NOT PROTECTIVELY MARKED

Sizewell C Project

Water Discharge Activity Permit Application Submission Sizewell C

Non-Technical Summary

Purpose of this report

This report supports the application for a water discharge activity environmental permit associated with a new nuclear power station to be situated directly to the north of the existing Sizewell B power station. The new power station will be referred to as Sizewell C. The power station will typically discharge 132m^3/s of cooling water to the Greater Sizewell Bay (GSB) and requires an environmental permit under the Environmental Permitting Regulations [1]. Discharges from other processes and facilities at Sizewell C will be disposed of with the cooling water. The Operator of the water discharge activity will be NNB Generation Company (SZC) Limited, hereafter referred to as SZC Co., which is a wholly owned subsidiary of NNB Holding Company (SZC) Limited which in turn is 80% owned by EDF Energy Holdings Limited and 20% owned by General Nuclear International Limited.

This submission presents details of the source of emissions, anticipated discharges and potential impacts on the environment. It demonstrates environmental optimisation of the design through the implementation of good practices to ensure an appropriate balance between costs to the operator and benefits to the environment. It also describes the commitments to implement Best Available Techniques (BAT), where appropriate, and good practices in areas where information and approach is yet to be fully developed. A Forward Action Plan (FAP) is proposed in **Section 7** to address these areas as the overall programme of work progresses and delivers more detailed information.

The scope of this submission relates to discharges from the cooling water system and its associated effluent streams during the hot functional testing phase of commissioning and the subsequent operation of Sizewell C. Activities related to construction and initial cold flush testing will be the subject of a separate environmental permit application.

Proposed activities

Each of the two UK European Pressurised Reactors (EPR^{TM}) units proposed for Sizewell C will require large volumes of cooling water to condense steam used in the turbines that generate electricity for export to the National Grid. This cooling water will be drawn from the GSB, passed through the condensers and then returned to the GSB approximately 3km out to sea from the site. In addition to the cooling water discharge, trade effluents will be produced as a result of normal operation of Sizewell C (e.g. process effluents and sanitary effluents). The volume and characteristics of the discharge will depend on the operational state of the each of the UK EPR^{TM} units. Normal operation includes the scenarios described below, which are routine and anticipated:

- **Standard Operation.** Electricity generation based on nuclear fission with both of the UK EPR^{TM} units operating at their full capacity with power changes in line with operational requirements;

- **Outage.** One reactor on outage and not operating due to scheduled maintenance activities and refuelling.

- **Maintenance.** Includes planned outages of a circulating water system [CRF] pump for maintenance with both reactors continuing to operate.

Emissions and monitoring

Emissions

The main potential impacts on the environment from discharge of the cooling water are associated with thermal load and chlorination for biofouling control. When the reactors are operating at full power the cooling water will be returned to the GSB at a temperature around 11.6°C higher than ambient. Under exceptional circumstances, the cooling water may be returned at a higher temperature (up to 23.2°C above ambient). Under these circumstances the load (and therefore condenser heat load) would be reduced across the generating units to ensure that the temperature is brought back down to around 11.6°C above ambient within a short timescale).

These potential impacts will be minimised as follows:

- **Thermal**. The diffusers (discharge heads) are located and orientated to ensure rapid rise to the surface to allow dispersion of the waste heat to air. Comprehensive modelling has been undertaken to demonstrate that the discharge of the waste heat will not interfere with the migration of key species such as salmon and eels.

- **Fish.** A fish recovery and return system will be installed to allow the majority of fish to be captured and returned to the sea.

- **Chlorination.** Seasonal chlorination to control the growth of biofilms and marine organisms such as mussels in the cooling water system (referred to as bio-fouling) is expected at Sizewell C. The proposed strategy to control bio-fouling will ensure that any chlorination necessary will be carefully managed and controlled.

The emissions will also contain substances associated with the operation of the plant and the welfare of employees. The main sources of emissions are:

- **Trade effluent potentially containing radioactivity.** This waste stream comprises chemical effluents from the primary and secondary circuits (potentially containing radioactivity) and will be treated, stored and monitored in the Effluent Treatment Building and Discharge Tanks Building within the Nuclear Island prior to discharge with the cooling water. Radioactive Discharges will be covered by a separate permit application which will be submitted at the same time as this application.

- **Oily water trade effluent.** This effluent comprises water potentially contaminated with oil from areas where hydrocarbons are used (except the Turbine Hall [HM]). The normal practice will be for this effluent to be directed to an oil/water separator resulting in an effluent that will be discharged with the site drainage. The oil fraction that has been separated will be sent for disposal at an appropriately permitted waste management facility.

- **Demineralised water production trade effluent.** This effluent arises from demineralising potable water for use in process operations. The effluent is generated from cleaning of membranes and ion exchange resins with acids and alkalis and will be characterised by high or low pH. The effluents will be treated by neutralisation using acids and alkalis before being discharged with the cooling water.

- **Sanitary effluent.** This effluent comprises water collected from black and grey wastewater and will be treated at the Sewage Treatment Plant before being discharged with the cooling water.

Monitoring

The monitoring systems associated with the water discharge activity to the GSB are still in the process of being designed. However, the water discharge monitoring locations will be selected to:

- enable monitoring to be undertaken so that representative measurements or samples can be made/taken; and

- locations will be designed so that they can be safely used and inspected by SZC Co. and the Environment Agency’s representatives as far as practicable.

In addition to the discharge monitoring infrastructure, the integrated management system will incorporate aspects to ensure the quality and reliability of the monitoring data obtained.

Decisions for Sizewell C on the arrangements for sampling, measurement and assessment of discharges to surface water will be made at the right time in accordance with the development of the project. It is, therefore, proposed that a description of both the monitoring infrastructure and management systems are provided to the Environment Agency as part of the FAP.

Environmental risk assessment

A comprehensive assessment has been undertaken on the environmental risks posed by cooling water and trade effluent discharges from Sizewell C and to demonstrate that these risks have been appropriately addressed by the design and operation of the power station.

This assessment also addresses the requirements of a range of environmental legislation, guidance and standards that have been developed to protect and enhance the marine environment. The key findings of the assessment are:

- **Thermal plume.** The plume will be thermally buoyant and would have less impact on species in or on the seabed. For cold and warm water early life stages of fish (ichthyoplankton), juveniles and adults, the thermal uplift is expected to have only a low level of effect. This would not be significant at the scale of the sea area and regional stock population. Similarly, the impact of the thermal plume on commercial fisheries is considered minor and not significant. Modelling has demonstrated that the migratory habits of fish such as eels will not be impacted at the mouth of the Alde-Ore or Blyth estuary or in terms of a transect from the coast to 3km offshore.

