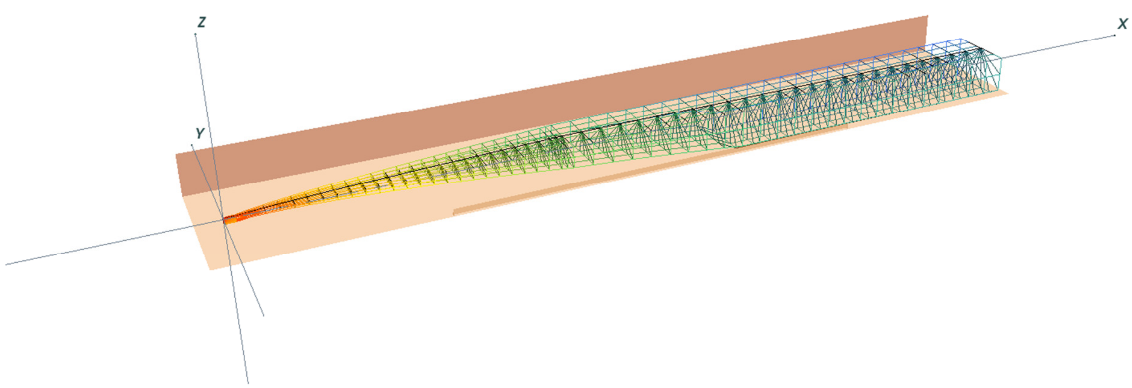
Coastal Science
LIMITED

A report for Knolton Farmhouse Cheese Ltd

Thermal Plume Modelling

R240801 August 2024



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Cover Image: 3D View of the Plume from a Knolton test simulation

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1 Background

Knolton Farmhouse Cheese have been requested by Natural Resources Wales to undertake thermal plume modelling of their effluent discharged to the River Dee at NGR SJ 36181 41183, in support of their application to increase the consented discharge volume to 1,500m^3day^{-1} and the discharge temperature to 30°C.

This report describes the thermal plume modelling undertaken in response to that request, using the industry standard CORMIX plume modelling system.

1.1 Coastal Science Ltd

Coastal Science (www.coastalscience.co.uk) is an independent UK consultancy specialising in:

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

Coastal Science has very extensive specialist experience in the build, calibration and application of hydrodynamic models throughout the UK and Ireland, as well as for projects in the Pacific, Africa, Australia and the Middle East, and management of associated surveys. It has an extensive client list which includes major utilities (including E.ON, RWE, Southern Water, South West Water and Wessex Water).

Of particular relevance to this study, Coastal Science has taken lead roles on numerous CORMIX thermal plume studies for a range of developments including a proposed biomass plant at Marchwood (adjacent to MPS), the Fawley power station, nuclear new build (NNB) projects (Bradwell, Oldbury, Moorside and Wylfa) and a number of conventional power plants (Ballylumford, Aberthaw, Pembroke and Humber). Smaller scale applications range from numerous studies for the water industry (Dwr Cymru-Welsh Water, Wessex Water, South West Water, Northumbrian Water etc.) to various assessments of plume behaviour associated with whisky distilleries.

2 CORMIX

The plume modelling was undertaken using the CORMIX modelling system. CORMIX is a USEPA-supported mixing zone model and decision support system for environmental impact assessment of mixing zones resulting from continuous point source releases. The system predicts mixing and resulting plume geometry in steady state conditions.

Effluents considered may be conservative, non-conservative, heated, brine or contain suspended sediments. CORMIX- unlike dynamic 2D / 3D models such as Delft3D or Mike21/3 - uses a simplified representation of the receiving environment under steady state conditions. It is generally considered to be the worldwide industry standard tool for assessment of plume characteristics and outfall design optimisation.

