HR Wallingford
Working with water

Bradwell Power Station

Response to Environment Agency questions

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1. Introduction

Magnox is in the process of decommissioning Bradwell Power Station in Essex. In recent years, HR Wallingford has advised Magnox on disposal of several types of effluent during decommissioning (References 1-4). Magnox has now submitted its application for discharge permits to the Environment Agency, and the Agency has asked some questions about various details of our earlier assessments. This report provides answers to these questions.

Magnox and HR Wallingford met with the Environment Agency on 23 October 2015 to discuss their initial questions. Table 1.1 summarises the key actions agreed at the meeting; the 'item' numbers correspond to the sub-heading numbers in Section 2.

Table 1.1: Action list from meeting on 23 October 2015

item	EA question
1	What is the reason for the discontinuity in Figure 5.1 and the inflection in Figure 5.3?
2	A Figure similar to Figure 5.6 for the FED discharge.
3	A Figure showing the distance to where the FED plume reaches the estuary bed in relation to current speed and give the plume dilution at this point.
4	Better linkage between the CORMIX modelling and the Environmental risk assessment is needed. Instances of a lack of clarity are: (a) the Telemac modelling uses an initial dilution from CORMIX of 240:1 while the annual average concentration dedicated discharge report (EBR4908-RT012-R05-00) assumes initial dilutions of either 1000 or 700. (b) Report EBR4908-RT012-R05-00 mentions that the core of the discharge plume is tens of metres across and up to two metres thick close to the estuary bed. Where does this prediction come from?
5	More detail about possible interaction between the plume and oyster beds.
6	Agency Table 1 provided updated EQS values for various species. Update relevant tables accordingly. (Action on Magnox)
7	The Agency would like to see additional sample data to back up statements about effluent composition. (Action on Magnox)
8	Details of how CORMIX was set up for each of the discharges.
9	More detail about the size and shape of the discharge's zone of influence.

Note: Unless otherwise stated, references in this table are to figures and tables in Reference 1.

2. Responses to questions

2.1. What is the reason for the discontinuity in Figure 5.1 and the inflection in Figure 5.3?

The initial dilution calculations were done using the CORMIX expert system (Cornell Mixing Zone Expert System). CORMIX is an internationally-accepted software system for the analysis, prediction and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. It incorporates an expert system that uses the characteristics of the discharge (flow rate and configuration) and of the receiving water (depth, width, current speed, etc.) to determine a flow class for the discharge jet. It then calculates the centre-line trajectory and dilution rate of the jet to the edge of the near-field area, and associated parameters.

For each flow class, CORMIX divides the regions of mixing into distinct modules for prediction. For example, in the case of a dense discharge, there may be a calculation of the trajectory and dilution of the jet as it falls to the seabed, followed by different modules for the impact with the seabed, the subsequent spreading as a density current, and the eventual wider-area transport by ambient currents. Each module simulates different physical processes, and therefore uses different method of prediction. For this reason, there can be discontinuities in dilution predictions, especially where the point of interest is close to the transition between two flow modules. However, the predictions on either side of the transition remain valid, within the typical confidence limits of the CORMIX system.

A critical feature of Figures 5.2 and 5.3 is that as current speeds increase, dilution at a point 100 m downstream increases, due to the increase in ambient turbulence. However, as the current speed increases further, the jet is deflected more strongly, and spreads less far across the width of the estuary. Therefore, it may reach a point 100 m downstream at higher concentrations (i.e. lower dilution).

