KEADBY 3
CARBON CAPTURE POWER STATION

A collaboration between **SSE Thermal** and **Equinor**

Document Ref: 5.12

Planning Inspectorate Ref: EN010114

The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order

Land at and in the vicinity of the Keadby Power Station site, Trentside, Keadby, North Lincolnshire

Habitats Regulations Assessment Appropriate Assessment Report

The Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 – Regulation 5(2)(g)

Conservation of Habitats and Species Regulations 2017 (as amended)

Applicant: Keadby Generation Limited

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GLOSSARY

Abbreviation	Description
AADT	Annual Average Daily Traffic - a measure of the total volume of vehicle traffic of a highway or road for a year divided by 365 days.
ADMS	Atmospheric Dispersion Modelling System - a proprietary model for the assessment of effect of emissions to air from point sources and road sources.
AIA	Atmospheric Impact Assessment
AIL	Abnormal Indivisible Load - a load that cannot be broken down into smaller loads for transport without undue expense or risk of damage. It may also be a load that exceeds certain parameters for weight, length and width.
APIS	Air Pollution Information System - provides a comprehensive source of information on air pollution and the effects on habitats and species. It supports the assessment of potential effects of air pollutants on habitats and species.
Applicant	Keadby Generation Limited.
BAT	Best Available Techniques
CCGT	Combined Cycle Gas Turbine – a CCGT is a combustion plant where a gas turbine is used to generate electricity and the waste heat from the flue-gas of the gas turbine is converted to useful energy in a heat recovery steam generator (HRSG), where it is used to generate steam. The steam then expands in a steam turbine to produce additional electricity.
CEMP	Construction Environment Management Plan - a plan to outline how a construction project will avoid, minimise or mitigate effects on the environment and surrounding area.
CERC	Cambridge Environmental Research Consultants
CIEEM	Chartered Institute of Ecology and Environmental Management
CJEU	Court of Justice of the European Union - interprets EU law to ensure it is applied in the same way in all EU countries.

Abbreviation	Description
DCO	Development Consent Order - made by the relevant Secretary of State pursuant to the Planning Act 2008 to authorise a Nationally Significant Infrastructure Project. A DCO can incorporate or remove the need for a range of consents which would otherwise be required for a development. A DCO can also include rights of compulsory acquisition.
DML	Deemed Marine Licence
EC	European Commission - the executive branch of the European Union.
EcIA	Ecological Impact Assessment - a process by which the potential ecological impacts of a development proposal are assessed.
EEA	European Economic Area - allows countries to be part of the EU’s single market.
EIA	Environmental Impact Assessment - a term used for the assessment of environmental consequences (positive or negative) of a plan, policy, program or project prior to the decision to move forward with the proposed action.
ES	Environmental Statement – a report in which the process and results of an Environment Impact Assessment are documented.
EU	European Union - an economic and political union of 27 countries.
HGV	Heavy Goods Vehicle - vehicles with a gross weight in excess of 3.5 tonnes.
HRA	Habitats Regulations Assessment – the assessment of the impacts of implementing a plan or policy on a Natura 2000 site required under the Habitats Directive.
INNS	Invasive Non-native Species - species established outside of their natural range and which considered damaging for native biodiversity and/or to economic activities.
IROPI	Imperative Reasons of Overriding Public Interest
km	Kilometre – unit of distance.
kV	Kilovolt – unit of voltage
LSE	Likely Significant Effects
MMO	Marine Management Organisation - an executive, non-departmental body in the United Kingdom with the responsibility of licensing, regulating and planning marine activities in the seas around England so that they are carried out in a sustainable way.
MW	Megawatt – unit of power

Abbreviation	Description
NGR	National Grid Reference - system of geographical grid references.
NLC	North Lincolnshire Council – the local planning authority with jurisdiction over the area within which the Keadby Power Station Site and Proposed Development Site are situated
NPPF	National Planning Policy Framework - The NPPF is part of the Government's reform of the planning system intended to make it less complex, to protect the environment and to promote sustainable growth. It does not contain any specific policies on Nationally Significant Infrastructure Projects, but its policies may be taken into account in decisions on DCOs if the Secretary of State considers them to be both important and relevant.
NSER	No Significant Effects Report – a report describing the findings of the Habitats Regulations Assessment (HRA).
NSIP	Nationally Significant Infrastructure Project - defined by the Planning Act 2008 and cover projects relating to energy (including generating stations, electric lines and pipelines); transport (including trunk roads and motorways, airports, harbour facilities, railways and rail freight interchanges); water (dams and reservoirs, and the transfer of water resources); waste water treatment plants and hazardous waste facilities. These projects are only defined as nationally significant if they satisfy a statutory threshold in terms of their scale or effect.
NSR	Noise Sensitive Receptors - locations or areas where dwelling units or other fixed, developed sites of frequent human use occur which may be sensitive to noise impacts.
PC	Process Contribution - represents the change caused by the Proposed Development.
PEA	Preliminary Ecological Appraisal - an ecological assessment method which evaluates the existing ecological value of a site.
PEC	Predicted Environmental Concentration - PC plus background concentration.
PEI	Preliminary Environmental Information – the information referred to in Part 1 of Schedule 4 of the EIA Regulations that has been reasonably compiled by the applicant and is reasonably required to assess the environmental effects of a development project.
PINS	Planning Inspectorate – executive agency of the Ministry of Housing, Communities and Local Government of the United Kingdom Government.

Abbreviation	Description
PV	Photovoltaic - captures the sun's energy and convert it into electricity.
RDF	Refuse Derived Fuel - produced from domestic and business waste, which includes biodegradable material as well as plastics.
SAC	Special Area of Conservation – high quality conservation sites that are protected under the European Union Habitats Directive, due to their contribution to conserving those habitat types that are considered to be most in need of conservation.
SCR	Selective Catalytic Reduction - the removal of nitrogen oxides from the flue gas.
SPA	Special Protection Area – strictly protected sites classified in accordance with Article 4 of the EC Birds Directive. Special Protection Areas are Natura sites which are internationally important sites for the protection of threatened habitats and species.
SUDs	Sustainable Urban Drainage System - a natural approach to managing drainage.
WFD	Water Framework Directive - European Union directive which commits member states to achieve good qualitative and quantitative status of all water bodies.
ZCH	Zero Carbon Humber - a consortium of energy and industrial companies and academic institutions aiming to develop the Humber region into a net-zero carbon cluster by 2040

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Revision History for Version VP2.0

Item	Nature of Revision
1	Updates made to the HRA for water pollution measures specific to Humber Estuary, where it is appropriate and to clarify in the document where measures are standard and therefore do not need to be brought into the AA.
2	Updates made to clarify minimal loss of bank habitat, including describing the existing Keadby 1 Power Station concrete apron and existing maintenance arrangements permitted for Keadby 1 Power Station and replenishment of silts along river bank at the intake, including inclusion of supporting photographic evidence/references.
3	Updated to include pre-mitigated air quality scenario, with explanation added around selection of stack height and use of SCR for IED/ permit compliance and human health protection rather than additional mitigation for habitats. Inclusion of reference to Keadby 2 ambient air monitoring data that has been gathered.
4	Reference to status of Environmental Permit application that has been submitted and is undergoing duly made checks. Further context added in relation to the future water discharge with Keadby 2 Power Station including the reduction in discharge rate expected as Keadby 1 Power Station will not operate concurrently with the Proposed Development.
5	Updated to describe additional results of sensitivity checks on construction noise assessment findings using an alternative agreed approach and presentation of accompanying noise contour plots.
6	Updated to confirm approach to protected species surveys and signposting to how these are secured in the CEMP.
7	Expanded narrative in relation to mudflat habitats

EXECUTIVE SUMMARY

1 Keadby Generation Limited (the 'Applicant') is seeking development consent for the construction, operation and maintenance of a new low carbon Combined Cycle Gas Turbine (CCGT) Generating Station ('the Proposed Development'). The Proposed Development is a new gas fired electricity generating station of up to 910 megawatts (MW) gross electrical output with state-of-the art carbon capture technology and including cooling water, electrical, gas and utility connections, construction laydown areas and other associated works on land to the west of the existing Keadby 1 and Keadby 2 Power Stations, the latter being currently under commissioning. The Proposed Development will therefore make a significant contribution toward the UK reaching its Net Zero greenhouse gas emissions target by 2050.

2 This Habitats Regulation Assessment (HRA) Appropriate Assessment Report describes the legislation that underpins the requirement to complete a HRA and describes the methodology applied when making the assessment. The assessment provides a screening of the Likely Significant Effects of the Proposed Development during construction, operation and decommissioning on the following European Sites:

- Humber Estuary SAC;
- Humber Estuary SPA;
- Humber Estuary Ramsar site;
- Thorne Moor SAC;
- Hatfield Moor SAC; and
- Thorne and Hatfield Moors SPA.

3 The assessment examines the following potential impact pathways, as relevant to each European Site and each phase of the Proposed Development:

- direct habitat disturbance;
- visual and noise/ vibration disturbance of qualifying species features;
- entrapment of river and sea lamprey;
- spread of invasive non-native species;
- emission to the atmosphere;
- deterioration in water quality; and
- temporary or permanent impacts on foraging resources for qualifying species features.

4 The first stage of the assessment involved an assessment of Likely Significant Effects. Following this initial assessment, no Likely Significant Effects were identified in relation to entrapment of lampreys, spread of invasive non-native

species, and temporary or permanent impacts on foraging resources for qualifying species features.

5 The other potential impact pathways of direct habitat disturbance during construction, visual and noise disturbance during construction, and emissions to the atmosphere during operation of the Proposed Development could not be screened out so were carried forward for the second stage of assessment, which is Appropriate Assessment. The Appropriate Assessment concluded no adverse effect on the integrity of the European Sites.

6 Potential in-combination effects of the Proposed Development with other plans and projects were also assessed and the same conclusion was reached i.e. no adverse effect on the integrity of the European Sites.

1.0 INTRODUCTION

1.1 Overview

1.1.1 This Habitats Regulations Assessment (HRA) Appropriate Assessment Report (**Application Document Ref. 5.12**) has been prepared by AECOM on behalf of Keadby Generation Limited (the 'Applicant') which is a wholly owned subsidiary of SSE plc. It forms part of the application (the 'Application') for a Development Consent Order (a 'DCO'), that has been submitted to the Secretary of State (the 'SoS') for Business, Energy and Industrial Strategy, under section 37 of 'The Planning Act 2008' (the '2008 Act').

1.1.2 The Applicant is seeking development consent for the construction, operation and maintenance of a new low carbon Combined Cycle Gas Turbine (CCGT) Generating Station ('the Proposed Development') on land at, and in the vicinity of, the existing Keadby Power Station, Trentside, Keadby, Scunthorpe DN17 3EF (the 'Proposed Development Site').

1.1.3 The Proposed Development is a new electricity generating station of up to 910 megawatts (MW) gross electrical output, equipped with carbon capture and compression plant and fuelled by natural gas, on land to the west of Keadby 1 Power Station and the (under commissioning) Keadby 2 Power Station, including connections for cooling water, electrical, gas and utilities, construction laydown areas and other associated development. It is described in **Chapter 4:** The Proposed Development of the Environmental Statement (ES) (ES Volume I - **Application Document Ref. 6.2**).

1.1.4 The Proposed Development falls within the definition of a 'Nationally Significant Infrastructure Project' (NSIP) under Section 14(1)(a) and Sections 15(1) and (2) of the 2008 Act, as it is an onshore generating station in England that would have a generating capacity greater than 50MW electrical output (50MWe). As such, a DCO application is required to authorise the Proposed Development in accordance with Section 31 of the 2008 Act.

1.1.5 The DCO, if made by the SoS, would be known as 'The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order' ('the Order').

1.2 The Applicant

1.2.1 The Applicant, Keadby Generation Limited, is the freehold owner of a large part of the Proposed Development Site and is a wholly owned subsidiary of the FTSE 100-listed SSE plc, one of the UK's largest and broadest-based energy companies, and the country's leading developer of renewable energy generation. Over the last 20 years, SSE plc has invested over £20bn to deliver industry-leading offshore wind, onshore wind, CCGT, energy from waste, biomass, energy networks and gas storage projects. The Applicant owns and operates the adjacent Keadby 1 Power Station and is in the process of constructing Keadby 2 Power Station. SSE operates the Keadby Windfarm which lies to the north and south of the Proposed Development Site and generates renewable energy from 34 turbines, with a total installed generation capacity of 68MW.

1.2.2 SSE has produced a 'Greenprint' document (SSE plc, 2020a) that sets out a clear commitment to investment in low carbon power infrastructure, working with government and other stakeholders to create a net zero power system by 2040. This includes investment in flexible sources of electricity generation and storage for times of low renewable output which will complement other renewable generating sources, using low carbon fuels and/ or capturing and storing carbon emissions. SSE is working with leading organisations across the UK to accelerate the development of carbon capture, usage and storage ('CCUS') clusters, including Equinor and National Grid Carbon.

1.2.3 The design of the Proposed Development demonstrates this commitment. The Proposed Development will be built with a clear route to decarbonisation, being equipped with post-combustion carbon capture technology, consistent with SSE's commitment to reduce the carbon intensity of electricity generated by 60% by 2030, compared to 2018 levels (SSE plc, 2020b). It is intended that the Proposed Development will connect to infrastructure that will be delivered by the Zero Carbon Humber (ZCH) Partnership and Northern Endurance Partnership (NEP) for the transport and offshore geological storage of carbon dioxide.

1.3 What is Carbon Capture, Usage and Storage?

1.3.1 CCUS is a process that removes carbon dioxide emissions at source, for example emissions from a power station or industrial installation, and then compresses the carbon dioxide so that it can be safely transported to secure underground geological storage sites. It is then injected into layers of solid rock filled with interconnected pores where the carbon dioxide becomes trapped and locked in place, preventing it from being released into the atmosphere. Plate 1 shows what is involved in the process.

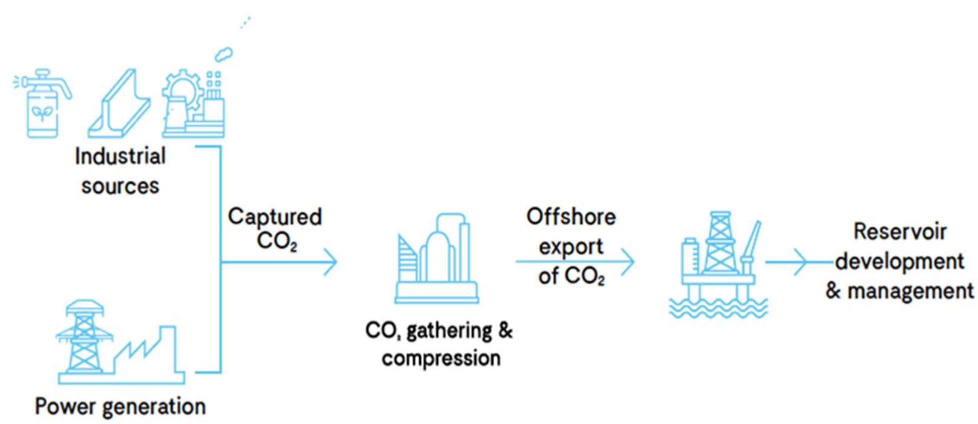


Plate 1: Illustration of the Carbon Capture, Usage and Storage

1.3.2 The technologies used in CCUS are proven and have been used safely across the world for many years. Geological storage sites are located far underground and are subject to stringent tests to ensure that they are geologically suitable. It is expected that the storage sites will be located offshore, in areas such as the North Sea. The NEP has been formed to develop the offshore infrastructure to transport and store carbon dioxide emissions in the North Sea.

1.3.3 CCUS is crucial to reducing carbon dioxide emissions and combatting global warming. The UK Government has committed to achieving Net Zero in terms of greenhouse gas emissions by 2050. This is a legally binding target. UK Government policy further states that the 'deployment of power CCUS projects will play a key role in the decarbonisation of the electricity system at low cost' (HM Government, 2020a, page 47).

1.3.4 The Proposed Development will provide up to 910MWe (gross) of dispatchable capacity and capture some 2 million tonnes of carbon dioxide per annum, dependent upon the turbine equipment chosen and the running hours of the plant. The Proposed Development could be up and running by the mid-2020s and will facilitate the timely development of a major CCUS cluster in the Humber region, making an important contribution towards the achievement of Net Zero by 2050.

1.4 The Proposed Development

1.4.1 The Proposed Development will work by capturing carbon dioxide emissions from the gas-fired power station and connecting into the ZCH Partnership export pipeline and gathering network for onward transport to the Endurance saline aquifer under the North Sea.

1.4.2 The Proposed Development would comprise a low carbon gas fired power station with a gross electrical output capacity of up to 910MWe and associated buildings, structures and plant and other associated development defined in the Schedule 1 of the draft DCO (**Application Document Ref. 2.1**) as Work No. 1 – 11 and shown on the Works Plans (**Application Document Ref. 4.3**).

1.4.3 At this stage, the final technology selection cannot yet be made as it will be determined by various technical and economic considerations and will be influenced by future UK Government policy and regulation. The design of the Proposed Development therefore incorporates a necessary degree of flexibility to allow for the future selection of the preferred technology in the light of prevailing policy, regulatory and market conditions once a DCO is made.

1.4.4 The Proposed Development will include:

- a carbon capture equipped electricity generating station including a CCGT plant (**Work No. 1A**) with integrated cooling infrastructure (**Work No. 1B**), and carbon dioxide capture plant (CCP) including carbon dioxide absorption unit(s) and stack(s), conditioning and compression equipment (**Work No. 1C**), natural gas receiving facility (**Work No. 1D**), supporting activities including control room, workshops, stores, raw and demineralised water tanks and permanent laydown area (**Work No. 1E**), and associated utilities, various pipework, water treatment plant, wastewater treatment, firefighting equipment, emergency diesel generator, gatehouse, chemical storage facilities, other minor infrastructure and auxiliaries/ services (all located in the area referred to as the 'Proposed Power and Carbon Capture (PCC) Site' and which together form **Work No. 1**);

- natural gas pipeline from the existing National Grid Gas high pressure (HP) gas pipeline within the Proposed Development Site to supply the Proposed PCC Site including an above ground installation (AGI) for National Grid Gas's apparatus (**Work No. 2A**) and the Applicant's apparatus (**Work No. 2B**) (the 'Gas Connection Corridor');
- electrical connection works to and from the existing National Grid 400kV Substation for the export of electricity (**Work No. 3A**) (the 'Electrical Connection Area to National Grid 400kV Substation');
- electrical connection works to and from the existing Northern Powergrid 132kV Substation for the supply of electricity at up to 132kV to the Proposed PCC Site, and associated plant and equipment (**Work No. 3B**) (the 'Potential Electrical Connection to Northern Powergrid 132kV Substation');
- Water Connection Corridors to provide cooling and make-up water including:
  - underground and/ or overground water supply pipeline(s) and intake structures within the Stainforth and Keadby Canal, including temporary cofferdam (**Work No. 4A**) (the 'Canal Water Abstraction Option');
  - in the event that the canal abstraction option is not available, works to the existing Keadby 1 power station cooling water supply pipelines and intake structures within the River Trent, including temporary cofferdam (**Work No. 4B**) (the 'River Water Abstraction Option');
  - works to and use of an existing outfall and associated pipework for the discharge of return cooling water and treated wastewater to the River Trent (**Work No. 5**) (the 'Water Discharge Corridor');
- towns water connection pipeline from existing water supply within the Keadby Power Station to provide potable water (**Work No. 6**);
- above ground carbon dioxide compression and export infrastructure comprising an above ground installation (AGI) for the undertaker's apparatus including deoxygenation, dehydration, staged compression facilities, outlet metering, and electrical connection (**Work No. 7A**) and an above ground installation (AGI) for National Grid Carbon's apparatus (**Work No. 7B**);
- new permanent access from A18, comprising the maintenance and improvement of an existing private access road from the junction with the A18 including the western private bridge crossing of the Hatfield Waste Drain (**Work No. 8A**) and installation of a layby and gatehouse (**Work No. 8B**), and an emergency vehicle and pedestrian access road comprising the maintenance and improvement of an existing private track running between

the Proposed PCC Site and Chapel Lane, Keadby and including new private bridge (**Work No. 8C**);

- temporary construction and laydown areas including contractor facilities and parking (**Work No. 9A**), and access to these using the existing private roads from the A18 and the existing private bridge crossings, including the replacement of the western existing private bridge crossing known as 'Mabey Bridge') over Hatfield Waste Drain (**Work No. 9B**) and a temporary construction laydown area associated with that bridge replacement (**Work No. 9C**);
- temporary retention, improvement and subsequent removal of an existing Additional Abnormal Indivisible Load Haulage Route (**Work No. 10A**) and temporary use, maintenance, and placement of mobile crane(s) at the existing Railway Wharf jetty for a Waterborne Transport Offloading Area (**Work No. 10B**);
- landscaping and biodiversity enhancement measures (**Work No. 11A**) and security fencing and boundary treatments (**Work No. 11B**); and
- associated development including: surface water drainage systems; pipeline and cable connections between parts of the Proposed Development Site; hard standings and hard landscaping; soft landscaping, including bunds and embankments; external lighting, including lighting columns; gatehouses and weighbridges; closed circuit television cameras and columns and other security measures; site preparation works including clearance, demolition, earthworks, works to protect buildings and land, and utility connections; accesses, roads, roadways and vehicle and cycle parking; pedestrian and cycle routes; and temporary works associated with the maintenance of the authorised development.

1.4.5 The Applicant will be responsible for the construction, operation (including maintenance) and eventual decommissioning of the Proposed Development, with the exception of the National Grid Gas compound works (**Work No. 2A**), the works within the National Grid Electricity Transmission 400kV substation (part of **Work No. 3A**), the works within the Northern Powergrid 132kV substation (part of **Work No. 3B**), and the National Grid Carbon compound works (**Work No. 7B**), which will be the responsibility of those named beneficiaries.

1.4.6 The Proposed Development includes the equipment required for the capture and compression of carbon dioxide emissions from the generating station so that it is capable of being transported off-site. ZCH Partnership will be responsible for the construction, operation and decommissioning of the carbon dioxide gathering network linking onshore power and industrial facilities including the Proposed Development in the Humber Region. The carbon dioxide export pipeline does not, therefore, form part of the Proposed Development and is not included in the Application but will be the subject of separate consent applications by third parties, such as the Humber Low Carbon Pipeline DCO Project by National Grid Carbon.

1.4.7 The Proposed Development is designed to be capable of operating 24 hours per day, 7 days a week, with plant operation dispatchable to meet electricity demand and with programmed offline periods for maintenance. It is anticipated that in the event of CCP maintenance outages, for example, it could be necessary to operate the Proposed Development without carbon capture, with exhaust gases from the CCGT being routed via the Heat Recovery Steam Generator (HRSG) stack.

1.4.8 Various types of associated and ancillary development further required in connection with and subsidiary to the above works are detailed in Schedule 1 'Authorised Development' of the draft DCO (**Application Document Ref. 2.1**). This along with **Chapter 4:** The Proposed Development section in the ES Volume I (**Application Document Ref. 6.2**) provides further description of the Proposed Development. The areas within which each numbered Work (component) of the Proposed Development are to be built are defined by the coloured and hatched areas on the Works Plans (**Application Document Ref. 4.3**).

1.5 The Proposed Development Site

1.5.1 The Proposed Development Site (the 'Order Limits') is located within and near to the existing Keadby Power Station site near Scunthorpe, Lincolnshire and lies within the administrative boundary of North Lincolnshire Council (NLC). The majority of land is within the ownership or control of the Applicant (or SSE associated companies) and is centred on national grid reference 482351, 411796.

1.5.2 The existing Keadby Power Station site currently encompasses the operational Keadby 1 and (under commissioning) Keadby 2 Power Station sites, including the Keadby 2 Power Station Carbon Capture and Readiness reserve space.

1.5.3 The Proposed Development Site encompasses an area of approximately 69.4 hectares (ha). This includes an area of approximately 18.7ha to the west of Keadby 2 Power Station in which the generating station (CCGT plant, cooling infrastructure and CCP) and gas connection will be developed (the Proposed PCC Site).

1.5.4 The Proposed Development Site includes other areas including:

- Previously developed land, along with gas, towns water and other connections, and access routes, within the Keadby Power Station site;
- the National Grid 400kV Substation located directly adjacent to the Proposed PCC Site, through which electricity generated by the Proposed Development will be exported;
- Emergency Vehicle Access Road and Potential Electrical Connection to Northern Powergrid Substation, the routes of which utilise an existing farm access track towards Chapel Lane and land within the existing Northern Powergrid substation on Chapel Lane;

- Water Connection Corridors:
  - Canal Water Abstraction Option which includes land within the existing Keadby Power Station site with an intake adjacent to the Keadby 2 Power Station intake and pumping station and interconnecting pipework;
  - River Water Abstraction Option which includes a corridor that spans Trent Road and encompasses the existing Keadby Power Station pumping station, below ground cooling water pipework, and infrastructure within the River Trent; and
  - a Water Discharge Corridor which includes an existing discharge pipeline and outfall to the River Trent and follows a route of an existing easement for Keadby 1 Power Station;
- an existing river wharf at Railway Wharf (the Waterborne Transport Offloading Area) and existing temporary haul road into the into the existing Keadby 1 Power Station Site (the 'Additional Abnormal Indivisible Load (AIL) Route');
- a number of temporary Construction Laydown Areas on previously developed land and adjoining agricultural land; and
- land at the A18 Junction and an existing site access road, including two existing private bridge crossing of the Hatfield Waste Drain lying west of Pilfrey Farm (the western of which is known as Mabey Bridge, to be replaced, and the eastern of which is termed Skew Bridge) and an existing temporary gatehouse, to be replaced in permanent form.

1.5.5 In the vicinity of the Proposed Development Site the River Trent is tidal, therefore parts of the Proposed Development Site are within the UK marine area. No harbour works are proposed.

1.5.6 Further description of the Proposed Development Site and its surroundings is provided in **Chapter 3:** The Site and Surrounding Area in ES Volume I (**Application Document Ref. 6.2**).

1.6 The Development Consent Process

1.6.1 As a NSIP project, the Applicant is required to obtain a DCO to construct, operate and maintain the generating station, under Section 31 of the 2008 Act. Sections 42 to 48 of the 2008 Act govern the consultation that the promoter must carry out before submitting an application for a DCO and Section 37 of the 2008 Act governs the form, content and accompanying documents that are required as part of a DCO application. These requirements are implemented through the Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 (as amended) ('APFP Regulations') which state that an application must be accompanied by an ES, where a development is considered to be 'EIA development' under the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (the EIA Regulations).

1.6.2 An application for development consent for the Proposed Development has been submitted to the Planning Inspectorate (PINS) acting on behalf of the Secretary of State. Subject to the Application being accepted (which will be decided within a period of 28 days following receipt of the Application), PINS will then examine it and make a recommendation to the Secretary of State, who will then decide whether to make (grant) the DCO.

1.7 The Purpose and Structure of this Document

1.7.1 When preparing a DCO application, applicants are required to consider the potential effects of the application on protected habitats designated as European Sites. This report has been prepared to meet this requirement. It has been prepared in accordance with Planning Inspectorate 'Advice Note Ten: Habitats Regulations Assessment for Nationally Significant Infrastructure Projects' (The Planning Inspectorate, 2017).

1.7.2 If a NSIP, when taken alone or with existing and known future plans or projects, is likely to affect a European Site, the applicant must provide a report with sufficient information to enable the competent authority (which in this case is the Secretary of State) to make an Appropriate Assessment, if required, under the terms of Regulation 63 of the Conservation of Habitats and Species Regulations 2017 (as amended) (HMSO, 2017) (commonly referred to as the 'Habitats Regulations'). Accordingly, the DCO application must include all such information as may reasonably be required 'for the purposes of the assessment' or 'to enable them to determine whether an Appropriate Assessment is required'. This information is provided in this report.

1.7.3 The document is structured as follows:

- Section 2 describes the legislation underpinning the requirement for this assessment;
- Section 3 describes the methodology applied when making the assessment;
- Section 4 defines the relevant European Sites and their qualifying features of interest;
- Section 5 provides a screening of the Likely Significant Effects of the Proposed Development during construction, operation and decommissioning;
- Section 6 examines in more detail the impact pathways that could not be screened out in Section 5 to provide an Appropriate Assessment;
- Section 7 provides an assessment of the potential in-combination effects of the Proposed Development with other pans and projects;
- Section 8 provides the conclusions of the assessment;
- **Appendix A** provides the HRA screening matrices required by the Planning Inspectorate;
- **Appendix B** summarises the results of the operational air quality assessment in relation to European Sites;
- **Appendix C** provides the HRA integrity matrices required by the Planning Inspectorate; and

- **Appendix D** provides information on the other plans and projects considered by the in-combination assessment.

2.0 LEGISLATIVE CONTEXT

2.1.1 The need to undertake HRA is implemented in English and Welsh law by the Conservation of Habitats and Species Regulations 2017 (as amended). This, through Regulation 63, transposes into English law the requirements of the Habitats Directive (European Council Directive 92/43/EEC) (European Commission, 1992) and the Birds Directive (European Council Directive 2009/147/EEC) (European Commission, 2009). As a consequence, as part of the assessment of a proposed project, it is necessary to consider whether the project is likely to have a significant effect on the national site network (i.e. European Sites as first defined in Section 1.7 of this report).

2.1.2 Over the years, the term HRA has become widely used to describe the overall process set out in the Habitats Regulations (as covered in Advice Note Ten (Planning Inspectorate, 2017)). This has arisen to distinguish the overall process from the individual stage of 'Appropriate Assessment'; which is the latter stage and responsibility of the competent authority (the Secretary of State). Throughout this report the term HRA is therefore used for the overall process and use of the term Appropriate Assessment is restricted to the specific stage of that name.

2.1.3 The UK left the European Union (EU) on 31 January 2020 under the terms set out in the European Union (Withdrawal Agreement) Act 2020 (UK Government, 2020). Through this Act, the body of existing EU-derived law within UK domestic law is retained. As such this assessment takes account of relevant EU case law.

3.0 METHODOLOGY

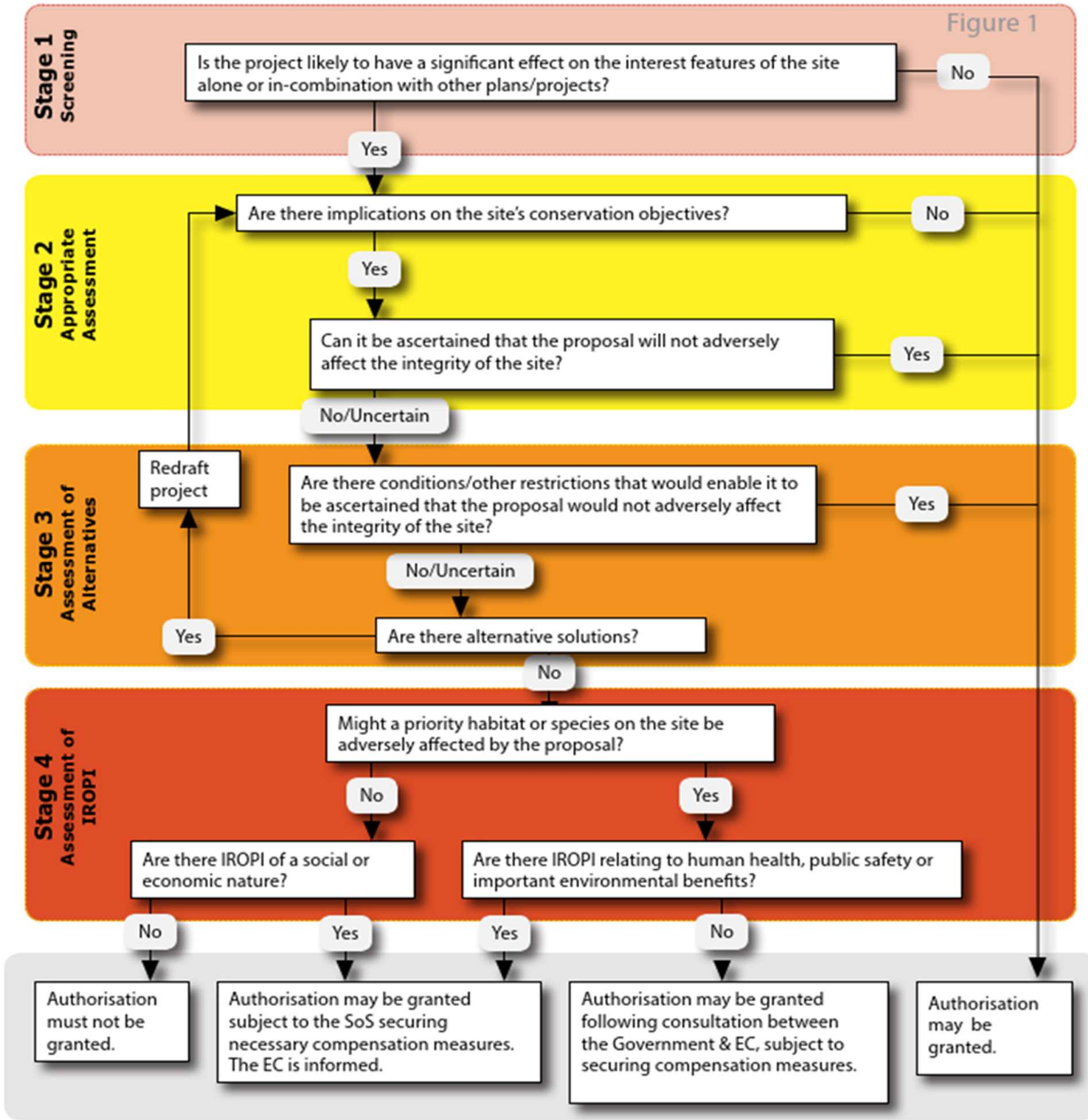
3.1 Introduction

3.1.1 The HRA has been carried out with reference to the general EU guidance on HRA (European Commission, 2001), general guidance on HRA published by the UK government in July 2019 (Ministry of Housing, Communities & Local Government, 2019) and February 2021 (Department for Environment, Food & Rural Affairs, Natural England, Welsh Government and Natural Resources Wales, 2021), and specific guidance issued for NSIP as Advice Note Ten (Planning Inspectorate, 2017).

3.1.2 The HRA has also been prepared having regard to relevant case law relating to the Habitats Regulations, the Habitats Directive and the Birds Directive. This includes the ruling by the Court of Justice of the European Union (CJEU) in the case of People Over Wind, Peter Sweetman v Coillte Teoranta (C-323/17). This case held that; '*it is not appropriate, at the screening stage, to take account of the measures intended to avoid or reduce the harmful effects of the plan or project on that site*' (paragraph 40). This establishes that 'mitigation measures' cannot be considered at the screening stage, but they can be considered in an Appropriate Assessment.

3.1.3 Plate 2 below outlines the stages of HRA according to Advice Note Ten.

Plate 2: The Four Stage Approach to Habitats Regulations Assessments of Projects



Source: Planning Inspectorate, 2017: Advice Note Ten

3.1.4 As shown in Plate 2, the first stage of HRA involves screening of the Proposed Development (alone and in-combination with other plans and projects) concerned for 'Likely Significant Effects' (LSE) as described in Sections 3 to 6 of this report. At this stage of HRA, options for the mitigation of LSE cannot be considered.

3.1.5 Should it be found that significant effects are likely, an 'Appropriate Assessment' should then be carried out in order to further assess those effects. Under Regulation 63 of the Habitats Regulations, it is required that '*A competent authority, before deciding to … give any consent for a plan or project which is likely to have a significant effect on a European site … must make an appropriate assessment of the implications for the plan or project in view of that site's conservation objectives… The competent authority may agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the European site*.' During Appropriate Assessment consideration can be given to potential mitigation options. Consent may only be given for a proposed scheme if, following appraisal of mitigation measures, it is established that it will not adversely affect the integrity of the European Site.

3.1.6 If adverse effects on integrity are identified, after accounting for mitigation measures, alternatives should be considered to avoid those effects. However, where no alternative solution exists and an adverse effect remains, a further assessment should be made of whether the scheme is required for imperative reasons of overriding public interest (IROPI). If the scheme meets that IROPI test, compensatory measures will be required in order to maintain the integrity of affected European Sites.

3.1.7 This assessment addresses HRA stages 1 and 2 only, as the results of the assessment indicate that there is no need to progress to the next stage of assessment.

3.1.8 Whilst the HRA decisions must be taken by the competent authority, the information needed to undertake the necessary assessments must be provided by the Applicant. The summary information needed for the competent authority to establish whether there are any LSE from the Proposed Development is therefore provided in this report. This information has been compiled with reference to **Chapter 4**: The Proposed Development, **Chapter 8**: Air Quality, **Chapter 9**: Noise and Vibration, **Chapter 11:** Biodiversity and Nature Conservation, **Chapter 12**: Water Environment and Flood Risk of the ES (ES Volume I - **Application Document Ref 6.2**).

3.2 HRA Stage 1 – Screening for Likely Significant Effects

3.2.1 The objective of the LSE test is to 'screen out' those aspects of a project that can, without any detailed appraisal or consideration of mitigation measures, be said to be unlikely to result in significant adverse effects upon European Sites. Usually this is achieved because there is no mechanism ('pathway') for an adverse interaction with the relevant European Sites. Any remaining aspects are then taken forward to Appropriate Assessment. The LSE assessment must also consider the potential for effects 'in-combination' with other plans and projects.

3.3 HRA Stage 2 – Appropriate Assessment

3.3.1 Where it is determined that a conclusion of 'no LSE' cannot be drawn, there is a need to proceed to the next stage of HRA known as Appropriate Assessment. Case law has clarified that Appropriate Assessment is not a technical term. In other words, there are no specific technical analyses, or level of detail, that are classified by law as belonging to Appropriate Assessment rather than the screening for LSE. The Appropriate Assessment constitutes whatever level of further assessment is required to determine whether an adverse effect on integrity would arise.

3.3.2 Because it follows the screening process, there is an implication that the analysis will be more detailed than undertaken at the previous stage. One of the key considerations during Appropriate Assessment is whether there is available mitigation that would entirely address the potential effect, allowing for a conclusion of no adverse effect on integrity of a European Site. In practice, the Appropriate Assessment takes any element of the Proposed Development that could not be dismissed following HRA Stage 1 and assesses the potential for an effect in more detail, with a view to concluding whether there would be an adverse effect on site integrity (i.e. disruption of the coherent structure and function of the European Site(s) and the ability of the site to achieve its conservation objectives).

3.4 The Rochdale Envelope

3.4.1 Within Advice Note Nine: Rochdale Envelope (Planning Inspectorate, 2018), the Planning Inspectorate explains how the principles of the Rochdale Envelope should be used within the EIA process.

3.4.2 The Rochdale Envelope is applicable where some of the details of a Proposed Development cannot be confirmed when an application is submitted, and flexibility is needed to address uncertainty. Notwithstanding, all significant potential effects of a Proposed Development must be adequately addressed.

3.4.3 It encompasses three key principles:

- the assessment should use a cautious worst-case approach;
- the level of information assessed should be sufficient to enable the LSE of a Proposed Development to be assessed; and
- the allowance for flexibility should not be abused to provide inadequate descriptions of projects.

3.4.4 This HRA has given due consideration to the Rochdale Envelope in the screening process for LSE. The worst-case (i.e. the potentially most impactful) construction, operational and decommissioning scenarios identified within the relevant EIA chapters (ES Volume I - **Application Document Ref. 6.2**) have been assessed in relation to impact pathways.

3.5 Interaction with Other Competent Authorities

3.5.1 PINS Advice Note Ten (Planning Inspectorate, 2017) requires an evaluation of the potential for the Proposed Development to require other consents which could also require HRA by different competent authorities, and a statement as to whether the Order Limits for the Application overlaps with devolved administrations or other European States.

3.5.2 The relevant competent authority in this instance is the Secretary of State as Examining Authority. It is confirmed that the Order Limits for the Proposed Development does not overlap with areas of devolved administrations, nor with those of other European States.

3.6 Consultation with Natural England and/ or General Public

3.6.1 Regulation 63(3) and (4) of the Habitats Regulations refer to the need for, and option of, consultation with Natural England and the public respectively.

3.6.2 At both EIA Scoping stage and Stage 2 statutory consultation on the Preliminary Environmental Information (PEI) report (AECOM, November 2020), Natural England was consulted on the proposed scope of the ecological impact assessment (EcIA) and the preliminary findings of the EcIA. Their responses to both scoping and formal consultation stages of the ES and a summary of the comments received from Natural England in respect of the potential for adverse effects on European Sites is provided in **Table 11.3** of **Chapter 11**: Biodiversity and Nature Conservation (ES Volume I - **Application Document Ref. 6.2**).

