3FMProject

Bringing
Dublin Port
To 2040

Environmental Impact Assessment Report

Appendix 13.1

Volume 3 Part 7

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Third & Final
Masterplan
Project

APPENDIX 13-1 – HYDRAULIC MODELLING SOFTWARE

This appendix describes the modelling systems used in to assess coastal processes in Chapter 13.

1.1 Modelling Software

RPS used a suite of coastal process models, based on the MIKE software developed by DHI to assess the potential impact of the proposed development on the coastal processes within Dublin Port and Bay. The MIKE 21 & 3 systems are state of the art, industry standard, modelling systems based on a flexible mesh approach. This software was developed for applications within oceanographic, coastal and estuarine environments and has been approved by numerous leading institutions and authorities including the US Federal Emergency Management Agency (FEMA).

The Hydrodynamic Module is the basic computational component of the entire MIKE 21 & 3 Flow Model Flexible Mesh (FM) modelling systems providing the basis for the Transport, ECO Lab, Mud Transport and Sand Transport modules.

The assessment presented in Chapter 13 utilised the Hydrodynamic, Mud Transport, Sediment Transport and Spectral Wave modules each of which are described further below. A full scientific description of this modules can be found online at https://manuals.mikepoweredbydhi.help/latest/MIKE_21.htm.

1.1.1 MIKE 21 & MIKE 3 Flexible Mesh (FM) mesh modelling system

This system is capable of simulating water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal regions. The HD Module is the basic computational component of the MIKE 21 and MIKE 3 Flow Model systems providing the hydrodynamic basis for the Mud & Sediment Transport and Spectral Wave modules.

The Hydrodynamic module solves the two/three-dimensional incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and of hydrostatic pressure. Thus the module consists of continuity, momentum, temperature, salinity and density equations. When being used in three dimensions, the free surface is taken into account using a sigma coordinate transformation approach whereby the vertical layer is divided equally into a discrete number of layers. The system solves the full time-dependent non-linear equations of continuity and conservation of momentum using an implicit ADI finite difference scheme of second-order accuracy. The effects and facilities incorporated within the model include:

- Convective and cross momentum;
- Bottom shear stress;
- Wind shear stress at the surface;
- Barometric pressure gradients;
- Coriollis forces;

- Momentum dispersion (e.g. through the Smagorinsky formulation);
- Wave-induced currents;
- Sources and sinks (mass and momentum);
- Evaporation;
- Flooding and drying.

1.1.2 The Spectral Wave (SW) module

The Spectral Wave (SW) module is a new generation spectral wind-wave model based on unstructured meshes that simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas.

The MIKE 21 SW module accounts for the following physical phenomena:

- Wave growth by wind action
- Non-linear wave-wave interaction
- Dissipation due to white-capping
- Dissipation due to bottom friction
- Dissipation due to depth-induced wave breaking
- Refraction and shoaling due to depth variations
- Diffraction
- Wave-current interaction
- Effect of time-varying depth and flooding and drying

The discretisation of the governing equation in geographical and spectral is performed using a cell-centred finite volume method. In the geographical domain, an unstructured mesh technique is used. The time integration is performed using a fractional step approach where a multi-sequence explicit method is applied for the propagation of wave action.

The MIKE 21 SW module includes two different formulations:

- Directional decoupled parametric formulation
- Fully spectral formulation

The directional decoupled parametric formulation is based on a parameterization of the wave action conservation equation. The parameterization is made in the frequency domain by introducing the zeroth and first moment of the wave action spectrum as dependent variables following Holthuijsen (1989).

1.1.3 The Sediment Transport (ST) module

The Sediment Transport Module simulates the erosion, transport, settling and deposition of cohesive sediment in marine and estuarine environments and includes key physical processes such as forcing by waves, flocculation and sliding. The module can be used to assess the impact of marine developments on erosion and sedimentation patterns by including common structures such as jetties, piles or dikes. Point sources can also be introduced to represent localised increases in current flows as a result of outfalls or ship movements etc.