The model version used in the present study was CORMIX 12.0 GT, being the current release at the time of the study. More information can be found here:

http://www.cormix.info/aboutcormix.php

The core modelling approach was conservative, considering the effluent under warm summer conditions (to minimise the temperature "loss" associated with a warm effluent to a cold receiving water) and for ambient flows of summer Q50 and summer Q95.

3 Model Set Up

CORMIX was set up with input parameters summarised as follows:

Effluent

Type: Heated Discharge.

Discharge Flow Rate: 1500 m^3day^{-1} (modelled as 0.017361 cumecs).

Discharge Temperature: 30°C.

Ambient

Ambient Water Temperature: 21.8°C from email correspondence with NRW.

Average Channel Depth: CORMIX is a rules based empirical model with restrictions relating to input values. In this case, the average depth cannot exceed the depth at the discharge by more than 30%. The depth at the discharge was set to 0.8m (from data provided by the client) and the average channel depth was therefore set to 1.0m. Note that this does not affect the ambient flow speed, which is specified by the user. It does limit how the plume can occupy the water column, but in the present case the plume is buoyant, and only occupies the full available water column at some distance downstream. The limited depth therefore restricts plume vertical dispersion after this point but see Section 4 for context.

Channel Width: 35m (from Google Earth measurements).

Channel Appearance: Slight Meander.

Ambient Flow Speed: 0.5 ms^{-1} (Summer Q50) and 0.2 ms^{-1} (Summer Q95). These values were initially derived from estimating the channel cross sectional area[1] and knowing the Q50 and Q95 values. They were carried forwards as being in line with expectation. Q50 and Q95 values themselves were taken from the summer Flow Duration Curve for the Dee at nearby Manley Hall (Figure 1) with selected values of 10 cumecs and 4 cumecs respectively.

[1] by taking the centre channel depth to be 2m, and taking the channel lateral profile shape as being the segment formed by a chord passing 2m above the lower point of a 35m diameter circle.

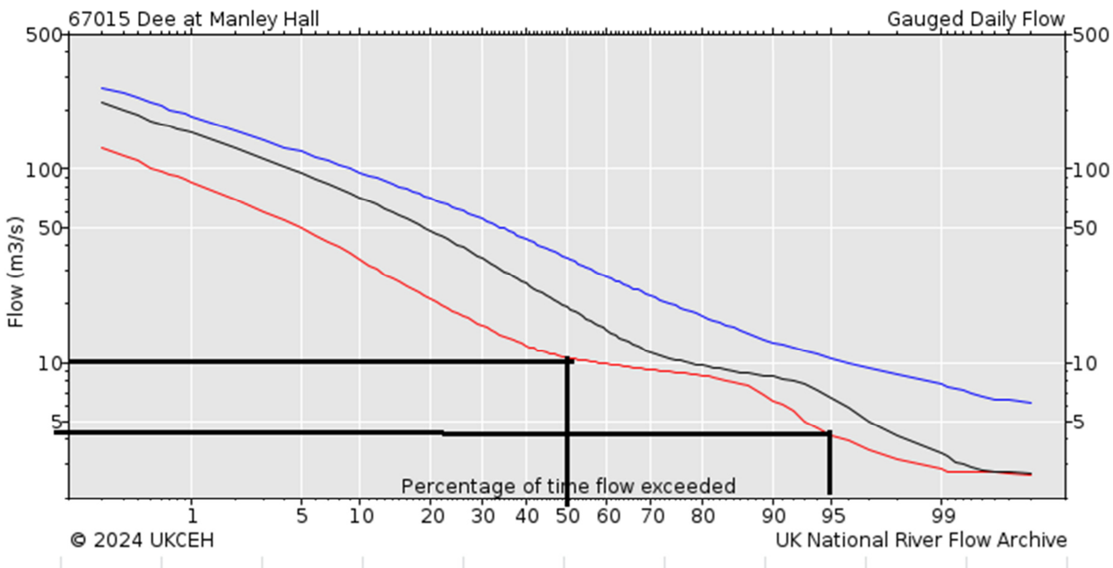


Figure 1 – Dee at Manley Hall Flow Duration Curve

Discharge

Depth: From data provided by the client the discharge is 0.7m above the bed (bed to underside of the discharge) with 0.755m water depth at the discharge. This was set to 0.8m in the model for internal consistency, with the discharge to the surface. (CORMIX allows either a surface or a near-bed discharge).

