

Carnsew Pool Tide Mill

Preliminary 2D Hydrodynamic Modelling

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Signed



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1 Background

Mojo Maritime are presently undertaking a high-level study to assess the feasibility of tidal power generation on the Hayle Estuary, Cornwall, in particular through the development of a tide mill at Carnsew Pool.

In support of that assessment, Coastal Science Ltd was asked to develop a 2-dimensional hydrodynamic model of the estuary, the purpose of the modelling being to predict changes to flow velocities in the estuary as a result of tide mill operation.

This report described the preliminary modelling undertaken, and the first-pass output provided to Mojo Maritime for use in their study. Further model development will be undertaken prior to any future studies.

1.1 Coastal Science Ltd

Coastal Science Ltd (www.coastalscience.co.uk) is an independent UK consultancy based near Exeter, whose specialist services can be summarised as:

- Modelling: Site Characterisation, Impact Assessment and Design Optimisation.
- Survey: Specification, Management and On-Site Client Representation.
- Consultancy: Water Quality, Hydrodynamics, Renewables.

A summary of tidal energy experience and capability is provided at Appendix A.

2 Hydrodynamic Modelling

The following chapter describes the preliminary development of the Coastal Science Hayle Estuary Model.

2.1 Model Operating Environment

The Hayle Estuary Model is a Delft3D coastal model. Delft3D, along with other market leader Mike-by-DHI, represents the state-of-the-art in terms of commercially available modelling software, offering high levels of flexibility and accuracy through a user-friendly interface. The Delft3D suite offers a range of hydrodynamic (2D and 3D), wave, sediment transport and water quality modelling tools. More information can be found at the following site:

<https://www.deltares.nl/en/software/delft3d-4-suite/>

2.2 Model Build

The set-up of the model, comprising construction and preliminary calibration, was undertaken as follows:

1. Boundary “driving” Conditions

Model boundary conditions are derived from UKHO Total Tide water level predictions for St Ives.

2. Bathymetry

Model bathymetry below the inter-tidal areas seaward of the estuary mouth is derived from available datasets available from UKHO Inspire.

The inter-tidal areas, both in the estuary and around its mouth are derived from EA Lidar data as provided by the client. The Lidar acquisition was flown around LW Springs, and good coverage is achieved.

The channels within the estuary – representing only a very small part of the tidal prism – are not measured by Lidar which does not penetrate the water surface (except in very clear water). The depths of these channels in the model was therefore incorporated manually. As this report was being prepared, new data became available which included a new

hydrographic survey of the estuary including the channels. This data will be interpolated into the model prior to any further work, but in the meantime the modelled flow speeds in the channels should be treated with some degree of caution. For this reason, the outputs presented below and as used by the client in their considerations show changes in predicted speeds between development scenarios, rather than actual speeds.

3. Model Gridding

Gridding is the process of dividing the model area into a large number of computational elements, or “cells”. For each instant in time the model calculates the water level and current velocity in each cell, and propagates the calculated values to that cell’s neighbours which in turn perform the same calculation. This derives a solution across the whole model domain, which is then repeated for the next timestep until the required time-frame has been completed. Correct gridding is important, since:

- It determines the resolution of the model, and hence the model accuracy on a local scale
- It drives the maintenance of computational efficiency

The model grid is shown in Figure 1. Resolution increases from approximately 75m at the open sea boundary, to approximately 10m in the area of interest. .