1.1.4 The Mud Transport (MT) module

The Mud Transport (MT) module of MIKE 21 Flow Model FM describes erosion, transport and deposition of mud or sand/mud mixtures under the action of currents and waves. The MT module is applicable for:

- Mud fractions alone, and
- Sand/mud mixtures.

The module can be used to simulation a range of relevant processes including:

- Forcing by waves.
- Salt-flocculation.
- Detailed description of the settling process.
- Layered description of the bed.
- Morphological update of the bed.

In the MT-module, the settling velocity varies, according to the salinity, if included, and the concentration taking into account flocculation in the water column. Waves, as calculated by MIKE 21 SW for example, may be included. Furthermore, hindered settling and consolidation in the fluid mud and under-consolidated bed are included in the model. Bed erosion can be either nonuniform, i.e. the erosion of soft and partly consolidated bed, or uniform, i.e. the erosion of a dense and consolidated bed. The bed is described as layered and characterised by the density and shear strength.

1.1.5 Boundary Conditions

The tidal boundary conditions for the 2D pre-project and post-project scenario models were taken from RPS' Irish Seas Tidal Surge Model (ISTSM). This model was developed using flexible mesh technology with the mesh size (model resolution) varying from circa 24km along the offshore Atlantic boundary to circa 200m around the Irish coastline. RPS also utilised their Irish Coastal Protection Strategy Study (ICPSS) east coast wave model to gather wave boundary data for the Dublin Bay model to ensure that the hydrodynamic influence of the offshore Kish and Codling banks were accounted for in the model.

The open sea boundaries were applied to the model as Flather boundaries in which the water level and velocities are specified along the boundary. The format of these boundaries is such that they vary temporally and also spatially along the length of the boundary. The Flather condition was chosen as it is one of the most efficient open boundary conditions as in downscaling coarse model simulations to higher resolution areas. The instabilities, which are often observed when imposing stratified density at a water level boundary, can be avoided using Flather conditions.

At the coastline where the water level intersects the bathymetry, a zero velocity condition was applied, which assumes the no slip condition is assumed to hold, that is, both the normal and tangential velocity components are zero.

For the calibration process the open sea boundaries were applied as Flather boundaries, whilst at the coastline a zero velocity boundary was applied. The open sea boundaries were taken from RPS' ISTSM tidal surge model during what was considered an average lunar month that experience a full range of spring and neap tidal conditions.

For the calibration process mean annual discharge rates for the Liffey, Dodder and Tolka were used - the values of which are presented in Table 1.

Table 1: Mean annual discharge rates from the Liffey, Dodder and Tolka used in the calibration process

Source	Mean annual discharge rate (m^3/s)
Liffey	15.6
Dodder	2.3
Tolka	1.4

1.1.6 Bed Roughness

When using the two-dimensional hydrodynamic models, the bed resistance was specified using the Manning number. According to the MIKE 21 manual, the relationship between the Manning number, M, and the Nikuradse roughness length, k_s can be estimated using

$$M = \frac{25.4}{k_s^{1/6}}$$

Using one of the several relationships recommended by Soulsby (1997), over flat beds of sediment, k_s is related to the median grain diameter (D_{50}) as approximately

$$k_s = 2.5\ D_{50}$$

For the three-dimensional models, the bed resistance was specified using the bed roughness height of the sea bed which is dependent on the von Karman constant.

It was therefore possible to impose a uniform bed resistance coefficient at the seabed for both the two and three dimensional models - the value of which was determined using the simple relationships presented above and by calibrating of the Dublin Port model.

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1.1.7 Turbulence module

The turbulence model used by MIKE is based on a standard k-epsilon model ($k - \varepsilon$) with a buoyancy extension. The model uses transport equations for the turbulent kinetic energy (TKE), k, and the dissipation of TKE, ε, to describe the turbulence.