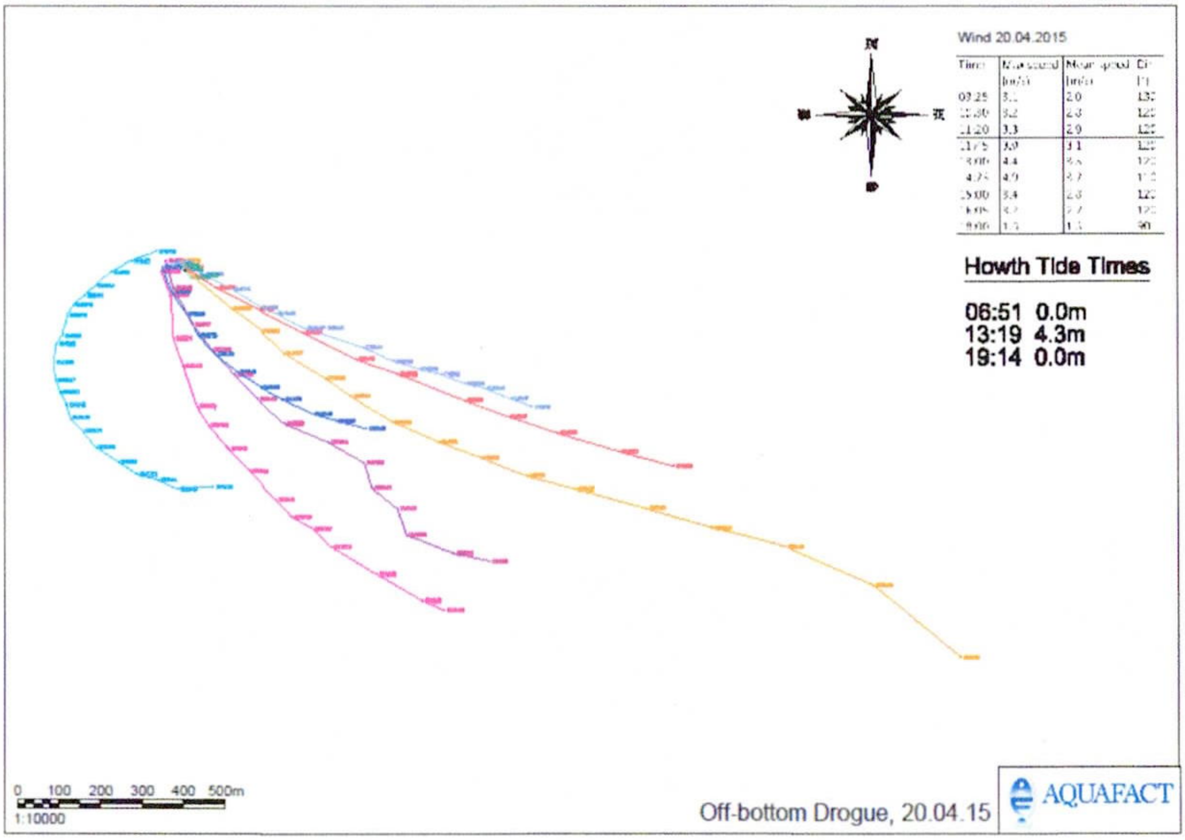


Figure 3-5 Spring off-bottom drogue tracks, 20/4/2015

6m



6M.

Figure 3-6 Spring off-bottom drogue tracks with time intervals, 20/4/2015

3.2.3. Dye Survey

Data recorded during the dye releases during the spring tide surveys are detailed in Excel files accompanying this report. Data include dye release times, the progress of the dye plume over time as plume perimeter coordinates and dye concentrations with position coordinates along transects through the dye plume. A sub-surface drogue was released to accompany the dye plume to aid in locating the plume and confirm its track. However, on return to the last known location of this drogue following the re-release of the drogue set at 11:30, and after an extensive search, the dye drogue could not be found. A number of boats were in the area at the time and the drogue may have been run over with the loss of the drogue and GPS tracker. A standby drogue was released with subsequent dye releases and it was found to remain with the dye plume as had the original drogue.

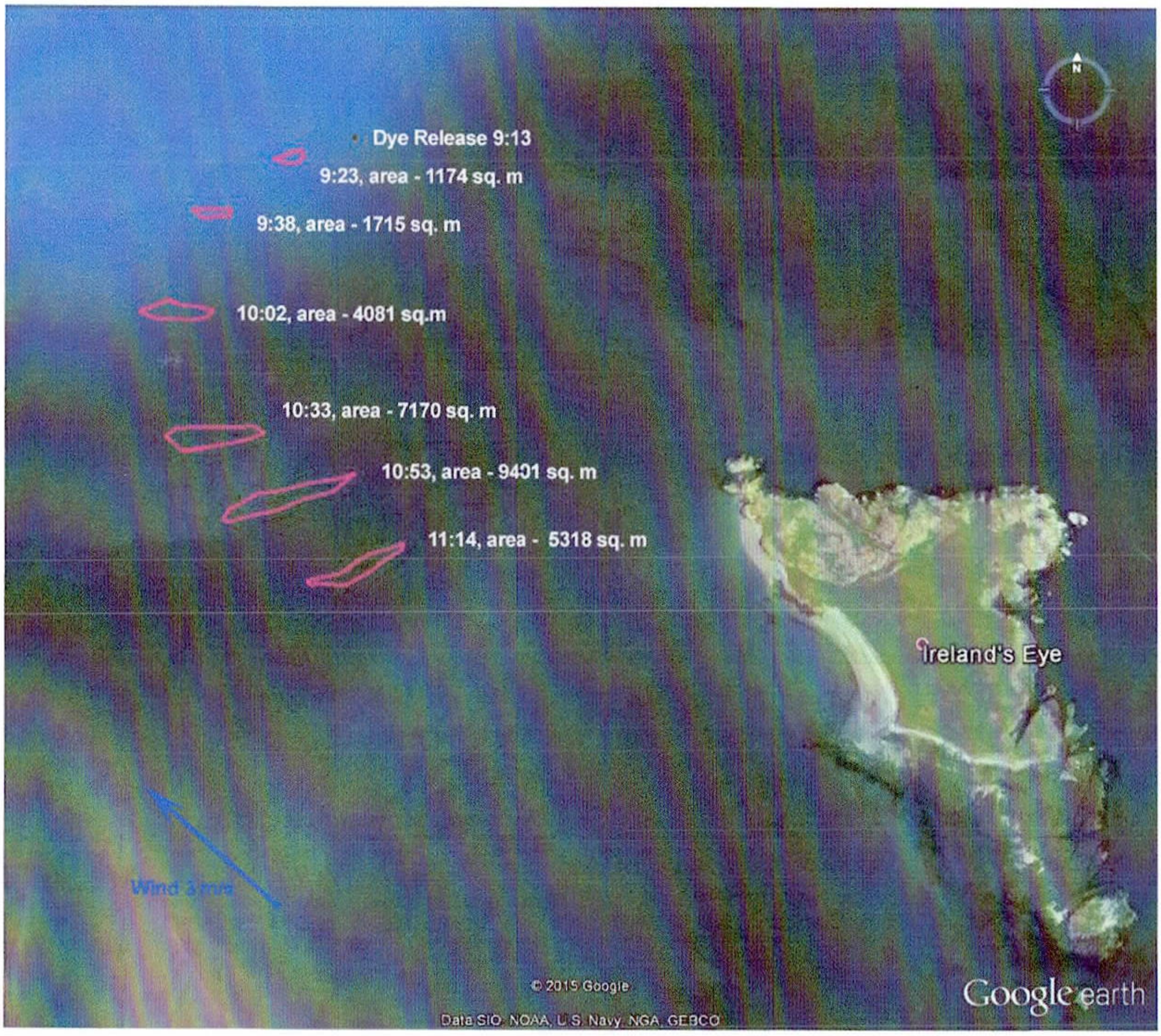
loss of Drogue

when did 2nd drogue start operating

Representative diagrams of the progress of the plumes as they progress over the survey periods are presented below. The position and size of the plumes were delineated by recording the visible perimeter of the plumes while dye concentrations were recorded along transects through the plumes. However, it must be remembered that the dye plume is constantly moving and the start and end position of the perimeter is slightly out of sync and the position of dye concentrations along one transect is not directly related to the position of concentrations along a second transect taken across the same plume shortly after the first.

The flow direction and dilution rate of the dye released at 9:13 on 20th April is visually portrayed in Figure 3-8. In the first hour following release, the dye plume continued in a south westerly direction with the plume expanding along an east-west axis. Shortly after 10:00 the direction of progress of the dye plume changed with it moving in a south easterly path. As the plume progressed the area of visible dye expanded in an oval shape, the longer axis in an east-west line. Dye concentrations recorded along the transects through the plume indicating highest concentrations initially (9:48) towards the leading western edge (1025 µg/l). As dye flow and dispersion continued concentrations progressively decreased with a highest concentration of 112.5 µg/l recorded in the centre of the plume two hours after its release. The plume progressed approximately 1.4 km in this two hour period at a mean speed of 0.19 ms^{-1}.

Flooding? Tide



LT 6.51
13.19 H Tide
19.14 LT

Figure 3-7 Spring Dye Release 1, flow and dispersion, 20th April 2015

The second dye release occurred during mid-flood at 11:24 and the flow direction and dilution rate of the dye is visually portrayed in Figure 3-9. The dye plume continued in a south easterly direction with the plume expanding along a southeast-northwest axis. Just over one hour after release the dye had progressed to the northwest corner of Irelands Eye where it proceeded to break up on the rocks and disperse along the north shore of the Island where a strong current had developed. It was not possible to follow the plume further from this point on. Dye concentrations recorded along the transects through the plume indicating highest concentrations initially (12:03) towards the middle of the plume (1525 µg/l), with dye concentrations reducing with time and by 12:37 a maximum concentration of 225 µg/l was recorded in the centre of the plume. The plume progressed approximately 1.2 km in the one hour period from when it was discernible giving it a mean speed of 0.33 ms^{-1} over the tracking period.

