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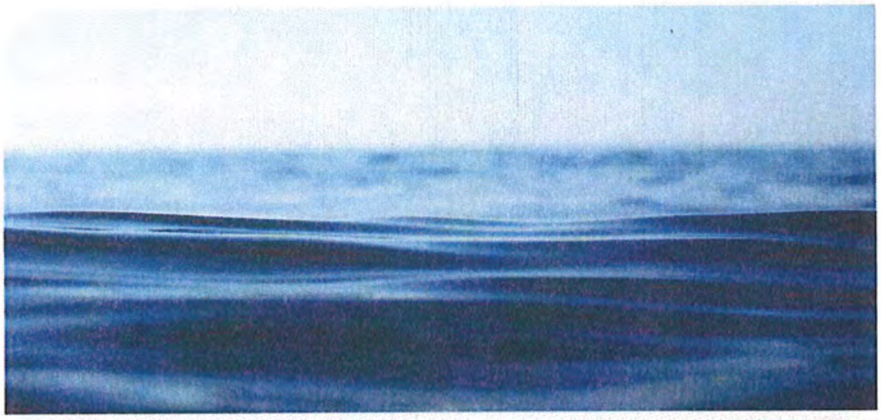

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HR Wallingford, Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
tel +44 (0)1491 835381 fax +44 (0)1491 832233 email info@hrwallingford.com
www.hrwallingford.com

BRADWELL SITE

FED DISCHARGE OUTLINE OUTFALL DESIGN UPDATE (INCLUDING HR WALLINGFORD REPORT EBR4908-RT008-R01-00)

BRAD/EN/REP/082

Prepared by: C. Calvert Date: 25/04/13

Print Name: C. CALVERT

Title: SAFETY & ENVIRONMENT ENGINEER

Agreed by: [signature] Date: 25/04/13

Print Name: K. BECKWITH

Title: Rad Pro Engineer (Env)

Authorised For Issue: [signature] Date: 7/5/13

Print Name: P. [illegible]

Title: Head of Environment

BRADWELL SITE

FED DISCHARGE OUTLINE OUTFALL DESIGN UPDATE (INCLUDING HR WALLINGFORD REPORT EBR4908-RT008-R01-00))

BRAD/EN/REP/082

PURPOSE

The purpose of this document is to provide an outline outfall design for the FED aqueous discharge from the Magnox Bradwell Site and is an update to a previous technical note, TN EBR4908-04. The present design incorporates revised design requirements and the findings from a hydrographic survey.

The report leads on from and supersedes TN EBR4908-04. Some relevant details and sections are reproduced from that technical note.

Please click on the link below to view the
FED Discharge Outline Outfall Design Update: HR Wallingford Report EBR4908-RT008-R01-00

Y:\readona\DOCS1\ENvironment\EN-REP\EN-REP-082 APPENDIX.pdf

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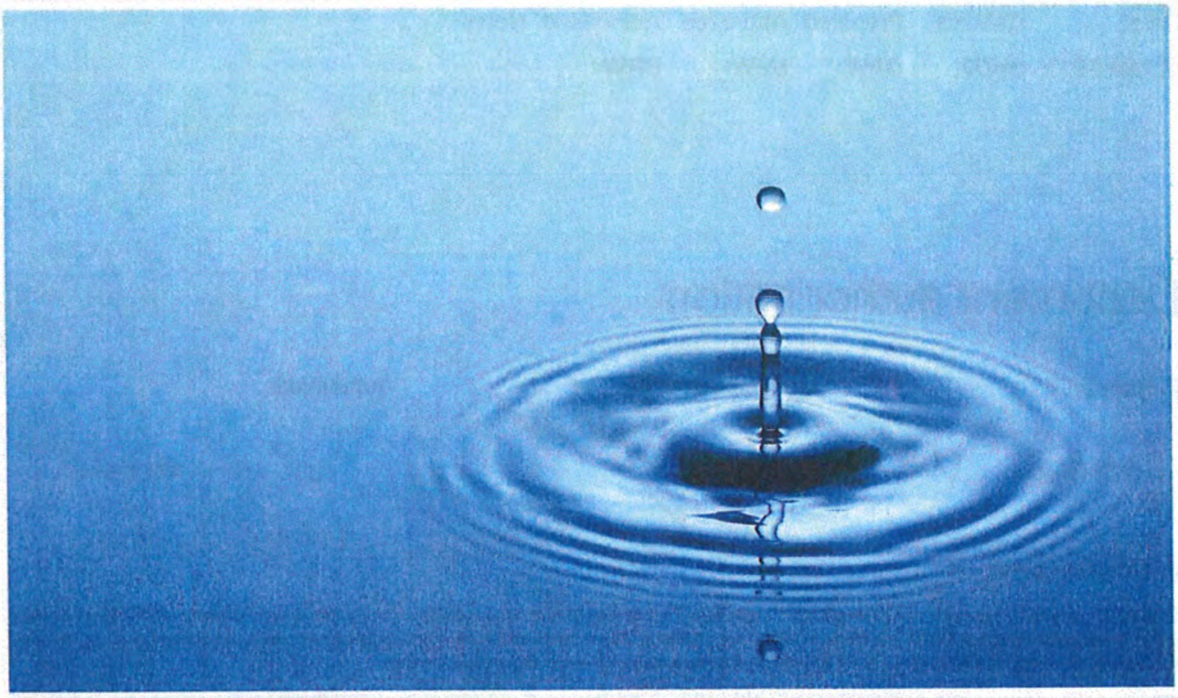
Working with water