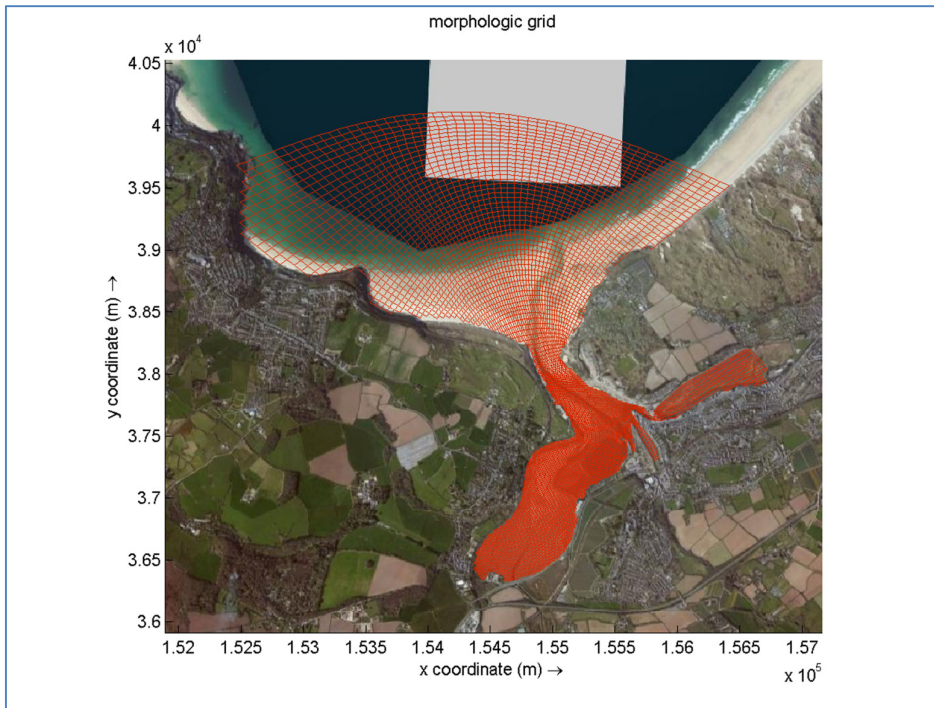


Figure 1 – Model Grid

Mapping © Google 2016

4. Bed Roughness

Adjustment of the bed roughness parameter was the primary means of model calibration.

5. Vertical Dimensionality

In 2D “Depth Averaged” mode the FLOW model assumes a standard vertical velocity profile; a 2D modelling approach was adopted for the present study. If subsequently required, conversion of the 2D model to 3D mode is straightforward.

2.3 Preliminary Calibration

The preliminary calibration was carried out against local water levels as measured inside the estuary close to the Carnsew sluice gates. It is clear that a good correlation between measured and modelled datasets has been achieved.

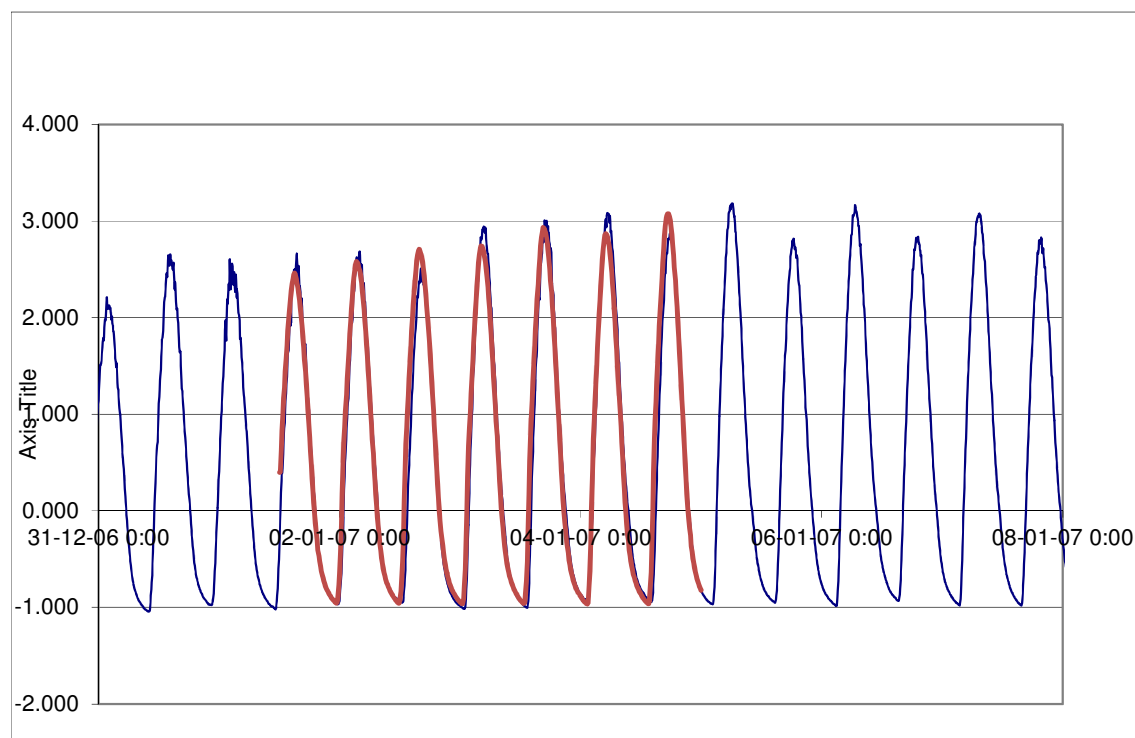


Figure 2 – Water Level Calibration, outside Carnsew Pool. Blue – Measured Red – Model. mODN

Calibration of the model for tidal stream velocities has not been carried out, in the absence of any suitable data. Velocity calibration should be carried against ADCP data out as part of any further work.

2.4 Model Outputs

The model was run for a spring tide, with the simulation starting its “spin up” on the previous intermediate tide to allow the model to achieve dynamic equilibrium.