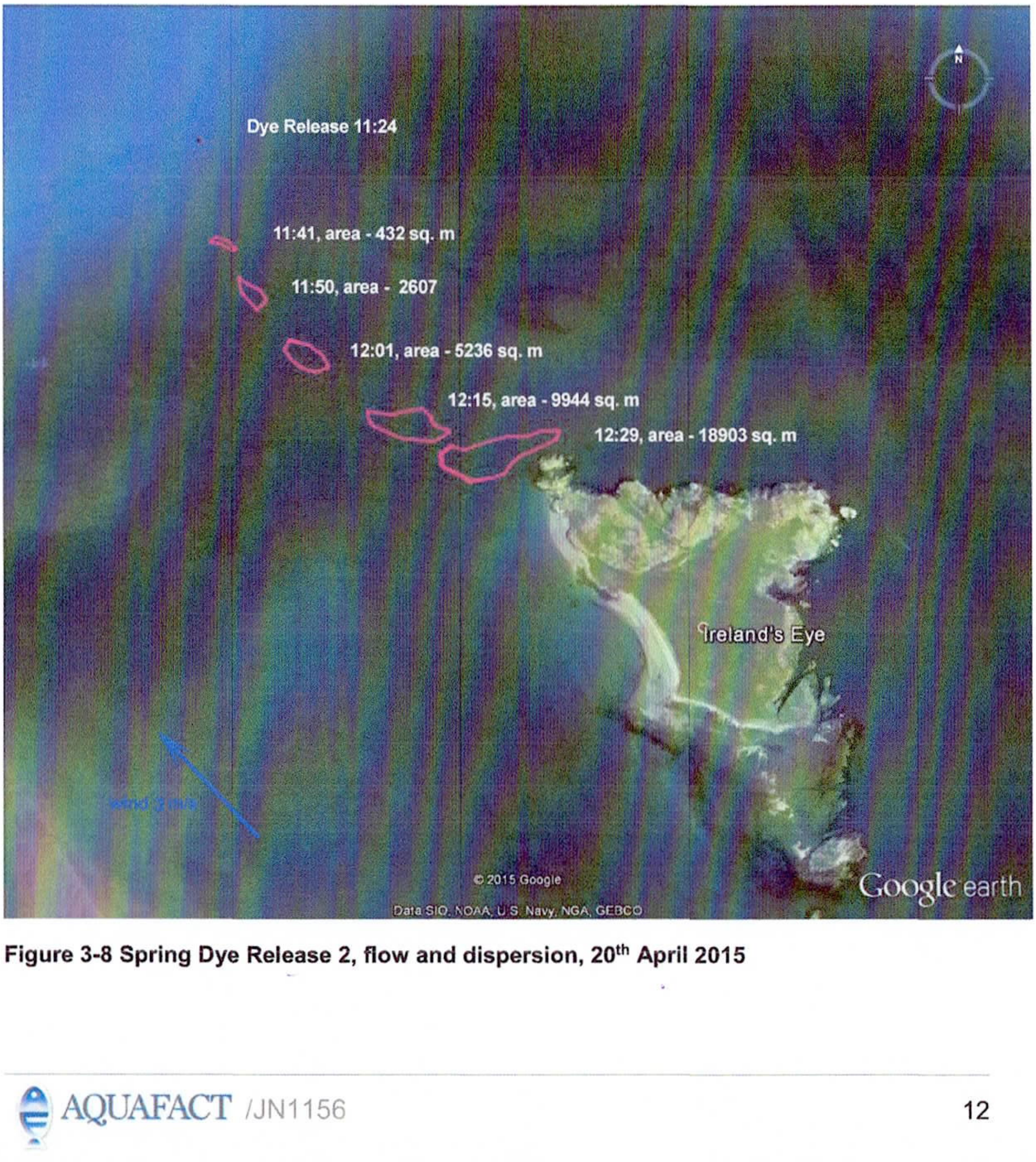


Figure 3-8 Spring Dye Release 2, flow and dispersion, 20th April 2015

The third dye release on the 20th April occurred at 14:18, approximately 1 hour after high water and the plume progress over time is presented in Figure 3-10. The plume progressed in a south-easterly direction forming an expanding thin oval along the direction of travel. Dye concentrations recorded along the transects through the plume indicating highest concentrations initially (14:52) towards the middle (1700 µg/l) which reduced as the plume progressed with time and by 15:20 a maximum concentration of 462.5 µg/l was recorded in the centre of the plume which diluted further to 212.5 µg/l recorded at 15:57. By 16:10 the plume had progressed approximately 4.4 km in the two hour period following release giving it a mean speed of 0.61 ms^{-1}.

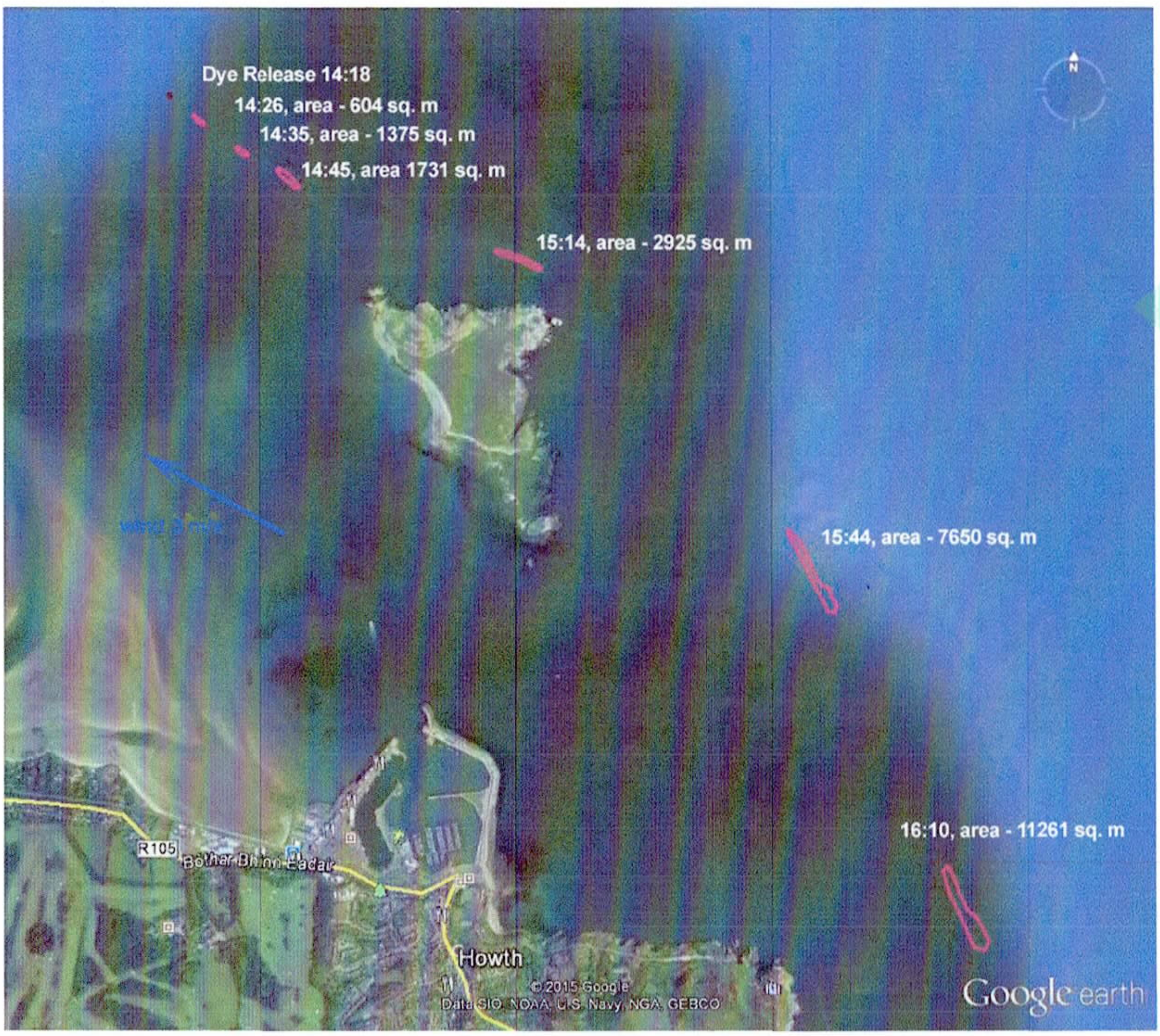


Figure 3-9 Spring Dye Release 3, flow and dispersion, 20th April 2015

The final dye release on 20th April occurred at 16:30 and the progress of the resulting plume is presented in Figure 3-11. Following release the dye progressed in a south easterly direction in an expanding plume. By 17:21 the plume had reached the north shore of Irelands Eye and transects through the plume at this time indicated a maximum concentration of dye of 662.5 µg/l near the leading edge. At this point the dye joined a turbulent current along the north shore of Irelands Eye and quickly dispersed with a maximum concentration of 100 µg/l recorded along a transect carried out at 17:48 with the majority of readings recording levels just above background at this location where the plume was passing. The fluorimeter did not record dye concentrations in the water body on subsequent transects through the water body close to the dye tracking drogue that travelled with the dye plume.

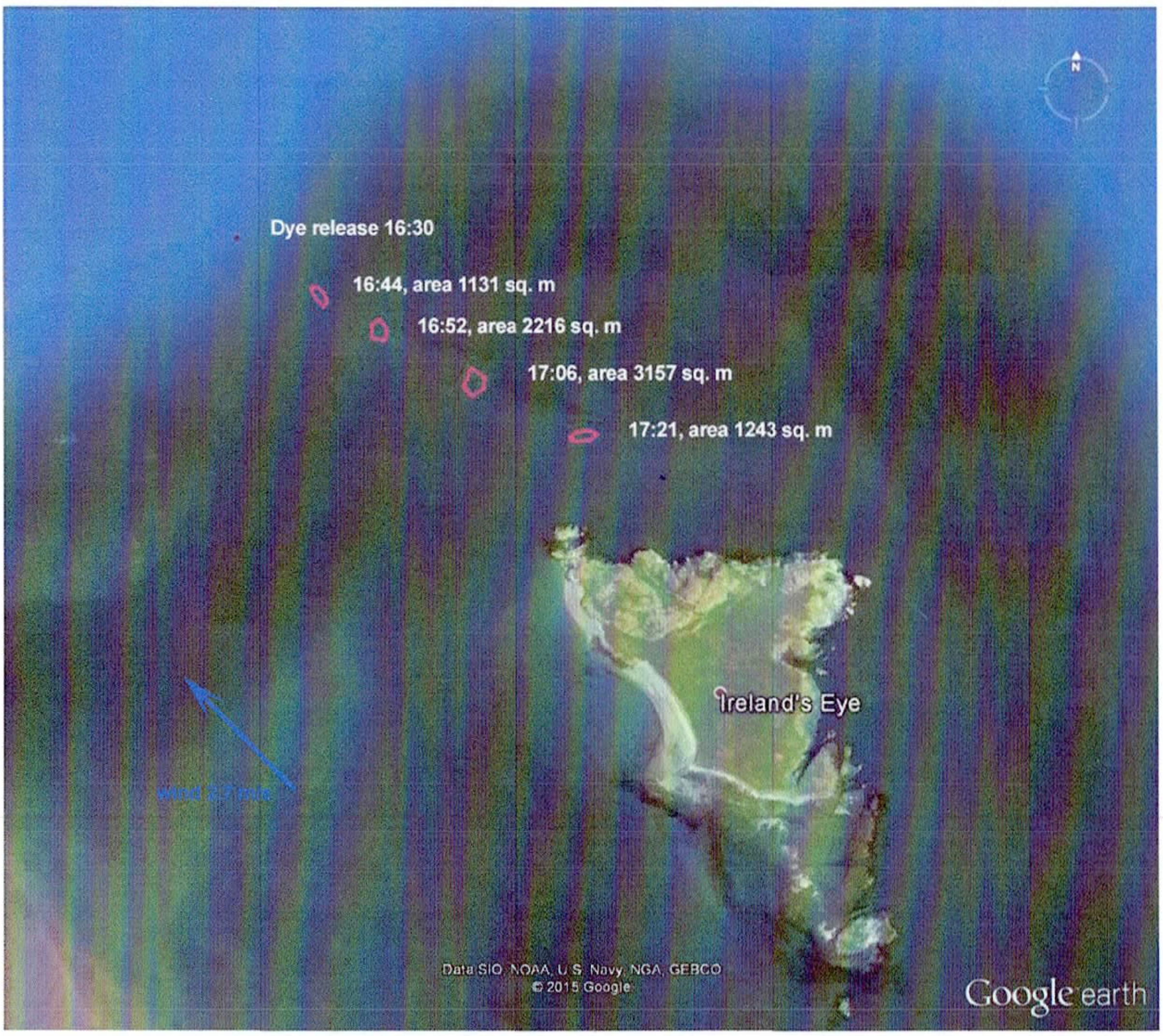


Figure 3-10 Spring Dye Release 4, flow and dispersion, 20th April 2015

3.3. Spring Tide

Spring or neap ?

