AECOM

Appendix A – Water Modelling Assessment

Environmental Permit Variation Application
Request for Further Information Response

Keadby Generation Limited

20 June 2022

Delivering a better world

Quality information

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Revision History

Revision	Revision date	Details	Name	Position
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1. Introduction

1.1 Background

AECOM has been commissioned by Keadby Generation Limited ('KGL') to undertake an effluent dispersion modelling study for development of the Keadby 3 low carbon combined cycle gas turbine (CCGT) generating station (the 'Proposed Installation'). The Proposed Installation site is near to the existing Keadby Power Station at Scunthorpe, Lincolnshire.

The discharge from Keadby 3 will be released via emission point W12, into the Keadby 1 cooling water culvert before final discharge to the River Trent via the existing outfall at Release Point W1. The location of the discharge outfall point from the site to the River Trent (W1) is approximately 1.8km upstream of Keadby Bridge, as shown in Figure 1.1.

Figure 1.1: Keadby Power Plant Outfall Location (W1)

The Environmental Agency (EA) has requested additional information on the emissions to controlled water from the Proposed Installation, for the Environmental Permit Variation application, including:

- Identification of emission points and pollutants released from the Proposed Installation;
- An Environmental Risk Assessment screening test to determine if the substances screen out as insignificant;
- Calculation of resulting pollutant concentrations in the receiving water body and comparison against relevant Environmental Quality Standards (EQS);
- Thermal plume modelling for the emission of cooling water from Keadby 3 into the River Trent;
- Quantitative risk assessment of the impact of discharges of water with thermal plume, process effluents and potentially contaminated runoff on receiving waters; and
- Consideration of the impact from emissions to surface water from all on-site plants (Keadby 1, 2 & 3.

AECOM has undertaken a data collection exercise including; river cross-section profiles, hydrodynamic model from EA, sampling for ambient temperature and concentration, discharge characteristics and wind conditions at Keadby. The study identified the pollutants released from the Proposed Installation and a H1 screening assessment was carried out to identify species requiring further modelling. Detailed water quality dispersion modelling has then been carried out using CORMIX software. This report presents the findings of the water quality assessment.

2. H1 Assessment

2.1 Methodology

EA guidance 'Surface water pollution risk assessments for your environmental permit' [1] includes a methodology for the assessment of potential environmental impacts associated with discharging hazardous chemicals and elements to surface water using their H1 screening assessment tool.

The H1 assessment tool can be used to carry out an initial screening assessment of the potential impact of a released wastewater to its receiving water, relative to established Environmental Quality Standards (EQSs). If the concentration of the pollutant fails the initial EQS screening criteria, then a number of other tests are also applied to the discharge, dependent upon the type of receiving water.

The River Trent is tidal at Keadby, and the EA classifies the river in this location as being freshwater, being part of the Humber Upper Catchment and part of the Humber Estuary. It has therefore been assumed that the release from K2 and K3 is to a riverine estuary (Transitional Rivers and Coastal - TRaC) for the purpose of the H1 assessment.

- **Test 1**

  Is the effluent concentration more than 10% of EQS? If not, the discharge is considered to have passed this test and can be considered to have "insignificant" impact. However, if either the long-term or short-term concentrations are above 10% of the EQS, then the next test (Test 2) is applied.

- **Test 2**

  The H1 tool estimates the process contribution (PC), taking into account dilution by the receiving water, of the discharge with respect to the EQS. If the PC is estimated to be <4% of the EQS, then the discharge is considered to have passed this test and can be considered to have "insignificant" impact. However, if the PC is found to be >4% of the EQS then the assessment is proceeded to Test 3.

- **Test 3**

  This test assesses whether the discharge increases the concentration of the pollutant in the river downstream of the discharge by more than 10% of the pollutant's EQS value. The tool calculates the Predicted Environmental Concentration (PEC) in the water downstream of the discharge as a combination of the PC and Background Concentration (BC) of the pollutant.

  If the difference between BC and PEC is less than 10% of the EQS then the next tests (4a and 4b) are applied to the discharge. It should be noted that even if the discharge 'passes' Test 3, the next tests still need to be applied, and it cannot be screened out unless it passes all three of the tests (i.e. 3, 4a and 4b).

  If the discharge fails any of the three tests (Tests 3, 4a and 4b) then further modelling of the discharged substances needs to be undertaken.

- **Test 4a**

  This test assesses the proportion of the PEC in comparison with the long term EQS (EQS-AA). If the PEC forms <100% of the EQS-AA, it is considered to have passed Test 4a, and Test 4b is then applied. As mentioned above, if the discharge fails any of the three tests (Tests 3, 4a and 4b) then further modelling of the discharged substances needs to be undertaken.

- **Test 4b**

  This test assesses the proportion of the PEC in comparison with the short term EQS (EQS-MAC). If the PEC forms <100% of the EQS-MAC, it is considered to have passed the test.

If the discharge has passed Tests 3 and 4a, in addition to test 4b, then it is deemed to be insignificant and is screened out.

[1] Surface water pollution risk assessment for your environmental permit - GOV.UK (www.gov.uk)

However, if the discharge fails any of the three tests (Tests 3, 4a and 4b) then further modelling of the discharged substances needs to be undertaken.

2.2 H1 Input Data

The discharge to water from the Keadby 3 Proposed Installation will comprise a continuous flow of concentrate water from the RO and intermittent regeneration water from the ion exchange plant, as detailed in the response to Point 2 in the Request for Further Information Response.

The discharge will be released via emission point W12, into the Keadby 1 cooling water culvert before final discharge to the River Trent at W1. It is considered that all the contaminants present within the release (except for ammonia, which is discussed in Section 2.4 below) are associated with the concentration up of existing contaminants present in the abstracted canal water utilised for cooling water make-up.

The H1 tool therefore examines the discharge of Keadby 3's cooling water in the absence of the Keadby 1 cooling water flow, as this represents the worst case for dispersion. The total volume of substances discharged remains the same regardless of the presence or absence of Keadby 1's cooling water discharge.

There is no readily available river flow data for the River Trent near to Keadby, and therefore river flow data for the upstream river monitoring station 28022 River Trent at North Muskham, which is the last upstream flow monitoring station on the River Trent, has been acquired from has been collated from the National River Flow Archive. North Muskham is located approximately 40 miles upstream of the location of W1, and hence may underestimate the flow in the river at the W1 discharge point.

A Q95 river water flow rate of 28.9m^3/s has been used in the assessment.

The details of the calculated K2 and K3 cooling water discharge that have been assessed are provided in Table 2.1.

Table 2.1: Details of Discharged Pollutants

Source	Keadby 2	Keadby 3	Combined Effluent
Release Rate (m^3/s)	0.1	0.1	0.2
Chloride (µg/l)	630,000	630,000	630,000
Copper (µg/l)	150	150	150
Fluoride (µg/l)	48	48	48
Iron (µg/l)	1,440	1,440	1,440
Sulphate SO_4 (µg/l)	1,000,000	1,000,000	1,000,000

2.3 H1 Output and Conclusions

Test 1 – of the pollutant species assessed, only copper and iron are deemed to fail test one and therefore require further assessment in the H1 tool.

Test 2 – iron passes Test 2, with copper failing and needing further assessment in the H1 tool.

Test 3, 4a and 4b – The Environment Agency's Water Quality Archive provides background concentrations for a range of pollutants at sample point MD-36693498 (River Trent at Keadby), however this does not include any sampling data for copper since 2013. Therefore, in line with the EA guidance it has been assumed that the background concentration is 50% of the EQS, for waters where there are other discharges of the pollutant, as a conservative assumption.

Copper fails Test 3, Test 4a, but passes Test 4b. As two of the tests are not passed, the H1 assessment requires detailed assessment.

The H1 assessment is provided in Annex A

As stated previously, it is considered that the presence of copper within the discharge via W1 is not as a result of its addition during activities carried out on site, but rather due to its presence in the canal water that will be used for cooling tower make-up water. As the canal water is recirculated within the cooling water circuit, the contaminants present are concentrated up, therefore resulting in the higher concentrations present in the cooling water blowdown. The Permit variation application for Keadby 2 also noted this, stating that the overall quantity of copper is not increased, given that the canal is in hydrological continuity with the River Trent. Therefore, no further assessment was carried out at that stage. As such, no further assessment is proposed in this instance.

2.4 Sanitary Pollutants

The only substance considered to be added to the wastewater that will be discharged at W1 is total ammonia from the Selective Catalytic Reduction abatement technology, which will be removed from the flue gas in the Direct Contact Cooler, with the resulting wastewater being treated to remove the ammonia, as described in the Request for Further Information Response (Point 2). There will however be some level of residual ammonia within the wastewater generated by this process.

'Sanitary pollutants,' which includes ammonia require the application of a different assessment methodology, detailed in EA guidance 'H1 Annex D2: assessment of sanitary and other pollutants in surface water discharges' [2].

The D2 calculation method is not routinely applicable for the assessment of sanitary pollutants to TRaC waters, and therefore detailed modelling of this release has been carried out.

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/489146/H1_annex_D2.pdf

3. Modelling Approach

3.1 Mixing Zone

Effluent dispersion within receiving waters is characterised by a two-stage process comprising initial dilution in the immediate vicinity of the discharge point followed by continued mixing through the water column within the so-called ‘near-field’ region.

Effluent dilution is dictated by the dynamics of effluent release and by differences in density between effluent and receiving waters. The dilution is a function of ambient current velocity and water depth at the outfall. The introduction of effluent is usually visualised as a rising jet (not necessarily vertical) to the water surface where it forms a streaming plume moving with the ambient current. The extent of the mixing zone should be optimised to minimise environmental impacts. The boundary of the mixing zone defines the point at which reasonable mixing has occurred and the water quality standards, where applicable, are met.

3.2 CORMIX Modelling

AECOM applied the CORMIX mixing zone model to simulate effluent dispersion characteristics discharged from the Keadby power station outfall into River Trent. CORMIX is a two-dimensional mixing zone model and decision support system for impact assessments resulting from continuous point source discharges to coastal and river environments. CORMIX accounts for the role of boundary interactions to predict steady-state mixing behaviour and plume geometry to assess near-field impacts.

CORMIX considers the momentum and buoyancy of the discharge to accurately predict mixing behaviour. It can be used to predict mixing behaviour from diverse discharge types ranging from cooling waters, desalination plants and industrial wastewater. CORMIX is internationally recognised as the leading software for such applications and has been widely used for dilution modelling of effluent discharges into coastal, estuary and river waters.

Key input data for CORMIX includes information on the ambient conditions of the receiving water body, discharge characteristics and outfall arrangements. A data review exercise was therefore undertaken to establish effluent discharge rates and temperature, river ambient water temperature and wind conditions. The modelling approach involved the analysis of results from a range of scenarios based on the available data. The following input parameters have been collected and calculated to carry out the CORMIX modelling study.

- Discharge flow rate and concentration;
- Water level (water depth) and river flow speed and at the outfall site;
- Ambient water temperature and salinity in the River Trent;
- Effluent discharge temperatures (winter and summer);
- Outfall pipe arrangement (invert level and size);
- Wind conditions;
- Heat loss coefficients; and
- Water quality standards.

