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Drift Analysis

The Marine Accident Investigation Branch

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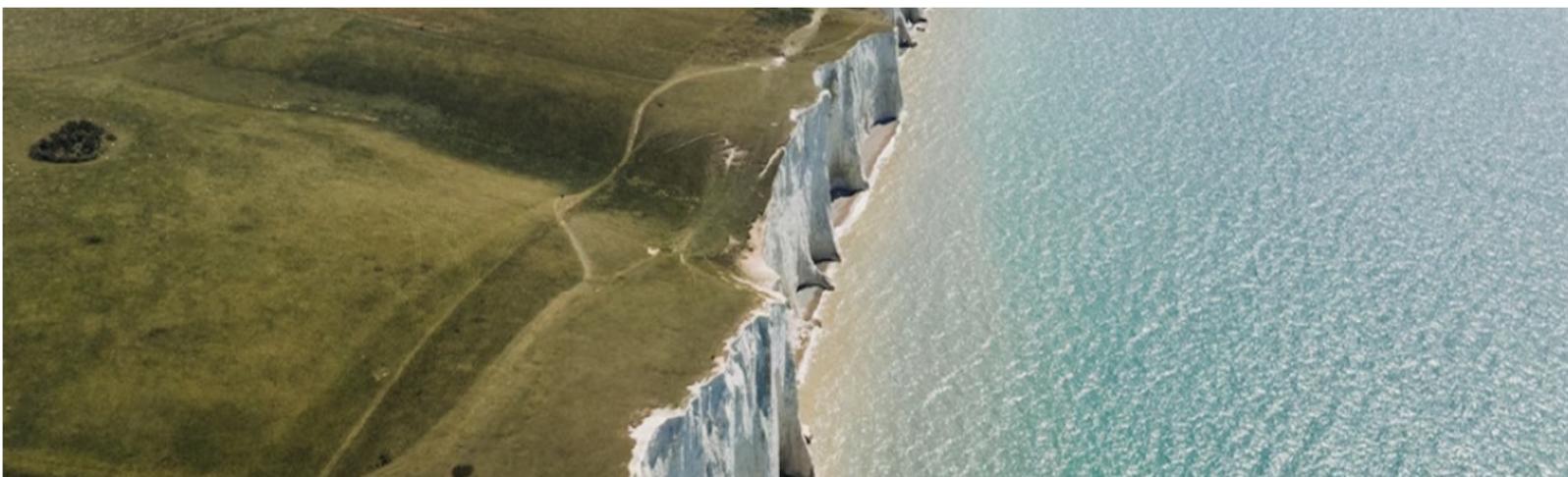
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EXECUTIVE SUMMARY

This document provides NASH Maritime Ltd.'s report on the drift analysis relating to the migrant incident that occurred in the Dover Straits on 24-Nov-2021.

NASH Maritime carried out the following steps.

1. Review available information on the incident.
2. Discuss with MAIB thoughts on possible confounding factors to simple drift explanations for the “known” start and end points.
3. Obtain suitable metocean data for the relevant period, to input into the drift model.
4. Set up and run the OpenDrift drift model using known information and relevant metocean data.
5. Review and analyse results from the drift modelling and (if necessary) carry out further drift modelling scenarios to test a range of possible scenarios with modified inputs/assumptions regarding locations, timings, drift rates and other confounding factors to allow consideration of any anomalies.

Surface flow data extracted from the North West European Shelf (NWS) model and wind data measured at Sandettie Lightvessel provide suitable data for the assessment and as a basis for input into the drift modelling.

The OpenDrift model used for the study has been developed at the Norwegian Meteorological Institute and is used in planning search and rescue operations. The OceanDrift (simple downwind drift model) and OpenLeeway (specific well calibrated drifting object model) components of the OpenDrift model were used in the study.

The closest match to the incident's last reported position and assumed found position was achieved using the OceanDrift model with a 3% wind drift applied to the fixed average measured wind data and modelled time/space varying surface flow data (see **Figure 12**). Note however that in this simulation the objects drift directly downwind, rather than at an angle to the wind, which is seen in most practical tests of asymmetric objects (such as people and small boats) as modelled with OpenLeeway. Nevertheless, it does indicate a possible route and timing which appears to match the observations.

The more rigorous approach of building on real field data of the behaviours of drifting objects which is embedded within the OpenLeeway model also introduces a wider possible range of outcomes. The OpenLeeway simulations with various object types showed similar (though subtly different) possible routes and outcomes. However in all cases the model results indicated it was possible that the wind and surface flow could largely explain the drift of the objects (whether they were conscious or unconscious persons in the water or in a small boat) from the last known position to the assumed found position reported by the French fishing vessel.

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ABBREVIATIONS

Abbreviation	Detail
CD	Chart Datum
CMEMS	Copernicus Marine Environmental Monitoring Service
ECMWF	European Centre for Medium Range Forecasting
FOAM	Forecasting Ocean Assimilation Model
GNSS	Global Navigation Satellite System
HAT	Highest Astronomical Tide
HW	High Water
JRCC	Joint Rescue Co-ordination Centres
kt	Knot (unit of speed equal to nautical mile per hour, approx 1.15 mph)
km	kilometre
Km/hr	Kilometre per hour
LAT	Lowest Astronomical Tide
LW	Low Water
m	Metre
m/s	Metre per second
MAIB	Marine Accident Investigation Branch
MCA	Maritime and Coastguard Agency
mCD	Metres above Chart Datum
MHWS	Mean High Water Springs (Note 1 & 3)
MHWN	Mean High Water Neaps (Note 2 & 3)
MLWN	Mean Low Water Neaps (Note 2 & 3)
MLWS	Mean Low Water Springs (Note 1 & 3)
MNR	Mean Neap Range
MRCC	Maritime Rescue Coordination Centres
m/s	Metres Per Second
MSR	Mean Spring Range
NEMO	Nucleus for European Modelling of the Oceans
N	North
nm	Nautical Mile
NNW	North North West
NW	North West
NWS	North West European Shelf Model
PIW	Person in water
RMS	Root Mean Square
SAROPS	Search and Rescue Optimum Planning System

US	United States
UTC	Coordinated Universal Time

Note 1 - *The height of mean high water springs is the average throughout the year (when the average maximum declination of the moon is 23.5°) of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest. The height of the mean low water springs is the average height obtained by the two successive low waters during the same period.*

Note 2 *The height of mean high water neaps is the average throughout the year (when the average maximum declination of the moon is 23.5°) of two successive high waters during those periods of 24 hours when the range of the tide is at its least. The height of the mean low water neaps is the average height obtained by the two successive low waters during the same period.*

Note 3 *The values of MHWS, MLWS, MHWN and MLWN vary from year to year with a cycle of approximately 18.6 years.*

1. INTRODUCTION

1.1 SCOPE

This document provides NASH Maritime Ltd.'s report on the drift analysis relating to the migrant incident that occurred in the Dover Straits on 24-Nov-2021.

It is understood that during the night of 23rd-24th November 2021, about 33 persons attempted to cross the English Channel in an inflatable dinghy. At some time between 0200 UTC and sunrise, the dinghy foundered, and the persons entered the water. The next day at around 1300 UTC, a fishing vessel reported bodies in the water. After rescue attempts were concluded, there were at least 27 fatalities and two survivors.

The Marine Accident Investigation Branch (MAIB) requires an investigation and report into the possible movement through the water of those persons/inflatable dinghy, including consideration for tidal flow and weather. Where tidal and weather factors cannot explain the track, the MAIB requires suggestions about alternatives that could explain the track, given the known information.

The MAIB requires a report including figures and the underlying data detailing any assumptions and known limitations to the method employed. The MAIB notes that parts of the report, including figures, may be incorporated in MAIB official publications.

1.2 APPROACH

NASH Maritime's approach to this study enabled a rapid response to the MAIB's questions using readily available tools and data, without the requirement for detailed and time-consuming bespoke model design/development/construction and validation.

The approach adopted by NASH Maritime was based on three core elements:

- **Clear understanding of the essential requirements of the study**

These are to provide an evidence-based view on the likely path of the persons/craft involved in the incident and probable causes, with a draft report by end July 2023

- **Environmental data: from proven global sources**

Well validated tidal stream data are available from global models with adequate resolution and from wind speed and direction measurements in the area of interest allowing for quick review, assimilation and deployment within the model solution.

- **Open-Source Drift Model:**

Application of the well-respected open-source drift model "OpenDrift"¹ developed and used by the Norwegian Meteorological Institute and used by the Irish Marine Institute to support search and rescue operations.

We believe that the findings of this study will be sufficient to provide appropriate answers to the questions raised by the MAIB scope.

¹ Dagestad, K.-F., Röhrs, J., Breivik, Ø., and Ådlandsvik, B.: OpenDrift v1.0: a generic framework for trajectory modelling, *Geosci. Model Dev.*, 11, 1405-1420, <https://doi.org/10.5194/gmd-11-1405-2018>, 201

2. METHODOLOGY AND DATA VALIDATION

The overall methodology adopted for the study is set out below.

1. Review available information on the incident.
2. Discuss with MAIB thoughts on possible confounding factors to simple drift explanations for the “known” start and end points.
3. Obtain suitable metocean data for the relevant period, to input into the drift model.
4. Set up and run the drift model using known information and relevant metocean data.
5. Review and analyse results from the drift modelling and (if necessary) carry out further modelling scenarios to test a range of possible scenarios with modified inputs/assumptions regarding locations, timings, drift rates and other confounding factors to allow consideration of any anomalies.
6. Prepare and issue draft report for MAIB review and comment.
7. Update and issue final report following MAIB comment.

The following sections provide more detail on our understanding of the information available and on the key elements of the analysis undertaken.

2.1 INCIDENT INFORMATION

2.1.1 Review of incident information supplied by MAIB

Attached to the email from the MAIB Business Support (received on 6-Jul-2023) inviting our proposal, the MAIB provided a document titled “Analysis of drift affecting persons in the water”. This document outlines the following information:

- **Scope** – as summarised in section 1
- **Known information** – comprising:
 - Last reported position (see **Figure 1**) from a mobile device associated with the inflatable dinghy sent via WhatsApp at 0221 UTC on 24-Nov-2021; a time when MAIB evidence indicates that persons were in the vessel, the vessel’s engine had stopped, and it was drifting.
 - Details of subsequent calls/messages with unknown locations received by UK authorities possibly from the dinghy/people in the water, including a phone call at 0312 UTC (position unknown) in which the caller indicated that the vessel was foundering and the MAIB information notes that some people may have been in the water at this time.
 - Position assumed to be of French fishing vessel Global Navigation Satellite System (GNSS) position (see **Figure 1**) reporting one or more bodies in the water at 1258 UTC on 24-Nov-2021. The MAIB has assumed the position represents at least one body. Bodies were located at or around this position.