- **Discharges of ammonia.** Ammonia is harmful to fish and other marine organisms. Routine discharges of ammonia from various process waste streams including treated sewage effluent do not result in a significant uplift in total ammonia concentration including background levels when considered in terms of the equivalent un-ionised ammonia relative to the Environmental quality standard. Temperature elevation increases the relative proportion of un-ionised ammonia. This was also considered and the influence was found to be negligible. The Fish Recovery and Return system would discharge a percentage of moribund fish and the decay of this biomass could contribute to elevation of ammonia concentrations closer inshore. It was confirmed that the areas affected would be small even making the most conservative assessments.

- **Discharges of hydrazine.** Hydrazine is a toxic, weak volatile base and a strong reducing agent. It may be present in very low concentrations in discharges from Sizewell C. Modelling has shown that the area in which any harmful effects could occur is small, would be localised around the discharge heads and would only have a minor impact.

- **Chlorination.** Chemicals and associated by-products used to prevent biofouling are harmful to marine species. Seasonal chlorination would be applied at Sizewell C. Modelling shows, the impacts will be minor. As described in the Forward Action Plan, these impacts will be mitigated further by the implementation of proposed chlorination strategy.

The assessment of the thermal and chemical plumes for Humber Estuary Special Area of Conservation (SAC) (for grey seals), the Southern North Sea SAC (for harbour porpoise) and The Wash and North Norfolk Coast SAC (for harbour seals) (based on the proportion of the Management Unit population potentially affected) concludes that there would be no adverse effect on the integrity of the above SACs.

The assessment of thermal and chemical plumes for the screened-in Special Protection Area and Ramsar qualifying features it is concluded that water discharge activities would not have an adverse effect on the integrity of the European sites.

Managing the Activities

Management systems

SZC Co. will implement an integrated management system of documented procedures covering quality, health and safety and environmental management. The environmental aspects of the management system will be developed to comply with an accredited standard and will meet the indicative BAT requirements of the Regulatory Sector and Environment Agency guidance. A description of the final operational management system will be delivered through the FAP.

Arrangements will be developed to manage lessons learnt and improvement and/or pre-operational conditions, as the requirements may be relevant to one or more permits and/or EDF sites.

Accident and incident management

An initial environmental accident risk assessment has been carried out on the plant that comprises the water discharge activity. The risk assessment focused on the engineered design, as the procedural aspects as discussed above, have yet to be determined. When the engineered and procedural mitigation has been completed, a quantified risk assessment will be completed.

SZC Co. will develop, implement and maintain a hazard and risk management system, which addresses the potential accidents, associated with the water discharge activity and provide an accident & incident management plan.

Emissions of substances management plan

The emissions of substances management plan will be developed alongside the other power station management systems as part of normal business development and will be communicated to the Environment Agency as part of the FAP. The purpose of this plan is to show how appropriate measures will be taken to prevent, or where that is not practicable, to minimise emissions not covered by emission limit values in the permit.

Contents

1 Introduction

1.1 Purpose of the report

This report supports the application for a Water Discharge Activity (WDA) environmental permit made by NNB Generation Company (SZC) Limited, Registered Number 09284825 (hereafter referred to as SZC Co., which is a wholly owned subsidiary of NNB Holding Company (SZC) Limited which in turn is 80% owned by EDF Energy Holdings Limited and 20% owned by General Nuclear International Limited). In turn:

- EDF Energy Holdings Limited is a wholly owned subsidiary of Electricité de France S.A; and
- General Nuclear International Limited is a wholly owned subsidiary of China General Nuclear Power Corporation Limited.

The EDF Group of Companies own and operate a number of nuclear power stations in the UK, including Sizewell B. The EDF Group of companies also operates 58 nuclear power reactors in France, with a combined capacity of approximately 63GWe, EDF is the largest nuclear utility in the world. In addition, the proposed UK European Pressurised Reactor (EPR^{TM}) units proposed for Sizewell C are also being operated or constructed in France, China, Finland, UK and India.

Although SZC Co. was a newly formed company in 2014 it does not have a pre-existing organisation and procedures. However, as a member of the EDF Group of companies, SZC Co. will have access to the resources, experience and expertise of the world's largest owner and operator of nuclear power stations. SZC Co. has taken and will take advantage of the experience and resources of its parents and affiliates. However, as the Intelligent Customer and knowledgeable owner and operator of Sizewell C, SZC Co. will establish its own organisation and procedures that account for the Office for Nuclear Regulation (ONR) and Environment Agency guidance, and these will be developed over time consistent with the status of the project as well as lessons learnt from the power station currently in construction at Hinkley Point C. SZC Co.'s company manual [2] includes the requirements of a safety and environmental management prospectus and describes the company structure, governance arrangements and key roles and responsibilities.

The water discharge activity is associated with the two proposed UK EPR^{TM} units at the Sizewell C site, immediately to the north of the existing Sizewell B power station. The application is being made under the Environmental Permitting (England and Wales) Regulations 2016 (as amended) [1]. For clarity, throughout this submission the Environmental Permitting Regulations will be referred to as "the EP Regulations" and the new reactor will be referred to as the UK EPR^{TM}.

As requested by the UK Government, following issue of the White Paper on Nuclear power in 2008 [3], the nuclear regulators in England and Wales set up a new process for assessing acceptability of the generic aspects of new nuclear reactor designs that might be constructed in the UK, such as the UK EPR^{TM}, before site specific applications were made, such as at Sizewell C. This process is called the Generic Design Assessment (GDA). The UK EPR^{TM} was the first new reactor design to complete the GDA process. The GDA for the UK EPR^{TM} was submitted by Framatome and EDF SA (Electricité de France Société Anonyme), known as the Requesting Party and assessed by the regulators, the ONR covering safety and security, and the Environment Agency covering waste management and environmental protection. The GDA involved a rigorous and structured examination of detailed environmental, safety and security aspects of the reactor design.

As part of the GDA process, information on discharges to surface water was identified in the Pre-Construction Environment Report (PCER) [4]. The information presented in this application is generally consistent with that detailed in the PCER with deviations stated below:

- Sizewell C will have two UK EPR^{TM} units; and
- Demineralised water will be produced from potable water supplies instead of from seawater.

The information provided in the GDA was used to inform the operational WDA permit application for Hinkley Point C. As part of the replication strategy between Hinkley Point C and Sizewell C this permit application reflects where possible developments in design and information available from the Hinkley Point C project.

1.2 Scope of the application

The scope of the application is limited to water discharges[1] to the Greater Sizewell Bay (GSB) during part of the commissioning and all of the operation of the Sizewell C power station. A separate environmental permit application is being made for discharges associated with construction of the power station which include cold flush testing.