3.6.3 Engagement continued leading up to submission of the Application, to provide copies of final draft documents and offer a pre-application meeting (which took place on 15 January 2021) to:

- discuss final proposals and assessments;
- obtain feedback prior to submission of Application; and
- agree an approach to drafting of Statements of Common Ground (SoCG) prior to submission of the Application

3.6.4 Technical engagement has then continued following submission of the Application, with further meetings in September 2021 to discuss and agree updates to the HRA.

3.6.5 Other consultees, including the Environment Agency, Marine Management Organisation (MMO), North Lincolnshire Council, and Lincolnshire Wildlife Trust, either deferred to Natural England's judgement regarding HRA, will await the results of the HRA once the application is submitted, or made no specific comment on HRA in their responses to statutory consultation (see **Table 11.3** within **Chapter 11**: Biodiversity and Nature Conservation (ES Volume I - **Application Document Ref. 6.2**)).

3.6.6 The public have been able to take part and provide their views of the Proposed Development through the Applicant's pre-application consultation processes. Information on responses is set out in the Consultation Report (**Application Document Ref 5.1**).

4.0 BASELINE EVIDENCE GATHERING

4.1 Scope of the Project

4.1.1 There is no guidance that dictates the scope of an HRA. Therefore, in considering the scope of the assessment, guidance was primarily provided by the identified impact pathways (called the 'source-pathway-receptor model').

4.1.2 Briefly defined, impact pathways are routes by which the implementation of a project can lead to an effect upon a European Site. An example of this would be visual and noise disturbance arising from the construction work or operational phase of a project. If there are sensitive ecological receptors within a nearby European Site (e.g. non-breeding overwintering birds), this could alter their foraging and roosting behaviour and potentially affect the integrity of the European Site. For some impact pathways (notably air pollution) there is guidance that sets out distance-based zones required for assessment. For others, a professional judgment must be made based on the best available evidence.

4.2 Relevant European Sites

4.2.1 Guidance published by the Environment Agency (Department for Environment, Food & Rural Affairs and Environment Agency, 2016) recommends that for large power generation developments greater than 50MW, a radius of search of 15km should be used when identifying relevant European Sites which may be affected by operational emissions to air. This is the approach adopted as originally identified in the Scoping Report (**Appendix 1A,** ES Volume II - **Application Document Ref 6.3**) and subsequently re-confirmed in the PEI Report (AECOM, 2020) for the Proposed Development.

4.2.2 The following European Sites were identified within a 15km radius of the Proposed Development:

- Humber Estuary Special Area of Conservation (SAC), which overlaps with the construction footprint for the Proposed Development and at its closest point is 1.3km east from the proposed location for the Proposed PCC Site;
- Humber Estuary Special Protection Area (SPA), which is located 9.2km north-east of the closest proposed construction activities and 9.8km north-east of the Proposed PCC Site;
- Humber Estuary Ramsar site, which is located as per the Humber Estuary SAC;
- Thorne Moor SAC, which is located 5.5km north-west of the closest proposed construction activities and 6.3km south-west of the Proposed PCC Site;
- Hatfield Moor SAC, which is located 8.2km south-west of the closest proposed construction activities and 10.4km north-west of the Proposed PCC Site; and

- Thorne and Hatfield Moors SPA, which at its closest point (Thorne Moor) is located 5.5km north-west of the closest proposed construction activities and 6.3km south-west of the Proposed PCC Site.

4.2.3 Therefore, these are the European Sites covered by the air quality impact assessment and discussed in Sections 5 and 6 of this report. Although Ramsar sites are not part of the formal network of European Sites, paragraph 176 of the National Planning Policy Framework (NPPF) (Ministry of Housing, Communities & Local Government, 2019) in England extends Ramsar sites the same level of protection as European Sites.

4.2.4 In addition to air quality, there are several other impact pathways such as construction and operational disturbance, temporary habitat disturbance and modification and water quality impacts that could arise from the Proposed Development. All relevant pathways are considered in this assessment.

4.2.5 Given the design and location of the Proposed Development, there are no likely impact pathways on European Sites located at greater than 15km from the Proposed Development. Therefore, the search radius applied to identify European Sites of relevance to the air quality impact assessment is considered worst-case and sufficiently precautionary for the requirements of the wider HRA of the Proposed Development.

4.2.6 An introduction to and a summary of the qualifying features, conservation objectives and threats/ pressures to the site integrity of the relevant European Sites, is provided in the following section. The location of these sites in relation to the Proposed Development is illustrated in **Figure 2**.

4.3 Humber Estuary SAC, SPA and Ramsar Site

Introduction

4.3.1 The Humber Estuary SAC/ Ramsar Site, the boundaries of which are almost contiguous, is a 36,657.15ha estuarine and coastal site located on the eastern coast of England (JNCC, 2015a; Natural England, 2019a). The boundaries of these sites overlap with the Proposed Development Site at the River Trent at Keadby.

4.3.2 The Humber Estuary SPA has a boundary that diverges more markedly from the above sites. As the boundary of the SPA excludes the River Trent it is not closely associated with the Proposed Development. The SPA applies to 37,630.24ha of estuarine and coastal habitat (JNCC, 2015b, Natural England, 2007).

4.3.3 The Humber Estuary is a large estuary with a high tidal range (macro-tidal). The high suspended sediment loads in the estuary feed a dynamic and rapidly changing system of accreting and eroding intertidal and sub-tidal mudflats and sandflats as well as saltmarsh and reedbeds. Other notable habitats include a range of sand dune types in the outer estuary, together with sub-tidal sandbanks and coastal lagoons. A number of developing managed realignment sites on the estuary also contribute to the wide variety of estuarine and wetland habitats. The estuary supports a full range of saline conditions from the open coast to the limit of saline intrusion. As salinity declines upstream, tidal reedbeds and brackish saltmarsh communities fringe the estuary.

4.3.4 Significant fish species include river lamprey (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*) which migrate through the estuary to breed in the upper reaches of the rivers of the Humber catchment. Grey seals (*Halichoerus grypus*) are species of the marine environment and come ashore in autumn to form large breeding colonies on the sandy shores of the south bank around Donna Nook, near Grimsby on the North Sea coastline. Natterjack toad (*Epidalea calamita*) is also relevant in the context of the Ramsar site and is present only on the North Sea coast between Saltfleetby-Theddlethorpe at the southern extremity of the Ramsar site.

4.3.5 The estuary is used by many species of wintering and passage waterbirds attracted by the different habitats of the SPA. For example, the sandy sediments of the outer estuary typically attract knot (*Calidris canutus*) and grey plover (*Pluvialis squatarola*), while waterfowl prefer the wetland zones of the upper estuary. At high tide, large mixed flocks congregate in key roost sites which are at a premium due to the combined effects of extensive land claim, coastal squeeze and lack of grazing marsh and grassland on both banks of the estuary. In summer, the SPA site supports important breeding populations of bittern (*Botaurus stellaris*), marsh harrier (*Circus aeruginosus*), avocet (*Recurvirostra avosetta*) and little tern (*Sternula albifrons*).

SAC Qualifying Features (Natural England, 2018a)

4.3.6 The site qualifies as a SAC under Article 4.4 of the Habitats Directive (Council Directive 92/43/EEC) (European Commission, 1992) by supporting the following Annex I habitats and Annex II species, as per the conservation objectives for the SAC updated in November 2018:

- Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*);
- coastal lagoons;
- dunes with *Hippophae rhamnoides*;
- embryonic shifting dunes;
- estuaries;
- fixed coastal dunes with herbaceous vegetation ("grey dunes");
- mudflats and sandflats not covered by seawater at low tide;
- *Salicornia* and other annuals colonizing mud and sand;
- sandbanks which are slightly covered by sea water all the time;
- shifting dunes along the shoreline with *Ammophila arenaria* ("white dunes");
- sea lamprey;

- river lamprey; and
- grey seal.

SPA Qualifying Features (Natural England, 2019b)

4.3.7 The site qualifies as a SPA under Article 4.1 of the Birds Directive (79/409/EEC) by supporting populations of the following features, as per the conservation objectives for the SPA updated in February 2019:

- *Botaurus stellaris*; Great bittern (Non-breeding);
- *Botaurus stellaris*; Great bittern (Breeding);
- *Tadorna tadorna*; Common shelduck (Non-breeding);
- *Circus aeruginosus*; Eurasian marsh harrier (Breeding);
- *Circus cyaneus*; Hen harrier (Non-breeding);
- *Recurvirostra avosetta*; Pied avocet (Non-breeding);
- *Recurvirostra avosetta*; Pied avocet (Breeding);
- *Pluvialis apricaria*; European golden plover (Non-breeding);
- *Calidris canutus*; Red knot (Non-breeding);
- *Calidris alpina alpina*; Dunlin (Non-breeding);
- *Philomachus pugnax*; Ruff (Non-breeding);
- *Limosa limosa islandica*; Black-tailed godwit (Non-breeding);
- *Limosa lapponica*; Bar-tailed godwit (Non-breeding);
- *Tringa totanus*; Common redshank (Non-breeding);
- *Sterna albifrons*; Little tern (Breeding); and
- non-breeding waterbird assemblage.

Ramsar Qualifying Features (JNCC, 2007)

4.3.8 The site qualifies as a Ramsar for the following Ramsar criteria:

- **Criterion 1** - The site is a representative example of a near-natural estuary with the following component habitats: dune systems and humid dune slacks, estuarine waters, intertidal mud and sand flats, saltmarshes, and coastal brackish/ saline lagoons;
- **Criterion 3** - The Humber Estuary Ramsar site supports a breeding colony of grey seals at Donna Nook, the second largest grey seal colony in England. The dune slacks at Saltfleetby-Theddlethorpe on the southern extremity of the Ramsar site are the most north-easterly breeding site in Great Britain of the natterjack toad;

- **Criterion 5** – The site supports an assemblage of international importance. This is an assemblage of 153,934 waterfowl during the non-breeding season (5-year peak mean 1996/97-2000/2001);
- **Criterion 6** – The site species/ populations occur at levels of international importance. These being:
  - common shelduck, 4,464 individuals, wintering, representing an average of 1.5% of the Great Britain wintering population (5-year peak mean 1996/7-2000/1);
  - Eurasian golden plover, 30,709 individuals, wintering, representing an average of 3.3% of the population (5-year peak mean 1996/7-2000/1);
  - red knot, 28,165 individuals, wintering, representing an average of 6.3% of the population (5-year peak mean 1996/7-2000/1);
  - dunlin, 22,222 individuals, wintering, representing an average of 1.7% of the population (5-year peak mean 1996/7-2000/1);
  - black-tailed godwit, 1,113 individuals, wintering, representing an average of 3.2% of the population (5-year peak mean 1996/7-2000/1);
  - bar-tailed godwit, 2,752 individuals, wintering, representing an average of 2.3% of the population (5-year peak mean 1996/7-2000/1); and
  - common redshank, 4,632 individuals, wintering, representing an average of 3.6% of the population (5-year peak mean 1996/7-2000/1).
- **Criterion 8** - The Humber Estuary acts as an important migration route for both river lamprey and sea lamprey between coastal waters and their spawning areas.

Conservation Objectives (Natural England, 2018a and 2019b)

4.3.9 Regarding the Humber Estuary SAC natural habitats and/ or species for which the site has been designated (the 'Qualifying Features') and subject to natural change (Natural England, 2018a), the conservation objectives are to '*ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring*:

- *the extent and distribution of qualifying natural habitats and habitats of qualifying species;*
- *the structure and function (including typical species) of qualifying natural habitats;*
- *the structure and function of the habitats of qualifying species;*
- *the supporting processes on which qualifying natural habitats and habitats of qualifying species rely;*
- *the populations of qualifying species; and*
- *the distribution of qualifying species within the site*.'

4.3.10 Regarding the Humber Estuary SPA and the individual species and/ or assemblage of species for which the site has been classified (the 'Qualifying Features'), and subject to natural change (Natural England, 2019b), the conservation objectives are to '*ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the aims of the Wild Birds Directive, by maintaining or restoring:*

- *the extent and distribution of the habitats of the qualifying features;*
- *the structure and function of the habitats of the qualifying features;*
- *the supporting processes on which the habitats of the qualifying features rely;*
- *the population of each of the qualifying features; and*
- *the distribution of the qualifying features within the site*.'

Threats/ Pressures to Site Integrity (Natural England, 2015)

4.3.11 The following threats/ pressures to the site integrity of the Humber Estuary SAC and SPA have been identified in Natural England's Site Improvement Plan (Natural England, 2015):

- water pollution;
- coastal squeeze;
- changes in species distributions;
- under-grazing;
- invasive species;
- natural changes to site conditions;
- public access/ disturbance;
- fisheries: fish stocking;
- fisheries: commercial marine and estuarine;
- direct land-take from development;
- air pollution: impact of atmospheric nitrogen deposition;
- shooting/ scaring;
- direct impact from third party; and
- inappropriate scrub control.

4.4 Thorne Moor SAC, Hatfield Moor SAC and Thorne and Hatfield Moors SPA

Introduction

4.4.1 The Thorne Moor and Hatfield Moors SAC, which both contain habitats designated as Thorne and Hatfield Moors SPA, together comprise 30,280.91ha of degraded raised bog with associated standing water, fen, heathland and woodland habitats and are located in South Yorkshire between Doncaster and Scunthorpe (JNCC, 2015c and 2015d). The boundaries of these sites do not overlap with the Proposed Development Site, and instead at the closest point are located 5.5km from the Proposed Development Site.

SAC Qualifying Features (Natural England, 2018b and 2018c)

4.4.2 Thorne Moor and Hatfield Moor both qualify as SAC under Article 4.4 of the Habitats Directive (Council Directive 92/43/EEC) (European Commission, 1992) as they both support 'degraded raised bogs still capable of natural regeneration' Annex I habitat, as per the conservation objectives set for each of the SAC and updated in November 2018.

SPA Qualifying Features (Natural England, 2019c)

4.4.3 The Thorne and Hatfield Moors SPA qualifies under Article 4.1 of the Birds Directive (79/409/EEC) by supporting populations of European nightjar (*Caprimulgus europaeus*) (Breeding), as per the conservation objectives for the SPA updated in February 2019.

Conservation Objectives (Natural England, 2018b, 2018c and 2019c)

4.4.4 With regard to natural habitats and/ or species for which both the Thorne Moor SAC and the Hatfield Moor SAC have been designated (the 'Qualifying Features'), and subject to natural change (Natural England, 2018b and 2018c), the conservation objectives are identical between the two sites and are to '*ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring*:

- *the extent and distribution of qualifying natural habitats;*
- *the structure and function (including typical species) of qualifying natural habitats; and*
- *the supporting processes on which qualifying natural habitats rely*.'

4.4.5 Regarding the Thorne and Hatfield Moors SPA, individual species and/ or assemblage of species for which the site has been classified (the 'Qualifying Features'), and subject to natural change (Natural England, 2019c), the conservation objectives are to '*ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the aims of the Wild Birds Directive, by maintaining or restoring:*

- *the extent and distribution of the habitats of the qualifying features;*
- *the structure and function of the habitats of the qualifying features;*
- *the supporting processes on which the habitats of the qualifying features rely;*

- *the population of each of the qualifying features; and*
- *the distribution of the qualifying features within the site*.'

Threats/ Pressures to Site Integrity (Natural England, 2014)

4.4.6 The following list of threats/ pressures to the site integrity of the Thorne Moor SAC, Hatfield Moor SAC and Thorne and Hatfield Moors SPA have been identified in Natural England's combined Site Improvement Plan (Natural England, 2014):

- drainage;
- inappropriate scrub control;
- air pollution: impact of atmospheric nitrogen deposition;
- public access/ disturbance;
- planning permission: general;
- peat extraction; and
- invasive species.

5.0 TEST OF LIKELY SIGNIFICANT EFFECTS

5.1 Overview

5.1.1 This section examines the LSE of the Proposed Development. It is structured by development phase, first by construction period and then by the operation and decommissioning periods.

5.1.2 Given the timeline for future decommissioning, which would not take place until circa 25 years following commencement of operations, the parameters for assessment of this are less certain. Given this, the construction phase is considered a reasonable and suitably precautionary proxy for potential impacts during decommissioning. This is because requirements at decommissioning (demolition and removal of infrastructure installed at construction) will be comparable to or of lesser scale and magnitude than those at construction. It is also assumed that comparable permitting and regulatory regimes will control the potential impact of decommissioning on the natural environment, in the same way that they do during construction and operation.

5.1.3 **Chapter 5**: Construction Programme and Management (ES Volume I - **Application Document Ref. 6.2**) identifies that the Proposed Development will not involve any demolition. This development phase is therefore not discussed and is excluded from the screening matrices.

5.1.4 The European Sites included within this screening assessment, as first identified and described above in Sections 4.3 and 4.4 of this report, are:

- Humber Estuary SAC;
- Humber Estuary SPA;
- Humber Estuary Ramsar site;
- Thorne Moor SAC;
- Hatfield Moor SAC; and
- Thorne and Hatfield Moor SPA.

5.1.5 The potential pathways for impact on these European Sites are drawn from those summarised in **Appendix A** of this report, which provides the completed 'Appendix 1 Screening Matrix' template required to comply with Advice Note Ten (Planning Inspectorate, 2017).

5.1.6 Each of the potential impact pathways identified in **Appendix A** (e.g. noise and visual disturbance, air quality etc.) is discussed separately for each development phase (construction and/ or operation) to which that impact pathway applies. A summary statement is also provided for decommissioning.

5.2 Construction Period

Habitat Disturbance and Modification

5.2.1 If the preferred cooling water abstraction from the Stainforth and Keadby Canal is not available (Work No. 4A in **Application Document Ref. 4.3**), localised and temporary in-channel and bank works may be required on the River Trent within the Humber Estuary SAC and Ramsar site.

5.2.2 This is because if the River Trent is used for cooling water abstraction there would be a need to upgrade the existing River Water Abstraction (Work No. 4B on **Application Document Ref. 4.3**) for the purposes of installation of an eel screen. The maximum worst-case working areas for these upgrade activities, if required, is 0.13ha. A cofferdam would be required to establish a safe working area during the upgrade works and the indicative extent of this is illustrated in **Figure 12C.10** of **Appendix 12C**: Navigational Risk Assessment (ES Volume II – **Application Document Ref. 6.3**). This does not require any new land-take from these European Sites, but assessment is required of the potential for these works to temporarily disturb qualifying habitat features. This assessment is provided below from paragraph 5.2.4 onwards. It should be noted that the extent of the cofferdam is smaller than the Order Limits, as the latter includes allowance for boat access during cofferdam installation.

5.2.3 The Applicant is also proposing to re-use existing assets and pipework for Keadby 1 Power Station for the discharge of treated cooling water effluent to the River Trent. A Water Discharge Corridor is included in the Proposed Development Site comprising the easement of the existing cooling water corridor north-east from Keadby 1 Power Station, connecting with the River Trent. Interconnecting pipework would extend from Proposed PCC Site to connect to this infrastructure. As part of refurbishment and/ or replacement works within the Water Discharge Corridor, various ancillary works may be required although works are not envisaged at the outfall structure (Work No. 5 - **Application Document Ref. 4.3)**. As no construction works are required within the European Sites in relation to the discharge structure, there would be no habitat disturbance or loss at this location. Consequently, no further assessment is required of this element of the Proposed Development.

5.2.4 At the location of the existing river water abstraction structures (as described in **Appendix 11C**: Preliminary Ecological Appraisal Report of ES Volume II - **Application Document Ref. 6.3**) the River Trent is a large (approximately 150m wide) tidal watercourse. An engineered flood embankment is present along the eastern bank of the river, protecting the village of Keadby, which supports species-poor improved grassland and is regularly mown. At the time of the surveys for the Proposed Development (April and July 2020) the water within the River Trent was highly turbid due to suspended sediment, as would be expected for a tidal river reach. No aquatic higher plant species were observed within the channel of the river, except for a few fronds of greater duckweed (*Spirodela polyrhiza*). No other in-channel higher plant species would reasonably be expected given this is a tidal reach of a very large river.

5.2.5 Along the margins of the River Trent (both banks), above the typical high tide water level, there are narrow strips of transitional vegetation dominated by common reed (*Phragmites australis*) with abundant to occasional hemlock water-dropwort (*Oenanthe crocata*), hedge bindweed (*Calystegia sepium* subsp. *sepium*), wild angelica (*Angelica sylvestris*), great willowherb (*Epilobium hirsutum*), reed canary-grass (*Phalaris arundinacea*) and cleavers (*Galium aparine*). At the base of this marginal vegetation but above the water line, the only plant species observed were New Zealand pigmyweed (*Crassula helmsii*) and creeping buttercup (*Ranunculus repens*). Below this zone is bare mud at low tide.

5.2.6 Natural England has advised that this species-poor riparian vegetation should be considered saltmarsh in the context of the Humber Estuary designations. However, this vegetation is not of a type listed as a qualifying interest feature of the Humber Estuary SAC and Ramsar site, as set out in Section 4.3. The only type of saltmarsh vegetation identified as a qualifying feature is the 'Salicornia and other annuals colonising mud' vegetation and this does not accord with the perennial vegetation observed along the margins of the River Trent as described above.

5.2.7 Therefore, the relevant qualifying habitat features of the Humber Estuary SAC and Ramsar site present at the locations of the proposed construction works are:

- estuaries – encompassing the main river channel; and
- mudflats and sandflats not covered by seawater at low tide – encompassing the marginal mud banks exposed at low tide (sandflats are not present, so henceforth are not referred).

5.2.8 The setting of the River Water Cooling Option (Work 4B) is shown below in **Plate 3**, which confirms the above statement on the habitats of relevance at the locations of the proposed construction works. The intention is that the cofferdam ties into the bank as close as possible to the footprint of the existing river water abstraction structure, which includes an existing submerged concrete apron located immediately in front of the visible structure. Therefore, based on **Plate 3**, it will coincide with the vertical reinforced banks of the existing wharf to the left of the existing structure, and the stand of dense scrub to the right of the existing structure.

5.2.9 Based on the setting shown in **Plate 3** there is potential for construction and use of a cofferdam to disturb mudflat and estuary habitats for which the relevant European Sites are designated. Therefore, this specific pathway is **screened in** for Appropriate Assessment.

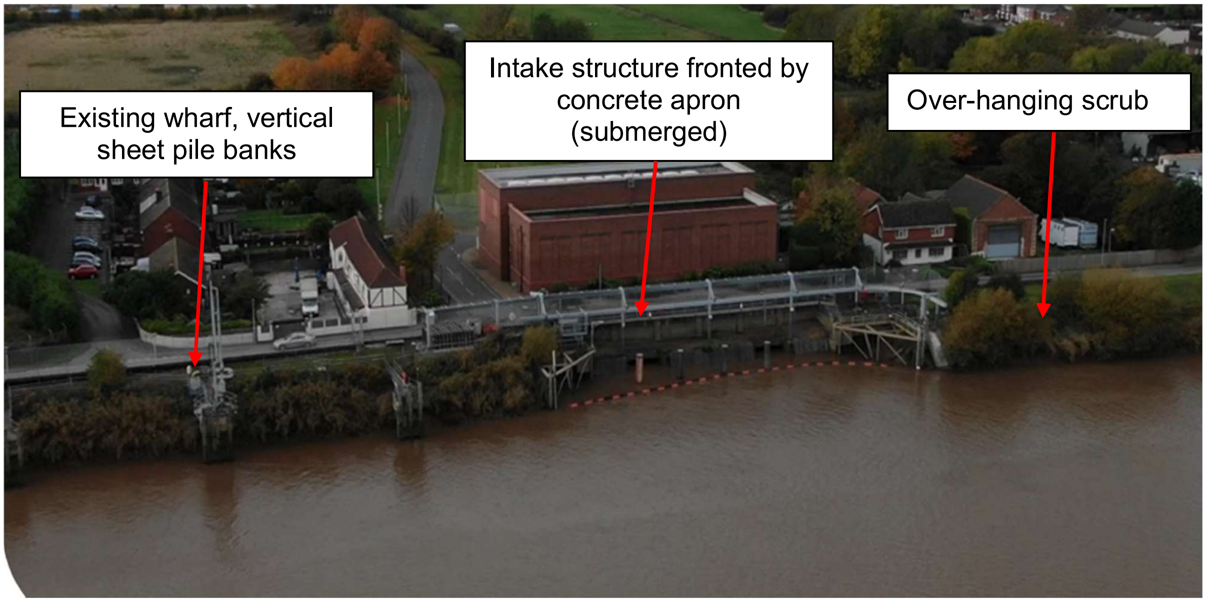


Plate 3: Location of the River Water Abstraction (Work 4B)/ existing Keadby 1 Power Station water intake structure (image taken at high tide)

Visual and Noise/ Vibration Disturbance

5.2.10 The designated interest features of relevance, in the sequence that they are assessed below, are:

- bird species for which the Humber Estuary SPA and Ramsar site are designated; and
- lamprey species for which the Humber Estuary SAC and Ramsar site are designated.

5.2.11 The Natural England Site Improvement Plan for the Humber Estuary SPA highlights that this site and its qualifying bird species are potentially sensitive to public access and disturbance, primarily because of recreational use (Natural England, 2014 and 2015). So, they are also sensitive to other potential sources of visual and noise disturbance, such as those that would arise during construction. While the Humber Estuary SPA is located more than 9km from the closest potential construction works for the Proposed Development, Natural England has advised that it cannot be discounted that the habitats along the River Trent have value as foraging habitat for qualifying bird species. Therefore, assessment is needed of potential visual and airborne noise disturbance in relation to such habitat usage.

5.2.12 Similarly, there is a need to consider visual and airborne noise disturbance on birds in relation to the Humber Estuary Ramsar site, as the boundary coincides with the location of the Proposed Development at the locations of the Waterborne Transport Offloading Area (**Work 10b** on **Application Document Ref. 4.3**), the River Water Abstraction Option (**Work No. 4B** on **Application Document Ref. 4.3**) and the Cooling Water Discharge (**Work No. 5A** on

Application Document Ref. 4.3). All other construction activities will be undertaken in locations at greater distance from the Ramsar site, to the west of Keadby village. Most construction activities, and the potentially most intrusive longer-term activities, will be focussed on the location of the Proposed PCC Site and are therefore located more than 1km from the Ramsar site.

5.2.13 Of the qualifying bird species listed in Section 4.3, it is wading birds (except for pied avocet) and shelduck that are of potential relevance to the Proposed Development. Great bittern can be scoped out given it is dependent on large stands of reedbed that only occur around the main estuary, with the closest habitat located in the Blacktoft Sands area. Marsh and hen harrier both require similar habitats for the purposes of breeding and/ or foraging, again meaning that they are unlikely to have more than incidental presence along the River Trent, and adjacent land (which is intensively farmed) is also not considered to be of functional importance for these species. Pied avocet is a wader species that breeds in association with saline lagoons, which again is a habitat only present around the main estuary and within Blacktoft Sands at the closest point. Finally, there are no breeding habitats for little tern along the River Trent given this is a strictly coastal species that favours beaches as nesting habitat.

5.2.14 Therefore, the qualifying bird species of potential relevance are non-breeding populations of common shelduck, European golden plover, red knot, dunlin, ruff, black-tailed godwit, bar-tailed godwit, common redshank, and a wider non-breeding waterbird assemblage. The latter encompasses the named waterbird species dependent on mudflat habitats, and other wading species making use of this habitat. None of the other bird species (black-bellied brent goose *Branta bernicla bernicla* and duck species) encompassed under the 'assemblage' criterion are likely to make use of the River Trent given the absence of optimal foraging habitats. Again, these latter species will be focussed at Blacktoft Sands and other habitats around the main estuary.

5.2.15 Of the potential construction Noise Sensitive Receptors (NSR) modelled for the Proposed Development (**Chapter 9:** Noise and Vibration, ES Volume I - **Application Document Ref. 6.2**), NSR 4 is located within Keadby village between the Proposed PCC Site and the River Trent. It is therefore the closest NSR to both the main construction activities for the Proposed Development and the river, and consequently provides a sound basis for determining the likely worst-case construction noise levels received at the River Trent from all construction activities except for installation of a cofferdam for the potential River Water Abstraction Option (if required) (the potential cofferdam is considered separately below).

5.2.16 As confirmed in **Chapter 9:** Noise and Vibration, ES Volume I - **Application Document Ref. 6.2**) the selection of the Proposed PCC Site and development of the indicative concept layout have already included consideration of potential noise effects and proximity to human and environmental NSR, and include measures such as positioning plant close to the existing Keadby 1 Power Station in order to increase the distance between plant and the NSR (the closest of which are the human NSR at Keadby village). Keadby 1 Power Station is located approximately 450m west of the River Trent and is screened from it by the existing flood embankment and housing along Trent Side Road.

5.2.17 The worst-case modelled airborne noise level as a result of construction activities for the Proposed PCC Site (i.e. the main civil engineering works) at NSR 4 is 45dB which is predicted to occur during weekday daytime construction hours. This noise level is comparable with the baseline sound levels at NSR 4 reported in Chapter 9 i.e. 44 to 45dB, and the combined worst-case noise level during construction is predicted to be 48dB (which is a 3dB increase over the baseline level). This is a very small increase over the baseline that would only just be discernible to the human ear. Regular construction noise below 50dB is also not likely to result in an impact on birds (Cutts *et al.*, 2009). It is therefore concluded that construction activities for the Proposed PCC Site would not result in noise levels that are likely to be adverse for qualifying bird species of the Humber Estuary SPA and Ramsar site. <u>The potential impact pathway from construction of the Proposed PCC Site can therefore be discounted</u>.

5.2.18 The construction activities that might directly affect the River Trent (i.e. the cofferdam and subsequent works to upgrade the existing River Water Abstraction Structure) would only be necessary if for any reason the preferred Canal Water Abstraction Option is not possible. If required, the extent of piling activities would be very limited relative to the size of the watercourse, extending into the river channel for up to 22m (focussed on a single intake structure) which is a relatively small distance in the context of a river channel that is circa 150m wide.

5.2.19 Construction of the cofferdam, if required in the River Trent, will be of limited duration, as explained in (**Appendix 11H:** Underwater Sound Effects on Fish, ES Volume II - **Application Document Ref. 6.3**). In summary, the worst-case construction parameters of relevance to this assessment are as follows:

- the cofferdam would require approximately 100m of sheet piles which equates to approximately 200 individual piles;
- based on the relatively shallow depth of water in which the cofferdam is proposed, it is assumed that the cofferdam will comprise a single wall, but the structure will require bracing and pile ties to secure the cofferdam wall before dewatering. Thus, periods of piling activity will be regularly interspersed with other construction activities that are not likely to diverge noticeably from baseline ambient sound levels;
- it is estimated that each pile will take 1-2 hours to install, depending on conditions, and that 4-5 piles can be installed per day based on the core construction working hours from 07:00 to 19:00 (**Chapter 5**: Construction Programme and Management (**ES Volume I - Application Document Ref. 6.2**));
- on this basis, the estimated piling installation time (vibratory and impact) for the cofferdam will be up to 25 days. This will be spread throughout the cofferdam construction period which is expected to also involve bracing and addition of pile ties as the construction progresses; and

- soft-start procedure will be applied to avoid generation of sudden large noises. Any break in impact piling greater than 10 minutes would trigger a new soft-start procedure allowing a period of lower sound intensity before the next peak.

5.2.20 Modelling of noise levels during installation of a cofferdam, using the methods described in **Chapter 9:** Noise and Vibration, ES Volume I - **Application Document Ref. 6.2**), has confirmed that noise levels above the 50dB (the threshold for a potential impact on birds) would occur as a result of piling works for the cofferdam. The contour maps showing the modelled noise levels resulting from piling of a cofferdam, if required in the River Trent, are reproduced as Figures 3 and 4 of this HRA Appropriate Assessment Report. This specific pathway is **screened in** for Appropriate Assessment in relation to the wading bird and shelduck qualifying interest features of the Humber Estuary.

5.2.21 Moving onto consideration of river and sea lamprey for which the Humber Estuary SAC and Ramsar site are designated, construction of a cofferdam on either watercourse being considered as the potential cooling water has the potential to result in underwater construction noise and vibration impacts from piling activities and this could potentially have a temporary deterrent effect on the ability of lamprey to access breeding habitats in the wider River Trent catchment, and to return to the Humber Estuary from these habitats. This specific pathway is **screened in** for Appropriate Assessment.

Entrapment of Lamprey

5.2.22 River and sea lamprey are anadromous migratory species (i.e. migrate upstream to breed) and live their adult life in the estuarine or marine environment, feeding parasitically on the tissue and blood of other fish. After one to two years, lamprey become sexually mature and begin their upstream migration to reach suitable spawning grounds within stony and well oxygenated riffle habitat (Maitland, 2003).

5.2.23 Young larvae of all lamprey species are known as ammocoetes and when they emerge from their spawning gravels, they drift downstream and spend several years burrowing in silt and feeding (Maitland, 2003). Lamprey ammocoetes and their habitat occupy the headwaters of the catchment, so this life stage is not relevant to this assessment as it does not occur in the zone of influence of the Proposed Development. Ammocoetes metamorphosize into a 'transformer' stage (a pre-breeding sub-adult stage) after three to five years, and then migrate downstream to estuaries and coastal regions (Maitland, 2003). The minimum likely size of the smallest life stage (transformer) of the smaller of the two lamprey species (river lamprey) at point of entry into estuary systems averages about 10cm in length (Environment Agency, 2005).

5.2.24 All resident and migratory fish species, including but not restricted to river and sea lamprey, could potentially (if present at the time of installation) be trapped within any cofferdam installed to create a dewatered area during construction works for the chosen Water Abstraction Option. Consequently, to comply with legislation protecting the welfare of all fish species, measures are committed that are suitable to protect all fish species from harm. The likelihood of fish becoming trapped would be markedly reduced by the deterrent effect arising from noise and vibration during cofferdam installation (which has been assessed separately) and the siting of the cofferdam to enclose (as far as reasonably practicable) only the sub-optimal habitats located over the existing concrete apron of the existing Keadby 1 Power Station abstraction infrastructure).

5.2.25 Should any fish, including but not exclusively lamprey, species become trapped within the cofferdam, then they would be at no immediate risk. Instead, the risk would arise during drawdown of water levels to create a dry working area for construction. If a cofferdam is required on the River Trent, it would also need to be installed in a manner that delivers legislative compliance with a deemed marine licence (DML) under Part 4 of the Marine and Coastal Access Act 2009, which is proposed to be secured as part of the Draft DCO (**Application Document Ref. 2.1**). Consequently, early regard has been given to specification and commitment to appropriate cofferdam construction working methods to achieve this. In relation to ecology these are set out in the Framework CEMP (**Application Document Ref. 7.1**) and within the Landscape and Biodiversity Management and Enhancement Plan (**Application Document Ref. 5.10**).

5.2.26 The committed good practice construction approach to safeguarding all species of fish during cofferdam installation and dewatering involves a 'fish rescue' comprising:

- use of screening on pump intakes to prevent all fish, including lampreys of the minimum size likely to be encountered (10cm), being drawn into the pipe/ pump during dewatering; and
- supervision of dewatering by an appropriately experienced fish ecologist so that legally binding fish welfare requirements are met, and to relocate any stranded fish, which would include lampreys, back to the main channel of the relevant watercourse as soon as possible after capture.

5.2.27 In comparison with many of the fish species protected by legislation and that need to be addressed during the fish rescue, lamprey species are known to be highly robust and therefore would not reasonably be expected to suffer injury through the above process. The anguilliform body shape of lampreys coupled with their adaptation to burrowing in sediments means that they are well-protected from collision and abrasion (Teague and Clough, 2014). The minimum size of the lampreys likely to be present also means they would be detectable by experienced fish ecologists.

5.2.28 Existing committed working methods, and legal and regulatory regimes applicable to all fish species are sufficient to remove the potential pathway for impact on lampreys through entrapment. The size range of lampreys likely to be encountered and their resilient morphology is also sufficient to conclude that they would be detected during general fish rescue procedures and suffer no injurious effect from fish rescue. Given this, construction works will not result in

LSE at the Humber Estuary SAC and Ramsar site or interfere with the ability of these sites to achieve their conservation objectives. This specific pathway is screened out from Appropriate Assessment.

Invasive Non-Native Species

5.2.29 The Preliminary Ecological Appraisal (PEA) of the Proposed Development (**Appendix 11C**, ES Volume II - **Application Document Ref. 6.3**) identified several invasive non-native plant and animal species present within the River Trent or the Stainforth and Keadby Canal. These include zebra mussel (*Dreissena polymorpha*) and Nuttall's waterweed (*Elodea nuttallii*) in the canal, and New Zealand pigmyweed (*Crassula helmsii*) which is widely scattered along the banks of the River Trent at and immediately downstream of the River Water Abstraction Option and the Cooling Water Discharge, within the boundary of the Humber Estuary SAC and Ramsar site. These species are already well established, and there are no barriers to the dispersal of these species between the canal and the river. Given this, construction works would not interact with these species in a manner that would pose a new threat to the Humber Estuary SAC and Ramsar site, and the Humber Estuary SPA located further downstream. The pathway for spread already exists, is uncontrolled, and these species are present where habitats are suitable for establishment.

5.2.30 The PEA identified no other invasive non-native species (INNS) in association with other waterbodies where construction works would take place. Given this, there are no other INNS that are likely to be transferred to the River Trent where construction vehicles, plant, materials etc. are proposed to be moved and/ or used between different parts of the construction site. Given the known presence of invasive species, and legal obligations in relation to this, the Framework Construction Environmental Management Plan (CEMP) (**Application Document Ref. 7.1**) for the Proposed Development includes general biosecurity measures to mitigate the risk of these known species being transferred from the construction site into the wider landscape. These committed measures will also be applied so that construction vehicles, plant, materials brought into the construction site from other locations do not serve as vectors for introduction of other INNS to the Proposed Development Site, including the River Trent.

5.2.31 In this context, construction works are not likely to introduce INNS and therefore will not result in LSE at the Humber Estuary SAC and Ramsar site or interfere with the ability of these sites to achieve their conservation objectives. This specific pathway is screened out from Appropriate Assessment.

Atmospheric Pollution

5.2.32 Construction activities have potential to impact European Sites through:

- dust, which may be generated by:
  - earthworks (soil stripping, spoil movement and stockpiling);
  - construction (including on-site concrete batching); and

  - trackout (HGV movements on unpaved roads and offsite mud on the highway).
- emissions of pollutants to air (oxides of nitrogen (NOx) and nitrogen deposition, although commentary on sulphur dioxide (SO_2) is also provided below) because of movements of construction traffic on-site and on the affected road network.

5.2.33 To assess this further in accordance with typical accepted good practice, as described in **Appendix 8A**: Air Quality – Construction Phase (ES Volume II – **Application Document Ref. 6.3**), a qualitative assessment has been made of construction dust, and modelling of construction phase road traffic emissions has been undertaken. The latter modelling was undertaken as detailed in current guidance (Institute of Air Quality Management, 2017), and is a 'detailed level' assessment that uses dispersion modelling to predict pollutant concentrations, considering additional variables. The assessment used the Atmospheric Dispersion Modelling System for Roads (ADMS Roads) model (version 4.1.1) to predict road pollutant contributions at identified sensitive receptors.

5.2.34 The only European Sites in the zone of influence of potential dust emissions from construction works (which is up to 500m from source) are the Humber Estuary SAC and Ramsar site. Dust could affect qualifying habitat features through mechanisms such as smothering and direct toxicity (although the latter is not likely given legal requirements and public health considerations). There are no species features for which construction dust would be a relevant consideration.

5.2.35 The qualifying habitat features within this zone of influence relevant to the assessment of dust are (as explained above in Sections 4.3 and 5.2):

- estuaries – encompassing the main river channel; and
- mudflats and sandflats not covered by seawater at low tide – encompassing the marginal mud banks exposed at low tide.

5.2.36 The estuary and mudflat habitats are either permanently submerged, or periodically exposed and re-submerged as part of the normal tidal cycle. Any dust deposited in these circumstances would add trivially to the existing high sediment load already carried by the estuary.

5.2.37 <u>In this context, dust deposition from construction works will not result in LSE at the Humber Estuary SAC and Ramsar site or interfere with the ability of these sites to achieve their conservation objectives. This specific pathway is screened out from Appropriate Assessment.</u>

5.2.38 The incomplete combustion of fuel in vehicle engines results in the presence of potential pollutants (combustion products), of which the main pollutants of concern for European Sites are SO_2 and NO_x.