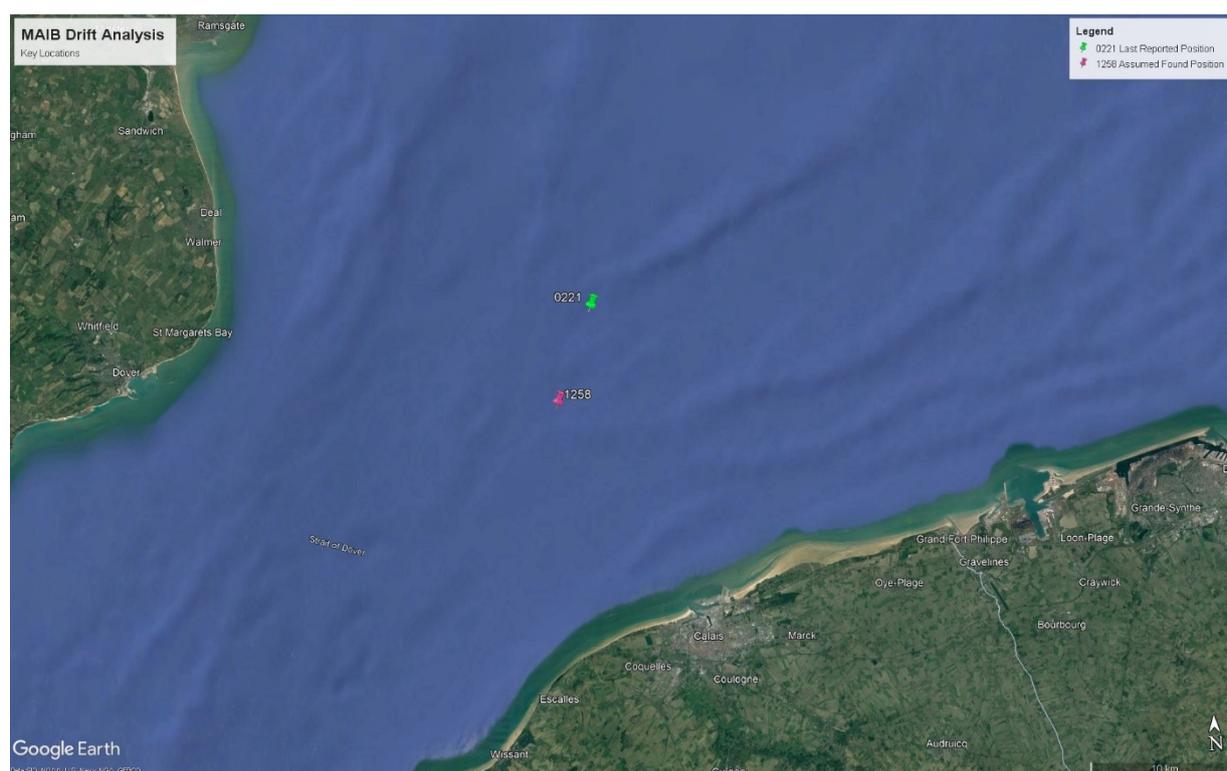


Figure 1 Key locations for drift analysis

- **Unknown information** – comprising:
 - The exact time the dinghy foundered is unknown.
 - The found location of the dinghy is unknown.
 - The exact location of each of the persons in the water is unknown.
 - The accuracy of the mobile devices and the fishing vessel position reporting is unknown.
 - The exact time associated with any of the positions cannot be verified.
 - There is some evidence that the vessel's outboard engine stopped before 0200 UTC. There is no evidence to suggest whether or not it was restarted later, and its condition is unknown.

Given the above unknowns, the exact time of when each individual entered the water when they separated from the dinghy is unknown.

2.1.2 Other information

In November 2022 MAIB published a report on the incident titled “*Interim report on the investigation of the search and rescue response to the accident involving a small migrant vessel resulting in the loss of at least 27 lives in the Dover Strait on 24 November 2021*”.

The report noted that “*The MAIB was aware of this incident at the time but did not take any action. This was because the reported events were assessed to fall outside the MAIB's*

investigative jurisdiction, given that the location where the survivors and bodies were found was in French waters, and the boat was not UK registered. In January 2022, the Chief Inspector of Marine Accidents started an investigation when it became evident that some of the events relating to this loss of life had occurred inside UK waters.”

The report further noted that *“The investigation has established that, during the evening of 23 November 2021, about 34 migrants left a beach near Dunkirk, France on board a small inflatable boat to proceed to the UK. During the passage, the migrants got into difficulties and entered the sea. Along with many other migrants that were transiting the Dover Strait that night, some of those on board the boat made phone calls to alert Maritime Rescue Coordination Centres (MRCC) ashore about their situation. Staff at the Dover MRCC responded to the calls for help and dispatched UK surface and air assets to search the area where the distressed migrants were assessed to be. However, nothing was found until the report from the French fishing vessel later on 24 November 2021.”*

2.2 METOCEAN DATA

The key drivers potentially affecting the drift of floating bodies (including people and the inflatable dingy) in this area of the English Channel are: surface currents, comprising primarily tidal streams and wind driven currents; direct wind effects and wave effects.

2.2.1 Tidal data

The water depth in the English Channel in the area of interest is typically less than 50m. In the middle of the Dover Strait, there are sandbanks oriented in the alongshore direction as illustrated in **Figure 1**. The semi-diurnal tides in the English Channel typically drive tidal streams roughly northeast (NE) from 1.5 hours before high water (HW) to 4 hours after HW at Dover and following a short period of slack water, the ebb tidal stream flows south west (SW) from 4.5 hours after HW to 2 hours before low water (LW) at Dover, again followed by a slack period. Tidal levels at Dover are as shown in **Table 1**.

Table 1 Tidal Levels at Dover

Parameter	Abbreviation	Level (mCD)
Highest Astronomical Tide	HAT	7.27
Lowest Astronomical Tide	LAT	0.24
Mean High Water Springs	MHWS	6.69
Mean High Water Neaps	MHWN	5.40
Mean Low Water Neaps	MLWN	2.14
Mean Low Water Springs	MLWS	0.87
Mean Spring Range	MSR	5.82
Mean Neap Range	MNR	3.26

Source: National Tidal and Sea Level Facility

Tidal heights and times at Dover for 24 Nov 2021 are shown in **Table 2**.

Table 2 Tidal heights and times at Dover on 24-Nov-2021

High/Low Water	Time (UTC)	Height (mCD)	Range (m)
High	01:08	6.19	4.59
Low	08:26	1.60	
High	13:18	5.98	4.38
Low	20:41	1.76	

During the period of interest on 24-Nov-2021 the tidal range in Dover was 4.59m to 4.38m and HW occurred at 0108 UTC and 1318 UTC. Thus, the event occurred from one to two hours after HW and continued to around the following HW.

2.2.2 Surface flow data

Surface flow² data was extracted from the North West European Shelf (NWS) – Ocean Physics Analysis and Forecast data set. This is produced by the Forecasting Ocean Assimilation Model (FOAM) 1.5km resolution Atlantic Margin model (AMM15). It is a hydrodynamic model, nested in a series of one-way nests to the Met Office global ocean model and the Copernicus Marine Environmental Monitoring Service (CMEMS) Baltic Model. Hydrodynamics are provided by the Nucleus for European Modelling of the Oceans (NEMO) with assimilation of sea surface temperature, sea level anomaly, sea water temperature and salinity profile data. FOAM is also coupled to the WAVEWATCH III wave model. Atmospheric forcing is provided by the European Centre for Medium Range Forecasting (ECMWF) Numerical Weather Prediction model and river discharges from daily climatology.

Example surface flow speeds are illustrated in **Figure 2**.

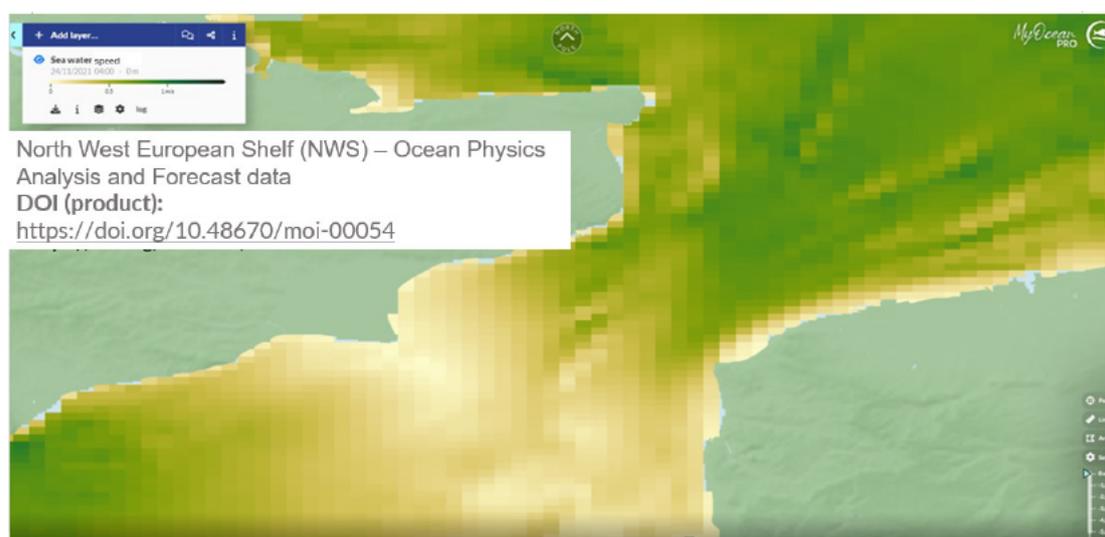


Figure 2 NWS model example surface flow speeds

² Surface Flow taken to be combination of tidal stream (the periodical horizontal oscillations of the sea in response to the tractive forces of the Sun and Moon) and current (the non-tidal horizontal movement of the sea which may be in the upper, lower or in all layers.) within the upper 3m of the water column

The quality of the NWS forecast system (AMM15) was assessed using two-year trial experiments (2016-2017). This showed that the tides are accurate across most of the domain for phase and amplitude. The root mean square (RMS) error for the M2³ (major tidal component) amplitude is in the order of 12cm (5% too low) in the eastern part of the Dover Strait (see **Figure 3**).

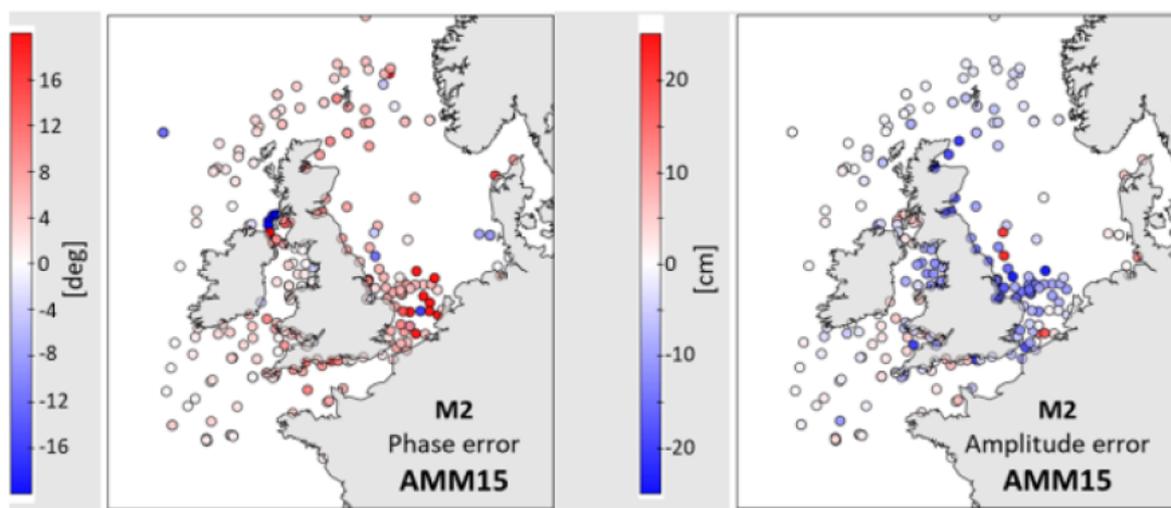


Figure 3 Tidal data validation

Given this systematic amplitude error in the M2 tidal constituent (which might lead to lower than actual tidal stream), we carried out a comparison of the Copernicus model data with information from the Admiralty Total Tide tool⁴, which provides accurate tidal height and surface tidal stream predictions for 3,000 tidal streams worldwide. The MAIB provided the relevant hourly tidal stream speed and direction data from Total Tide at four locations in the vicinity of the incident over the period of interest. These were compared with the Copernicus model predictions for the relevant period, as illustrated in **Figure 4** and **Figure 5**. This shows a good match in speed, direction and phasing of the surface flow at all locations, giving confidence in use of the Copernicus model data as a basis for the drift modelling. Note that the current directions for SN009V appear to show a big discrepancy at about 0600 UTC where the Copernicus data goes to 360° while the Total Tide data shows 30°. This is only a 30° difference between directions in the two data sets and it occurs for only 1 hour.

Note that to run the model efficiently we need a gridded data set, as obtained directly from the Copernicus model. We are not able to get a gridded data set out of Total Tide without a significant manual effort to extract the data and create a regular grid. We thus chose to use the readily available gridded Copernicus data which has already been validated against other data sources and validated it further against Total Tide as shown below.