1.3 Regulatory requirements

1.3.1 Environmental permits

The need for a permit to discharge trade effluent, sewage and other polluting materials to controlled waters is set out in Regulation 12 (1) (b) of the EP Regulations [1], which state:

> *"A person must not, except under and to the extent authorised by an environmental permit, cause or knowingly permit a water discharge activity or groundwater activity."*

[1] It should be noted that throughout this application document the terms "discharges" and "emissions" are used interchangeably. This reflects the terminology used in the various Environment Agency guidance documents.

An application will therefore be submitted in accordance with the requirement of Part 2, Chapter 2 of the EP Regulations [1], which states:

> *"On the application of an operator, the regulator may grant the operator a permit (an "Environmental Permit") authorising the operation of a regulated facility."*

The scope of this application is limited to the water discharge activity for non-radioactive substances, as described in Schedule 21 of the EP Regulations [1]. Separate environmental permit applications will also be made to cover the following activities on the Sizewell C site:

- The operation of the back-up diesel generators, which will be a combustion installation defined under Section 1.1, Part A(1), paragraph (a) of Part 2 of Schedule 1 of the EP Regulations [1] as *"Burning any fuel in an appliance with a rated thermal input of 50 or more megawatts".*

- The disposal of radioactive waste from Sizewell C which will be a radioactive substances activity under Schedule 23 of the EP Regulations [1].

Other legislation addressed through this environmental permit application is listed in **Table 1.3.1** (please note that the list is not an exhaustive list).

Table 1.3.1 Legislation addressed through the water discharge activity permit

Legislation	Summary
Water Resources Act 1991 (Amendment (England and Wales)) Regulations 2009 [5]	Implements the requirements of the Water Framework Directive and allows for the designation of Water Protection Zones which will be protected in terms of water quality. The EP Regulations replace those parts of the act that relate to the regulation of discharges to controlled waters.
The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 [6]	Transposes the Water Framework Directive in the UK. The Regulations outline the duties of regulators in relation to environmental permitting, abstraction and impoundment of water.
Water Framework Directive (2000/60/EC) [7] and Daughter Directive (2008/105/EC) [8]	The aims of these Directives are to: • prevent further deterioration of aquatic ecosystems; • protect and enhance their status; • promote sustainable water use; and • provide further protection to the aquatic environment. The Water Framework Directive repealed and brought under the Freshwater Fish Directive (2006/44/EC) and Shellfish Waters Directive (2006/113/EC).

Legislation	Summary
Directive 2013/39/EU of the European Parliament and of the Council amending Directives 2000/60/EC and 2008/105/EC as regards Priority Substances in the Field of Water Policy [9].	Directive 2013/39/EU revised a number of environmental standards for some current substances and added further additional substances to the original list.
Water Framework Directive (Standards and Classification) Directions (England and Wales, 2015) [10]	Sets out the environmental standards to be used for the second cycle of river basin plans. Along with the updated Water Environment (Water Framework Directive (England and Wales) Regulations 2017, they transpose Directive 2013/39/EC on environmental quality standards for priority substances.
The Eels (England and Wales) Regulations 2009 [11]	Implements the Protection of European Eels Regulation and imposes requirements for regulations of eel fisheries, eel passes, eel screens and by-wash arrangements.
Protection of European Eels Regulation Council Regulation (EC) No 1100/2007 of 18 September 2007 [12].	Requires EU member states to develop management plans to improve eel stocks.
Salmon and Freshwater Fisheries Act 1975 (as amended) [13] .	To protect salmon and freshwater fish including migration routes.
The Bathing Water Regulations 2013 (as amended) [14].	Implement the Bathing Water Directive 2006/7/EC.
Bathing Waters Directives (2006/7/EC [15])	The main objective of this Directive is to protect public health and the environment from faecal pollution of bathing waters. This has been adopted into UK policy in 2012 and implemented in 2015. The Bathing Waters Directive replaced EC 76/160/EEC.
Habitats Directive (92/43/EEC) [16]	The main aim of this Directive is to promote the maintenance of biodiversity, including taking measures to maintain or restore natural habitats and wild species at a favourable conservation status, introducing robust protection for those habitats and species of European importance. This was transposed into UK legislation by The Conservation of Habitats and Species Regulations (2017)

Assessments have been undertaken to address specific legislative requirements including a Habitats Regulation Assessment and Water Framework Directive Assessment.

1.4 Proposed permitted activity

1.4.1 Location and Land Ownership

When in operation Sizewell C will abstract sea water (cooling water) and generate a number of trade effluent streams which, it is proposed, will be discharged to the GSB area. **Figure 1.4.1** shows the location of the site.

The power station will be located in a coastal area adjacent to the North of Sizewell B Power Station Nuclear Licensed Site Boundary. The main effluent Outfalls [HCT] will be located at National Grid Reference (NGR) TM 51080 64125 for Outfall 1 and TM 51155 64125 for Outfall 2.

The two outfalls associated with the Fish Recovery and Return System are located at NGR TM 47980 64000 for Fish Recovery and Return System 1 and 47980 64254 for Fish Recovery and Return System 2. Valued engineering has suggested moving the location of the Fish Recovery and Return System outfall for EPR Unit 2 (i.e. Fish Recovery and Return System 2) further south to this location by ca 46m from the modelled position in order to shorten the length of the tunnel slightly and move it away from close proximity to the Combined Drainage Outfalls (CDO). Such a move would have the benefit of slightly reducing transit times for fish. The modelling of environmental impacts from dead and moribund being discharged from the Fish Recovery and Return System is not sensitive to such a small difference in discharge point given the large scale of the system and the environmental impact assessment is considered robust for either location.

The location of all of these outfalls are provided with a centre maximum radius of 25m. The final location will be confirmed through the FAP (see **Section 7.3.1** Action 1: Design description).

The land on which SZC will be built is currently owned by EDF Energy Nuclear Generation Limited. SZC Co. is securing legally binding arrangements with EDF Energy Nuclear Generation Limited for the ultimate purchase of the land. These arrangements ensure SZC Co. has control of the land prior to permit issue and in advance of finally purchasing the land which will take place after Financial Investment Decision (FID). Notwithstanding this, no activities will actually be undertaken on the site that relate to the RSR permit in advance of FID and until after land ownership is secured.

Part of the proposed Sizewell C site is currently part of the Sizewell B area. **Figure 1.4.2** shows the interim boundary of Sizewell C, indicated by the green line. At a future date, SZC Co. is securing legally binding arrangements with EDF Energy Nuclear Generation Limited for the ultimate purchase of the land to include the area of land presented in **Figure 1.4.3**. This land is referred to as being within the final permitted boundary, indicated by the green line. No activities will be undertaken on the site that relate to the Sizewell C WDA permit until after land ownership is secured.

The following figures are provided in Appendix A:

- **Figure 1.4.2** Location of the proposed cooling water inlets (A) and discharge outfall (B) (Interim); and
- **Figure 1.4.3** Location of the proposed cooling water inlets (A) and discharge outfall (B) (Final).