5.2.39 Although SO_2 is of theoretical relevance, detailed consideration of the associated impacts on local air quality is not considered necessary in relation to the construction activities for the Proposed Development. This is because the relevant construction activities are of types that are not generally considered likely to produce concentrations of SO_2 high enough to result in LSE. In addition, no areas within the administrative boundaries of the relevant council (North Lincolnshire Council, 2019) are considered at risk of exceeding the relevant objectives for SO_2. Consequently, the risks to the attainment of the relevant air quality objectives in the vicinity of the Proposed Development Site are considered negligible. Emissions of SO_2 from construction traffic therefore do not require further assessment.

5.2.40 NO_x can be toxic at very high concentrations (at levels far above the annual average critical level). But counter to this, APIS identifies that direct toxic effects are only likely to arise in the presence of equivalent concentrations of sulphur dioxide (SO_2) which, as stated above, would not occur. However, and therefore of greater relevance, high levels of NO_x can also increase the total nitrogen deposition to soils, potentially leading to deleterious knock-on effects in resident ecosystems. For example, an increase in the total nitrogen deposition from the atmosphere is widely known to enhance soil fertility and to lead to eutrophication. This often has adverse effects on the community composition and quality of semi-natural, nitrogen-limited terrestrial and aquatic habitats (Wolseley *et al*, 2006; Dijk, 2011). The total nitrogen deposition resulting from a plan or project is therefore often assessed as the overarching parameter of relevance for determining the impact of atmospheric pollution from traffic sources. Indeed, current air quality guidance issued by Highways England (2019) focusses solely on nitrogen deposition in relation to ecological features.

5.2.41 The potential zone of influence of construction traffic movements, as defined and used in **Appendix 8A:** Air Quality - Construction Phase (ES Volume II – **Application Document Ref. 6.3**), is 200m from road links in the study area. According to Highways England (2019), beyond 200m the contribution of vehicle emissions from the roadside to local pollution levels can be considered insignificant. The only European Sites in the zone of influence of construction traffic movements are the Humber Estuary SAC and Ramsar site, and the relevant habitats are again estuaries and mudflats. The Humber Estuary SPA may also be relevant where certain qualifying bird species also make use of (are functionally dependent on) habitats present in the SAC and Ramsar site.

5.2.42 The atmospheric dispersion modelling and predicted impacts on European Sites reported in **Appendix 8A**: Air Quality – Construction Phase (ES Volume II – **Application Document Ref. 6.3**) uses traffic data (Annual Average Daily Traffic (AADT)), as reported in **Chapter 10:** Traffic and Transportation (ES Volume I - **Application Document Ref. 6.2**) which anticipates that there would be in the order of 1,020 two-way vehicle movements per day during the peak construction period.

5.2.43 Chartered Institute of Ecology and Environmental Management (CIEEM) (2021) states that in the UK, the approach to assessing impacts, particularly at the screening stage of HRA, concentrates on the change in levels arising from a proposed plan or project (either alone or in combination) irrespective of whether critical loads or levels are currently being exceeded at a site. For example, Natural England guidance (2018d) states that a project that will result in an increase of no more than 1% of critical loads or levels (either alone or in combination) can be regarded as insignificant in terms of air quality assessment. It is argued that such an approach can be supported by Advocate General Sharpston's Opinion in Case C-258/11 (Peter Sweetman and Others v An Bord Pleanála, 11 April 2013) where at paragraph 48 she stated '*the requirement for an effect to be 'significant' exists in order to lay down a de minimis threshold. Plans and projects that have no appreciable effect on the site can therefore be excluded. If all plans and projects capable of having any effect whatsoever on the site were to be caught by Article 6(3), activities on or near the site would risk being impossible by reason of legislative overkill*' (European Court of Justice, 2013).

5.2.44 The Air Pollution Information System (APIS) forms the major source of information regarding the air quality impact pathway. It specifies a critical NO_x concentration (critical level) for the protection of vegetation of 30μgm^{-3}. This critical level would only be exceeded at one of the 20 locations modelled for the Humber Estuary SAC and Ramsar site (where the A18 Station Road crosses the River Trent), with 46.6μgm^{-3} predicted at 5m from the affected road network. Therefore, the predicted exceedance would affect only a minimal part of the European Sites. While the critical level is predicted to be exceeded this also does not automatically mean there would be an impact within the very limited zone of influence, only that the results of the modelling should be considered further. In this case, the relevant estuary and mudflat habitats within the River Trent at this location do not support vegetation and therefore the critical level set for an impact from NO_x on vegetation has no relevance. Saltmarsh (reedbed) is not relevant at the affected location for the reasons given under the heading 'Habitat Disturbance and Modification', and as further confirmed by Google Streetview imagery dated June 2021 which shows the absence of this habitat at this location.

5.2.45 Ecological studies have also determined 'critical loads' of atmospheric nitrogen deposition. The APIS website has a Site Relevant Critical Load Function tool which enables the sensitivity of each interest feature of each European Site to be examined. Scrutiny of that tool for the Humber Estuary SAC and Ramsar site identifies that the relevant habitats (see above) are, or may be, sensitive to nitrogen deposition. A lower critical load of 20 kgN/ha/yr is set for estuary habitats (albeit in relation to upper well-vegetated saltmarsh habitats). There is no specified critical load for mudflat habitats, but it is considered reasonable to assume that this is also in the order of 20 kgN/ha/yr which is the advised lower critical load for sparsely vegetated pioneer saltmarsh habitats. None of the more sensitive SAC habitats occur in proximity to the Proposed Development within the study area for the construction air quality impact assessment. Instead, these are to be found around the margins of the main estuary, at distances greater than 9km from the Proposed Development.

5.2.46 During construction of the Proposed Development, the worst-case total nitrogen deposition rate predicted at these European Sites (as reported in reported in

Appendix 8A: Air Quality – Construction Phase (ES Volume II – **Application Document Ref. 6.3**)) would be 21.1 kgN/ha/yr, slightly exceeding the critical load of 20 kgN/ha/yr. However, as with NO_x, this would only be within 5m of the affected road network and the relevant estuary and mudflat habitats in the zone of influence do not support vegetation. Therefore, there would be no impact from nitrogen deposition on the qualifying habitat features of the European Sites.

5.2.47 There is also a need to consider potential impacts on species for which the European Sites are designated.

5.2.48 The bird species of the Humber Estuary Humber Estuary SPA and Ramsar site, which may utilise habitats (as defined in APIS) present within the Humber Estuary SAC and Ramsar site within the zone of influence, are no more sensitive than the habitats assessed above. Similarly, lamprey species when passing through the Humber Estuary SAC and Ramsar site within the zone of influence will be dependent on, and therefore no more sensitive than, the habitats assessed above.

5.2.49 In this context, emissions from construction traffic will not result in LSE at the Humber Estuary SAC, SPA and Ramsar site or interfere with the ability of these sites to achieve their conservation objectives. This specific pathway is screened out from Appropriate Assessment.

Water Pollution

5.2.50 The potential water pollution risks arising during construction of the Proposed Development are assessed in **Chapter 12:** Water Environment (ES Volume I – **Application Document Ref. 6.2**) and consider a worst-case zone of influence of 1km, along with case-by-case consideration of any potential for impacts to propagate further downstream via the flow of affected watercourses. Based on the assessment in **Chapter 12**: Water Environment and Flood Risk (ES Volume I – **Application Document Ref. 6.2**), the only European Sites considered to be in the potential zone of influence of water pollution from construction activities are the Humber Estuary SAC and Ramsar site.

5.2.51 If it occurred, water pollution could impact both the affected qualifying habitats and dependent qualifying species (birds and lamprey). Several potential water pollution pathways are identified within **Chapter 12:** Water Environment and Flood Risk along with mitigation to address these. It is considered that the latter are generic measures applicable to all waterbodies, regardless of any designations applied, and that these are necessary to meet general legislative, regulatory and good practice requirements. Under the Environmental Damage (Prevention and Remediation) (England) Regulations 2015 and the Environmental Permitting (England and Wales) Regulations 2016, it is illegal to pollute watercourses, irrespective of their designation. However, for purposes of clarity and as requested by Natural England, it is considered that this impact pathway should be **scoped in** from Appropriate Assessment.

Impacts on Foraging Resources

5.2.52 The Humber Estuary SPA and Ramsar site is designated for breeding and overwintering birds that forage on invertebrates or small fish and therefore could be present in the vicinity of the Proposed Development Site. Adult river lamprey for which the Humber Estuary SAC and Ramsar site is designated will spend one to two years feeding on fish in estuaries before returning to breeding grounds (sea lamprey primarily feeds at sea, and ceases feeding before entering river systems on migration to breeding grounds).

5.2.53 Elements of the Proposed Development have the potential to temporarily affect the habitats within the River Trent in the area associated with and downstream of the Proposed Development. The installation and operation of any temporary cofferdam will result in dewatering and a temporary and very localised impact on these habitats and associated invertebrate fauna. Underwater noise and vibration may also result in periodic temporary but highly localised disturbance to fish species, deterring fish activity in areas close to construction activities. Therefore, there is potential for temporary changes to the abundance and spatial distribution of the foraging resources of the qualifying species.

5.2.54 The relevant habitats and their associated invertebrate faunal communities will be directly impacted because of any cofferdam construction and dewatering, if required. However, the soft sediments which make up the affected habitats around the Proposed Development are highly resilient to direct physical disturbance (as explained under the Habitat Disturbance and Modification headings of Sections 5.2 and 6.2). The affected area of habitat also coincides with the existing concrete apron on the Keadby 1 Power Station cooling water intake structure. So, this habitat is not pristine, and maintenance is undertaken periodically (up to twice per year) under existing permissions to maintain the function of the existing Keadby 1 Power Station river water abstraction. Further, the spatial extent of the construction works would be very small (0.13ha maximum extent if the cofferdam is required in the River Trent) and the habitat within the cofferdam (the periodically disturbed sediments over the concrete apron) is likely to be recoverable within two years given the currently permitted maintenance intervals (up to twice per year) indicate rapid sediment accretion at this location.

5.2.55 The temporary impact on the affected habitats, while detrimental for invertebrates within the footprint of the construction works for the cofferdam, are therefore not expected to be meaningful for qualifying bird and lamprey species in the context of the wider availability of these habitats in the area. As noted above the affected mudflats represent less than 0.01% of the total extent of mudflats within the Humber Estuary SAC and Ramsar site.

5.2.56 Fish, the foraging resource for some bird species and adult river lamprey, could also be affected by the temporary impact and physical disturbance in habitats affected by the marine construction works. While adult fish are able to move away from stressors and are considered less vulnerable to construction works, less mobile benthic life stages (e.g. eggs and larvae) are unable, or less able, to do so. However, the area affected by the proposed construction works does not present habitat features that would render it a particular focal area for large numbers of fish compared to the wider estuary and it is a geographically small part of the overall habitat available to fish and species which feed on fish. Furthermore, re-establishment of fish species presence would also be expected on cessation of works (both during breaks in construction activity, and immediately after construction of the cofferdam – a process estimated to take up to 25 days). There are no barriers to re-establishment of prey species given connectivity to the main estuary and upstream watercourses, and prevailing tidal regimes.

5.2.57 Given the above assessment, no effects on the conservation status of the relevant qualifying species are considered likely.

5.2.58 <u>The temporary effects of construction activities on the foraging resources of qualifying species of the Humber Estuary SAC, SPA and Ramsar site is therefore screened out from Appropriate Assessment as it would not affect the conservation objectives.</u>

5.3 Operation Period

<u>Habitat Disturbance and Modification</u>

5.3.1 The outflow of discharged cooling water into the River Trent could, if not appropriately regulated, cause scour and erosion of intertidal mudflat habitats within the Humber Estuary SAC and Ramsar site. However, this is not likely to occur as the outflow of cooling water will replace – and not be additive to - the existing consented discharge from Keadby 1 Power Station regulated by the Environment Agency under Environmental Permit EPR/YP3133LL/V011, originally issued in April 2006. This allows a maximum daily discharge of $15m^3$/sec (average over a 24-hour period). There is no evidence that the existing operational discharge from Keadby 1 Power Station is influencing habitats within the River Trent. Examination of the setting of the existing outfall structure during ecological surveys in 2020 found no evidence of erosion other than that consistent with the natural tidal rise and fall of the river. The banks of the river were well vegetated by common reed, and marginal mudflats are apparent downstream of the outfall at low tide.

5.3.2 It is anticipated that the rate of discharge from the Proposed Development will be less than $1m^3$/sec and be discharged intermittently, in combination with the $0.016m^3$/sec proposed to be discharged from Keadby 2 Power Station. Consequently, it is considered that the Proposed Development will be operating well within the existing consented parameters of Keadby 1 Power Station (**Chapter 12**: Water Environment and Flood Risk – ES Volume I, **Application Document Ref. 6.2).**

5.3.3 <u>Habitat disturbance and modification from discharges of cooling water is therefore screened out from Appropriate Assessment as it would not affect the conservation objectives.</u>

Visual and Noise/ Vibration Disturbance

5.3.4 During operation, the only direct interaction of the Proposed Development with European Sites will relate to the discharge of cooling water to the River Trent, which is part of the Humber Estuary SAC and Ramsar site; and potentially abstraction, if the preferred Canal Water Abstraction Option is not available and instead the River Water Abstraction Option is implemented. Operation of this infrastructure would be consistent with the usage of the same cooling water intake and outfall structures for Keadby 1 Power Station and the consented use of the existing outfall structure for the discharge of cooling water from Keadby 2 Power Station. So, the baseline airborne and underwater noise and vibration from operation of this infrastructure would not change.

5.3.5 It is likely that the water intake and outfall structures will need periodic maintenance during the operational life of the Proposed Development. Maintenance needs in relation to the outfall structure also have direct relevance for the routine operation of the consented Keadby 1 and 2 Power Stations. Given this, it is not an issue specifically related to the Proposed Development as periodic maintenance would be needed with or without the Proposed Development.

5.3.6 Accordingly, no adverse noise or visual disturbance from operation and maintenance of existing water intake and outfall structures are considered likely as no changes from the existing baseline maintenance regimes are anticipated.

5.3.7 The wider Proposed Development is also not likely to result in airborne noise levels that could affect these European Sites. The noise assessment (**Chapter 9:** Noise and Vibration, ES Volume I – **Application Document Ref. 6.2**) estimates a worst-case operational noise level of 38dB at NSR 4 (located within Keadby village between the Proposed PCC Site and the River Trent). Existing baseline ambient sound levels at this location are already in the order of 44 to 45dB, so operational noise from the Proposed Development would be less than the existing baseline that birds are habituated to. As explained in Section 5.2 (construction), this is also well below the level of noise (50dB) where there could be an impact on birds.

5.3.8 Operational noise is therefore screened out from Appropriate Assessment as it would not affect the conservation objectives of the relevant European Sites.

Invasive Non-Native Species

5.3.9 The PEA of the Proposed Development (**Appendix 11C**, ES Volume II – **Application Document Ref. 6.3**) identified the presence of zebra mussel and Nuttall's waterweed within the Stainforth and Keadby Canal. Should the Canal Water Abstraction Option be implemented, then there is a theoretical pathway for dispersal of propagules of these species to the Humber Estuary SAC and Ramsar site via the cooling water discharge into the River Trent.

5.3.10 While acknowledging the theoretical impact pathway for dispersal of INNS, this is not likely given the implications of these species for effective operation of the

Proposed Development. Zebra mussel has the potential to settle and proliferate within water supply infrastructure such that. without intervention, it would be likely (ultimately) to cause a failure of this infrastructure. Accordingly, screening will be used at the water intake to exclude plant material and animals above 2mm size from the water supply, and approved biocide treatments will be used to control smaller life stages and propagules. As such, the design and operational parameters for the Proposed Development preclude potential for dispersal of viable propagules of INNS to the River Trent.

5.3.11 It should also be noted that currently there are no existing barriers to the dispersal of the above species from the canal to the River Trent, as the existing lock structure at the point of junction between these two waterbodies allows for partial mixing of waters and is therefore permeable to INNS.

5.3.12 Given the design and operational parameters and other relevant considerations, operation of the Proposed Development is not likely to result in the spread of INNS and therefore will not result in LSE at the Humber Estuary SAC and Ramsar site or interfere with the ability of these sites to achieve their conservation objectives. This specific pathway is screened out from Appropriate Assessment

Atmospheric Emissions

5.3.13 The Proposed Development and in particular, operation of the power and carbon capture infrastructure within the Proposed PCC Site will give rise to atmospheric emissions during the operational phase. The CCGT unit will generate electricity through the combustion of natural gas. The resulting combustion gases will contain NO_x, a pollutant that can be toxic to vegetation in addition to contributing to nitrogen and acid deposition. However, regulatory regimes dictate that NO_x concentrations be minimised to achieve BAT-Achievable Emission Levels (BAT-AEL). In addition, NO_x concentrations need to be minimised to optimise the carbon dioxide capture efficiency. Therefore, there are operational requirements to minimise NO_x emissions which are unrelated to the impact that NO_x emissions may have on European Sites.

5.3.14 These considerations have led the Applicant to propose selective catalytic reduction (SCR) to control NO_x levels to the BAT-AEL before entering the carbon capture system. SCR is widely used in the power industry and typically involves either injection of ammonia or urea into flue gas to react with any NO_x present in the presence of a catalyst. However, SCR can increase emissions of ammonia (via ‘ammonia slip’), another pollutant that can have a direct toxic effect on vegetation, as well as contributing to nitrogen and acid deposition.

5.3.15 No sulphur dioxide will be emitted since the Proposed Development will be gas-fired.

5.3.16 An initial Atmospheric Impact Assessment (AIA) was undertaken to determine the potential air quality impacts arising from NO_x and ammonia emissions and nitrogen and acid deposition from the operational power station using detailed atmospheric dispersion modelling, for a study area of 15km from the Proposed PCC Site.

5.3.17 The modelled predicted impacts are those relating to the operational Proposed Development. These have been used to produce isopleth plots (contours) to enable an assessment of the process contribution (PC) and the predicted environmental concentrations (PEC) of NO_x and ammonia and the deposition of nitrogen and acidic atmospheric pollutants, at the identified European Sites.

5.3.18 APIS provides information on site relevant critical levels for atmospheric NO_x concentrations for the protection of vegetation of 30µgm^{-3} and critical levels of either 3µgm^{-3} or 1µgm^{-3} for ammonia (depending on the sensitivity of the species present, with the critical level of 3µgm^{-3} being applicable to less sensitive higher plant species, and the critical level of 1µgm^{-3} being applicable to more sensitive lichen and bryophyte species). In addition, ecological studies have determined 'critical loads' for atmospheric nitrogen deposition (i.e. nitrogen derived from NO_x and ammonia) and acid deposition. Critical load criteria for the deposition of nitrogen and acid reflect the qualifying habitats and species present.

5.3.19 As explained in Section 5.2 (paragraph 5.2.42), available guidance (CIEEM, 2021; Natural England 2018d) indicates that a project that will result in an increase of no more than 1% of critical levels or loads (either alone or in combination) can be regarded as insignificant in terms of air quality effects, irrespective of whether critical levels or loads are currently being exceeded at a site.

5.3.20 Potential exceedances of the critical levels and loads were identified for European Sites as follows (see also Appendix B1):

- a process contribution of NO_x at the Humber Estuary SAC and Ramsar site of 0.49 µgm-^{3}, 1.6% of the critical level;
- a process contribution of ammonia at the Humber Estuary SAC and Ramsar site of 0.05 µgm-^{3}, 1.6% of the upper critical level; and
- a process contribution of nitrogen at the Humber Estuary SAC and Ramsar site of 0.31 kg/Ha/year, 1.5% of the critical load for saltmarsh habitats (this habitat is not present in proximity to the Proposed Development, as explained above in Section 5.2, but may occur in the wider zone of influence for an operational air quality impact).

5.3.21 Given the above, stack emissions of NO_x and ammonia from operation of the Proposed PCC Site, and deposition of nitrogen resulting from stack emissions of NO_x and ammonia, could result in LSE on the Humber Estuary SAC and Ramsar site and therefore interfere with the ability of these sites to achieve their conservation objectives. This specific pathway is **screened in** for Appropriate Assessment.

5.3.22 The operational phase of the Proposed Development will generate site traffic (primarily staff vehicles and HGV deliveries of consumables to site) entering and exiting the Proposed Development Site off the A18 and accessing via North Pilfrey Bridge. Section 4.5 of **Appendix 10A:** Transport Assessment (ES Volume II – **Application Document Ref. 6.3**) identifies that the Proposed Development will have approximately 50 full-time staff, with a similar shift pattern to the existing Keadby 1 Power Station i.e. a two-shift system of 07:00 – 19:00 and 19:00 – 07:00. Office staff are anticipated to work a core working day between 09:00 and 17:00. Assuming a conservative car occupancy of one person, this equates to 50 cars driving to the Proposed Development per day and a total of 100 two-way vehicle movements. On this basis, a detailed assessment of the operational phase of the proposed development is not considered necessary as the vehicle numbers generated would be considerably lower than the DMRB screening threshold for a more detailed assessment (e.g. >200 vehicles per day).

5.3.23 Traffic movements would therefore have a negligible effect on air quality. Pollution from operational vehicle movements is therefore screened out from Appropriate Assessment.

Water Pollution

5.3.24 The Proposed Development requires a supply of cooling water for heat rejection purposes. The preferred cooling method is hybrid cooling of both the CCGT and CCP using water abstracted from the Stainforth and Keadby Canal (Canal Water Abstraction Option), or alternatively the River Trent (River Water Abstraction Option). Used cooling water will be returned, following initial cooling in hybrid cooling towers, to the River Trent and therefore the Humber Estuary SAC and Ramsar site. Cooling water will be discharged via the existing outfall structure that was originally installed to serve Keadby 1 Power Station, and which will also serve Keadby 2 Power Station once that scheme becomes operational.

5.3.25 Discharges would be treated and would be regulated by the Environment Agency through the Environmental Permit required for the operation of the Proposed Development. In setting discharge limits, the Environment Agency will also have regard to the requirements of The Water Environment (Water Framework Directive (WFD)) (England and Wales) Regulations 2017 (UK Government, 2017) which requires that all groundwater and surface waters (rivers, lakes, transitional waters, and coastal waters) achieve ‘good ecological status’ and ‘good chemical status’. Ecological status is defined by the biological condition or health of a watercourse, in combination with water quality and physical conditions that underpin biological conditions. Compliance with the WFD Regulations is therefore consistent with requirements for maintenance of the extent/ distribution, structure/ function and/ or conservation status of European Sites and their qualifying features.

5.3.26 The Proposed Development will not ‘in combination’ add to the existing baseline Keadby 1 and Proposed Keadby 2 Power Station water discharge volumes and temperatures as the Keadby 1 Power Station and the Proposed Development will not discharge cooling water return to the river concurrently.

5.3.27 It is anticipated that the volume of discharge from the Proposed Development will be less than 1m^3/s and would discharge intermittently, in combination with the 0.016 m^3/s proposed to be discharged from Keadby 2 Power Station. As such it is considered that the Proposed Development will be operating well within the parameters of what was determined to be not significant for Keadby 1 Power Station, where the existing permit (EPR/YP3133LL/V011) allows a maximum daily discharge of 15m^3/s (average of 24-hour period).

5.3.28 It is considered that there will be negligible impact on temperature status of the River Trent, and the thermal discharge would therefore not represent a barrier to migratory routes for fish. Prior modelling of the greater thermal discharge from Keadby 1 Power station concluded that there would be no impact to the overall status of fish populations as a result of temperature-related mortality or thermal barriers to migratory fish movements (including consideration of lamprey species). It was also considered that this finding confirmed a previous conclusion reached by the Environment Agency that it is unlikely that thermal discharge of the level assessed would have any significant impact on the migration of river and sea lamprey between the river and the Humber Estuary (APEM, 2011).

5.3.29 Cooling water could, if not adequately treated and monitored prior to discharge, contain potential pollutants, including residual biocides and other blowdown products. However, the discharge of cooling water is subject to existing pollution control and environmental protection regulation and permitting regimes, which it is reasonable to assume will be properly applied and enforced by the relevant regulators including the Environment Agency. Therefore, the adequate treatment of cooling water prior to discharge was a consideration during the design of the Proposed Development, as it would not be allowed to operate if the requirements for use of best available techniques (BAT), for instance, are not met. These BAT are concerned with preventing pollution by avoiding or limiting the releases of substances to the environment from different sources to the lowest reasonably practicable level. The BAT adopted are good practice for this type of development and have not been applied to mitigate potential impacts on European Sites.

5.3.30 The above considerations relating to the design and operation of the Proposed Development mean that the return of cooling water to the River Trent at the outfall location will not result in LSE on European Sites and can be screened out of Appropriate Assessment.

Entrapment of Lampreys

5.3.31 The preferred water supply for the Proposed Development is the Keadby and Stainforth Canal. If the preferred Canal Water Abstraction Option is not feasible, an alternative option would be to utilise the existing Keadby 1 Power Station cooling water abstraction infrastructure from the River Trent for the Proposed Development (River Water Abstraction Option). Water abstraction represents a potential pathway for injury and mortality of migrating lamprey species through impingement (the capture and trapping of organisms on intake screens) and entrainment (the passing of small organisms through screens and the transfer of these into the main cooling water transfer system).

5.3.32 In relation to entrainment, it should be noted that compliance with current legislative regimes for European eel (*Anguilla anguilla*) (The Eels (England & Wales) Regulations 2009) (UK Government, 2009) requires screening of water intakes (so called 'eel screens') and typically a maximum screen mesh size of 2mm is required by the regulator (Environment Agency). The design for the Proposed Development assumes this mesh size for legal compliance purposes. Consequently, because the Proposed Development has been designed to protect European eel, entrainment of lamprey species could not occur. This potential impact pathway can therefore be discounted. The minimum likely size of the smallest life stage (transformer) of the smaller of the two lamprey species (river lamprey) at point of entry into estuary systems averages about 10cm in length (Environment Agency, 2005), so could not pass through an eel screen of 2mm mesh size.

5.3.33 Impingement is also not a relevant consideration in relation to the passage and conservation status of adult lampreys as they are strong swimmers that can orientate themselves away from the margins of the river channel (Lucas & Bracken, 2010). Therefore, bankside water intakes are not likely to interact with adult lampreys and where present they would be able to escape the pull of water into the intake. Impingement is therefore very unlikely, and adult lamprey are too large to pass through standard fish/ eel screens. Additionally, their anguilliform body shape and burrowing behaviour means that they are well-protected from collision and abrasion if rare impingement events occur (Teague and Clough, 2014).

5.3.34 In contrast, lamprey transformers migrate primarily through drifting downstream and consequently are at much higher risk of impingement because they are not strong swimmers, with a maximum escape velocity of 0.3m/s (Environment Agency, 2005).

5.3.35 Whilst acknowledging the potential risk of impingement, this pathway does not exist as it is constrained by regulatory and permitting regimes. The Environment Agency, when giving advice on general requirements and eel screens, advised AECOM (correspondence between C Bradley (Environment Agency) and P McCambridge (AECOM) 8th July 2020) that the water abstraction velocity would not be permitted to exceed 0.25m/s at the lowest possible level at which maximum abstraction can take place i.e. the lowest astronomical tide level of -0.81m below ordnance datum. Therefore, the abstraction would be required to operate at a velocity that is below the maximum escape velocity for all life stages of the relevant lamprey species.

5.3.36 <u>Given the commitment to appropriate screening at the water intake and to operate the abstraction at or below the maximum permittable velocity, it is therefore concluded that impacts on European Sites from impingement or entrainment of lamprey at the potential water intake location on the River Trent will not result in LSE and can be screened out of Appropriate Assessment.</u>

Impacts on Foraging Resources

5.3.37 The Humber Estuary SPA and Ramsar site is designated for breeding and overwintering birds that forage on invertebrates or small fish. Similarly, adult river lamprey will spend one to two years feeding on fish in estuaries before returning to breeding grounds (sea lamprey primarily feeds at sea, and ceases feeding before entering river systems on migration to breeding grounds).

5.3.38 Operation of the Proposed Development will not affect the estuary and mudflat habitats within the River Trent in the area for the reasons given above under habitat disturbance and modification and water pollution. Operational impacts on foraging resources are therefore screened out from Appropriate Assessment as it would not affect the conservation objectives.

5.4 Decommissioning Period

5.4.1 The potential impacts during decommissioning are considered comparable to or less than those associated with construction. Above ground structures would be removed at the Proposed PCC Site which is located 450m to the west of the nearest European Sites (the Humber Estuary SAC and Ramsar site), and consequently no meaningful increase in noise or visual disturbance is anticipated at the European Sites. No removal of below ground structures is proposed, so there would be no works undertaken on the banks of the River Trent in the vicinity of the existing water intake and outfall structures.

5.4.2 No potential impacts on European Sites are identified that have potential to result in LSE and decommissioning can be screened out of Appropriate Assessment.

6.0 APPROPRIATE ASSESSMENT

6.1 Impact Pathways Screened in for Appropriate Assessment

6.1.1 The relevant impact pathway that could not be screened out at Stage 1 are:

- modification and disturbance of mudflat and estuary habitats during installation of cofferdams and related works at the existing water abstraction structure. This impact pathway is relevant to the Humber Estuary SAC and the Humber Estuary Ramsar site only;
- visual, noise and vibratory disturbance to SPA/Ramsar birds during installation of cofferdams and other works at the existing water abstraction structure. This impact pathway is relevant to the Humber Estuary SPA and the Humber Estuary Ramsar site only;
- noise and vibratory disturbance to SAC/Ramsar lamprey species during installation of cofferdams. This impact pathway is relevant to the Humber Estuary SAC and the Humber Estuary Ramsar site only;
- water pollution arising during construction of the Proposed Development. This impact pathway is relevant to the Humber Estuary SAC and Ramsar site only; and
- atmospheric pollution arising during operation of the Proposed Development, specifically atmospheric pollution from operation of the Proposed PCC Site. This impact pathway is of relevance to all the European Sites covered by this HRA.

6.1.2 To meet the requirements of the Planning Inspectorate, the completed 'Appendix 2 Screening Matrix' template required to comply with Advice Note Ten (The Planning Inspectorate, 2017) is provided in Appendix A.

6.2 Habitat Disturbance and Modification During Installation of a Cofferdam and Upgrades to the Existing Keady 1 Power Station River Water Abstraction Structure (if Required) During the Construction Period

6.2.1 If the existing river Keadby 1 River Water abstraction is used as the cooling water supply, then the associated upgrade of the existing abstraction structure (installation of an eel screen) would require a temporary cofferdam. Installation of a cofferdam could disturb and/ or modify qualifying mudflat and estuary habitats of the Humber Estuary SAC and the Humber Estuary Ramsar site, but only in the immediate vicinity of the existing river water abstraction structure. As explained in Section 5.2 the cofferdam would extend no more than 22 m into the river channel and would tie into the banks of the river as close as possible to the footprint of the existing structure.

6.2.2 The extent of estuary habitat encompasses the full width of the river channel at this location, while the extent of inter-tidal mudflat is very limited as shown below in Plate 4 which is considered representative of this location. **Plate 4** shows only a very narrow width of mudflat (in the order of 1 - 2m), with the deeper water area immediately in front of the existing structure only showing exposed sediments where this has accumulated over the existing concrete apron since the last permitted maintenance event (see below for further comment on maintenance regimes). **Plate 4** also shows that most of the intertidal mudflat habitat at this location is along the western bank beyond the potential zone of influence of the cofferdam. The image also indicates that these mudflats are likely to be of higher quality, being clearly comprised of fine sediments in comparison with the coarser substrates (which are less typical of mudflat habitats) visible in the vicinity of the existing river water abstraction structure.

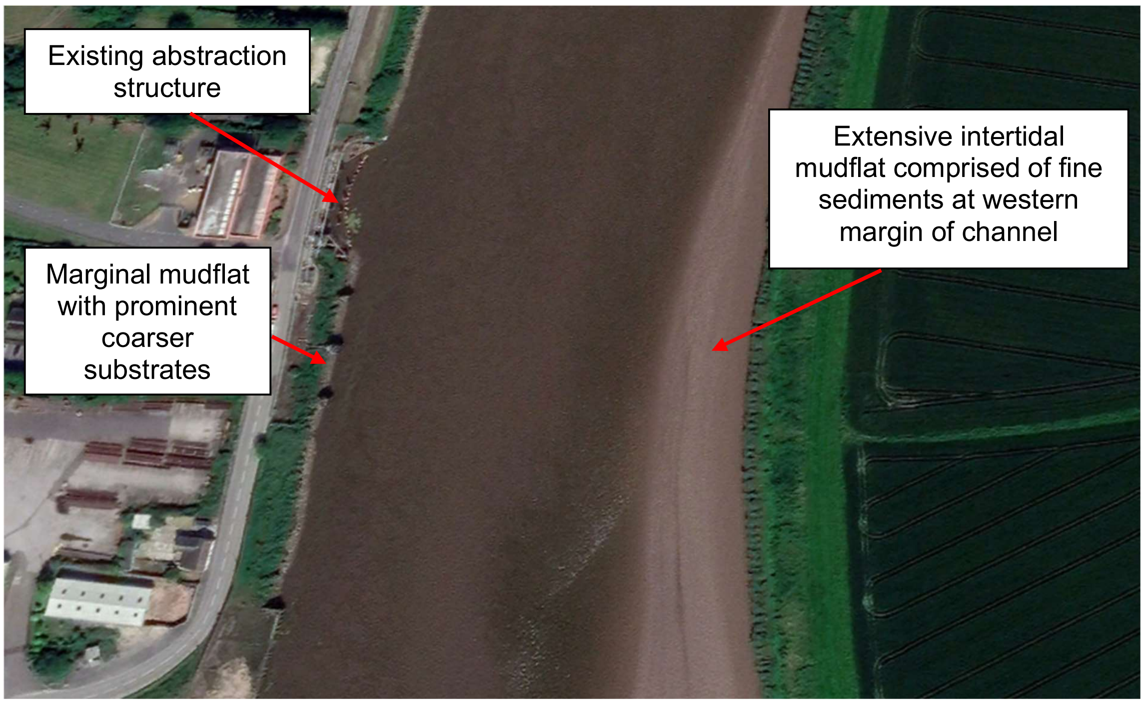


Plate 4: Representative view of the River Trent at low tide

6.2.3 As explained in **Chapter 12**: Water Environment and Flood Risk (ES Volume I – **Application Document Ref. 6.2**), while a cofferdam may be used to create and maintain a temporary dry in-channel working areas, it will also be designed (in accordance with standard good practice requirements for works in watercourses) to minimise changes in riverbed and bank erosion and toe scour over the duration of its temporary use. On that basis, there is no likely potential for adjacent, west bank, and downstream estuary and mudflat habitats to be adversely affected (e.g. by erosion or smothering) by the cofferdam after installation. The cofferdam design would not permit this.

6.2.4 Sediment could be generated during installation of the cofferdam (e.g. during piling), but it is considered that this would not be ecologically damaging for the mudflat and estuary habitats present in this highly turbid estuarine environment. Previous Water Framework Directive (WFD) assessments (e.g. AECOM, 2015) of the permitted maintenance operations at the same locations concluded no likely significant adverse effects on water quality or water biodiversity. The MMO has also previously been involved in licensing for the Keadby 1 Power Station Intake & Outfall Dredging (MLA/2017/00312, covering a maximum volume of 25,000m^3) and concluded that disturbance to bed sediments is not likely to impact water quality or biodiversity within the estuary. Natural England was also consulted on this licence and advised '*it can be excluded that the application will have a significant effect on any SAC, SPA or Ramsar site, either individually or in-combination with other plans or projects*.' The proposed worst-case construction works are of broadly comparable extent and scale to these previous works and therefore the findings of these previous assessments remain valid for the Proposed Development. It is therefore considered that sediment generation, if this was to occur, would not adversely affect the extent or structure and function of in-channel habitats or the integrity of the Humber Estuary SAC and Ramsar site.

6.2.5 Whilst in use, any cofferdam will temporarily reduce the extent and quality of intertidal mudflat habitats in the immediate vicinity of the cofferdam through removal and/ or drying of sediments in the dewatered area. However, it is emphasised that this would occur in the artificial setting of the existing concrete apron. In other words, the sediments that may be removed or experience drying are those largely deposited over the concrete apron. As stated above, periodic maintenance (up to twice per year) of sediments is already permitted under existing Keadby 1 Power Station consents at this location and therefore removal of sediments is already a periodic occurrence at this location.

6.2.6 The area of habitat that might be affected is considered trivial in the context of the size of the Humber Estuary and the extent of comparable intertidal mudflat habitats (worst-case estimate of 0.13ha (<0.01%) in the Proposed Development Site, compared to 9,384ha of mudflat habitat stated on the citation for the Humber Estuary SAC). Further, this very small-scale loss of mudflat habitat would only be temporary as natural tidal processes will rapidly reintroduce sediments and reinstate mudflats once any cofferdam is removed on the completion of works. The affected area of marginal mudflat/ estuary habitat would be expected to recover rapidly (worst-case within 2 - 5 years from point of impact (Elliott *et al*. 1998; Natural England, 2020b)) from temporary disturbance through recharge with sediments naturally present in this highly turbid river reach once water levels are restored, and through natural tidal scour and movement of sediments.

6.2.7 The existing permitted maintenance regimes at the structure support the above assessment and indicate that sediment accretion is likely to occur at the lower end of this timeframe (i.e. within 2 years). The permitted maintenance regime permits routine silt removal up to twice per year, and therefore indirectly provides a location specific indication of the speed at which sediments accrete at this location. Sediment removal would not be needed, and would not be likely to be permitted, twice per year if it re-charged at a slower rate at this location.

6.2.8 Considering the scale, location and type of construction activities (if use of a cofferdam is required), any associated temporary and very minor habitat disturbances are not likely to meaningfully alter the extent and structure and function of mudflat and estuary habitats. It is concluded that there will be no adverse effect on the integrity of the relevant European Sites as a result of habitat disturbance and modification during construction of the Proposed Development.

6.3 Appropriate Assessment of Visual and Noise Disturbance on Bird Species During Installation of a Cofferdam and Upgrades to the Existing Keadby 1 Power Station River Water Abstraction Structure (if Required) During the Construction Period

6.3.1 As explained in more detail in Sections 4.3 and 5.2, the qualifying bird species of the Humber Estuary SAC and Ramsar site of relevance to this assessment are non-breeding populations of wading bird species and shelduck occurring in association with mudflat habitats.

6.3.2 The need for construction activities, including construction of a temporary cofferdam, within the River Trent is dependent on the final selection of the location of the cooling water supply. Construction within the river would only be necessary if for any reason the preferred Canal Water Abstraction Option is not possible. Therefore, use of the River Trent represents the worst-case scenario and impact pathway. If required, the extent of piling activities would be very limited relative to the size of the watercourse, extending into the river channel for up to 22m (focussed on a single intake structure) which is a relatively small distance in the context of a river channel that is circa 150m wide at this location. Construction is estimated to take up to 25 days, as explained in Section 5.2.

6.3.3 Vibratory piling (vibro-piling) will be the main construction method used over the 22 day construction period, but it is often necessary to drive the final stages of a pile with a hammer (impact piling). It is therefore important to make the distinction between these two methods. With impact piling there are frequent noise peaks for the duration of piling activity and these peak noise events are of greater magnitude (in terms of sound levels and zone of influence), and birds are demonstrably more sensitive to loud peak noise events. Whereas some degree of habituation is possible to vibro-piling as the noise is of lesser magnitude and more predictable; consequently birds are much less likely to be disturbed by vibro-piling. The committed soft-start approach and use of vibratory piling as standard, with percussive piling only used if required to drive a pile to its design depth, (secured via the Deemed Marine Licence 'During Construction, Operation and Maintenance' condition (No. 18 DML) in the draft DCO (**Application Document Ref. 2.1**) is also supportive of this.

6.3.4 A noise impact assessment has been completed to assess the impacts of the Proposed Development during the construction phase on qualifying bird species in the nearest part of the Humber Estuary (the River Trent at Keadby). The dB L_{Aeq},1hr values provide an 'average' of noise levels expected to occur in any one hour because of each activity. Such 'continuous equivalent noise levels' form the basis of most noise assessment protocols, but are of limited relevance when considering the effect of noise on waterbirds because waterbirds are perceived to be more susceptible to being disturbed by short, sharp 'peaks' of noise e.g. during impact sheet piling (Cutts *et al.*, 2009). Therefore, for piling activities, the L_{Amax} values have been predicted at the NSR to provide an indication of the likely 'peak' noise events so that they can be compared to the ambient conditions.