³ Results for S2 (the second major tidal component are not reported)

⁴ <https://www.admiralty.co.uk/publications/admiralty-digital-publications/admiralty-totaltide>

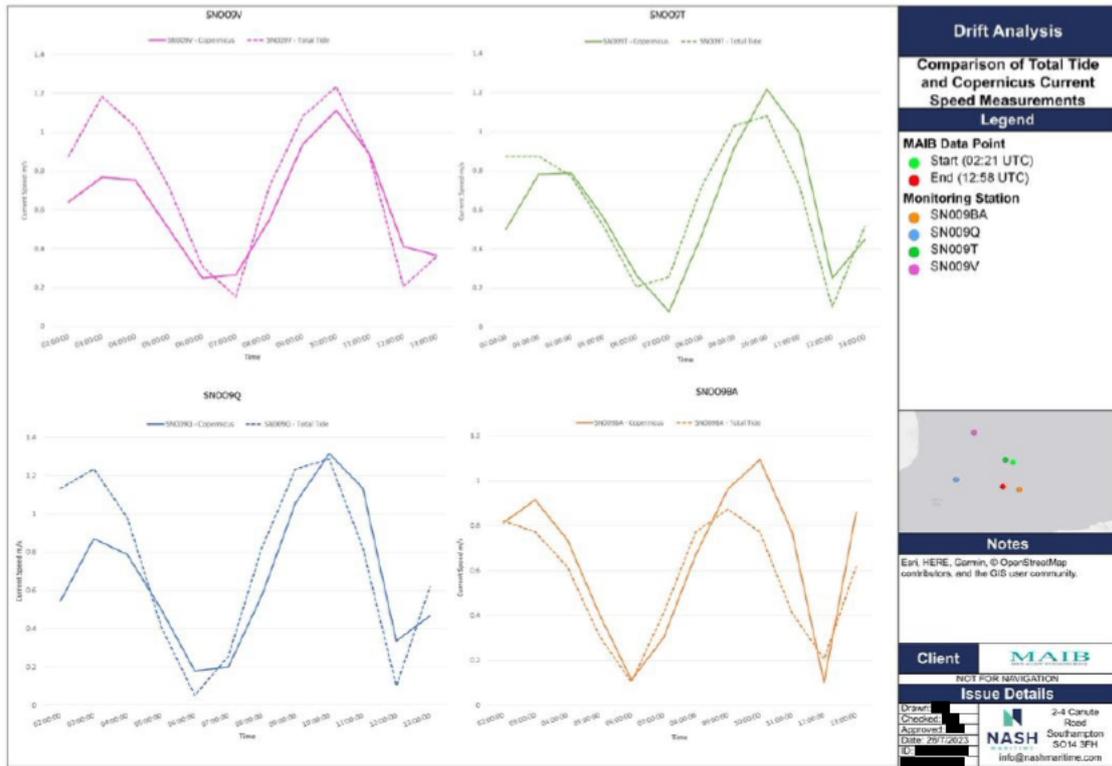


Figure 4 Comparison of Total Tide and Copernicus current speeds

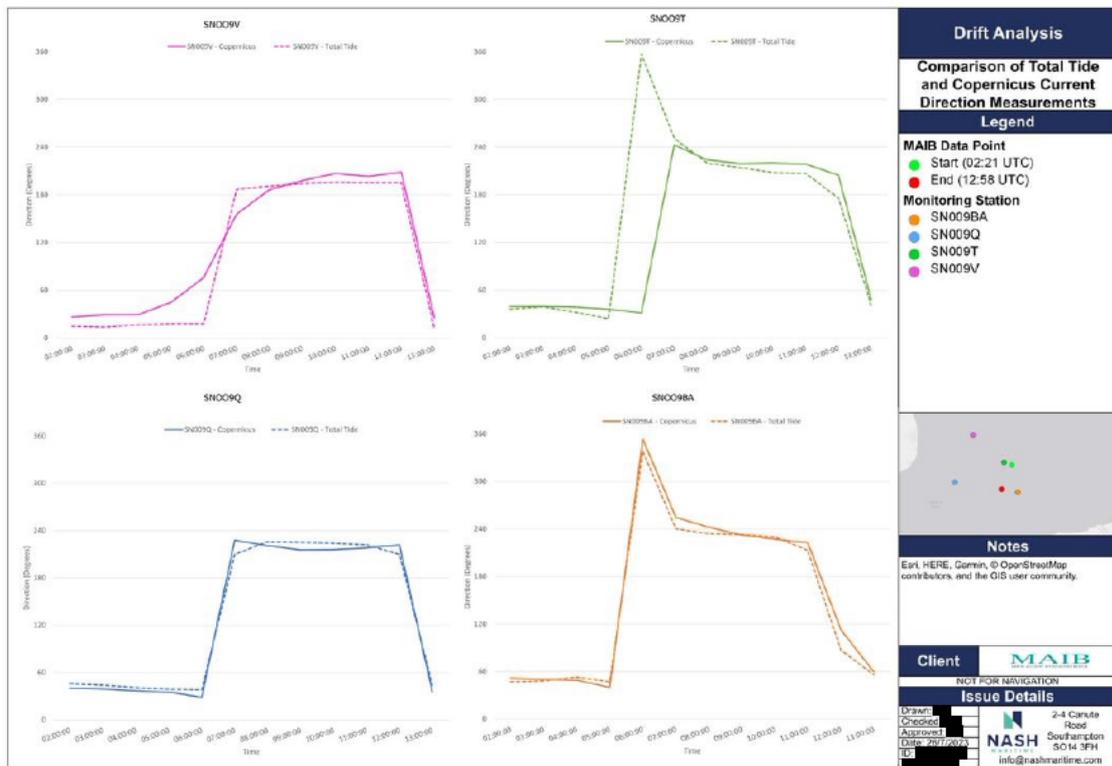


Figure 5 Comparison of Total Tide and Copernicus current directions

The hourly surface flows used in the modelling are shown in **Figure 6** and **Figure 7**.

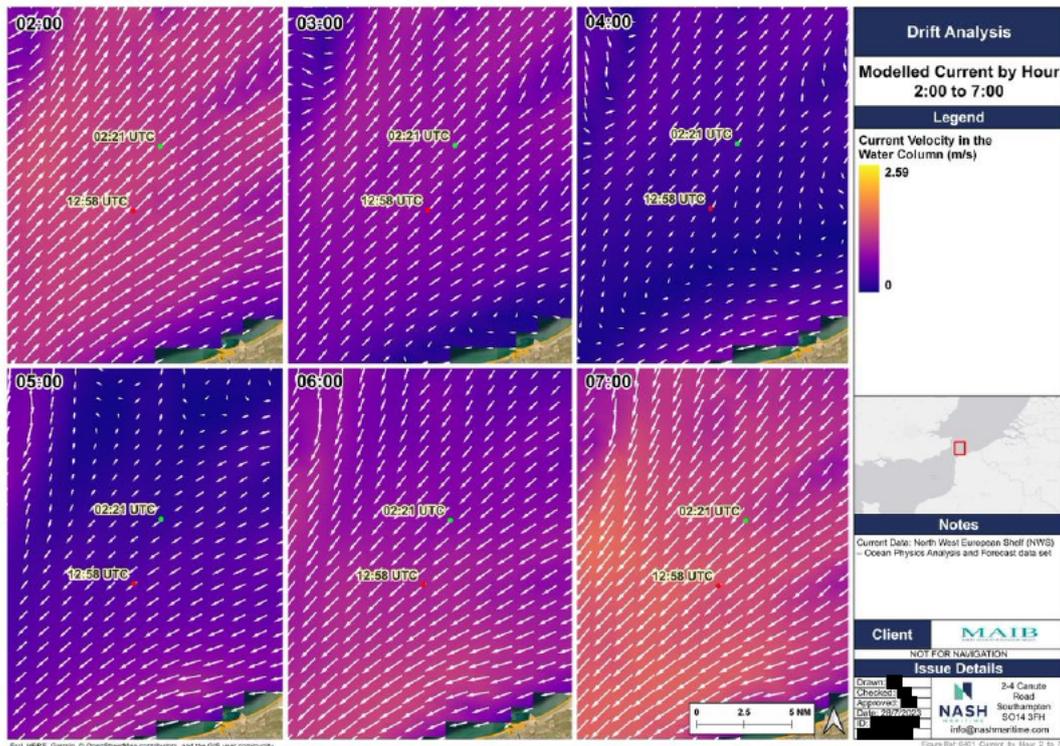


Figure 6 Gridded model surface flow 24 Nov 2021 0200-0700 UTC

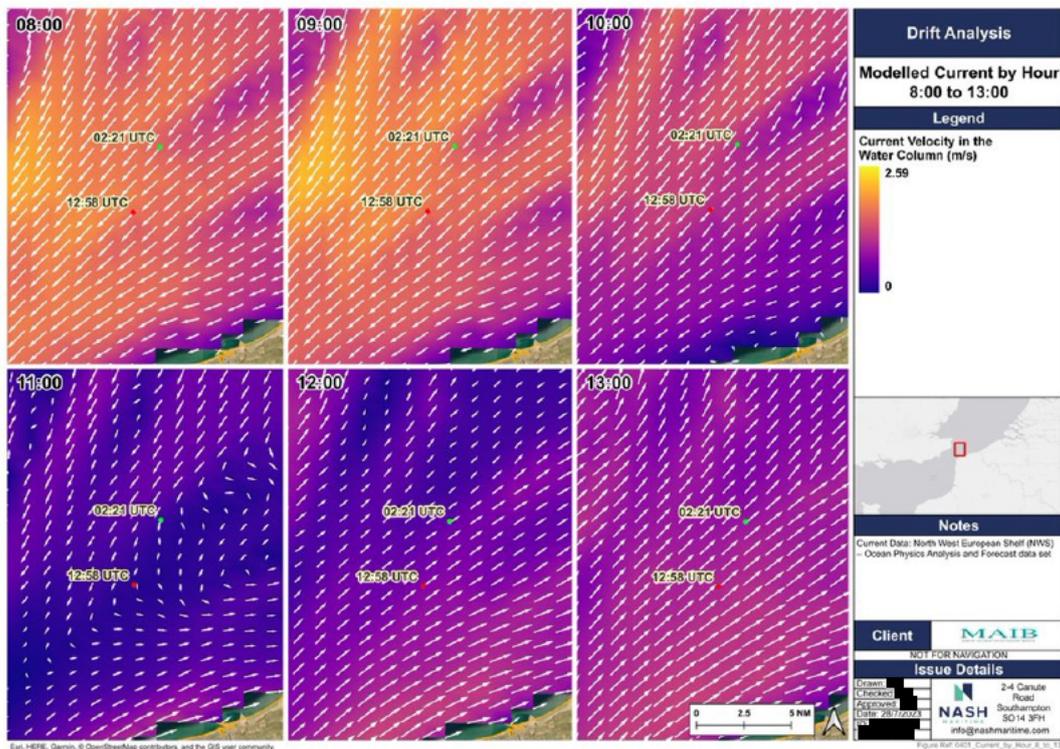


Figure 7 Gridded model surface flow 24 Nov 2021 0800-1300 UTC

2.2.3 Wind data

Met Office metocean data from the Sandettie Lightvessel covering the period of interest was provided to NASH Maritime by the MAIB (Excel file ESandetti_23_24). This included the measured mean hourly wind speed and direction.

Figure 8 shows the location of the Sandettie Lightvessel relative to the key locations identified in **Figure 1**. The lightvessel marks the position of the Sandettie Bank in the English Channel and is managed and operated by Trinity House, the General Lighthouse Authority for England, Wales, the Channel Islands and Gibraltar. The lightvessel records metocean information which is collated and published by the UK Met Office.