1.5 Application guidance

The current regulatory guidance used in preparing this submission is listed below:

- The Department for Environment, Food and Rural Affairs (DEFRA) (2010) Environmental Permitting Guidance for Water Discharge Activities for the Environmental Permitting (England and Wales) Regulations 2010, December 2010 [17].
- Environment Agency (2010a). Nuclear New Build - Guidance on Hydrodynamic Modelling Requirements [18].
- Environment Agency (2011). Chemical discharges from nuclear power stations: historical releases and implications for Best Available Techniques Report. SC090012/R1 [19].
- CIS, 2011. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 27 Technical Guidance for Deriving Environmental Quality Standards. ISBN: 978-92-79-16228-2. DOI: 10.2779/43816 [20].
- UKTAG, 2013. UK Technical Advisory Group (UKTAG) on The Water Framework Directive. Updated Recommendations on Environmental Standards. River Basin Management (2015-21), November 2013 (minor amendments January 2014) [21].
- DEFRA. 2014. Water Framework Directive implementation in England and Wales: new and updated standards to protect the water environment https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307788/river-basin-planning-standards.pdf [22].
- Environment Agency (2014) Modelling: Surface Water Pollution Risk Assessment,https://www.gov.uk/government/publications/modelling-surface-water-pollution-risk-assessment [23].
- Environment Agency (2014) H1 Annex D2: Assessment of Sanitary and other Pollutants in Surface Water Discharges, https://www.gov.uk/government/publications/h1-annex-d2-assessment-of-sanitary-and-other-pollutants-in-surface-water-discharges [24].

- Clearing the Waters for All Guidance. DEFRA 2016. Last updated 9 November 2017, https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters [25].
- Environment Agency (2016) Risk Assessments for your Environmental Permit, https://www.gov.uk/guidance/risk-assessments-for-your-environmental-permit [26].
- Environment Agency (2016) Risk Assessments for Specific Activities: Environmental Permits, https://www.gov.uk/government/collections/risk-assessments-for-specific-activities-environmental-permits [27].
- Environment Agency (2016) Control and Monitor Emissions for your Environmental Permit, https://www.gov.uk/guidance/control-and-monitor-emissions-for-your-environmental-permit [28].
- Environment Agency (2016) Guidance for Best Available Techniques: Environmental Permits https://www.gov.uk/guidance/best-available-techniques-environmental-permits [29].
- Environment Agency (2016). Guidance for Polluting Prevention for Business, https://www.gov.uk/guidance/pollution-prevention-for-businesses [30].
- Environment Agency (2017) Collection of Groundwater Protection Guides Covering: Requirements, Permissions, Risk Assessments and Controls (previously covered in GP3), https://www.gov.uk/government/collections/groundwater-protection [31].
- Environment Agency (2018) Water Discharge and Groundwater Activity Environmental Permits, https://www.gov.uk/government/collections/water-discharge-and-groundwater-activity-environmental-permits [32].
- Environment Agency (2018) Surface Water Pollution Risk Assessment for your Environmental Permit, https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit [33].
- Environment Agency (2018) Discharges to Surface Water and Groundwater: Environmental Permits, https://www.gov.uk/guidance/discharges-to-surface-water-and-groundwater-environmental-permits [34].
- Environment Agency (2018) Collection of Technical Guidance for Regulated Industry Sectors: Environmental Permitting, https://www.gov.uk/government/collections/technical-guidance-for-regulated-industry-sectors-environmental-permitting [35].
- Environment Agency (2018) Monitoring Emissions to Air, Land and Water (MCERTS), https://www.gov.uk/government/collections/monitoring-emissions-to-air-land-and-water-mcerts [36].

- Environment Agency (2018), Oil Storage Regulations for Businesses 'How to store oil, design standards for tanks and containers, where to locate and how to protect them, and capacity of bunds and drip trays', https://www.gov.uk/guidance/storing-oil-at-a-home-or-business [37].
- Environment Agency (2018) Environment Agency Guidance for Fire Prevention Plans: Environmental Permits https://www.gov.uk/government/publications/fire-prevention-plans-environmental-permits [38].
- Environment Agency (2019) Legal Operator and Competence Requirements: Environmental Permits https://www.gov.uk/guidance/legal-operator-and-competence-requirements-environmental-permits [39].
- Environment Agency (2019) Environment Agency Guidance, Developing a Management System (updated January 2019), https://www.gov.uk/guidance/develop-a-management-system-environmental-permits [40].
- Environment Agency (2019) Environment Agency Guidance for Pollution Prevention for Business, https://www.gov.uk/guidance/pollution-prevention-for-businesses [41].
- Environment Agency (2019), Adapting to Climate Change: Risk Assessment for your Environmental Permit [42].
- Environment Agency M Series Modelling Technical Guidance Notes (TGNs) [43].
- Environment Agency Forms and Guidance (Forms Part A, Part B2, Part B3 and Part F1) [44].
- Technical Guidance Document in support of Commission Directive 93/67/EEC on Risk Assessment of new Identified Substances and Commission Regulation (EC) no. 1488/94 on Risk Assessment for Existing Chemical Substances, EC-1996, revised 2003 [45].

1.6 Other consenting regimes and environmental assessments

SZC Co. will also require other assessments, Licenses and environmental permits related to the construction and operation of Sizewell C, which are in addition to this application for a water discharge activity environmental permit. The other assessments, licenses and environmental permits are described below.

1.6.1 Generic design assessment

As part of developing the EPR™ for use in the UK, a suite of generic documentation has been produced to aid the site specific adoption of the reactors and to formalise the basic principles to be applied in the regulatory processes. This process is called the GDA. The GDA reference reactor is based on the Flamanville 3 design.

The GDA process is carried out jointly by the ONR and the Environment Agency separate to the licensing process. Under the GDA process, the ONR and Environment Agency engage with nuclear reactor vendors on the generic aspect of their design, perform technical assessment work on their submissions, consult with overseas regulators, implement a comments process and consult. This is done in order to assess the environmental, safety and security aspects of reactor designs before construction of the reactor starts.

In December 2012 the ONR issued a Design Acceptance Confirmation (DAC) and the Environment Agency issued a Statement of Design Acceptability (SoDA) for the UK EPR^{TM} Reactor Design, concluding the corresponding GDA process.

The information provided in the GDA was used to inform the operational WDA permit application for Hinkley Point C. As part of the replication strategy between Hinkley Point C and Sizewell C this permit application reflects where possible developments in design and information available from the Hinkley Point C project. The Sizewell C replication strategy is described in **Section 2.1.1**.

This Sizewell C application draws on the work undertaken from the GDA to support the Hinkley Point C permit and where possible duplicates and updates this information as available from Hinkley Point C.