The spring tide surveys occurred on the 9th June 2015. Weather forecasts indicated a light to moderate north easterly breeze. Tidal forecasts for Howth are presented in Table 3.6.

Day	Date	Time	Height(m)
Tue	9/6/15	05:05	3.9
		11:16	0.6
		17:53	3.6

H
L
H

NEAP
Z

neap

Table 3-6 Tide Forecast, Howth, 9th June 2015

3.3.1. Wind Records

Wind records recorded during the neap tide survey are presented in Table 3.7. In general the forecasts were correct with a light north east breeze occurring throughout the day with a mean speed of 1-2 ms^{-1} (3.6- 7.2 kmh^{-1}) predominating during the survey on the 9th June.

Time	Mean speed (m/s)	Direction (°)
07:23	0.2	50
08:10	0.5	50
08:55	3.3	50
09:15	2.7	45
09:39	1.2	50
09:53	1.5	45
10:36	2.1	45
11:38	2.0	50
12:40	2.5	50
13:38	2.3	50
14:40	2.0	50
15:00	1.9	50
16:00	2.5	50
17:00	1.8	50
17:30	1.2	50

Table 3-7 Wind Speed and Direction, Howth, 9th June 2015

3.3.2. Drogue Survey

Drogue track data recorded during the neap tide survey are detailed in Excel files and AutoCAD drawings accompanying this report. A brief summary of this data is included in Tables 3-8 to 3-10 and the tracks of the drogues presented in Figures 3-12 to 3-17.

In general, the three drogues followed similar paths with the surface drogue travelling slightly further on each of the deployments compared to the three drogues tracking currents at mid-water and off-bottom. On the ebbing tide all three drogues initially followed south east paths with distances travelled reducing on approach of predicted low water (11:16). On the fourth deployment (10:30) the drogues reversed direction and followed paths in a north west direction even though the time of predicted low water had not been reached. The paths of the drogues on further deployments moved from a predominantly northern trajectory to the south east over the flooding tide

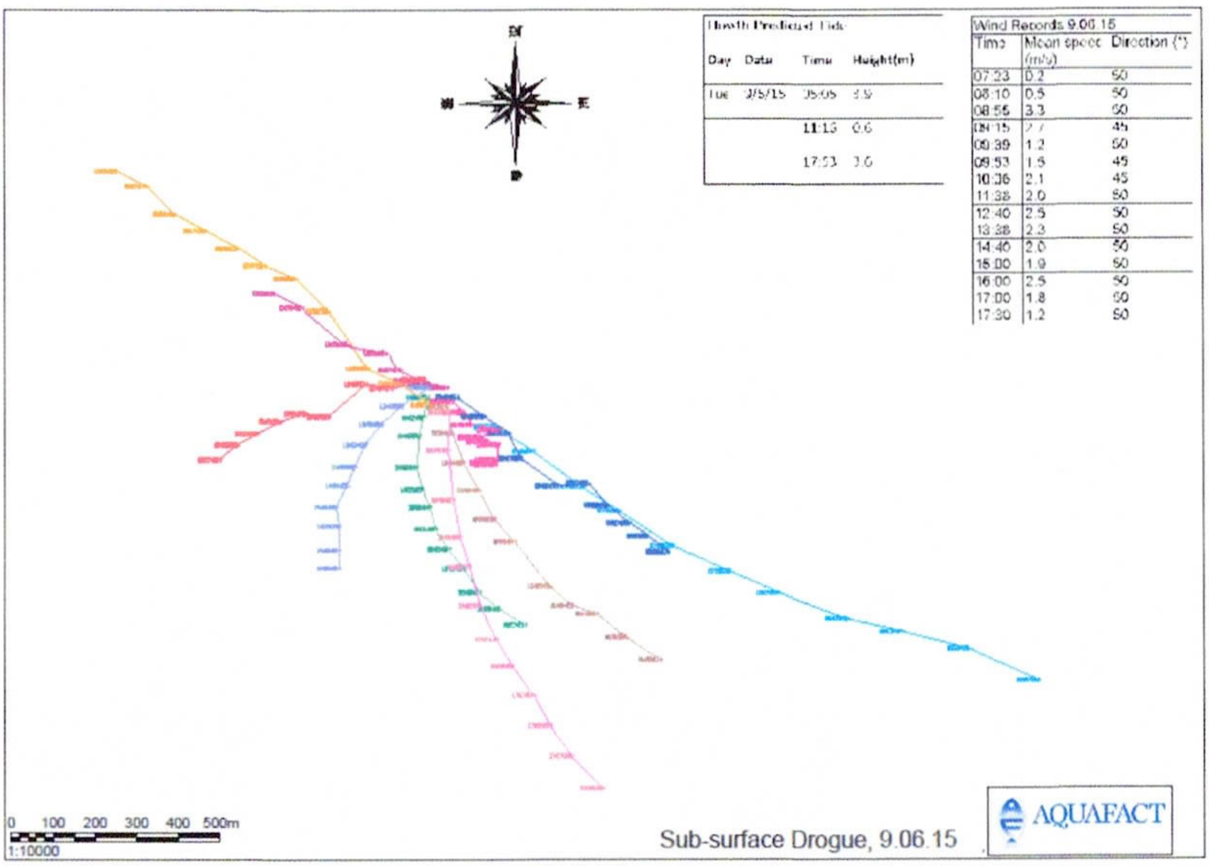


Figure 3-11 Neap sub-surface drogue tracks with time intervals, 9/6/2015

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:25:04	63	1630	0.43	140
2	08:40:36	49	650	0.22	140
3	09:39:10	51	350	0.11	140
4	10:35:39	59	530	0.15	310
5	11:38:54	55	980	0.30	310
6	12:44:25	45	650	0.24	250
7	13:38:01	49	560	0.19	180
8	14:36:45	51	690	0.23	160
9	15:34:57	51	890	0.29	160
10	16:33:49	63	1130	0.30	170