6.3.5 Consistent with the above, noise contour maps are provided for the following two modelled cofferdam construction scenarios:

- Vibro-piling, which is the piling method that is proposed to be most likely to be used for most of the up to 22 day construction period (**Figure 3**). This is presented as dB L_{Aeq}. There is no requirement to model as dB L_{Amax} as vibro-piling is a more continuous noise source without definable 'max' events; and
- Impact sheet piling, which would only be used to drive a pile to it design depth (**Figure 4**). This is presented as dB L_{Amax}. dB L_{Aeq} has not been modelled as this would be only 3dB more than the worst-case value used for vibro-piling, and the latter method will be the main construction method and will take place for longer durations of time.

6.3.6 As stated in Section 5.2, the minimum noise threshold for a potential impact on birds from regular construction noise, such as vibro-piling, is 50dB (Cutts *et al.*, 2009). Therefore, only noise levels above 50dB require further consideration and assessment. Adoption of this threshold does not automatically mean that noise levels above 50dB would be adverse for the nature conservation status of affected qualifying bird species. In this context, an impact would be some form of behavioural response on a spectrum between relatively trivial responses such as a 'heads-up' response, through physical movement on the ground away from the disturbance source, to at the most extreme level taking flight and leaving the affected area (displacement).

6.3.7 Previous studies such as Institute of Estuarine and Coastal Studies (1999) and ERM (1996) have demonstrated that qualifying birds occupying habitats elsewhere in the Humber Estuary, such as the Salt End and Pyewipe mudflats, are relatively tolerant of construction activities including piling noise levels (e.g. marine piling to construct new jetties). Based on bird behaviour and noise monitoring studies undertaken by Xodus Group during construction piling for the Grimsby River Terminal (Xodus Group, 2012), the significance criteria for disturbance to birds are summarised below:

- > 50 to ≤ 65 dB LAmax – negligible;
- > 65 to ≤ 75 dB LAmax – minor adverse;
- > 75 to ≤ 85 dB LAmax – moderate adverse; and
- > 85 dB LAmax – major adverse

6.3.8 The above criteria have recently been applied by AECOM for the South Humber Bank Energy Centre HRA Signposting report (EP Waste Management Ltd, 2020) and were referred to by the Department for Business, Energy & Industrial Strategy in the formal HRA (Department for Business, Energy & Industrial Strategy, 2021). Natural England has also advised AECOM that they consider this an appropriate assessment approach during additional technical engagement on the draft HRA for the Proposed Development (September 2021).

6.3.9 Baseline ambient sound levels at NSR 4 (on Trent Road adjacent to the River Trent and the existing River Water Abstraction Structure) are 44 - 45dB (**Chapter 9:** Noise and Vibration, ES Volume I - **Application Document Ref. 6.2**). Sources of noise at this location include those arising from vehicle movements, other activities within the settlement of Keadby, boat movements associated with the ports along the River Trent and associated onshore activities at Keadby Port.

6.3.10 Predicted noise levels for the majority of construction activities, i.e. vibro-piling for a cofferdam if the River Trent (if selected as the cooling water supply) are predicted to be in the range of 70 - 75db L_{Aeq} within the immediate vicinity of the cofferdam location (**Figure 3**), attenuating to <65db L_{Aeq} within approximately 120m of the cofferdam (which is the threshold defined above for an impact of negligible significance), and <50dB L_{Aeq} at approximately 750m from the cofferdam (the threshold for no impact). The maximum extent of tidally exposed mudflat habitat (the habitat supporting the relevant qualifying bird species potentially utilising this section of the River Trent) within this worst-case zone of influence for a noise disturbance impact is less than 3ha (with reference to the extent of mudflat shown on the Google Earth imagery used to generate **Plate 4**). This represents just 0.03% of the total mudflat resource of 9,384ha available to dependent qualifying birds within the Humber Estuary SAC and Ramsar site.

6.3.11 The worst-case construction activity of impact sheet piling (**Figure 4**) when this is required in order to drive piles to the final design depth would have a greater noise impact on the River Trent. When this activity is taking place, noise levels would exceed 75dB along the River Trent to approximately 1.2km from the cofferdam, and rapidly attenuate thereafter to <65dB (the threshold given above for an impact of negligible significance) at approximately 1.7km distance. While this impact would be greater than the impact from vibro-piling, it is re-emphasised that this would not be the standard construction method used during the 25 days which may be required for installation of any cofferdam. During impact sheet piling, it is estimated that up to 10ha of mudflat habitat could be affected, representing no more than 0.1% of the total mudflat resource of 9,384ha available to dependent qualifying birds within the Humber Estuary SAC and Ramsar site.

6.3.12 The above noise impacts can reasonably be expected to extend well beyond the potential zone of visual disturbance from human activities associated with installation of the cofferdam. Given this, specific assessment of visual disturbance is not required as the noise assessment represents the worst-case scenario and visual disturbance will only occur when construction works are being undertaken.

6.3.13 Any displacement effect on foraging wading birds and shelduck is only likely to occur during low tide, when mudflats are exposed. At high tide there would be negligible foraging habitat available due to the prevailing channel and bank profiles along the affected section of river (the river is embanked on both sides).

6.3.14 Given the foregoing, it is considered reasonable to assume that any birds temporarily displaced by construction noise and visual disturbance during use of either piling method and related construction activities would be able to find alternative foraging habitat in the wider area of suitable mudflat habitat (9,384ha) within the European Site where >99.9% of mudflat habitats would remain available for foraging when piling is taking place. It must be assumed that the relevant bird species utilising this section of the River Trent are already highly mobile given the foraging habitats are only available at low tide and outside these periods, birds would need to relocate elsewhere to access suitable foraging habitats. The affected habitats are also located near the upper limit of the Humber Estuary Ramsar site as it applies to the River Trent, so noise and visual intrusion during construction would not prevent access by birds to favoured habitats; and instead the most likely effect would be to displace birds towards the main body of the Humber Estuary where the most optimal and extensive mudflat habitats occur.

6.3.15 The likelihood and magnitude of disturbance of qualifying bird species will also depend on whether the relevant bird species are likely to be present within the potential zone of influence (which relates to the noise bands shown on **Figures 3** and **4**) at the time of cofferdam construction. The qualifying bird species that are likely to utilise the limited mudflat habitats in the zone of influence are non-breeding (i.e. over-wintering) wader species: knot, dunlin, godwit species, ruff and redshank, as well as non-breeding shelduck. In contrast, the anticipated timing for installation of the cofferdam and associated piling works is when water levels within the River Trent are at their lowest and avoiding winter when the river is likely to be at full flow or in spate for prolonged periods of time. This timing is also needed to meet the commitment to avoid September to November inclusive when salmon could be migrating along the River Trent (Framework Construction Environmental Management Plan (CEMP) (**Application Document Ref. 7.1**)). Consequently, piling works timed for the period May to August when flows are at their lowest would not coincide with the period of presence for the non-breeding populations of the relevant bird species. So, irrespective of the noise levels that would be generated by piling, it is not likely that qualifying bird species would be affected.

6.3.16 Placing weight on the timing of the relevant construction activities, which would not coincide with the period when qualifying bird species are likely to be present and giving weight to the very small area of suitable mudflat habitat within the potential zone of influence of these construction activities (<0.1% of the total available mudflat habitat if the worst case piling method is used) no impacts on the conservation status of any qualifying bird species are likely. <u>It is concluded that there will be no adverse effect on the integrity of the relevant European Sites as a result of visual and noise disturbance of qualifying bird species during construction of the Proposed Development</u>.

6.4 Appropriate Noise/ Vibration Disturbance on Lamprey Species During Installation of a Cofferdam and Upgrades to the Existing Keadby 1 Power Station River Water Abstraction Structure (if Required) During the Construction Period

6.4.1 The Humber Estuary SAC and Ramsar site are designated for river and sea lamprey. Construction of a cofferdam on either the River Trent or the Stainforth and Keadby Canal would result in underwater construction noise and vibration impacts from piling activities (albeit of lower magnitude and lesser duration on the canal relative to the river, given the cofferdam would be smaller). This in turn could potentially have a temporary deterrent effect on the ability of lamprey to access breeding habitats in the wider River Trent catchment, and to return to the Humber Estuary from these habitats.

6.4.2 This potential impact pathway acknowledged, the physiology and ecology of the relevant lamprey species makes this unlikely, as explained in more detail below. A standalone detailed assessment of potential underwater noise and vibration impacts on fish has also been prepared for the Proposed Development (**Appendix 11H**, ES Volume II – **Application Document 6.3**) and concludes that no fish species (i.e. including fish species of higher sensitivity than lamprey species) would experience an impact to their conservation status as a result of injury from underwater noise and vibration.

6.4.3 The impact of underwater noise and vibration on fish ranges from behavioural responses to auditory injury, with the magnitude of impact dependent on the intensity and duration of the sound. In the most extreme cases, such as explosions from the detonation of unexploded ordnance, underwater noise and vibration results in tissue injury or mortality. Sound propagation calculations indicate that physical injury to fish is highly unlikely to occur unless fish are in very close proximity i.e. within 10m of the sound source from impact piling. The basis for this statement is explained in more detail in **Appendix 11H** (ES Volume II – **Application Document 6.3**).

6.4.4 Even within this limited potential zone of influence for physical injury, not all fish species are equally sensitive/ vulnerable. Lamprey species are categorised as low hearing sensitivity fish species (Popper *et al*., 2014) because they lack specialist hearing structures and consequently their ear is relatively simple (they have no swim bladder or anatomical structure tuned to amplify sound signals). Instead, lamprey species are generally considered to be sensitive only to sound particle motion within a narrow band of frequencies (indeed some research indicates that they may only be sensitive to particle motion (Popper & Hawkins, 2019)).

6.4.5 Because of this physiology they are inherently resilient to the kinds of physical injury (e.g. barotrauma) that other fish species can experience as result of adverse levels of underwater noise and vibration.

6.4.6 For the same reason, it is usually considered that adverse changes in behaviour (e.g. behavioural changes that affect migration) as a result of underwater noise and vibration on lamprey are also not likely to occur. Lampreys would need to be very close to a powerful noise source for a behavioural response to occur (Popper, 2005; Popper and Hastings, 2009). Lenhardt and Sismour (1995) carried out experiments on sea lamprey and detected a startle response to frequencies between 20 and 100Hz. However, the response was considered likely to be more due to vibration than waterborne noise. Startles while swimming were rare, suggesting that direct contact with the vibrating surface was needed to trigger the reaction. As further indirect evidence of this, the river lamprey was included in a study on the effect of a playback system (with emission frequencies between 20 and 600Hz) in reducing estuarine fish intake rates at a power plant cooling water inlet (Maes *et al*. 1999, 2004). No significant reductions in river lamprey catches were observed confirming a lack of behavioural response to the noise deterrent.

6.4.7 Regardless of the above conclusions, in order to protect other fish species that are not qualifying features of the Humber Estuary SAC and Ramsar site, the Proposed Development will adopt the standard mitigation for protection of marine receptors from the effect of underwater sound (JNCC, 2010), specifically a soft-start for all hammer driven piling activity. Whilst these measures are designed for the protection of marine mammals, they also provide protection for fish. These measures ensure that sound intensity from piling, and any associated particle motion, will increase only gradually before reaching full power. This soft start will allow opportunity for individual lampreys located within the potential zone of influence for an adverse noise or vibration impact (i.e. within 10m of the noise/ vibration source) opportunity to move away from the construction area before there is potential for an impact to be realised. This approach would also be applied on the Stainforth and Keadby Canal.

6.4.8 So, given the inherent lack of sensitivity of lamprey species and the adopted good practice construction methods it <u>is concluded that there will be no adverse effect on the integrity of the relevant European Sites because of use of cofferdams</u>.

6.5 Appropriate Assessment of Water Pollution During the Construction Period

6.5.1 **Chapter 12:** Water Environment and Flood Risk (ES Volume I – **Application Document Ref. 6.2**) identified potential direct and indirect water pollution pathways for an impact on the Humber Estuary SAC and Ramsar site along with the committed mitigation that would be applied to prevent this. If it occurred, water pollution could impact qualifying habitats and dependent qualifying species. However, as explained below, such impacts are not likely to occur.

6.5.2 Under the terms of relevant legislation and regulatory regimes, consents/ licences would be required from the Environment Agency and/ or the MMO for temporary construction discharges (i.e. water activity permits), and for certain works affecting main rivers, including the River Trent which is part of the relevant European Sites, as well as any temporary dewatering, abstractions or impoundments and in-channel works related to construction activities (i.e. abstraction, impoundment or transfer licences). These regimes apply irrespective of whether main rivers are subject to nature conservation designations. The good practice requirements for protection of surface waters arising from regulation and permitting regimes have therefore been considerations when determining construction requirements and methods, as construction would not be allowed to commence if these requirements cannot be met. The Proposed Development has been designed to meet these requirements and it should also be assumed that the mandatory regulatory regimes will be properly applied and enforced by the relevant regulators (as advised in DECC, 2011).

6.5.3 During construction, accidental water pollution may occur directly from spillages of polluting substances into waterbodies, or indirectly by being conveyed in runoff from hardstanding, other sealed surfaces or from construction machinery. Fine sediment may also be disturbed in waterbodies directly or also wash off working areas and hard standing (including approach roads) into waterbodies indirectly via existing drainage systems or overland. This sediment may potentially contain contaminants that could be harmful to the aquatic environment. Good construction practice measures to avoid, prevent and reduce adverse effects on the water environment and deal with any accidental release form part of the design and impact avoidance measures in **Chapter 12:** Water Environment and Flood Risk (ES Volume - **Application Document Ref. 6.2**) and are thus committed. These measures have been specified irrespective of whether any nature conservation designations are applied to the relevant watercourses, although such designations have been identified in **Chapter 12** where they apply.

6.5.4 The Framework CEMP (**Application Document Ref. 7.1**) provided with the DCO Application also sets out standard best practice measures to minimise the risk of water pollution on all watercourses irrespective of any nature conservation designations applied. The CEMP comprises an integral part of the committed construction approach for the Proposed Development so that regulatory and permitting requirements can be and are met by the Applicant and their appointed contractor(s) who would be required to take measures in the Framework CEMP into account.

6.5.5 If a cofferdam is required within the River Trent then, as per good industry practice, this would be suitably designed to minimise changes to the estuary bed and bank erosion and toe scour, and associated impacts on water quality. Similarly, dewatering within any cofferdam areas will only be undertaken following any necessary fish rescue and once any fine sediment has settled out such that it is consistent with the turbidity of the flowing River Trent. The rate and location of the discharge will be controlled and carefully chosen to avoid/ minimise erosion of any nearby soft sediments.

6.5.6 Comparable measures are committed if a cofferdam is required in the Keadby and Stainforth Canal and therefore would similarly prevent releases of sediment with potential to impact the relevant downstream European Sites on the River Trent.

6.5.7 Given the measures specified in the Framework CEMP (**Application Document Ref. 7.1**) there are no likely pathways for dispersal of construction water pollution to the Humber Estuary SAC and Ramsar site.

6.5.8 In addition to the above considerations, during the construction phase of the Proposed Development, sewage and 'grey water' will also be produced, primarily by toilets, washrooms and kitchen facilities for construction staff. This will either be discharged directly into the existing local sewerage system serving Keadby 2 Power Station, or it will be captured for transportation via tankers to an off-site authorised treatment works. Therefore, it is concluded that there is no available pathway for organic pollution from sewage effluent to affect the River Trent during the construction period.

6.5.9 <u>Given the above, it is concluded that there will be no adverse effect on the integrity of the relevant European Sites as a result of water pollution during operation of the Proposed Development.</u>

6.6 Appropriate Assessment of Emissions to Air from the Proposed PCC Site During Operation

6.6.1 As described above in Section 5.3 (see also Appendix B1, Table B1), the annual average contribution of the Proposed Development to NO_x (in terms of the PC) is predicted to exceed 1% of the critical level at the Humber Estuary SAC and Ramsar site due to its proximity to the Proposed Development. The relevant qualifying feature of the Humber Estuary SAC and Ramsar site to which this exceedance of the critical level relates is saltmarsh (as established previously in Section 5.2, the qualifying mudflats and estuary habitats do not support vegetation sensitive to NO_x). However, the PEC (i.e. the existing baseline plus the Proposed Development emissions) of 14.2μgm^{-3} reported for the Humber Estuary SAC and Ramsar site is predicted to remain below the critical level of 30μgm^{-3} set for NO_x (at 47% of the critical level) so no exceedances of the annual critical level are therefore predicted.

6.6.2 Since the critical levels for NO_x will not be exceeded, the only potential effect that NO_x could have on saltmarsh habitats is through the contribution they make to nitrogen deposition (with ammonia), rather than through direct effects of this pollutant in the atmosphere. This is assessed below.

6.6.3 As described above in Section 5.3, the need to design the Proposed Development to meet regulatory requirements for NO_x emissions and to reduce the NO_x levels entering the CCP is anticipated to result in emissions of ammonia (via 'ammonia slip'). Without abatement (which is reflected in the design of the Proposed Development, refer to **Chapter 4**: The Proposed Development in ES Volume I - **Application Document Ref. 6.2**), ammonia levels and the contribution this makes to nitrogen deposition (acid deposition was scoped out in Section 5.3) would result in PCs that exceed the 1% screening criteria for both the critical levels and loads set for these pollutants in relation to the qualifying saltmarsh habitats of the Humber Estuary SAC and Ramsar site (see Section 5.3 and Appendix B1).

6.6.4 However, even without the required ammonia abatement the PEC of 2.4µgm^{-3} reported for the Humber Estuary SAC and Ramsar site is still predicted to remain below the critical level of 3µgm^{-3} set for ammonia (at 80% of the critical level). So, no exceedance of the annual critical level for ammonia is predicted and consequently the required ammonia abatement is not required to prevent an adverse effect from ammonia on the Humber Estuary SAC and Ramsar site (but it does minorly but beneficially further reduce the ammonia level reaching the designations).

6.6.5 Since the critical level will not be exceeded, the only potential impact that ammonia could have on habitats (in combination with NO_x) is through the contribution it makes to nitrogen deposition, rather than through direct effects of this pollutant in the atmosphere. Prior to ammonia abatement the process contribution towards nitrogen deposition would exceed 1% of the critical load set for saltmarsh habitats and the PEC of 20.5kg N/ha/yr would also exceed the critical load (103% of the critical load). After ammonia abatement through the acid wash, the process contribution towards nitrogen deposition is not predicted to exceed 1% of the critical load at the Humber Estuary SAC and Ramsar site, and it remains below the 1% critical load for all other relevant European Sites (Appendix B2, Table B6).

6.6.6 There is also a need to consider potential impacts on species for which the European Sites are designated. In this case, for all relevant species (birds and lamprey) the broad habitats of relevance are covered by the critical levels and loads already assessed above. No species-specific impacts and effects are therefore likely within the boundary of the European Sites because of operation of the Proposed Development.

6.6.7 In conclusion, the AIA demonstrates that the design of the Proposed Development to meet regulatory requirements and the proposed mitigation (abatement) measures for ammonia are sufficient to manage atmospheric pollutants so that they remain below the critical levels/ loads set for all the relevant European Sites. Accordingly, it is concluded that there will be no adverse effect on the integrity of the relevant European Sites because of atmospheric emissions during operation of the Proposed Development.

7.0 IN-COMBINATION EFFECTS WITH OTHER PLANS OR PROJECTS

7.1.1 It is a requirement of Regulation 63(a) of the Habitats Regulations to not only assess the impacts of a development project alone, but also to investigate whether there might be 'in-combination' effects with other projects or plans (schemes).

7.1.2 For the purposes of this HRA, potentially relevant schemes which may act in-combination with the Proposed Development (see **Appendix D**) have been identified with reference to the information collated for **Chapter 19:** Cumulative and Combined Effects (ES Volume I – **Application Document Ref. 6.3**).

7.1.3 There is only potential for in-combination effects where the Proposed Development has the same potential impact pathways as other schemes on the same European Sites. Based on the findings presented in Section 5 and 6 of this report, there are only potential pathways for in-combination effects from:

- noise and vibration during construction on the Humber Estuary SAC and Ramsar site;
- emissions to air during construction on the Humber Estuary SAC and Ramsar site; and
- emissions to air during operation of the Proposed PCC Site on all the identified European Sites.

7.1.4 Most of the identified schemes, as screened in **Appendix D**, are confirmed to be of insufficient scale and/ or are located at too great a distance from the relevant European Sites to be likely to interact with the Proposed Development to produce a LSE through the above impact pathways. In two cases, schemes are of potential relevance during construction or operation but are insufficiently advanced or defined in the planning/ consenting process to be a certain part of the future baseline within which the Proposed Development needs to be assessed. Consequently, it is considered that these schemes will need to undertake their own HRA, including an in-combination assessment taking account of the Proposed Development, when they are ready to be submitted under the relevant consenting regimes. It will be the responsibility of these future schemes to consider the Proposed Development (the DCO for which will have been submitted at that time) when undertaking this process.

7.1.5 In specific relation to air quality impact assessment (**Chapter 8:** Air Quality, ES Volume I - **Application Document Ref. 6.2**), it should be noted that the assessment presented above in Sections 5 and 6 of this report has already considered potential in-combination effects with relevant consented schemes (including the Keadby 2 Power Station) as this is a requirement of good practice air quality impact assessment methods. Specifically, the air quality impact assessment:

- confirms that cumulative impacts from existing sources of pollution in the area are accounted for in the adoption of site-specific background pollutant concentrations from archived and published sources; and
- recognises that there is a potential impact on local air quality from emission sources, and therefore considers relevant schemes identified in **Chapter 19:** Cumulative and Combined Effects of the ES (ES Volume I - **Application Document Ref. 6.2**) (as listed in Appendix D of this report).

7.1.6 Consequently, for certain schemes, potential in-combination air quality effects have already been assessed and, as the contribution from the Proposed Development is predicted to be insignificant from an air quality point of view and/or would not affected sensitive vegetation, there is no need to consider these schemes further (CIEEM, 2021. See paragraph 5.2.42). The relevant schemes are clarified in **Appendix D**.

7.1.7 Based on the information given in **Appendix D**, there are no likely in-combination effects associated with the Proposed Development and this can be screened out of Appropriate Assessment.

8.0 CONCLUSIONS

8.1.1 Following assessment of the potential pathways by which the Proposed Development might impact European Sites, alone or in-combination with other schemes, it is concluded that there were only a limited number of potential pathways for a LSE on European Sites. These related to direct habitat disturbance during construction, visual and noise disturbance during construction, and emissions to the atmosphere during operation of the Proposed Development.

8.1.2 Following Appropriate Assessment, and consideration of mitigation options which form part of the committed design of the Proposed Development and are proposed to be secured by Requirement of the draft DCO, including DML, it is concluded that the relevant impact pathways would not have an adverse effect on the integrity of any European Sites.

8.1.3 Accordingly, it is not necessary to carry out any further stages of HRA.

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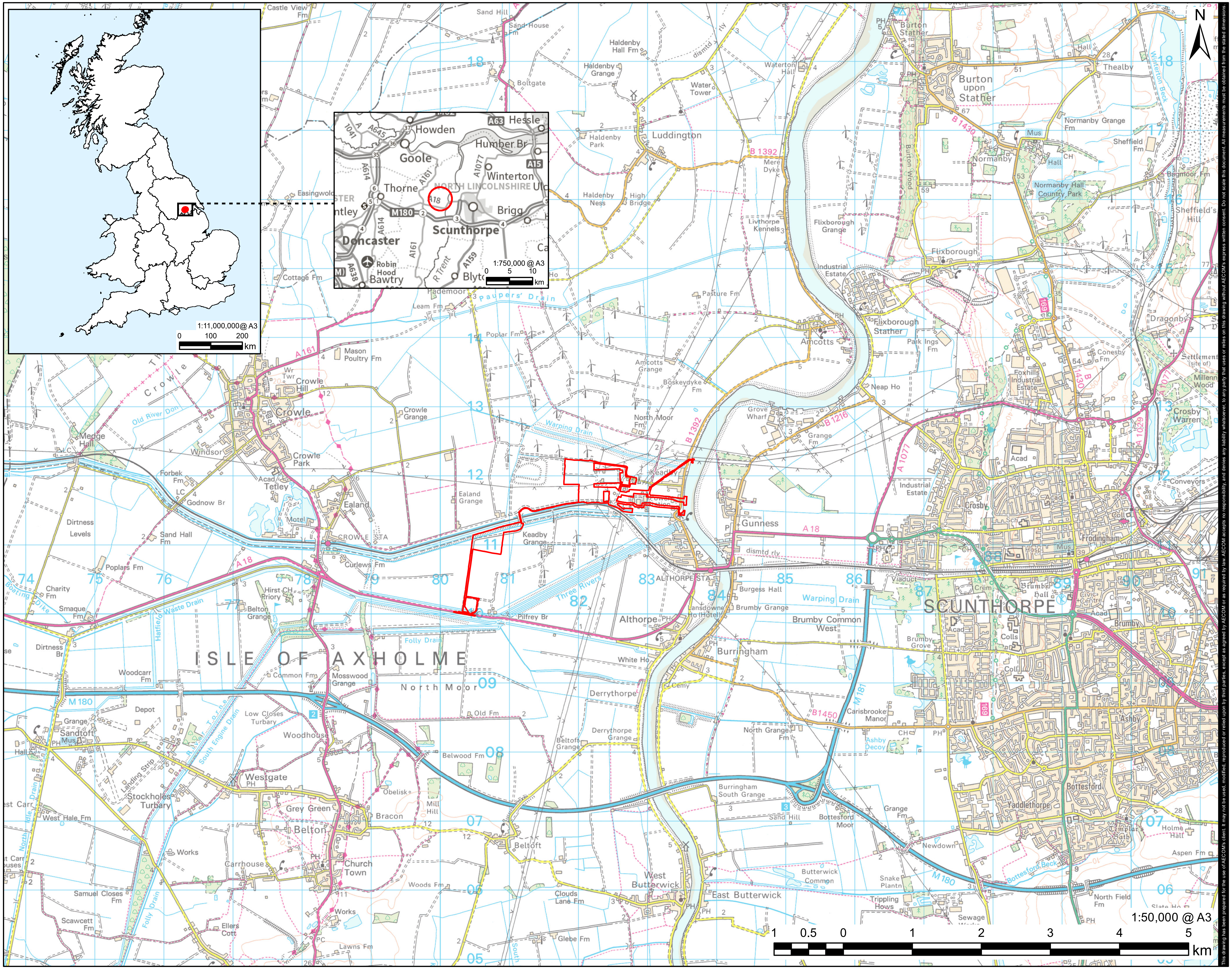
FIGURES

Figure 1: Site Location Plan

Figure 2: European sites screened for likely significant effects

Figure 3: Cofferdam Sheet Piling LAeq Noise Level Predictions

Figure 4: Cofferdam Impact Sheet Piling LAmax Noise Level Predictions



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Revision: 01

Drawn: JW Checked: CN Approved: RW Date: 27/05/2021

AECOM

PROJECT

The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order

APPLICANT

Keadby Generation Limited

CONSULTANT

AECOM Limited
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LS11 9AR
T: 0113 391 6800
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LEGEND

The Order Limits

NOTES

The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order Regulation 5(2)(o) - Infrastructure Planning (Applications: Prescribed Forms and Procedures) Regulations 2009

ISSUE PURPOSE

DCO APPLICATION

PROJECT NUMBER

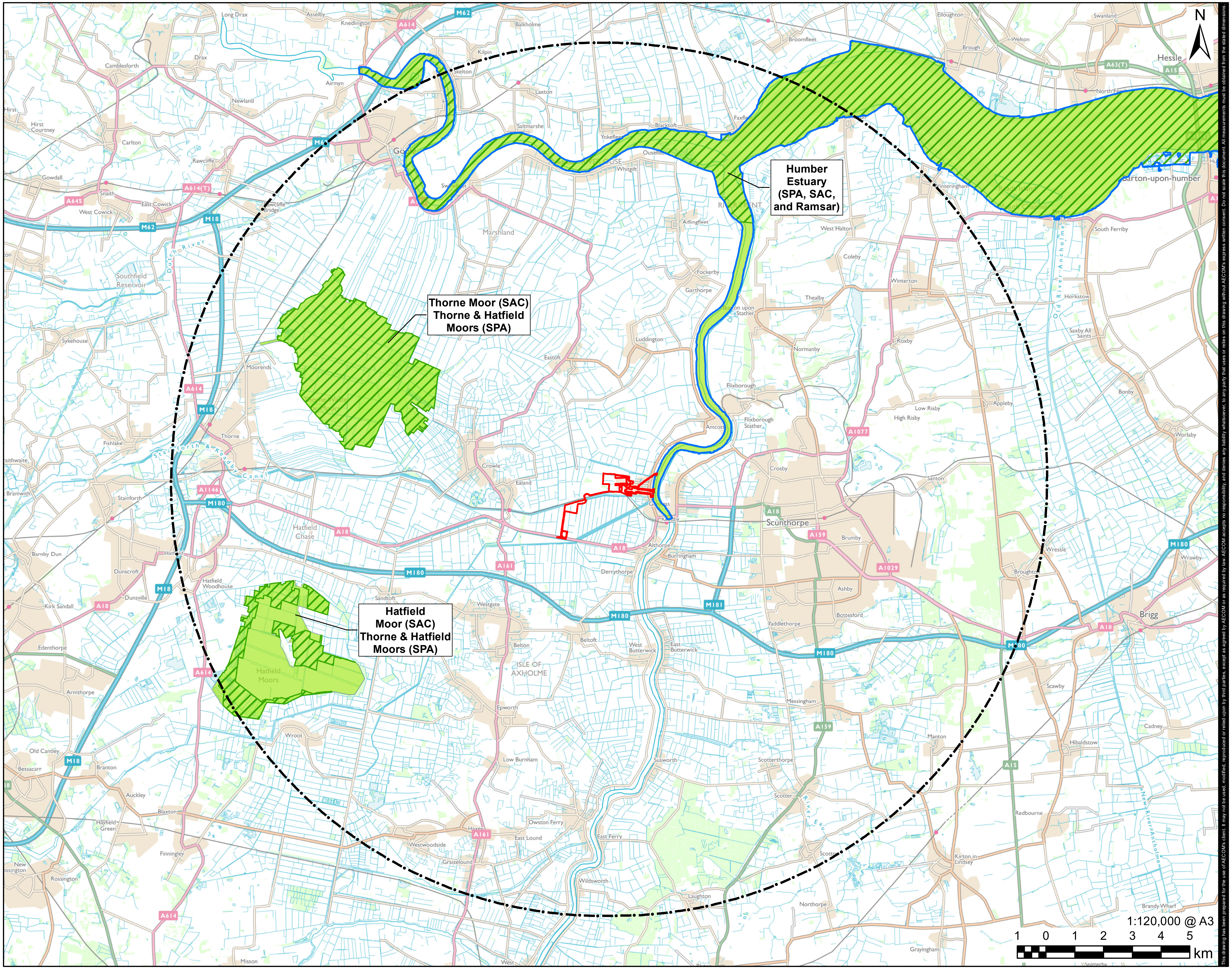
60625943

SHEET TITLE

Site Location Plan
Figure 1

SHEET NUMBER

Application Document Ref No. 5.12



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AECOM

PROJECT

The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order

CLIENT

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LEGEND

- The Order Limits
- 15km Study Area (Measured From Main Site)
- Ramsar Site
- Special Area of Conservation (SAC)
- Special Protection Area (SPA)

NOTES

The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order Regulation 5(2)(o) - Infrastructure Planning (Applications: Prescribed Forms and Procedures) Regulations 2009

ISSUE PURPOSE

DCO APPLICATION

PROJECT NUMBER

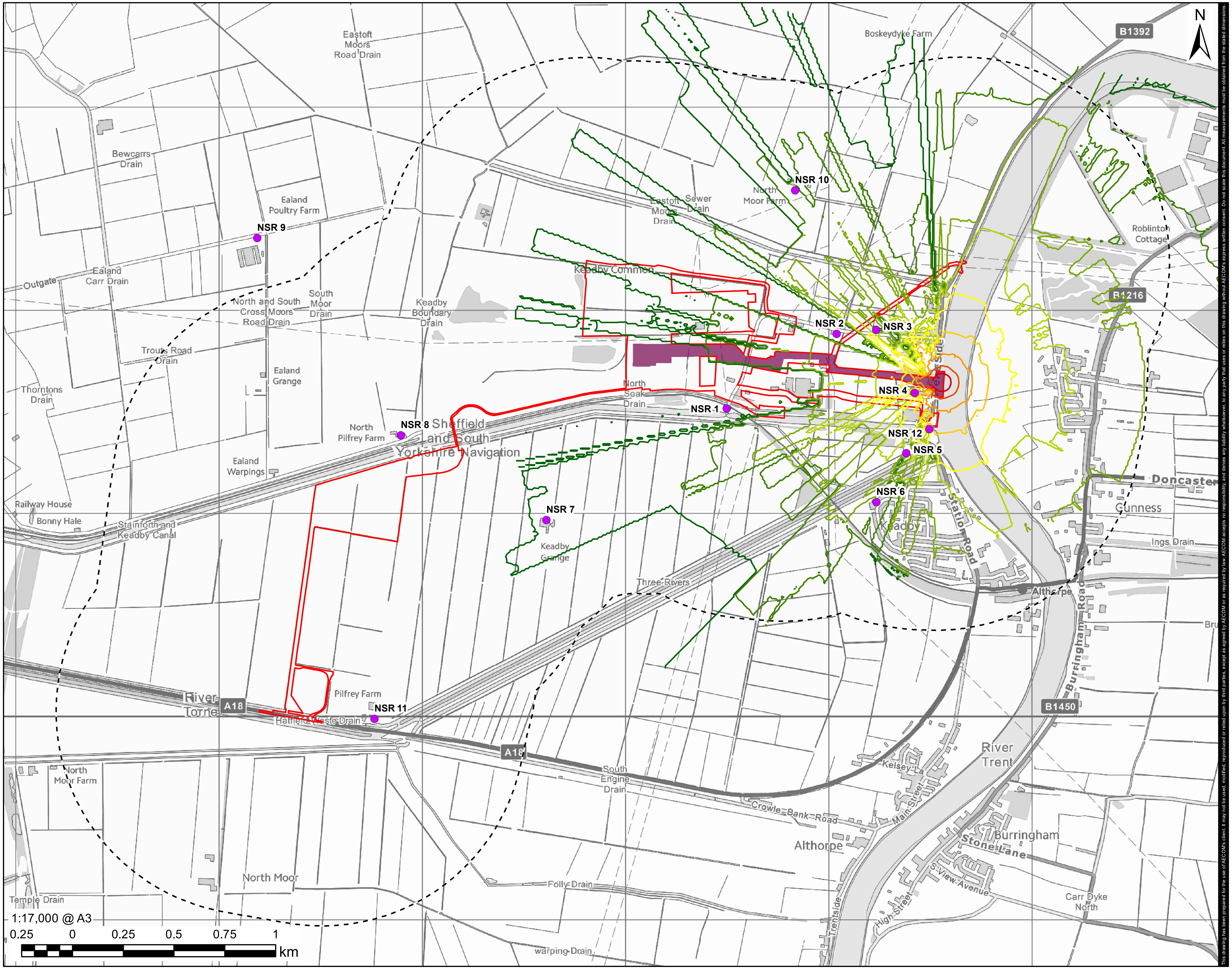
60625943

SHEET TITLE

European Sites Screened For Likely Significant Effects
Figure 2

SHEET NUMBER

Application Document Ref No. 5.12



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Drawn: TG Checked: JW Approved: SE Date: 02/11/2021

Revision: 01

AECOM

PROJECT

The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order

APPLICANT

Keadby Generation Limited

CONSULTANT

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LEGEND

- The Order Limits
- 1km Study Area
- Noise Sensitive Receptor (NSR)
- River Water Supply Connection Works - 4B

Daytime Cofferdam Sheet Piling Noise Level Contours (dB LAeq 12hr)

- <=35
- <=40
- <=45
- <=50
- <=55
- <=60
- <=65
- <=70
- <=75

NOTES

Noise level predictions in this figure based on the methodologies outlined in Chapter 9:Noise and Vibration and Appendix 9A: Construction Noise Information

ISSUE PURPOSE

HRA

PROJECT NUMBER

60665962

SHEET TITLE

Cofferdam Sheet Piling Noise Level Predictions

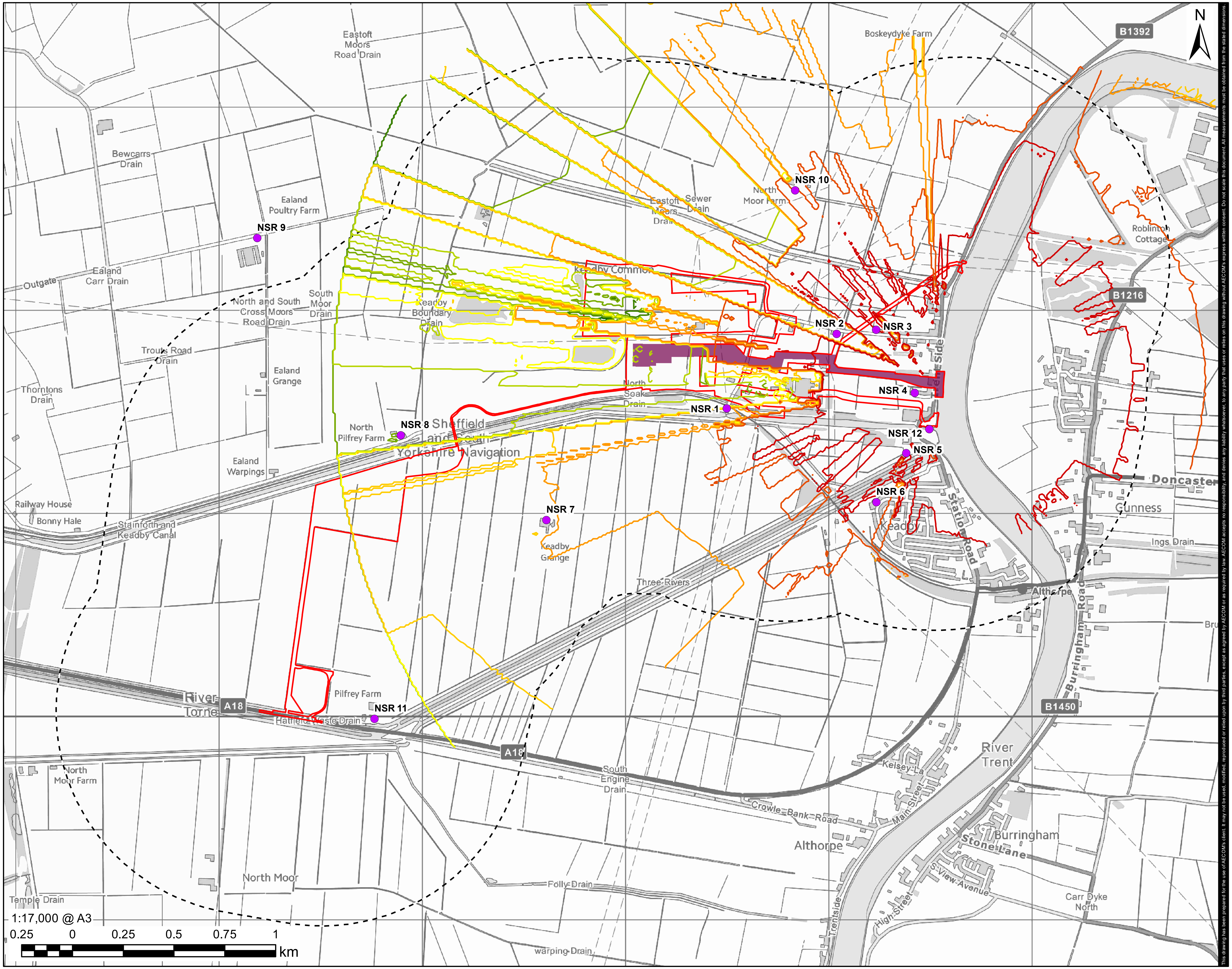
SHEET NUMBER

Figure 9.4a

Filename: \\na.aecomnet.com\lfs\EMEA\Leeds-UKLDS2\Legacy\UKLDS2PFPSW001\WIP\LE_Projects\Newproje\60625943 - SSE Keadby and Medway DCO\02 SSE Keadby\07 CAD & GIS\02_Maps\HRA\K_HRA_Fig_9_4b_CofferdamImpactSheetPilingLmaxNoisePredictions_A3_20211102_R01.mxd

Drawn: TG Checked: JW Approved: SE Date: 02/11/2021

Revision: 01



AECOM

PROJECT

The Keadby 3 (Carbon Capture Equipped Gas Fired Generating Station) Order

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LEGEND

- The Order Limits
- 1km Study Area
- Noise Sensitive Receptor (NSR)
- River Water Supply Connection Works - 4B

Daytime Cofferdam Impact Sheet Piling LAmax Noise Level Contours (dB LAmax)

- <=35
- <=40
- <=45
- <=50
- <=55
- <=60
- <=65
- <=70
- <=75

NOTES

Noise level predictions in this figure based on the methodologies outlined in Chapter 9:Noise and Vibration and Appendix 9A: Construction Noise Information

ISSUE PURPOSE

HRA

PROJECT NUMBER

60665962

SHEET TITLE

Cofferdam Impact Sheet Piling Lmax Noise Level Predictions

SHEET NUMBER

Figure 9.4b

APPENDIX A RELEVANT IMPACT PATHWAYS

A.1.1 The completed mandatory Appendix 1 screening templates required by Advice Note Ten (The Planning Inspectorate, 2017) are provided below and summarise (in the required format) the potential impacts of the Proposed Development on the identified relevant European Sites. This provides the basis for the more detailed screening assessment provided above in Section 5 of the main report.