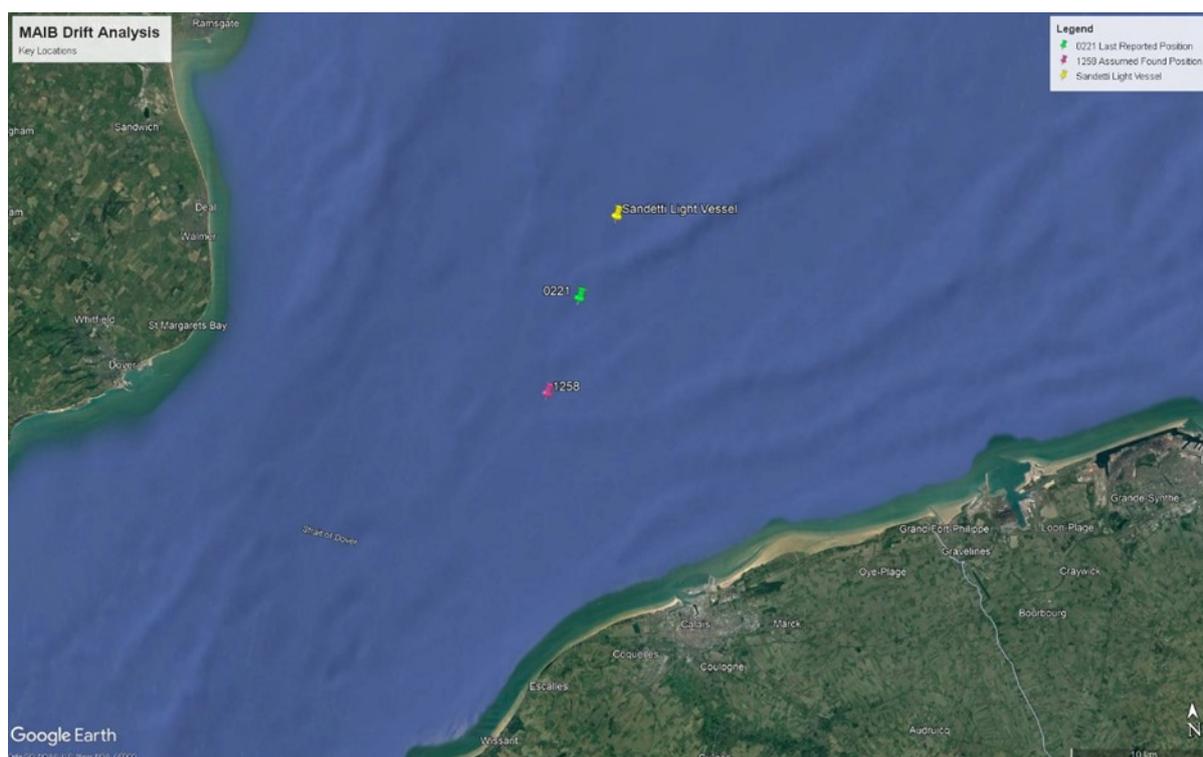


Figure 8 Sandettie Lightvessel Location

The Sandettie data provided by MAIB is illustrated in **Figure 9**. This shows small change in wind speed and direction over the period of interest. Wind is principally from N to NNW occasionally NW and mostly about 4m/s (8 knots) with a peak at just over 5m/s (10 knots) at 0600 (UTC) and reducing to about 2.5m/s (5 knots) at 1300.

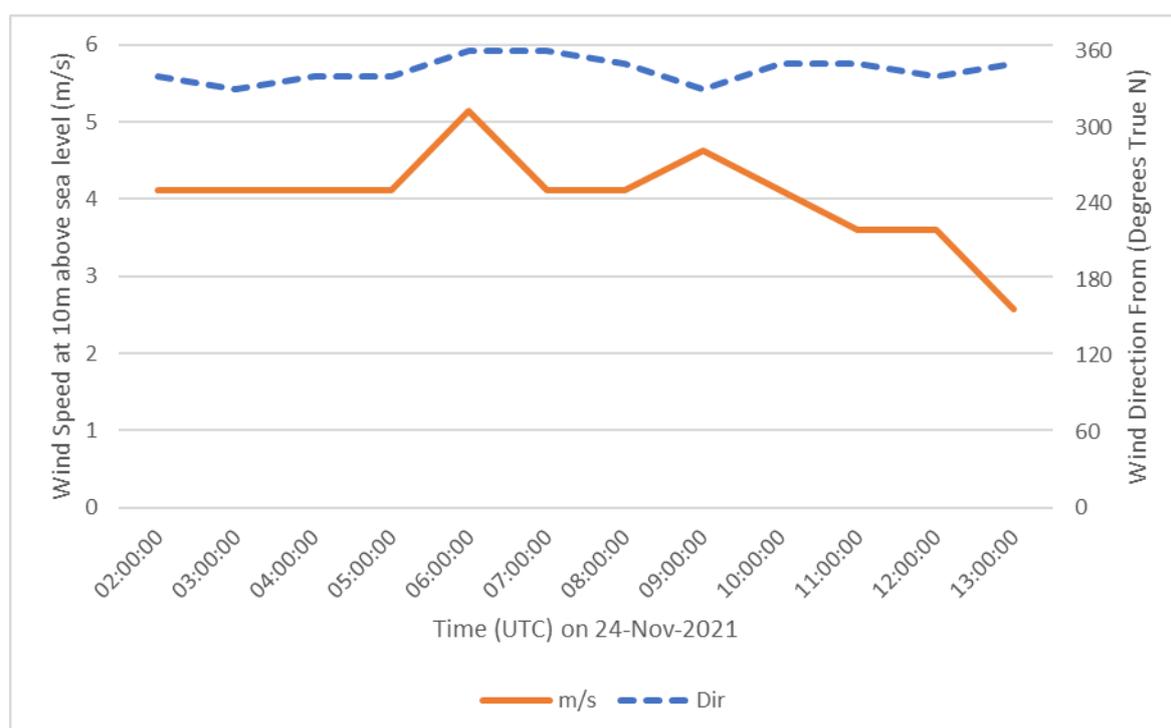


Figure 9 Measured wind speed and direction at Sandtette Lightvessel

2.2.4 Waves

Wind directions measured at Sandtette Lightvessel in the 12 hours preceding the incident were from the north with speeds typically 5-6m/s [10-12 knots]. These winds give an estimated (from the Beaufort Scale⁵) sea state of 3-4 with probable wave heights 1m and maximum wave height of 1.5m. Wind conditions measured at the Sandtette Lightvessel during the incident were (5-2.5 m/s [10-5 knots]), giving an estimated sea state of 3, the probable wave heights of about 0.6m with a maximum of 1m. Thus there is an expectation of small and declining wave heights from the period preceding the incident to the period of the incident.

Given these conditions and the drift model selected (see later), we determined that a gridded data set of surface tidal streams and fixed winds from the Sandtette Lightvessel would be suitable for the assessment, as wave conditions were unlikely to be sufficient to have a significant impact on drift rates or trajectories.

2.3 DRIFT MODELLING

2.3.1 OpenDrift software

As outlined above, we used “OpenDrift” for the drift modelling. This is an open-source Python-based framework for Lagrangian⁶ particle modelling. It was first released in 2017 and has been under continuous development at the Norwegian Meteorological Institute with contributions

⁵ Royal Meteorologic Society - <https://www.rmets.org/metmatters/beaufort-wind-scale>

⁶ The Lagrangian model is one in which fluid flow is described through the tracking of individual fluid “parcels” in space and time, based on the principles developed by Joseph-Louis Lagrange in 1788.

from the wider scientific community since then. This work uses the most recent version (at time of writing the report) v1.10.7 released on 02-May-2023. The framework is highly generic and modular and is designed to be used for any type of drift calculations in the ocean or atmosphere. OpenDrift is fast and simple to set up to assess a range of problems and contains core functionality around data reading/ingestion and interaction with a range of specialised modules, many not used in this study.

The OceanDrift module corresponds to a Lagrangian particle model in the traditional sense. This simply simulates the advection of particles in the current and wind fields presented to the model. We use this module for some initial simulations reported in this study.

The Leeway module is a stochastic search and rescue module for tracking/forecasting drift of people and vessels. We use this model in more depth as described below.

The framework allows for the use of any number of forcing fields (scalar and vector) from various sources, including Eulerian⁷ ocean, atmosphere and wave models, but also measurements or priori values for the same variables.

A basic backtracking mechanism is built into the software, using sign reversal of the total displacement vector and negative time stepping. This feature is key for this study as it allows for reverse track modelling to identify a starting location from a known end location.

2.3.2 OpenLeeway

Within this study we used the basic OpenOcean model but also the OpenDrift Leeway (OpenLeeway) module. This module calculates downwind and crosswind drift speed which various floating objects will take.

This module is based on the operational search and rescue model of the Norwegian Meteorological Institute. The model ingests a list of object classes, where each drifting object has specific properties such as downwind and crosswind leeway in a way similar to SAROPS, the operational system used by the US Coast Guard. The object classes are illustrated in **Appendix A**. Each object class has an assigned downwind and crosswind drift velocity and leeway angle which are calibrated functions of the 10m above sea level wind speed, as used in this work and typically reported in oceanographic measurements and model results. They also have a divergence angle, which represents the range of leeway angles found in experimental studies and thus recognising some inherent uncertainty in the model predictions.

These properties vary greatly from object to object and are based on field work by a number of search and rescue organisations, where specific objects of relevance in search and rescue have been studied. All objects are assumed to be small enough that direct wave scattering forces are insignificant. Furthermore, the Stokes drift⁸ (wave related drift) is inherently part of the leeway obtained from field work observations.

As wind-generated waves have a mean direction closely aligned with the local wind direction it is neither practical nor desirable to disentangle the Stokes drift from the wind drag for leeway simulations.

⁷ A Eulerian model is one in which fluid motion is modelled as it passes through specific locations over time. The approach was developed by Leonhard Euler in the 1700s.

⁸ During its periodic motion, a particle floating at the free surface of a water wave experiences net drift in the direction of wave propagation, known as Stoke Drift (Stokes 1847 Trans Camb. Philos. Soc. 8 441-455)

Once an object class has been chosen and the relevant wind and current forcing fields have been selected, the particles are seeded based on the available information. If the particles hit the coast they stick by default. This can however be relaxed so that particles detach from the coastline if the wind direction changes.

As noted above, the OpenLeeway module along with all other sub-modules have the option of being run in reverse. The model developers note that *“this is a convenient feature in cases where for example a debris field is observed, and the location of the accident is sought”*. It should be noted that this method is fundamentally different from the traditional BAKTRAK model where a large number of particles are “seeded” in potential initial locations at various times, and only those that ended up close to the location of the observed object are retained in the results. That approach is an iterative procedure which in principle can deal with nonlinearities in the flow field as well as nonlinear behaviour of the object itself (such as capsizing and swamping). Although in principle this allows for a more realistic mapping of initial locations, the difficulties associated with this iterative process means that real-time operations and fast paced historical analysis (of the type required for this study) are normally better suited to a simpler and quicker negative-time integration.

OpenLeeway is used operationally at the Norwegian Meteorological Institute and is also currently being implemented as the operational search and rescue model for the Joint Rescue Co-ordination Centres (JRCC) of Norway.

3. OPENDRIFT APPLICATION TO THIS STUDY

In all simulations described below we have used OceanDrift or OpenLeeway modules, simulating drifting particles (objects) either:

- Forwards in time from the last known position at 0221 UTC until 1258 UTC, the time at which the French fishing vessel reported bodies in the water, or
- Backwards in time from 1258 UTC from the assumed found position (position at which the French fishing vessel reported bodies in the water) until 0221 UTC.

In all cases we have then considered the final position of the particles or the estimated probability of start point or end point with the known positions at 0221 UTC or 1258 UTC as appropriate.

To balance model efficiency and ensure the simulations provided a consistent and easy to interpret results, all simulations used:

- 3,000 particles - to allow for probabilistic calculations within the OpenLeeway results and keep model run times acceptable
- a 1000m grid for the probabilistic plots to give consistent easy to interpret results
- a 250m release radius for the particles (in both forwards and backwards simulations) – to allow for some uncertainty in start/end locations in the information provided by MAIB
- a 10-minute model timestep – to interpolate the hourly time steps in the wind and tide data sets driving the models and to keep model run times acceptable

3.1 INITIAL OCEANDRIFT SIMULATIONS

We carried out four simulations using OceanDrift to make an initial assessment of the situation. The OceanDrift model moves the particles (objects) with at the speed of and in the direction of the surface flow and at a percentage (specified for each run) of the wind speed and in the wind direction.

The first two runs used the modelled surface flow only, with no additional wind drift applied.

Figure 10 shows a simulated forward drift from the last reported position (green dot and green particles) with tidal streams only applied to the drift. The tracks taken by the 3,000 particles are shown in grey and the predicted end point (blue particles) is some 2-2.5NM north of the assumed found position (red dot).

Figure 11 shows a simulated backward drift from the assumed found position (red dot and green particles) with tidal streams only applied to the drift. The tracks taken by the 3,000 particles are shown in grey and the predicted end point (blue particles) is some 2-2.5NM south of the last reported position (green dot).

In summary, the modelled surface flow alone do not show a clear basis for the likely drift paths of the migrants.