Table 3-8 Sub-surface drogue, 9/6/2015

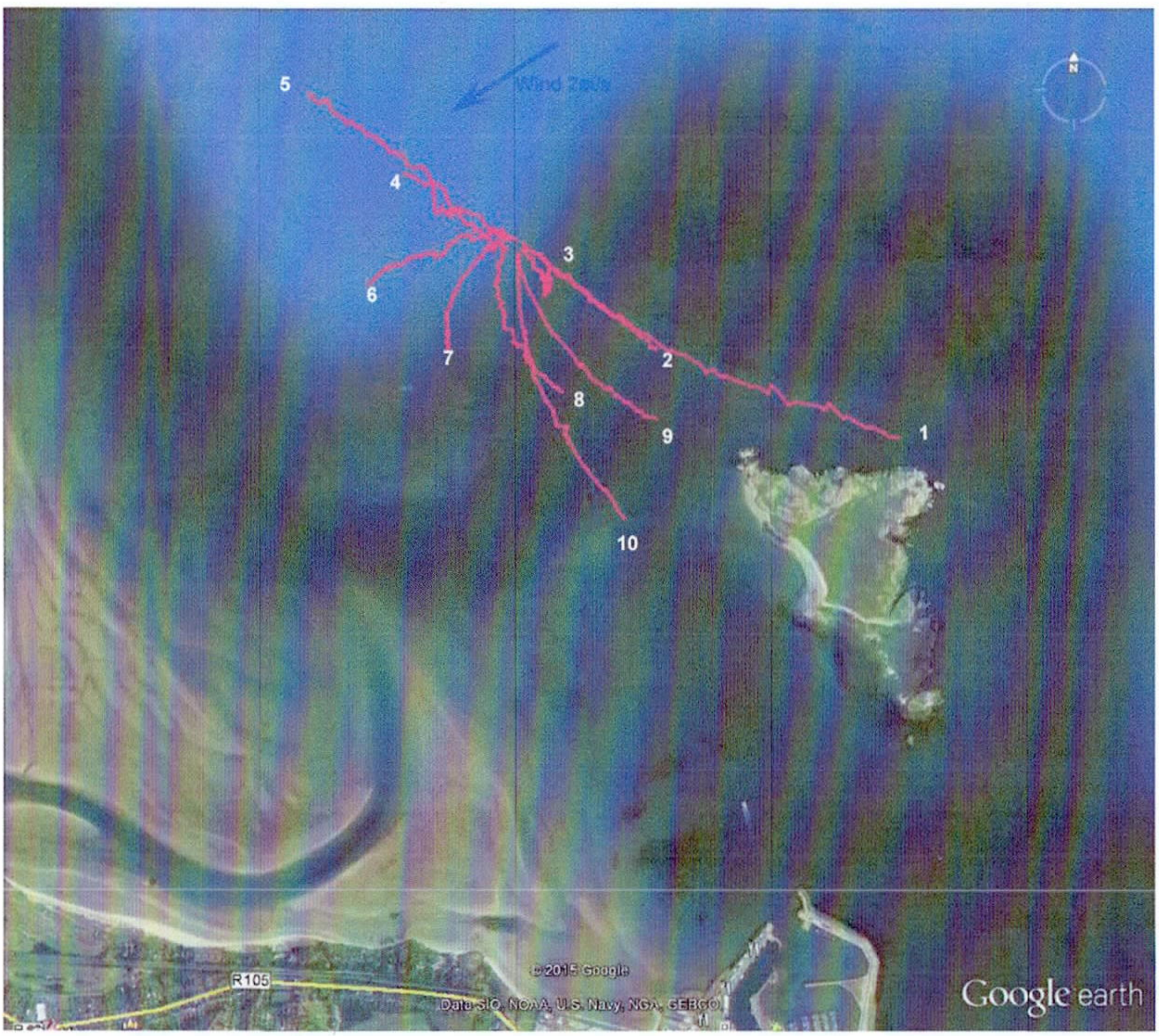


Figure 3-12 Neap sub-surface drogue tracks, 9/6/2015

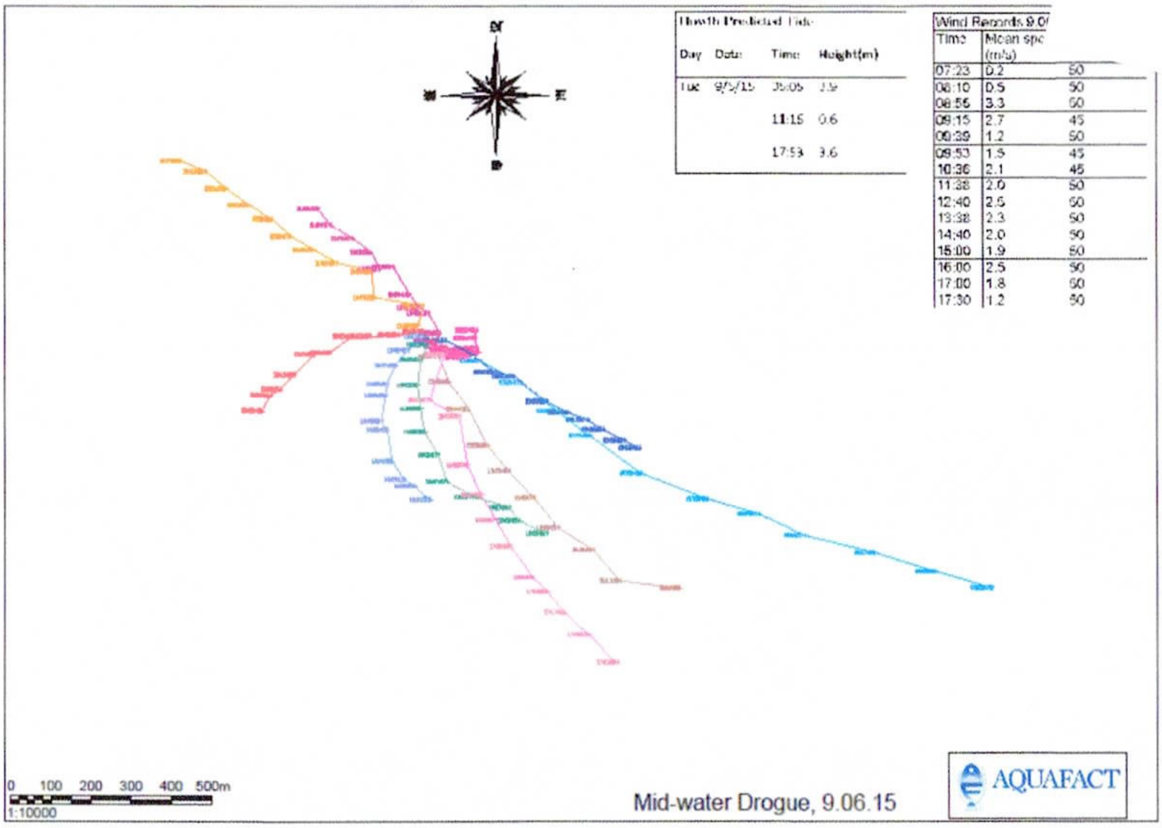


Figure 3-13 Neap mid-water drogue tracks with time intervals, 9/6/2015

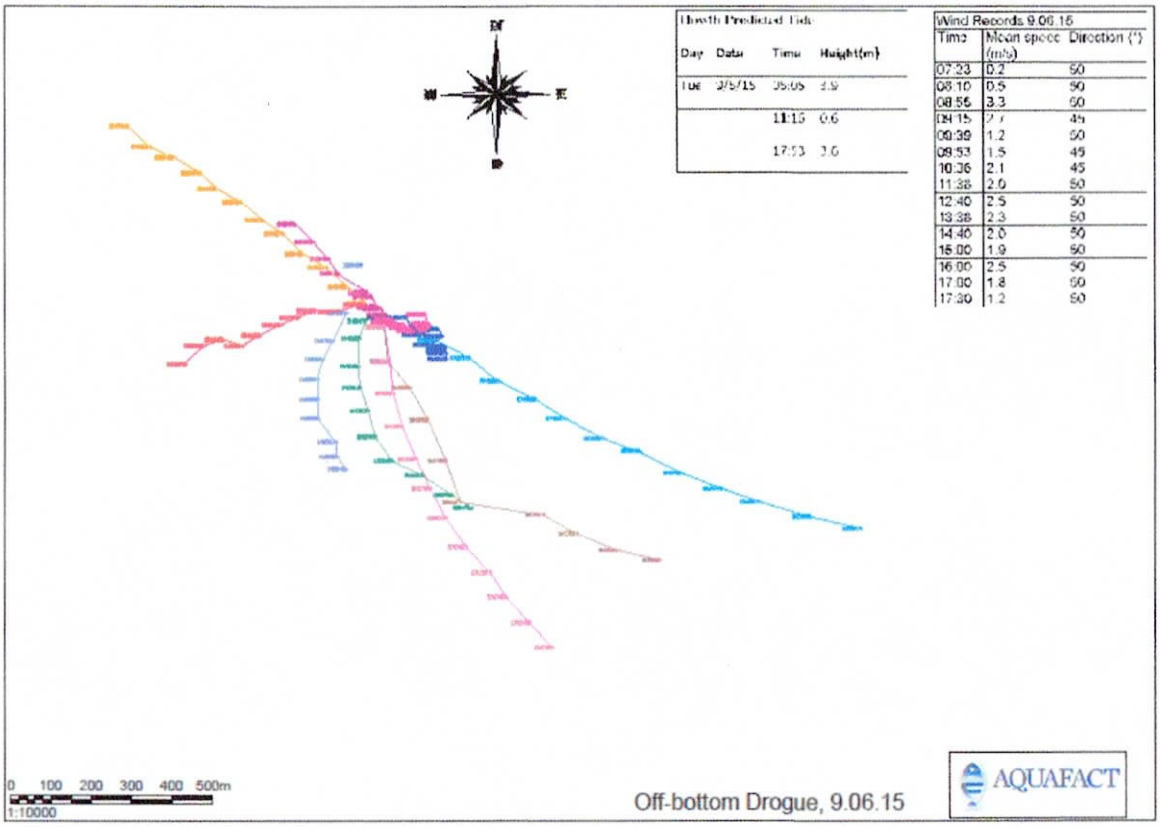


Figure 3-14 Neap off-bottom drogue tracks with time intervals, 9/6/2015

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:24:32	66	1580	0.40	140
2	08:40:13	52	570	0.18	140
3	09:38:41	54	170	0.05	140 - 0
4	10:35:35	54	450	0.14	340
5	11:38:53	59	750	0.21	330
6	12:43:40	49	510	0.17	250
7	13:37:25	54	520	0.16	160
8	14:35:41	54	710	0.22	160
9	15:33:47	53	810	0.25	170
10	16:33:22	54	950	0.29	170

Table 3-9 Mid-water drogue, 9/6/2015

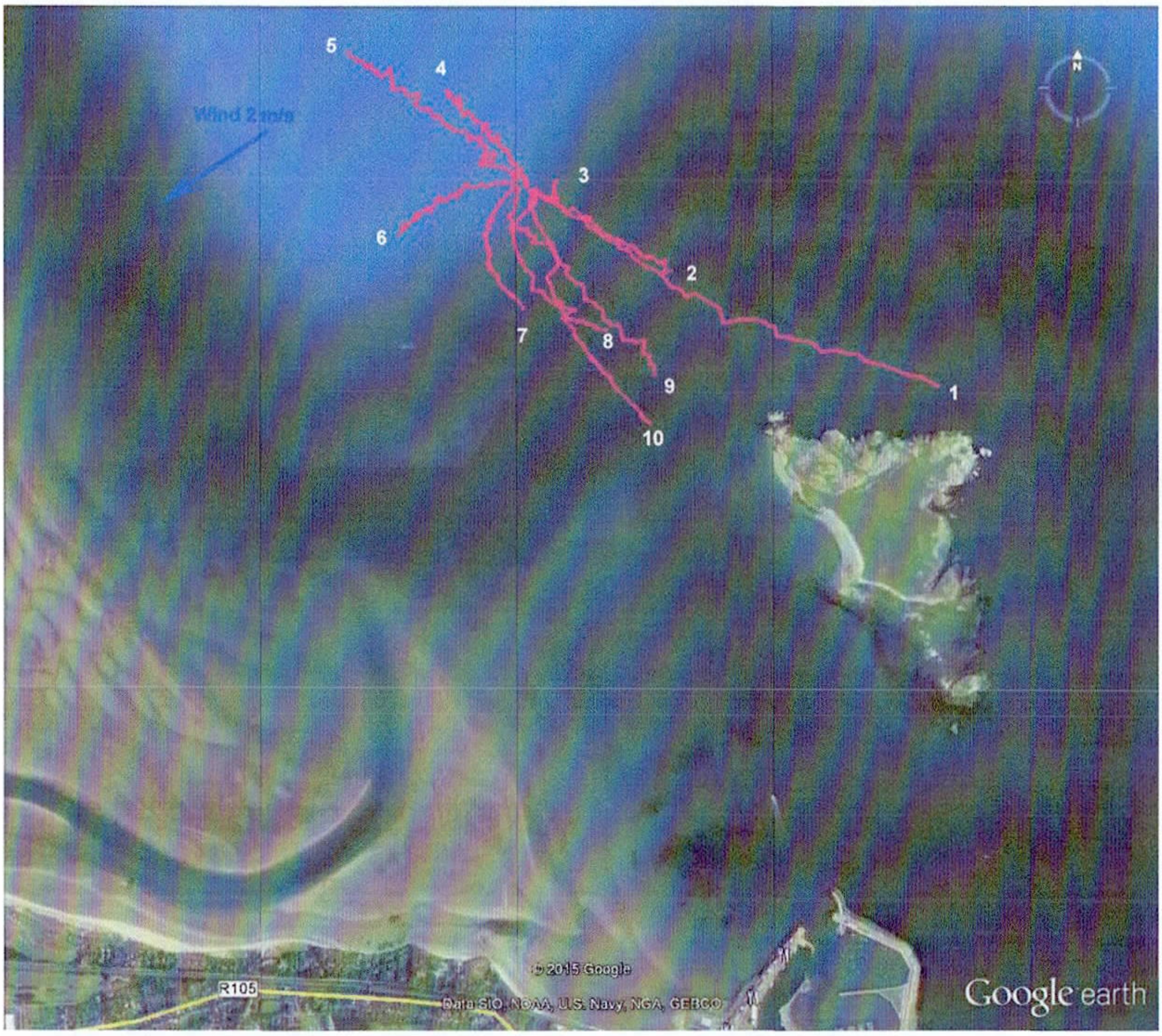


Figure 3-15 Neap mid-water drogue tracks, 9/6/2015

Drogue Number	Release Time	Time in Water (min)	Total Distance (m)	Mean Speed (ms^{-1})	Course (deg)
1	07:27:23	65	1450	0.37	140
2	08:39:36	56	190	0.06	140
3	09:38:14	54	160	0.05	140 - 0
4	10:35:29	56	340	0.10	340
5	11:38:26	57	760	0.22	330
6	12:43:56	47	480	0.17	250
7	13:37:39	51	500	0.16	180
8	14:36:24	52	680	0.22	160
9	15:34:16	54	880	0.27	140
10	16:32:38	59	1010	0.29	170