A.1.2 The European Sites included within the screening assessment are:

- Humber Estuary SAC;
- Humber Estuary SPA;
- Humber Estuary Ramsar site;
- Thorne Moor SAC;
- Hatfield Moor SAC; and
- Thorne and Hatfield Moors SPA.

A.1.3 The required information is provided below as follows:

- Table A1 – Summary effects considered within the screening matrices;
- HRA Screening Matrix 1 – Screening matrix for Humber Estuary SAC;
- HRA Screening Matrix 2 – Screening matrix for Humber Estuary SPA;
- HRA Screening Matrix 3 – Screening matrix for Humber Estuary Ramsar site;
- HRA Screening Matrix 4 - Screening matrix for Thorne Moor SAC;
- HRA Screening Matrix 5 - Screening matrix for Hatfield Moor SAC; and
- HRA Screening Matrix 6 - Screening matrix for Thorne and Hatfield Moors SPA.

Table A1: The impact pathways considered in this Habitats Regulations Assessment, which are referred to in the detailed screening matrices below.

Designation(s)	Impact Pathways identified on the current evidence base	Presented in Screening Matrices as
Humber Estuary SAC, SPA and Ramsar site	Direct habitat disturbance and modification during construction, operation and decommissioning, including in terms of quality for dependent qualifying species. Visual and noise/ vibration disturbance of qualifying species during construction, operation and decommissioning. Entrapment of river and sea lamprey during operation and decommissioning. Spread of INNS during construction, operation and decommissioning. Emissions to atmosphere during construction, operation and decommissioning. Deterioration in water quality during construction, operation and decommissioning from a variety of sources, including thermal pollution. Temporary and/ or permanent effects on foraging resources of fish of qualifying bird and lamprey species during construction, operation and decommissioning.	Habitat disturbance and modification Visual and noise/ vibration disturbance Entrapment of lamprey INNS Atmospheric pollution Water quality Impacts on foraging resources
Thorne Moor SAC, Hatfield Moor SAC and Thorne and Hatfield Moors SPA	Emissions to atmosphere during operation.	Atmospheric pollution

HRA Screening Matrix 1: Humber Estuary SAC

Within this table:

C = Construction

O = Operation

D = Decommissioning

✓ = Likely significant effect cannot be excluded

X = Likely significant effect can be excluded

NA = Not Applicable

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Coastal lagoons		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Dunes with *Hippophae rhamnoides*		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Embryonic shifting dunes		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Estuaries		✓b	✓b	NA	NA	NA	NA	**X**f	**X**f	✓g	✓g	✓i	✓i	**X**	**X**	✓bgi	✓bgi
Fixed coastal dunes with herbaceous vegetation (“grey dunes”)		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Mudflats and sandflats not covered by seawater at low tide		✓b	✓b	NA	NA	NA	NA	**X**f	**X**f	✓g	✓g	✓i	✓i	**X**	**X**	✓bgi	✓bgi
Salicornia and other annuals colonizing mud and sand		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Sandbanks which are slightly covered by sea water all the time		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Shifting dunes along the shoreline with Ammophila arenaria ("white dunes");		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Sea lamprey		✓d	✓d	✓d	**X**c	✓e	✓e	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓deg	✓deg
River lamprey		✓d	✓d	✓d	**X**c	✓e	✓e	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓deg	✓deg
Grey seal		**X**a	**X**a	**X**a	**X**a	NA	NA	**X**f	**X**f	**X**h	**X**h	**X**aj	**X**aj	**X**a	**X**a	**X**ah	**X**ah

a. These qualifying habitats and species are not identified (see Section 5.2 paragraphs 5.2.4-7, and Section 4.3 paragraph 4.3.4 respectively) to occur along the tidal River Trent at and downstream of the Proposed Development. No likely effects from these impact pathways are therefore likely given the parameters of the Proposed Development.

b. These qualifying habitats are present in association with the River Trent at the location of the Proposed Development (see Section 5.2 paragraphs 5.2.4-7) so occur within the construction and/ or operational zone of influence (see Sections 5.2 and 5.3).

c. These qualifying species are present in association with the River Trent at the location of the Proposed Development (see Section 4.3 paragraph 4.3.4) but this impact pathway would not occur during operation (see Section 5.3).

d. These qualifying species are present in association with the River Trent at the location of the Proposed Development (see Section 4.3 paragraph 4.3.4) so occur within the construction and/ or operational zone of influence (see Sections 5.2 and 5.3).

e. If a cofferdam is used during construction of the River Water Abstraction option (if required) then, depending on the timing of works (lamprey are only present during periods of migration), lamprey could become trapped in areas to be dewatered (see Section 5.2). During operation there is a theoretical risk of lamprey becoming trapped in water abstraction infrastructure, but again, only if the River Trent is used as the cooling water supply source. The operational pathway could not occur in practice due to the requirements of regulators which have been considered during design of the Proposed Development (see Section 5.3).

f. There are no likely pathways for impacts on species and habitats from INNS, given the existing baseline conditions (existing presence of INNS in River Trent and/ or no existing barriers to spread from connected watercourses affected by the Proposed Development). The proposed construction approach, as set out in the Framework CEMP (**Application Document Ref. 7.1**), includes mandatory biosecurity provision that also serves to close this pathway. However, to provide clarity on this aspect, it is further explained in the main screening assessment (see Sections 5.2 and 5.3).

g. Habitats and species located within the worst-case study areas for construction and/ or operational air quality impact assessment and therefore require further screening (see Sections 5.2 and 5.3).

h. Species located in and/ or primarily reliant on marine habitats located beyond the worst-case (15km) study areas for construction and/ or operational air quality impact assessment (see Section 4.3 paragraph 4.3.4). No pathways for impact on that basis.

HRA Screening Matrix 2: Humber Estuary SPA

Within this table:

C = Construction

O = Operation

D = Decommissioning

✓ = Likely significant effect cannot be excluded

X = Likely significant effect can be excluded

NA = Not Applicable

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Botaurus stellaris; Great bittern (breeding and non-breeding)		**X**a	**X**a	**X**a	**X**a	NA	NA	**X**e	**X**e	**X**g	✓f	**X**ai	**X**ai	**X**ai	**X**ai	**X**ag	✓f

Qualifying features	Effect	Habitat disturbance and modification		Visual and noise/ vibration disturbance		Entrapment of lamprey		Invasive non-native species		Atmospheric pollution		Water quality		Impacts on foraging resources		In-combination effects	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Tadorna tadorna; Common shelduck (non-breeding)		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef
Circus aeruginosus; Eurasian marsh harrier (breeding)		**X**a	**X**a	**X**a	**X**a	NA	NA	**X**e	**X**e	**X**g	✓f	**X**a	**X**a	**X**a	**X**a	**X**ag	✓f
Circus cyaneus; Hen harrier (non-breeding)		**X**j	**X**j	**X**a	**X**a	NA	NA	**X**e	**X**e	**X**g	✓f	**X**a	**X**a	**X**a	**X**a	**X**g	✓f
Recurvirostra avosetta; Pied avocet (breeding and non-breeding)		**X**a	**X**a	**X**a	**X**a	NA	NA	**X**e	**X**e	**X**g	✓f	**X**a	**X**a	**X**a	**X**a	**X**ag	✓f
Pluvialis apricaria; European golden plover (non-breeding)		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Calidris canutus; Red knot (non-breeding)		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef
Calidris alpina; Dunlin (non-breeding)		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef
Philomachus pugnax; Ruff (non-breeding)		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef
Limosa limosa islandica; Black-tailed godwit (non-breeding)		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef
Limosa lapponica; Bar-tailed godwit (non-breeding)		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef
Tringa totanus; Common redshank (non-breeding)		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef

Qualifying features	Effect	Habitat disturbance and modification		Visual and noise/ vibration disturbance		Entrapment of lamprey		Invasive non-native species		Atmospheric pollution		Water quality		Impacts on foraging resources		In-combination effects	
	Stage of Proposed Development	C/ D	O	C/ D	O	C/ D	O	C/ D	O	C/ D	O	C/ D	O	C	O	C/D	O
Sterna albifrons; Little tern (breeding)		**X**a	**X**a	**X**a	**X**a	NA	NA	**X**e	**X**e	**X**g	✓f	**X**a	**X**a	**X**a	**X**a	**X**ag	✓f
Water bird assemblage		✓b	✓b	✓d	✓c	NA	NA	**X**e	**X**e	✓f	✓f	✓b	✓b	✓b	✓b	✓bdef	✓bdef

a. These qualifying species do not occur along the tidal River Trent at and downstream of the Proposed Development (see Section 5.2 paragraphs 5.2.13-14). At their closest, the identified habitats present potentially occur at Blacktoft Sands more than 9km to the north of the Proposed Development. No likely effect at distances concerned given the parameters of the Proposed Development.

b. These qualifying species may occur in association with the River Trent at the location of the Proposed Development (see Section 5.2 paragraphs 5.2.14).

c. These qualifying species may occur in association with the River Trent at the location of the Proposed Development (see Section 5.2 paragraphs 5.2.14) but this impact pathway would not occur during operation (see Section 5.3).

d. These species potentially occur within the construction and/ or operational zone of influence (see Section 5.2 paragraphs 5.2.14).

e. There are no likely pathways for impacts on species from INNS, given the existing baseline conditions (existing presence of INNS in River Trent and/ or no existing barriers to spread from connected watercourses affected by the Proposed Development). The proposed construction approach, as set out in the Framework CEMP (**Application Document Ref. 7.1**), includes mandatory biosecurity provision that also serves to close this pathway. However, to provide clarity on this aspect, it is further explained in the main screening assessment (see Sections 5.2 and 5.3).

f. These are species located within the worst-case study areas for construction and/ or operational air quality impact assessment and therefore require further screening (see Sections 5.2 and 5.3).

g. Species located and/ or primarily reliant on coastal habitats (see Section 5.2 paragraph 5.2.13) located beyond the worst-case (15km) study areas for construction and/ or operational air quality impact assessment (see Sections 5.2 and 5.3). No pathways for impact on that basis.

HRA Screening Matrix 3: Humber Estuary Ramsar site

Within this table:

C = Construction

O = Operation

D = Decommissioning

✓ = Likely significant effect cannot be excluded

X = Likely significant effect can be excluded

NA = Not Applicable

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Coastal lagoons		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Dunes with *Hippophae rhamnoides*		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Embryonic shifting dunes		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Estuaries		✓b	✓b	NA	NA	NA	NA	**X**f	**X**f	✓g	✓g	✓i	✓i	**X**	**X**	✓bgi	✓bgi
Fixed coastal dunes with herbaceous vegetation (“grey dunes”)		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Mudflats and sandflats not covered by seawater at low tide		✓b	✓b	NA	NA	NA	NA	**X**f	**X**f	✓g	✓g	✓i	✓i	**X**	**X**	✓bgi	✓bgi
Salicornia and other annuals colonizing mud and sand		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Sandbanks which are slightly covered by sea water all the time		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Shifting dunes along the shoreline with Ammophila arenaria (“white dunes”);		**X**a	**X**a	NA	NA	NA	NA	**X**f	**X**f	**X**a	✓g	**X**a	**X**a	**X**	**X**	**X**a	✓g
Sea lamprey		✓d	✓d	✓d	**X**c	✓e	✓e	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓deg	✓deg
River lamprey		✓d	✓d	✓d	**X**c	✓e	✓e	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓deg	✓deg
Grey seal		**X**a	**X**a	**X**a	**X**a	NA	NA	**X**f	**X**f	**X**h	**X**h	**X**aj	**X**aj	**X**a	**X**a	**X**ah	**X**ah

Qualifying features	**Effect**	**Habitat disturbance and modification**		**Visual and noise/ vibration disturbance**		**Entrapment of lamprey**		**Invasive non-native species**		**Atmospheric pollution**		**Water quality**		**Impacts on foraging resources**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C/ D**	**O**	**C**	**O**	**C/D**	**O**
Tadorna tadorna; Common shelduck (non-breeding)		✓d	✓d	✓d	**X**c	NA	NA	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓dfg	✓dfg
Pluvialis apricaria; European golden plover (non-breeding)		✓d	✓d	✓d	**X**c	NA	NA	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓dfg	✓dfg
Calidris canutus; Red knot (non-breeding)		✓d	✓d	✓d	**X**c	NA	NA	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓dfg	✓dfg
Calidris alpina; Dunlin (non-breeding)		✓d	✓d	✓d	**X**c	NA	NA	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓dfg	✓dfg
Limosa limosa islandica; Black-tailed godwit (non-breeding)		✓d	✓d	✓d	**X**c	NA	NA	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓dfg	✓dfg

Qualifying features	Effect	Habitat disturbance and modification		Visual and noise/ vibration disturbance		Entrapment of lamprey		Invasive non-native species		Atmospheric pollution		Water quality		Impacts on foraging resources		In-combination effects	
	Stage of Proposed Development	C/ D	O	C/ D	O	C/ D	O	C/ D	O	C/ D	O	C/ D	O	C	O	C/D	O
Limosa lapponica; Bar-tailed godwit (non-breeding)		✓d	✓d	✓d	**X**c	NA	NA	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓dfg	✓dfg
Tringa totanus; Common redshank (non-breeding)		✓d	✓d	✓d	**X**c	NA	NA	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓dfg	✓dfg
Water bird assemblage (non-breeding)		✓d	✓d	✓d	**X**c	NA	NA	**X**f	**X**f	✓g	✓g	✓d	✓d	✓d	✓d	✓dfg	✓dfg
Natterjack toad		**X**a	**X**a	**X**a	**X**a	NA	NA	**X**a	**X**a	**X**h	**X**h	**X**a	**X**a	**X**a	**X**a	**X**ah	**X**ah

a. These qualifying habitats and species are not identified (see Section 5.2 paragraphs 5.2.4-7, Section 4.3 paragraph 4.3.4 and Section 5.2 paragraph 5.2.13 respectively) to occur along the tidal River Trent at and downstream of the Proposed Development. No likely effects from these impact pathways are therefore likely given the parameters of the Proposed Development.

b. These qualifying habitats are present in association with the River Trent at the location of the Proposed Development (see Section 5.2 paragraphs 5.2.4-7) so occur within the construction and/ or operational zone of influence (see Sections 5.2 and 5.3).

c. These qualifying species may occur in association with the River Trent at the location of the Proposed Development (see Section 4.3 paragraph 4.3.4 and Section 5.2 paragraphs 5.2.14) but this impact pathway would not occur during operation (see Section 5.3).

d. These species potentially occur within the construction and/ or operational zone of influence (see Section 4.3 paragraph 4.3.4 and Section 5.2 paragraphs 5.2.14).

e. If a cofferdam is used during construction of the River Water Abstraction option (if required) then, depending on the timing of works (lamprey are only present during periods of migration), lamprey could become trapped in areas to be dewatered. During operation there is a theoretical risk of lamprey becoming trapped in water abstraction infrastructure, but again, only if the River Trent is used as the cooling water supply source. This pathway would not exist due to the requirements of regulators which have been considered during design of the Proposed Development. However, to provide clarity on this, this aspect it is further explained in in the main screening assessment (see Sections 5.2 and 5.3).

f. There are no likely pathways for impacts on species and habitats from INNS, given the existing baseline conditions (existing presence of INNS in River Trent and/ or no existing barriers to spread from connected watercourses affected by the Proposed Development). The proposed construction approach, as set out in the Framework CEMP (**Application Document Ref. 7.1**), includes mandatory biosecurity provision that also serves to close this pathway. However, to provide clarity on this aspect, it is further explained in the main screening assessment (see Section 5.2).

g. Habitats and species located within the worst-case study areas for construction and/ or operational air quality impact assessment and therefore require further screening (see Sections 5.2 and 5.3).

h. Species located in and/ or primarily reliant on marine habitats located beyond the worst-case (15km) study areas for construction and/ or operational air quality impact assessment (see Section 4.3 paragraph 4.3.4). No pathways for impact on that basis.

HRA Screening Matrix 4: Thorne Moor SAC

Within this table:

C = Construction

O = Operation

D = Decommissioning

✓ = Likely significant effect cannot be excluded

X = Likely significant effect can be excluded

NA = Not Applicable

Qualifying features	**Effect**	**Atmospheric pollution**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/D**	**O**
Degraded raised bogs still capable of natural regeneration		**X**a	✓b	**X**a	✓b

a. Located well beyond the worst-case 500m study area for construction air quality impact assessment and therefore there is no potential for significant air quality effects (see paragraph 4.2.2).

b. Habitat located within the worst-case 15km study area for operational air quality impact assessment and therefore requires further screening (see paragraph 4.2.2 and Section 5.3 of the main assessment).

HRA Screening Matrix 5: Hatfield Moor SAC

Within this table:

C = Construction

O = Operation

D = Decommissioning

✓ = Likely significant effect cannot be excluded

X = Likely significant effect can be excluded

NA = Not Applicable

Qualifying features	**Effect**	**Atmospheric pollution**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/D**	**O**
Degraded raised bogs still capable of natural regeneration		**X**a	✓b	**X**a	✓b

a. Located well beyond the worst-case 500m study area for construction air quality impact assessment and therefore there is no potential for significant air quality effects (paragraph 4.2.2).

b. Habitat located within the worst-case 15km study area for operational air quality impact assessment and therefore requires further screening (see paragraph 4.2.2 and Section 5.3 of the main assessment).

HRA Screening Matrix 6: Thorne and Hatfield Moors SPA

Within this table:

C = Construction

O = Operation

D = Decommissioning

✓ = Likely significant effect cannot be excluded

X = Likely significant effect can be excluded

NA = Not Applicable

Qualifying features	**Effect**	**Atmospheric pollution**		**In-combination effects**	
	Stage of Proposed Development	**C/ D**	**O**	**C/D**	**O**
Caprimulgus europaeus; European nightjar (breeding)		**X**a	✓b	**X**a	✓b

a. At the closest point these designations are 5.5km from the Proposed Development (see paragraph 4.2.2), so too distant for any reasonable likelihood of direct impacts on nightjar. The SPA is therefore also well beyond the worst-case 500m study area for construction/ decommissioning air quality impact assessment and therefore there is no potential for significant construction/ decommissioning air quality effects.

b. Species dependent on habitats located within the worst-case 15km study area for operational air quality impact assessment and therefore requires further screening (see paragraph 4.2.2 and Section 5.3 of the main assessment).

APPENDIX B RESULTS OF THE OPERATION AIR QUALITY ASSESSMENT

Appendix B1: Results Prior to Mitigation For LSE

Table B1: NO_x Dispersion modelling results for ecological receptors

Receptor ID	Site Name	Annual average (µg/m³)						24-hour average (µg/m³)					
		CL	PC	PC % of CL	BC	PEC	PEC % of CL	CL	PC	PC % of CL	BC	PEC	PEC % of CL
OE1-5	Humber Estuary Ramsar/ SAC/ SSSI	30	0.49	1.6%	13.7	14.23	47%	75	9.9	13%	20.6	30.5	41%
OE10	Thorne Moor SAC and SPA		0.05	0.2%	11.2	11.25	38%		1.7	2%	16.8	18.6	25%
OE13	Hatfield Moor SAC and SPA		0.03	0.1%	11.7	11.78	39%		1.4	2%	17.6	19.1	25%
OE32	Humber Estuary (at Blacktoft Sands) Ramsar, SAC, SPA and SSSI		0.13	0.4%	13.1	13.19	44%		1.4	2%	19.6	21.0	28%
CL = Critical Level, PC = Process Contribution, BC = Background Concentration (modified to include the contribution from the Keadby 2 Power Station), PEC = Predicted Environmental Concentration													

Table B2: Dispersion modelling results for ecological receptors – NH_3

Receptor ID	Site Name	Annual Average (µg/m3)					
		CL	PC	PC % of CL	BC	PEC	PEC % of CL
OE1-5	Humber Estuary SSSI, SAC, Ramsar	3	0.05	1.6%	2.36	2.41	80%
OE10	Thorne Moor SAC and SPA	1	0.005	0.5%	2.60	2.60	260%
OE13	Hatfield Moor SAC and SPA	1	0.003	0.3%	2.39	2.40	240%
OE32	Humber Estuary (at Blacktoft Sands) Ramsar, SPA, SAC and SSSI	3	0.01	0.4%	2.28	2.29	76%

CL = Critical Level, PC = Process Contribution, BC = Background Concentration (modified to include the contribution from the Keadby 2 Power Station), PEC = Predicted Environmental Concentration

Table B3: Dispersion modelling results for ecological receptors – Nutrient nitrogen deposition (Kg N/ha/yr)

Receptor ID	Site name	Background nitrogen deposition[1] (kg N/ha/yr)	Most stringent Critical Load class applicable for the site	Lower value of applicable Critical Load range	PC (kg N/ha/yr)	PC % Critical Load	PEC (kg N/ha/yr)	PEC % Critical Load
OE1-5	Humber Estuary Ramsar, SSSI, SAC	20.2	Pioneer, Low-mid, mid-upper saltmarshes	20	0.31	1.5%	20.5	103%
OE10	Thorne Moor SAC	21.3	Degraded Raised Bogs	5	0.03	0.6%	21.3	427%
OE13	Hatfield Moor SSSI	20.9	Raised and blanket bogs	5	0.02	0.4%	20.9	418%
OE32	Humber Estuary at Blacktoft Sands (Ramsar, SAC, SPA and SSSI)	18.2	Rich Fens	15	0.08	0.5%	18.3	122%

[1] The background concentration has been modified to include the contribution from the Keadby 2 Power Station

Table B4: Dispersion modelling results for ecological receptors – Acid deposition N (Keq/ha/yr)

Receptor ID	Site name	Acid deposition				PC acid deposition (keq/ha/yr)		
		Critical Load (keq/ha/yr)	Baseline[1] (keq/ha/yr)	Lowest Critical Load class applicable	Baseline % of Critical Load	PC	PC % of Critical Load	PEC% of Critical Load
OE1-5	Humber Estuary Ramsar/ SAC/ SSSI	Pioneer, Low-mid, mid-upper saltmarshes – not sensitive to acidity						
OE10	Thorne Moor SAC and SPA	Min CL Min N: 0.321 Min CL Max N: 0.462 Min CL Max S: 0.141	N: 1.5 S: 0.2	Bogs	374%	0.002	0.0%	374.5%
OE13	Hatfield Moor SAC and SPA	Min CL Min N: 0.321 Min CL Max N: 0.475 Min CL Max S: 0.154	N: 1.5 S: 0.2	Bogs	356%	0.001	0.0%	355.8%
OE32	Humber Estuary at Blacktoft Sands (Ramsar, SAC, SPA and SSSI)	Fen, Marsh and Swamp - Not sensitive to acidity						

[1] The background concentration has been modified to include the contribution from the Keadby 2 Power Station

Appendix B2: Results After Mitigation (Abatement of Ammonia Through Acid Wash)

Table B5: Dispersion modelling results for ecological receptors – NH_3 (after acid wash)

Receptor ID	Site Name	Annual Average (µg/m3)					
		CL	PC	PC % of CL	BC	PEC	PEC % of CL
OE1-5	Humber Estuary SSSI, SAC, Ramsar	3	0.02	0.5%	2.36	2.38	79%
OE10	Thorne Moor SAC and SPA	1	0.002	0.2%	2.60	2.60	260%
OE13	Hatfield Moor SAC and SPA	1	0.001	0.1%	2.39	2.40	240%
OE32	Humber Estuary (at Blacktoft Sands) Ramsar, SPA, SAC and SSSI	3	0.004	0.1%	2.28	1.91	64%

CL = Critical Level, PC = Process Contribution, BC = Background Concentration (modified to include the contribution from the Keadby 2 Power Station), PEC = Predicted Environmental Concentration

Table B6: Dispersion modelling results for ecological receptors – Nutrient nitrogen deposition (Kg N/ha/yr) (after acid wash)

Receptor ID	Site name	Background nitrogen deposition[1] (kg N/ha/yr)	Most stringent Critical Load class applicable for the site	Lower value of applicable Critical Load range	PC (kg N/ha/yr)	PC % Critical Load	PEC (kg N/ha/yr)	PEC % Critical Load
OE1-5	Humber Estuary Ramsar, SSSI, SAC	20.2	Pioneer, Low-mid, mid-upper saltmarshes	20	0.13	0.7%	20.4	102%
OE10	Thorne Moor SAC	21.3	Degraded Raised Bogs	5	0.01	0.2%	21.3	426%
OE13	Hatfield Moor SSSI	20.9	Raised and blanket bogs	5	0.01	0.2%	20.9	418%
OE32	Humber Estuary at Blacktoft Sands (Ramsar, SAC, SPA and SSSI)	18.2	Rich Fens	15	0.04	0.2%	18.2	121%

[1] The background concentration has been modified to include the contribution from the Keadby 2 Power Station

Table B7: Dispersion modelling results for ecological receptors – Acid deposition N (Keq/ha/yr) (after acid wash)

Receptor ID	Site name	Acid deposition				PC acid deposition (keq/ha/yr)		
		Critical Load (keq/ha/yr)	Baseline[1] (keq/ha/yr)	Lowest Critical Load class applicable	Baseline % of Critical Load	PC	PC % of Critical Load	PEC% of Critical Load
OE1-5	Humber Estuary Ramsar/ SAC/ SSSI	Pioneer, Low-mid, mid-upper saltmarshes – not sensitive to acidity						
OE10	Thorne Moor SAC and SPA	Min CL Min N: 0.321 Min CL Max N: 0.462 Min CL Max S: 0.141	N: 1.5 S: 0.2	Bogs	374%	0.001	0.0%	374%
OE13	Hatfield Moor SAC and SPA	Min CL Min N: 0.321 Min CL Max N: 0.475 Min CL Max S: 0.154	N: 1.5 S: 0.2	Bogs	356%	0.001	0.0%	356%
OE32	Humber Estuary at Blacktoft Sands (Ramsar, SAC, SPA and SSSI)	Fen, Marsh and Swamp - Not sensitive to acidity						

[1] The background concentration has been modified to include the contribution from the Keadby 2 Power Station

APPENDIX C EFFECTS ON INTEGRITY

C.1.1 The completed mandatory Appendix 2 screening template matrices required by Advice Note Ten (The Planning Inspectorate, 2017) are provided below. The purpose of the matrices is to confirm the potential LSE requiring Appropriate Assessment based on the potential impact pathways identified in Annex A of this report and the detailed examination of the potential impact pathways provided in section 5 of this HRA report. Therefore, the matrices do not list LSE that have already been excluded with section 5 of the main report.

C.1.2 The European Sites listed below have been subject to further assessment in order to establish if the NSIP could have an adverse effect on their integrity:

- Humber Estuary SAC (HRA Integrity Matrix 1);
- Humber Estuary SPA (HRA Integrity Matrix 2);
- Humber Estuary Ramsar site (HRA Integrity Matrix 3);
- Thorne Moor SAC (HRA Integrity Matrix 4);
- Hatfield Moor SAC (HRA Integrity Matrix 5); and
- Thorne and Hatfield Moors SPA (HRA Integrity Matrix 6).

C.1.3 The required Appropriate Assessment is provided in Section 6 of this HRA report, which should be referred to for the conclusions on whether there is a likely effect on the integrity of any European Sites.

C.1.4 Within the following matrices:

O = Operation

✓ = Adverse effect on integrity cannot be excluded

X = Adverse effect on integrity can be excluded

NA = Not Applicable

HRA Integrity Matrix 1: Humber Estuary SAC

Qualifying features	Effect	Habitat disturbance and modification	Noise and visual disturbance	Atmospheric pollution	Water quality
	Stage of Proposed Development	**C**	**C**	**O**	**C**
Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)		Xa	Xa	✓d	Xa
Coastal lagoons		Xa	Xa	✓d	Xa
Dunes with *Hippophae rhamnoides*		Xa	Xa	✓d	Xa
Embryonic shifting dunes		Xa	X	✓d	Xa
Estuaries		✓b	Xa	✓d	✓b
Fixed coastal dunes with herbaceous vegetation ("grey dunes")		Xa	Xa	✓d	Xa
Mudflats and sandflats not covered by seawater at low tide		✓b	Xa	✓d	✓b
Salicornia and other annuals colonizing mud and sand		Xa	Xa	✓d	Xa

Qualifying features	**Effect**	**Habitat disturbance and modification**	**Noise and visual disturbance**	**Atmospheric pollution**	**Water quality**
	Stage of Proposed Development	**C**	**C**	**O**	**C**
Sandbanks which are slightly covered by sea water all the time		Xa	Xa	✓d	Xa
Shifting dunes along the shoreline with *Ammophila arenaria* ("white dunes");		Xa	Xa	✓d	Xa
Sea lamprey		Xa	✓c	✓e	✓b
River lamprey		Xa	✓c	✓e	✓b
Grey seal		Xa	Xa	Xa	Xa

a. Pathway not relevant see Appendix A.

b. The identified habitats occur at the location of construction activities and LSE cannot be discounted (see Section 5.2).

c. Species for which LSE cannot be discounted due to their being present within potential the zone of influence of construction noise if a cofferdam is required on the River Trent (see Section 5.2).

d. The identified habitats occur within the 15km study area. Through the air quality impact assessment, it was determined that abatement of ammonia emissions would be necessary due to potential LSE (see Section 5.3). For the purposes of this HRA, such abatement measures constitute mitigation and consequently cannot be considered until HRA stage 2 i.e. Appropriate Assessment (Section 6 of this report).

e. Species for which LSE cannot be discounted due to their being a potential air quality impact on key habitats (see Section 5.3).

HRA Integrity Matrix 2: Humber Estuary SPA

Qualifying features	**Effect**	**Noise and visual disturbance**	**Atmospheric pollution**	**Water quality**
	Stage of Proposed Development	**C**	**O**	**C**
Botaurus stellaris; Great bittern (breeding and non-breeding)		Xa	✓c	Xa
Tadorna tadorna; Common shelduck (non-breeding)		✓b	✓c	✓b
Circus aeruginosus; Eurasian marsh harrier (breeding)		Xa	✓c	Xa
Circus cyaneus; Hen harrier (non-breeding)		Xa	✓c	Xa
Recurvirostra avosetta; Pied avocet (breeding and non-breeding)		Xa	✓c	Xa
Pluvialis apricaria; European golden plover (non-breeding)		✓b	✓c	✓b
Calidris canutus; Red knot (non-breeding)		✓b	✓c	✓b
Calidris alpina alpina; Dunlin (non-breeding)		✓b	✓c	✓b

Qualifying features	Effect	Noise and visual disturbance	Atmospheric pollution	Water quality
	Stage of Proposed Development	**C**	**O**	**C**
Philomachus pugnax; Ruff (non-breeding)		✓b	✓c	✓b
Limosa limosa islandica; Black-tailed godwit (non-breeding)		✓b	✓c	✓b
Limosa lapponica; Bar-tailed godwit (non-breeding)		✓b	✓c	✓b
Tringa totanus; Common redshank (non-breeding)		✓b	✓c	✓b
Sterna albifrons; Little tern (breeding)		Xa	✓c	Xa
Water bird assemblage		✓b	✓c	✓b

a. Pathway not relevant see Appendix A.

b. Species that may be dependent on habitats present in the zone of influence for a construction noise impact, so LSE cannot be discounted (see Section 5.2).

c. Species for which LSE cannot be discounted due to their being a potential air quality impact on key habitats (see Section 5.3).

HRA Integrity Matrix 3: Humber Estuary Ramsar Site

Qualifying features	Effect	Habitat disturbance and modification	Noise and visual disturbance	Atmospheric pollution	Water quality
	Stage of Proposed Development	**C**	**C**	**O**	**C**
Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)		Xa	Xa	✓d	Xa
Coastal lagoons		Xa	Xa	✓d	Xa
Dunes with *Hippophae rhamnoides*		Xa	Xa	✓d	Xa
Embryonic shifting dunes		Xa	X	✓d	Xa
Estuaries		✓b	Xa	✓d	
Fixed coastal dunes with herbaceous vegetation ("grey dunes")		Xa	Xa	✓d	Xa
Mudflats and sandflats not covered by seawater at low tide		✓b	Xa	✓d	✓b
Salicornia and other annuals colonizing mud and sand		Xa	Xa	✓d	Xa

Qualifying features	**Effect**	**Habitat disturbance and modification**	**Noise and visual disturbance**	**Atmospheric pollution**	**Water quality**
	Stage of Proposed Development	**C**	**C**	**O**	**C**
Sandbanks which are slightly covered by sea water all the time		Xa	Xa	✓d	Xa
Shifting dunes along the shoreline with *Ammophila arenaria* ("white dunes");		Xa	Xa	✓d	Xa
Sea lamprey		Xa	✓c	✓e	✓b
River lamprey		Xa	✓c	✓e	✓b
Grey seal		Xa	Xa	Xa	Xa
Tadorna tadorna; Common shelduck (non-breeding)		Xa	✓c	✓e	✓b
Pluvialis apricaria; European golden plover (non-breeding)		Xa	✓c	✓e	✓b
Calidris canutus; Red knot (non-breeding)		Xa	✓c	✓e	✓b
Calidris alpina alpina; Dunlin (non-breeding)		Xa	✓c	✓e	✓b

Qualifying features	**Effect**	**Habitat disturbance and modification**	**Noise and visual disturbance**	**Atmospheric pollution**	**Water quality**
	Stage of Proposed Development	**C**	**C**	**O**	**C**
Limosa limosa islandica; Black-tailed godwit (non-breeding)		Xa	✓c	✓e	✓b
Limosa lapponica; Bar-tailed godwit (non-breeding)		Xa	✓c	✓e	✓b
Tringa totanus; Common redshank (non-breeding)		Xa	✓c	✓e	✓b
Water bird assemblage		Xa	✓c	✓e	✓b
Natterjack toad		Xa	Xa	Xa	Xa

a. Pathway not relevant see Appendix A.

b. The identified habitats occur at the location of construction activities and LSE cannot be discounted (see Section 5.2).

c. Species that may be dependent on habitats present in the zone of influence for a construction noise impact, so LSE cannot be discounted (see Section 5.2).

d. The identified habitats occur within the 15km study area. Through the air quality impact assessment, it was determined that abatement of ammonia emissions would be necessary due to potential LSE (see Section 5.3). For the purposes of this HRA, such abatement measures constitute mitigation and consequently cannot be considered until HRA stage 2 i.e. Appropriate Assessment (Section 6 of this report).

e. Species for which LSE cannot be discounted due to their being a potential air quality impact on key habitats (see Section 5.2).

HRA Integrity Matrix 4: Thorne Moor SAC

Qualifying features	Effect	Atmospheric pollution
	Stage of Proposed Development	**O**
Degraded raised bogs still capable of natural regeneration		Xa

a. The air quality impact assessment identified no LSE in relation to the qualifying features of this European Site (see Section 5.3).

HRA Integrity Matrix 5: Hatfield Moor SAC

Qualifying features	Effect	Atmospheric pollution
	Stage of Proposed Development	**O**
Degraded raised bogs still capable of natural regeneration		Xa

a. The air quality impact assessment identified no LSE in relation to the qualifying features of this European Site (see Section 5.3).

HRA Integrity Matrix: Thorne and Hatfield Moors SPA

Qualifying features	Effect	Atmospheric pollution
	Stage of Proposed Development	**O**
Caprimulgus europaeus; European nightjar (breeding)		Xa

a. The air quality impact assessment identified no LSE in relation to the qualifying features of this European Site (see Section 5.3).

APPENDIX D OTHER PLANS AND PROJECTS OF POTENTIAL RELEVANCE TO THE IN-COMBINATION ASSESSMENT

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
1	Humber Low Carbon Pipelines PINS Ref: EN070006	Development of 'Zero Carbon Industrial Cluster' with the principal area of interest being the construction of a CO_2 transport and storage system across the Humber region. Strategic proposals also encompass a Hydrogen demonstration and test facility, installation of carbon capture technology at Drax Power Station and a geologically secure long-term CO_2 storage facility in the North Sea. Application listed on PINS' National Infrastructure Planning website: DCO Application anticipated to be submitted to PINS in Q3 2022.	**Scoped out of in-combination assessment.** The Proposed Development has been sited to be able to connect into the emerging proposals for the Humber Low Carbon Pipeline carbon dioxide (CO_2) pipeline. This scheme is currently at pre-feasibility stage and a detailed design is therefore not available for purposes of in-combination assessment. It is assumed that the CO_2 pipeline could be constructed in parallel with the Proposed Development, which would allow commercial operation of the Proposed Development to commence at the earliest in late 2026. Or it may be the case that construction of the Humber Low Carbon pipeline proposals occurs later than construction of the Proposed Development commences, and construction timescales would therefore not overlap. Construction of the pipeline, if it were to coincide with the Proposed Development construction, will result in cumulative effects. However, it is not possible to fully assess those cumulative effects until the details of the Humber Low Carbon pipeline are available - an assessment based on the best available information is therefore included within **Chapter 19:** Cumulative and Combined Effects (ES Volume I – **Application Document Ref. 6.2**).

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
			It is noted that a detailed cumulative assessment will be included as part of the Humber Low Carbon Pipeline application and that it will be a requirement for the National Grid Carbon – the pipeline proposer, to take account of the effects of the Proposed Development as a committed development. It is envisaged that the mechanism by which any likely significant cumulative effects found within the Humber Low Carbon Pipeline DCO application(s) would be considered within the Proposed Development would be, for example, in the form of updates to Proposed Development CEMP and construction method statements to accommodate any likely cumulative effects once known. On the assumption that construction of the Proposed Development would commence before construction of the Humber Low Carbon Pipeline but that construction timescales could overlap, it is unlikely that construction works in-combination would exceed the 70db threshold set for an adverse noise effect on birds (see Section 5 of this report) given the conclusions of the noise modelling for the Proposed Development in isolation. The worst-case noise levels during the main civils works for the Proposed Development (i.e. the locations where the Proposed Development would construct pipeline connections) for the Proposed Development would be no more than 40dB. Noise levels arising from pipeline

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
			construction would reasonably not give rise to levels which in combination would be classed as significant. Given the nature of the Humber Low Carbon Pipeline, operation would not result in emissions to air that could be relevant to this in-combination assessment. So, there is no pathway for an in-combination operational effect.
2	Keadby 2 Keadby II S36 Consent	Keadby Developments Limited (part of SSE). Keadby 2 Section 36 Variation Application(s) 2016/2017/2018	**Scoped out of in-combination assessment.** As the construction period for Keadby 2 Power Station is due to be completed early in 2022, before the Proposed Development construction period commences, there is no potential for cumulative construction phase impacts and effects. Operationally, the Keadby 2 Power Station project is considered as part of the baseline and is scoped out of **Chapter 19**: Cumulative and Combined Effects (ES Volume I – **Application Document Ref. 6.2**).
3	Keadby Wind Farm Extension EN010070	SSE. Keadby Windfarm Extension	**Scoped out of in-combination assessment.** Planning Inspectorate (DCO) Project on hold as of 27/05/15. The Applicant has confirmed that there are no plans to take this project forward at the present time.
4	Biodiversity Enhancement Area PA/2020/952	Keadby Developments Limited (part of SSE). Keadby Developments Limited (part of SSE). Planning permission for the creation of a Biodiversity Enhancement Area (comprising the use of 70,000 m^3 of excavated soil).	**Scoped out of in-combination assessment.** Scheme currently refused planning permission. Minor scheme with biodiversity purpose. No potential for adverse in-combination effects.