4. Hydraulic Conditions

4.1 Tidal Regime

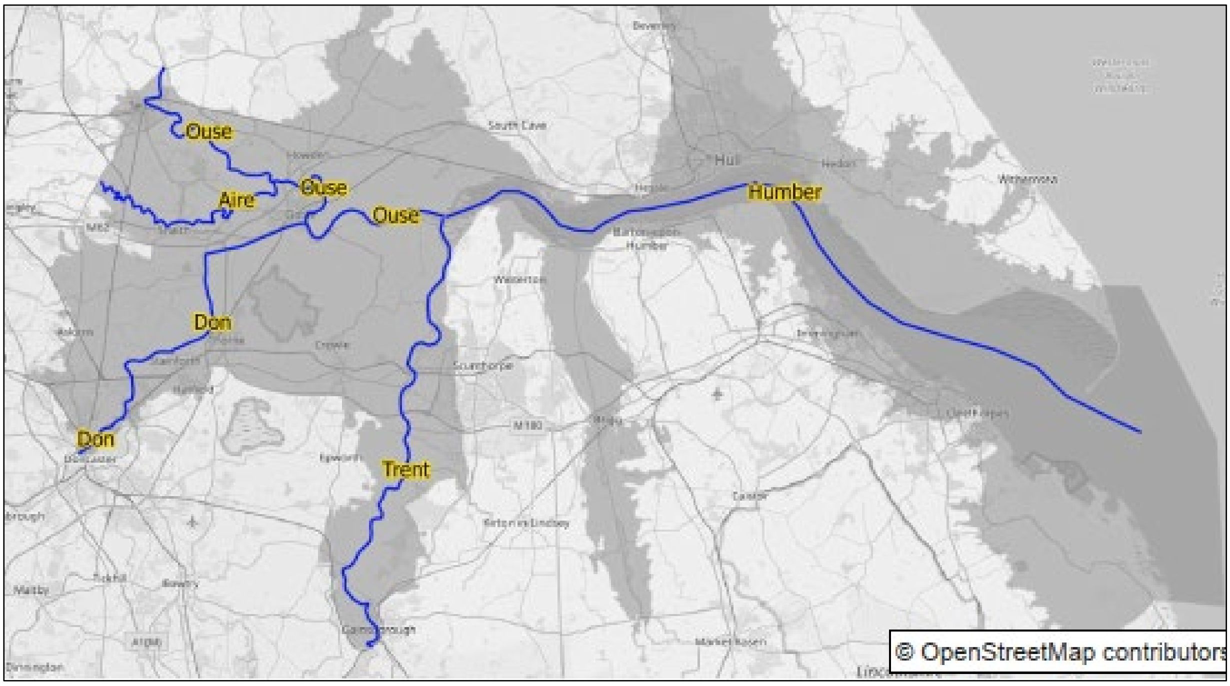
The River Trent at Keadby is characterised by a semi-diurnal tide which has two high and two low tides a day. A tidal cycle has a period of approximately 12 hours 25 minutes. A complete tidal cycle from high tide to low tide to high tide comprises two distinct elements – the flood tide (the incoming tide when water levels are rising) and the ebb tide (the outgoing tide when water levels are falling).

The tidal cycle seen in the River Trent estuary is not symmetrical, i.e. flood and ebb portions of the cycle are of unequal lengths. The time between ebb slack and flood slack is approximately three hours, while the difference between flood slack and ebb slack is approximately nine hours. This gives rise to a very rapid rise in tide level followed by a slow decline in the tide level.

4.2 Hydrodynamic Modelling

There is no measured data available for tidal level and river flow speed at the Keadby power station outfall location (W1). AECOM therefore obtained a hydrodynamic model from the EA to provide information on the local water levels and currents for the near-field modelling exercise. The hydrodynamic model was constructed from existing EA approved 1D/2D models (Flood Modeller and TUFLOW). The model domain covers River Trent as shown in Figure 4 1.

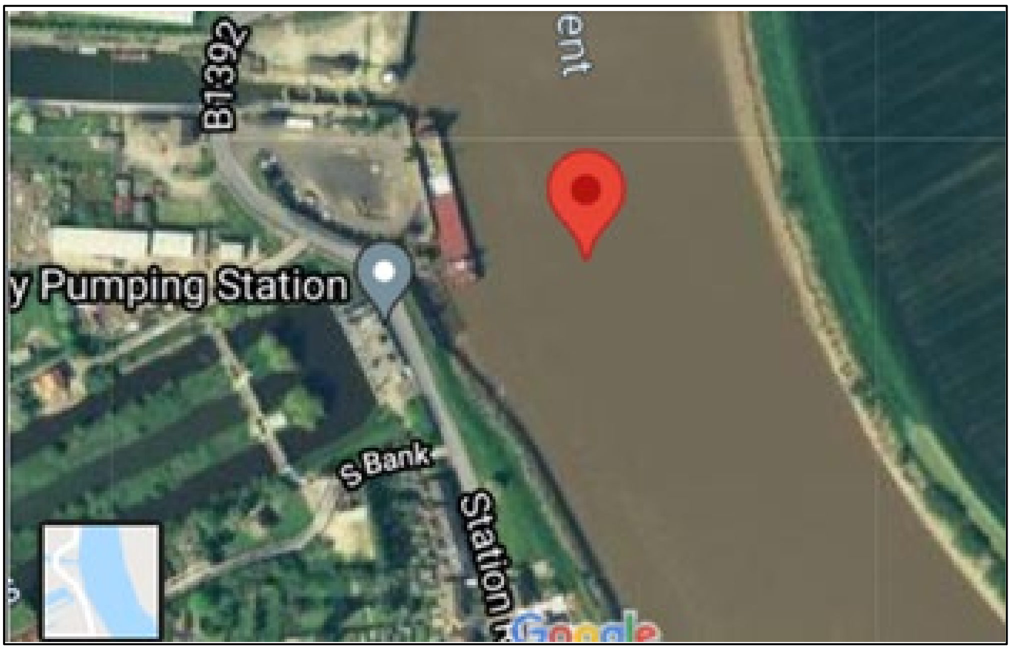
Figure 4.1: Model Domain (Source: Jacobs 2020)



Upon receiving the hydrodynamic model from EA, the model performance was reviewed for Keadby site. The measured water levels were obtained from the EA tidal gauge at Keadby (Figure 4 2). Figure 4 3 shows the comparison between the measurements and modelled water levels. In general, the model outputs for tidal levels and currents are in good agreement with the measured data in terms of both tidal level and phase. The level of agreement between predicted and modelled tides demonstrates that:

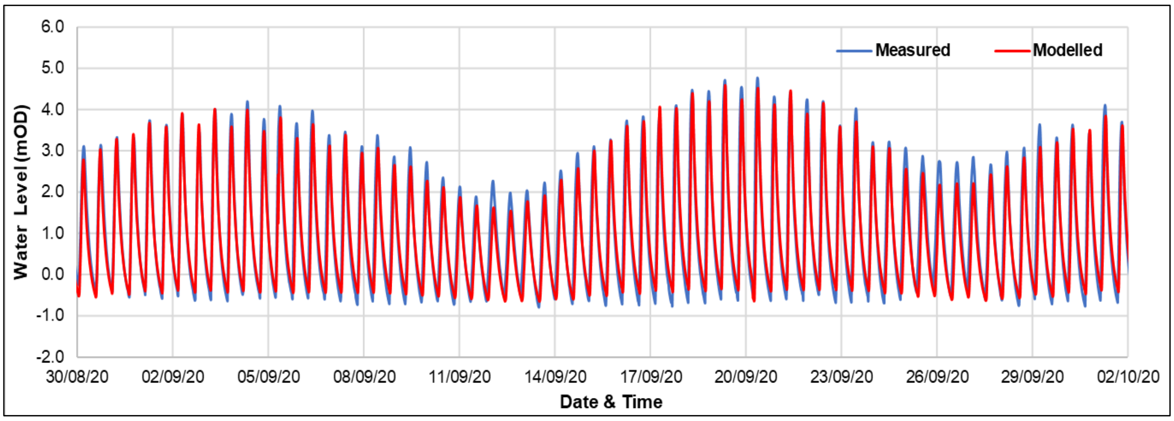
- The applied offshore boundary conditions provide an accurate description of tidal conditions;
- The river cross-section bathymetry is appropriately resolved in the model;
- A bed roughness used in the model is suitable; and
- A high level of confidence has been achieved for the model performance.

Figure 4.2: EA Tidal Gauge at Keadby



- **Environment Agency Location ID:** 4098
- **Environment Agency Gauge ID:** 4098-level-stage-i-5_min-mASD
- **Operational Area:** Humber Estuary TraC
- **Catchment Area:** Humber Transitional & Coastal
- **UK Hydrometric Area:** Trent
- **Environment Agency Region:** Midlands
- **Datum Type:** Above Stage Datum (ASD)
- **Stage Datum:** -1.052m AOD

Figure 4.3: Modelled Water Level-vs-Measurements



4.3 Hydrodynamic Conditions

4.4 Hydrodynamic Conditions

At the Keadby power station location, the typical mean tidal range is 4.7m between -0.4mOD (Mean Low Water Springs (MLWS)) to +4.3mOD (Mean High Water Springs (MHWS)) with a maximum astronomical tide range of 7.62m (i.e. - 0.81mOD to +5.81mOD). From 28 years' time-series data at the EA's Keadby tidal gauge (Figure 4.4), 95%ile and 5%ile ambient water levels were derived for low water and high water, and are shown in Figure 4.4.

Figure 4.4: Water Level at Keadby Tidal Gauge

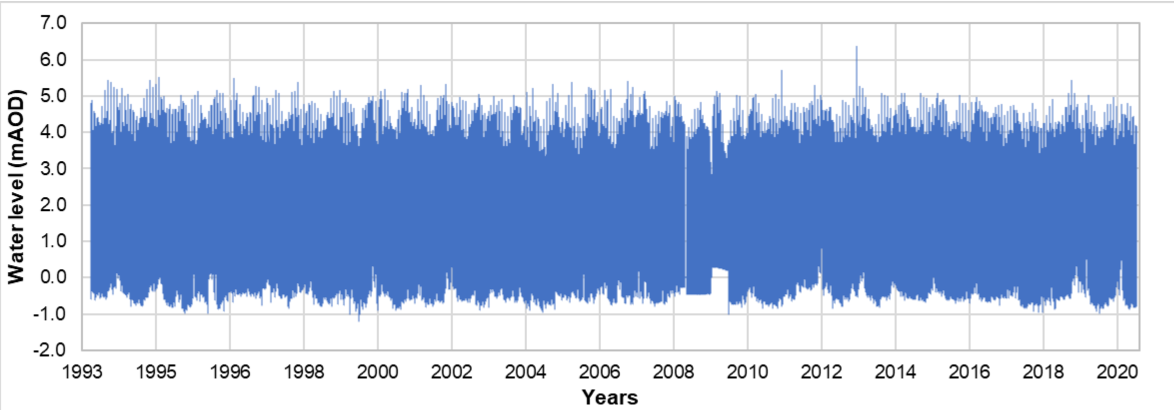


Table 4.1: Tide Level Statistics at Keadby (mOD)

MHWS	MLWS	HW (5%ile)	LW (95%ile)
4.3	-0.4	+3.7	-0.4

The hydrodynamic model was run to provide detailed tide levels and current speeds at the Keadby power station outfall location (W1). These results were then used to establish the hydrodynamic inputs at flood, ebb and slack tide states. Typical water levels (depths) and corresponding flow speed were set out in Figure 4.5.