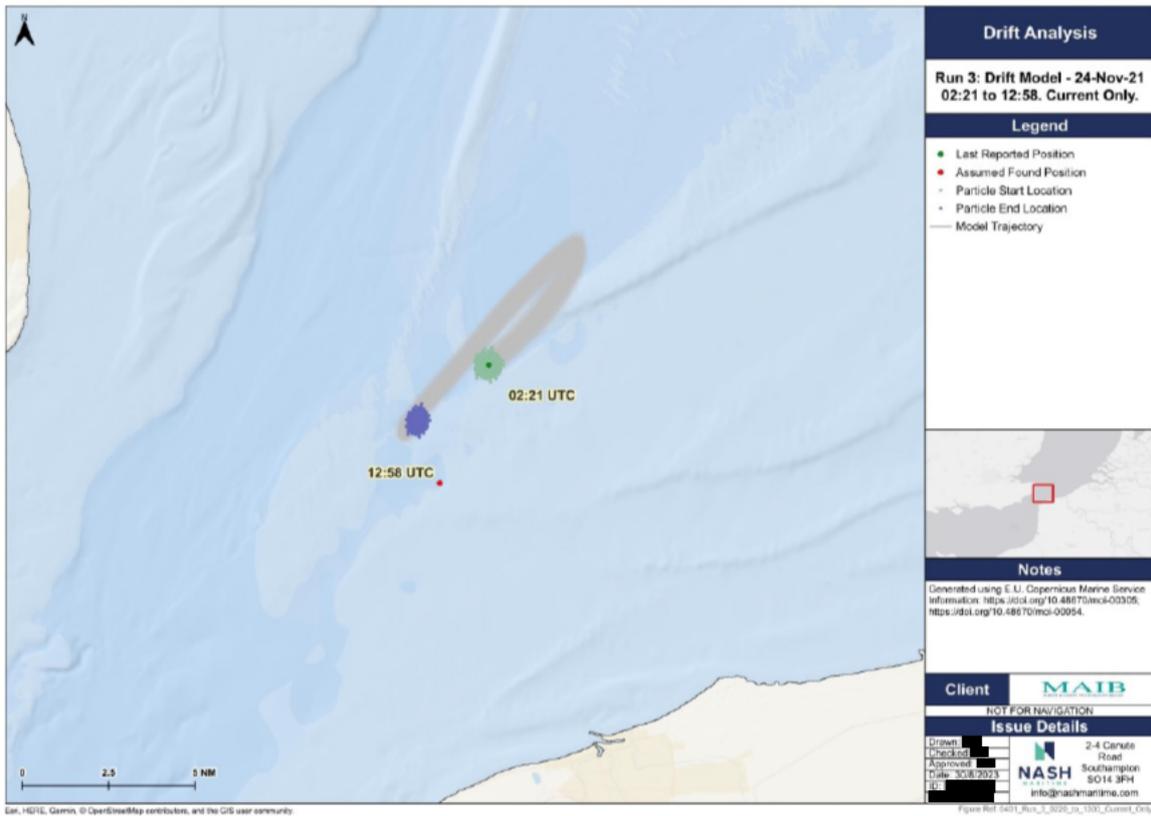


Figure 10 OceanDrift forwards with model surface flow only

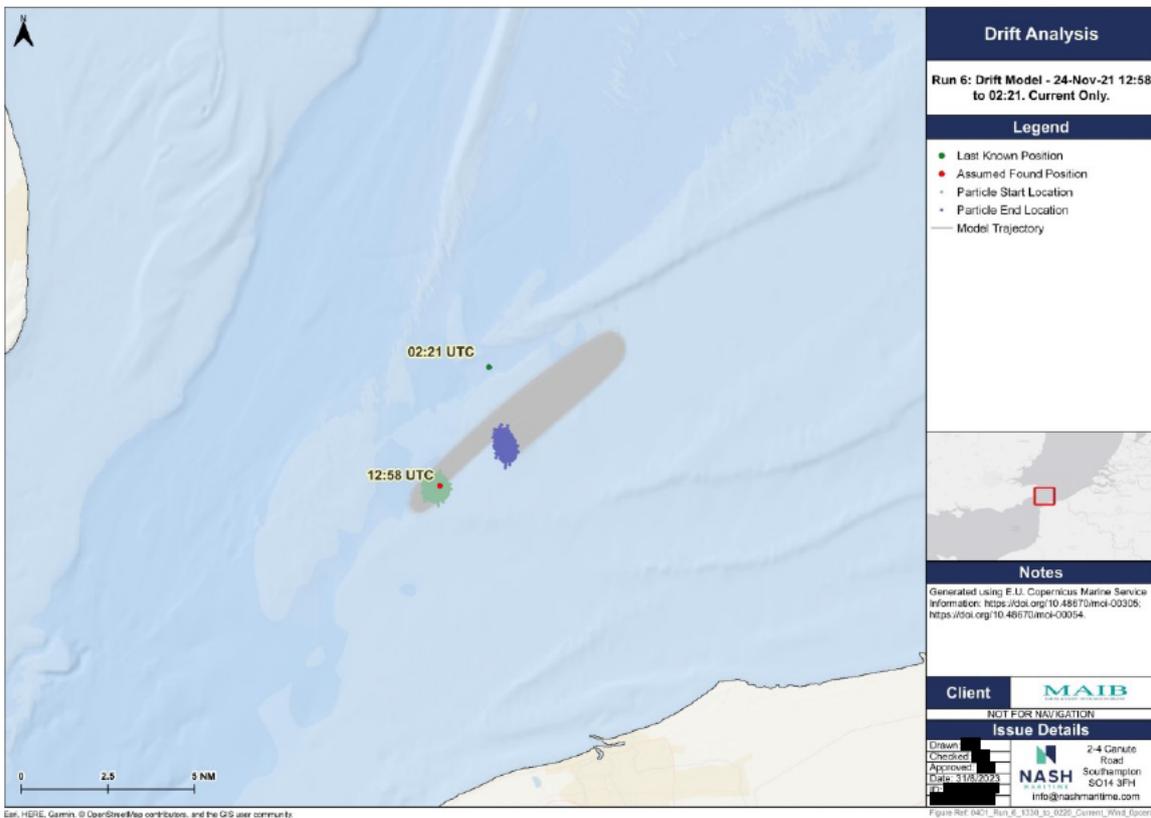


Figure 11 OceanDrift backwards with model surface flow only

The third and fourth runs used the modelled surface flow with a 3% additional wind drift applied to the average wind speed and direction at the Sandtette Lightvessel over the period of interest (4m/s at 345 degrees). A 3% wind drift factor was selected as the drift current at the ocean surface is and has been for a long time generally estimated at roughly 3% of the wind speed (at 10m height)⁹.

Figure 12 shows a simulated forward drift from the last reported position (green dot and green particles) with surface flow and 3% wind drift applied. The tracks taken by the 3,000 particles are shown in grey and the predicted end point (blue particles) is at or within 50m of the assumed found position (red dot).

Figure 13 shows a simulated backward drift from the assumed found position (red dot and green particles) with surface flow and 3% wind drift applied. The tracks taken by the 3,000 particles are shown in grey and the predicted end point (blue particles) is at or within 50m of the last reported position (green dot).

In summary, the OceanDrift modelled surface flow and 3% wind drift applied show a clear basis for the likely drift paths of the migrants in both forward and backward simulations.

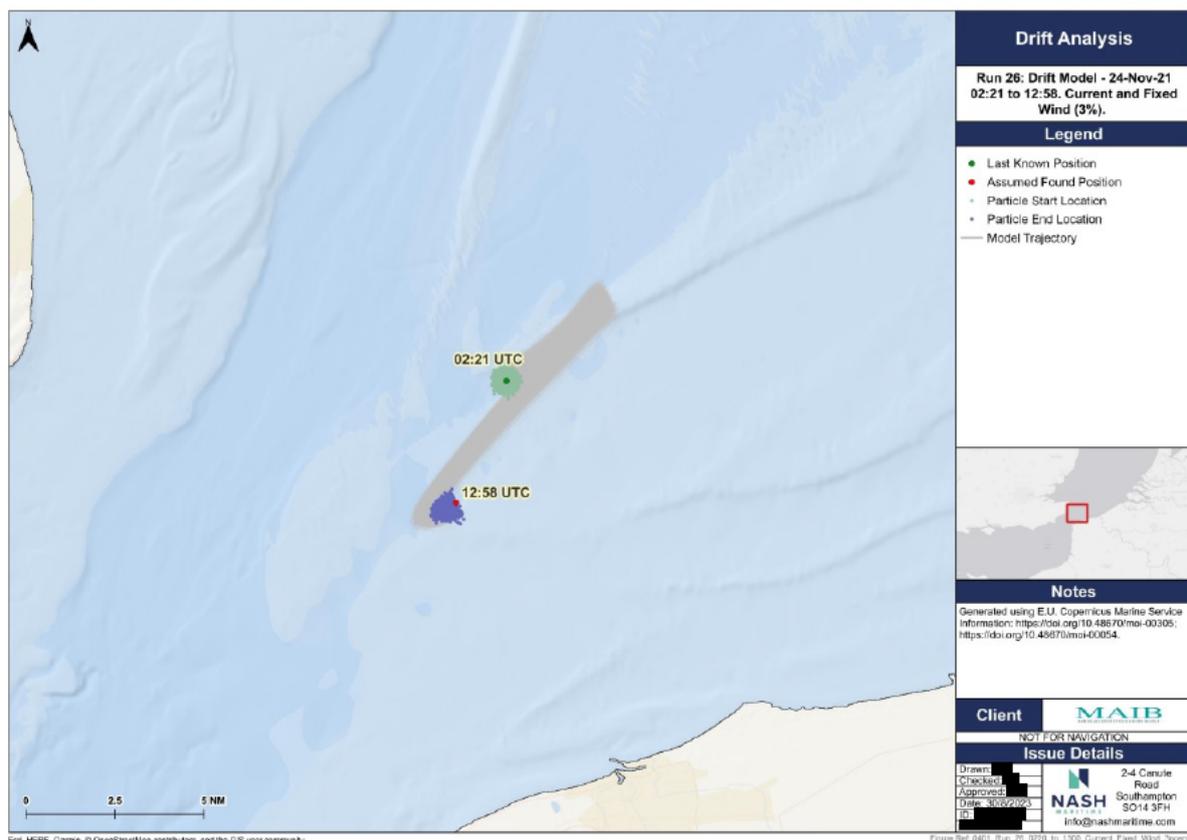


Figure 12 OceanDrift forward with model surface flow and 3% wind drift

⁹ Hughes, P. (1956). A determination of the relation between wind and sea-surface drift. Q. J. R. Meteorol. Soc. 82, 494–502. doi: 10.1002/qj.49708235412

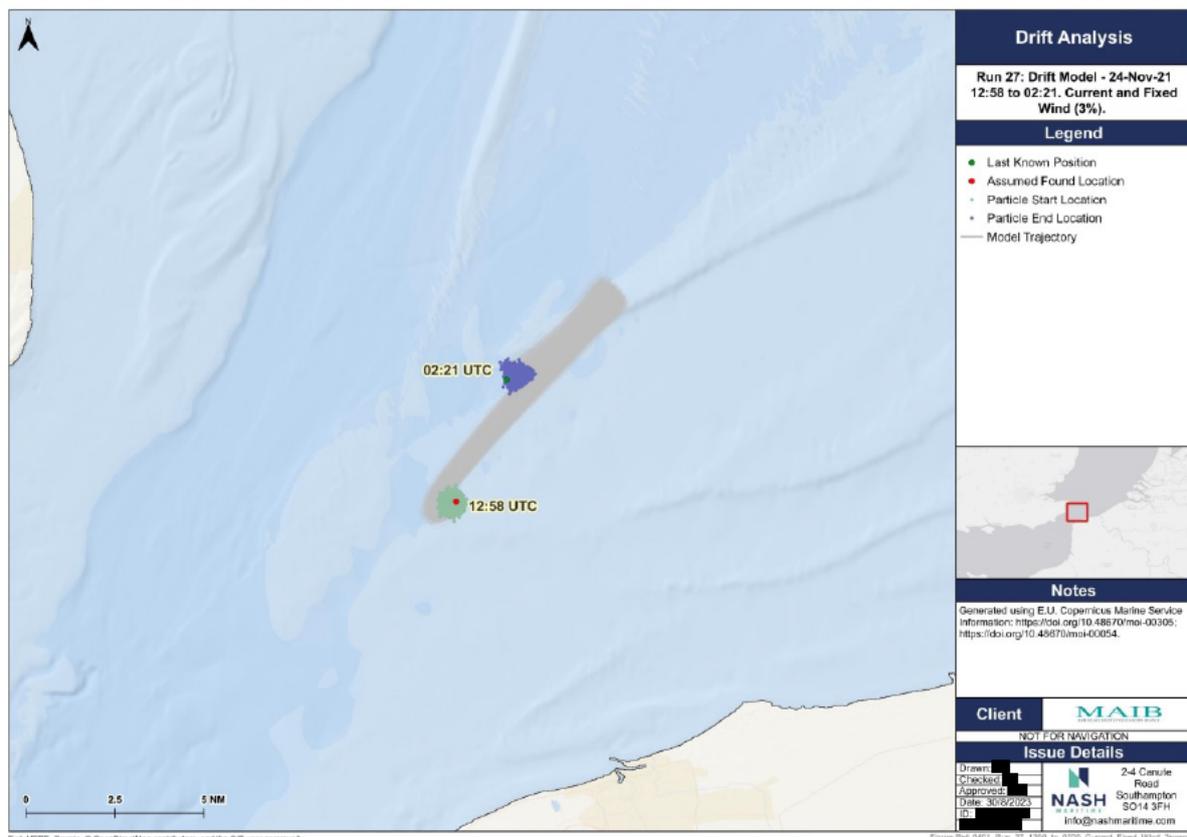


Figure 13 OceanDrift backward with model surface flow and 3% wind drift

3.2 OPENLEEWAY SIMULATIONS

OpenLeeway simulations include examples of five different object classes. The characteristics of objects have been calculated from studies by organisation such as the US Coastguard, Royal Norwegian Navy and Norwegian Meteorological Institute. These cover a range of different drifting objects typical of targets in search and rescue operations, but do not cover all possible object types/conditions.