The Baseline Scenario was configured with the Carnsew and Copperhouse gates open, allowing free flow with the gates being set at 9.5 and 10.3m wide respectively, and sill heights of -0.1m and -0.5m ODN. While model results were not, in terms of current speeds in the navigation channel, found to be particularly sensitive to the sluice details, their description in the model would need to be more robustly defined as part of any further work.

For the Carnsew Turbine Scenario, the Carnsew gates were closed in the model, with flows in and out of the pool being defined by timeseries data provided by the client. Copperhouse Pool remained as per the Baseline Scenario.

A further Sluicing Scenario was then simulated, with Carnsew gates closed at HW, and then opened at HW+3. This was to simulate the effects of sluicing operations being carried out. Sluicing at Copperhouse Pool was not simulated - although the modelling of this operation would be straightforward if this option comes under consideration – and so Copperhouse was maintained in the Baseline Scenario configuration.

In post-processing, the flow magnitude outputs from the Carnsew Turbine and the Sluicing Scenarios were subtracted from the Baseline Scenario outputs. The resulting files were provided to Mojo Maritime as maps and animations (.avi) in which positive magnitude differences denote the Baseline magnitude being higher, and negative difference denote the Baseline being lower. The maps are presented below.

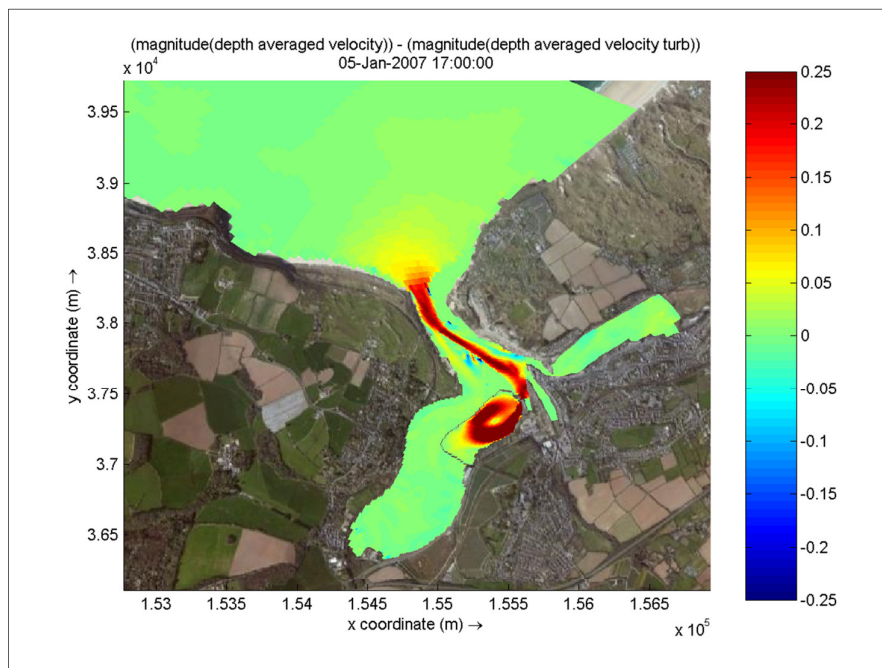


Figure 3 – Predicted Tidal Stream Magnitude Differences, Sp. Flood Tide Carnsew Turbine Scenario.