Figure 4.5: Water Level-vs-Flow Speed

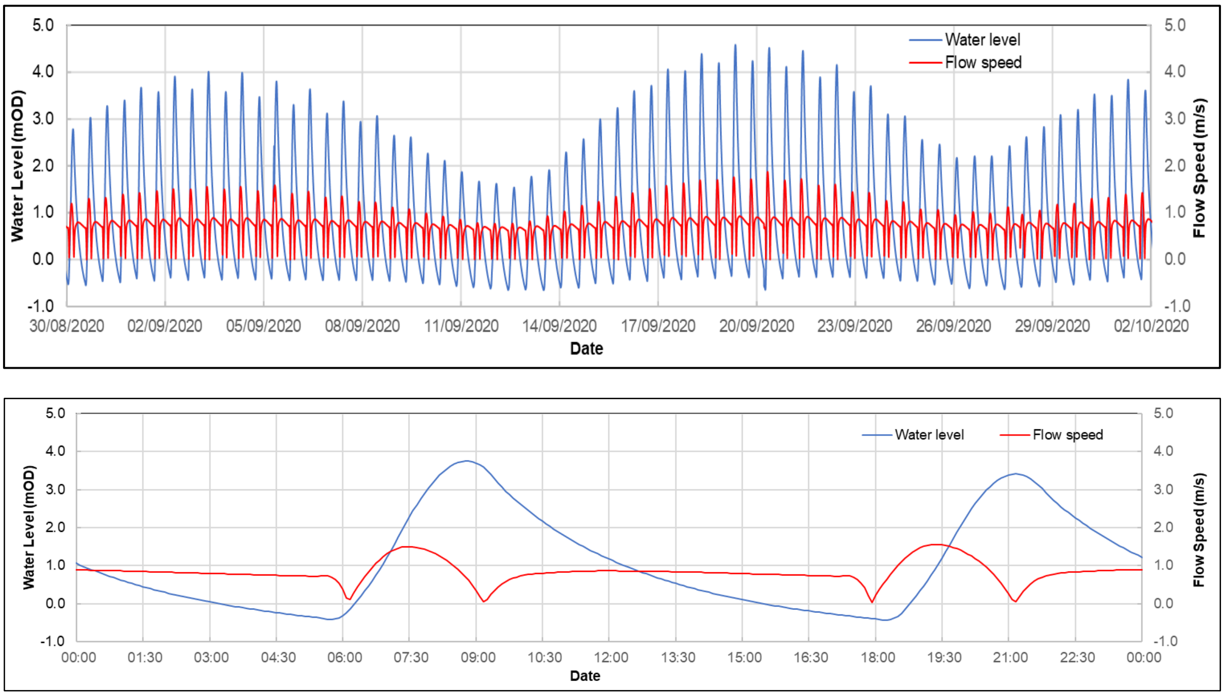


Table 4.2: Hydrodynamic Conditions at Keadby Power Station Site Outfall

Tidal State		Tide Level (mOD)	Water Depth (m)	Flow Speed (m/s)
1	**Low Water Slack**	-0.40	2.10	0.11
2	Flood Tide	0.20	2.70	0.58
3	Flood Tilde	0.60	3.10	0.84
4	**High Water Slack**	3.70	6.20	0.11
5	Ebb Tide	2.54	5.04	0.75
6	Ebb Tide	0.90	3.40	0.86
7	Ebb Tide	0.00	2.50	0.77
8	**Low Water Slack**	-0.40	2.10	0.89

5. CORMIX Modelling

5.1 Water Quality Standard

EA (2011) - Basic Surface Water Discharges provides a standard for thermal discharges to rivers (http://www.fwr.org/WQreg/Appendices). The criteria are summarised in Table 6 considering the river species and water temperature as an annual 98-percentile standard. Data analysis of the measured historical ambient river temperature suggests the annual 98%ile value is 21.2ºC detailed in Section 5.2.4, which is less than 25ºC. Therefore, the River Trent can be classified as high status with respect to temperature. Based on EA (2011), increases /decrease in temperature in relation to the ambient river water should not change by more than 2ºC as an annual 98-percentile standard.

To consider the potential impact causing a fish barrier preventing migration and/ or spawning, the lateral dispersion will be controlled to confine the thermal plume within a limit area in the cross-section direction. The mixing zones with excess temperature more than 2ºC will not occupy greater than 25% of the whole channel width.

Environment standards for total ammonia are provided in detailed in EA guidance H1 Annex D2. The concentration of 0.3mg/l has been selected as a quality standard for Keadby 3 dispersion modelling study, which is relevant for rivers with ‘Good’ water quality.

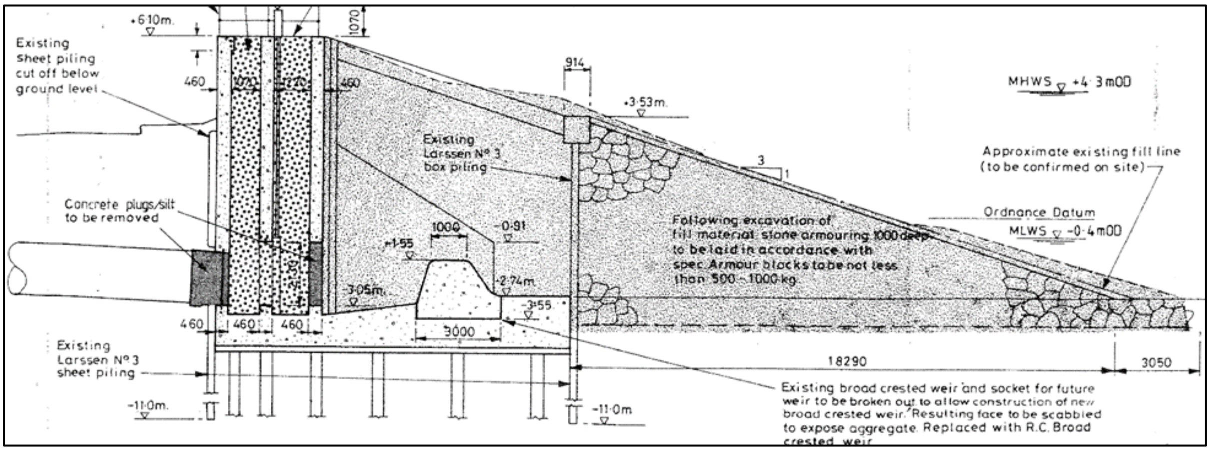
5.2 Model Set-Up

CORMIX model uses effluent discharge rates, concentrations, bathymetry data, tide level, flow speed, ambient salinity and temperature, and wind speed to model the size of a dispersal plume and the concentrations of substances within the outfall discharge.

5.2.1 Outfall Arrangements

The location of the discharge point at the River Trent is approximately 1.8km upstream of Keadby Bridge. The existing discharge pipe reaches the riverbank at a 90° angle to facilitate water recirculation. The outfall pipe has a diameter of 1830mm to accommodate both the flow rates from Keadby 2 & 3, which is fixed at the left riverbank, as indicated in Figure 5.1 (looking in a downstream direction). The invert level of discharge pipe is -3.05mAOD, which is 2.65m below the low water level (-0.40mOD).

Figure 5.1: Configuration of the W1 Outfall



5.2.2 Outfall Discharge Characteristics

Combinations of discharge rates, temperatures, concentration and velocity are summarized in Table 5.1 for Keadby 2 and Keadby 3 power stations. CORMIX uses concentrations of pollutants in mg/l and flow in m^3/s to model dispersal plumes.

AECOM (2020) identified potential issues with the required design of the River Trent outfall to achieve compliance with the Eel Regulations for all hybrid and direct cooling water options, to ensure minimum velocities are maintained at all times to prevent the ingress of eels. The study suggested that if a discharge velocity of 1.32m/s is maintained there is unlikely to be issues with young eels entering the outfall. Based on this guidance, it requires pumped outfalls if the required velocity is not achievable for gravity systems. As a result, the discharge velocity of 1.32m/s has been used as a model input.

A summary calculation of the temperatures, discharge rates and concentrations are given in Annex B showing how these inputs were derived.

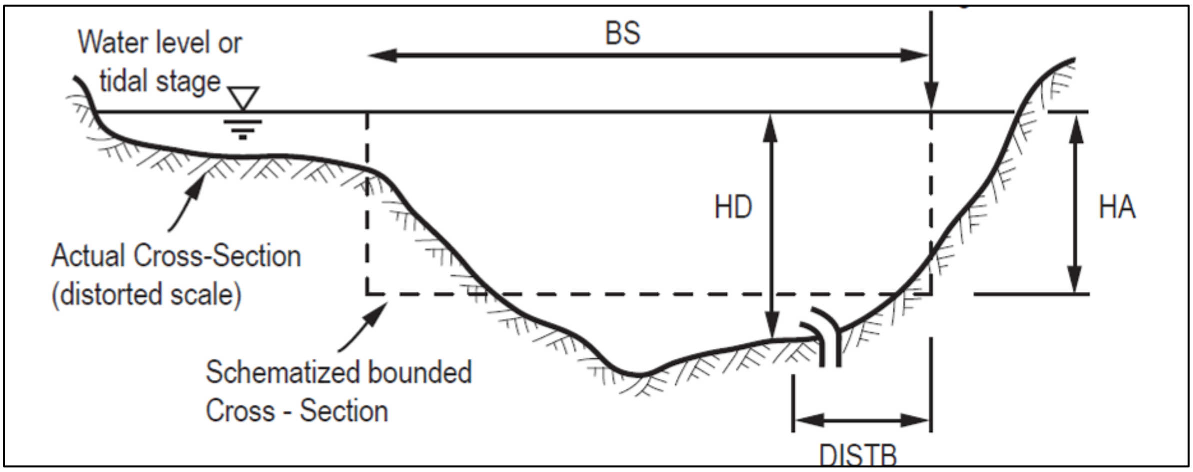
Table 5.1: Outfall Discharge Characteristics

Options	Temperature (°C)	Discharge Rate (m^3/s)	Ammonia Concentration (mg/l)	Effluent Velocity (m/s)
Keadby 3 Option 1	25.0	0.0582	13.23	1.32
Keadby 3 Option 2	31.0	0.0835	10.98	1.32
Keadby 2	26.0	0.1100	N/A	1.32

5.2.3 Channel Schematisation

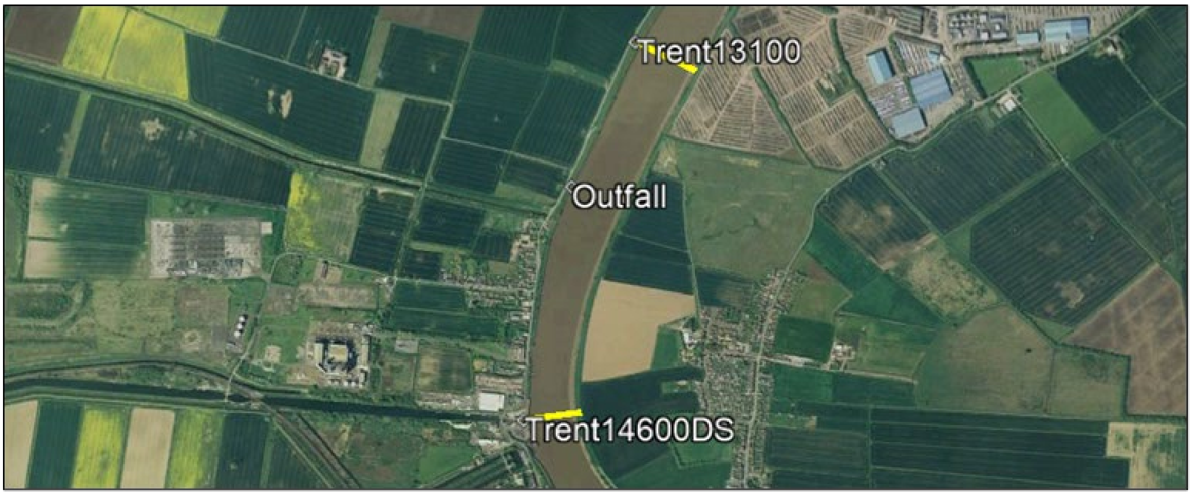
The river in the CORMIX model is represented by the one-dimensional channel and is further simplified to a rectangular cross-section with an average depth and width over the area of interest (see Figure 5.2).