Due to the limited information about when the people entered the water, the condition of people found in the water, and to cover a range of the possible scenarios, the following object classes have been selected for use in this study.

- **PIW - 1** – representing a person in the water in an unknown state with or without a personal flotation device or survival suit (average of several PIW objects).
- **PIW - 2** – representing a conscious person in the water with a personal flotation device.
- **PIW - 6** – representing a deceased person floating face down.
- **Life raft** – based on a 46-man aviation life raft/evacuation slide
- **Skiff** – based on a swamped/capsized skiff

The OpenDrift parameter values for these object classes are presented in **Appendix A**.

All simulations were carried out with the same parameter values noted for the OceanDrift modelling above, except that in all cases the Sandettie Lightvessel average wind speed and direction over the period of interest (4m/s at 345 degrees).was used in combination with the time/space varying Copernicus surface flow data.

3.2.1 Person in water simulations

Initial simulations were performed using the PIW-1 object class, simulating forwards (from last known position) and backwards (from assumed found position). Results are shown in **Figure 14** and **Figure 15**. In these figures the run start point is shown by the green point for forward simulation and the red point for backward simulation. The tracks of the particles are in grey, the mean of all tracks is in black, and the probability of the end (or start) location is shown by the density maps, with blue being low probability and red being high probability. Each square is 1km². The results show a wide spread of possible tracks with an 8km² area of highest (2-2.7%) probable end points for the forward track simulations and 6km² area of highest (2-2.6%) probable start point for the backward simulation. Notably, neither of the simulations put the most probable start/end locations at the reported last known position/assumed found position. Nevertheless in the forward simulation, some of the tracks arrive within 1km of the assumed found position and the density grid indicates there is a 1-1.5% probability of this being the end location for the PIW-1 released from the last known position.

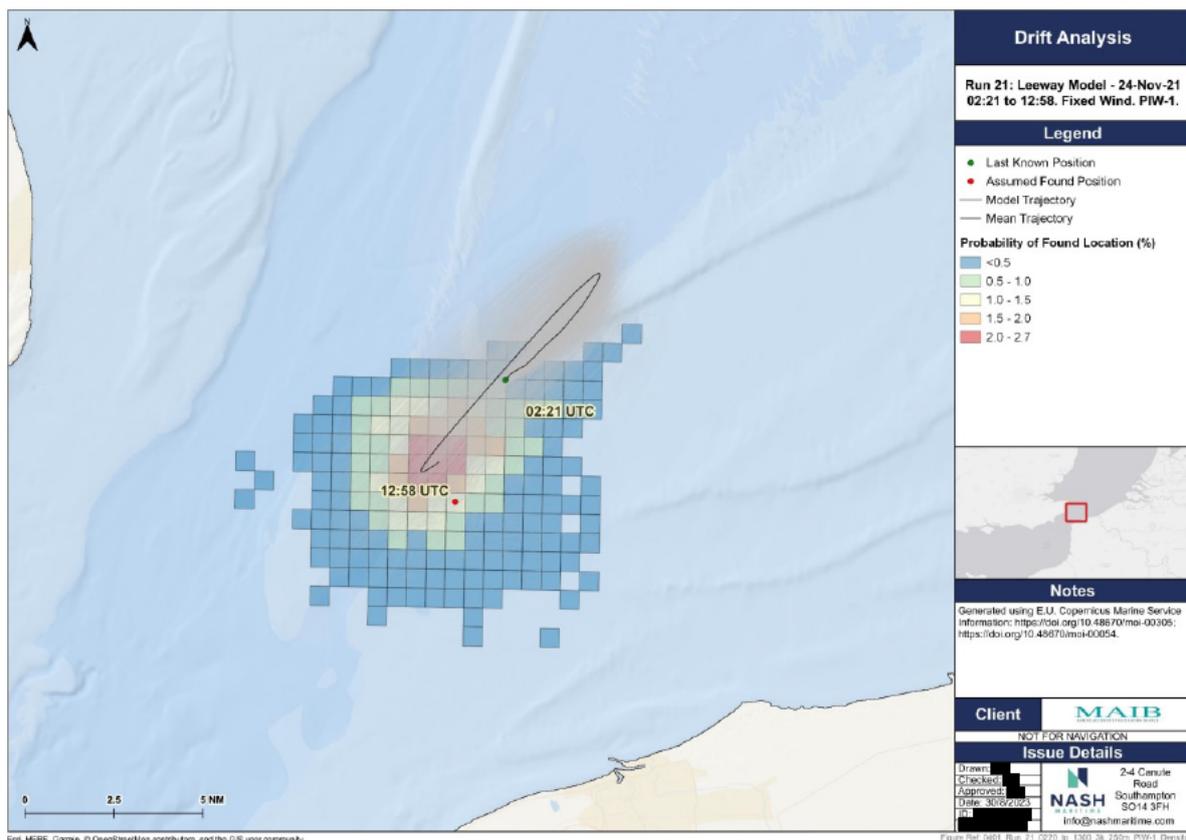


Figure 14 Forward leeway for PIW-1 with model surface flow and fixed wind

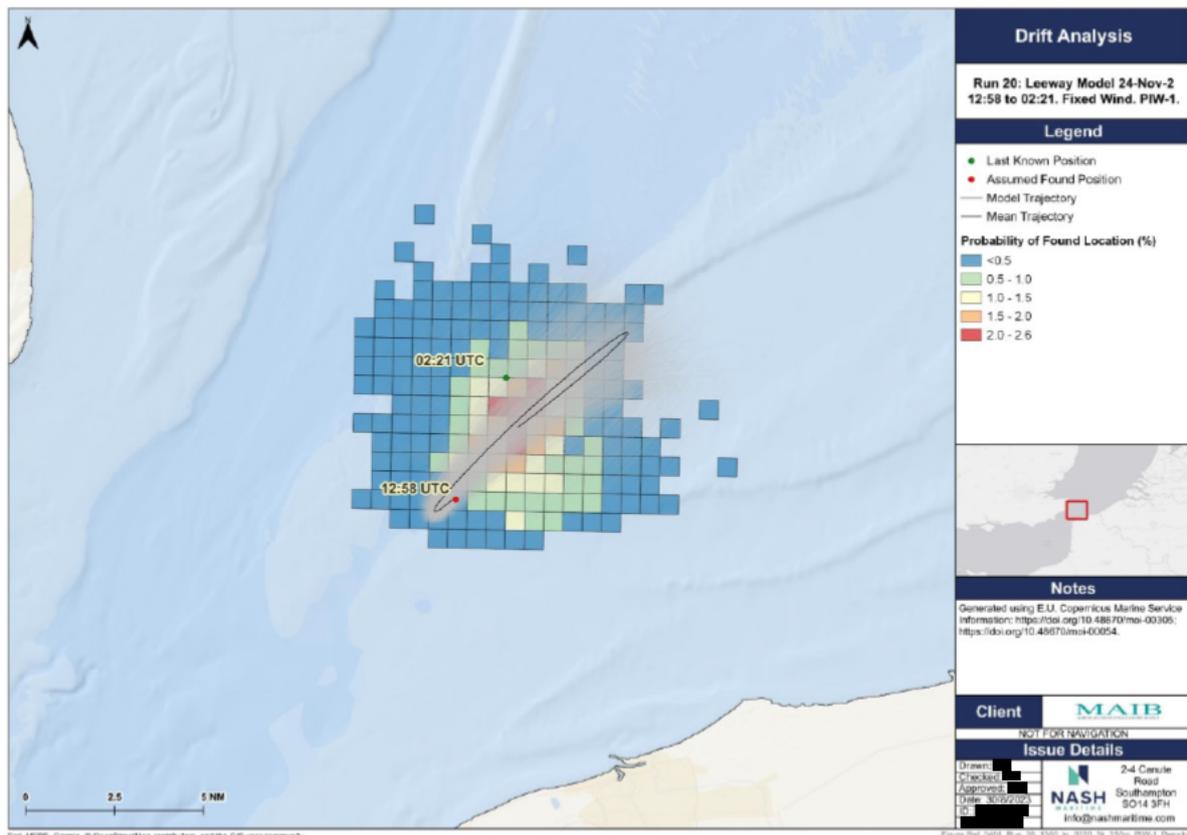


Figure 15 Backward leeway for PIW-1 with model surface flow and fixed wind

Figure 16, Figure 17, Figure 18, and Figure 19 show forward and backward leeway simulation results for the other object types PIW-2 and PIW-6 respectively

The PIW-2 results (Figure 16, Figure 17) show a similar, or slightly lower probability (0.5-1.5%) than PIW-1 results of the end/start point aligning with the assumed found position/ last known position.

The PIW-6 results (Figure 18, Figure 19) show a higher probability (4-5%) than PIW-1/PIW-2 results of the end/start point aligning with the assumed found position/ last known position. The results also show a smaller overall spread of possible locations.

While none of the object classes simulated may be truly reflective of the condition of the migrants when they entered the water or as they drifted, all results show possible tracks which start at the last known position and end at or near the assumed found position.