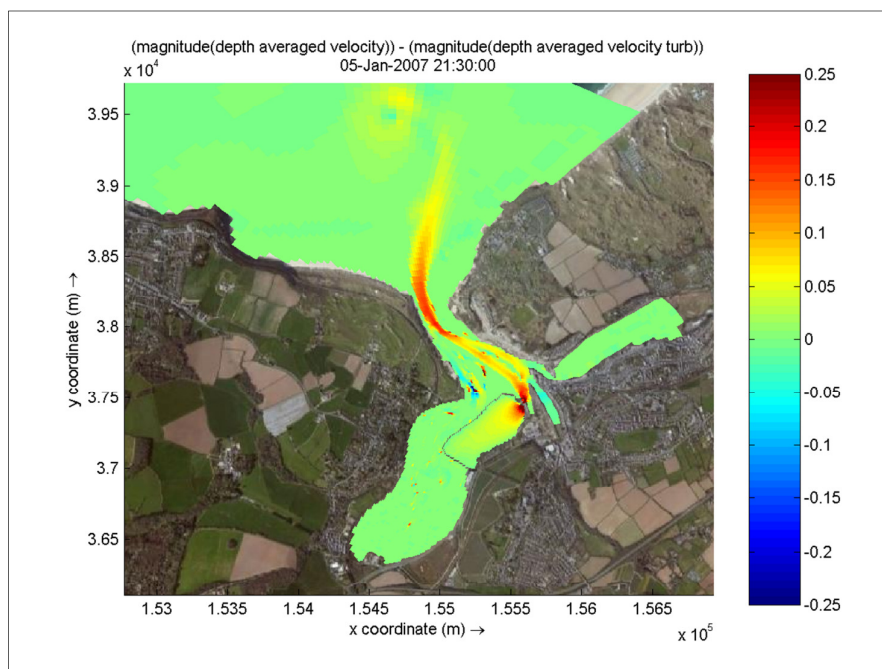


Figure 4– Predicted Tidal Stream Magnitude Differences, Sp. Ebb Tide Carnsew Turbine Scenario

Figure 3 predicts that the flow magnitudes on the flood tide are reduced by approximately 0.25m/s in the navigation channel under the Carnsew Turbine Scenario. For the ebb tide (Figure 4), the change in magnitudes is less, at approximately 0.15m/s. Away from the main channel changes are significantly less.

Placing these changes into context, Figure 5 shows the velocity components of the flow for a location in the navigation channel. As emphasised above, these values are indicative pending incorporation of channel bathymetry into the model, and subsequent further calibration.

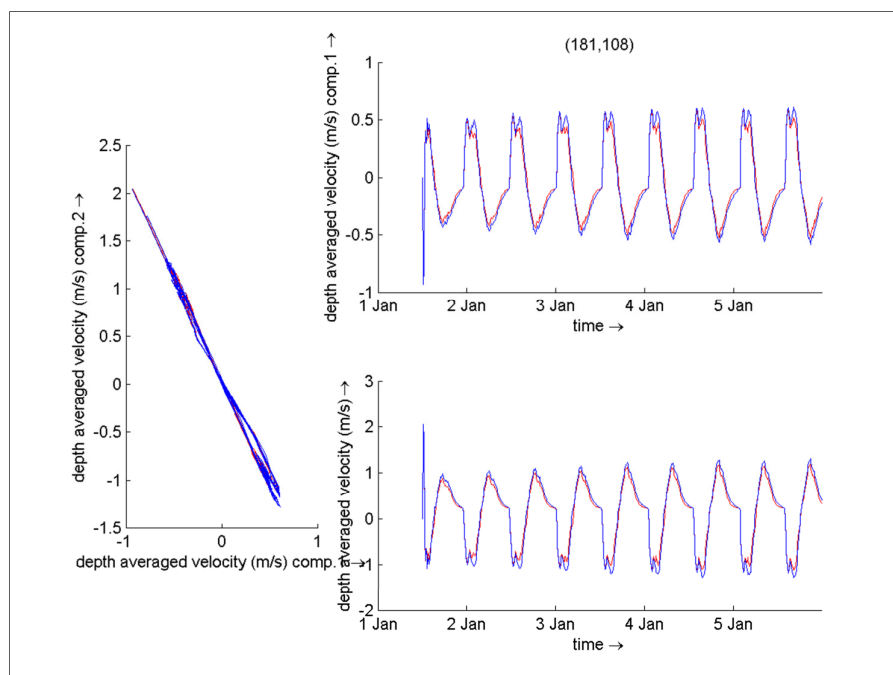


Figure 5 – Main Channel Velocity Components, Baseline (blue) & Carnsew Turbine (red) Scenarios.