2.2. A Figure similar to Figure 5.6 for the FED discharge

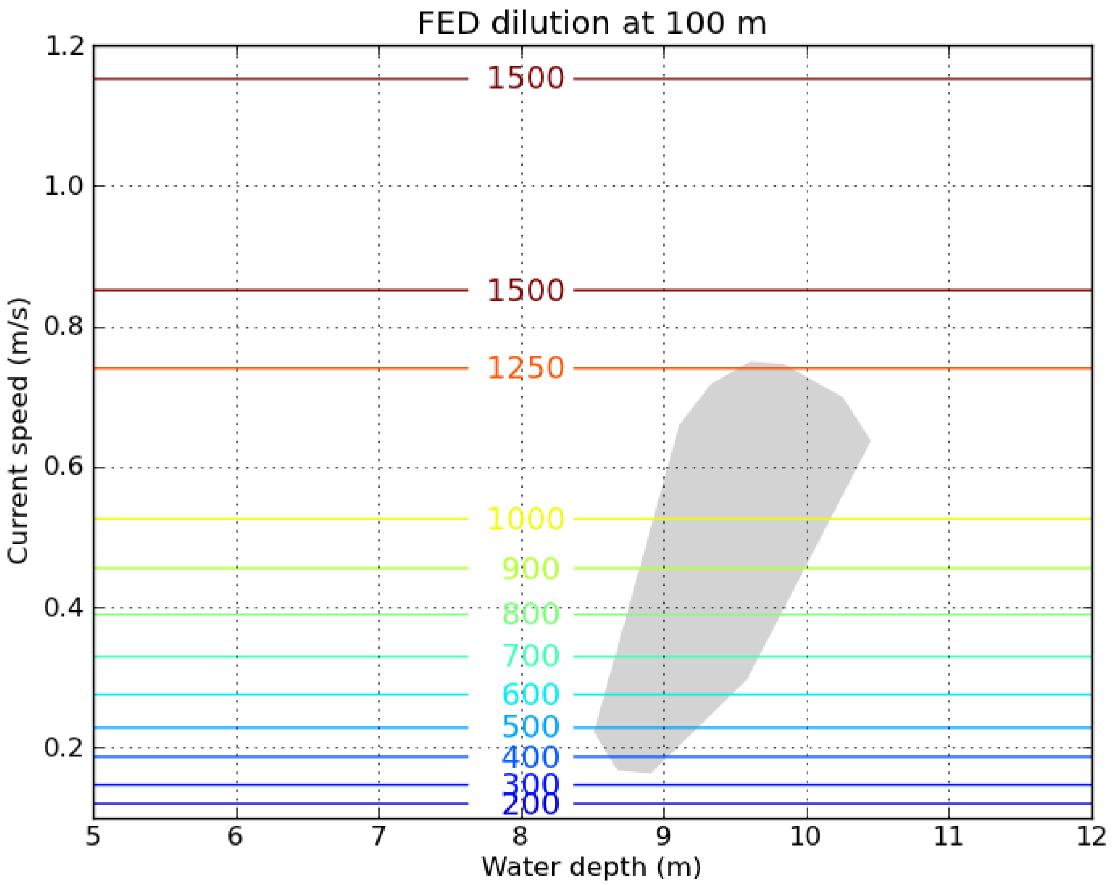

Figure 2.1: Predicted FED dilution 100 m from outfall

Grey shaded area denotes conditions predicted to occur during the discharge window.

Figure 2.1 shows the predicted FED dilution 100 m from the outfall. The contours of dilution are straight lines because the dilution does not depend on the water depth. The area shaded grey marks the combinations of water depth and current speed that are expected to occur during the discharge window.

2.3. Position and concentration of FED plume at bed impact

Figure 2.2 shows the distance to the point where the FED plume reaches the bed, as a function of current speed. Figure 5.2 in Reference 1 showed the dilution at this point – reproduced here as Figure 2.3 for convenience.