Figure 5.2: Example of Schematised Channel (Source: CORMIX User Manual)



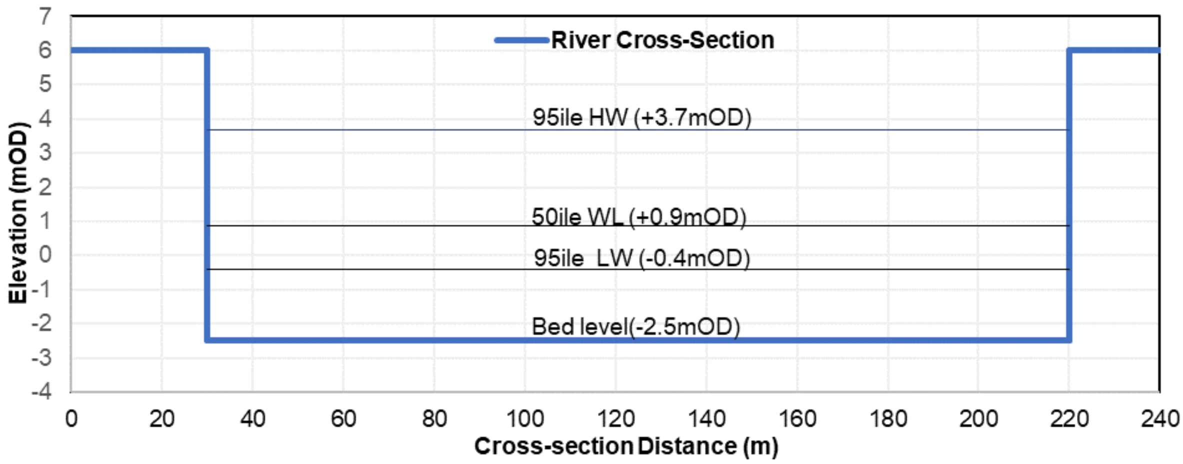
The River Trent cross-sectional data was abstracted from the EA model to establish the morphology at the Keadby W1 outfall. Two cross-sections (Trent13100 & Trent14600DS) were available adjacent to the project site (1200m spacing between cross sections), approximately 600m upstream/ downstream of the outfall. Figure 5.3 shows the cross-section locations to the outfall.

Figure 5.3:Cross Section Locations



The river cross sections were reviewed to identity a schematised channel with a comparable area to the channel shape. An averaged river width of 190m and averaged bed level of -2.5mOD were estimated from the two cross-sections closest to the outfall (Figure 5.4).

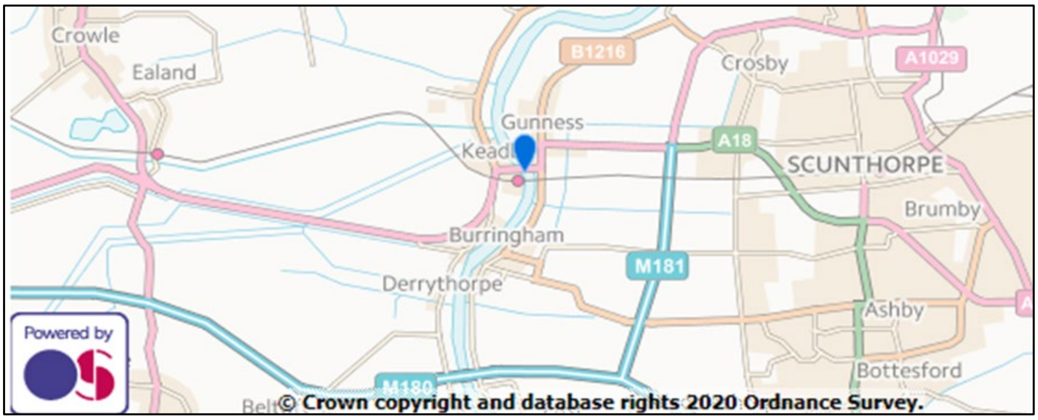
Figure 5.4: Schematised Channel at the Outfall



5.2.4 Ambient Water Temperature

Time series of water temperatures near Keadby in the River Trent have been obtained from water temperature database operated by EA (https://environment.data.gov.uk/water-quality/view/sampling-point/MD-36693490?_all=true). The sampling site ID is MD-36693490 at Keadby (Tidal) within the River Trent, which is 1.8km upstream of the outfall site (Figure 5.5).

Figure 5.5: Sampling Site at Keadby



The dataset provides the measured water temperature between 2003 and 2015 (Figure 5.6 5.6). Analysis of the time series data established an average winter temperature of 5.6°C (December-February) and summer temperature of 18.4°C (June-August) (Figure 5.6 and Figure 5.7). In addition, the statistics of daily water temperature has been derived from 13-year time series dataset. The 98th %ile of daily water temperature is calculated as 21.2°C, which will used to establish the water quality standards in River Trent required by EA.

Figure 5.6: Recorded Water Temperature

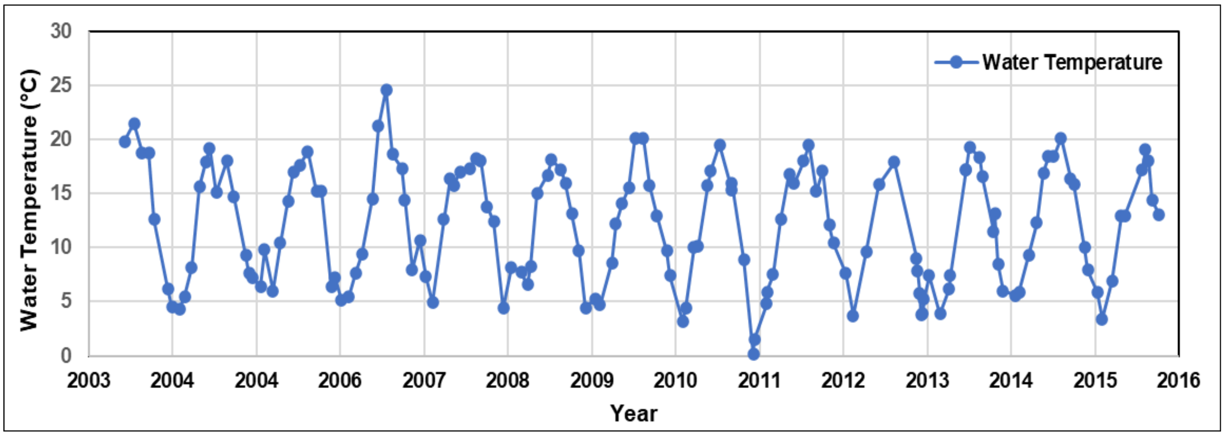
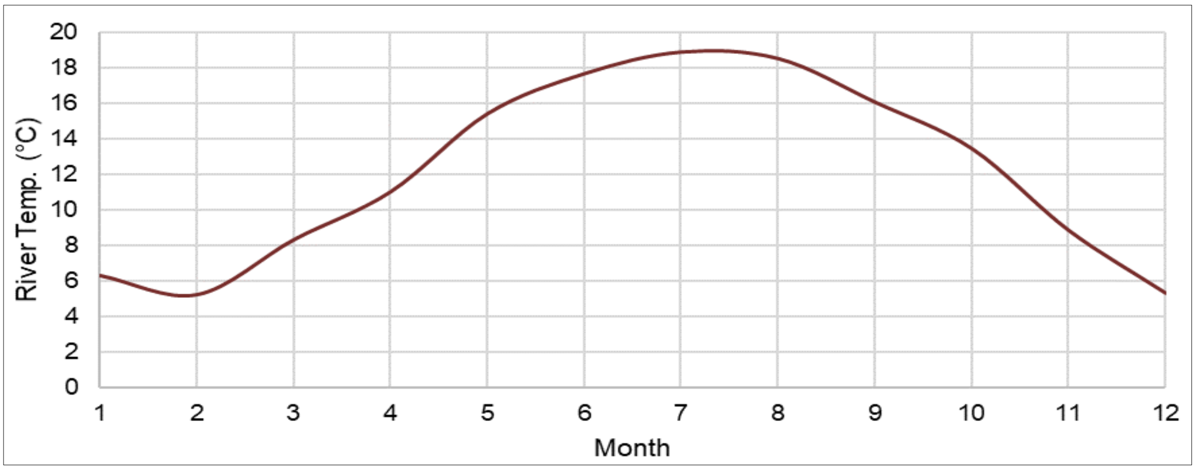


Table 5.2: Ambient Water Temperature (°C)

Summer Mean	Winter Mean	98%ile
18.4	5.6	21.2

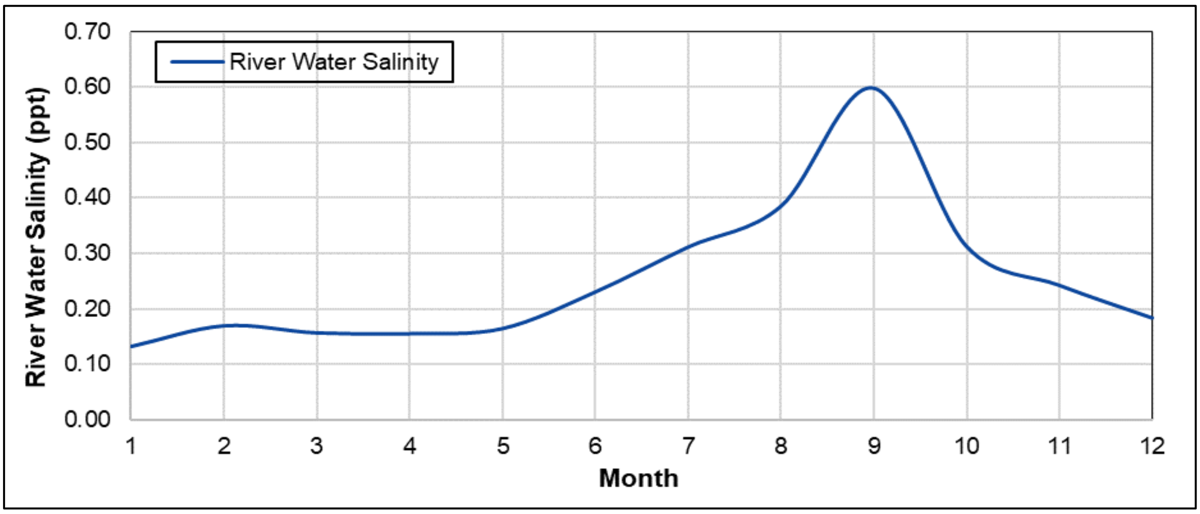
Figure 5.7: Average River Water Temperatures (2003 to 2015)



5.2.5 Ambient Water Salinity

Water salinity in River Trent was obtained from the dataset at the sampling site MD-36693490 at Keadby Bridge. From the graph (Figure 5 8) it can be seen that there is a distinct variation in mean salinity level throughout the year, which is likely to be influenced by seasonal variation in freshwater flows in the river from upstream. The mean salinity is 0.16ppt in winter and 0.43ppt in summer.