Diameter: 0.2m.

Configuration: Single pipe, flush with and discharging perpendicular to the bank.

Other

After several test simulations, the final model applications were set up with a Region of Interest extending 500m downstream of the discharge point.

4 Model Application Results

The CORMIX model simulations were undertaken as described in Section 3, and outputs are summarised below.

NOTE: CORMIX outputs are in terms of Excess Temperature, i.e. temperature above ambient. In selecting a conservatively high ambient temperature we are minimising the heat “loss” from the plume as it enters cooler water since the difference between plume and ambient temperatures is small.

4.1 Summer Q50

The Plan View of the plume under summer Q50 ambient conditions is shown in Figure 2. The plume is predicted to remain attached to the near bank and to extend no further than 8m across the channel, with 1°C excess temperature not extending beyond ~1m across.

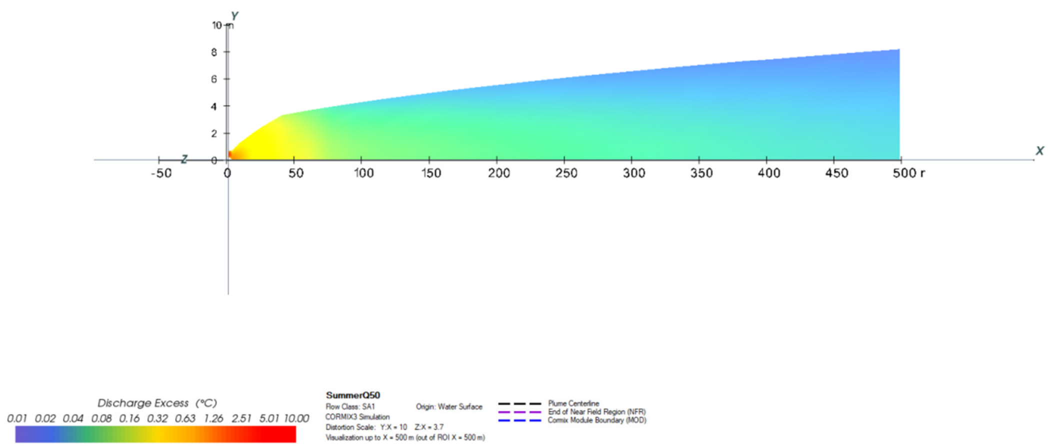


Figure 2 – Summer Q50 Plume Plan View.

The Excess Temperature is shown against distance downstream as measured by Plume Centreline Distance in Figure 3. Excess temperature very rapidly drops below 2°C and is not discernible on this plot within 100m.