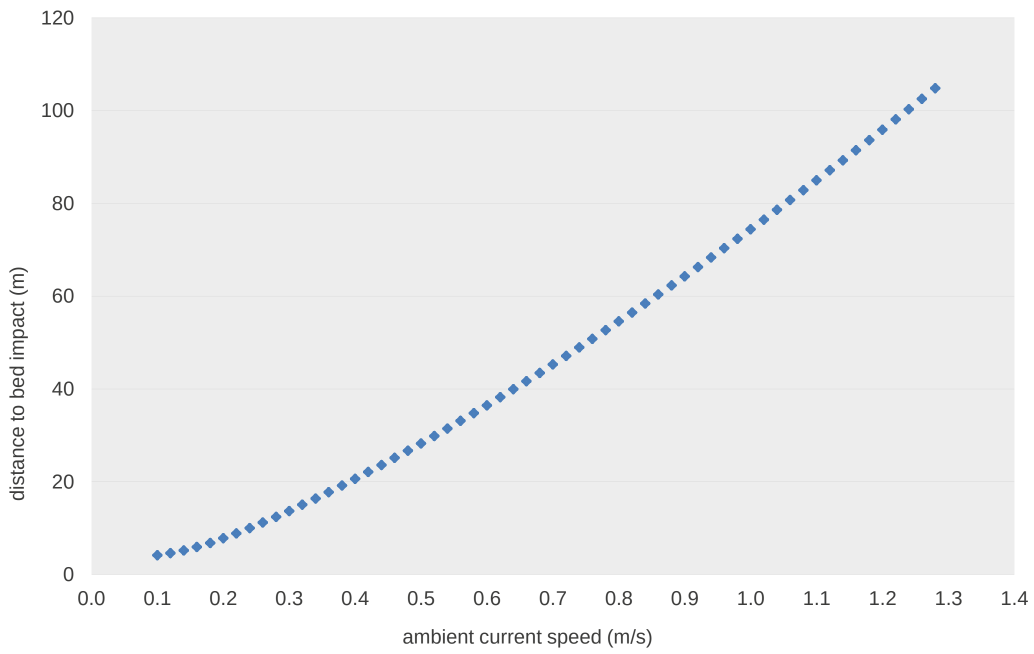

Figure 2.2: Predicted distance to bed impact

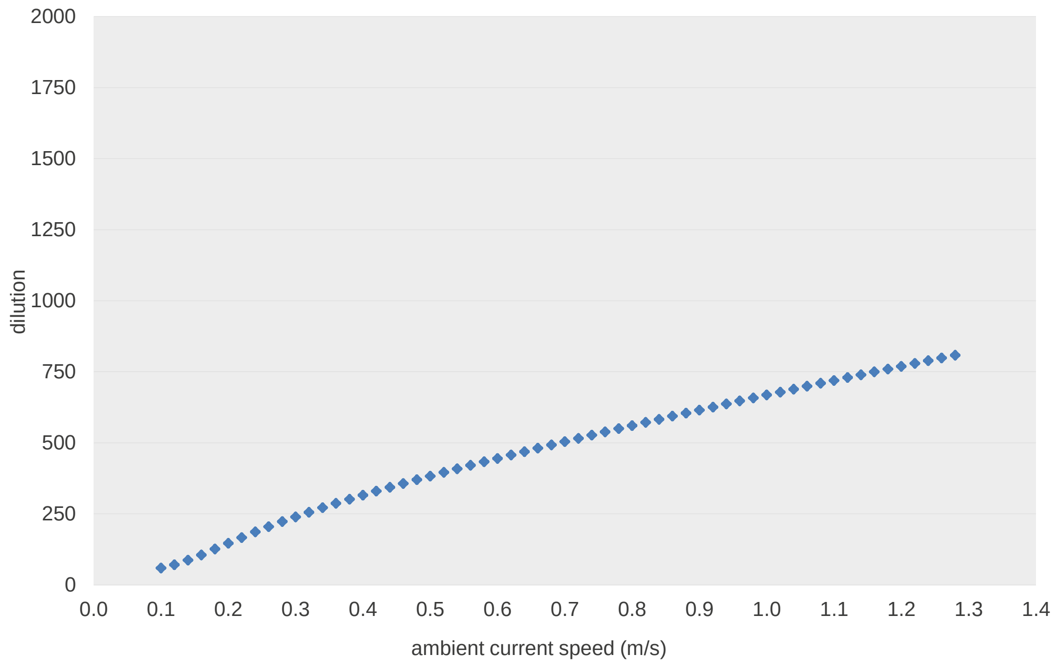

Figure 2.3: Predicted minimum dilution where the plume reaches the bed

2.4. Linkage between the CORMIX modelling and far-field analysis

Better linkage between the CORMIX modelling and the Environmental risk assessment is needed. Instances of a lack of clarity are:

(a) the Telemac modelling uses an initial dilution from CORMIX of 240:1 while the annual average concentration dedicated discharge report (EBR4908-RT012-R05-00) assumes initial dilutions of either 1000 or 700.