Bradwell power station

FED discharge - outline outfall design update



EBR4908-RT008-R01-00

March 2013

Document information

Document permissions	Confidential - client
Project number	EBR4908
Project name	Bradwell power station
Report title	FED discharge - outline outfall design update
Report number	RT008
Release number	R01-00
Report date	March 2013
Client	Magnox Ltd
Client representative	Adrian Ridler
Project manager	G A Watt
Project director	B R Wild

Document history

Date	Release	Prepared	Approved	Authorised	Notes
01 Mar 2013	01-00	GAW	MJW	BRW	

Document authorisation

Prepared

Graham Watt

Approved

Authorised

B.R. Wild

Contents

1. Introduction

This report describes an outline outfall design for FED discharge from the Bradwell Power Station, and is an update to a previous technical note, TN EBR4908-04. The present design incorporates revised design requirements, and the findings from a hydrographic survey. This report leads on from and supersedes TN EBR4908-04. Some relevant details and sections are reproduced from that technical note.

Magnox is decommissioning the Bradwell Nuclear Power Station. During the decommissioning process, Magnox will dispose of spent fuel element debris (FED) by dissolving it in nitric acid. The radioactive component of this solution will be separated, leaving a solution high in magnesium nitrate which can be discharged into the Blackwater Estuary.

The disposal of this effluent using the existing discharge arrangements has been studied by HR Wallingford as described in HR Wallingford report EX 3699 (2011). The possibility of discharging this residual FED solution through the outfall designed for the active effluent (AE) was discussed in our Technical Note EBR4908-03, which concluded that this arrangement would not be satisfactory. TN EBR4908-04 presented an initial outline design for a dedicated outfall, which led to further discussions and a revision of the design requirements. This report leads on from TN EBR4908-04 and makes use of hydrographic survey data, described in TN EBR4908-07.

This document describes the modified design for a dedicated discharge structure for the FED solution discharge.

2. Discharge characteristics

The FED effluent is expected to have a nitrate concentration of around 22,000 mg/l as N in the final delay tank, and will be discharged in batches of 30 m^3. Initially a discharge of one batch per day is anticipated, with a lower rate of discharge later on in the process. The present arrangement would discharge one batch of 30 m^3 over a period of half an hour, beginning on the early ebb tide.

The undiluted FED effluent will have density of around 1154 kg/m^3. This density is very much higher than the receiving water (around 1030 kg/m^3) and as a result the FED discharge will be negatively buoyant ('dense').

Initially the behaviour of the dense discharge is dominated by the diffuser characteristics and initial momentum. The effluent will then tend to sink and form a thin stable layer (or density current) at the bed of the estuary and may flow down bed gradients. The plume will also be deflected by ambient currents, but once it has reached the bed mixing between the discharge and ambient water is generally weak.

At present the FED discharge is mixed with the a makeup flow driven by the power station cooling water pumps to give a dilution of around 500:1 before discharge. We have used this dilution as a target value during the assessment.

3. Dilution investigation

3.1. Appropriate discharge structure

The aim in designing an outfall structure for a dense discharge is to increase dilution of the effluent before it reaches the bed. Generally, this is done by arranging for the effluent to mix through as much depth in the receiving water as can be achieved, in order to maximise dilution in the initial stages of its trajectory.