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
5	30 residential dwellings at Old Railway Sidings PA/2019/1904	WFW Development Ltd. Erect 30 affordable dwellings with associated access and other works, Old Railway Sidings, A18 From Althorpe To Gunness, Althorpe, DN17 3HN. Refused planning permission (at the time of submission)	**Scoped out of in-combination assessment.** Located in Althorpe village 1km away from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.
6	27 residential dwellings PA/2017/1513	Roger Burnett Promotions, Retirement & Death Benefit Scheme. Outline planning permission granted to erect 27 dwellings with access and layout to be determined and all other matters reserved for subsequent approval, Land off the A18, Althorpe	**Scoped out of in-combination assessment.** Located within the existing curtilage of Althorpe village, 1km away from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed
7	14 residential dwellings at Old Railway Sidings PA/2017/464	Mr T Webster. Outline planning permission granted for up to 14 dwellings. Yet to be built.	**Scoped out of in-combination assessment.** Not relevant as superseded by Scheme 5 (above), which is a resubmission for a larger development.
8	Mixed use developmen	Rafkins (Scunthorpe) Leisure Park Limited.	**Scoped out of in-combination assessment.** 2km from the Humber Estuary SAC and Ramsar site and located

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
	t.PA/2020/6 60	Planning application for mixed use development – hotel (Class C1), gym (Class D2), retail units (Class A1), food and drink and drive-thru restaurants (Class A3/A5) – access, car parking, landscaping and associated works. Approved 27/04/21.	within the existing curtilage of Scunthorpe. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed
9	11 industrial units. PA/2019/18 07	Mr Singh. Application to erect 11 industrial units. Not determined.	**Scoped out of in-combination assessment.** 3.4km from the Humber Estuary SAC and Ramsar site and located within the existing curtilage of Scunthorpe. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed
10	North Lincolnshire Green Energy Park North Lincolnshire Green Energy Park PINS Ref. EN010116	North Lincolnshire Green Energy Park Limited. DCO for an energy Recovery Facility converting up to 650,000 tonnes per annum of Refuse Derived Fuel (RDF) to generate a maximum of 95 megawatts of electrical output (MWe) and/or 380 Mega Watts of thermal output (MWt) to provide power, heat and steam on the site of the operating Flixborough Wharf on the River Trent. Expected to be submitted to the Planning Inspectorate in Q3 2021.	**Scoped out of in-combination assessment.** This scheme is at an early stage (EIA scoping opinion received) and consequently the DCO for the Proposed Development will have been submitted prior to any application for this scheme. The scoping report (ERM, 2020) notes that 'assuming that the DCO Application is submitted in Q3 2021, the earliest approval would be Q4 2022. Construction would therefore begin no sooner than Q1 2023 and will take three years to complete. Operation is expected to begin in 2025/26 and to operate for 25-40 years. A technology refresh would be

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
			anticipated by 2050/51, subject to future changes in technology'. Based on available information, there is potential for an in-combination air quality effect which will be assessed in **Chapter 19:** Cumulative and Combined Effects of the ES, using available information. However, it will be the responsibility of the developer to consider the Proposed Development as part of the future baseline to meet legal requirements for HRA.
11	Residential development PA/2017/824	Mr C Muscroft. Outline application for residential a development. Submitted but not determined.	**Scoped out of in-combination assessment.** 5.3km from the Humber Estuary SAC and Ramsar site and located within the existing curtilage of Crowle. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.
12	144 dwellings. PA/2020/1333	DDM Agriculture Ltd. Outline application to erect 144 dwellings with appearance, landscaping, layout and scale reserved for subsequent consideration. Submitted but not determined.	**Scoped out of in-combination assessment.** 3km from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
13	88 dwellings. PA/2019/1607	Harron Homes. Application to erect 88 dwellings with associated roads, drainage, service infrastructure and public open space (including demolition of existing agricultural buildings). Submitted but not determined.	**Scoped out of in-combination assessment.** 4km from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.
14	Engineering operations for railway line extension. PA/2020/537	Mr Bailey – Crowle Peatland Railway Society. Application to carry out engineering operations in connection with laying a 373 m railway line extension and construction of two railway platforms 12.2m x 2.3m. Submitted but not determined.	**Scoped out of in-combination assessment.** 8.4km from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.
15	Residential development (110 dwellings) PA/2020/1207	Moorwalk Limited Outline application for residential development (up to 110 dwellings), with public open spaces, the creation of a play area and sustainable drainage systems (SUDs) including detention basins with appearance, landscaping, layout and scale reserved for subsequent consideration. Refused permission	**Scoped out of in-combination assessment.** 6.2km from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
16	88 dwellings PA/2019/1088	Linden Homes. Application to erect 88 dwellings with associated access, drainage and landscaping. Approved 19/02/21.	**Scoped out of in-combination assessment.** 6.4km from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.
17	122 dwellings PA/2019/1107	Linden Homes. Application to erect 122 dwellings with associated access, drainage and landscaping. Submitted but undetermined.	**Scoped out of in-combination assessment.** 7.8km from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.
18	Little Crow Solar Park Little Crow Solar Park	INRG SOLAR (Little Crow) Ltd. DCO energy scheme comprising ground mounted solar photovoltaic arrays, electrical storage, grid connection infrastructure and other infrastructure integral to the construction and/or operation of the energy scheme. The solar park will have an installed maximum capacity of 150MW and battery storage of up to 90MW. Application submitted and in DCO Examination.	**Scoped out of in-combination assessment.** 9.1km from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.

ID	Application reference	Applicant for 'other development' and a brief description	Potential for in-combination effects
19	66 dwellings PA/2019/14 14	Mark Simmonds Planning Services. Outline application for residential development of up to 66 dwellings with all matters reserved or subsequent approval. Submitted but undetermined.	**Scoped out of in-combination assessment.** 6.4km from the Humber Estuary SAC and Ramsar site. Too distant to contribute to an in-combination effect through construction noise and vibration. Not in zone of influence for a construction traffic in-combination effect. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.
20	Solar PV farm and associated infrastructur e 20/01345/F UL	Lightsource BP. Variation of condition 3 of planning permission 14/01554/FULM (Solar Photovoltaic (PV) Farm with associated infrastructure (ancillary equipment includes inverters, transformers, small embedded sub-stations and a grid connection building)) granted on 20/04/15 to allow for an additional 15 years of operation.	**Scoped out of in-combination assessment.** Existing development located 7.5km from the Humber Estuary SAC and Ramsar site. No construction activities proposed. Would not contribute to the operational air quality baseline against which the Proposed Development has been assessed.

APPENDIX E THERMAL MODELLING

KEADBY THERMAL PLUME STUDY

PRELIMINARY REPORT

Final REPORT

Date: October 2011

APEM REF: 411099

CLIENT: **Andrew Barlow**

ADDRESS: **Scottish and Southern Energy**
Keadby Power Station
Keadby
Scunthorpe
South Humberside
DN17 3EF

PROJECT No: **411099**

DATE OF ISSUE: **October 2011**

PROJECT DIRECTOR: **Nicola O'Keeffe**

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CONTENTS

1 INTRODUCTION

1.1 Background

Keadby is a direct-cooled power station situated on the west bank of the tidal River Trent near Scunthorpe (NGR SE 833 116). The current station, which was commissioned in January 1996, was built on the former site of a coal-fired power station, and is now operated by Scottish and Southern Energy (SSE). Keadby power station uses a once-through cooling system which transfers 1 million cubic metres per day of water from the River Trent into a network of condensers, which provide thermal energy for a system of steam turbines. The cooling water is then discharged directly into the tidal River Trent section of the Humber Estuary Special Area of Conservation (SAC).

1.2 History of the Keadby power station permit and previous thermal discharge assessments

A pre-construction cooling water dispersion study of Keadby Power Station was undertaken by HR Wallingford during the design phase in 1991 using a one dimensional farfield model and a three dimensional midfield model from the HR Wallingford TIDEWAY system (HR Wallingford, 1992). This predicted that the thermal plume from the discharge would not present a thermal barrier to fish migration as it would not extend across the entire width of the river, being confined to the west bank with cooler water underneath. The model also concluded that "*during all tests there were areas of water less than 3°C above ambient in the reach of the river beside the outfall*". The discharge from the power station was modelled as $12m^3/s$, with two alternative temperature scenarios: ΔT +10°C and ΔT +5°C. This modelling was not however, verified with regular monitoring post-construction, and is now almost 20 years old.

In 2007 the Environment Agency undertook a Stage 3 Review of Consents study to investigate thermal loading on the Humber Estuary SAC (Environment Agency, 2007). The aim of this report was to quantify the impacts originating from permits issued by the Environment Agency. The study focussed on the interest features of the Humber Estuary SAC (see Table 1.1). Of these interest features, the majority were assessed as having low or zero vulnerability to the thermal regime, with the exception of river and sea lamprey, which were identified as highly sensitive to changes in water temperature, as their upstream migration is thought to be temperature dependent, relying on detection of a small increase in temperature. The Review of Consents study therefore focussed on river and sea lamprey, and specifically on potential impacts on these species during the migration season (April-July for the Humber catchment).

Table 1.1 Interest Features of the Humber Estuary SAC

Name of site	Reasons for designation
Humber Estuary SAC	***Primary reasons for selection:*** o Estuaries o Mudflats and sandflats not covered by sea water at low tide ***Qualifying features:*** o Sandbanks which are slightly covered by sea water all the time o Coastal lagoons o *Salicornia* and other annuals colonising mud and sand o Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) o Embryonic shifting dunes o Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes') o Fixed dunes with herbaceous vegetation ('grey dunes') o Dunes with *Hippophae rhamnoides* o Sea lamprey (*Petromyzon marinus*) o River lamprey (*Lampetra fluviatilis*) o Grey seal (*Halichoerus grypus*)

The maximum recorded ambient water temperature for the month of June (19^{o}C) in the River Wharfe at Tadcaster (a nearby un-impacted site) was used as the basis of the modelling for the Review of Consents study, representing the perceived at risk period for the migration of river and sea lamprey. The Environment Agency used a QUESTs-2D hydrodynamic model to predict the impacts of thermal discharges on the Humber Estuary. The model was run with a repeating spring-neap tidal cycle for 30 days and included 28 separate thermal discharges in the region to provide an "in combination" assessment. Dispersion runs for temperature were allowed to run for 60 days to ensure stable repeating concentrations. For the modelling exercise the ambient temperature of 19^{o}C was assumed estuary-wide. It is not known if the model was calibrated against measured data.

Among the other thermal discharges, the model included a representation of Keadby Power Station (thermal discharge 11.57m^3/s and ΔT +8^{o}C) and concluded that there was no adverse effect on the interest features of the Humber SAC (including sea and river lamprey), or on the SAC as a whole, due to the thermal inputs covered by the model. The Keadby thermal discharge parameters assumed for this study were based on optimum condenser performance at the power station, however, and it is now understood that optimum condenser performance cannot be achieved at Keadby due to challenging site-specific conditions including high levels of debris in the river and the variable tidal cycle, both of which influence the amount of cooling water that can be drawn from the river. On occasions when less water can be drawn through the power station (e.g. due to a build-up of debris on the band screens or low tide conditions), the ΔT of the cooling water discharged to the river is necessarily higher than optimum. Thus the Environment Agency's Review of Consents modelling may not be representative of the current operation of Keadby power station and its thermal discharge. Despite this limitation, the other assumptions made within the Environment Agency's Review of Consents modelling are considered to be a sound basis for further assessment of the thermal discharge from Keadby power station. The assumptions made within the Environment Agency's Review of Consents modelling are as follows:

- The model assumes complete vertical mixing (the EA notes that this is a reasonable assumption given the locations where significant thermal outfalls are located; the major ones are either to the relatively shallow tidal rivers Ouse and Trent, or to the deep channel which is very turbulent and generally regarded as well mixed). It should, be noted however that the previous model by HR Wallingford suggested that the thermal discharge from Keadby was likely to form a buoyant plume underlain by cooler water in the near field.
- The various freshwater river flows used within the model were all constant mean summer flows.
- All thermal discharges were included at maximum flow and maximum thermal load (and Keadby Power Station was represented by a thermal discharge of $11.57 m^3/s$ and ΔT +8^{o}C)
- Thermal load was treated as a conservative substance[1].
- Dispersion runs for temperature were allowed to run for 60 days (the EA notes that theoretically, thermal discharges could still be affecting background temperature after this time, as the residence time in the Humber Estuary may exceed 60 days under low freshwater flow conditions, however, because temperature was modelled without cooling mechanisms such as heat exchange with the atmosphere, the EA notes that the predicted increase in background should not be an underestimate).
- An ambient temperature of 19°C was assumed estuary-wide, corresponding to the maximum observed temperature at Tadcaster in June (this is also a high temperature for July).
- It was assumed that high temperature conditions which might occasionally happen in July would not result in an adverse effect on sea lamprey populations. After a dry spring however, some individuals might be affected.

Potential issues with the historical licensing at Keadby were identified by the Environment Agency in an internal memo dated February 2010 (Brewington, 2010), which notes that the current discharge permit for Keadby does not limit the maximum

[1] A substance which incurs no losses due to chemical reactions or biochemical degradations.

temperature of the cooling water discharge. This memo stated that when the original (IPC) permit was issued, it included a condition limiting the temperature of the river as detailed in Table 1.2.

Table 1.2 Thermal parameters from original (IPC) permit for Keadby Power Station, taken from Brewington (2010)

Inclusive Period	Maximum normal river temp.	4 day maximum river temp.
May to September	24^{O}C	28^{O}C
October to April	21.5^{O}C	24^{O}C

The memo also notes however, that this IPC condition was inappropriate for two significant reasons;

1. It required the use of fixed point monitoring devices in the river channel (10 metres from the bank and 0.5 metres below the surface). The Harbour Authority, however, has consistently refused to allow the positioning of permanent monitors in the river channel.

2. The condition related to the river temperature not the discharge and was not related to upstream river temperatures. The station could theoretically therefore be in breach of its permit when not even discharging thermally heated effluent.

The memo stated that until fixed point monitors were established, the IPC required that river temperature was surveyed by boat twice a month and whenever river temperatures rose above 22.5° C. The boat surveys were carried out during the late 1990s and despite limitations seemed to have confirmed the predictions of the preconstruction models i.e. that the plume did not extend across the entire width of the river. The requirement to undertake river monitoring was removed from the IPC authorisation in April 2000 and from this time on cooling water temperature has not been controlled by the EA.

When the new PPC permit was issued in 2007, no maximum temperature was given, but SSE was asked to review station performance and propose a limit that would prevent environmental harm, as well as providing justification that this limit would represent BAT (Best Available Technique) for the station. This limit would be used to update the discharge permit. The Environment Agency indicated that they would like to see further assessment of historical data from the power station, followed by updated modelling if the data indicated that the thermal discharge was routinely different to that assumed for the Review of Consents modelling. They also indicated that if percentile standards were proposed, they would like to see consideration of the impact on the River Trent during the time when no maximum limit would apply.

Since the above studies were carried out, historical thermal discharge data for Keadby power station has been collated by SSE covering the period February 1998 to September 2009. SSE and APEM carried out a review of this historical discharge data in 2010

(APEM, 2010a). The data indicated that in contrast to the assumptions made in the Environment Agency's Review of Consents modelling, the hourly mean ΔT of the thermal discharge regularly exceeded $+8^{o}C$, although the cooling water flow only very rarely exceeded $11.57 m^3/s$. It was therefore recognised that further modelling was required to assess the impacts of the thermal discharge from Keadby Power Station upon the ecology of the tidal River Trent.

1.3 Project Overview

A meeting between the Environment Agency, SSE and APEM was held on 30th November 2010 to discuss the details of the proposed modelling and environmental assessment phase. It was proposed that sensitivity testing would be undertaken using a simple CORMIX model. CORMIX is designed for investigating effluent discharges into receiving water bodies and it was anticipated that its use would allow a number of different temperature, velocity and tide scenarios to be tested, whilst incurring relatively low set-up costs. It should be noted that unlike some previous models, the CORMIX model does not rely on an assumption of complete vertical mixing. It was recognised that although the use of CORMIX in this way could be sufficient to meet the needs of this study, depending on the results, further and more detailed modelling using different packages might be required at a later stage.

In addition to the setting up and testing of the CORMIX model, a key element of this phase of the project was to obtain aerial thermal imaging data and in-situ plume temperature data (boat-based), to provide a direct in-situ evidence base of the features of the thermal plume, and for use as calibration data for the model to offset the potential impacts of its limitations and uncertainties. The methodology and results of these field surveys are also presented.

2 FIELD SURVEY METHODOLOGY

In-situ plume temperature data were collected in the field on 10th June 2011 using a handheld probe from a boat and aerial thermal imaging. This date was selected for the survey as tidal conditions were at mid-height (half way between a spring and a neap tide) and as such represented an intermediate case from which the extent and shape of the plume under these conditions can be visualised.

The boat-based survey was undertaken within a 200m by 200m grid with a sampling site at every vertex, leading to a total of 25 sampling sites. At each sampling site, water temperature was measured just below the surface (0.25m) and at every 1m between the water surface and the river bed. Each transect (one water temperature profile at 25 sites) started at point A5 and proceeded in the direction indicated by the arrows on Figure 2.1, taking approximately 45 minutes to complete.

The boat was launched at 09:00 and manoeuvred into position near to the outfall at Keadby and the first transect commenced at 11:37. A total of 6 transects were completed during the survey on 10th June, covering the mid flood, high water slack, and mid ebb tidal states (Figure 2.2).

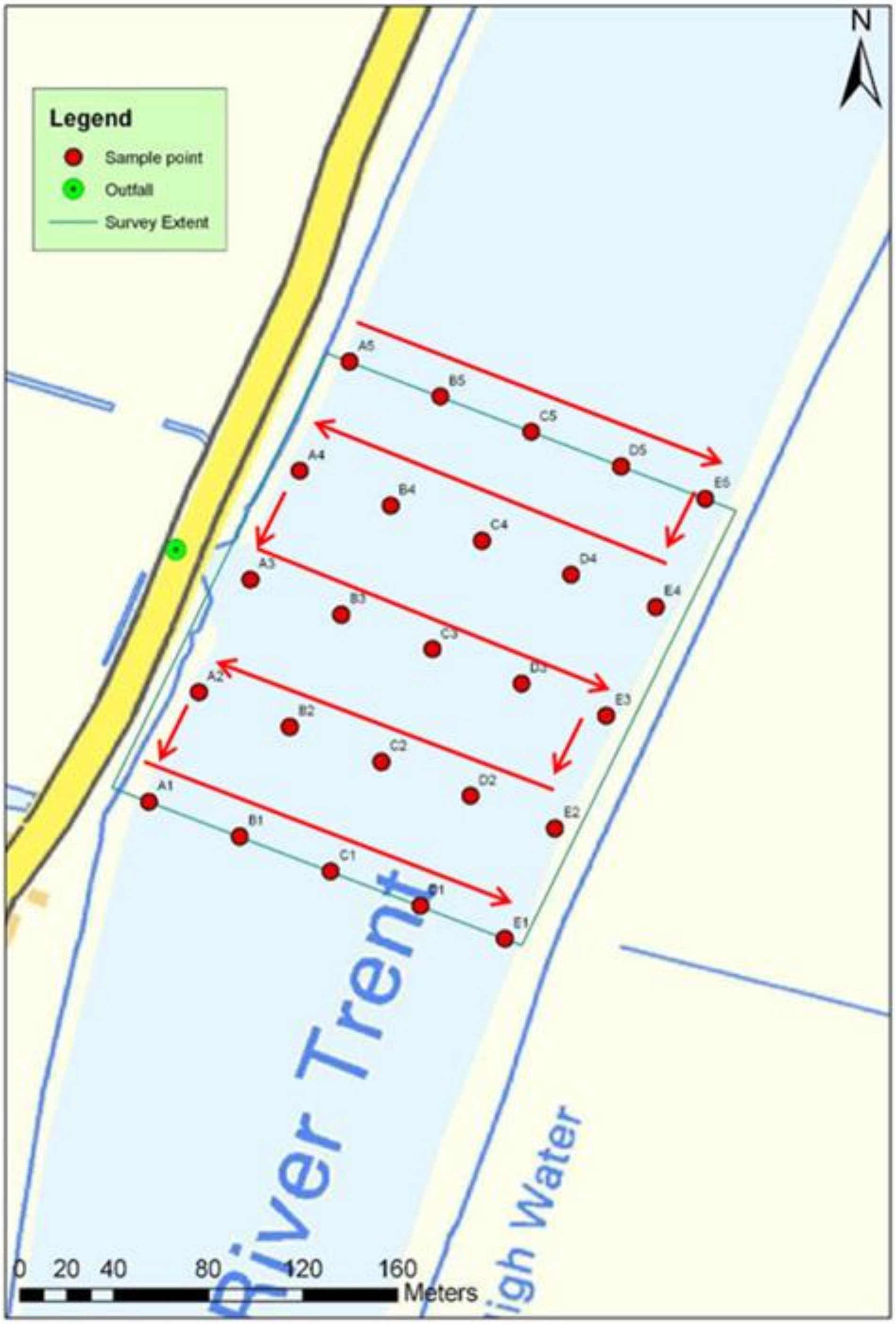

Figure 2.1 Boat-based survey locations

The aerial survey comprised 3 low level transects (not related to the boat based transects shown above) of the channel during each tidal state. An FLIR SC655 thermal imagery camera was used. This camera achieves a 640 x 480 resolution, and also records radiometric information, allowing improved post-processing of the data. The majority of the survey was conducted at 7,000ft, however increased cloud coverage meant that the aircraft had to descend to 4,000ft during part of the survey. Images covered an area from approximately 1km upstream from the power station to the confluence of the River Trent and the Humber Estuary.

The data were collected between 14:45 and 14:49 for the high water slack tidal state; between 17:23 and 17:27 for the ebb tidal state; and between 11:56 and 12:01 for the flood tidal state (Figure 2.2). The average time taken to complete a survey for one tidal state (one set of transects) was 5 minutes.

On return to base, each transect was georeferenced and mosaiced to produce a continuous temperature image of the area of interest.

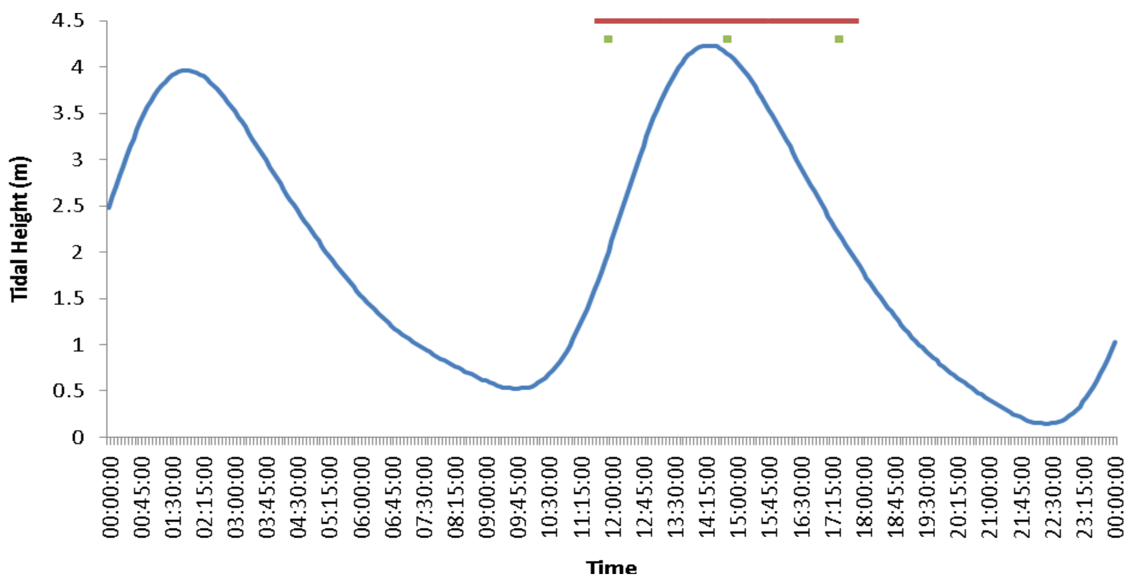

Figure 2.2 Tidal Coverage of Field Survey. Blue line = tidal range, red line = timing of boat based survey, green line = timing of aerial survey

3 FIELD SURVEY RESULTS

Plots of the boat-based data for the high water slack, ebb and flood tidal states taken from the surface are presented in Figures 3.1 to 3.3 below. Overall the temperatures shown near to the outfall location in close proximity to the left hand bank remained relatively stable within the first few metres of the water column and decreased with increasing depth, indicating that the thermal plume is buoyant and rises to the surface. An example temperature versus depth plot for site A3 is shown in Figure 3.4. The aerial thermal images for the high water slack, ebb and flood tidal states are presented in Figures 3.5 to 3.7.

The combined results of the surveys indicate that the plume dimensions were as detailed in Table 3.1

On the day of survey (10 June 2011) river flows in the Trent were at approximately Q_{95} following a period of very low rainfall during the end of 2010 and beginning of 2011 (EA, 2011). The EA (2011) also noted that daily mean flows in the River Trent on 7 June 2011, immediately prior to the survey, were exceptionally low relative to an analysis of historic daily mean flows for the same time of year.

Keadby Power Station was operating at full power on the day of survey, with both generators operational. The mean outfall temperature over the tidal states surveyed was 32.6°C whilst the mean discharge was 7.57m^3/s.

Ambient river temperatures on the day of survey were 18.3°C on average during the period of survey. This is higher than the historic mean June temperature measured by the EA either at Keadby or just upstream at Gainsborough (17.5 and 17.6°C respectively, based on data collected between 1987 and 2010).

The mean daily wind speed measured at Humberside meteorological station on 10 June 2011 was 4.42m/s, slightly higher than the historical mean June wind speed (2005-2010) of 3.97m/s.

The environmental data detailed above indicate that the prevailing conditions during the survey represent a conservative case with lower river flow and higher ambient river temperatures than would normally be expected during June. The operating conditions of the power station were at the higher end of the historical outfall temperature range during the survey. The discharge flow rate was correspondingly at the lower end of the range, since higher discharge temperatures are associated with lower flow rates.

Table 3.1 Results of boat based and aerial surveys on 10th June

		28°C Isotherm Dimensions			**21.5°C Isotherm Dimensions**			**+2°C Isotherm Dimensions**			**Channel Dimensions**	
		Downstream extent (m)	**Maximum width (m)**	**Depth at maximum extent (m)**	**Downstream extent (m)**	**Maximum width (m)**	**Depth at maximum extent (m)**	**Downstream extent (m)**	**Maximum width (m)**	**Depth at maximum extent (m)**	**Depth (m)**	**Width (m)**
Boat Based**	High Water Slack	0***	22	2.5	54.7	86.7	2	72.3	97.7	2	4.5	200
	Mid Ebb	4.1	26.6	2	>124	41.9	0.5	>124	48.1	3	3.8	200
	Mid Flood	3.8	21	2	>124	48.6	1.5	>124	55.6	4	4.1	200
Thermal Imaging	High Water Slack	17	8		166*	61		666*	94		4.5	200
	Mid Ebb	47	20		489	37		683	47		3.8	200
	Mid Flood	39	30		634	39		1129	46.2		4.1	200

*image captured at start of high water slack so remnants of previous plume still visible

** boat based data is at lower resolution, interpolated from 50m grid spacing

*** plume extends straight out into the channel

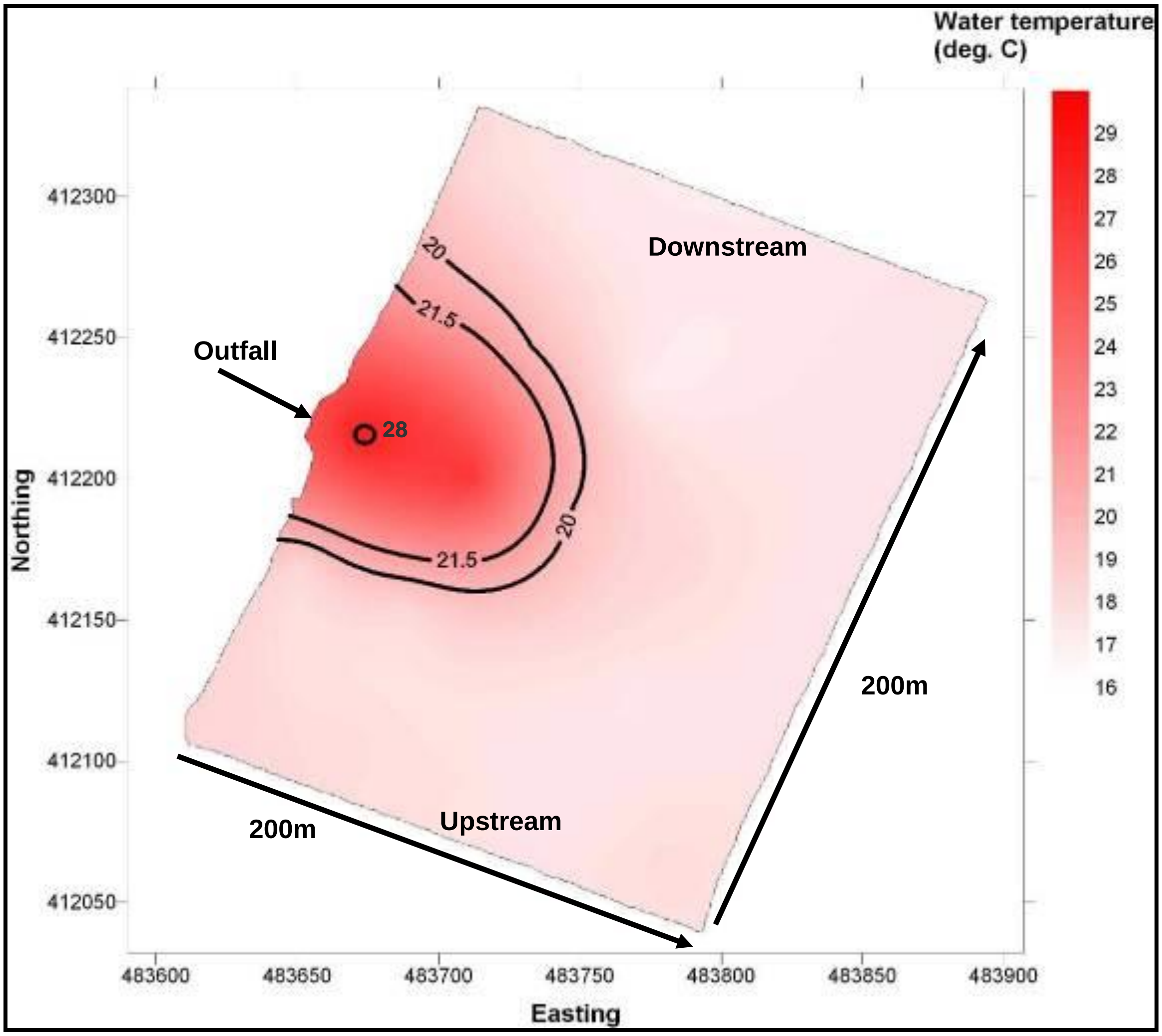

Figure 3.1 Interpolated temperature contours for the boat based survey at high water slack tide at the surface

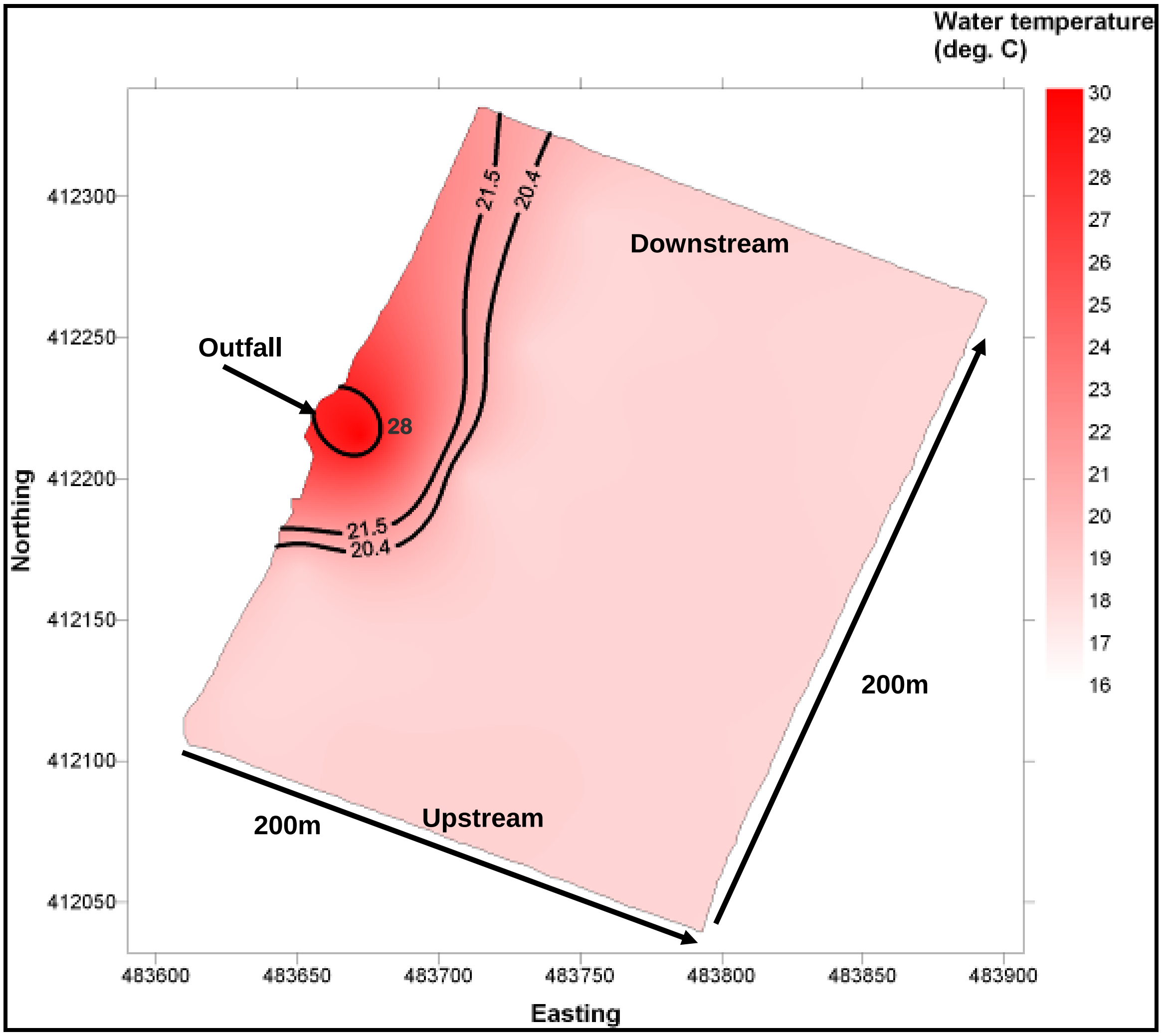

Figure 3.2 Interpolated temperature contours for the boat based survey during ebb tide at the surface

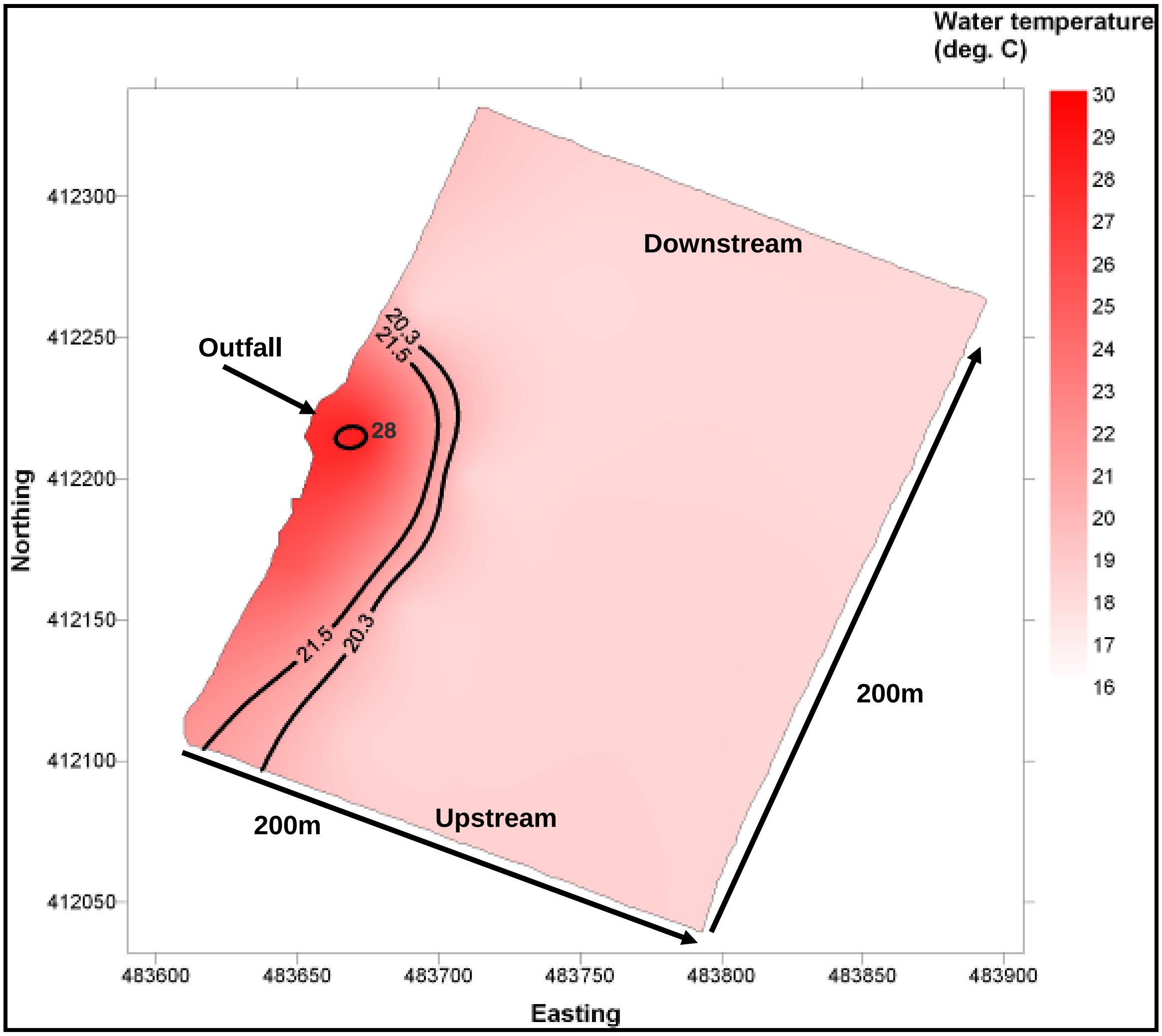

Figure 3.3 Interpolated temperature contours for the boat based survey during flood tide at the surface