First we identify the numbers quoted by the Agency:

- The value 240:1 is the (pessimistic) minimum dilution calculated for the FED at 100 m from the outfall. This value may occur **for an instant** at the start of a discharge release on a neap (smallest) tide, when current speeds are relatively low. The dilution will then increase as the current speeds increase through the ebb tide, and the minimum value will be larger for larger tides. (The corresponding value for AE is similar – 250:1).
- 1000:1 is the dilution of the FED at 100 m from the outfall, averaged over the discharge window. The dilution starts at a low value (such as 240:1) and then increases over the 30 minute period of the discharge. 1000:1 is the average calculated over these 30 minutes, and over all tides in a spring-neap cycle. This is not a time-average, as it does not include the values between discharge windows.
- 700:1 is the dilution of the AE, averaged over the discharge window, over all tides in a spring-neap cycle.

The discharge is represented in the far-field model without any initial dilution (this is called “actual source” representation). This means that the zone of initial dilution (less than 100 m from the outfall) is not accurately represented in the far-field model – in particular the concentrations here may be higher than expected – but the results at its edge and further away are compatible with the initial dilution predictions. For this reason, all of our comments on the zone of initial dilution are based on the CORMIX calculations; the value of 240:1 has been used to give conservative estimates of extreme values.

(b) Report EBR4908-RT012-R05-00 mentions that the core of the discharge plume is tens of metres across and up to two metres thick close to the estuary bed. Where does this prediction come from?

This observation is based on the CORMIX calculations. The distances quoted refer (roughly) to the plume’s half-width relative to the its centre-line; CORMIX predicts the concentrations will be uniform within this region. The point of this comment was that the concentration within this relatively small volume is already 1000 times less than the discharge concentration, and the depth-average concentration will be lower still.

It is important to explain the implications of this comment for the discharge density. The undiluted effluent has density around 1122 kg/m^3, while the estuary water’s is around 1030 kg/m^3. The effluent is therefore denser by approximately 100 kg/m^3. After dilution, the density difference will reduce to 0.1 kg/m^3 which is a negligible difference. Therefore after the initial dilution phase, the effluent will be virtually neutrally buoyant in the estuary and will mix readily through the water depth. For this reason, we consider that a depth-average approach is appropriate outside the zone of initial dilution.

2.5. Oyster beds

Impacts at the oyster beds were considered in Reference 2. The Agency has asked for further details. Figure 2.4 shows a zoomed-in picture of the plume footprint on spring tides and neap tides. These images are based directly on the relevant panels of Figures 4.3 and 4.4 in Reference 2, for the discharge window starting at HW+1.

The figure shows the mixing zone (approximated to a circle of radius 100 m around the outfall), the location of Bradwell Pacific Oysters, and the contour of Low Water Springs (LWS). Oysters only grow in intertidal areas, and so the LWS contour is the offshore limit of their viable habitat – areas further from the shore are never uncovered.

The figure shows that the plume footprint is confined largely offshore of LWS, and since the oysters are confined onshore of LWS, there is expected to be negligible overlap of the plume with the oyster beds. Notice also that the separation of the oyster bed location from the edge of the mixing zone is around 500 m (five times the size of the zone radius).