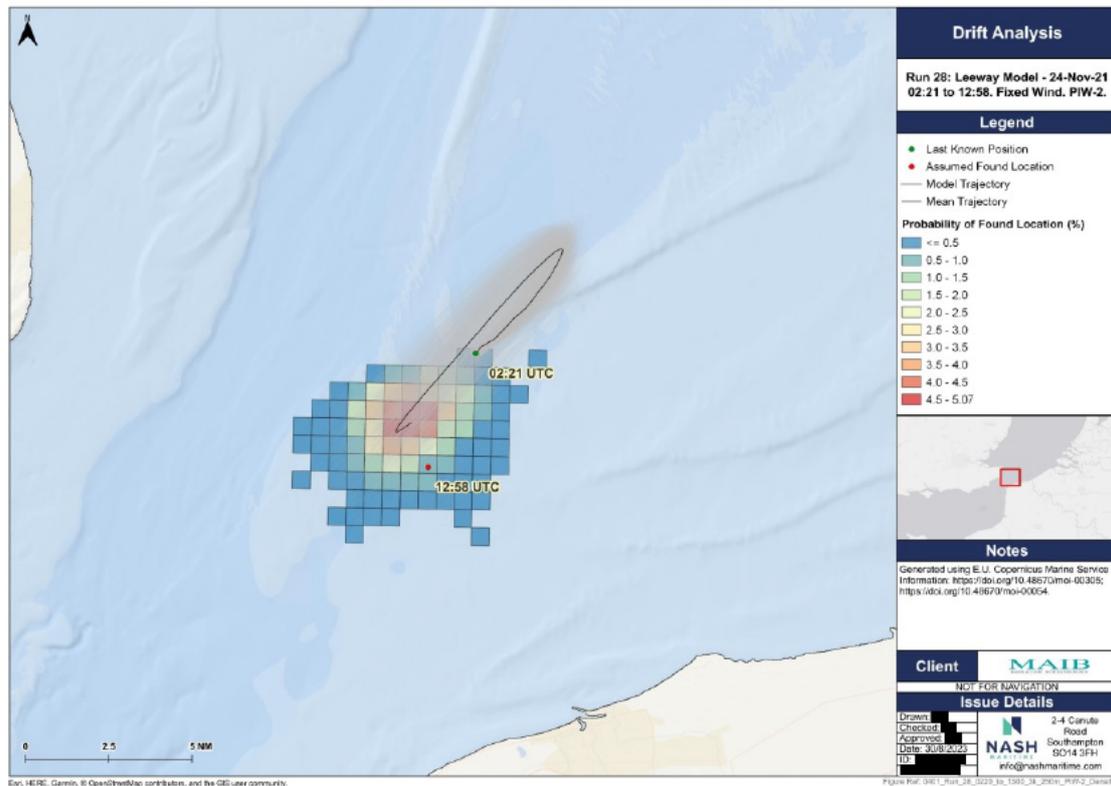


Figure 16 Forward leeway for PIW-2 with model surface flow and fixed wind

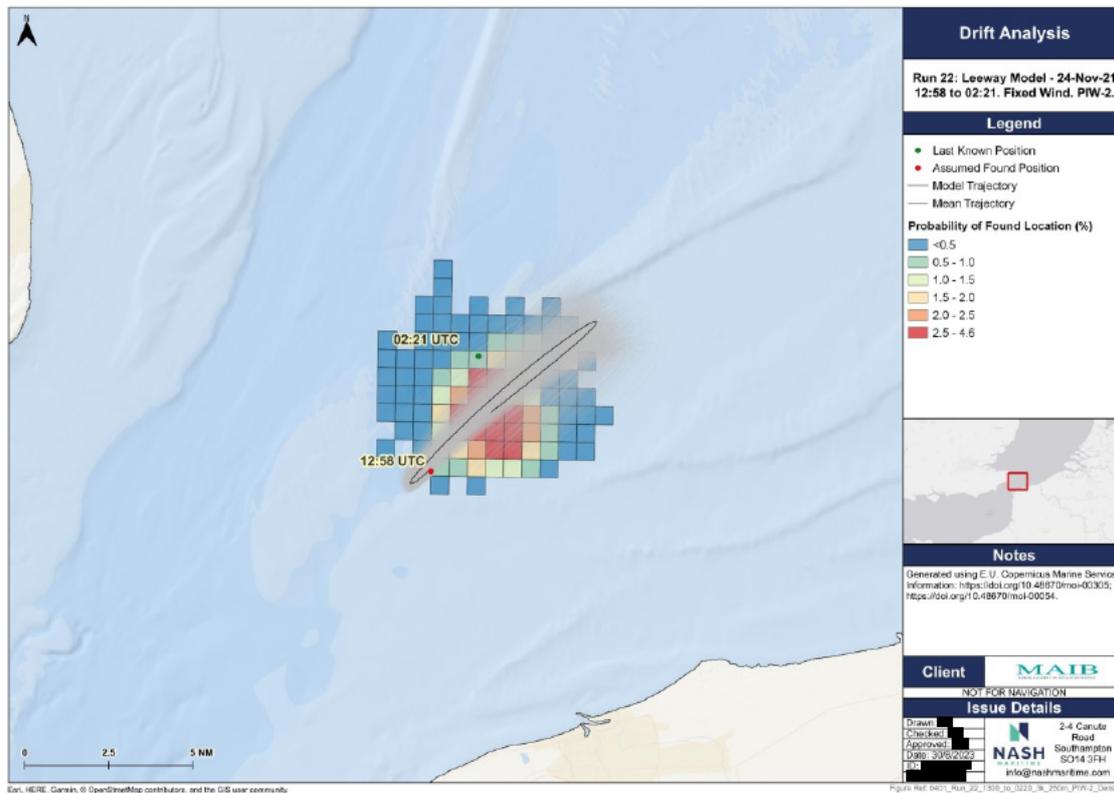


Figure 17 Backward leeway for PIW-2 with model surface flow and fixed wind

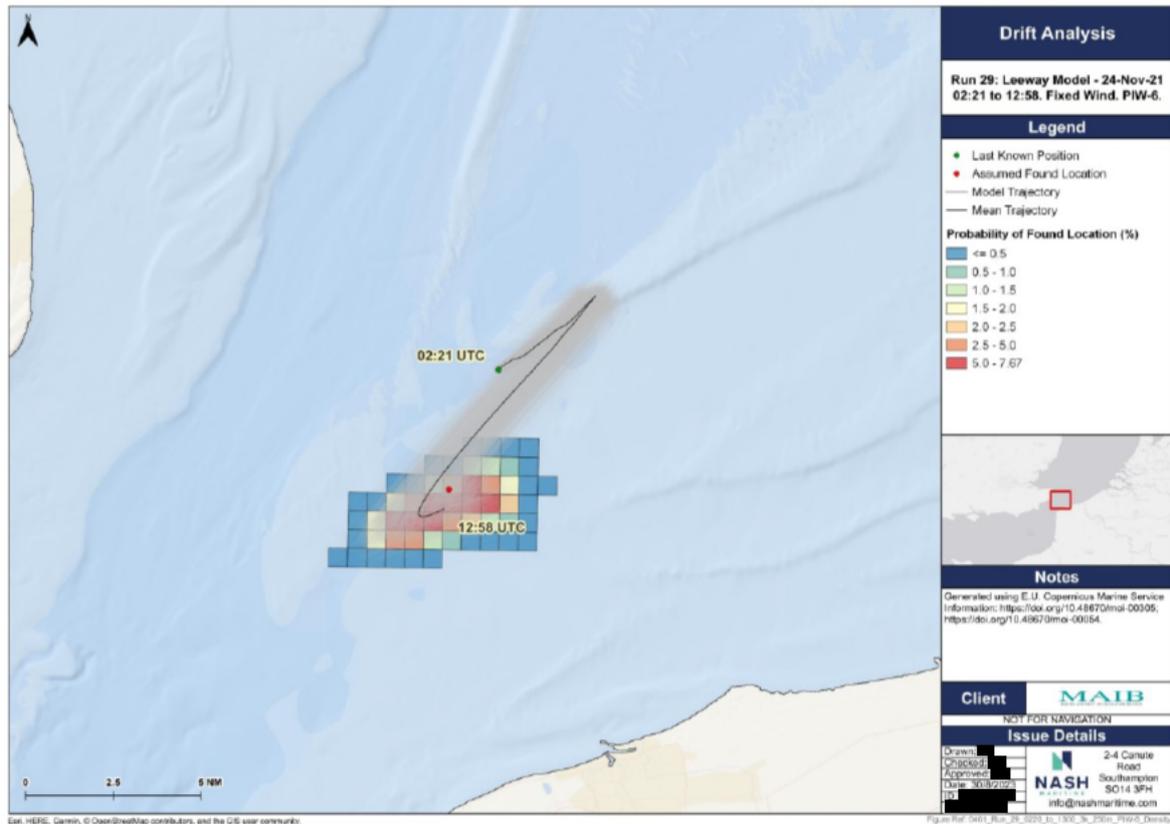


Figure 18 Forward leeway for PIW-6 with model surface flow and fixed wind

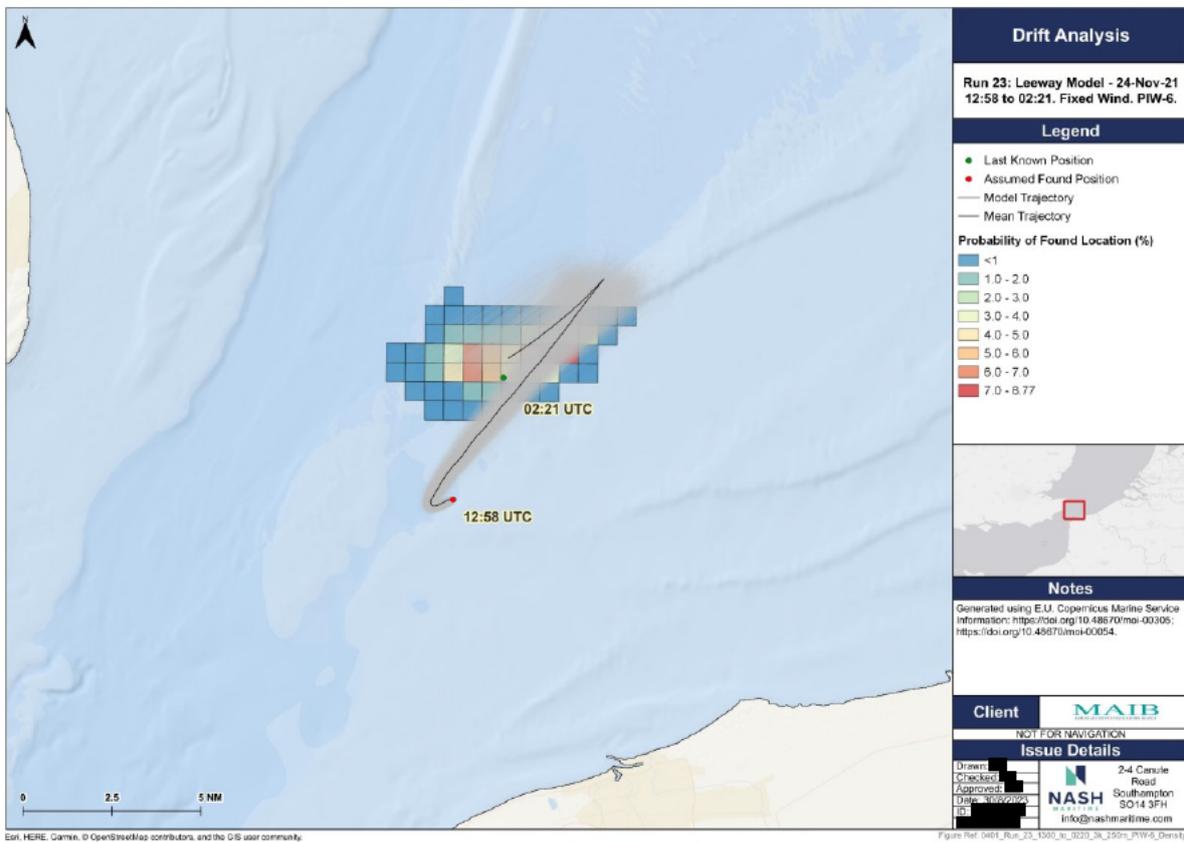


Figure 19 Backward leeway for PIW-6 with model surface flow and fixed wind

3.2.2 Small boat simulations

While the MAIB-provided data states that the migrants were in an inflatable dinghy, no further information is available. The OpenDrift object classes do not include an inflatable dinghy capable of accommodating about 33 persons. The closes available object classes for modelling the drift of the migrant’s vessel were thus considered to be the 46 person aviation evacuation slide life raft and the swamped/and capsized skiff.

The forward leeway life raft simulation (**Figure 20**) shows a good match between assumed found position and the predicted probability of the end position, with the modelled mean path ending within 500m of the assumed found position with a probability of the end point being at the assumed found position of 8-10.6%. This might indicate that the dinghy was drifting for some/most/all of the time before the individuals entered the water, but as there is no data available on the found location of the migrant vessel, this cannot be confirmed.