1.6.2 Nuclear site licence

Nuclear Sites are required to apply for a Nuclear Site Licence (NSL) under The Nuclear Installations Act 1965 (as amended) [46]. The ONR regulates Licensees via the NSL. The NSL sets out 36 standard licence conditions for which the Licensee develops and implements arrangements. These conditions are available on the ONR website. Prior to being granted an NSL, the Licensee must demonstrate that it complies with its arrangements to meet the licence conditions and have appropriate organisational capabilities and governance in place to ensure nuclear safety. Licensees must also be able to demonstrate they have control over the site in terms of security of tenure. The arrangements are proportionate to the activities being carried out by the Licensee.

1.6.3 Development consent order

The proposed development exceeds 50 megawatts (MWe) installed generating capacity so is therefore designated as a Nationally Significant Infrastructure Project under the Planning Act 2008 [47]. Accordingly, development consent must be obtained to authorise the development.

The Proposed Development also falls within Schedule 1 of The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (‘the EIA Regulations’) [48], and therefore constitutes ‘EIA development’. As such an EIA is being undertaken and a summary of this will form the basis of an Environmental Statement (ES) that will accompany the Development Consent Order (DCO) Application.

At the time of writing SZC Co. is preparing an application for a DCO. The application will be accompanied by an ES and, if successful, will be accepted by the Planning Inspectorate on behalf of the Secretary of State for Business Energy and Industrial Strategy (BEIS). SZC Co. currently anticipates that the application for a DCO will be made in 2020 and at the same time as this permit application.

1.6.4 Marine licence

Under the Marine and Coastal Access Act 2009 (MCAA) [49] all development in the sea, below the Mean High Water Spring (MHWS) tidal mark requires a Marine Licence to be issued by the Marine Management Organisation (MMO). Under the MCAA [49], and in relation to works associated with this environmental permit application, Sizewell C will require a Marine Licence for construction of the outfall diffusers and Fish Recovery and Return Systems, including dredging and disposal of sediment.

The DCO application will contain an application for a Marine Licence under the MCAA [49] and determination and approval will be 'deemed' within the DCO application.

1.6.5 Regulatory justification

Before any new class or type of practice involving radiation can be introduced in the UK it must undergo Regulatory Justification. The principle of justification is that no practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. With the support of Areva NB, the Nuclear Industry Association, as the trade association for the civil nuclear industry in the UK, submitted an application for the justification of the UK EPR™ practice, which was given effect in The Justification Decision (Generation of Electricity by the EPR Nuclear Reactor) Regulations 2010 No. 2844 [50].

1.6.6 Environmental permits

In addition to this application for a water discharge activity environmental permit, Sizewell C will also require additional environmental permits under the EP Regulations, which will be subject to public consultation. The three key permits are:

- Combustion activity (CA) permit.
- Radioactive Substances Regulation permit (RSR).
- Construction water discharge activity (CWDA) permit.

The CA and RSR permits will be submitted at the same time as this application. The CWDA will be submitted at a later date. Additional permits will also be required to support the construction and commissioning activities.

1.7 Content of the application technical reports and supporting data

Table 1.7.1 below outlines the structure of this application support document. This structure is based on the current Environment Agency guidance for water discharge activities [32], surface water pollution risk assessment for your environmental permit [33], legal operator and competence requirements [39] and guidance for developing a management system [40].

Table 1.7.1 Application technical report structure

Section reference	Title	Brief Description
1	Introduction	Demonstration of the need for an environmental permit and how the EP Regulations apply.
2	Source of Discharges from Proposed Activities	Provides a more detailed description of the proposed water discharge activities and demonstrates the use of BAT.
3	Pollution control measures and application of BAT	Provides a comprehensive demonstration that the techniques adopted to minimise emissions and their associated impacts represent good practice and that the Cooling Water System represent BAT.
4	Emissions and Monitoring	Characterises the proposed emissions during operations and outlines how these will be monitored.
5	Environmental Risk Assessment	Provides an environmental risk assessment for operating the power station, which reflects the EIA ES submitted to the Planning Inspectorate for England and Wales (PINS). This information is intended to support the Appropriate Assessment of the proposals required by the Habitats Directive.
6	Managing the Water Discharge Activity	Outlines how the water discharge activity will be managed and addresses the requirement for management systems and an ‘emissions of substances management plan’.
7	Forward Action Plan (FAP)	There are some areas where the process information is not fully developed. These are detailed here along with a programme for developing information to address any shortfalls identified and identifying further work that will be undertaken prior to commencement of discharges to surface water from operating the power station.
8	References and Acronyms	Provides references used in the production of this document as well as definitions of the acronyms/abbreviations used.
Appendix A	Site maps, plans and drawings	Drawings, including details of the site location and discharge point.
Appendix B	H1 screening assessment	Discharges H1 Type Assessment.

Section reference	Title	Brief Description
Appendix C	Information for the Habitats Regulations Assessment	Information for the Habitats Regulations Assessment in **Section 5**. Applicable to this permit application
Appendix D	Water Framework Assessment	Water Framework Assessment in **Section 5**. Applicable to this permit application
Appendix E	Supporting Information	Other supporting documents to the WDA permit
Appendix F	Applications forms	Application forms A, B2, B6 and F1.

2 Sources of Discharges from Proposed Activities

This section describes aspects of the planned Sizewell C power station that are relevant to the proposed water discharge activity, and includes the following subsections:

- Simplified overview of the UK EPR^{TM}.
- About the effluent – details and type.
- Simplified description of the source of the planned discharges from the Sizewell C power station.
- Summary of plant items and structures from which the discharges will arise.
- Summary of plant and infrastructure for handling the cooling water and effluent.
- Abnormal/ Emergency Sources of Discharges.
- Commissioning of Sizewell C.

2.1 Simplified overview of the UK EPR^{TM}

At the centre of the UK EPR^{TM} is the reactor core capable of producing a thermal output of 4,500MW$_{(th)}$ from a controlled fission reaction contained within a thick-walled steel pressure vessel. The thermal power is transferred into steam which operates a turbo generator with a net electrical output of 1,670MW$_{(e)}$. The operation of the UK EPR^{TM}, as a Pressurised Water Reactor (PWR) is based on a primary system, a secondary system and a cooling system.

Appendix A, **Figure 2.1.1** shows the conceptual diagram of the proposed Sizewell C power station.

The primary system is a closed water-filled pressurised system installed in a leak tight concrete enclosure, the Reactor Building. It comprises a reactor, namely a steel vessel containing the nuclear fuel (reactor core) and four cooling loops, each containing a reactor coolant pump and a steam generator. The heat produced by the nuclear reaction inside the reactor vessel is extracted with pressurised water (the primary system coolant) which circulates in the primary system. The heated water then passes through the steam generators. Here the heat is transferred to the water of the secondary system which flows between the steam generators tubes.