The principal features of an outfall design for the FED were discussed in TN EBR4908-04. Sensitivity tests confirm that most of the parameters do not require to be changed in this study. However, it has been necessary to review the outfall port height.

3.1.1. Outfall port height

The outfall port should be positioned as high as possible in the water column, to give the greatest fall height before the effluent impacts on the estuary bed, but should remain submerged at all times.

The hydrographic survey (TN EBR4908-07) indicated that the bathymetry at the present outfall tower is 5.8 m below Chart Datum (-5.8 mCD), where Chart Datum is roughly the level of lowest astronomical tide (LAT). This means that the minimum water depth at this place (due to tidal factors) should be not less than 5.8 m. The lowest measured water depth was around 5.7 m, which shows that tidal factors are not the only ones determining actual water depths at the site; meteorological factors are the most likely other considerations, including wind and 'surge' variations in atmospheric pressure.

The model predictions used previously show broadly consistent water level variations, as shown in Figure 4.1, but with lower minimum depths (down to 5.3 m). Note that the model has not been run for the survey period; the simulated depths used previously have simply been overlaid on the survey data. We consider that the model depth value may be overly conservative (0.5 m below LAT), and so we have assumed a port elevation of 5.5 m above the bed. This allows a safety margin of 0.3 m for non-tidal variations.

3.1.2. Outline outfall design

In summary, the following outline outfall configuration is suggested:

- single port of internal diameter 0.065 m;
- discharging horizontally;
- raised 5.5 m above the bed;
- angled offshore, perpendicular to the tidal current direction.

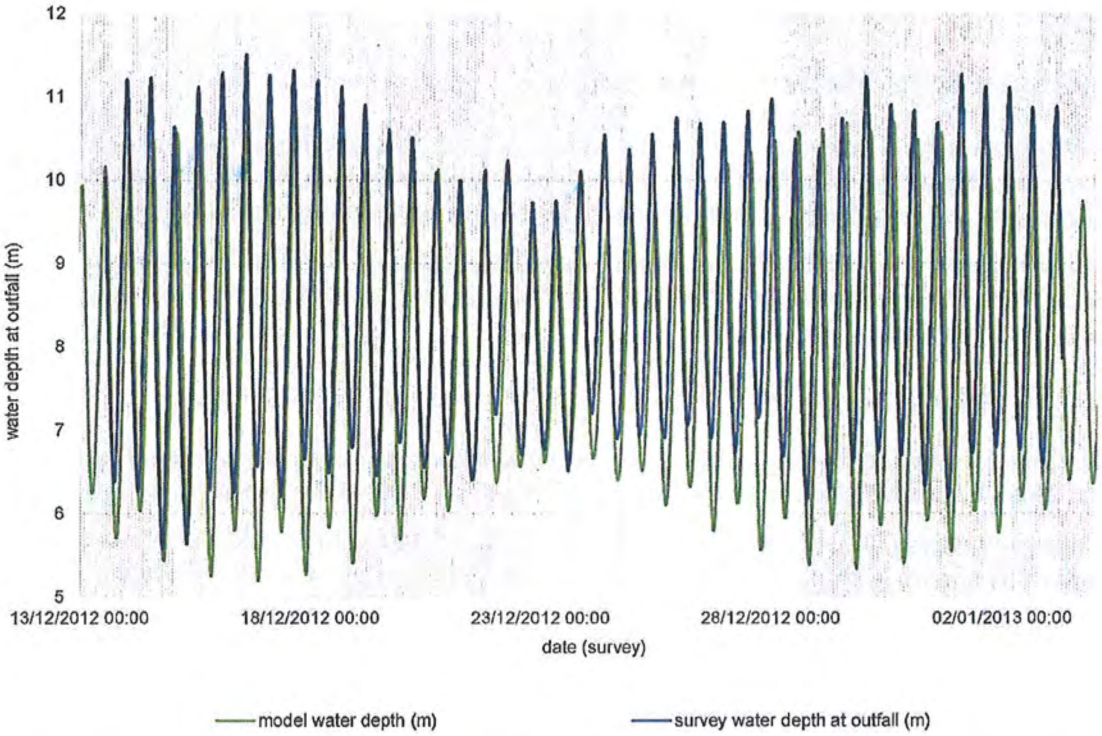


Figure 3.1: Comparison of model and surveyed water depths at outfall (model results shifted in time)

4. Dilution calculations

Initial dilution tests were carried out for the range of hydrodynamic conditions likely to be found near the outfall location. These tests used the method described in Technical Note EBR4908-02, with a range of current speeds and water depths representative of the whole tide.