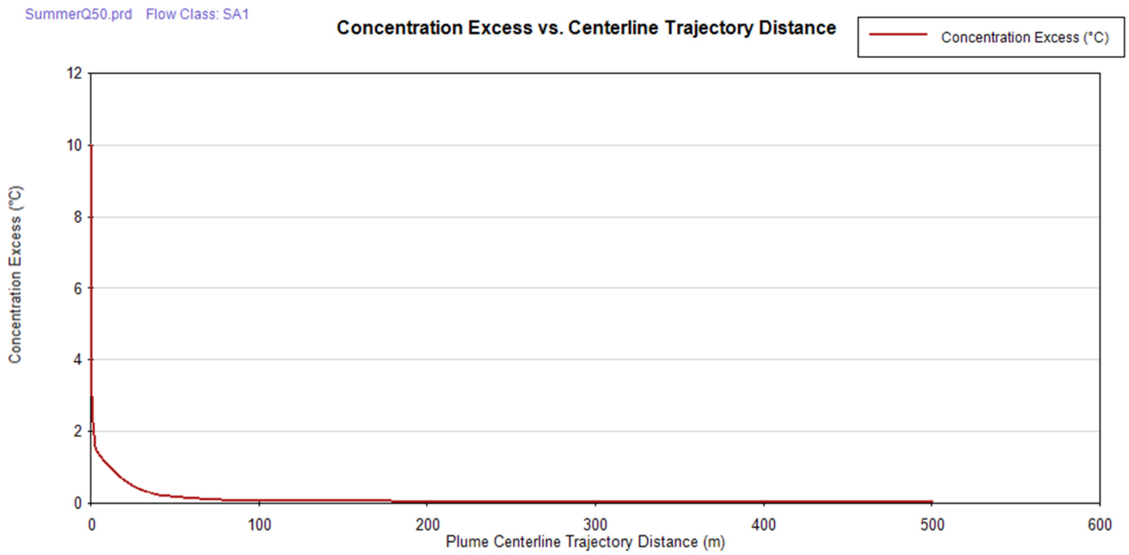


Figure 3 – Summer Q50 Excess Temperature v Plume Centreline Distance

In order to discern plume excess temperature in greater detail, plume isolines are shown in Figure 4. Note the exaggerated y-axis.   Excess temperature is predicted to fall below 0.5°C at 24.4m downstream from the outfall, and below 0.2°C at 45.7m. Cross-stream penetration of the plume is restricted to <2.5m at the 0.2°C isoline.

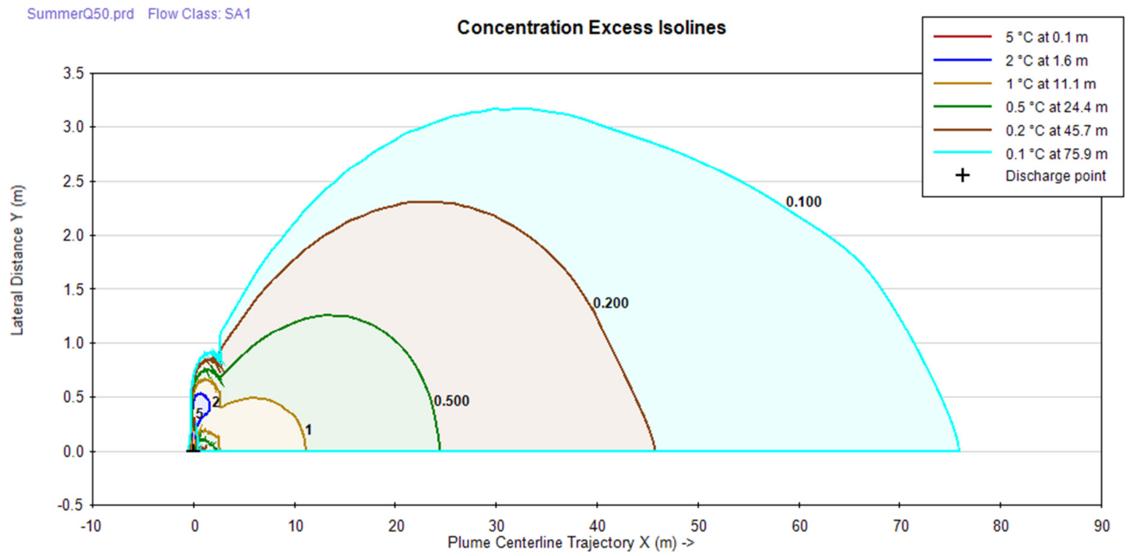


Figure 4 – Summer Q50 Plume Isolines

From CORMIX output text, the plume is restricted to the upper 1m of the water column for the first 77m of its travel at which point the centreline excess temperature is 0.1°C.