The secondary system is a closed system which is independent of the primary system. It supplies steam to the turbo generator set located in the Turbine Hall [HM]. Water in this system evaporates in the steam generators heated by the primary system water. The steam drives a turbine coupled to the generator which produces electrical energy. After leaving the turbine, the steam is cooled and returned to its liquid state in the condenser and then returned to the steam generator.

The cooling system_is independent of the primary and secondary systems. It cools the condenser by circulating seawater. This system is an open system at Sizewell C. An open system refers to circulating water which is directly drawn from, and discharged back into, the sea. The Sizewell C condensers will be directly cooled by seawater from the GSB area.

Electricity from the generator is stepped-up to high voltage (400kV) via transformers before being exported on EDF Energy overhead lines to the National Grid substation which connects the generation output to the national grid transmission system. The nuclear power station at Sizewell C is designed for 60 years of operation.

2.1.1 Sizewell C replication strategy

The Sizewell C Replication Strategy allows the project to maximise the opportunity to derive value from a ‘Next of a Kind’ series effect, duplicating the Hinkley Point C plant and adopting a systematic approach to capturing, quantifying and applying lessons learnt to Sizewell C.

Lessons learnt during the construction, commissioning, operation and decommissioning of Hinkley Point C will be applied directly to Sizewell C if considered relevant and the benefits of the change are not grossly disproportionate to the impacts including consideration of the impacts to replication.

The replication strategy is supported by all the current major stakeholders. The ONR has recognised that the proposed replication approach is appropriate regarding the sequence between Hinkley Point C and Sizewell C for maintaining a high level of safety.

The replication strategy is based on the replication of the final Hinkley Point C design used for construction and erection activities. Sizewell C documentation will be based on the most mature state from Hinkley Point C available in line with the Sizewell C schedule. Considering the gap between Hinkley Point C and Sizewell C, the most advanced and relevant detailed design is the design established on the Hinkley Point C Reference Configuration 2 (Hinkley Point C RC2). This will include the necessary batch of design changes and design maturity to finalise civil construction, carry out erection works on the Hinkley Point C site and enable Hinkley Point C on-site commissioning, including all feedback from design, safety requirements, supply chain design, manufacturing and in-factory testing.

As discussed in **Section 6**, the design configuration will be managed through the Sizewell C No Change Committee in order to maximize the scope of common documentation and data which will be applicable on both sites without any changes.

The replication strategy will be based on the following key assumptions:

- The codes and standards applied during the design, manufacturing and construction of Hinkley Point C will be applicable to Sizewell C.

- The same sequence of construction at Hinkley Point C and Sizewell C.
- Review and acceptance of design documentation, qualification of equipment, manufacturing processes and supplier qualification does not have to be repeated for replicated scope.
- Sizewell C site data are assumed to be bounded by Hinkley Point C site data, except for key specific areas where the evolution in site data only has a limited impact on the overall design.
- The supply chain can be fully replicated from Hinkley Point C. Future operational arrangements at Hinkley Point C including the type, installation, maintenance, examination, inspection and testing of equipment can be applied to Sizewell C, ensuring suitable equipment and suitably qualified and experienced resources are available.

2.2 About the effluent

2.2.1 Discharges included in this application

The operation of Sizewell C will lead to the production of a range of effluents which can be categorised into effluent streams. These effluents arise though a number of different processes. **Table 2.2.1** provides an overview of the effluent waste streams associated with the operation of Sizewell C.

Table 2.2.1 Discharges included within this application

Effluent Stream	Effluent Type	Brief Overview	Links to other streams
A	Trade – returned abstracted water	Return of abstracted cooling water, which will be characterised by thermal content and will be dosed with sodium hypochlorite after the pump house to prevent biofouling of the cooling water infrastructure. This will be the main discharge in terms of flow.	The cooling water supply from sea water abstraction receives discharges from Stream E at the forebay. A small flow from the abstracted sea water serves the Fish Recovery and Return System and will be discharged through separate outfalls as Stream H
B	Trade – known volume	Trade effluent from operations within the nuclear island discharged on a batch basis to the Outfall Pond [HCA], excluding effluent from the Steam Generator Blowdown System.	Discharged with the significant flow of Stream A Receives discharges from the steam generator blowdown system– Stream C.

Effluent Stream	Effluent Type	Brief Overview	Links to other streams
C	Trade – known volume	Trade effluent from the Steam Generator Blowdown System that cannot be recycled	Discharged with the significant flow of Stream A Discharged on a batch basis in admixture with Stream B.
D	Trade – known volume	Trade effluent from the Turbine Hall [HM] and uncontrolled area floor drains discharged on a batch basis to the Outfall Pond [HCA], excluding blowdown from the Steam Generator Blowdown System.	Discharged with the significant flow of Stream A Links to Stream B if further treatment is required.
E	Trade – known volume	Includes drainage from the road and roof surface together with atmospheric condensate from chillers and uncontaminated water from the oily water network. Discharged to the forebay.	Combines with the main cooling water of Stream A at the forebay and consequently a small proportion discharges to Stream H
F	Trade – known volume	Trade effluent from the production of demineralised water which will be treated to neutralise extremes of pH before joining the main discharge at the Outfall Pond [HCA].	Discharged with the significant flow of Stream A
G	Domestic sewage	Sanitary effluent from administration, catering and accommodation facilities, which will be treated in an appropriate effluent treatment plant before joining the main discharge.	Discharged with the significant flow of Stream A.
H	Trade-returned abstracted water	Effluent from the fish recovery and return system discharged to sea continuously through a dedicated separate outfall (one outfall for each UK EPR^{TM} unit).	Intake to the forebay the same as for Stream A with small proportion of water diverted to serve the fish recovery and return system. Receives small proportion of the non-contaminated effluent from Stream E at forebay.

An overview of these discharge streams contributing to the surface water discharge is provided in Appendix A, **Figure 2.2.2**. These effluent streams are broken down and discussed in more detail in **Section 2.3.**

2.2.2 Discharges excluded from this application

Construction discharges

A separate environmental permit application is being made for aqueous discharges to the GSB associated with construction of the power station which will include the cold flush testing phase of commissioning. The reasons for this are:

- emissions to surface water associated with construction have very different characteristics than those associated with operations and as such require different control techniques, discharge routes and management arrangements; and
- the discharges associated with the cold flush testing phase of commissioning will be made through the construction discharge route as the cooling water system will not then be functional. As a result, discharges associated with the cold flush testing phase of commissioning will be included in a construction phase water discharge activity environmental permit when required and are not included in this application.

2.3 Simplified description of the sources of the planned discharges from Sizewell C Power Station

2.3.1 Introduction

The key systems and processes of the UK EPR^{TM} nuclear power station with relation to effluent production are:

- Seawater cooling system.
- Primary system.
- Secondary system.
- Site drainage system.
- Production of demineralised water.
- Sanitary effluent treatment.
- Fish Recovery and Return.