Figure 5.8: Average River Salinity (2003 – 2015)

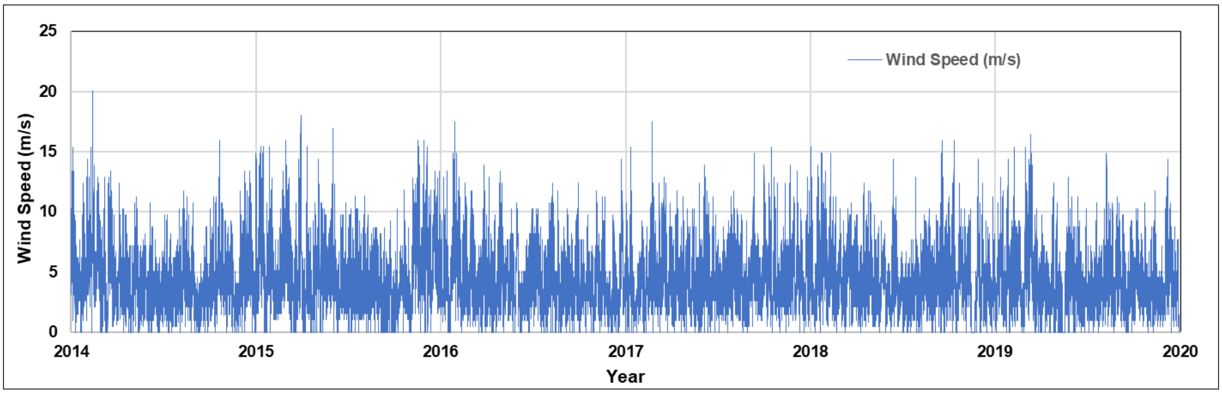


5.2.6 Wind Speed

Wind information was obtained from the EA at Robin Hood Doncaster Sheffield Airport - Station Finningley (Figure 5 9). Finningley is the nearest climate station and is approximately 20km from Keadby. Figure 5 10 shows 6-year time series wind speed between 2014 and 2019. The yearly average wind speed is 4.4m/s. An average wind speeds of 5.0m/s in winter (December-February) and 4.1m/s in summer (June-August), which can be described as a 'Gentle Breeze' according to the Beaufort scale, have been assumed as representative conditions.

Figure 5.9: Location of Finningley Meteorological Station

Figure 5.10: Time Series Wind Speed at Finningley Meteorological Station



5.2.7 Manning's Coefficient

Manning's n is a measure of river channel roughness and is used to estimate the degree to which the flow of water is slowed by friction with the channel bed and banks. The model calibration for thermal dispersion by SSE (2011) concluded a very low value of n produced the best calibration results. The final value of n was set as 0.015, which is the lowest realistic value of n for the type of channel being modelled.

5.2.8 River Channel Appearance

CORMIX takes account of the effect of channel appearance on far field mixing. Three channel appearance types are supported in CORMIX: Type 1 - Uniform; Type 2 - Slightly meander and Type 3 - Highly irregular. The type 2 channel appearance type has been used for this study.

5.2.9 Heat Loss Coefficient

Heat loss coefficients during summer and winter can be interpolated using Table 4.1 in CORMIX Manual (CORMIX 2017). Based on the ambient water temperature and wind speed, the coefficients of 42.8 W/m^2 for wintertime and 51W/m^2 for summertime were estimated and used.

5.3 Model Runs

5.3.1 Operational Scenarios

As stated previously, the operation of the Keadby 1 power station simultaneously with Keadby 3 is precluded because of the natural gas connection size (SSE 2022). However, Keadby 2 may operate simultaneously with Keadby 3. Therefore, the dispersion modelling has considered discharge from operation of Keadby 3 both with and without discharge from Keadby 2.

For Keadby 3, two operational options have been proposed under different released concentrations and temperature. Moreover, no total ammonia is discharged from Keadby 2. This led to the following five modelling scenarios.

Pollutant Dispersion Modelling:

- Scenario 1: Keadby 3 Option 1: total ammonia concentration =13.23mg/l
- Scenario 2: Keadby 3 Option 2: total ammonia concentration =10.98mg/l

Thermal Plume Dispersion Modelling:

- Scenario 3: Keadby 3 Option 1: effluent temperature = 25°C (summer), 12.2°C (winter)
- Scenario 4: Keadby 3 Option 2: effluent temperature = 31°C (summer), 18.2°C (winter)
- Scenario 5: Keadby 3 Option 2 + Keadby 2: worst combination of Scenario 4 and Keadby 2

Table 5.3: Ambient and Effluent Temperatures

Item	Scenario 3		Scenario 4		Scenario 5	
	Summer	Winter	Summer	Winter	Summer	Winter
Effluent	25.0	12.2	31.0	18.2	28.3	15.5
Ambient	18.4	5.6	18.4	5.6	18.4	5.6
Excess	6.6	6.6	12.6	12.6	9.9	9.9

Note: the ambient water temperatures are provided in Section 5.2.4

5.3.2 Tidal States

The CORMIX model takes into account the re-entrainment of a previous plume due to tidal reversal, although it is essentially steady state and does not fully take into account the changing dimensions and position of the plume as a result of the unsteady tidal conditions in the river. Under the tidal environment, both water depth and current speed affects the plume size and its concentration. Eight tidal stages have been tested including slack, flood tide, high water, ebb tide and low water (95th %ile). The use of the 95th %ile value for the water level provides a statistical value that represents an extreme condition that is only exceeded for 5% of the time.

5.3.3 Seasonal Variation

Seasonal variations of water density and heat exchange coefficient are associated with ambient river water, discharged effluent and wind speed. To investigate the impact of seasonality on the plume extent and concentration, the models were run for the conditions corresponding to winter and summer months.

5.3.4 Model Runs

Considering the seasonality, tidal state and dispersion type, each scenario has 16 model runs. The number of total models is 80. The combinations and inputs are summarised in Table 5 4 to Table 5 8.

Table 5.4: Scenario 1 (pollutant dispersion) – Keadby 3 Option 1

Season	Concentration (mg/l)	Ambient Temp. (°C)	Runs	Tidal State	Flow Speed (m/s)	Water Depth (m)
Summer	13.23	18.4	Run01	Low Water	0.11	2.10
			Run02	Flood Tide	0.58	2.70
			Run03	Flood Tilde	0.84	3.10
			Run04	High Water	0.11	6.20
			Run05	Ebb Tide	0.75	5.04
			Run06	Ebb Tide	0.86	3.40
			Run07	Ebb Tide	0.77	2.50
			Run08	Low Water	0.89	2.10
Winter	13.23	5.6	Run09	Low Water	0.11	2.10
			Run10	Flood Tide	0.58	2.70
			Run11	Flood Tilde	0.84	3.10
			Run12	High Water	0.11	6.20
			Run13	Ebb Tide	0.75	5.04
			Run14	Ebb Tide	0.86	3.40
			Run15	Ebb Tide	0.77	2.50
			Run16	Low Water	0.89	2.10

Table 5.5: Scenario 2 (pollutant dispersion) – Keadby 3 Option 2

Season	Concentration (mg/l)	Ambient Temp. (°C)	Runs	Tidal State	Flow Speed (m/s)	Water Depth (m)
Summer	10.98	18.4	Run01	Low Water	0.11	2.10
			Run02	Flood Tide	0.58	2.70
			Run03	Flood Tilde	0.84	3.10
			Run04	High Water	0.11	6.20
			Run05	Ebb Tide	0.75	5.04
			Run06	Ebb Tide	0.86	3.40
			Run07	Ebb Tide	0.77	2.50
			Run08	Low Water	0.89	2.10
Winter	10.98	5.6	Run09	Low Water	0.11	2.10
			Run10	Flood Tide	0.58	2.70
			Run11	Flood Tilde	0.84	3.10
			Run12	High Water	0.11	6.20
			Run13	Ebb Tide	0.75	5.04
			Run14	Ebb Tide	0.86	3.40
			Run15	Ebb Tide	0.77	2.50
			Run16	Low Water	0.89	2.10

Table 5.6: Scenario 3 (thermal dispersion) – Keadby 3 Option 1

Season	Excess Temp. (°C)	Ambient Temp. (°C)	Model Run	Tidal State	Flow Speed (m/s)	Water Depth (m)
Summer	25	18.4	Run01	Low Water	0.11	2.10
			Run02	Flood Tide	0.58	2.70
			Run03	Flood Tilde	0.84	3.10
			Run04	High Water	0.11	6.20
			Run05	Ebb Tide	0.75	5.04
			Run06	Ebb Tide	0.86	3.40
			Run07	Ebb Tide	0.77	2.50
			Run08	Low Water	0.89	2.10
Winter	12.2	5.6	Run09	Low Water	0.11	2.10
			Run10	Flood Tide	0.58	2.70
			Run11	Flood Tilde	0.84	3.10
			Run12	High Water	0.11	6.20
			Run13	Ebb Tide	0.75	5.04
			Run14	Ebb Tide	0.86	3.40
			Run15	Ebb Tide	0.77	2.50
			Run16	Low Water	0.89	2.10

Table 5.7: Scenario 4 (thermal dispersion) – Keadby 3 Option 2

Season	Excess Temp. (°C)	Ambient Temp. (°C)	Model Run	Tidal State	Flow Speed (m/s)	Water Depth (m)
Summer	31	18.4	Run01	Low Water	0.11	2.10
			Run02	Flood Tide	0.58	2.70
			Run03	Flood Tilde	0.84	3.10
			Run04	High Water	0.11	6.20
			Run05	Ebb Tide	0.75	5.04
			Run06	Ebb Tide	0.86	3.40
			Run07	Ebb Tide	0.77	2.50
			Run08	Low Water	0.89	2.10
Winter	18.2	5.6	Run09	Low Water	0.11	2.10
			Run10	Flood Tide	0.58	2.70
			Run11	Flood Tilde	0.84	3.10
			Run12	High Water	0.11	6.20
			Run13	Ebb Tide	0.75	5.04
			Run14	Ebb Tide	0.86	3.40
			Run15	Ebb Tide	0.77	2.50
			Run16	Low Water	0.89	2.10

Table 5.8: Scenario 5 (thermal dispersion) – Keadby 3 Option 2 + Keadby 2

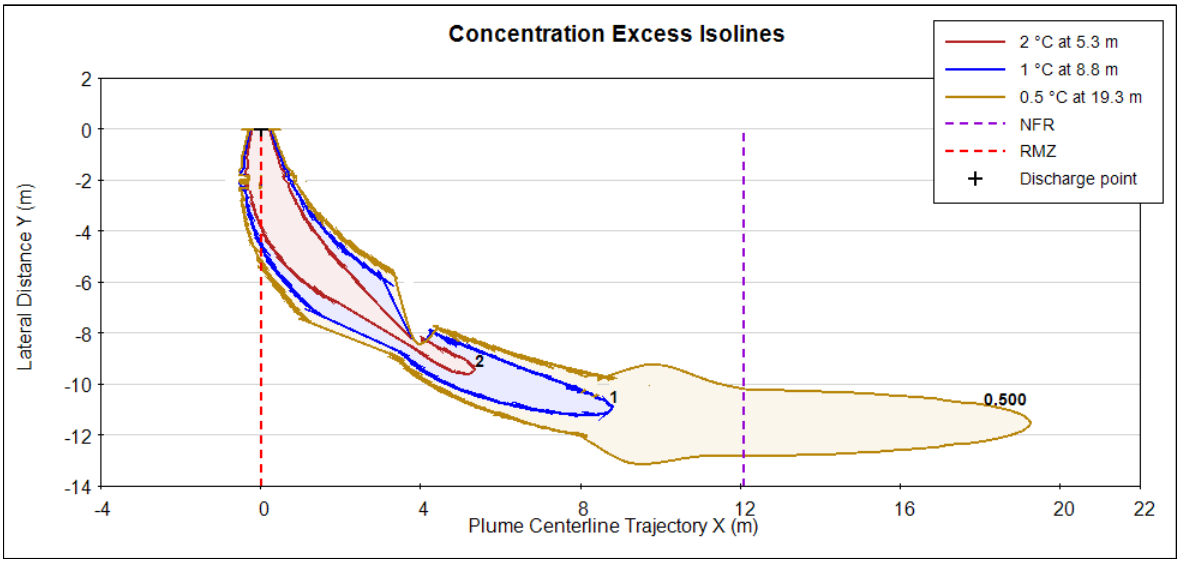
Season	Discharge Temp. (°C)	Ambient Temp. (°C)	Model Run	Tidal State	Flow Speed (m/s)	Water Depth (m)
Summer	28.3	18.4	Run01	Low Water	0.11	2.10
			Run02	Flood Tide	0.58	2.70
			Run03	Flood Tilde	0.84	3.10
			Run04	High Water	0.11	6.20
			Run05	Ebb Tide	0.75	5.04
			Run06	Ebb Tide	0.86	3.40
			Run07	Ebb Tide	0.77	2.50
			Run08	Low Water	0.89	2.10
Winter	15.5	5.6	Run09	Low Water	0.11	2.10
			Run10	Flood Tide	0.58	2.70
			Run11	Flood Tilde	0.84	3.10
			Run12	High Water	0.11	6.20
			Run13	Ebb Tide	0.75	5.04
			Run14	Ebb Tide	0.86	3.40
			Run15	Ebb Tide	0.77	2.50
			Run16	Low Water	0.89	2.10