4.2 Summer Q95

The Plan View of the plume under summer Q50 ambient conditions is shown in Figure 5. The plume is predicted to remain attached to the near bank and to extend further across the channel than in the higher flow scenario. The 1°C excess temperature plume is not predicted to extend beyond 5m across the channel.

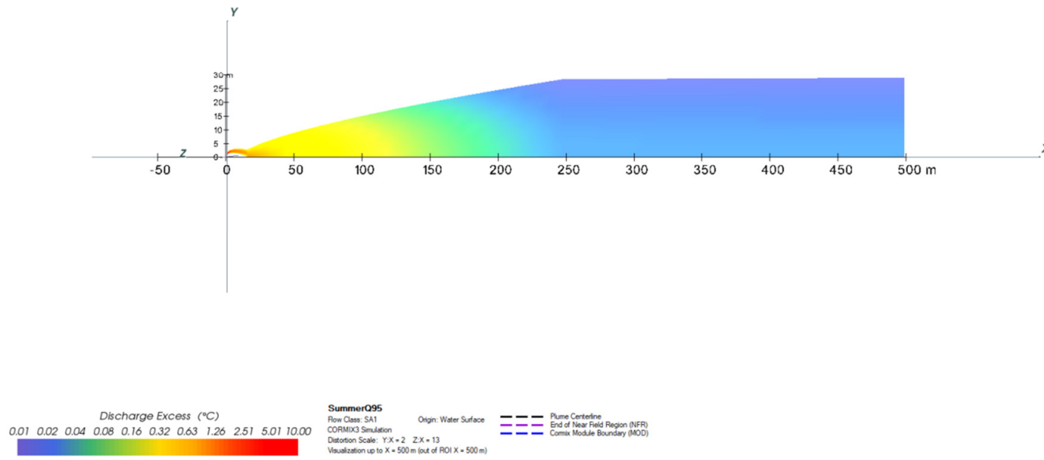


Figure 5 – Summer Q95 Plume Plan View

The Excess Temperature is shown against distance downstream as measured by Plume Centreline Distance in Figure 6. Excess temperature very rapidly drops below 2°C and is not discernible on this plot within <200m.