Section 2.3 provides a high-level overview of these key systems and processes and the associated effluent streams. The location of the relevant main systems associated with each effluent stream is listed in **Table 2.4.2**.

2.3.2 Seawater cooling system

The steam turbine condenser and seawater cooling system

The seawater cooling system is independent of the primary and secondary systems. In accordance with the second law of thermodynamics, not all of the thermal energy in the steam produced by the steam generators can be converted to rotational energy in the steam turbine. The steam turbine condenser is a heat exchanger, the primary function of which is to cool the steam from the turbine exhaust so it can be converted back to liquid water to allow it to be re-used.

A complex array of preheaters and use of moisture separator reheaters and high and low pressure turbines, maximises the energy that can be recovered from the steam which minimises the amount of heat that cannot be recovered.

Seawater abstracted from the GSB will be used to condense steam using a direct (or once through) cooling system. A large volume of seawater will pass through the condenser in a single pass and will be discharged back to the GSB with a temperature above that extracted. This is Effluent Stream A.

In addition to heat, the cooling water returned to the GSB will also contain residual oxidants arising from chlorination. Seawater used for the once through cooling system contains a range of entrained species, including both micro-organisms such as biofilms and planktonic stages of macro-organisms (such as mussels). Build-up of such species within the cooling system is known as biofouling and can either reduce the efficiency of the condenser or damage it. Systems will be included to enable the incoming seawater to be dosed with sodium hypochlorite to prevent biofouling should it be found to be an issue. The sodium hypochlorite will be generated in an on-site electrochlorination plant [CTE] or imported by tanker.

For each unit, the cooling water structures comprise two Intake Heads and an Intake Tunnel [HPT], Forebay [HPF] and Pumping Station [HP]. Seawater is transferred to the Forebay via the Intake Tunnel. The water feed to the buildings is via the Forebay which is a basin located adjacent to the Pumping Station. The outfall structures comprise the Outfall Buildings (Filtering Debris Recovery Pit (pre-discharge section)) [HCB] and the Outfall Pond (discharge pond) [HCA], and Outfall Tunnel [HCT]. The Outfall Pond is connected to the common Outfall Tunnel via an onshore discharge tunnel. The onshore discharge tunnels of both Outfall Ponds (Unit 1 and Unit 2) meet at a junction that connects to the single, common Outfall Tunnel.

The cooling water contains a degree of suspended sediments and silt is expected to accumulate to some extent in the Forebays. It is common practice in the UK power industry at coastal sites to undertake periodic de-silting of the Forebays; SZC Co. has therefore included these activities within the scope of the permit. The removed silt will be returned to the outfall for discharge back to the GSB. The details of which will be considered at a later stage in line with the FAP (see **Section 7.3.3** Action 3: Development of the operational management plans).

Appendix A, **Figure 2.3.1** Effluent Stream A summarises the effluent collection, processing and storage techniques that will be applied before Effluent Stream A is transferred to the Outfall Pond, from the cooling water system, prior to release to the GSB via the common Outfall Tunnel. Further details on the seawater cooling system can be found in **Section 2.5**.

2.3.3 Primary System

The reactor coolant system (primary circuit)

The Reactor Coolant System includes the reactor vessel, steam generators, pressuriser, control rod assemblies and ancillary equipment such as pumps and instrumentation that form the primary circuit. The Nuclear Steam Supply System is the term applied to the engineered systems, including the equipment, structures and components that form the Reactor Coolant System [RCP]. The water in the primary circuit is heated in the reactor by the fuel assemblies and pumped through a steam generator. The UK EPR^{TM} has four steam generators. The steam generators act as heat exchangers transferring heat to the secondary circuit. The primary coolant having passed through the steam generators is then returned to the reactor vessel.

The water in the core also slows down (moderates) the neutrons released in the nuclear fission process, which is necessary to sustain the fission reaction. The reactor operating pressure and temperature are such that the primary coolant does not evaporate in the primary circuit but remains in the liquid state, increasing the effectiveness with which heat is transferred from the reactor core to the steam generators. The primary coolant is contained in the Reactor Coolant System within the Reactor Building [HR] containment and is isolated from the environment.

Control of reactivity

The nuclear fission reaction, and therefore heat generation, can be controlled in two ways.

Slow changes in the fission reaction are achieved by changing the concentration of boron in the primary coolant system. Boron absorbs neutrons and therefore reduces the rate of fission. Increases in the boron concentration are achieved by dosing boric acid to the primary coolant. To counteract any changes in pH, the primary coolant is also dosed with small amounts of lithium hydroxide. Decreases in the boron concentration are achieved by topping up the primary coolant with low concentration borated water and releasing primary coolant to the Coolant Storage and Treatment System [TEP]. These systems are described in more detail below as they involve treatment that can affect non-radioactive discharges.

Rapid changes in the fission reaction can be achieved by deploying control rods, containing neutron absorbing material, in the reactor core. This does not significantly affect non-radioactive discharges.

Sources of non-radioactive and radioactive contaminants

The primary circuit will contain a range of radioactive and non-radioactive contaminants, which are summarised in the table below. As well as disposal of radioactive effluent, the SZC Co. RSR environmental permit submission [51] provides detail on how radioactive contaminants are minimised at source and on the abatement techniques employed.

Table 2.3.1 Radioactive and non-radioactive contaminants in the primary circuit

Source	Non-Radioactive Contaminants	Radioactive Contaminants (Activation and Fission Products)		
Erosion/corrosion of structural metals make up the main structural materials in the primary circuit.	Principal corrosion products: Iron. Nickel. Cobalt. Chromium. Manganese. Antimony. Silver.	The corrosion products circulate in the primary circuit some pass through the reactor core, where they are activated by neutrons. The principal activated corrosion products are identified below:		
		Nickel-58	→	Cobalt-58
		Cobalt-59	→	Cobalt-60
		Silver-109	→	Silver-110m
		Iron-54	→	Manganese-54
		Antimony-123	→	Antimony-124
		Iron-58	→	Iron-59
		Chromium-50	→	Chromium-51
		Nickel-62	→	Nickel-63
		Antimony-121	→	Antimony-122
		Antimony-124	→	Antimony-125

<table>
<tr><th>Source</th><th>Non-Radioactive Contaminants</th><th colspan="3">Radioactive Contaminants (Activation and Fission Products)</th></tr>
<tr><td rowspan="6">Chemicals dosed to the primary circuit.</td><td rowspan="6">Boric acid is added to assist in reactivity.
Small amounts of lithium hydroxide are also added to control pH of the primary water coolant.
Hydrazine to remove oxygen prior to operation.
Hydrogen to help minimise the corrosion of the main structural materials.
Hydrogen peroxide to remove hydrogen prior to an operational outage.
Zinc acetate, depleted in zinc-64, to help minimise the corrosion of the main structural materials.</td><td colspan="3">Activation of elements in the primary circuit:</td></tr>
<tr><td>Oxygen-17, Carbon-13 and dissolved Nitrogen-14</td><td>→</td><td>Carbon-14</td></tr>
<tr><td>Boron-10 and Lithium-6</td><td>→</td><td>Tritium</td></tr>
<tr><td>Dissolved Argon-40</td><td>→</td><td>Argon-41</td></tr>
<tr><td>Oxygen-16</td><td>→</td><td>Nitrogen-16[2]</td></tr>
<tr><td>Oxygen-17</td><td>→</td><td>Nitrogen-17[2]</td></tr>
</table>

[2] The half-lives of nitrogen-16 and nitrogen-17 are 7.3 and 4.2 seconds respectively, therefore these radionuclides are not considered further.