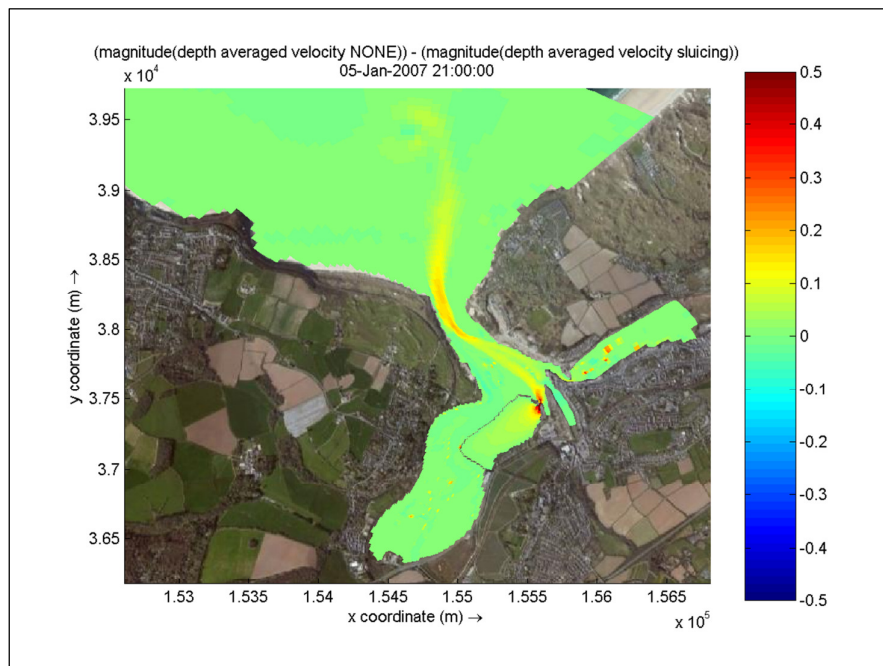


Figure 6 – Predicted Tidal Stream Magnitude Differences, Sluicing HW+3

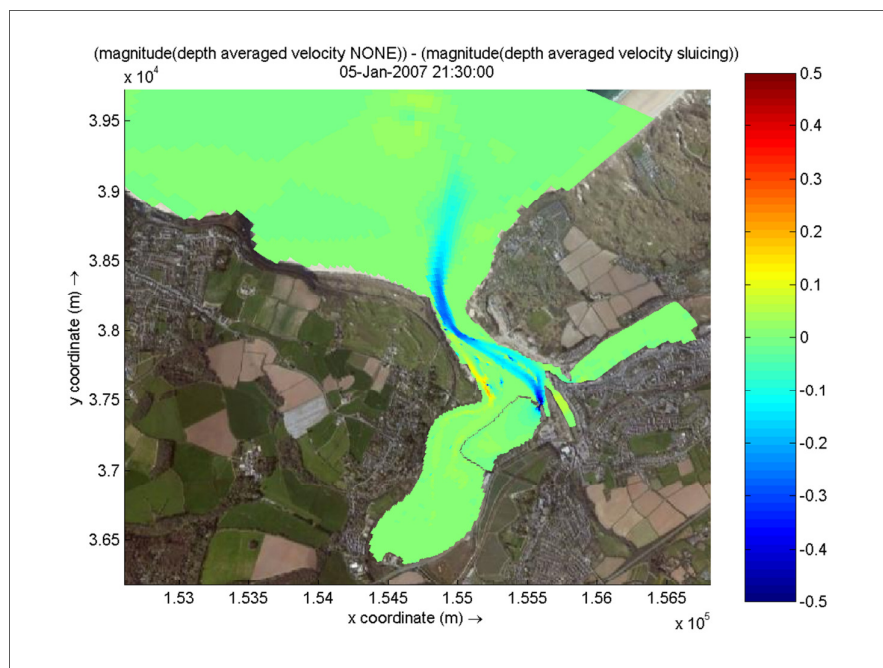


Figure 7 – Predicted Tidal Stream Magnitude Differences, Sluicing HW+3.5

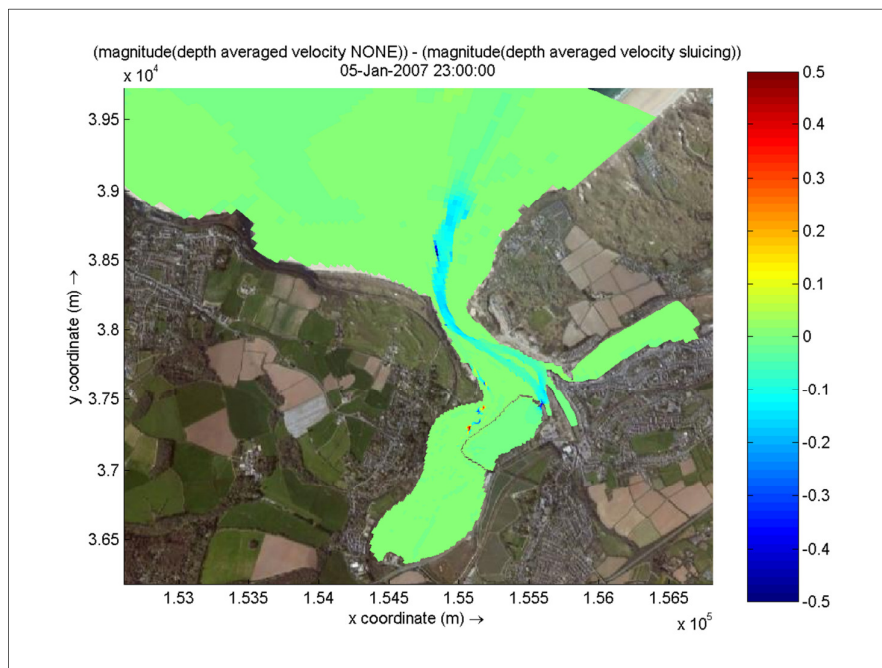


Figure 8 – Predicted Tidal Stream Magnitude Differences, Sluicing HW+5

Figure 6 shows the reduced flow speeds under the Sluicing Scenario compared with Baseline at the moment the sluices begin to open. Thereafter, in Figure 7 & 8, the increases in flow speeds as the sluicing operation proceeds are apparent.