5.4 Model Results

5.4.1 Model Outputs

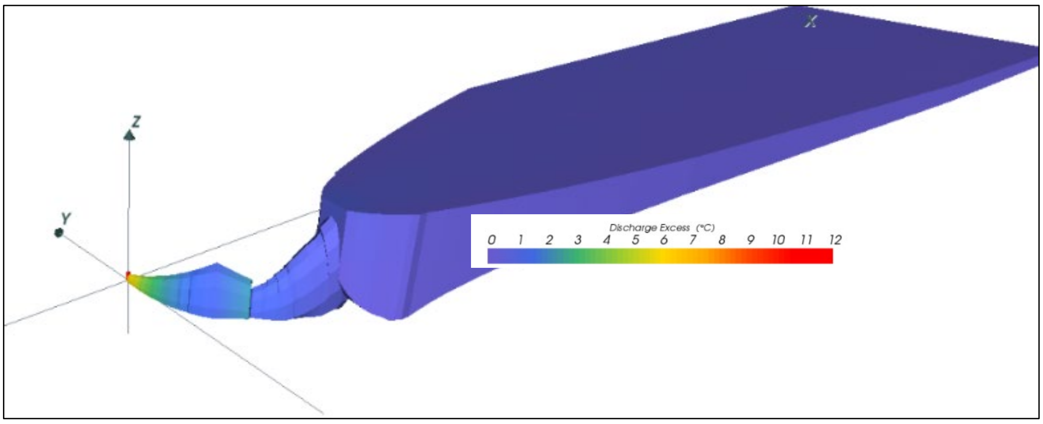
Typical CORMIX outputs include near-field and far-field plume trajectory, shape, vertical thickness and horizontal half-width, centreline excess concentration and isolines (Figure 5 11), and centreline dilutions.

Figure 5.11: Concentration Excess Isolines

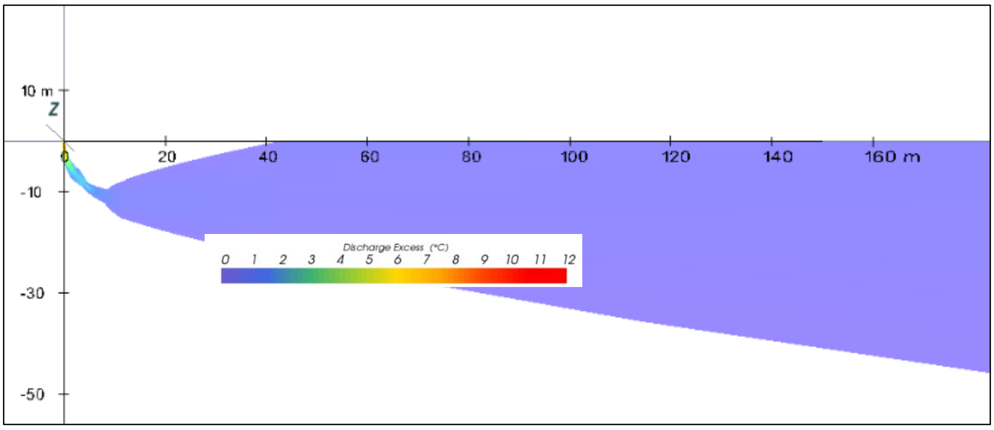


The advanced 'CorVue' tool within CORMIX allows the modelled plume behaviour to be visualised. Figure 5 12 shows typical 3-dimensional (3D) and x-y (2D) views of modelled plumes. Changes in dilution and concentration along the centreline of the plume can be generated for the detailed sensitivity analysis.

Figure 5.12: Modelled plumes (a) 3D view and (b) 2D plan view



(a)



(b)

5.4.2 Model Results

Having finalised the input parameters in each scenario run, CORMIX models were run to investigate dispersion processes of the total ammonia and thermal effects within the mixing zone. The plume extents were modelled for 5 different scenarios with varying tide states, ambient temperature, effluent temperature and discharge rate. The model outputs include initial dilution calculations, near-field size and concentration variation over distance from the outfall point. Results of dilution and concentration are presented in the tabular format at a distance of 50m, 100m, 200m from the outfall point. Analysis of the model results examined the zone of influence defined as the distance from the discharge location along the centreline of the plume.

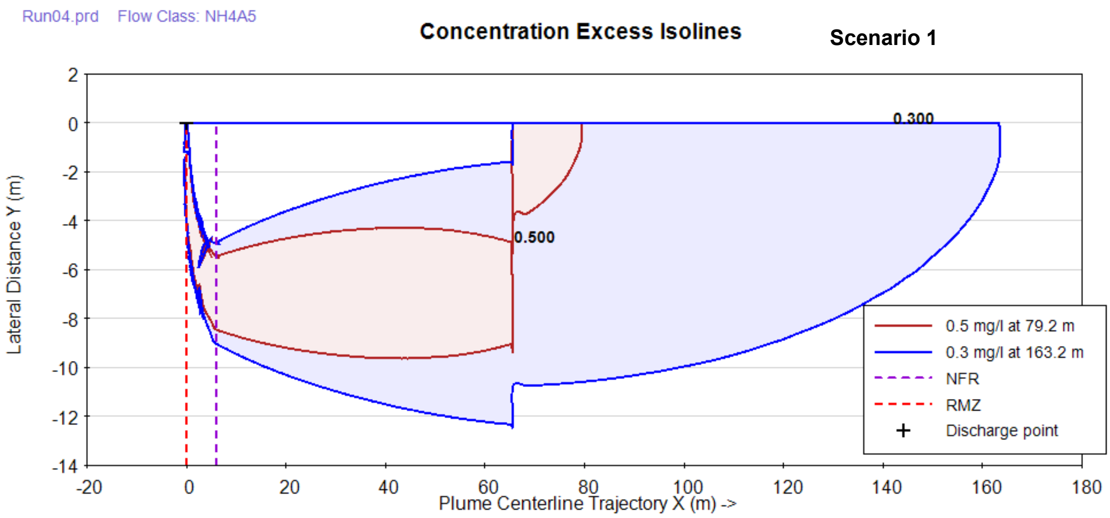
Tables 5 11 - 5 15 provide the dilution, concentration and distance for each model run defined.

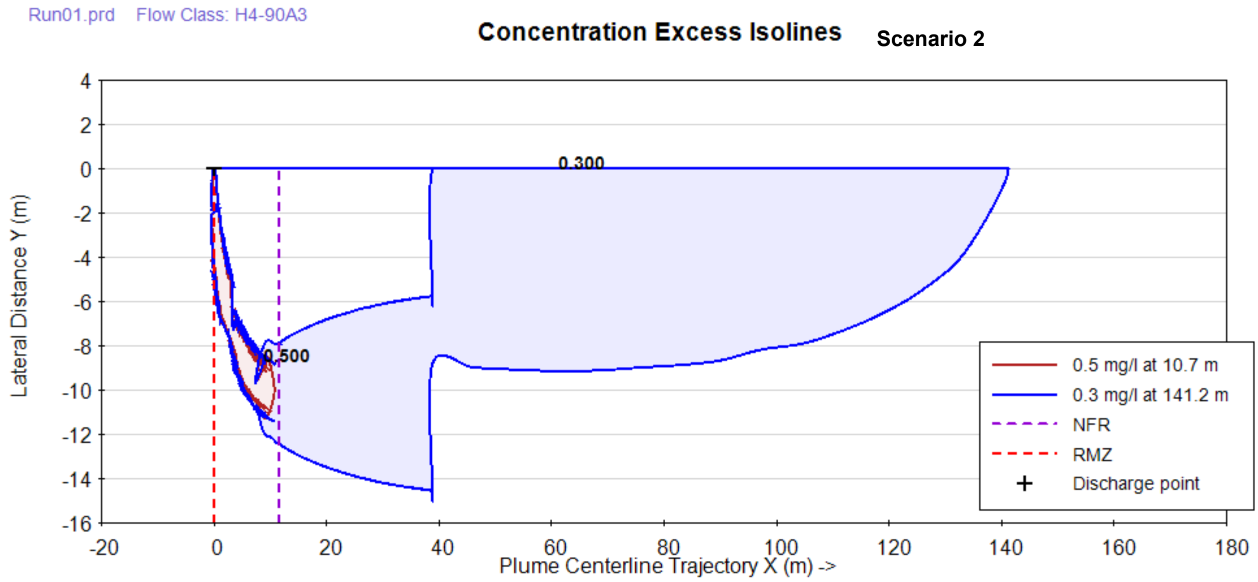
- **Dilution and Concentration**

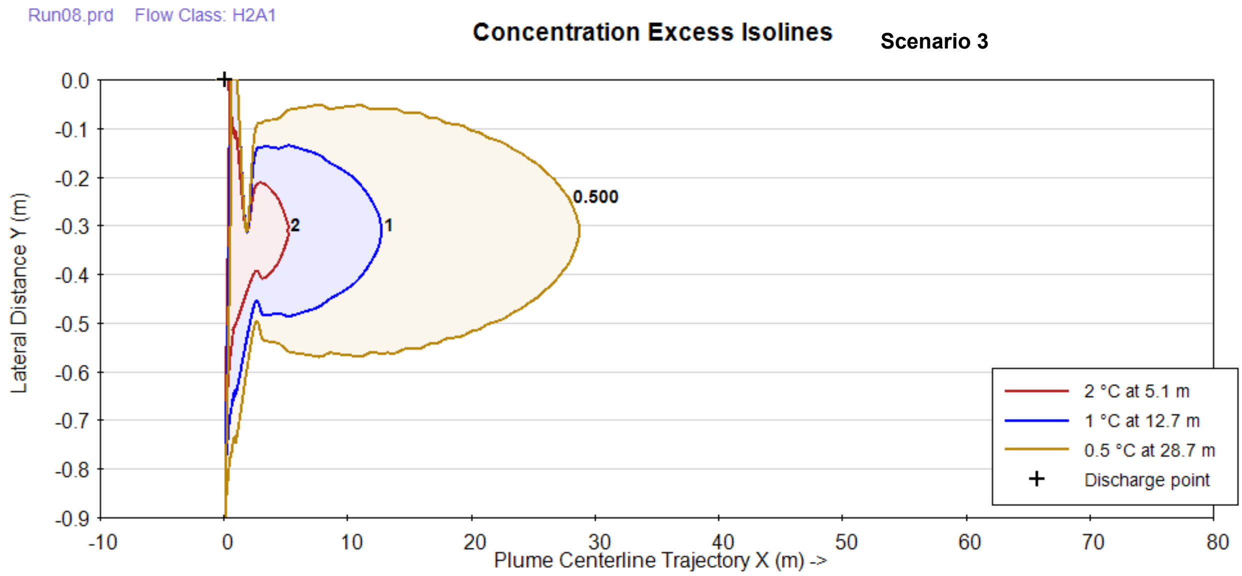
It was found that the lowest dilution is experienced during slack water at low and high tide states, whilst the best dilution occurs at the tidal states where the river flow current is strong. However, it should be noted that spreading speeds are extremely low due to the slow current speeds and the plume would not spread over this area before the tidal conditions change and water levels and current speeds increase. The slack water condition does not prevail for extended periods of time at this part of the River Trent. The rapid change of tidal flow in the channel will increase the mixing and push the plume upstream or downstream. This would in turn increase mixing and reduce the distance from the outfall over which a given level of dilution is reached.