The results were found to be insensitive to the water depth and therefore a representative shallow depth of 6 m was assumed for all tests. The graphs in Figure 4.1 to 4.3 display:

- the predicted minimum dilution 100 m from the outfall;
- the predicted minimum dilution where the plume reaches the bed;
- the distance required to reach a predicted minimum dilution of 500:1.

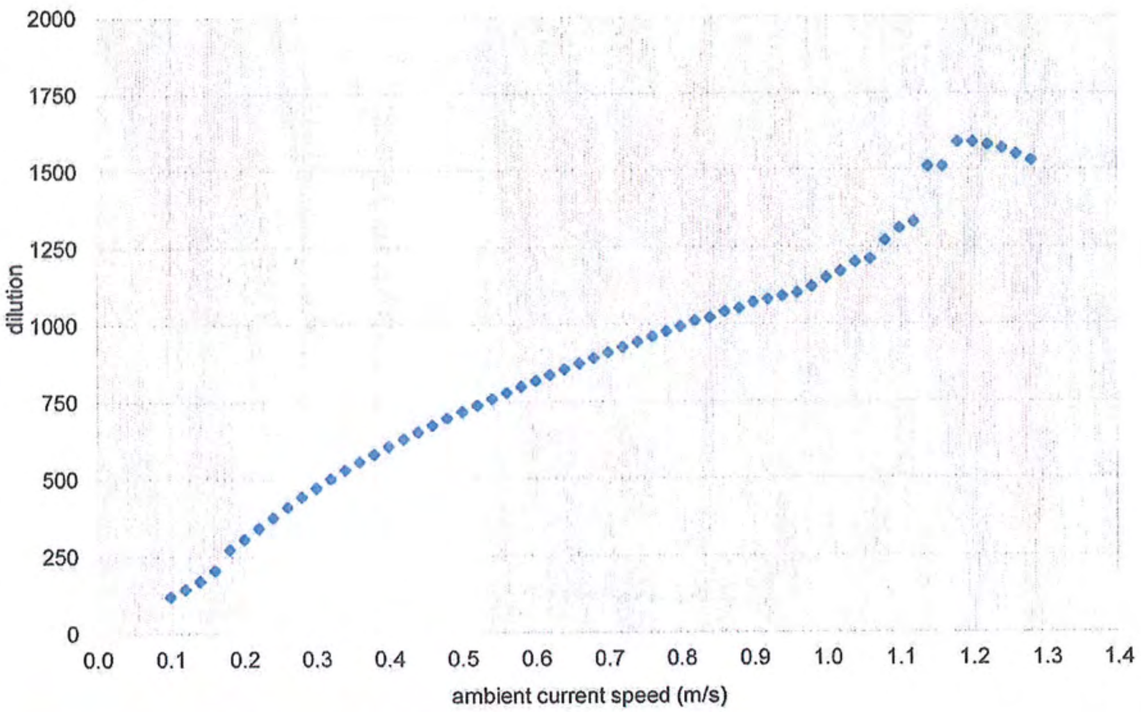


Figure 4.1: Predicted minimum dilution 100m from the outfall