Figure 9 shows a timeseries of flow speeds for a location in the navigation channel for the Sluicing and Baseline Scenarios. The above caveats regarding predicted flow speeds apply.

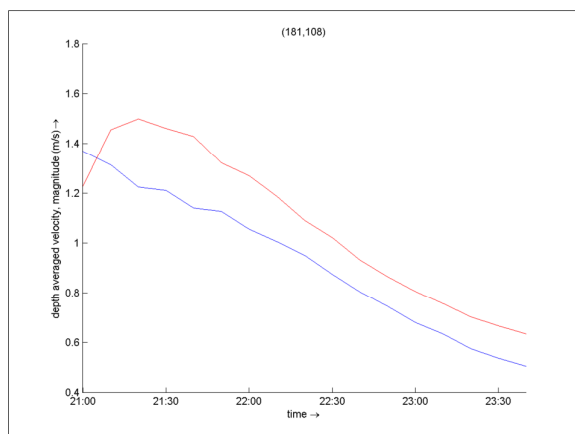


Figure 8 – Predicted Tidal Stream Magnitude Differences, Sluicing (red) & Baseline (blue) Scenarios

3 Conclusions

A new Delft3D model of the Hayle estuary has been constructed, using up to date Lidar data and with a local resolution of ~10m. Water level calibration against data from within the estuary is good.

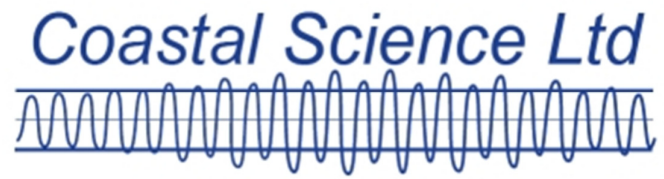
New bathymetry data for the navigational channel has since become available and should be incorporated prior to any further modelling work. The opportunity should also be taken to calibrate flow velocities in the estuary against ADCP data.

Preliminary model output has then been generated for a spring tide, for a Baseline, Carnsew Turbine and a Sluicing Scenario.

The output shows slightly reduced flows in and out of the estuary when comparing the Carnsew Turbine Scenario against the Baseline Scenario. The reduction on the flood tide is greater than on the ebb.

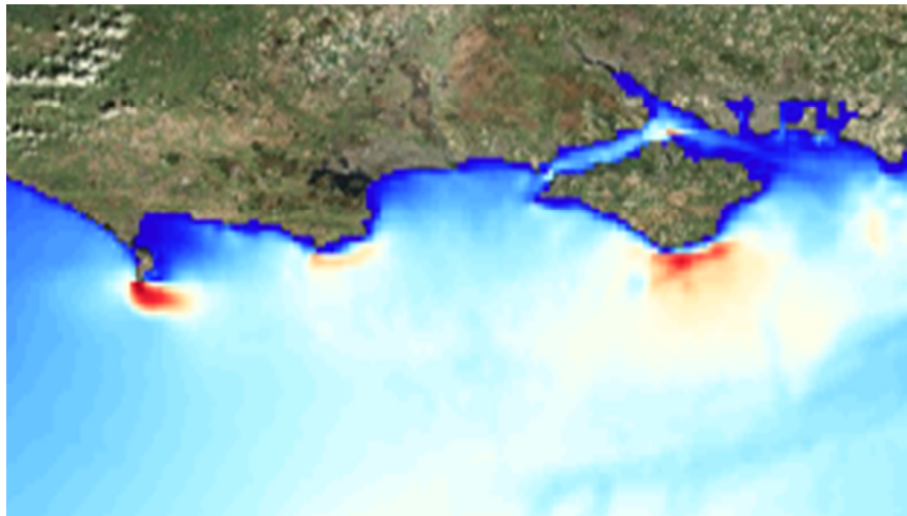
As would be expected, the Sluicing Scenario shows increased flow speeds on the ebb.

More detailed and extensive output can be generated if required. These outputs should be produced once the model has been further developed and calibrated.



Appendix 1 – Tidal Energy Cap Stat

Tidal Energy Capability Summary



About

Coastal Science Ltd (www.coastalscience.co.uk) is an independent UK consultancy whose specialist services can be summarised as:

- Modelling - Predictive Site Characterisation, Impact Assessment and Design Optimisation.
- Survey - Specification, Management and On-Site Client Representation.
- Consultancy - Water Quality, Hydrodynamics, Renewables.