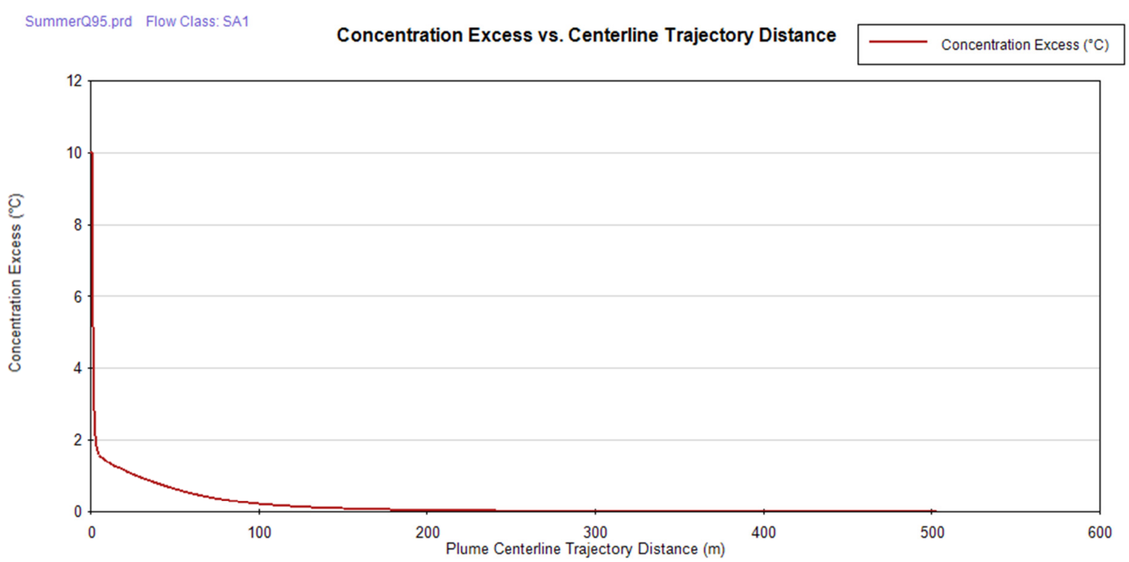
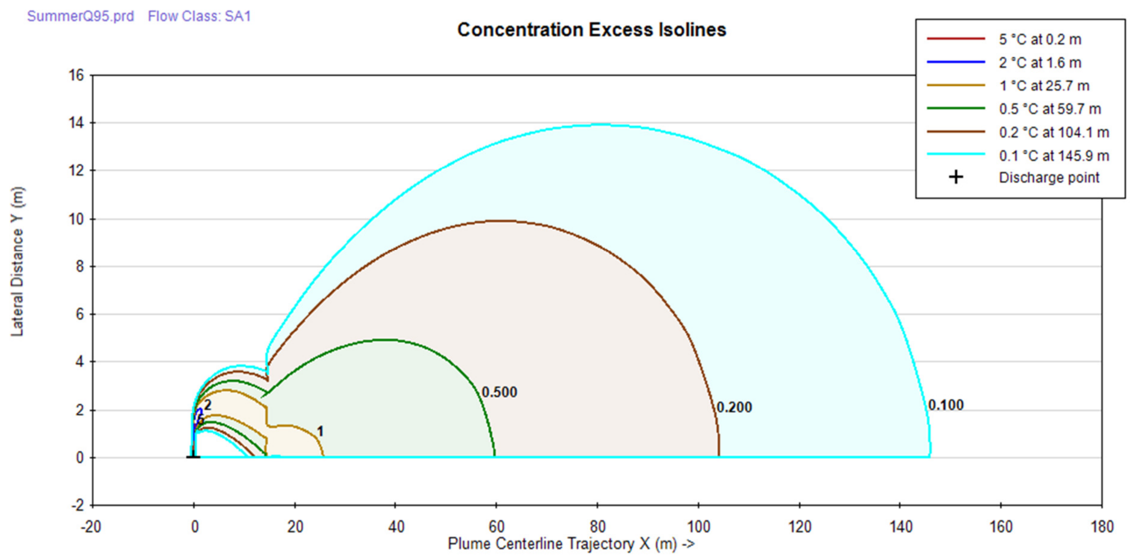


Figure 6 - Summer Q95 Excess Temperature v Plume Centreline Distance

Plume isolines are shown in Figure 4. Note again the exaggerated y-axis. Excess temperature is predicted to fall below 0.5°C at 59.7m downstream from the outfall, and below 0.2°C at 104.1m. Cross-stream penetration of the plume is restricted to <10m at the 0.2°C isoline.



From CORMIX output text, the plume is restricted to the upper 1m of the water column for the first 247m of its travel at which point the centreline excess temperature is 0.03°C.

5 Conclusions

The industry-standard CORMIX plume modelling system has been used to model the Knolton Farm Cheese thermal effluent plume to the River Dee.

The effluent has been modelled at the maximum required values of 1,500 $m^3 day^{-1}$ and 30°C

Summer values for river temperature and flow rates have been selected.

Under Summer Q50 conditions excess temperature is predicted to fall below 0.5°C at 24.4m downstream from the outfall, and below 0.2°C at 45.7m. Cross-stream penetration of the plume is restricted to <2.5m at the 0.2°C isoline.

Under the worse case low flow (Summer Q95) conditions, excess temperature is predicted to fall below 0.5°C at 59.7m downstream from the outfall, and below 0.2°C at 104.1m. Cross-stream penetration of the plume is restricted to <10m at the 0.2°C isoline.

In both cases the plume is essentially restricted to the upper 1m of the water column.