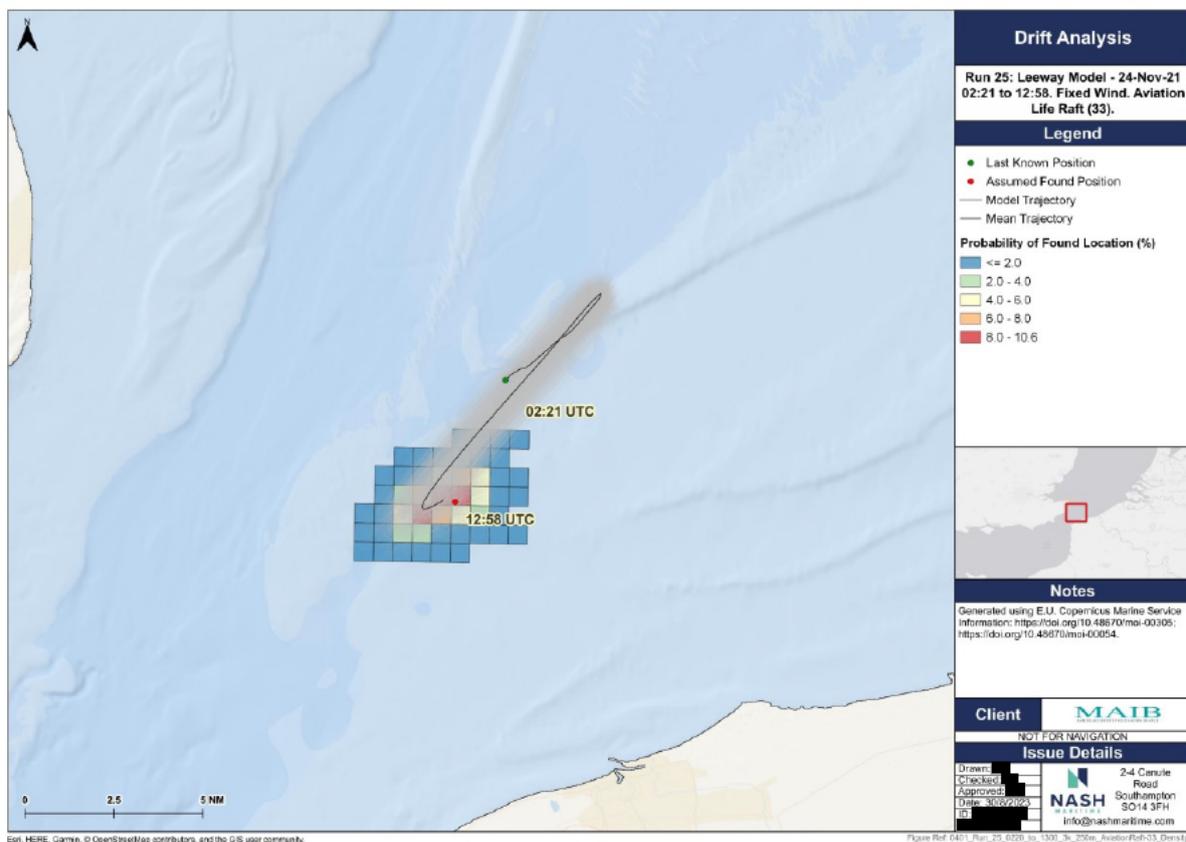


Figure 20 Forward leeway for Life raft with model surface flow and fixed wind

The forward leeway swamped/capsized skiff simulation (**Figure 21**) shows a reasonable match between assumed found position and the predicted probability of the end position, with the modelled mean path ending just over 500m of the assumed found position but with a lower probability of the end point being at the assumed found position of 1-1.5%. This might indicate that this object class is less appropriate than the life raft for the migrant vessel type, but as there is no data available on the found location of the migrant vessel, this cannot be confirmed.

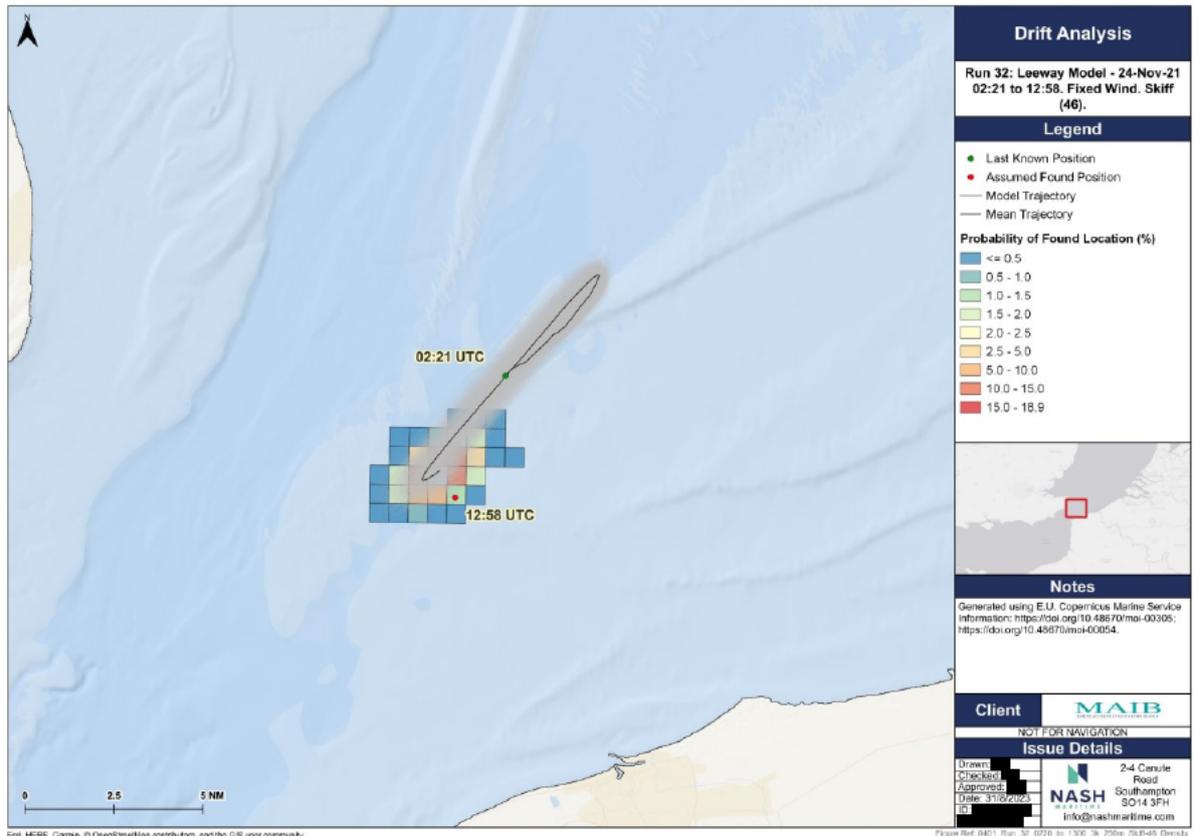


Figure 21 Forward leeway for Skiff with model surface flow and fixed wind

4. SUMMARY AND CONCLUSIONS

The OceanDrift and OpenLeeway simulations described in this report indicate a range of similar trajectories the migrants and the dinghy may have taken on 24-Nov-2021 between the last known position at 0221 UTC and the assumed found position reported by the French fishing vessel at 1258 UTC.

The modelled North West European Shelf (NWS) tidal data and the wind data measured at Sandettie Lightvessel provide suitable data for the assessment and as a basis for input into the drift modelling.

The closest match to the reported start and end locations of the incident was achieved using the OceanDrift model with a 3% wind drift applied to the fixed average measured wind data (see **Figure 12** and **Figure 13**). Note however that in this simulation the objects drift directly downwind, rather than at an angle to the wind, which is seen in most practical tests of asymmetric objects (such as people and inflatable dinghies). Nevertheless, it does indicate a possible route and timing which match the observations/data provided by MAIB.

The more rigorous approach to building real field data on the behaviours of drifting objects, which is embedded within the OpenLeeway model, also introduces a wider possible range of outcomes. The simulations with various object types showed similar (though subtly different) possible routes and outcomes. However in all cases the model results indicated it was possible that the wind and tidal currents could largely explain the drift of the objects (whether they were conscious or unconscious persons in the water or an inflatable life raft or swamped/capsized skiff) from the last known position to the assumed found position reported by the French fishing vessel.

While no single figure from the modelling simulations can capture the full range of possibilities that have been explored in this report, **Figure 22** illustrates the range of probabilities of found locations from the given start location for the generic person in water model, including the mean trajectory and the range of possible trajectories. The wide range of possible trajectories inevitably leads to low probabilities of the end location being within a single 1km square, at no more than 2.7%. It does however illustrate multiple possible pathways which connect the last known location of the dinghy and the assumed found position reported by the French fishing vessel.

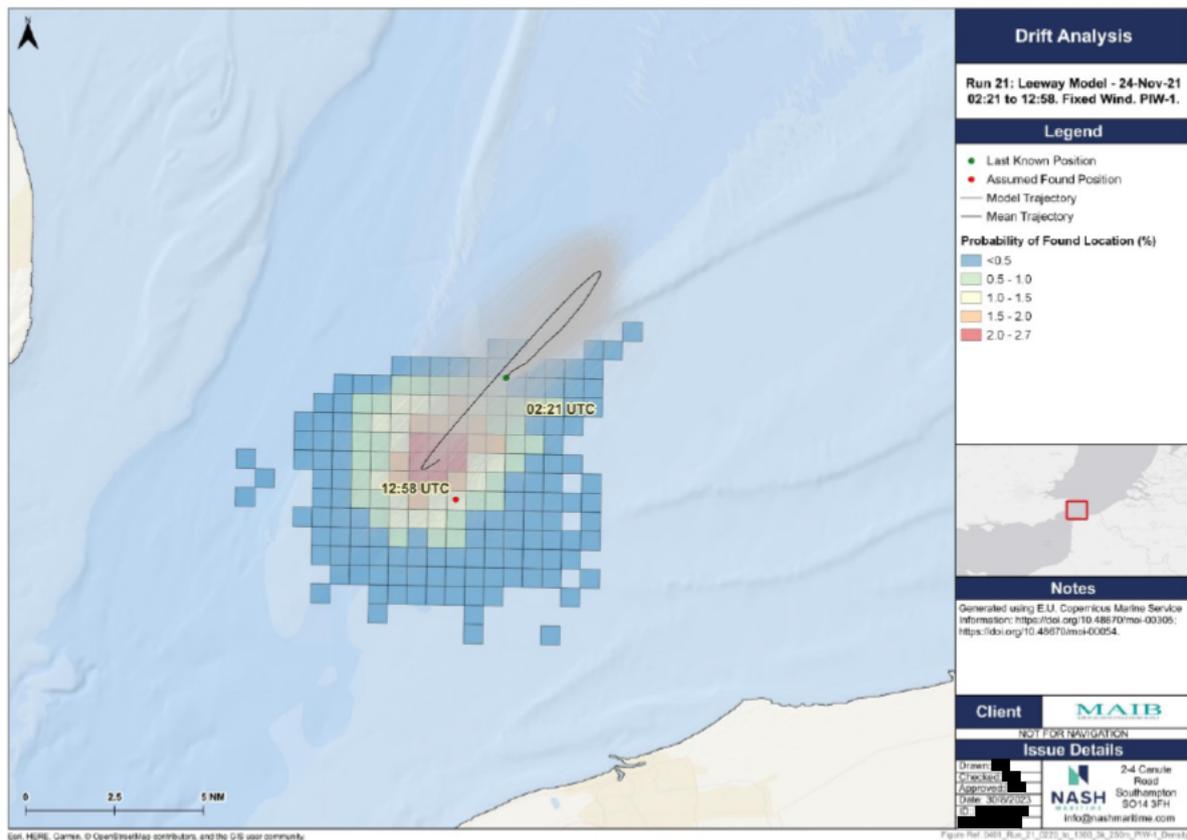


Figure 22 Example forward OpenLeeway simulation for PIW-1

Appendix A
OpenLeeway Object Types used
in the simulation

Object Class	Object Description	Downwind			Right			Left		
		slope	offset	std-dev	slope	offset	std-dev	slope	offset	std-dev
		[%]	[cm/s]	[cm/s]	[%]	[cm/s]	[cm/s]	[%]	[cm/s]	[cm/s]
PIW-1	Person-in-water (PIW), unknown state (mean values)	0.96	0	12	0.54	0	9.4	-0.54	0	9.4
PIW-2	PIW, vertical PFD type III conscious	0.48	0	8.3	0.15	0	6.7	-0.15	0	6.7
PIW-6	>PIW, deceased (face down)	1.117	10.2	3.04	0.04	3.9	4.05	-0.04	-3.9	4.05
AVIATION-2	Evacuation slide with life-raft, 46 person capacity	2.71	0	3.8	0.72	0	3.4	-0.72	0	3.4
SKIFF-3	Skiffs, swamped and capsized	1.65	0	3.1	0.39	0	2.9	-0.39	0	2.9



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