Table 3-10 Off-bottom drogue, 9/6/2015

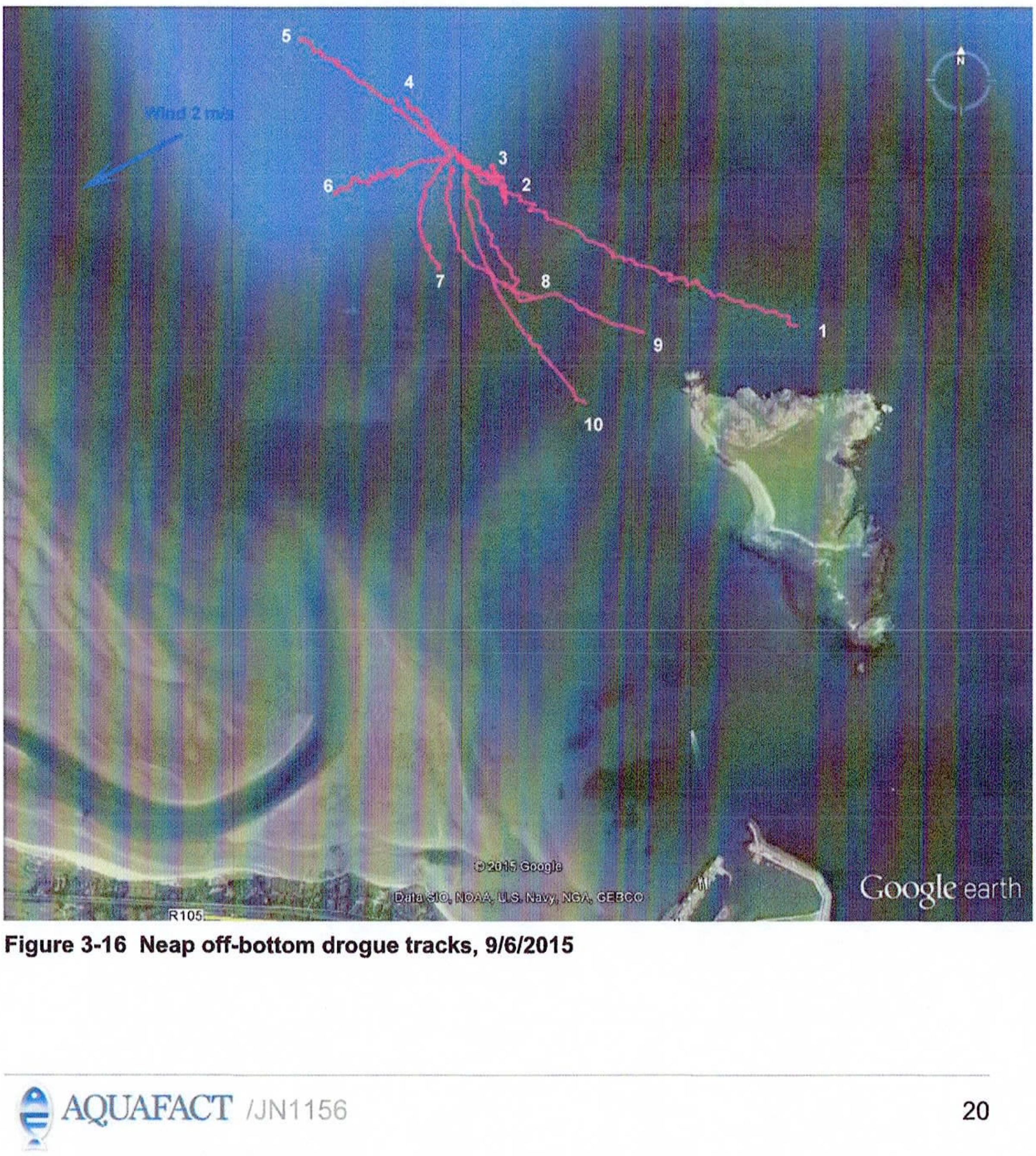


Figure 3-16 Neap off-bottom drogue tracks, 9/6/2015

3.3.3. Dye Survey

Data recorded during the dye releases during the neap tide surveys are detailed in Excel files along with AutoCAD drawings accompanying this report. Data include dye release times, the progress of the dye plume over time as plume perimeter coordinates and dye concentrations with position coordinates along transects through the dye plume.

Representative diagrams of the progress of the plumes as they progress over the survey periods are presented below. The position and size of the plumes were recorded by recording the visible perimeter of the plumes while dye concentrations were recorded along transects through the plumes. However, it must be remembered that the dye plume is constantly moving and the start and end position of the perimeter is slightly out of sync and the position of dye concentrations along one transect is not directly related to the position of concentrations along a second transect taken across the same plume shortly after the first.

The flow direction and dilution rate of the dye released at 7:30 on 9th June is visually portrayed in Figure 3-17. Following release, the dye plume continued in a south east direction. As the plume progressed the area of visible dye expanded in an oval shape, the longer axis along a north-south line. Dye concentrations recorded along the transects through the plume indicating highest concentrations initially (8:03) towards the leading eastern edge (1525 µg/l). As dye flow and dispersion continued concentrations progressively decreased with a highest concentration of 37.5 µg/l recorded in the centre of the plume approximately one and a half hours after release. The plume progressed approximately 1.7 km in this time at a mean speed of 0.33 ms^{-1} with the plume reaching the north east corner of Irelands Eye. Dye was not picked up by the fluorimeter in the vicinity of the dye drogue that accompanied the plume on further transects in this area off Irelands Eye as the dye dispersed in this relatively turbulent area at this time.

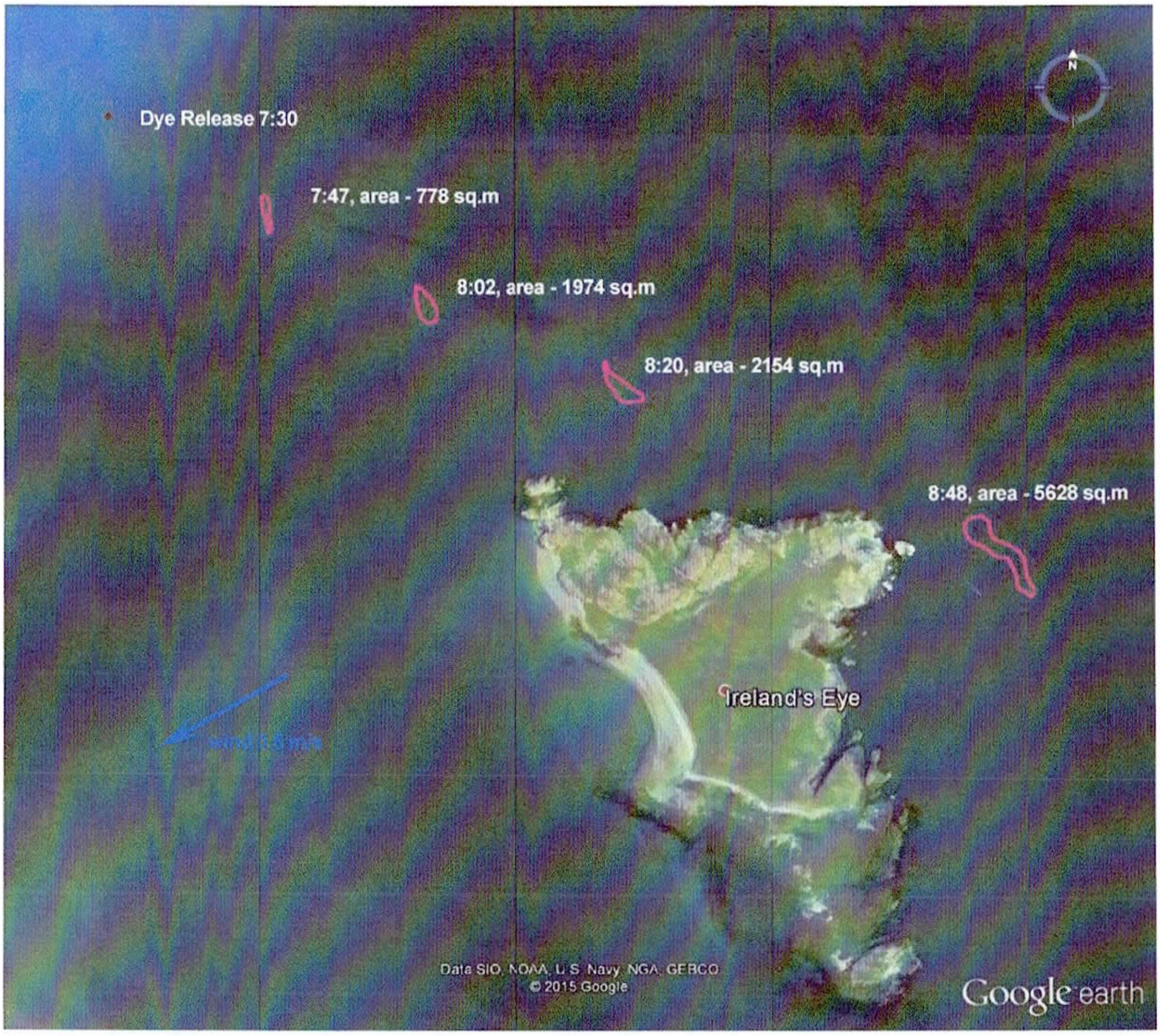


Figure 3-17 Neap Dye Release 1 flow and dispersion, 9th June 2015

The flow direction and dilution rate of the dye released at 9:15 on 9th June is visually portrayed in Figure 3-18.

In the first hour following release, the dye plume continued in a south easterly direction and expanded slowly along a north-south axis. Dye concentrations along the first series of transects were recorded at 9:44 with a maximum concentration of 3150 µg/l recorded towards the leading edge of the patch. The location of the plume was again recorded at 10:20 and it was found to have travelled approximately 400 m with a maximum dye concentration of 662 µg/l recorded towards the leading edge. However, by 10:40, when the perimeter of the plume was again delineated, it was found that the plume had reversed direction and was now heading in a northwest direction. The plume continued to expand with dye concentrations decreased progressively over the study and by 11:45 a maximum concentration of 125 µg/l was recorded towards the centre of the plume.

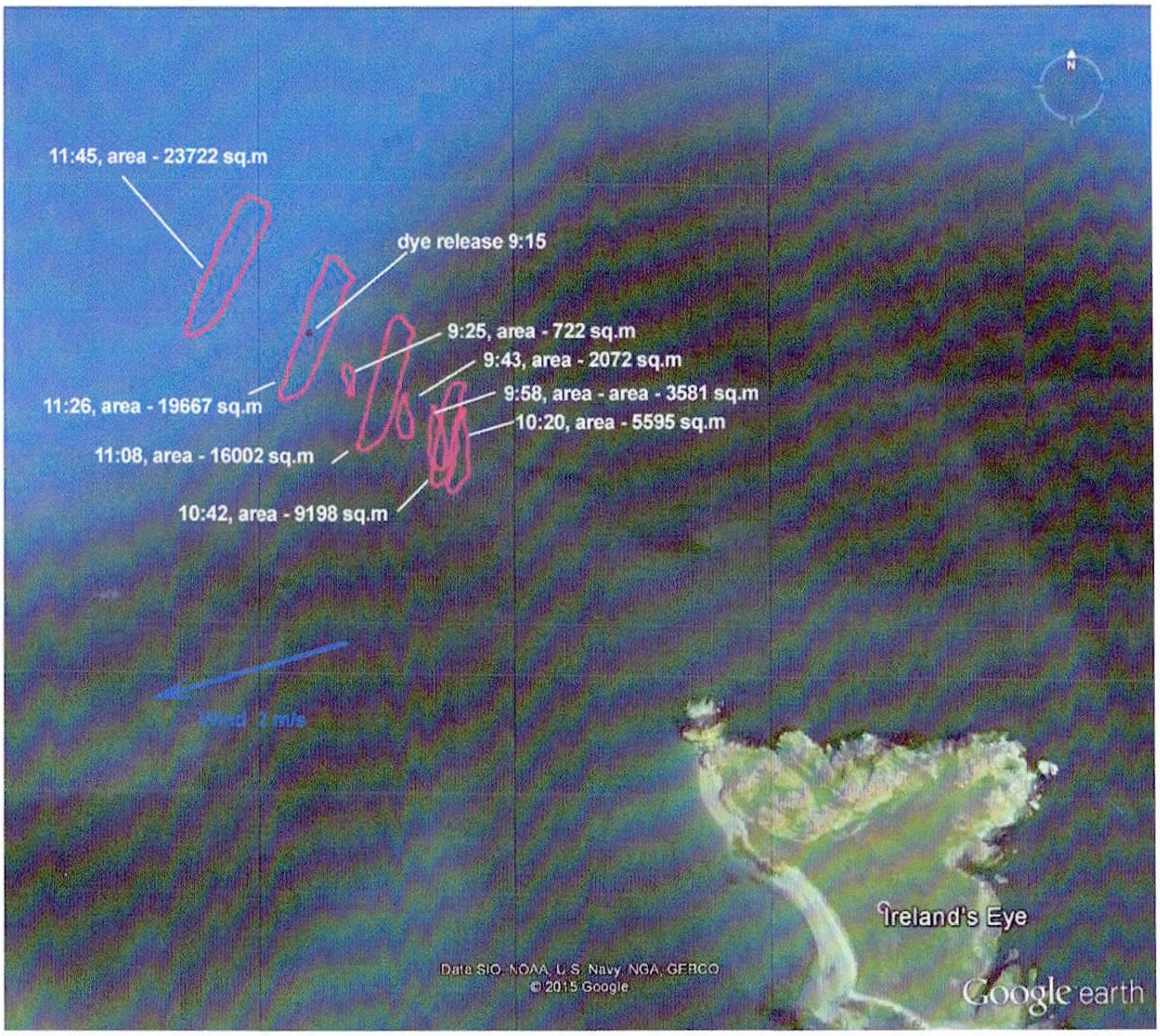


Figure 3-18 Neap Dye Release 2 flow and dispersion, 9th June 2015

The third dye release occurred at 12:00, just after predicted low water and the flow direction and dilution rate of the dye is visually portrayed in Figure 3-19.