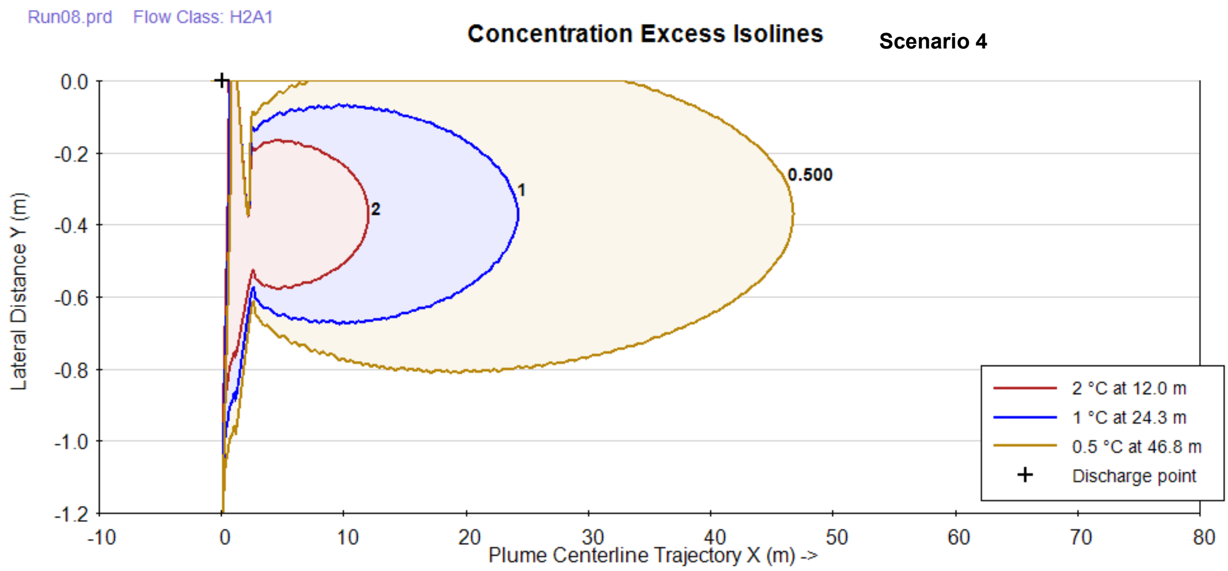
Modelled concentration excess isolines for 5 scenarios are displayed in Figure 5.13. The plots shows the plume shapes and extents at various excess isolines, 0.3mg/l and 0.5mg/l for the total ammonia 0.5°C, 1.0°C and 2.0°C for the thermal plume.

Figure 5.13: Modelled Plume Isolines for Scenarios 1, 2, 3, 4, 5









- **Modelled Plume Extent**

Modelled plume extents were explored for the specified concentrations in details, i.e. 0.3mg/l for the total ammonia and excess temperatures of 2.0°C and 0.5°C. Table 5.9 and Table 5.10 provide the maximum plume width across the channel and plume length along the channel downstream/ upstream from the outfall location.

None of plumes within 5 scenarios was predicted to cross the entire channel. For the total ammonia, the widths are 19.6m for Scenario 1 and 37.4m Scenario 2 as the worst cases in each 16 runs, which are equivalent to 10% and 20% of total channel width (190m).

For the thermal dispersion, the maximum predicted extents of 2°C and 0.5°C above the ambient water temperature were 1.2m and 4.8m (in Scenario 4) respectively, representing only <1% and 2.5% of the total channel width. These results suggest that the impact on the water quality in all established scenarios will be small relative to the width of the whole channel.

The maximum predicted plume lengths along the riverbank downstream/ upstream were 163.1m (Scenario 1) and 141.2m (Scenario 2) for the total ammonia.

For the thermal dispersion, the maximum lengths are 14.5m (2°C) and 75.6m (0.5°C) in Scenario 4. The thermal dispersion simulations show that the excess temperature in the plume drops substantially within the first 50m from the outfall point.

Based on these predictions it is unlikely that the plumes would extend as far downstream as the confluence with the Humber Estuary, approximately 12km away. Both total ammonia and thermal plumes are attached to the left riverbank (looking downstream) in a confined small area. The thermal effects are expected to be localised and an excess temperature of 2.0ºC is achieved at a distance of 5m -15m.

Table 5.9: Modelled Maximum Plume Across the Channel (m)

Model Type		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Ammonia	C=0.3mg/l	19.6	37.4	n/a	n/a	n/a
Thermal	Excess ΔT=2.0°C	n/a	n/a	0.9	1.2	1.2
	Excess ΔT=0.5°C	n/a	n/a	3.7	4.8	3.7

Table 5.10: Modelled Maximum Plume Along the Channel (m)

Model Type		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Ammonia	C=0.3mg/l	163.1	141.2	n/a	n/a	n/a
Thermal	Excess ΔT=2.0°C	n/a	n/a	5.1	14.5	11.3
	Excess ΔT=0.5°C	n/a	n/a	28.7	75.6	46.5

Table 5.11: Modelled Results for Scenario 1 - Keadby 3 Option 1

Model Run	50m			100m			200m			Distance to 0.3mg/l		
	D	C (mg/l)	W (m)	D	C (mg/l)	W (m)	D	C (mg/l)	W (m)	D	L (m)	W (m)
Run01	49.9	0.27	8.2	57.0	0.23	23.8	69.6	0.19	31.0	44.0	25.1	5.1
Run02	27.8	0.48	0.8	92.4	0.14	2.4	149.2	0.09	6.8	44.0	85.5	1.0
Run03	25.8	0.51	0.7	43.5	0.30	0.9	148.0	0.09	4.7	44.0	102.0	0.9
Run04	111.0	0.12	6.6	128.0	0.10	22.9	141.5	0.09	31.0	44.0	26.4	2.2
Run05	25.8	0.51	0.7	44.7	0.30	0.9	85.0	0.16	1.3	44.0	97.3	0.9
Run06	22.2	0.60	0.6	42.2	0.31	0.9	81.8	0.16	1.2	44.0	103.8	0.9
Run07	25.9	0.51	0.7	44.6	0.30	0.9	145.0	0.09	5.5	44.0	98.7	0.9
Run08	21.9	0.60	0.6	41.4	0.32	0.8	120.0	0.11	4.9	44.0	107.0	0.9
Run09	50.7	0.26	6.4	65.0	0.20	9.5	101.1	0.13	24.8	44.0	24.4	1.4
Run10	43.0	0.31	3.8	94.8	0.14	4.9	177.0	0.07	6.7	44.0	51.0	3.7
Run11	71.9	0.18	3.6	154.0	0.09	4.9	281.3	0.05	6.8	44.0	33.7	3.1
Run12	21.7	0.61	5.9	30.0	0.44	16.0	50.8	0.26	20.8	44.0	163.0	19.5
Run13	44.2	0.30	4.2	139.0	0.10	5.8	331.3	0.04	8.0	44.0	49.0	4.0
Run14	54.6	0.24	1.4	126.1	0.10	4.8	81.8	0.16	1.2	44.0	43.0	3.4
Run15	63.4	0.21	3.4	129.2	0.10	4.6	248.3	0.05	6.9	44.0	35.0	0.8
Run16	45.6	0.29	2.9	95.0	0.14	4.6	142.0	0.09	5.9	44.0	48.5	2.8

D: Dilution; **C**: Modelled concentration (mg/l); **W**: Top-hat half-width; **L**: Downstream/upstream extent of plume from the outfall at 0.3mg/l

Table 5.12: Modelled Results for Scenario 2 - Keadby 3 Option 2

Model Run	50m			100m			200m			Distance to 0.3mg/l		
	D	C (mg/l)	W (m)	D	C (mg/l)	W (m)	D	C (mg/l)	W (m)	D	L (m)	W (m)
Run01	31.2	0.35	22.4	34.2	0.32	31.1	39.7	0.28	44.0	36.6	141.2	37.4
Run02	57.6	0.19	2.0	72.1	0.15	6.2	116.0	0.09	8.2	36.6	45.1	1.4
Run03	28.1	0.39	0.8	96.0	0.11	3.5	145.8	0.08	5.9	36.6	63.9	0.9
Run04	79.7	0.14	10.5	87.4	0.13	31.3	95.4	0.12	44.3	36.6	20.8	2.3
Run05	31.6	0.35	0.9	63.3	0.17	1.3	204.0	0.05	6.9	36.6	58.0	1.0
Run06	27.8	0.39	0.8	58.2	0.19	1.2	161.0	0.07	5.8	36.6	64.9	0.9
Run07	31.4	0.35	0.9	88.5	0.12	4.9	118.5	0.09	6.6	36.6	58.8	0.9
Run08	27.0	0.41	0.8	75.3	0.15	3.9	100.2	0.11	5.7	36.6	66.6	0.9
Run09	43.0	0.26	8.8	50.7	0.22	25.7	65.1	0.17	33.0	36.6	21.0	5.2
Run10	23.2	0.47	0.9	39.1	0.28	1.2	113.7	0.10	7.4	36.6	92.6	1.1
Run11	17.9	0.61	0.6	33.6	0.33	0.9	63.6	0.17	1.3	36.6	110.2	1.0
Run12	92.5	0.12	6.5	108.0	0.10	11.7	125.0	0.09	32.9	36.6	28.4	36.7
Run13	22.0	0.50	0.8	35.6	0.31	1.0	64.2	0.17	1.4	36.6	103.8	1.0
Run14	17.8	0.62	0.6	33.0	0.33	0.9	62.3	0.18	1.3	36.6	111.7	1.0
Run15	22.1	0.50	0.8	35.5	0.31	1.0	109.0	0.10	5.8	36.6	104.0	1.0
Run16	17.5	0.63	0.6	32.3	0.34	0.9	114.5	0.10	5.1	36.6	115.0	0.9

D: Dilution; **C**: Modelled concentration (mg/l); **W**: Top-hat half-width; **L**: Downstream/upstream extent of plume from the outfall at 0.3mg/l