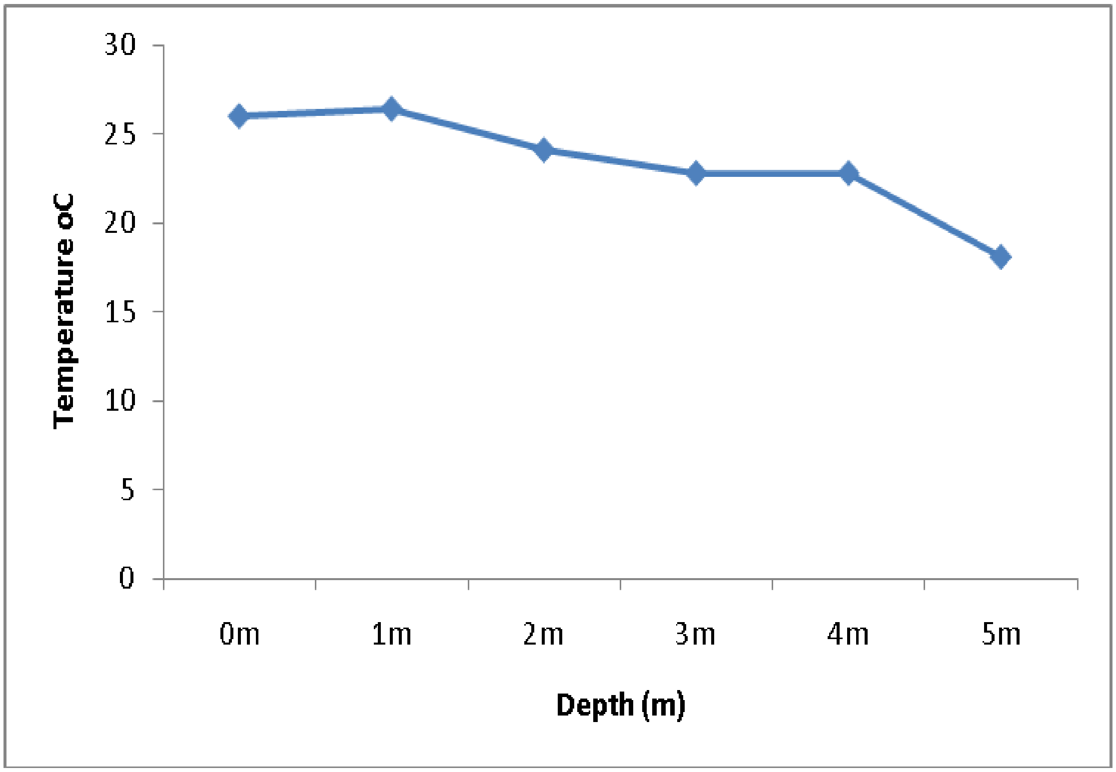

Figure 3.4 Example depth vs temperature plot from site A3

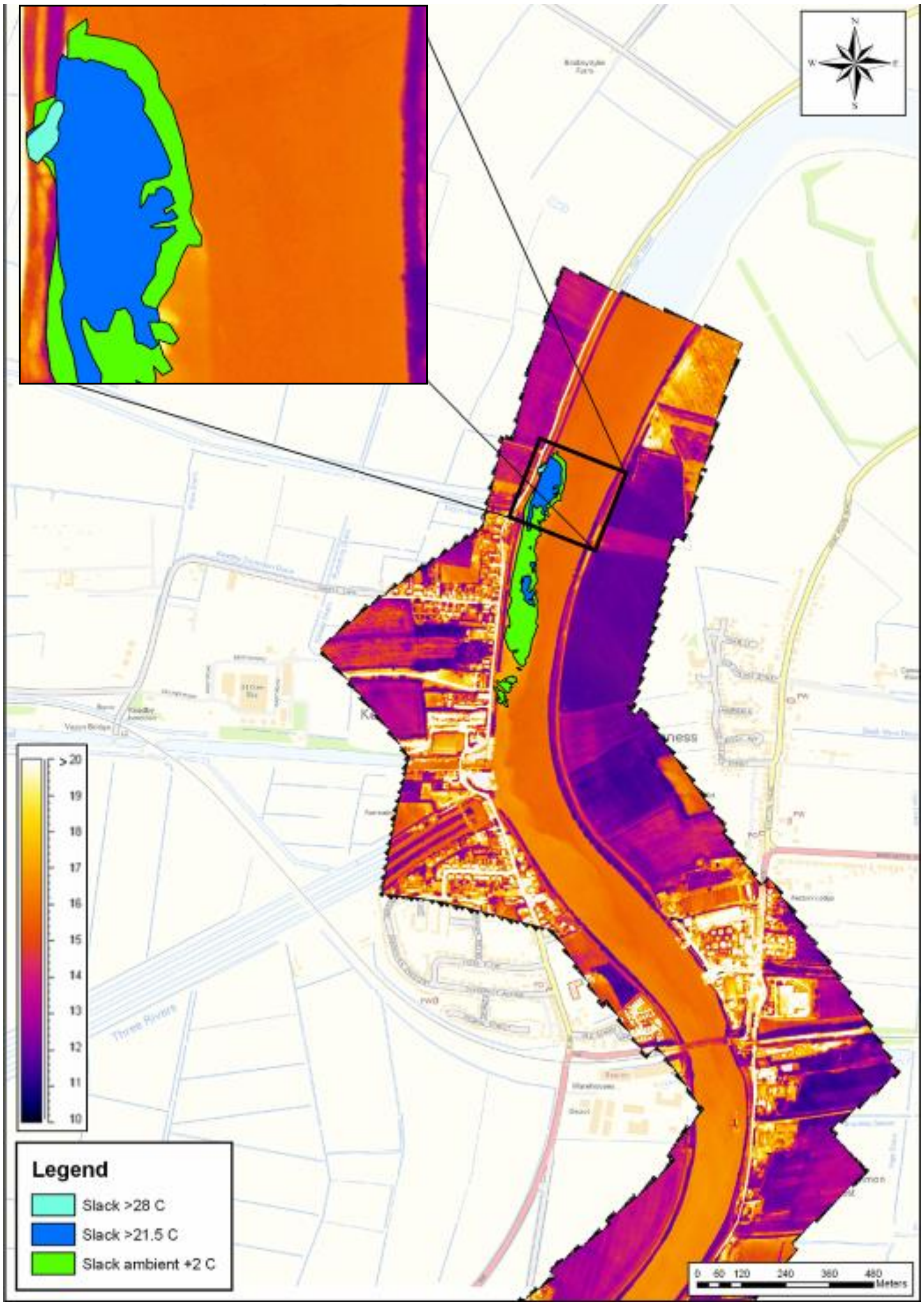

Figure 3.5 Aerial thermal imaging data at the start of high water slack tide (remains of flood tide plume still visible)

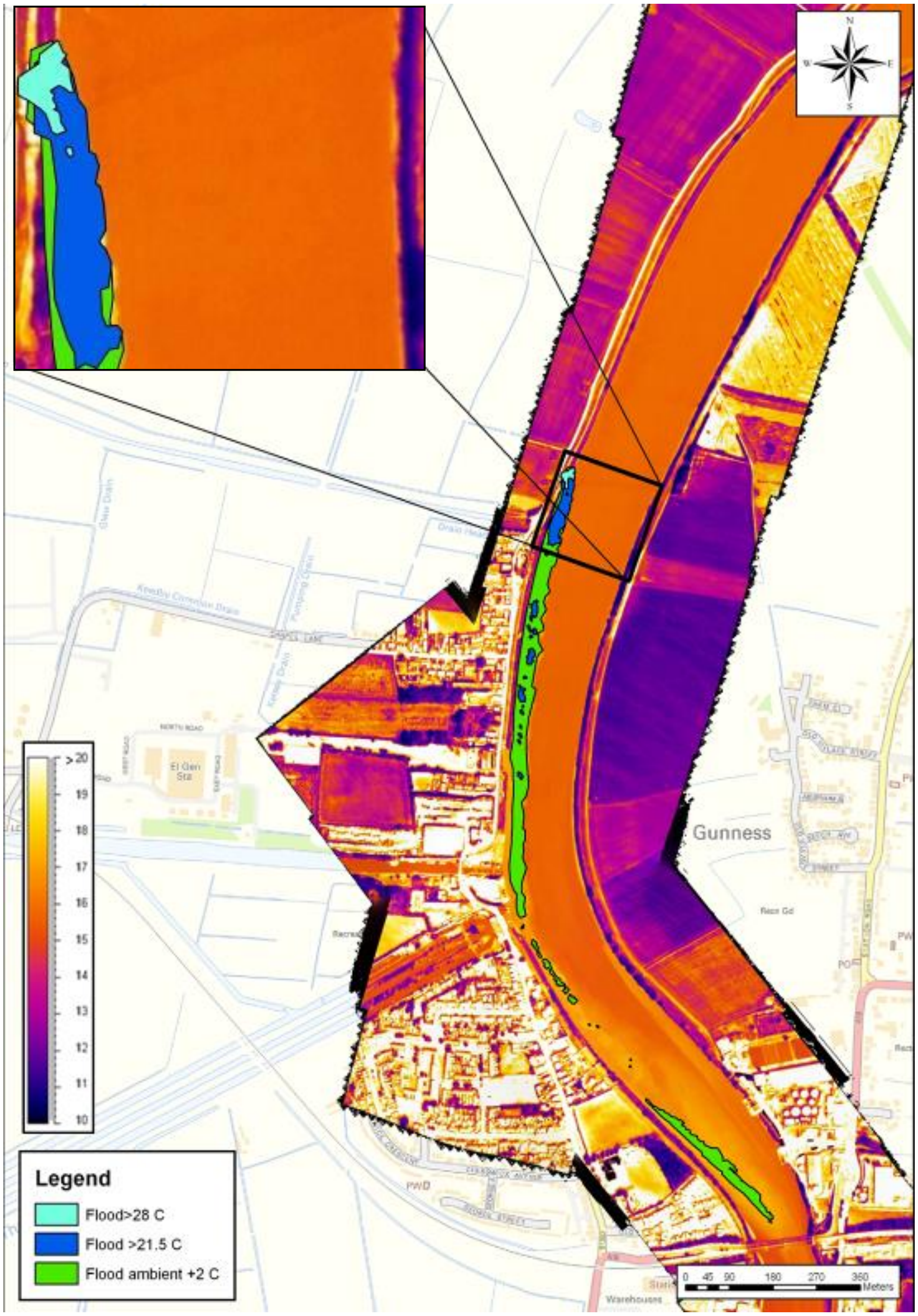

Figure 3.6 Aerial thermal imaging data during flood tide

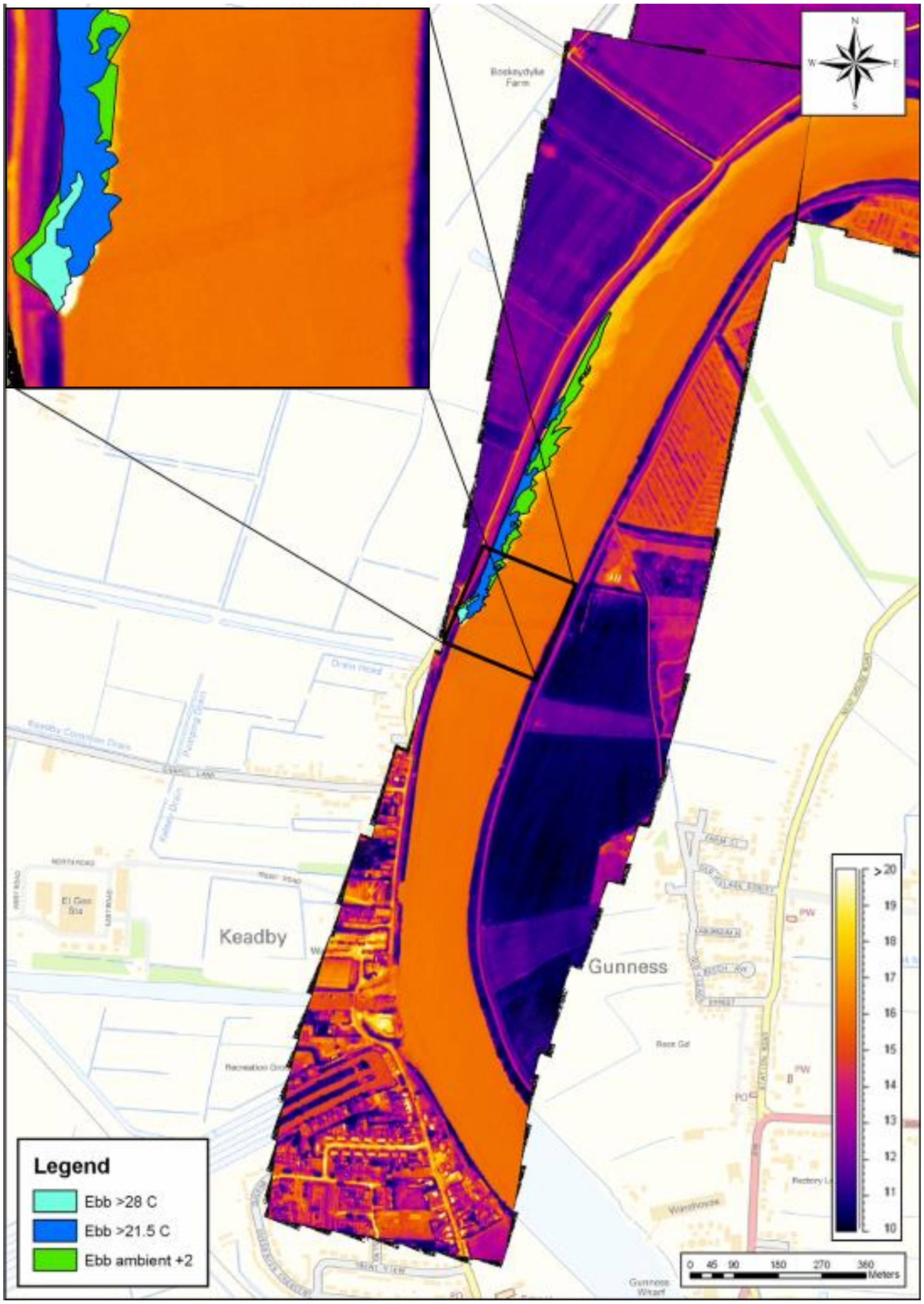

Figure 3.7 Aerial thermal imaging data during ebb tide

4 MODELLING APPROACH AND OBJECTIVES

The aim of the modelling work was to predict the dimensions and temperature of the plume during four stages of the tidal cycle (low water slack (LWS), high water slack (HWS), mid flood and mid ebb) during a mid-height tide (i.e. between spring and neap) under a range of ambient and effluent temperature and velocity scenarios. The objective was to determine the likely extent of the plume under the worst case scenario.

Use of a simple model (CORMIX) was advantageous because of its fast run time, meaning that a large number of scenarios could be tested. There are, however, some potential limitations associated with the simplicity of the model. Potential limitations are that output temperature values have a quoted accuracy of ± 50% and that although the model takes into account re-entrainment of a previous plume due to tidal reversal, 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. The representation of the river channel in CORMIX is one dimensional and is further simplified to a rectangular cross section with an average depth and average width over the area of interest. Account is taken of the sinuosity of the channel (to take account of the effect of channel appearance on far field mixing, three channel appearance types are supported in CORMIX: type 1 are fairly straight and uniform channels; type 2 have moderate downstream meander with a non-uniform channel; and type 3 are strongly winding and have highly irregular downstream cross-sections). The type 2 channel appearance type has been used for this study. Although the changing cross-sectional profile is not fully represented, the changes are small in the context of the overall channel width and depth, and the channel representation is considered adequate for the purposes of this modelling exercise.

The modelling process is split into six distinct stages, which are described in detail in Section 5:

1. **Determine initial model input values:** Obtain realistic values for each model parameter/variable based on data from the boat-based and aerial survey and existing data for the site.
2. **Calibration (a):** Run model for one tidal state (mid ebb) on 10 June, with input values based on data measured on the day, and test modelled plume dimensions against measured dimensions. Adjust values of parameters, where some uncertainty surrounding value exists, to provide a best possible fit.
3. **Validation:** Run model for two further tidal states (HWS and mid flood) on 10 June, using parameter values established in Stage 1, and use field data to test whether correct plume dimensions can be reproduced.
4. **Calibration (b):** If fit in Stage 2 is unsatisfactory, adjust parameter values where valid to do so, to obtain better fit (this additional calibration is done at the expense of having an independent validation).
5. **Sensitivity testing:** Test sensitivity of model output to various parameters for which there is still some uncertainty surrounding the initial values used.

6. **Scenario runs:** Once satisfactory fit to field data obtained, use values to run a range of scenarios for four tidal states (HWS, LWS, mid ebb and mid flood).

5 MODELLING PROCESS AND RESULTS

In the following sub-sections the various stages of the modelling process are described, detailing the parameter values used and the results obtained.

5.1 Initial model input values

The input parameter values required by the model are summarised in Table 5.1, together with the initial values used and their sources. The values which were based on measured data are highlighted (together with an associated description of the certainty in each value) other values were those determined during the calibration process. Further details about the reasons for use of several of the values are given below.

5.1.1 Water depth value adjustments

Although measured data for water depths on the day of the field survey were available, these values had to be adjusted to meet the specific requirements of the model and allow it to run successfully. The model requirements and subsequent adjustments made were as follows:

1. *The depth at the outfall must be at least three times the port diameter.*[2]
The outfall is modelled as a single port, even though in reality it is comprised of two pipes. The total area of the pipes is 5.09m^2, giving an effective diameter of 2.55m. This is the best way to represent the outfall within the fixed environment of the model because it will not unduly affect the velocity or orientation of the thermal discharge. It is considered unlikely to significantly affect the model outputs.

The depth at outfall in the model must therefore be greater than 7.65m at all times. This is not the case at mid flood, mid ebb and LWS. The outfall depths for these tidal states were therefore adjusted to the minimum value of 7.65m. Increasing the depth in this way is unlikely to significantly affect the model outputs, since the aerial and boat-based field data both indicate that because the discharge is at a higher temperature than the river, the plume is buoyant and will rise to the surface almost immediately, rather than becoming attached to the bottom of the channel.

2. *The port depth must be more than two thirds of the water depth at the discharge*[2]
Where depths were increased to satisfy model requirements, port height above channel bottom was adjusted so that the depth of the port below the surface was maintained as close as possible to the actual value, whilst also satisfying the model requirements that the port depth must be more than 2/3 of the water depth at the discharge. This resulted in a port height above channel bottom of 2.55m. Port depth below surface was assumed to be of greater importance than port height above channel bottom in this study because of

[2] These are fixed rules within the model that must be met before simulations can be successfully run and completed.

the positively buoyant nature of the discharge. This is the best way to represent the outfall within the fixed environment of the model and is considered unlikely to significantly affect the model outputs, given that the plume is buoyant and the aerial and boat-based field data both indicate that it will rise to the surface almost immediately after discharge.

3. *The depth at discharge must be within 30 percent of the average depth*[2]

Where measured values of average depth did not meet this criteria they were adjusted so that they did. The depth at discharge is more important for near field mixing, while the average depth is of greater importance for far field plume dynamics. Given that the plume is positively buoyant and likely to be located at the surface, it was considered best to preserve depth at discharge values at their most realistic value and adjust average depth values to meet the model criteria. This is the best way to represent the outfall within the fixed environment of the model and is considered unlikely to significantly affect the model outputs, given that the plume is buoyant and the aerial and boat-based field data both indicate that it will rise to the surface almost immediately after discharge.

Table 5.1 Summary of input values required by CORMIX, the initial values used and their sources

CORMIX category	Input parameter	Units	Information	Initial value(s) used	Certainty	Static (a fixed value) or Variable (to be determined during calibration)	Source of value
Effluent (Heated discharge)	Heat loss coefficient	-	Function of wind speed and ambient water temperature, as defined within model	**20** (based on wind speed of 2.16m/s and ambient water temperatures as given below).	Ambient water temperature: High (measured) Wind speed: Moderate (daily average for site nearby)	Static (water temperature Variable (wind speed)	• Ambient water temperature measured from boat based survey at specified tidal state • Mean daily wind speed measured at Humberside Meteorological Station on 10 June
	Discharge temperature excess over ambient temperature	°C		*Tide* / *Effluent* / *Ambient* / *Excess* Flood 33.48 18.32 **15.16** HWS 32.47 18.06 **14.41** Ebb 31.96 18.40 **13.56**	High (measured)	Static	• Effluent temperature taken from measured outfall temperature data from Keadby Power Station on 10 June at time corresponding to specified tidal state. • Ambient water temperature measured from boat based survey at specified tidal state.
	Discharge velocity or flow rate	m^3/s		Flood tide: **7.48** HWS: **7.62** Ebb tide: **7.62**	High (measured)	Static	Taken from measured outfall data on 10 June at time corresponding to specified tidal state
	Effluent density (non fresh)	kg/m^3	Function of salinity and discharge temperature. Salinity varies with tidal state. Calculation for density value carried out within model.	Salinity values: Flood tide: **0.262** ppt HWS: **0.763** ppt Ebb tide: **0.420** ppt Effluent temperatures as given above.	Temperature: High – (measured) Salinity: Moderate (average value taken from long term EA data set)	Static (water temperature) Variable (salinity)	Salinity converted from mean June chloride concentration between 1980 and 2010 at Keadby for the given tidal state
Ambient (Unsteady flow)	Average depth	m	Varies with tidal state	Flood tide: **5.90** HWS: **6.93** Ebb tide: **5.90**	High (measured in field, although adjusted to meet model requirement)	Static (for given tidal state)	Mean of 25 depth measurements taken from a boat in a 200x200m grid across the channel adjacent to the outfall at the time corresponding most closely to the specified tidal state. Depth value then had to be adjusted to satisfy model requirements – see Section 3.1.1.
	Depth at discharge	m	Varies with tidal state	Flood tide: **7.65** HWS: **9.00** Ebb tide: **7.65**	High (measured in field, although adjusted to meet model requirement)	Static (for given tidal state)	Depth measurement taken at outfall from a boat at the time corresponding most closely to the specified tidal state. Depth value then had to be adjusted to satisfy model requirements – see Section 3.1.1.
	Wind speed	m/s		**2.16**	Moderate (daily average for site nearby)	Variable	Mean wind speed measured at Humberside Met Station on 10 June.
	Tidal period	hours		**12.1**	Moderate (average of neap and spring periods taken from previous model)	Static	Taken from previous modelling study (HR Wallingford, 1992). Mid-height tide period taken as mean of the neap and spring tidal periods at Keadby given in the above report.

CORMIX category	Input parameter	Units	Information	Initial value(s) used	Certainty	Static (a fixed value) or Variable (to be determined during calibration)	Source of value
	Max tidal velocity	m/s		**1.1**	Moderate (average of neap and spring maximum velocities taken from previous model)	Static	Taken from modelled velocities given in previous modelling study (HR Wallingford, 1992). Mid-height tide maximum velocity taken as arithmetic mean of the maximum spring (1.2m/s) and neap (1.0m/s) velocities given in the above report.
	Time of prediction relative to slack tide	hours	Calibration/validation carried out for the 3 tidal states for which field data were available.	Flood tide: **2.3 before** HWS: **0.2 after** Ebb tide: **2.7 after**	High (known)	Static (for given tidal state)	HWS time on 10 June (14:39) taken from tide tables and confirmed during boat based survey • Flood taken as 12:10, middle time of first set of boat based measurements; aerial thermal image captured at 11:58. • HWS: 0.2h after slack (allowed model to run for sufficient length of time to show plume development). • Ebb taken as 17:20, middle time of last set of boat based measurements; aerial thermal image captured at 17:24.
	Tidal velocity at specified time	m/s	Varies with tidal state	Flood tide: **0.3** HWS: **0.2** Ebb tide: **0.9**	Moderate (average of spring and neap velocities at corresponding time, taken from previous model)	Variable (for each tidal state)	Taken from modelled velocities given in previous modelling study (HR Wallingford, 1992). Mid-height tide velocity for each tidal state taken as mean of the spring and neap velocities given in the above report.
	Channel width in vicinity of discharge	m		**200**	High (measured)	Static	Measured from map
	Channel appearance	-	From list of options	**slight meander**	High (known)	Static	Observed from map
	Bottom friction coefficient (Manning's *n*)	-		**0.02**	Low	Variable	Realistic range of values for Manning's *n* for channel type found at Keadby taken from literature (Chow, 1959). Middle value used initially.
	Average ambient density	kg/m^3	Function of salinity and ambient temperature	Salinity and ambient water temperatures as given above.	Temperature: High Salinity: Moderate –see above.	Static (water temperature) Variable (salinity)	• Salinity converted from median June chloride concentration between 1980 and 2010 at Keadby for the given tidal state. • Ambient water temperature measured from boat based survey at specified tidal state.
Discharge	Nearest bank		Varies with tidal state (due to change in direction of ambient flow)	Flood tide: **right** HWS: **left** Ebb tide: **left**	High (known)	Static	From map
	Distance to nearest bank	m		**0**	High (measured)	Static	From outfall drawings
	Vertical angle	degrees		**-6.16**	High (measured)	Static	Angle of outfall pipe from engineering drawings

CORMIX category	Input parameter	Units	Information	Initial value(s) used	Certainty	Static (a fixed value) or Variable (to be determined during calibration)	Source of value
	Horizontal angle	degrees	Varies with tidal state (due to change in direction of ambient flow)	Flood tide: **90** HWS: **270** Ebb tide: **270**	High (measured)	Static	From engineering drawings
	Height above channel bottom	m		Flood tide: **2.55** HWS: **1.27** Ebb tide: **2.55**	High (measured)	Static	From depth measurements taken at outfall during boat based survey. Values then had to be adjusted to satisfy model requirements – see Section 3.1.1.
	Port diameter/cross sectional area	m^2		**5.09**	High (measured)	Static	Total diameter of two outfall pipes, taken from engineering drawings.
Mixing zone	Maximum downstream region of interest	m		**14500**	High (known)	Static	From map (distance to Humber Estuary)

5.2 Calibration (a)

The initial calibration was performed on the model run for the ebb tide. The ebb tide was selected because it was expected that this would be the tidal state during which the plume would extend for the furthest distance in the longitudinal direction (i.e. downstream) and was therefore the tidal state for which the best model fit would be preferred. The criteria for assessing the fit of the model were based on the longitudinal (x, maximum downstream plume extent in metres) and lateral (y maximum cross-channel plume width in metres), respectively) positions of the various critical temperature thresholds (see Figure 5.22).

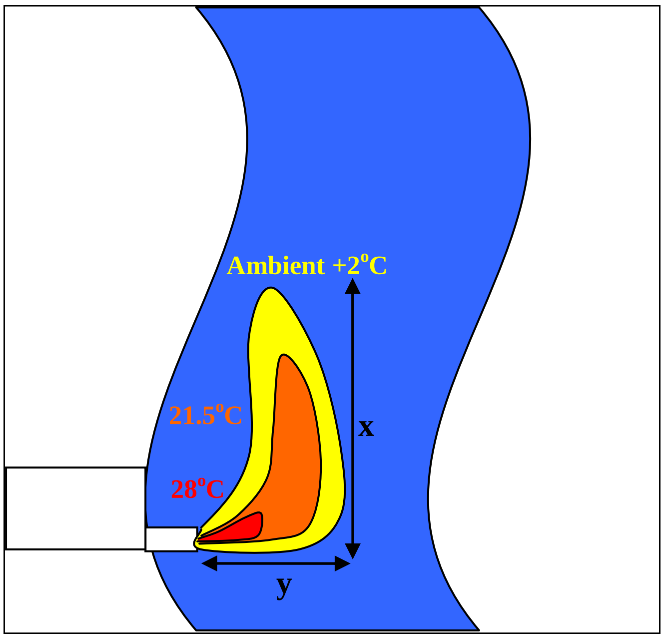

Figure 5.2 Diagram showing key plume dimensions (x = maximum downstream plume extent in metres and y = maximum cross-channel plume width in metres)

For the purposes of this modelling exercise, the most important plume dimensions were the maximum downstream (or upstream) extent, and the maximum cross-channel extent in the context of the total channel dimensions. During the calibration, preference was given to obtaining the best fit in the y (cross-channel), rather than the x direction, as this was considered to be the most important factor for the purposes of this study, due to the potential for this to result in a barrier to fish movement. Other properties of the plume were also checked during each simulation, including whether the plume was attached to the river bed or to either bank.

Three critical temperature thresholds were considered: 28°C; 21.5°C; and 2°C above ambient, taken from the Habitats Directive Technical Advisory Group on Water Quality SAC guidance on assessment of thermal discharges (WQTAG160, 2006) and a review of temperature standards for marine and freshwater environments (Turnpenny and Liney, 2007), see Table 5.2 . In the absence of detailed temperature tolerance data for river and sea lamprey, the use of these thresholds which relate to the effects of temperature on salmonids, were taken as proxy.

Table 5.2 Temperature assessment thresholds for assessing the impact of thermal discharge

Criteria	Deviation from ambient	Maximum temperature
Upper lethal temperature for transitional and coastal water bodies (Type 1) for Atlantic salmon (Turnpenny & Liney (2007), originally cited in Jobling, 1981)		28^{o}C
Temperature thresholds for assessing the impact of thermal discharges on SAC sites (any designated for estuary or embayment habitat and/or salmonid species) (WQTAG160, 2006)	2°C as a Maximum Allowable Concentration (MAC) at the edge of the mixing zone	21.5°C as a 98 percentile at the edge of the mixing zone

Measured values of the upstream, downstream and cross-channel extent of the temperature contours of interest were taken from the aerial thermal imagery in preference to the boat-based data. Aerial thermal remote sensing provides a highly effective method for large-scale examination of spatial patterns of river temperature at a resolution and extent previously unobtainable through conventional methods of river temperature measurement using data recorders (Torgerson et al 2001). A significant advantage of the use of aerial thermal imagery over the boat-based data was that the position and full extent of the plume was captured within a very short space of time, whereas a single set of boat-based measurements took up to 45 minutes to complete, during which time the plume shape and dynamics may have altered due to changes in tidal conditions. The aerial imagery also provides complete coverage of the river channel that was of interest, and captured the full extent of the plume, whereas the boat-based data only covered a 200m length of channel. The temperatures measured from the boat were, however, used to calibrate the aerial thermal imagery and to provide information about the depth of the plume (the aerial imagery only gives information about surface temperatures). The data collected using both methods (boat based survey and aerial thermal imaging) indicated that the extent of the 28°C isotherm was very small in the context of the total channel width and the upstream and downstream length of the area of interest.

The model literature states that the temperature values given in the CORMIX model are accurate to ± 50 % (Doneker and Jirka, 2007). The x and y values for the extent of each critical temperature threshold extracted from the model were therefore those corresponding to the actual value together with those corresponding to the +50% and -50% values, creating an envelope of possible plume dimensions for each temperature

threshold. The calibration process is described below, with the results shown in Table 5.3
.

Calibration was carried out on the ebb tidal state by varying the values of parameters where some uncertainty surrounding the value existed. Parameters were changed one at a time (within realistic limits) and the results compared against the aerial thermal imaging data for the ebb tidal state to obtain the best fit. The sensitivity of the model to the different parameters was established and values for the most sensitive parameters established through calibration first.

Run 1: Initial Run

The modelled plume extent was very small, relative to the measured plume size. Examination of the representation of the plume by the model indicated that the plume was attached to the bottom of the channel for the first 50m downstream. This was not realistic. Boat-based survey data show that surface water temperatures were high immediately adjacent to the outfall, indicating that the plume is buoyant.

Runs 2, 3 and 4: Establishing Pipe Characteristics

The pipe was modelled as a surface discharge to prevent bottom attachment and to test the sensitivity of the outcome to pipe characteristics. Where the plume did not attach to the bottom its extent became closer to the measured values. The pipe was then modelled as a submerged discharge but the vertical angle was increased to 8.75 degrees and then 22.6 degrees to account for the apron in front of the outfall that has the effect of deflecting effluent flow upwards (the apron itself could not be represented physically within the model). The 22.6 degree angle produced the best result in comparison with the observed data and was taken as the value for this parameter.

Runs 5 and 6: Sensitivity to Heat Loss Coefficient

Sensitivity to the heat loss coefficient was tested by changing this parameter to zero and to 100. This had a negligible effect on the model result and it was considered that the model is not sensitive to this parameter.

Runs 7 and 8: Sensitivity to Salinity

Sensitivity to salinity was tested by reducing the value to 0.098ppt (the lowest recorded June salinity value at Keadby). This caused the plume to extend slightly further downstream (on the ebb tide) and also slightly further across the channel. The original salinity value (based on the mean) was then reduced by using the median June ebb tide salinity at Keadby between 1980 and 2010 (0.2ppt), which was thought, based on the distribution of the salinity values, to be a better representation of the average salinity at Keadby. The density of the plume was calculated using the El-Dessouky, Ettouny (2002) formula, a standard option within the model.

Runs 9, 10 and 11: Manning's Coefficient

Sensitivity to the value of Manning's *n* was tested. Manning's *n* is a measure of 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, and in-channel structures. It was found that the modelled plume length varied by over a kilometre when different values of *n* were used. The low value of *n* (0.01) gave plume dimensions that matched those measured, however, this is a very low value and the final value of *n* was set as 0.015, considered to be the lowest realistic value of *n* for the type of channel being modelled.

Runs 12 and 13: Wind Speed

Given that the wind speed associated with each modelled condition was not measured at Keadby (values were a daily average from Humberside), sensitivity of the model output to wind speed was tested by running with wind speed as 0m/s and as 15m/s (the highest and lowest values allowed by the model). Results indicate a low sensitivity to this variable (Table 5.3). The Humberside daily average wind speed for 10 June was therefore considered a suitable value to use.

Table 5.3 Summary of results of the calibration model simulations of the plume extent for the ebb tide state. Green cells indicate measured data from aerial thermal imaging. Yellow cells indicate where the envelope of modelled values contains the measured value.

	Variables altered		28 °C		21.5 °C		2 °C above ambient	
			x (m) longitudinal	y (m) lateral	x (m) longitudinal	y (m) lateral	x (m) longitudinal	y (m) lateral
Aerial thermal imaging data			47	20	489	37	683	47
Run 1 (calibration (a))		+50%			6.78	10.04	25.43	14.38
			2.59	7.30	32.67	15.59	50.9	17.73
		-50%	6.36	9.83	49.03	17.54	61.22	26.73
Run 2 (calibration (a))	Pipe as surface discharge	+50%			3.66	11.19	10.18	13.75
			2.3	3.38	64.76	19.59	768.14	109.43
		-50%	3.66	3.64	768.14	109.43	1056.70	135.67
Run 3 (calibration (a))	Pipe angle increased to 8.75 degrees	+50%			3.71	5.4	10.37	7.66
			1.21	3.61	31.22	14.95	340.94	45.41
		-50%	3.43	5.25	302.48	42.83	610.16	61.80
Run 4 (calibration (a))	Pipe angle increased to 22.6 degrees	+50%			3.57	5.09	16.57	9.8
			1.12	3.37	100.91	26.28	392.43	46.42
		-50%	3.37	4.99	392.43	46.42	611.07	58.91
Run 5 (sensitivity)	Heat loss coefficient reduced to zero	+50%			3.57	5.09	16.57	9.8
			1.12	3.37	100.91	26.28	392.87	46.45
		-50%	3.37	4.99	392.87	46.45	611.85	58.96
Run 6 (sensitivity)	Heat loss coefficient increased to 100	+50%			3.57	5.09	16.57	9.8
			1.12	3.37	100.97	26.29	390.50	46.29
		-50%	3.37	4.99	390.50	46.29	607.65	58.68
Run 7 (sensitivity)	Salinity reduced to 0.098 ppt	+50%			3.59	5.1	16.80	10.12
			1.06	3.31	132.47	29.43	447.08	51.54
		-50%	3.21	4.9	407.75	49.07	643.71	63.09

	Variables altered		28 °C		21.5 °C		2 °C above ambient	
			x (m) longitudinal	**y (m) lateral**	**x (m) longitudinal**	**y (m) lateral**	**x (m) longitudinal**	**y (m) lateral**
Aerial thermal imaging data			47	20	489	37	683	47
Run 8 (calibration (a))	Salinity as 0.2 ppt	+50%			3.59	5.1	16.85	10.12
			1.06	3.31	132.57	29.44	447.17	51.54
		-50%	3.21	4.9	407.85	49.08	643.80	63.10
Run 9 (sensitivity)	*n* as 0.01 (salinity as 0.42 ppt)	+50%			3.57	5.09	16.57	9.8
			1.12	3.37	453.49	50.01	1158.65	85.13
		-50%	3.37	4.99	1158.65	85.13	1687.53	107.03
Run 10 (sensitivity)	*n* as 0.2 (salinity as 0.42 ppt)	+50%			3.57	5.09	14.41	9.12
			1.12	3.37	15.63	9.95	306.90	41.58
		-50%	3.37	4.99	306.90	41.58	306.90	41.58
Run 11 (calibration (a))	*n* as 0.015 (salinity as 0.2 ppt)	+50%			3.59	5.1	16.85	10.12
			1.06	3.31	231.54	37.10	715.75	66.96
		-50%	3.21	4.9	646.58	63.17	992.45	81.17
Run 12 (sensitivity)	Wind speed as 0 m/s	+50%			3.53	5.07	17.06	10.16
			1.09	3.35	231.11	36.57	701.57	65.00
		-50%	3.28	4.95	634.37	61.38	970.41	78.59
Run 13 (sensitivity)	Wind speed as 15 m/s	+50%			3.53	5.07	17.06	10.16
			1.09	3.35	152.57	30.73	599.27	59.40
		-50%	3.28	4.95	543.43	56.26	878.45	73.99

Calibration (a) Summary

Table 5.3 above presents a summary of the results of the calibration (a) model runs. Calibration run 11 was considered to be the "best fit" model, where all parameters were set at realistic values, and the model output was closest to the measured values (the measured value from the aerial thermal imaging for the 21.5°C and 2°C above ambient isotherms were within the predicted values, ± 50 %).

The model did not reliably reproduce the extent of the 28°C isotherm recorded during the thermal imaging survey. However, the measured area of this isotherm from the aerial thermal imaging (and from the boat-based data) is small in the context of the total channel width and the size of the upstream and downstream area of interest. The lack of success in reproducing this contour in the model is therefore not considered to be a major limitation for the purposes of impact assessment because the measured extent of the 28°C isotherm is very small.

The ± 50 % errors/uncertainties in the maximum predicted cross-channel width of the plume are in the order of several tens of metres (in the context of a total channel width of 200m) whilst the errors/uncertainties in the maximum length of the plume are in the order of several hundreds of metres (in the context of an area of interest of 29km). The modelled plume dimensions are therefore a fair representation of the behaviour of the plume within the wider channel.

The values used in run 11 (final calibration run for mid ebb tidal state) were, therefore, taken forward to validation using the other two tidal states (HWS and mid flood) (Table 5.4).

Table 5.4 Values taken forward from Calibration (a) (ebb tide) to validation/calibration against flood and high water slack tidal states

CORMIX category	Input parameter	Units	Value(s) used
Effluent (Heated discharge)	Heat loss coefficient	-	20
	Discharge temperature excess over ambient temperature	°C	13.56
	Discharge velocity or flow rate	m/s	7.62
	Effluent density (non fresh)	kg/m^3	Salinity: 0.2 ppt Effluent temperature: 31.96°C
Ambient (Unsteady flow)	Average depth	m	5.90
	Depth at discharge	m	7.65
	Wind speed	m/s	2.16

CORMIX category	Input parameter	Units	Value(s) used
	Tidal period	hours	12.1
	Max tidal velocity	m/s	1.1
	Time of prediction relative to slack tide	hours	2.7 after
	Tidal velocity at specified time	m/s	0.9
	Channel width in vicinity of discharge	m	200
	Channel appearance	-	slight meander
	Bottom friction coefficient (Manning's *n*)	-	0.015
	Average ambient density	kg/m^3	Salinity and ambient water temperatures as given above.
Discharge	Nearest bank		left
	Distance to nearest bank	m	0
	Vertical angle	degrees	22.6
	Horizontal angle	degrees	270
	Height above channel bottom	m	2.55
	Port diameter/cross sectional area	m^2	5.09
Mixing zone	Maximum downstream region of interest	m	14500

5.3 Calibration (b) - Extension to other tidal states

5.3.1 High water slack (HWS) scenario

The values for parameters that are not tidally variable were kept the same as for Calibration Run 11. Tidally variable values (i.e. those parameters listed in Table 5.1 that have different values for flood tide, HWS and ebb tide) were altered to reflect the HWS tidal state, using the values shown in Table 5.1. The tidally varying values were as follows:

- Effluent temperature
- Ambient temperature
- Effluent velocity
- Effluent density

- Average channel depth
- Depth at discharge
- Time of prediction relative to slack tide
- Tidal velocity
- Ambient density
- Nearest bank to discharge
- Discharge horizontal angle
- Discharge height above channel bottom

The aerial thermal imagery for HWS showed the plume extending over 600m upstream. This is an effect of the preceding flood tide, rather than the ambient conditions at HWS, and would not be reproduced by the model, which is effectively steady state and does not take preceding tidal conditions explicitly into account. At slack water the ambient velocity is at its lowest value, meaning that the extent of the plume across the channel (lateral extent) is likely to be of greater importance than its downstream extent. The model output was therefore validated against the lateral extent of the plume (y value) as measured from the thermal imagery.

Runs 14 and 15: Initial Validation

The initial validation run (Run 14) did not produce a satisfactory result because the 21.5 and +2^{o}C contours were not reached before the end of the simulation (Table 5.35). The ambient velocity value in the model was altered from the value of 0.2m/s to 0.01m/s (the lowest value allowed in the model) (Run 15). Justification for the reduced velocity value was that velocity must reach zero at tidal reversal and that observations made during the boat based survey indicated that there was no current at HWS. This produced an output with 21.5°C and 2°C above ambient isotherms that corresponded well to the aerial thermal imaging data.

Runs 16 to 19: Sensitivity to Timing

The sensitivity of the model to the timing of the run, relative to slack tide was tested (Table 5.35, Runs 16 and 17). Running the model closer to slack tide reduces the run time of the model (CORMIX automatically terminates simulations when the conditions become significantly unsteady i.e. the rapid rate of change of the ambient flow that occurs during tidal reversal means that predictions of the plume may be unreliable and there is therefore an automatic prevention of model outputs at these times). This automatic model termination means that several simulations for times close to slack tide did not continue long enough to allow the plume temperature to drop below 2°C above ambient. The modelled plume could not therefore be fully tested against the field data. The 21.5°C isotherm for the run 0.1h after slack corresponded well to the field data, but other isotherm values were not reached so could not be tested. In all cases the model under-predicted the extent of the 28°C isotherm. To avoid this issue, two runs were carried out without the tidal parameters in the model (i.e. as steady state), with velocities of 0.01m/s and 0.1m/s (Runs 18 and 19). This allowed the model to continue running for longer so that the plume could be allowed to develop further. Both runs produced a

21.5°C isotherm that corresponded well to the field data, while the 28°C isotherm extent was, again, under-predicted. The large y (cross-channel) values associated with the 2°C above ambient isotherm are not realistic as in reality the steady state condition would not continue for long enough to allow this plume extent to develop.