Following release the dye plume continued in a north westerly direction and expanded slowly along the same axis. Dye concentrations along the first series of transects were recorded at 12:27 with a maximum concentration of 2200 μg/l recorded towards the leading edge of the patch. By 14:06 the plume had travelled approximately 1.3 km when a maximum dye concentration of 100 μg/l recorded towards the centre. The dye plume had progressed at a mean rate of 0.17 ms^{-1} over the two hour recording period.

(3)

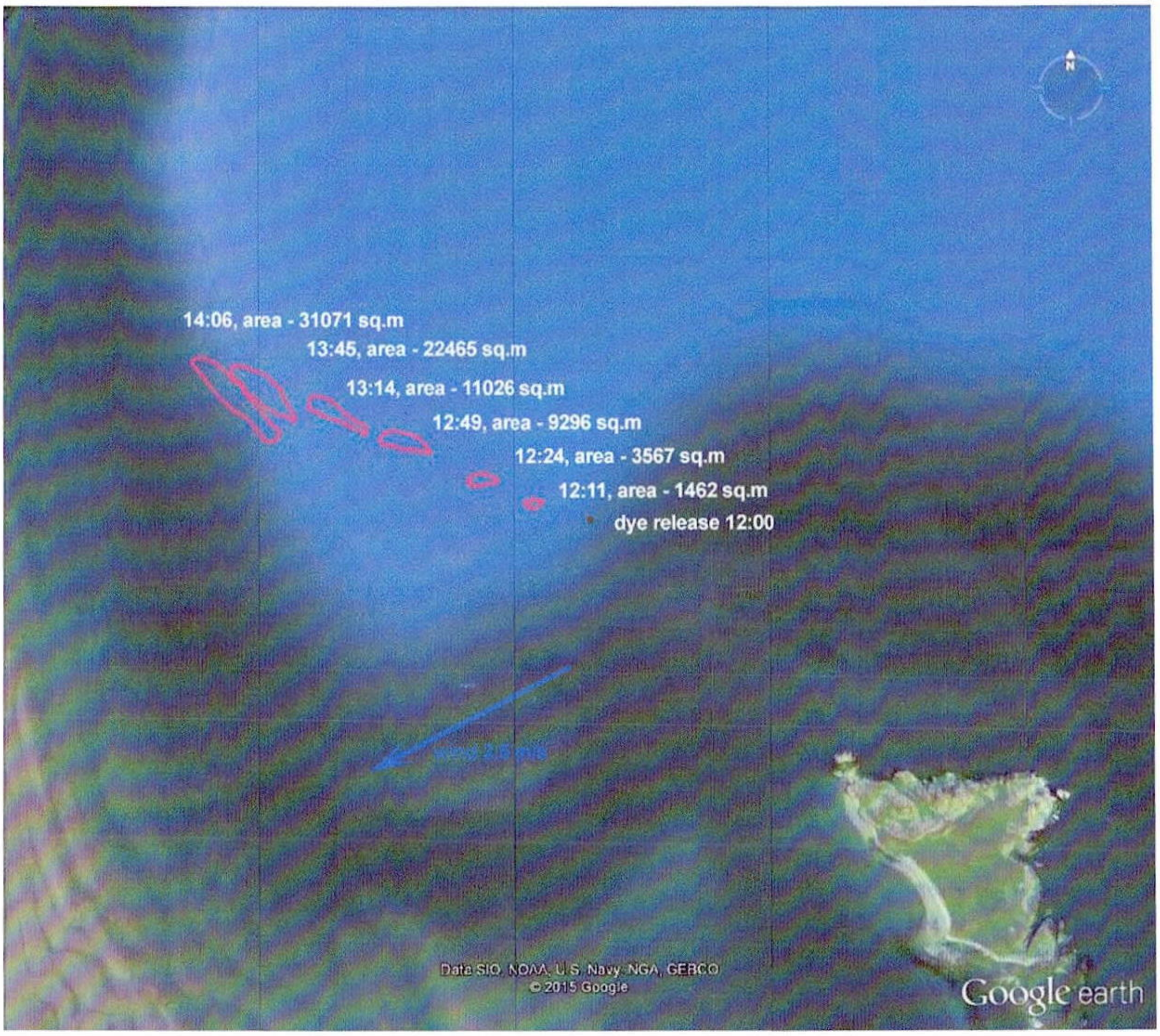


Figure 3-19 Neap Dye Release 3 flow and dispersion, 9th June 2015

The fourth and final dye release occurred at 14:40, approximately 3 hours prior to predicted high water and the flow direction and dilution rate of the dye is visually portrayed in Figure 3-20.

Following release the dye plume continued in a south westerly direction and expanded slowly along an east west axis. As the plume progressed the direction of travel became more easterly until it reached the northwest corner of Irelands Eye after which it followed the contour of the north shore of the island. Dye concentrations along the first series of transects were recorded at 15:12 with a maximum concentration of 3987 µg/l recorded towards the leading edge of the patch. By 16:40 the plume had travelled approximately 1.8 km when a maximum dye concentration of 75 µg/l recorded towards the centre. The dye plume had progressed at a mean rate of 0.25 ms^{-1} over the two hour recording period.