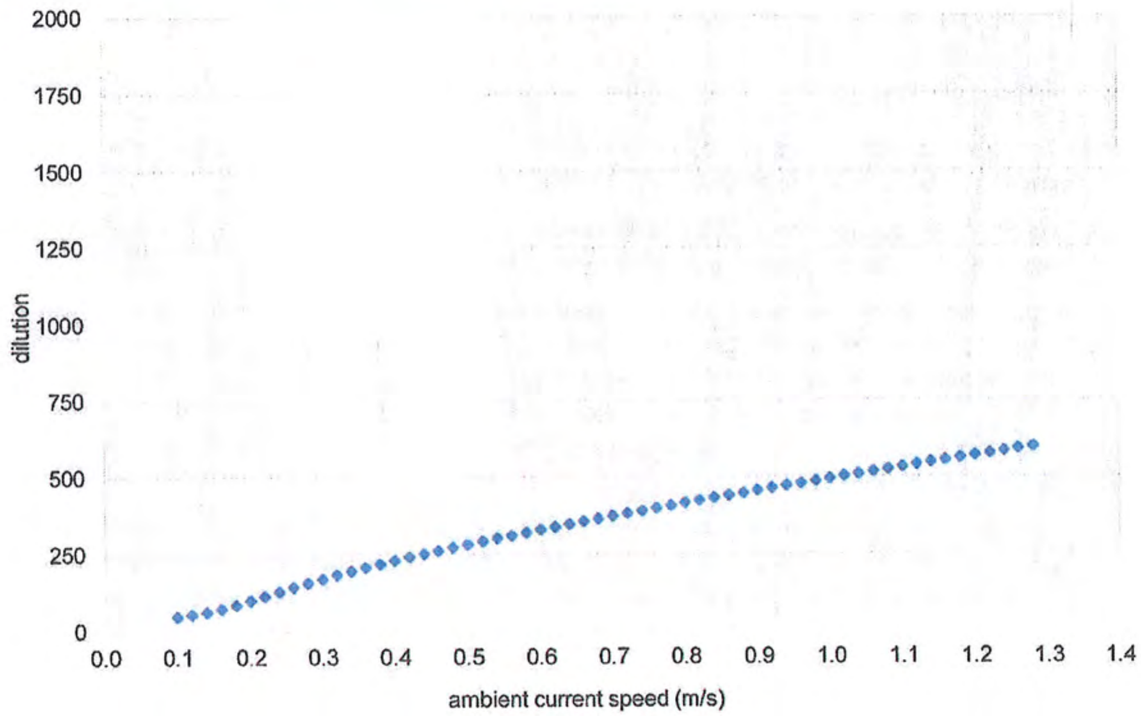


Figure 4.2: Predicted minimum dilution where the plume reaches the bed

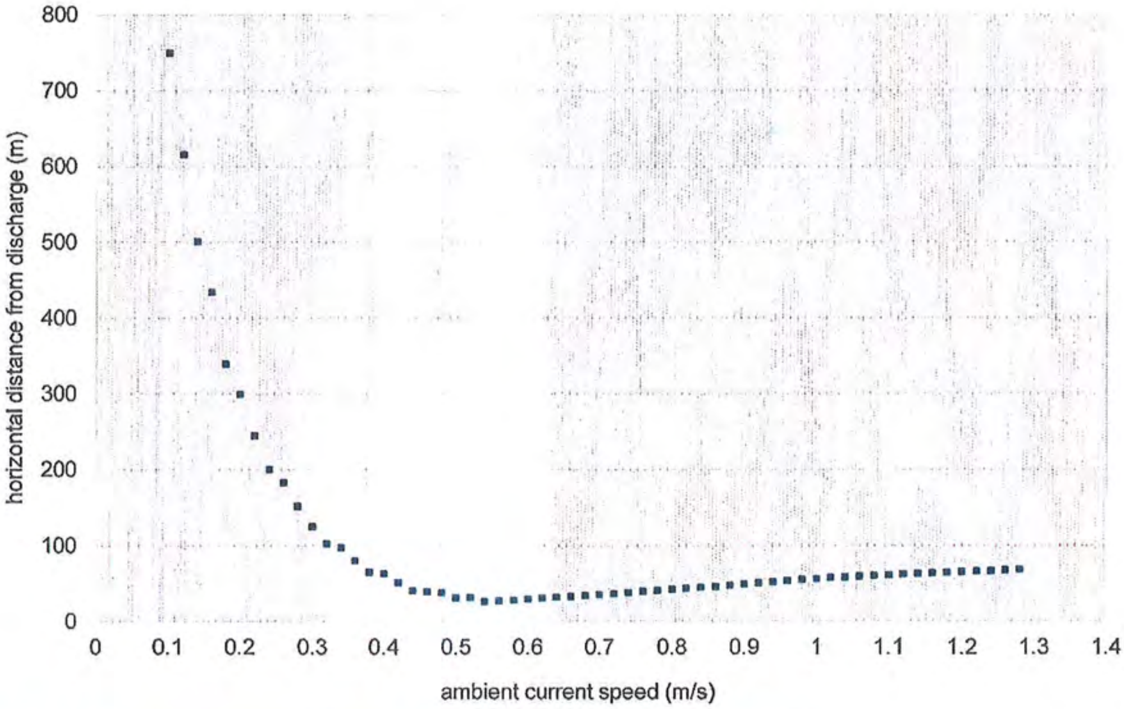


Figure 4.3: Distance required to reach a predicted minimum dilution of 500:1

4.1. Discussion

4.1.1. Initial dilution

Dilution factors of at least 500:1 are predicted about 100 m away from the point of discharge when ambient current speeds are higher than 0.3 m/s. At 0.1 m/s, the dilution at 100 m is around 120:1.