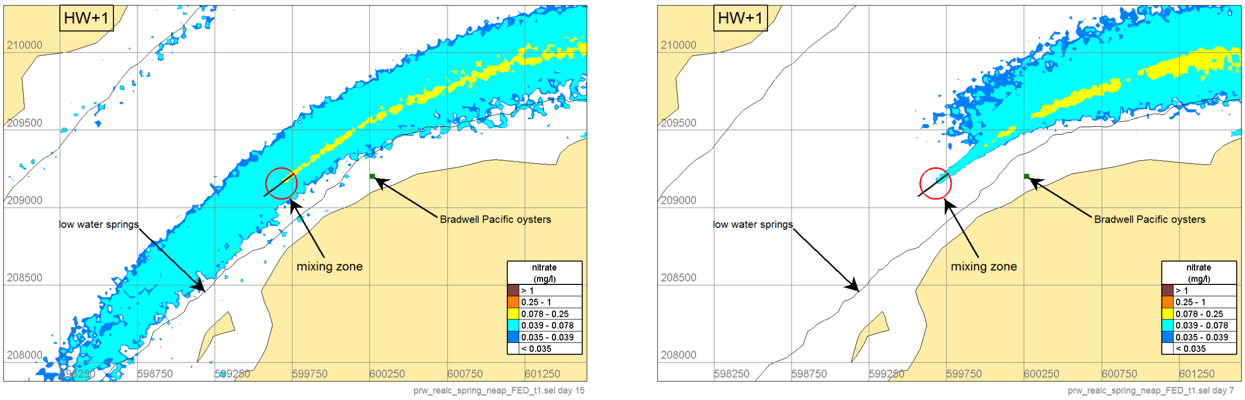

Figure 2.4: Predicted nitrate concentrations, averaged over one day, spring tide (left) and neap tide (right)

Source: Based on Reference 2, Figures 4.3 and 4.4. (Release at HW+1)

2.6. Updated EQS values

Action on Magnox.

The Agency is referred to Magnox's document Discharges Clarification, reference EA52537.

2.7. The Agency would like to see additional sample data to back up statements about effluent composition.

Action on Magnox.

The Agency is referred to Magnox's documents: Metal concentrations for abated FED, Metal Concentration explanation and BRAD/22429/OI/00140, Issue 3 New Main Metals ICP-MS Method and Sample Preparation.

2.8. Details of how CORMIX was set up for each of the discharges

A sample CORMIX input file has been provided to the Agency.

2.9. More detail about the size and shape of the FED discharge's zone of influence

The plume will have a very complex shape, as its motion is affected by its momentum leaving the outfall, the effect of gravity as it falls towards the bed under its higher density, and deflection by the ambient currents. The sketches in Figure 2.5 and Figure 2.6 illustrate the general size and shape of the plume as it leaves the outfall, until it impacts with the bed. As has been noted previously, the dilution at this point is around 1000:1 (averaged over discharge windows) and so the concentrations of all constituents in the FED are very low outside this region – see the tables in Section 2.6. For this reason, it is appropriate to regard this region, extending less than 100 m from the outfall as the "zone of influence" of the discharge.

After bed impact, as noted above, the effluent will continue to mix, through the water depth and also laterally.