5.3.2 Flood tide scenario

The values for parameters that are not tidally varying were kept the same as for Calibration Run 11. As for the HWS scenario described above, other values had to be altered to reflect the different tidal conditions as per Table 5.1.

Run 20: Initial Validation

The initial validation run terminated before the temperature had dropped to 2°C above ambient. Where the temperature was 5.67°C above ambient however, the plume extended across the whole channel, which was not observed in the field data (Table 5.46). Validation was not, therefore, considered to have been successful. Given that the ambient velocity value used was taken from a previous model, and not from values measured on the day, it is subject to a degree of uncertainty.

Runs 21-25: Calibration (b)

Calibration was carried out by changing the ambient velocity to alter the plume shape and size (Table 5.46, Runs 21-25). Increasing the ambient velocity causes a reduction in predicted plume area (i.e. mixing occurs more quickly).

Validation / Calibration (b) Summary

For the high water slack tidal state, Run 15 was considered to be the “best fit” model in that it produced a plume that fitted most closely to the measured data for the 21.5°C above ambient and 2°C above ambient isotherms (the measured cross-channel plume width (y) from the aerial thermal imaging for the 21.5°C and 2°C above ambient isotherms was within the predicted values, ± 50 %).

For the flood tidal state, Run 24 was considered to be the “best fit” model in that it produced a plume that fitted most closely to the measured data for the 21.5°C above ambient and 2°C above ambient isotherms (the measured values from the aerial thermal imaging for the 21.5°C and 2°C above ambient isotherms were within the predicted values, ± 50 %). The fit to the aerial thermal imaging data was not as good for the flood tide as for the ebb tide, with the downstream extent of the plume being over-predicted, and the cross-channel width of the plume being under-predicted. This suggests that the flood tide plume shape was not as well represented by the model.

The model did not reliably reproduce the extent of the 28°C isotherm under either the ebb, high water slack or flood tidal scenarios. As discussed above however, the measured area of this isotherm from the aerial thermal imaging is small in the context of the total channel width and the size of the upstream and downstream area of interest, for all tidal states observed on 10 June.

The ± 50 % errors/uncertainties in the maximum predicted cross-channel width of the plume are in the order of several tens of metres (in the context of a total channel width of 200m) whilst the errors/uncertainties in the maximum length of the plume are in the order of several hundreds of metres (in the context of an area of interest of 29km). The modelled plume dimensions are therefore a fair representation of the behaviour of the plume within the wider channel.

Table 5.3 Summary of results of the validation model simulations of the plume extent for the high water slack (HWS) tide state. Green cells indicate measured data. Yellow cells indicate where the envelope of modelled values contains the measured value.

	Variables altered		28 °C	21.5 °C	2 °C above ambient
			y (m) lateral	y (m) lateral	y (m) lateral
Aerial Thermal Imaging data			8	61	94
Run 14 (validation)		+50%		20.21	25.4
			13.17	not reached	not reached
		-50%	20.21	not reached	not reached
Run 15 (calibration) (b))	Ambient velocity reduced to 0.01m/s	+50%		19.77	32.33
			17.46	40.60	99.76
		-50%	20.10	79.60	not reached
Run 16 (sensitivity)	Time after slack reduced to 0.01 h	+50%		19.77	32.00
			17.46	40.27	not reached
		-50%	20.10	not reached	not reached
Run 17 (sensitivity)	Time after slack changed to 0.1 h	+50%		19.77	32.33
			17.46	40.60	not reached
		-50%	20.10	79.27	not reached
Run 18 (sensitivity)	Run as steady state; ambient velocity as 0.01m/s	+50%		20.21	33.41
			17.57	42.32	106.01
		-50%	20.54	84.23	221.83
Run 19 (sensitivity)	Run as steady state, ambient velocity as 0.1	+50%		18.62	29.33
			14.99	36.15	87.75
		-50%	19.60	71.20	200.00[a]

[a] These values correspond to a temperature of 1.6°C

Table 5.4 Summary of results of the validation model simulations of the plume extent for the flood tide state. Green cells indicate measured data. Yellow cells indicate where the envelope of modelled values contains the measured value.

	Variables altered		**28 °C**		**21.5 °C**		**2 °C above ambient**	
			x (m) longitudinal	**y (m) lateral**	**x (m) longitudinal**	**y (m) lateral**	**x (m) longitudinal**	**y (m) lateral**
Aerial Thermal imaging data			-39	30	-634	39	-1129	46.2
Run 20 (validation)		+50%			-464.05	152.66		
			- 5.57	20.64	model stops when x is 1250.48 and y is 199.55, at which point T is 5.67 above ambient			
		-50%	-437.14	147.92				
Run 21 (calibration (b))	Ambient velocity increased to 0.4m/s	+50%			-42.21	34.15	-761.10	154.53
			-1.64	7.55	-1093.38	190.51	Not reached	
		-50%	-36.61	31.39	Not reached		Not reached	
Run 22 (calibration (b))	Ambient velocity increased to 0.5m/s	+50%			-8.08	11.66	-391.98	86.89
			-1.57	5.49	-708.27	120.47	-1277.59	170.60
		-50%	-8.08	11.66	-1182.70	162.84	Not reached	
Run 23 (calibration (b))	Ambient velocity increased to 0.6m/s	+50%			-3.99	7.08	-205.74	53.13
			-1.61	4.93	-539.48	86.85	-1040.10	127.08
		-50%	-3.87	7.0	-956.66	120.89	-1415.56	153.26
Run 24 (calibration (b))	Ambient velocity increased to 0.7m/s	+50%			-4.10	6.38	-77.41	19.93
			-1.55	4.4	-398.80	63.44	-872.82	98.76
		-50%	-3.97	6.3	-820.15	95.19	-1241.50	122.14
Run 25 (calibration (b))	Ambient velocity increased to 0.9m/s	+50%			-4.37	5.37	-33.76	16.12
			-1.53	3.72	-231.30	37.71	-668.53	66.16
		-50%	-4.17	5.29	-595.66	61.91	-960.02	81.93

5.4 Sensitivity testing

Sensitivity testing was carried out as part of the calibration and validation process. The parameter values altered and the sensitivity of the model output to these are summarised in Table 5.57.

Table 5.5 Summary of parameter certainty and sensitivity testing undertaken. Grey shading indicates measured or known variables where values were fixed, rather than to be determined by calibration.

Variable	Certainty	Sensitivity testing	Model sensitivity
Heat loss coefficient (function of wind speed and ambient water temperature)	Ambient water temperature: high (measured), wind speed: moderate (daily average for site nearby)	Set as 20 initially. Value set to 0 and to 100	Model not sensitive
Discharge temperature	High (measured)	Not tested because value known	
Discharge flow rate	High (measured)	Not tested because value known	
Effluent density (function of salinity and temperature)	Temperature: High – see above Salinity: Moderate (average value taken from long term EA data set)	For ebb tide: reduction of salinity to lowest measured value, then to median measured value	Model slightly sensitive (small change in plume dimensions)
Average depth	High (measured in field, although adjusted to meet model requirement)	Not tested because value constrained by model	
Wind speed	Moderate – see above	Wind speeds of 0 and 15m/s tested (extremes of values allowed by model)	Slightly sensitive in far field (small change in plume dimensions)
Tidal period	Moderate (average of neap and spring periods taken from previous model)	Not tested	
Maximum tidal velocity	Moderate (average of neap and spring maximum velocities taken from previous model)	Not altered	

Variable	**Certainty**	**Sensitivity testing**	**Model sensitivity**
Time of prediction relative to slack tide	High (known)	HWS timing altered to investigate effect on model run time	Length of time for which model runs is sensitive to the timing of the scenario relative to slack water
Tidal velocity	Moderate (average of spring and neap velocities at corresponding time, taken from previous model)	Range of values tested for flood tide state	High
Channel width	High (measured)	Not tested as value fixed	
Channel appearance	High	Not tested	
Bottom friction coefficient (n)	Low	Tested for ebb tide state	Highly sensitive to extreme (but probably unrealistic) values of n. Less sensitive when n varied within what was considered a reasonable range (Chow 1959).
Ambient density (function of salinity and temperature)	Temperature: High, salinity: Moderate –see above.	Salinity tested for ebb tide – see above	See above
Nearest bank	High	Not tested	
Distance to nearest bank	High	Not tested	
Vertical angle of discharge port	Moderate (effect of concrete apron on plume angle could not be represented physically in model)	Three values tested for ebb tide state	High
Horizontal angle of discharge port	High	Not tested	

Variable	**Certainty**	**Sensitivity testing**	**Model sensitivity**
Height of discharge port above channel bottom	High (but adjusted to meet model requirement)	Not tested	
Port diameter	High (but represented in model as one large pipe instead of two smaller ones)	Not tested	

5.5 Summary of calibration and validation

The calibration and validation showed that, with some adjustment of parameter values within realistic ranges, the model was able to reproduce the extents of the 21.5°C and 2°C above ambient isotherms for all three tidal states (± 50 %); mid ebb, mid flood and high water slack. There are however, some uncertainties and limitations associated with the model predictions. These should be recognised:

1. The model was unable to reproduce the extent of the 28°C isotherm for any of the scenarios. It should be noted, however, that the measured area of this isotherm from the aerial thermal imaging (and from the boat-based data) is small in the context of the total channel width and the size of the upstream and downstream area of interest. The lack of success in reproducing this contour in the model is therefore not considered to be a major limitation for the purposes of impact assessment.

2. The ± 50 % accuracy of the modelled temperature values results in a very large range of possible plume dimensions for a given scenario, as can be seen in Table 5.3 to Table 5.46. Modelling of the 'worst case scenario' (i.e. plume +50%) however, predicted the maximum measured plume extent in both cross channel and upstream/downstream directions (based on the aerial thermal imaging data). Furthermore, ± 50 % errors/uncertainties in the maximum predicted cross-channel width of the plume are in the order of only several tens of metres (in the context of a total channel width of 200m) whilst the errors/uncertainties in the maximum length of the plume are in the order of several hundreds of metres (in the context of an area of interest of 29km). The modelled plume dimensions are therefore considered to be a fair representation of the behaviour of the plume within the wider channel.

3. Validation based on the high water slack and flood tide states did not produce as good a fit to the observed data as for the ebb tidal state and required adjustment of model values to reproduce the observed plume extent from the thermal imaging survey. Even with these adjustments, the model fit to the aerial thermal imaging plume shape was not as good as for the ebb tidal state. Nevertheless, the measured extents (and most importantly, the lateral extent) of the 21.5^{o}C and 2^{o}C above ambient isotherms matched the model predictions (± 50 %) for both scenarios.

Overall, the calibration has had some success in representing plume characteristics but there remain some aspects that are not well represented; specifically the 28°C isotherm. The measured extent of this however was small, so this is not considered to be critical for the purposes of this study. Given that it was recognised at the outset that CORMIX was a relatively simple model, the fit of the model predictions for the 21.5 and 2^{o}C above ambient isotherms to the aerial thermal imaging data is considered to provide a fair representation of the behaviour of the plume within the wider channel.

It should also be noted that the results of the calibration and validation runs agree with previous models that the plume does not extend across the whole channel and this is considered to be the critical success criterion for this study. This is also supported by the results of the in-situ aerial and boat-based field measurements that were taken.

The sets of parameter values producing the best calibration or validation result for each tidal state were therefore taken forward as the basis for the modelling of different temperature and effluent velocity scenarios (Section 6). Interpretation of the results must however, take into account the limitations and uncertainties of the model predictions, as described above.

6 SCENARIO TESTING

The plume extent was modelled for 24 different scenarios with varying tide states, ambient temperature, effluent temperature and effluent flow rate. The parameter values used in the scenario runs are presented in Table 6.1. The choice of values for high and low discharge temperatures and flow rates are based on the values proposed in APEM, 2010b, to incorporate high and low ambient water temperatures, high and low discharge temperatures and high and low discharge flow rates.

Table 6.1 Summary of scenarios and values for CORMIX simulations of Keadby thermal plume

Parameter	Number of scenarios	Scenarios	Scenario values
Ambient water temperature	3	High (mean + 2 standard deviations)	21.06°C
		Medium (mean)	17.5 °C
		Low (mean – 2 standard deviations)	13.94°C
Discharge temperature	2*	High (98th percentile from long term measured data)	16.7 °C above ambient
		Low (95th percentile from long term measured data)	13°C above ambient
Discharge flow rate	2*	High	11.57m^3/s
		Low	5m^3/s
Tide	4	Mid flood	Values as determined in Section 3, above
		High water slack	
		Mid ebb	
		Low water slack	
Total number of scenarios	**24**		

* N.B. discharge temperature and flow rate were only run as two combinations: high discharge, low flow rate and low discharge, high flow rate.

The results of each scenario run are presented in Table 6.2 and Figure 6.1.

It should be noted that:

a) CORMIX automatically terminates model runs that are carried out close to high and low water after a few minutes because the rapid rate of change of the ambient flow that occurs during tidal reversal means that predictions of the plume may be unreliable. There is therefore an automatic prevention of model outputs at these times (see discussion in Section 5.3.1). The outcome of this is that model runs for the HWS and LWS scenarios were occasionally terminated before the lower temperature thresholds have been reached.

Slack water conditions do not however prevail for extended periods of time within this part of the Trent before the increasing tidal flow in the channel begins to push the plume upstream or downstream, and therefore the termination of model runs in these cases is appropriate. Where model runs were terminated, the maximum extent of the plume and the associated temperature at the point of run termination were recorded.

b) Modelling of the 28^{o}C isotherm did not reproduce the detail of measured data well during calibration and validation, but more generally, there was consistency with measured data in the extent 28^{o}C isotherm being small relative to the channel width.

Table 6.2 Summary of results of the scenario model runs

Run	Tidal state	Ambient water temp	Effluent temp	Effluent flow rate		28 degrees					21.5 degrees						2 deg above ambient					
						x (m)	y (m)	z (m)	half width (m)	y extent (m)	x (m)	y (m)	z (m)	half width (m)	y extent (m)	T (°C)	x (m)	y (m)	z (m)	half width (m)	y extent (m)	T (°C above ambient)*
					50% +	0.50	0.85	2.95	1.49	1.90	1320.46	0.00	7.65	115.40	115.40		64.15	0.00	7.65	22.73	22.73	
1	Mid flood	High	High	Low		4.36	2.70	4.37	2.03	4.67	1890.95	0.00	7.65	145.29	145.29		719.61	0.00	7.65	78.97	78.97	
					50% -	20.52	7.04	7.65	4.12	11.10	2291.51	0.00	7.65	164.59	164.59		1010.93	0.00	7.65	97.49	97.49	
					50% +						1836.89	0.00	7.65	175.64	175.64		146.17	0.00	7.65	51.09	51.09	
2	Mid flood	High	Low	High		2.51	5.03	4.89	2.33	6.97	2641.74	0.00	7.65	200.00	200.00	21.64	963.71	0.00	7.65	120.27	120.27	
					50% -	50.56	20.36	7.65	10.27	30.43	2641.74	0.00	7.65	200.00	200.00	21.64	1383.18	0.00	7.65	148.16	148.16	
					50% +						3.06	2.31	3.94	1.90	4.17		64.60	0.00	7.65	22.56	22.56	
3	Mid flood	Medium	High	Low		1.39	1.57	3.36	1.69	2.77	64.60	0.00	7.65	22.56	22.56		713.46	0.00	7.65	76.91	76.91	
					50% -	4.29	2.69	4.30	2.02	4.50	483.22	0.00	7.65	60.85	60.85		1006.50	0.00	7.65	95.14	95.14	
					50% +						1.82	4.29	4.49	2.12	5.79		141.70	0.00	7.65	50.02	50.02	
4	Mid flood	Medium	Low	High		0.80	2.73	3.74	1.74	3.28	141.70	0.00	7.65	50.02	50.02		947.45	0.00	7.65	116.69	116.69	
					50% -	2.46	4.99	4.85	2.31	6.62	644.37	0.00	7.65	94.72	94.72		1368.81	0.00	7.65	144.13	144.13	
					50% +						0.30	0.61	2.82	1.43	1.25		54.28	10.66	7.65	10.39	21.05	
5	Mid flood	Low	High	Low		0.47	0.83	2.93	1.48	1.72	3.58	2.48	4.06	1.96	4.40		697.15	0.00	7.65	74.12	74.12	
					50% -	1.99	1.88	3.57	1.78	3.47	10.85	3.88	7.65	2.23	6.09		990.37	0.00	7.65	92.01	92.01	
					50% +												138.88	24.64	7.65	24.51	49.15	
6	Mid flood	Low	Low	High							2.09	4.61	4.64	2.20	6.17		931.13	0.00	7.65	113.07	113.07	
					50% -	1.19	3.42	4.06	1.90	4.47	26.20	15.70	7.65	6.49	22.02		1345.80	0.00	7.65	139.48	139.48	
					50% +	0.04	11.07	6.58	1.67	11.07	3.60	107.54	9.00	95.11	113.66	22.60	0.24	25.08	9.00	14.04	25.21	
7	HWS	High	High	Low		0.13	17.48	9.00	5.68	17.58	3.60	107.54	9.00	95.11	113.66	22.60	1.58	69.65	9.00	57.03	71.74	
					50% -	0.19	21.82	9.00	10.67	22.02	3.60	107.54	9.00	95.11	113.66	22.60	3.60	107.54	9.00	95.11	113.66	1.54**
					50% +						3.60	141.33	9.00	78.14	144.02	22.88	0.30	34.71	9.00	16.08	34.71	
8	HWS	High	Low	High		0.08	20.67	9.00	5.66	20.78	3.60	141.33	9.00	78.14	144.02	22.88	2.60	116.96	9.00	64.09	119.52	
					50% -	0.20	28.69	9.00	12.02	28.93	3.60	141.33	9.00	78.14	144.02	22.88	3.60	141.33	9.00	78.14	144.02	1.82**
					50% +						0.11	16.34	9.00	3.89	16.34		0.26	25.90	9.00	14.61	25.90	
9	HWS	Medium	High	Low		0.08	13.89	9.00	2.08	13.93	0.26	25.90	9.00	14.61	25.90		1.69	71.74	9.00	58.16	74.38	
					50% -	0.12	16.99	9.00	4.81	16.99	0.71	44.80	9.00	32.57	46.28		3.60	107.09	9.00	93.06	112.89	1.59**
					50% +						0.06	19.20	9.00	4.14	19.28		0.32	35.23	9.00	16.25	35.55	
10	HWS	Medium	Low	High		0.03	17.20	9.00	2.23	17.20	0.32	35.23	9.00	16.25	35.55		2.77	119.92	9.00	64.73	122.51	
					50% -	0.08	20.70	9.00	5.63	20.81	1.10	69.31	9.00	36.32	70.76		3.60	139.91	9.00	76.02	143.36	1.85**
					50% +						0.04	10.64	6.05	1.59	10.64		0.28	26.70	9.00	15.13	27.42	
11	HWS	Low	High	Low		0.04	11.32	6.56	1.67	11.32	0.12	16.94	9.00	4.51	16.94		1.88	75.54	9.00	60.76	78.43	
					50% -	0.10	15.85	9.00	2.88	15.85	0.18	21.28	9.00	9.64	21.28		3.60	106.56	9.00	90.80	111.33	1.64**
					50% +												0.34	35.72	9.00	16.39	36.05	
12	HWS	Low	Low	High							0.06	19.70	9.00	4.63	19.70		2.94	122.83	9.00	65.23	125.44	
					50% -	0.04	18.20	9.00	2.99	18.26	0.18	26.71	9.00	10.38	26.92		3.60	138.29	9.00	73.77	141.64	1.88**
					50% +	2.40	2.46	0.00	3.45	5.91	774.19	0.00	7.65	63.08	63.08		35.80	2.46	1.47	2.25	4.71	
13	Mid ebb	High	High	Low		6.00	2.46	0.00	3.52	5.98	1411.74	0.00	7.65	93.41	93.41		58.20	2.46	7.65	4.48	6.94	
					50% -	31.63	2.46	0.93	2.07	4.53	1782.89	0.00	7.65	108.91	108.91		61.99	2.46	7.65	6.01	8.47	
					50% +						1396.17	0.00	7.65	117.28	117.28		55.55	17.99	7.65	8.84	26.83	
14	Mid ebb	High	Low	High		2.46	3.85	4.30	2.19	5.67	2116.12	0.00	7.65	150.99	150.99		622.92	0.00	7.65	74.47	74.47	
					50% -	15.96	10.44	7.65	4.13	14.57	2611.87	0.00	7.65	172.18	172.18		1008.26	0.00	7.65	97.00	97.00	
					50% +						4.80	2.46	0.00	3.50	5.96		36.44	2.46	1.46	2.26	4.72	
15	Mid ebb	Medium	High	Low		3.60	2.46	0.00	3.48	5.94	36.44	2.46	1.46	2.26	4.72		59.43	2.46	7.65	4.49	6.95	
					50% -	6.00	2.46	0.00	3.52	5.98	49.40	2.46	3.26	2.81	5.27		63.23	2.46	7.65	6.03	8.49	
					50% +						1.75	3.24	3.99	2.01	4.91		55.62	18.02	7.65	8.68	24.16	

Run	Tidal state	Ambient water temp	Effluent temp	Effluent flow rate		28 degrees					21.5 degrees						2 deg above ambient					
						x (m)	y (m)	z (m)	half width (m)	y extent (m)	x (m)	y (m)	z (m)	half width (m)	y extent (m)	T (°C)	x (m)	y (m)	z (m)	half width (m)	y extent (m)	T (°C above ambient)*
16	Mid ebb	Medium	Low	High		0.74	1.99	3.41	1.67	2.92	55.62	18.02	7.65	8.68	24.16		781.76	0.00	7.65	82.47	82.47	
					50% -	2.42	3.83	4.28	2.19	5.38	500.11	0.00	7.65	65.35	65.35		1155.55	0.00	7.65	102.74	102.74	
					50% +						2.40	2.46	0.00	3.45	5.91		36.94	2.46	1.44	2.26	4.72	
17	Mid ebb	Low	High	Low		2.40	2.46	0.00	3.45	5.91	4.80	2.46	0.00	3.50	5.96		61.21	2.46	7.65	4.51	6.97	
					50% -	3.60	2.46	0.00	3.48	5.94	9.59	2.46	0.00	3.57	6.03		65.03	2.46	7.65	6.05	8.51	
					50% +												55.74	18.04	7.65	8.51	26.55	
18	Mid ebb	Low	Low	High							2.02	3.49	4.11	2.09	5.23		762.11	0.00	7.65	79.64	79.64	
					50% -	1.15	2.58	3.67	1.82	3.87	4.80	5.24	5.01	2.63	7.79		1130.83	0.00	7.65	99.21	99.21	
					50% +	0.04	11.76	7.65	2.32	11.76	3.60	104.72	7.65	85.57	111.28	23.26	0.53	36.98	7.65	25.95	38.16	
19	LWS	High	High	Low		0.12	17.20	7.65	8.56	17.59	3.60	104.72	7.65	85.57	111.28	23.26	3.60	104.72	7.65	85.57	111.28	2.20
					50% -	0.34	29.15	7.65	19.27	30.03	3.60	104.72	7.65	85.57	111.28	23.26	3.60	104.72	7.65	85.57	111.28	2.20
					50% +						3.60	62.99	7.65	32.25	64.10	24.14	3.01	37.62	7.65	19.20	38.00	
20	LWS	High	Low	High		2.63	16.05	7.65	6.35	16.18	3.60	62.99	7.65	32.25	64.10	24.14	3.60	62.99	7.65	32.25	64.10	3.08
					50% -	2.84	28.59	7.65	14.24	28.87	3.60	62.99	7.65	32.25	64.10	24.14	3.60	62.99	7.65	32.25	64.10	3.08
					50% +						0.09	15.28	7.65	6.51	15.28		0.55	37.65	7.65	26.06	37.65	
21	LWS	Medium	High	Low		0.06	12.89	7.65	3.81	13.06	0.55	37.65	7.65	26.06	37.65		3.60	104.15	7.65	83.19	104.15	2.24
					50% -	0.12	17.23	7.65	8.46	17.23	2.00	75.89	7.65	58.34	78.54		3.60	104.15	7.65	83.19	104.15	2.24
					50% +						2.60	14.11	7.65	4.76	14.20		3.02	37.66	7.65	19.01	38.04	
22	LWS	Medium	Low	High		2.57	12.10	7.65	2.94	12.16	3.02	37.66	7.65	19.01	38.04		3.60	62.03	7.65	31.36	63.01	3.12
					50% -	2.63	16.11	7.65	6.31	16.24	3.60	62.03	7.65	31.36	63.01	20.62**	3.60	62.03	7.65	31.36	63.01	3.12
					50% +												0.58	38.31	7.65	26.12	38.31	
23	LWS	Low	High	Low		0.04	11.83	7.65	2.28	11.83	0.10	16.17	7.65	7.30	16.17		3.60	103.49	7.65	80.66	103.49	2.29
					50% -	0.07	13.79	7.65	4.80	13.79	0.29	26.59	7.65	16.51	26.59		3.60	103.49	7.65	80.66	103.49	2.29
					50% +												3.05	38.19	7.65	19.06	38.57	
24	LWS	Low	Low	High							2.62	15.16	7.65	3.88	15.24		3.60	60.98	7.65	30.43	62.15	3.17
					50% -	2.59	13.16	7.65	3.88	13.24	2.79	25.18	7.65	12.00	25.42		3.60	60.98	7.65	30.43	62.15	3.17

NB Yellow highlight indicates that temperature threshold was not reached before simulation termination. The plume extent values relate to the last output of the model before simulation termination.

* This column indicates the temperature of the plume at the last output of the model before simulation termination. Values are only included in this column for scenarios where termination occurred before specified temperature thresholds were reached.

** Although temperature at last output was below the specified threshold, it was still above the 50% error limit of the threshold and the threshold was not considered to have been fully reached.

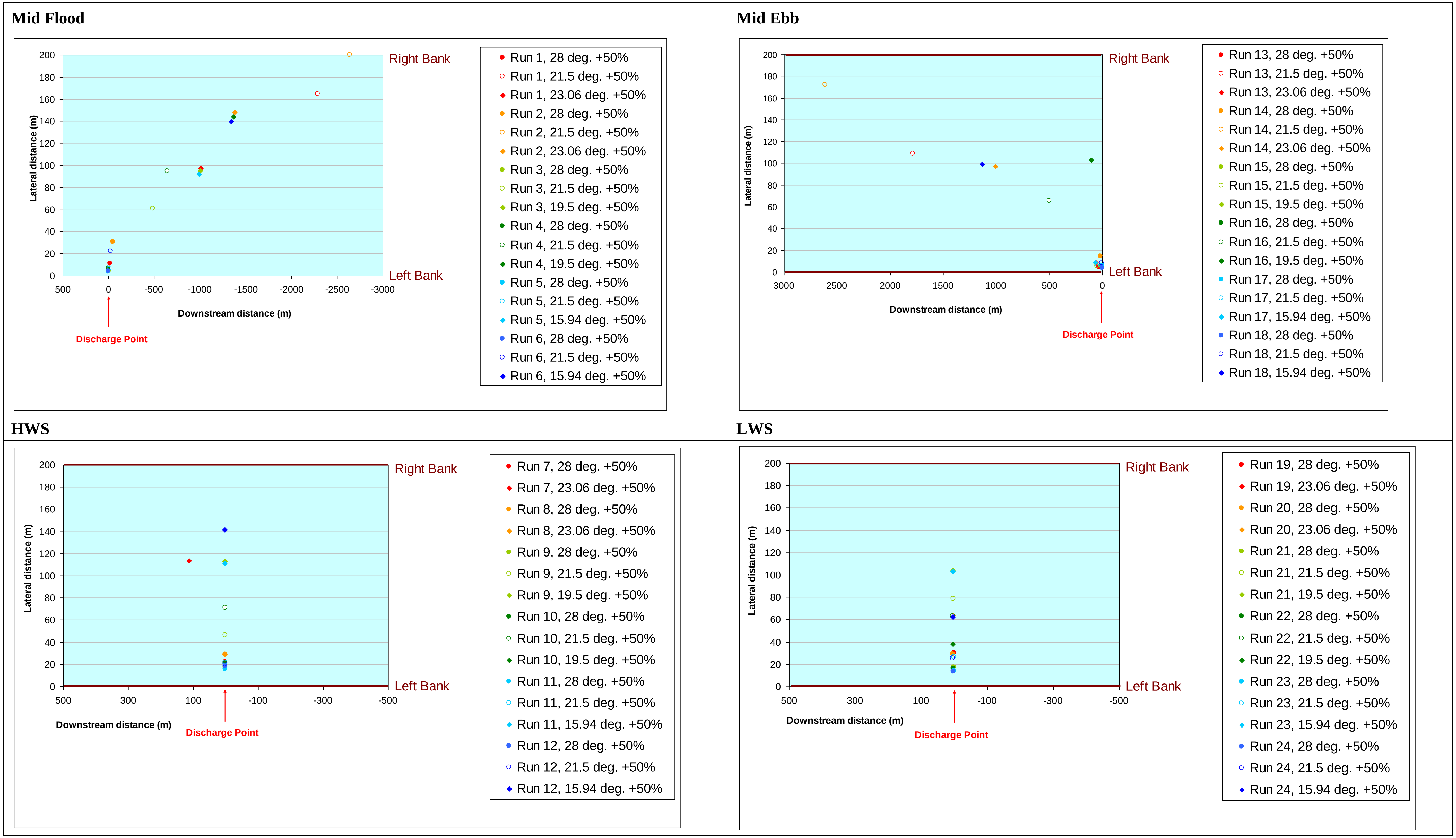

Figure 6.1 Summary of results of the scenario model runs

6.1 Predicted plume width across the channel

For 23 out of the 24 scenarios, the model predicted that neither the 21.5°C nor +2°C isotherm would extend across the whole width of the channel, even when a +50% error band was included. The remaining scenario (Scenario 2) was a mid flood tide scenario with a high ambient temperature of 21.06°C, where effluent temperature was 13°C above ambient and effluent flow rate was 11.57 m^3/s. The results of this run show that the 21.5°C isotherm was predicted to extend across the entire channel width (200m) when the +50% error band was included. Sensitivity analysis with the model suggests that the effluent temperature would need to be reduced to 9°C above ambient for the 21.5°C isotherm (+50%) not to extend across the entire channel. It is important to note however that:

- In this scenario the ambient temperature of the receiving water was already set at 21.06°C, so that a temperature increase of less than 0.5°C was sufficient to cross the 21.5°C threshold.
- An effluent temperature of 13°C above ambient would be most likely to coincide with a lower effluent flow rate than 11.57 m^3/s.
- Ambient temperatures above 17.5°C (where the plume was not predicted to cross the whole channel) were only recorded during June mid flood tides on 7 occasions since 1988.

In all other scenarios the predicted plume (including a +50% error band) did not extend across the entire channel width and the maximum predicted extent of the 2°C above ambient isotherm across the channel was 144.13m (in Scenario 4). The maximum predicted across-channel extent of the 28°C isotherm was 30m, representing only 15% of the total channel width. Although the detail of behaviour of the 28°C isotherm was not well represented by the model in calibration, these results do suggest that the extent of the 28°C isotherms in all scenarios will be small relative to the width of the channel.

The model predictions indicate that, while a situation where temperatures of 21.5°C extend across the entire channel width cannot be ruled out, they are only likely to arise from a combination of high ambient temperatures (in Scenario 2 the ambient temperature was only 0.44°C below the 21.5°C temperature threshold), a high effluent flow rate and a 95th percentile effluent temperature (based on 10 years of measured data). This combination of conditions represents a worst case and is considered very unlikely to occur.

The conclusion that other conditions do not cause a situation where temperatures of 21.5°C extend across the entire channel width is supported by the results of the in-situ aerial and boat-based field measurements that were collected during a period of lower than average June river flow and higher than average June river temperature in 2011, which indicated that the plume did not extend across the entire channel width under any of the tidal states surveyed.

6.2 Predicted downstream plume extent

The maximum predicted downstream extent of the plume was 2611.87m. The 21.5°C (+50%) isotherm was predicted to reach this extent in Scenario 14 (a mid ebb tide with a high ambient temperature). The maximum downstream extent of the 28°C (+50%) isotherm was 31.63m in Scenario 13 (a mid ebb tide with a high ambient temperature).

Based on these predictions it is considered unlikely that the thermal plume would extend as far downstream as the confluence with the Humber Estuary, approximately 12km away. This is supported by the results of the in-situ aerial and boat-based field measurements, which indicated that the plume hugged the left hand bank (looking downstream) and did not extend as far as the confluence with the Humber Estuary during the ebb tide (where this extent would be expected to be greatest).

6.3 Predicted upstream plume extent

The maximum predicted upstream extent of the plume was 2641.74m. The 21.5°C (+50%) isotherm was predicted to reach this extent in Scenario 2, a mid flood tide with a high ambient temperature. The maximum predicted upstream extent of the 28°C (+50%) isotherm was 50.56m (Scenario 2).

7 SUMMARY AND RECOMMENDATIONS

On the day of the aerial and boat-based surveys (10 June 2011) the discharge temperature at the outlet of Keadby Power Station, the ambient river temperature, and the ΔT were as detailed in **Table 7.1**.

Table 7.1 Summary of temperature data during aerial and boat-based surveys on 10th June 2011

Tidal state	Discharge outlet temperature (°C)	Ambient river temperature (°C)	ΔT (°C)
Flood	33.48	18.32	**15.16**
HWS	32.47	18.06	**14.41**
Ebb	31.96	18.40	**13.56**

The maximum outlet temperature scenario tested was 16.7°C above ambient, and the minimum was 13°C above ambient. These are 98^{th} and 95^{th} percentile outlet temperatures for Keadby Power Station based on a 10 year historical dataset measured between 1998 and 2008 (APEM, 2010a). The highest ambient temperature tested was 21.06°C (i.e. the mean river temperature measured by the EA at Keadby (based on monthly data collected between 1987 and 2010), plus two standard deviations). The highest temperature tested was therefore 37.76°C, and this was tested in Scenarios 1, 7, 13 and 19 (corresponding to the mid-flood, HWS, mid-ebb and LWS tidal states respectively). A full list of the parameters tested is included in Table 6.1, and the combinations in which these were tested are detailed in Table 6.2.

The calibration and validation showed that, within the quoted error range of the model, and with some adjustment of parameter values within realistic ranges, the model was able to reproduce the extents of the 21.5°C and 2°C above ambient isotherms for all three tidal states (± 50 %); mid ebb, mid flood and high water slack. There were however, some uncertainties and limitations associated with the model predictions and there remain some aspects that are not well represented; specifically the 28°C isotherm. Nevertheless, given that the measured extent of this isotherm was small, this is not considered to be critical for the purposes of this study. In other respects, and given that it was recognised at the outset that CORMIX was a relatively simple model, the fit of the model predictions for the 21.5 and 2^{o}C above ambient isotherms to the aerial thermal imaging data is considered to provide a fair representation of the behaviour of the plume within the wider channel.

The modelled scenario runs indicated that, for 23 out of the 24 scenarios tested, neither 28^{o}C, 21.5^{o}C nor +2^{o}C isotherms would extend across the whole width of the channel, even when a +50% error band was included. The results of the Scenario 2 run indicated that the 21.5°C isotherm was predicted to extend across the entire channel width (200m) when the +50% error band was included. While a situation where temperatures of 21.5°C extend across the entire channel width cannot be ruled out, this effect is largely due to high ambient temperatures (in Scenario 2 the ambient temperature was only 0.44°C below the 21.5°C temperature threshold) in combination with a high effluent flow rate and a 95th percentile effluent temperature (based on 10 years of measured data). This combination of conditions represents a worst case and is considered very unlikely to occur in reality. This is also supported by the results of the in-situ aerial and boat-based field measurements that were collected during a period of lower than average June river flow and higher than average June river temperature in 2011, which indicated that the plume did not extend across the entire channel width under any of the tidal states surveyed.

It should also be noted that the results of the calibration and validation runs agree with previous models that the plume does not extend across the whole channel and this is also supported by the results of the in-situ aerial and boat-based field measurements.

Elliott et al (2011) lists average summer high and winter low sea surface temperatures at the southern and northern limits of the range of lampreys as 3.2 to 23.5°C (summer) and -0.09 to 15.5°C (winter) for river lamprey and 1.7 to 24.7°C (summer) and ice to 22.0°C (winter) for sea lamprey to illustrate the range of temperature to which they can be expected to adapt.. In the case of salmon (*Salmo salar*), average summer high and winter low sea surface temperatures at the southern and northern limits of their range are quoted as being 1.7 to 23.5°C (summer) and ice to 15.0°C (winter), and for eel (*Anguilla anguilla*) as 0.2 to 27.8°C (summer) and ice to 27.7°C (winter) (Elliott et al, 2011). According to these figures, river lamprey, sea lamprey, salmon and eel should be capable of adapting to the 21.5°C and 2°C above ambient plumes experienced at Keadby.

In terms of the 28°C isotherm, Waede, 1954 (in Turnpenny & Linney, 2007) suggested that 26-27°C was the lethal limit for lamprey species, therefore temperatures of 28°C and greater may potentially result in mortality if they cannot be avoided by individual lamprey. Potter and Beamish, 1975 (in Elliott et al, 2011) however, state an upper lethal temperature of 31°C for sea lamprey ammocoetes (which tend to have lower temperature tolerances than adults), and Elliott et al, 2011 hypothesise that due to the similarities between the river and sea lamprey species, it is unlikely that temperatures experienced in UK transitional waters would be lethal to river lamprey.

For salmon, a lethal limit of 28°C is suggested for adults by Danie et al, 1984 and Jonsson and Jonsson, 2009 (in Elliott et al, 2011) and 27°C for larvae (Elliott, 1991, in Elliott et al, 2011). For adult eels, a lethal limit of 38°C is referenced by Sadler, 1979 (in Elliott et al, 2011). It is therefore possible that salmon adults and larvae may experience mortality if they cannot avoid the 28°C isotherm, however this temperature is well within the range that eels are known to tolerate.

Coarse fish species are not thought to be at risk as these generally have higher lethal temperature theresholds than the diadromous species discussed. For example the following lethal temperatures have been quoted for coarse fish species by Alabaster and Lloyd 1980 (in Turnpenny & Linney, 2007); perch (*Perca fluviatilis*) up to 35.8°C; pike (*Esox lucius*) up to 34°C; bream (*Abramis brama*) up to 35.7°C; roach (*Rutilus rutilus*) 37.8°C; chub (*Squalius cephalus*) 38.8°C and gudgeon (*Gobio gobio*) 36.7°C.

According to a report which proposes temperature standards for marine and freshwater environments in relation to the Water Framework Directive (WFD) (Turnpenny & Linney, 2007), WFD standards must attempt to distinguish normative boundary values for the 'high', 'good', 'moderate', 'poor' and 'bad' classes of fishery status. The proposed temperatures related to each classification for a transitional water body are as follows:

- 20 to 23°C = Good
- 23 to 28°C = Moderate
- 28 to 30°C = Poor
- 30°C + = Bad

Under these classifications, it can be concluded that the majority of the river channel would fall under 'good' status, however the presence of the 28°C isotherm falls within the 'poor' category. These temperature ranges however are based on the 98 percentile values at the edge of the mixing zone, and therefore the Keadby discharge is likely to be less than 23°C and therefore classified as 'good'.

Overall the results of this study have indicated that none of the modelled isotherms extend across the width of the river channel, and the 28°C isotherm (the only modelled isotherm with the potential to create a lethal effect), extends a very short distance from the outfall itself and into the channel. It is widely accepted that fish are usually able to avoid exposure to lethal temperatures provided that the plume does not pervade the full channel width and depth (Elliott et al, 2011). No impacts to the overall status of the populations of lamprey, salmon, eels or coarse fish species as a result of mortality or as a barrier to migratory movements are therefore anticipated. It is considered that the findings of this study confirm the Environment Agency's previous conclusion that it is unlikely that the thermal discharge would have any significant impact on the migration of river and sea lamprey between the river and the Humber Estuary.

It is recommended that the 98th percentile temperature of 37.76°C is the appropriate maximum temperature to be included in the licence conditions for the thermal discharge at Keadby Power Station. It is proposed that exceedances of this temperature up to a maximum of 44.6°C (the historical maximum measured at Keadby between 1998 and 2008) be permitted for 200 hours within a year to allow maintenance operations to take place, in line with the conditions of the South Humber Banks power station permit.

8 REFERENCES

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