Predicted dilutions at the bed are above 250:1 for ambient current speeds above 0.45 m/s. For ambient current speeds of 0.1 m/s, the minimum predicted dilution at the bed is around 50:1.

For the lowest current speeds considered, the predicted minimum dilutions are below 500:1 over a region extending some 800 m from the outfall. This is comparable to the distance from the outfall to the centre of the Blackwater Estuary, and the predicted time to reach this distance is around two hours. It should be noted that the CORMIX model assumes steady-state conditions. In a strongly tidal estuarine environment, it is unlikely that currents as low as 0.1 m/s would persist for such periods, and therefore such large mixing zones are considered unlikely to develop.

To maximise dilution it may be desirable to revise the discharge window to ensure current speeds are above 0.3 m/s. Figure 4.4 shows the predicted current speeds, as used for the previous analysis. Although some of the predicted neap tide peak speeds are less than 0.3 m/s, they are all above 0.2 m/s, which corresponds to a dilution around 300:1 at 100 m, or dilution of 500:1 around 300 m from the outfall.

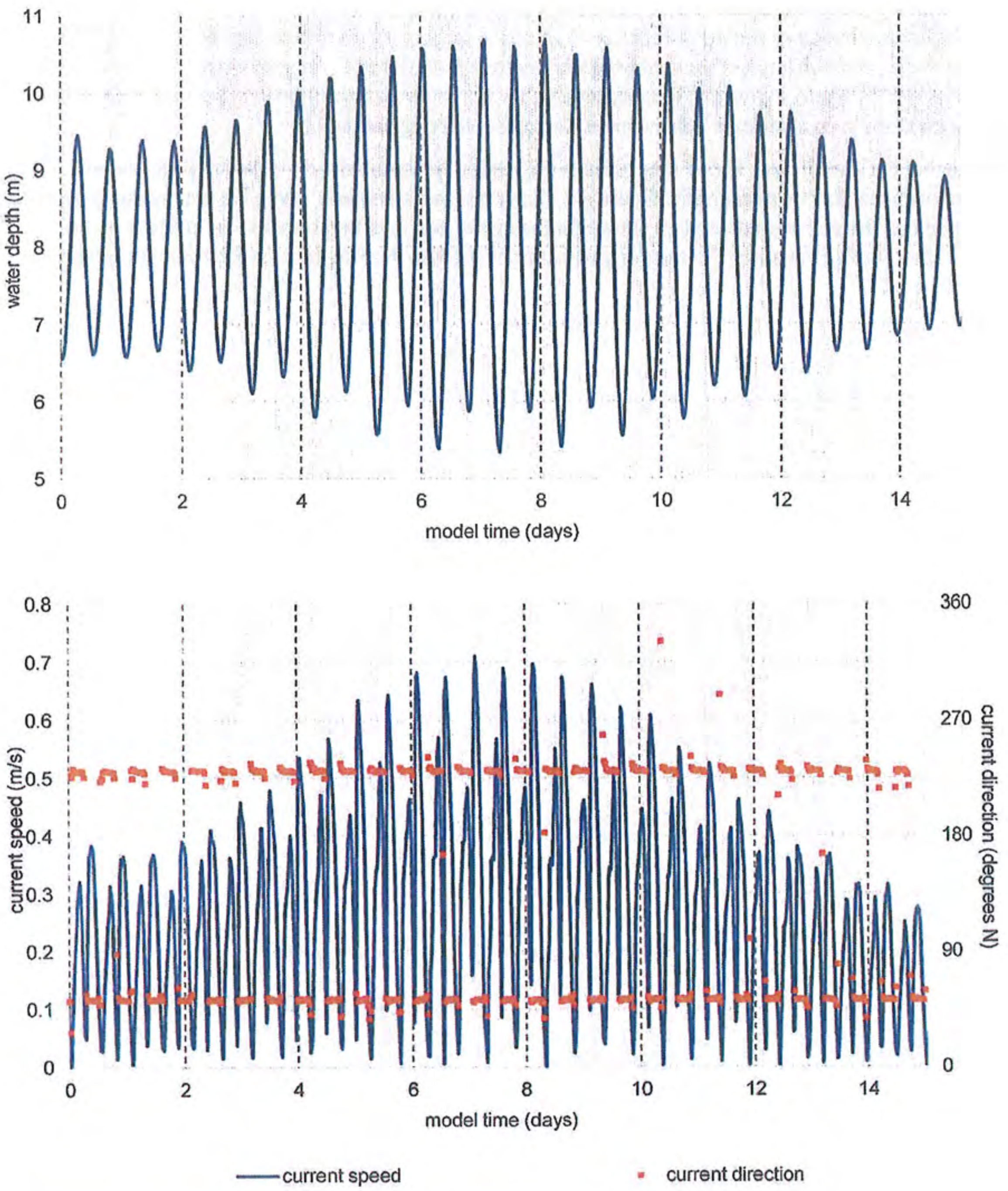


Figure 4.4: Predicted current speeds at the outfall location

Achievement windows have been calculated from these initial dilution predictions, using the model current speeds and the original target dilution. (This form of presentation was also used in TN EBR4908-02.) Figure 4.5 shows the times during the tidal cycle when the target dilution of 500:1 (or better) is predicted at 100 m from the outfall. The achievement windows are the green shaded areas; the rest of the tidal period is shaded grey. This figure shows that (as discussed above) there may be days during the neap part of the tidal cycle when there is no significant achievement window for the original target.

We note that the lowest peak speed measured in the survey was around 0.5 m/s which suggests that the model predictions may be pessimistic. Figure 4.6 shows the same analysis, using the survey data as input. The period has the same length as that shown for the model, but note that here the neap tide is in the middle, rather than at the ends. For the surveyed current speeds, the longest non-achievement window is around 6 hours.