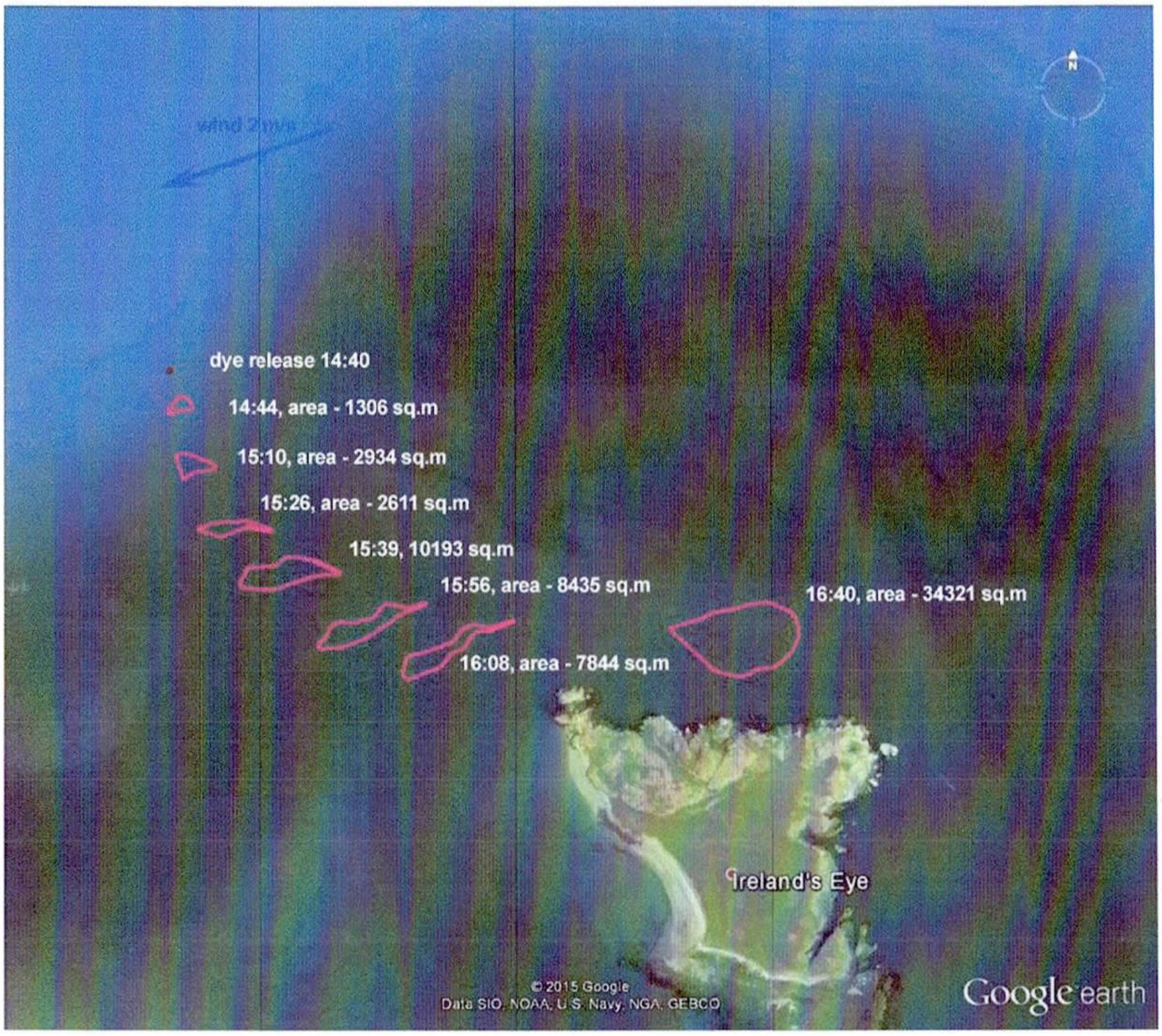


Figure 3-20 Neap Dye Release 4, flow and dispersion, 9th June 2015

No mention of drogues 2-

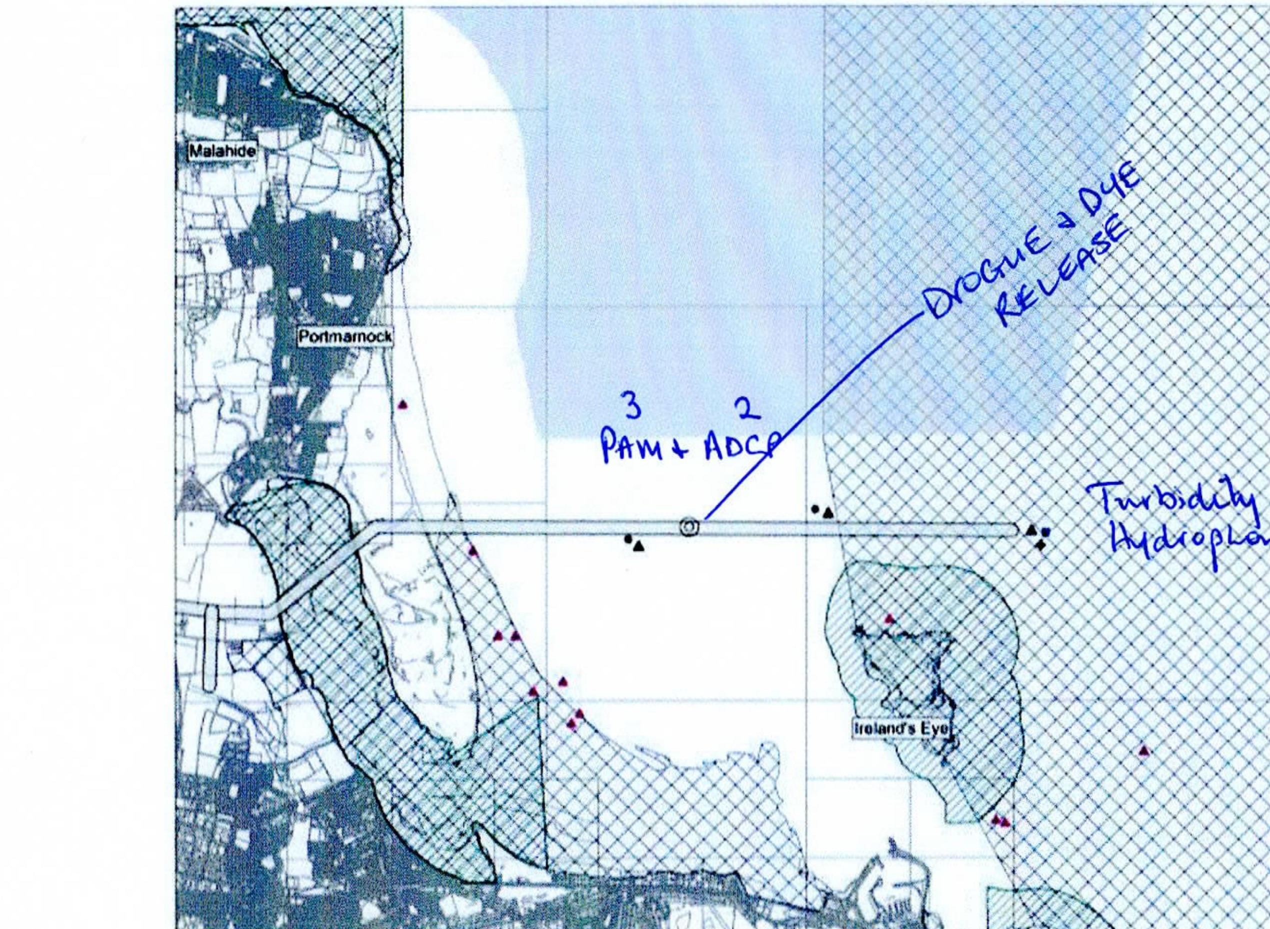


Figure 1 The location of the TWM monitoring buoys

APP. 6

APP 7

Hydrographic Monitoring

Drogue, Dye and Dye Drogue

Portmarnock and Skerries – undertaken on behalf of FCC in 2012

Portmarnock - undertaken on behalf of Irish Water in 2015

Hydrographic Monitoring – Drogue, Dye and Dye drogue

	FCC	Irish Water
Year	2012	2015
	Dye and Drogue	Dye and Drogue
Date	12th July to 23rd August	20th April to 19th June
1st	26th July Neap tide Portmarnock (C) 27TH July Neap tide Skerries (A)	20th April Spring tide
2nd	18th August Spring tide Portmarnock (C) 19th August Spring tide Skerries (A)	9th June Neap tide

Wind speed	Hand held anemometer And compass	Same
Dye	Diluted methanol and Distilled water	Same
5 litres	Neap tide	High tide Mid Ebb and Low Water Mid Flood
10 litres	Spring	n/a
Releases	8	8
1 metre below surface		Same
Individual transects - Neap Continuous - Spring		Individual transects
Drogue 3 No. 1 hour + 1 single sub surface		?

2012

FCC Dye Drogue Results

Portmarnock		Skerries
Date	26/07/2012	27/07/2012
Tide	NEAP	NEAP
Ebb flow	5.2km S/SW	7.1km S
4 hour drift		n/a
End up off south Howth Head		End up west Lambay
Flood tide	7.5km N/NW	Flood tide 5.9km N/NW
End up SW Lambay		End up N/E Skerries
		Terminated due to sea condition
Date	18/08/2012	19/08/2012
Drogue run over by boat Replace – No GPS		

Tide SPRING
(flood?) 6km N
31/2 hour drift
End up South Lambay
Tide 7km S
End up SE Howth Head
21/2 hour drift
Terminated – shipping zone

SPRING
Flood tide 8.5km N
n/a
End up NE Skerries
Ebb tide 4.2km S
n/a
2 hours
Terminated early deteriorating weather

2012
FCC Drogue Study

Portmarnock 10 releases
26/07/2012
NEAP
NE/SW axis
Max speed – Flood
Over 3km – 58 mins

Skerries 11 releases
27/07/2012
NEAP
N/S axis
Max speed - EBB
Over 2km - 54 mins

Portmarnock 11 releases
18/08/2012
SPRING
NE/SW axis
Max speed – Ebb
Under 3 km – 55 mins
Off bottom drogue dragged by boat on Ebb tide

Skerries 9 releases
19/08/2012
SPRING
N/S axis
Max speed - Ebb
Terminated due to wind speed

Dye Study

Portmarnock
26/07/2012
NEAP
7am – 11am Ebb
Southerly direction
12.10 – 16.45 Flood
Northerly direction

Skerries
27/07/2012
NEAP
7.15 – 9.25 Ebb
Southerly direction
13.10 – 15.46 Flood
Northerly direction
Terminated due to sea conditions

Portmarnock
18/08/2012
SPRING
8.13- 10.00 Flood
Northerly direction
13.32 –
Southerly direction
Terminated due to shipping lane

Skerries
19/08/2012
SPRING
8.18 – 10.30 Flood
Southerly direction ??
13.47 - ? Ebb
Southerly direction??
Terminated die to weather

2015 Portmarnock High water Mid Ebb Low Water Mid Flood

20 April 2015
SPRING
Drogue
SE Flood
SE Ebb
Flooding tide – Ireland's Eye west
Ebb tide turbulent Ireland's Eye north shore
Mid water drogue GPS error
Haven't put dye out at low tide
8 drogues
Not full tidal cycle

Dye Release 9.13

1. 2 hour period? - SW – SE. Where did it end up? Low water or F??
2. 11.24 SE – SE/NW – 1 hour to Ireland's Eye. NW Rocks Strong Mid Flood
3. 14.18 SE 4.4km 2 hours. Where did it end up? High water
4. 16.30 SE. Turbulent at Ireland's Eye. North. Dispersed. Mid Ebb

Dye Drogue
Sub surface drogue
Disappeared after 11.30
Release – run over
How many missed cycles?

9 June 2015 Portmarnock
NEAP
High Water Mid Ebb Low Water Mid Flood

DROGUE
SE on approach of Low Water
Reversed before LW and went NW even though Low Tide was not reached
Then from North to SE over flooding cycle
Very vague

DYE

1. 7.30 SE 1.7km to NE Ireland's Eye Turbulent area
2. 9.15 SE reversed NW. Where did it end up?
3. 12.00 NW 1.3km – 2hours Where did it end up?
4. 14.40 SW – E 1.8km – 2 hours Ireland's Eye. Where did it end up?

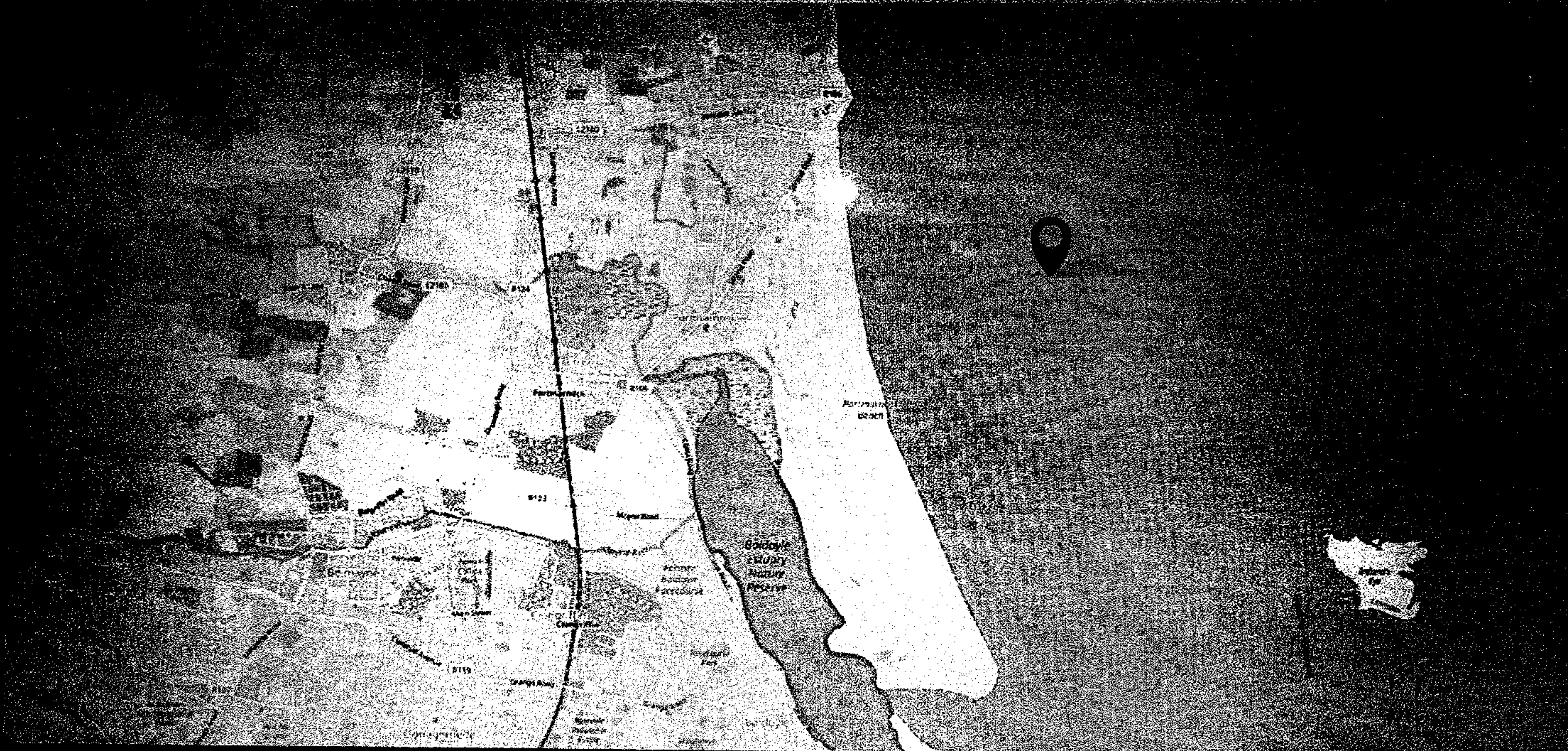
Dye Drogue
No. 1 of dye release mentions the dye drogue. Then no mention after that.