Coastal Science has an extensive client list which includes major utilities and consultancies, such as::

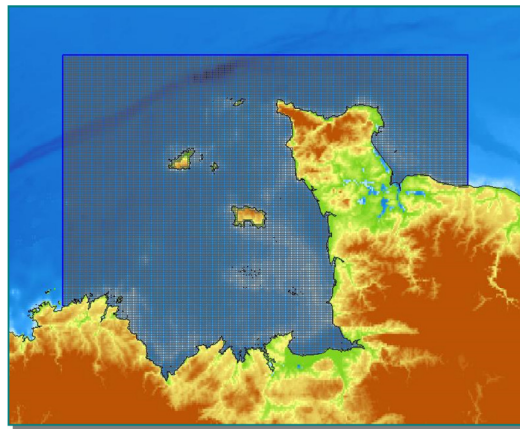


An **RWE** company



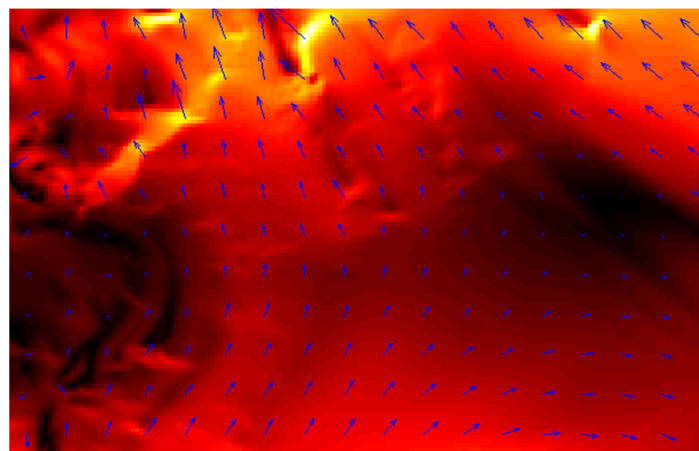
Experience

Coastal Science is directed by Phil Shepperd, with eighteen years full time experience (Hyder Consulting 1997 to 2005; Independent Consultant, Coastal Science Ltd, 2005 to date) of marine modelling for the renewables, water and conventional power industries. He has extensive experience of DELFT3D & MIKE by DHI, and, with particular focus on the construction, calibration and application of 2D and 3D hydrodynamic and water quality models.



Coastal Science also provides services relating to the Specification and Management of Marine Survey contracts, specialising in surveys commissioned in support of marine discharge assessments and offshore renewables. Phil has acted as Client Representative on numerous coastal surveys undertaken for clients such as Tidal Lagoon Power, Scottish Water and United Utilities (through Intertek Metoc) and E.ON.

Phil is also the Coxswain, and a Trustee of, the Sidmouth Lifeboat.



Project Examples

Tidal Lagoon Power - Swansea Bay

Specification of oceanographic and geophysical surveys, followed by tender assessments, contractor review, on-site client representation and overall survey management. Additional oceanographic consultancy services.

Tocado – Mulroy Bay

Construction, detailed calibration and application of a high resolution model of Mulroy Bay, for detailed quantification of the annual tidal stream resource (GWh/year) at numerous points.

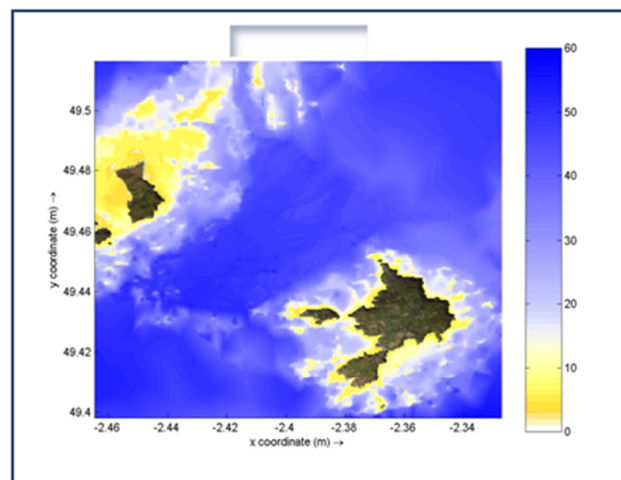
Output included animations, annual resource maps and an interactive Resource Screening Tool.

States of Guernsey – Guernsey Waters

Construction, detailed calibration and application of a high resolution model of the waters around Guernsey and Sark, for detailed quantification of the annual tidal stream resource (GWh/year).