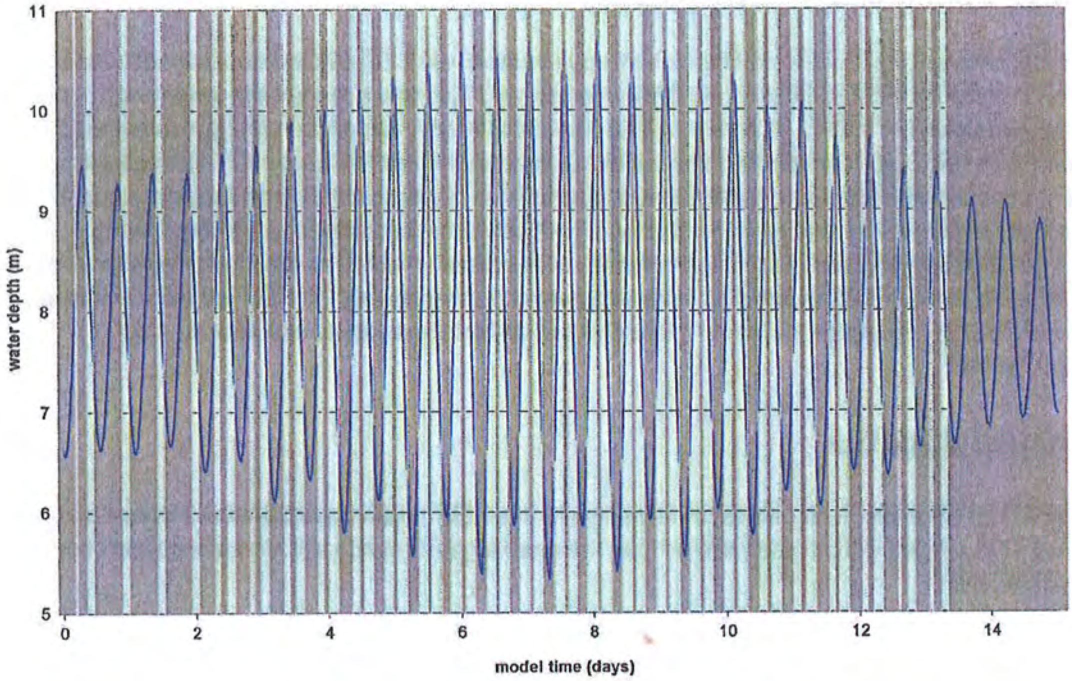


Figure 4.5: Predicted achievement windows (green) for model currents

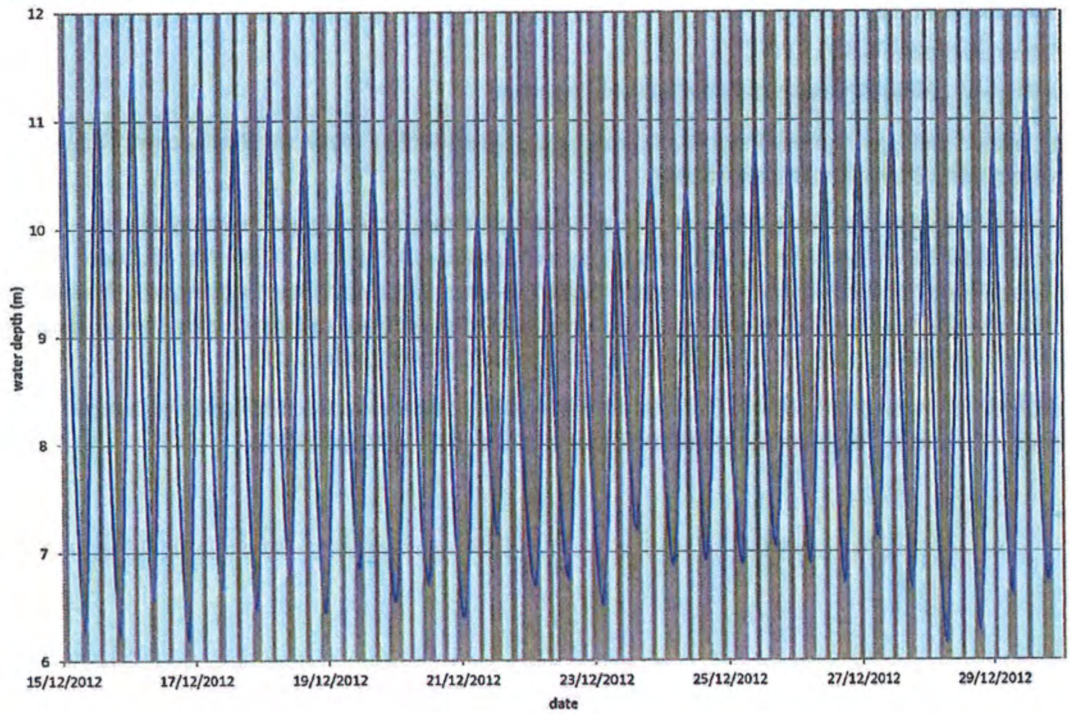


Figure 4.6: Predicted achievement windows (green) for surveyed currents

4.1.2. Further dispersion in the estuary

Following initial dilution in the near-field of the discharge structure, the FED effluent would continue to be dispersed and further diluted by the tidal currents in the estuary. This has already been examined in detail in our earlier study (report EX 3699). However, at low dilutions the wider dispersion and dilution of the FED effluent would be significantly affected by its negative buoyancy, as noted in Chapter 2. Wider area dispersion of strongly stratified plumes would require use of a 3D hydrodynamic model that includes the important effects of buoyant spreading and inhibition of vertical mixing associated with sharp density gradients. The dilution levels predicted for the present outfall suggest that the plume footprint in the wider area should be similar to those modelled previously. However, if discharge of the FED effluent with these dilutions is considered acceptable, the wider dispersion should be investigated explicitly with a 3D hydrodynamic model.

5. Conclusions

HR Wallingford has established an outline outfall design for the FED discharge at Bradwell Power Station. The undiluted FED effluent will be much denser than the receiving water and will form a negatively buoyant plume in the estuary.

An outfall port placed close to the water surface (but always submerged) has been suggested to allow for increased mixing with the ambient water to occur before the plume reaches the bed:

- single port of diameter 0.065 m;
- discharging horizontally;
- raised 5.5 m above the bed;
- angled offshore, perpendicular to the tidal current direction.

This outline design would give an exit velocity of 5 m/s and a densimetric Froude number around 18, which should be associated with rapid turbulent mixing.

The initial dilution obtained with this outfall design has been estimated for a range of hydrodynamic conditions likely to be found near the outfall location (current speeds 0.1-1.3 m/s). The initial dilution predictions were found to be insensitive to the water depth (so long as the port was submerged). Predicted dilutions of at least 500:1 about 100 m away from the point of discharge were obtained when the ambient current speed is higher than 0.32 m/s. At 0.1 m/s, the dilution at 100 m is around 120:1.

Predicted dilutions at the bed are above 250:1 for ambient current speeds above 0.45 m/s. For ambient current speeds of 0.1 m/s, the minimum predicted dilution at the bed is around 50:1.