Table 5.13: Modelled Results for Scenario 3 – Keadby 3 Option 1

Model Run	50m			100m			200m			Distance to 0.5 °C (m)			Distance to 2.0 °C (m)		
	D	ΔT (°C)	W (m)	D	ΔT (°C)	W (m)	D	ΔT (°C)	W (m)	D	L (m)	W (m)	D	L (m)	W (m)
Run01	49.9	0.13	8.2	57.0	0.12	23.8	69.7	0.09	31.0	13.2	9.4	1.1	3.3	0.8	0.6
Run02	27.8	0.24	0.8	92.4	0.07	2.4	149.2	0.04	6.8	13.2	14.4	0.6	3.3	0.7	0.3
Run03	25.8	0.26	0.7	43.5	0.15	0.9	148.0	0.04	4.7	13.2	15.9	0.5	3.3	0.8	0.2
Run04	111.0	0.06	6.6	128.0	0.05	22.9	141.5	0.05	31.0	13.2	9.3	1.1	3.3	0.8	0.6
Run05	25.8	0.26	0.7	44.7	0.15	0.9	85.0	0.08	1.3	13.2	16.4	0.5	3.3	1.0	0.3
Run06	22.2	0.30	0.6	42.2	0.16	0.9	81.8	0.08	1.2	13.2	28.1	0.5	3.3	4.9	0.2
Run07	25.9	0.25	0.7	44.6	0.15	0.9	145.0	0.05	5.5	13.2	16.0	0.5	3.3	1.0	0.3
Run08	21.9	0.30	0.6	41.4	0.16	0.8	120.0	0.06	4.9	13.2	28.7	0.4	3.3	5.1	0.2
Run09	50.7	0.13	6.4	65.0	0.10	9.5	101.1	0.07	24.8	13.2	6.0	1.6	3.3	0.8	0.6
Run10	43.0	0.15	3.8	94.8	0.07	4.9	177.0	0.04	6.7	13.2	10.5	3.7	3.3	1.1	0.3
Run11	71.9	0.09	3.6	154.0	0.04	4.9	281.3	0.02	6.8	13.2	10.2	1.9	3.3	1.0	0.4
Run12	21.7	0.30	5.9	30.0	0.22	16.0	50.8	0.13	20.8	13.2	4.9	1.7	3.3	0.8	0.6
Run13	44.2	0.15	4.2	139.0	0.05	5.8	331.3	0.02	8.0	13.2	12.8	2.4	3.3	1.0	0.3
Run14	54.6	0.12	1.4	126.1	0.05	4.8	81.8	0.08	1.2	13.2	20.0	2.2	3.3	1.2	0.8
Run15	63.4	0.10	3.4	129.2	0.05	4.6	248.3	0.03	6.9	13.2	9.5	1.9	3.3	0.9	0.3
Run16	45.6	0.14	2.9	95.0	0.07	4.6	142.0	0.05	5.9	13.2	16.3	1.7	3.3	1.3	0.9

D: Dilution; **ΔT**: Modelled excess temperature; **W**: Top-hat half-width; **L**: Downstream/upstream extent of plume from the outfall at 0.5°C or 2.0°C

Table 5.14: Modelled Results for Scenario 4 – Keadby 3 Option 2

Model Run	50m			100m			200m			Distance to 0.5 °C (m)			Distance to 2.0 °C (m)		
	D	ΔT (°C)	W (m)	D	ΔT (°C)	W (m)	D	ΔT (°C)	W (m)	D	L (m)	W (m)	D	L (m)	W (m)
Run01	31.2	0.40	22.4	34.2	0.37	31.1	39.7	0.32	44.0	25.2	15.9	4.8	6.3	4.9	0.9
Run02	57.6	0.22	2.0	72.1	0.17	6.2	116.0	0.11	8.2	25.2	33.4	0.9	6.3	3.5	0.5
Run03	28.1	0.45	0.8	96.0	0.13	3.5	145.8	0.09	5.9	25.2	45.2	0.8	6.3	11.9	0.4
Run04	79.7	0.16	10.5	87.4	0.14	31.3	95.4	0.13	44.3	25.2	16.5	1.9	6.3	2.7	1.2
Run05	31.6	0.40	0.9	63.3	0.20	1.3	204.0	0.06	6.9	25.2	38.8	0.8	6.3	4.7	0.4
Run06	27.8	0.45	0.8	58.2	0.22	1.2	161.0	0.08	5.8	25.2	45.8	0.8	6.3	11.8	0.4
Run07	31.4	0.40	0.9	88.5	0.14	4.9	118.5	0.11	6.6	25.2	39.1	0.8	6.3	4.3	0.4
Run08	27.0	0.47	0.8	75.3	0.17	3.9	100.2	0.13	5.7	25.2	46.8	0.7	6.3	12.2	0.4
Run09	43.0	0.29	8.8	50.7	0.25	25.7	65.1	0.19	33.0	25.2	18.7	3.9	6.3	2.7	1.2
Run10	23.2	0.54	0.9	39.1	0.32	1.2	113.7	0.11	7.4	25.2	56.5	0.9	6.3	3.7	0.5
Run11	17.9	0.70	0.6	33.6	0.38	0.9	63.6	0.20	1.3	25.2	72.6	0.8	6.3	15.0	0.4
Run12	92.5	0.14	6.5	108.0	0.12	11.7	125.0	0.10	32.9	25.2	20.1	2.0	6.3	2.7	1.2
Run13	22.0	0.57	0.8	35.6	0.35	1.0	64.2	0.20	1.4	25.2	61.5	0.8	6.3	4.0	0.4
Run14	17.8	0.71	0.6	33.0	0.38	0.9	62.3	0.20	1.3	25.2	74.3	0.8	6.3	14.5	0.4
Run15	22.1	0.57	0.8	35.5	0.35	1.0	109.0	0.12	5.8	25.2	61.5	0.8	6.3	4.0	0.4
Run16	17.5	0.72	0.6	32.3	0.39	0.9	114.5	0.11	5.1	25.2	75.6	0.8	6.3	14.5	0.4

D: Dilution; **ΔT**: Modelled excess temperature; **W**: Top-hat half-width; **L**: Downstream/upstream extent of plume from the outfall at 0.5°C or 2.0°C

Table 5.15: Modelled Results for Scenario 5 – Keadby 3 Option 2 + Keadby 2

Model Run	50m			100m			200m			Distance to 0.5 °C (m)			Distance to 2.0 °C (m)		
	D	ΔT (°C)	W (m)	D	ΔT (°C)	W (m)	D	ΔT (°C)	W (m)	D	L (m)	W (m)	D	L (m)	W (m)
Run01	29.3	0.34	24.2	31.6	0.31	32.3	36.4	0.27	44.6	19.8	12.5	3.7	5.0	2.2	1.2
Run02	30.0	0.33	1.4	62.5	0.16	6.5	92.7	0.11	8.0	19.8	31.8	0.9	5.0	2.6	0.5
Run03	22.1	0.45	0.8	46.6	0.21	1.5	112.0	0.09	6.1	19.8	44.8	0.8	5.0	11.2	0.4
Run04	65.5	0.15	10.6	71.8	0.14	31.8	78.0	0.13	44.6	19.8	14.5	2.0	5.0	2.2	1.2
Run05	23.7	0.42	0.9	50.0	0.20	1.4	163.0	0.06	6.0	19.8	41.9	0.8	5.0	11.1	0.4
Run06	21.8	0.45	0.8	44.8	0.22	1.2	123.0	0.08	5.9	19.8	45.6	0.8	5.0	11.3	0.4
Run07	23.3	0.42	0.9	66.0	0.15	4.3	85.8	0.12	6.2	19.8	42.8	0.8	5.0	11.2	0.4
Run08	21.3	0.46	0.8	60.0	0.17	4.1	78.0	0.13	5.9	19.8	46.5	0.8	5.0	11.2	0.4
Run09	29.4	0.34	7.4	37.5	0.26	10.6	57.9	0.17	27.5	19.8	13.2	2.7	5.0	2.2	1.2
Run10	48.9	0.20	5.1	58.0	0.17	7.0	88.0	0.11	10.2	19.8	26.7	0.9	5.0	2.6	0.5
Run11	27.0	0.37	0.9	82.0	0.12	4.0	115.9	0.09	6.2	19.8	37.6	0.8	5.0	10.3	0.4
Run12	56.1	0.18	24.8	61.2	0.16	35.4	67.7	0.15	50.3	19.8	11.7	1.9	5.0	4.2	0.9
Run13	29.4	0.34	1.0	63.9	0.15	1.5	147.0	0.07	6.5	19.8	35.4	0.8	5.0	10.4	0.4
Run14	26.5	0.37	0.9	89.0	0.11	3.9	129.4	0.08	6.2	19.8	38.3	0.8	5.0	11.4	0.4
Run15	28.6	0.35	1.0	65.2	0.15	4.7	88.9	0.11	6.5	19.8	36.0	0.8	5.0	10.4	0.4
Run16	26.0	0.38	0.9	61.8	0.16	4.2	78.6	0.13	5.9	19.8	38.9	0.8	5.0	10.1	0.4

D: Dilution; **ΔT**: Modelled excess temperature; **W**: Top-hat half-width; **L**: Downstream/upstream extent of plume from the outfall at 0.5°C or 2.0°C

6. Conclusions

AECOM has undertaken an effluent dispersion modelling study to assess the impacts on water quality in the River Trent for the development of Keadby 3 power plant.

As requested by the EA for the Environmental Permit Variation application, a H1 assessment has been completed. Screening tests determined the pollutants such as Chloride, Copper, Fluoride, Iron and Sulphate are insignificant. However, the total ammonia within the wastewater should be considered for detailed water quality modelling study.

A regional hydrodynamic model has been collected from EA to provide the water level and flow speed information for CORMIX model inputs. The model review showed that the tidal levels over spring-neap tidal cycles are well reproduced, and the model shows a reasonable simulation of the Keadby site.

The discharge velocity of 1.32m/s and existing invert level of pipe at -3.05mAOD have been used as inputs for the modelling study. It requires pumped outfalls if the required velocity is not achievable for gravity systems.

CORMIX water quality modelling was carried out for the total ammonia and thermal discharge. 5 model scenarios were identified, total ammonia for Keadby 3 - Option 1 and Keadby 3 – Option 2, thermal discharge for Keadby 3 - Option 1, Keadby 3 - Option 2 and Keadby 3 - Option 2 + Keadby 2.

Modelled plume extents were explored for the specified concentration, 0.3mg/l for the total ammonia and 2.0°C excess for temperatures. The results provide the maximum plume width across the channel and plume length along the channel downstream/ upstream from the outfall location.

- None of plumes in five established scenarios is predicted to cross the entire channel. All plume widths are within 25% of total channel width.
- For the total ammonia, the widths are 19.6m for Scenario 1 and 37.4m Scenario 2 as the worst cases, which are equivalent to 10% and 20% of total channel width (190m).
- For the thermal dispersion, the maximum predicted extents of 2°C above the ambient water temperature were 1.2m, representing only <1% of the total channel width.
- For the total ammonia, predicted maximum plume length along the riverbank was 163.1m (Scenario 1). For the thermal dispersion, the maximum length was 14.5m (2°C) in Scenario 4. The thermal dispersion simulations show that the excess temperature in the plume drops substantially within the first 50m from the outfall point.
- Results from the modelling confirm that it is unlikely that the plumes would extend as far downstream into the Humber Estuary (Special Area of Conservation). Both total ammonia and thermal plumes are attached to the left riverbank (looking downstream) in a confined small area. The thermal effects are expected to be localised and an excess temperature of 2.0ºC is achieved in a range of 5m to 15m.

It can be concluded from the present modelling simulations that the total ammonia and thermal effluent discharged from Keadby 3 power station via W12 into the Keadby 1 cooling water culvert into the River Trent at outfall (W1) has very limited impact on the water quality in the River Trent, being demonstrated that the plumes are rapidly diluted and reach the established water quality standards.

7. References

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Annex A – H1 Assessment Tool

Electronic Access database – Annex B

Annex B – Water Input Calculations

Excel Spreadsheet

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