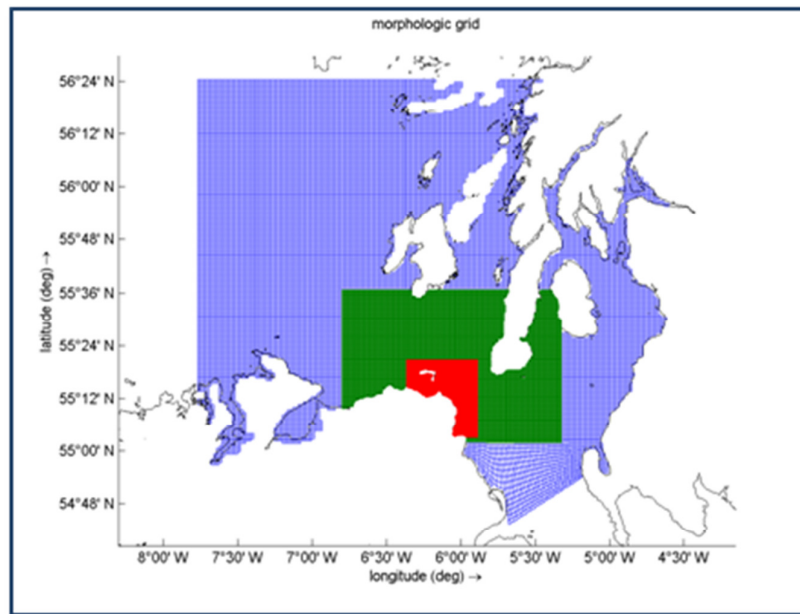
Output included animations, annual resource maps, location specific timeseries and an interactive Resource Screening Tool.

Work also included and extensive analysis of numerous ADCP survey datasets leading to location specific annual resource predictions (GWh/year).



DP Energy – Islay and Fair Head

Development of an area model, covering south west Scotland and Northern Ireland, leading to separate high resolution Resource Assessment Modelling studies of waters off of Islay and also off of Fair Head on the Antrim coast; maps, animations, interactive Site Screening Tools, annual GWh resource timeseries.



Scottish Power Renewables – Pentland Firth

Consultancy services, including the specification of large scale marine modelling works and specification of associated geophysical and ADCP survey programmes for the Pentland Firth; detailed and extensive tender assessments and part of interview panel for short-listed applicants.

Marine Current Turbines – PFOW Marine Modelling Enabling Action

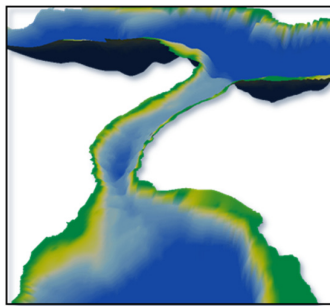
Developer representative for MCT on the PFOW MMEA scoping panel.

Pulse Tidal – Kyle Rhea

Consultancy services, including specification of marine geophysical and ADCP surveys, and analysis of complex field data for Resource Assessment.

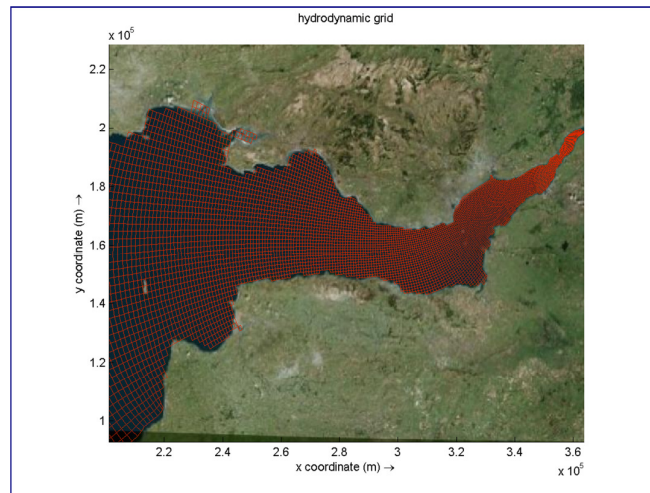
Marine Current Turbines – Kyle Rhea and Skerries

Development of a high-resolution Delft3D model of the Kyle Rhea, Scotland, for detailed resource assessment and to inform a second round of marine survey deployments; analysis of ADCP and model data for Kyle Rhea and Skerries leading to annual power predictions; detailed technical support on resource assessment topics. Specification of further ADCP deployments; tender assessments.



ABPmer – Bristol Channel / Severn Estuary

Assisting delivery of complex SEA water quality modelling studies for the initial five DECC short-listed Severn Barrage or Lagoon options. Assessments undertaken by Coastal Science included thermal plume dispersion from Aberthaw, Hinkley Point and Oldbury Power Stations, and pathogen fate from key WWTW outfalls under baseline and a number of development options.



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..... or connect  to Phil Shepperd