LOAD LOCATION ?	
LAT:	53.4169
LNG:	-6.075
LOC:	portmarnock
ZIP:	input postal code

SELECTED LOCATION ?	
LATITUDE:	
LONGITUDE:	

MAP COORDINATES ?	
LATITUDE:	N 53° 25' 0.84"
LONGITUDE:	W 6° 4' 30"
LATITUDE:	N 53° 25.014'
LONGITUDE:	W 6° 4.5'
LATITUDE:	53.4169°
LONGITUDE:	-6.075°

CURSOR COORDINATE	
LATITUDE:	cursor off
LONGITUDE:	
LATITUDE:	
LONGITUDE:	
LATITUDE:	
LONGITUDE:	



LOCATION ?

LAT: 53.42466
LNG: 6.098956
LOC: portmarnock
ZIP:

SELECTED LOCATION ?

LATITUDE:
LONGITUDE:

MAP COORDINATES ?

LATITUDE:	N 53° 25' 28.776"
LONGITUDE:	W 6° 5' 56.238"
LATITUDE:	N 53° 25.4796'
LONGITUDE:	W 6° 5.9373'
LATITUDE:	
LONGITUDE:	

CURSOR COORDINATES ?

LATITUDE:	cursor off map
LONGITUDE:	
LATITUDE:	
LONGITUDE:	
LATITUDE:	
LONGITUDE:	

Greater Dublin Drainage

Project: Greater Dublin Drainage (GDD) Project

Drawing Title: Figures 9.5 Inshore Shellfish Grounds along the Fingal Coast

Rev.	Date	Purpose of Revision	Drawn	Check'd	Rev'd	Appr'd
2	19/10/17	FINAL	KT	IW		
1	24/10/16	FINAL	KT	IW		
0	05/04/16	Draft	KT	IW		

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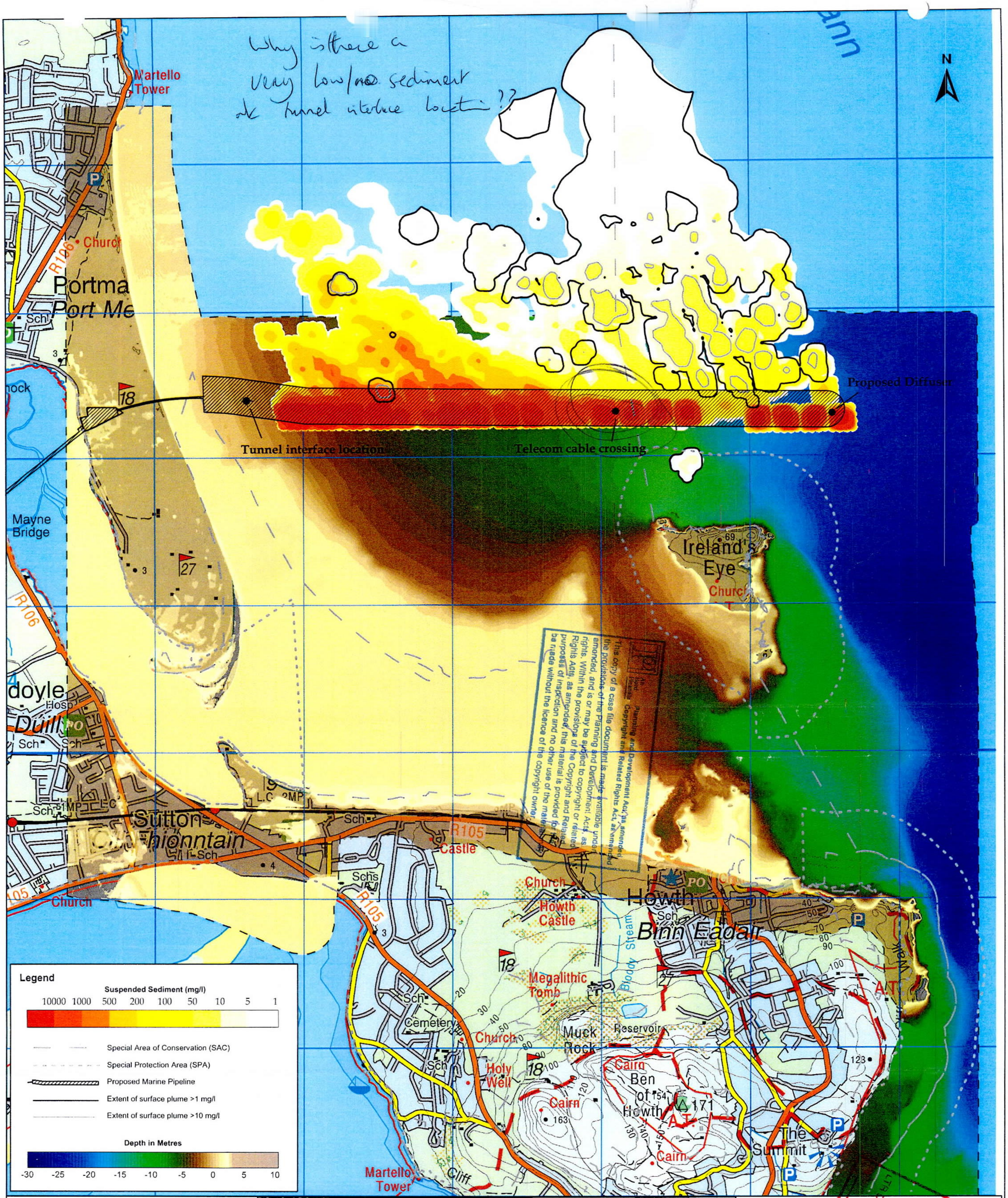
TOBIN

Drawing Status: DRAFT
Scale @ A4: 1:50,000
Job No: 32102902
Drawing No: 32102902-EIAR-905

App 10



Greater Dublin Drainage

Rev.	Date	Purpose of Revision	Drawn	Check'd
4	02/11/17	Final	KT	IW
3	02/11/17	For issue	KT	IW
2	19/10/17	For issue	KT	IW
1	24/10/16	For issue	KT	IW
0	05/04/16	Draft	KT	IW

Project: Greater Dublin Drainage Project

Drawing Title: Figure 9.6 - Maximum Suspended Sediment Plume Concentrations arising from dredging over the duration of the dredging Works for the proposed outfall pipeline route (Marine Section)

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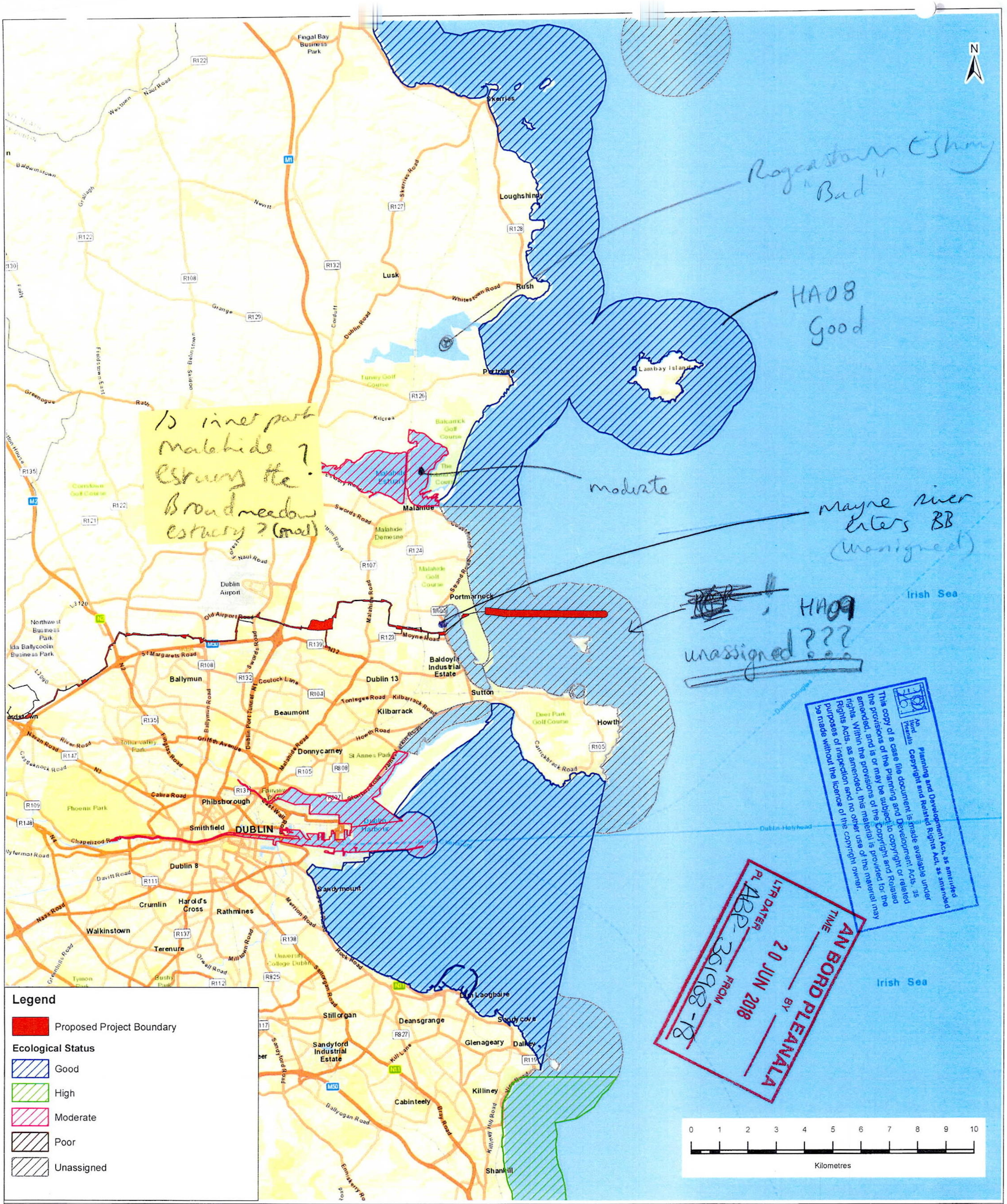
JACOBS TOBIN

Drawing Status	FINAL
Scale @ A3	1:25,000
Job No.	32102902
Drawing No.	32102902-EIAR-906



Greater Dublin Drainage

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
B	26/01/2018	Final	AB	SM	AB	AB
A	25/11/2016	For Issue	AB	AB	CD	AB

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JACOBS TOBIN

Project: Greater Dublin Drainage Project

Drawing Title: Figure 8.11 - Ecological Status (EPA)

Drawing Status: Final
Scale @ A3: 1:125,000 DO NOT SCALE
Job No.: 32102902
Drawing No.: 32102902-EIAR-811 EPA

Greater Dublin Drainage

Project: Greater Dublin Drainage Project

Drawing Title: Figure 8.12 - Quality of Bathing Waters

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
B	26/01/2018	Final	AB	SM	AB	AB
A	25/11/2016	For Issue	AB	AB	CD	AB

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JACOBS TOBIN

Drawing Status: Final

Scale @ A3: 1:125,000 DO NOT SCALE

Job No.: 32102902

Drawing No.: 32102902-EIAR-812