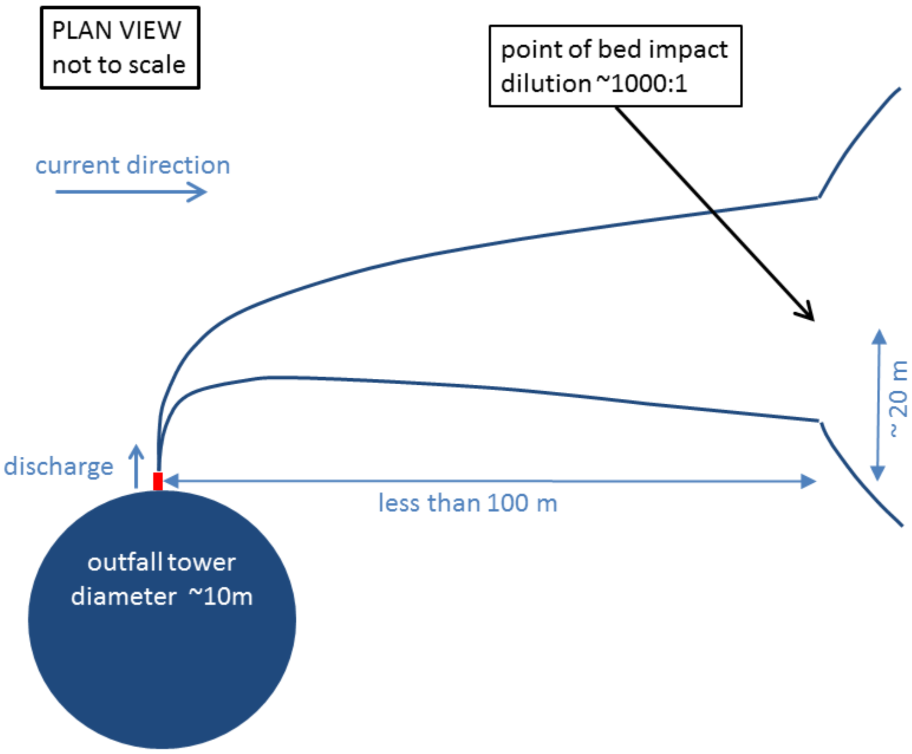

Figure 2.5: Sketch of the FED plume in the zone of influence: plan view looking downwards

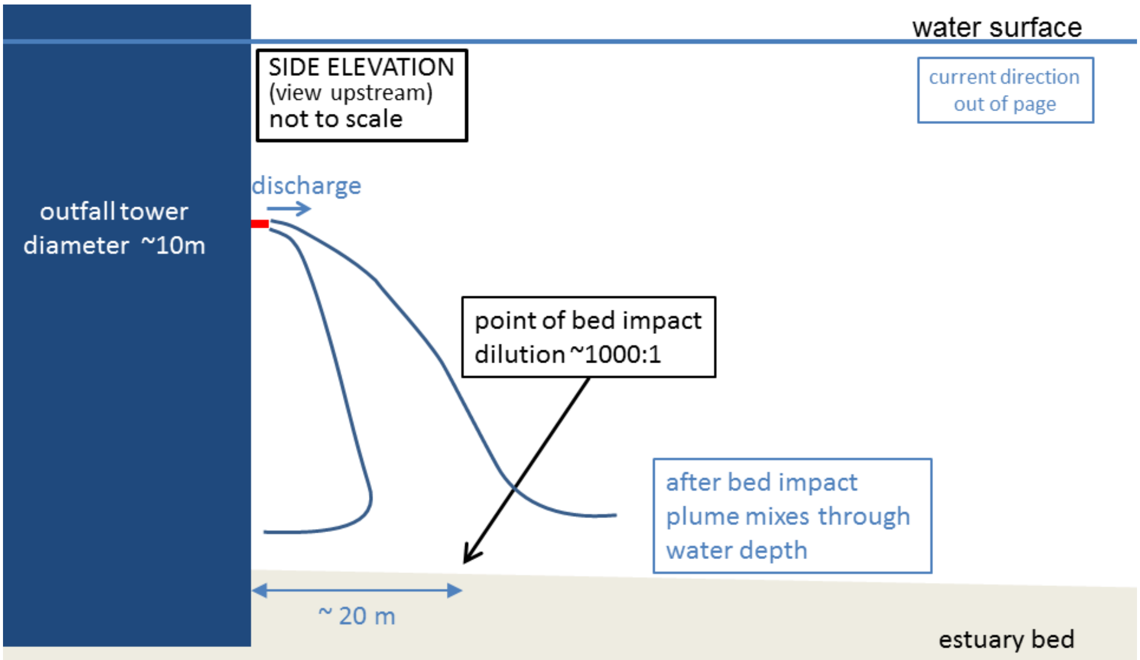

Figure 2.6: Sketch of the FED plume in the zone of influence: side view looking upstream

3. References

1. Bradwell Power Station: Effluent discharge arrangements: Initial dilution. Report EBR4908-RT009-R04-00, HR Wallingford Ltd, March 2014.
2. Bradwell Power Station: FED discharge arrangements: Far-field dispersion. Report EBR4908-RT010-R04-00, HR Wallingford Ltd, March 2014.
3. Bradwell Power Station: Annual average concentration of FED constituents. Report EBR4908-RT011-R02-00, HR Wallingford Ltd, July 2014.
4. Bradwell Power Station: Annual average concentration - dedicated discharge. Report EBR4908-RT012-R05-00, HR Wallingford Ltd, January 2015.

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