Source	Non-Radioactive Contaminants	Radioactive Contaminants (Activation and Fission Products)
The nuclear reactor creates fission products in the nuclear fuel, some of which are soluble. The fuel cladding is designed to contain these materials in the fuel as far as possible, but a small number of fuel pins unavoidably have a small number of minute leaks through which these fission products can escape into the primary circuit. Moreover, despite a high standard of cleanliness, trace quantities of uranium can remain on external fuel surfaces after the manufacturing process. Once the fuel is in the reactor, this uranium will fission, producing fission products in the primary circuit.	Not applicable.	Main soluble fission products include: Caesium-134. Caesium-137. Iodine-131. Tritium. Other soluble fission products include Strontium-89, Strontium-90, Caesium-136, Caesium-138, Iodine-132, Iodine-133, Iodine-134 and Iodine-135.

Treatment systems to remove contaminants

With the exception of steam generator blowdown, all of the discharges from the Nuclear Island are grouped into Effluent Stream B. The treatment systems for Effluent Stream B are designed, depending on their specific function, to remove radioactive and non-radioactive contaminants from the primary circuit and effluents. See Appendix A, **Figure 2.3.2** Effluent Stream B.

There are three main systems which remove contaminants from the water in the primary circuit and treat effluents prior to discharge:

- **Chemical and Volume Control System [RCV]:** This system is used to maintain the chemistry of the primary coolant by taking some of the primary coolant, known as let-down, cleaning it and returning it back to the system (known as make-up). Water is treated by the use of ion exchange resins and filters. Boric acid and lithium chemistry can be modified as required to meet the prescribed conditions in the reactor. This system also provides volume control for the primary coolant and contains any leaks/bleeds from reactor coolant pump seals.

- **Coolant Storage and Treatment System [TEP]:** This system treats the liquid effluent from the primary circuit. The purpose of treatment is that, as far as possible, the boron and water may be recycled through the primary reactor circuit. Treatment for recycling involves demineralisation by ion exchange resins and filtration, evaporation and degassing. The evaporator is used to recover the enriched boric acid[3] for reuse within the Reactor Coolant System via the Reactor Boron Water Make-up System. Non-recyclable liquid effluents are transferred to the Liquid Radwaste Monitoring and Discharge System via the Liquid Waste Processing System.

- **Liquid Waste Treatment System [TEU]:** This system is designed to ensure optimisation of the management of effluents by enabling treatment through a variety of techniques, this allows effluents to be retreated and pass through different treatment techniques before being sampled and monitored and, if acceptable, discharged.

The segregated Process, Chemical and Floor drains of the Nuclear Vent and Drain System [RPE] which transport effluents to the Liquid Waste Treatment System comprise of:

- Process drains which receive primary coolant drained or leaked from systems or equipment after flushing;

- Chemical drains which receive only weakly radioactive and/or chemically contaminated water from the Nuclear Auxiliary Building. These consist of water from the Nuclear Sampling System laboratory and the primary coolant decontamination systems that is more polluted than water from the process drains; and

- Floor drains which receive effluent from areas where there is the potential for radioactive contamination. These are divided into two types:

  - Floor Drains 1: These are potentially contaminated and come from leaks from equipment carrying primary coolant and from floor washing. The sumps and the connected floor drains are installed in areas containing equipment transporting primary coolant;
  - Floor Drains 2: These are slightly contaminated or uncontaminated and come from leaks, from floor washing and from the bleeding of equipment (feedwater or Component Cooling Water System). The sumps and the connected floor drains are installed in controlled areas that do not contain equipment transporting primary coolant.

[3] The use of enriched boric acid (37% at boron-10) minimises the concentration of boric acid required and consequently reduces the amount of lithium required to maintain pH and thus reduce the tritium produced.

It is of note that there is also Floor Drains 3, part of the Nuclear Vent and Drain System, which normally receives uncontaminated effluent from bleeding of equipment, leaks and floor washing in uncontrolled zones of the auxiliary buildings. Floor Drains 3 are part of Effluent Stream D.

The spent liquid effluents, i.e. those effluents which are not recycled within the primary circuit, are segregated at source and stored in tanks of the Liquid Waste Treatment System assigned to a dedicated type of effluent. The exact treatment approach is determined on the basis of results from sampling, but can be generalised as follows:

Process effluents undergo demineralisation using ion exchange techniques and filtration;

Chemical effluents will be filtered and evaporated. The concentrate will be managed as a radioactive solid waste under the Sizewell C RSR environmental permit [51]. The distillates will be sampled and either cleared for discharge or treated again by evaporation; and

Floor drain effluents will be filtered in the Liquid Waste Treatment System to remove any potential radioactive particulates.

Other types of spent liquid effluent include arisings from the Maintenance and Decontamination services [SBE] and Nuclear Island Pools (including the Spent Fuel Pool). Discharges from the Nuclear Island Pools for Intermediate Level Waste (ILW) are not considered as a separate waste stream as they do not make a significant contribution to the chemical or thermal content or the volume of the overall discharges from Sizewell C. These effluents will form a minor contribution to Effluent Stream B.

In addition to the above treatments, all effluents are passed through a 5µm filter before being sent to tanks for interim storage, pending monitoring and discharge.

Other relevant systems contributing to the source of Effluent Stream B

Nuclear Island Sampling System [REN/RES]: This system comprises of two separate sub-systems:

- Sampling system of the primary system and adjacent nuclear auxiliaries.
- Sampling system of the secondary side of the steam generators and Steam Generator Blowdown System [APG].

The Nuclear Island Sampling System collect samples from the primary and secondary circuit and enables centralisation for analysis and determination of the chemical and radio-chemical characteristics of liquid samples taken from various systems.

Reactor Boron Water Make-up System [REA]: This system contributes to the reactivity control of the primary coolant. It regulates the boric acid and the degassed demineralised water make-ups to the Reactor Coolant System. The Reactor Boron Water Make-up System also supplies the spent fuel pool and the In-Containment Refuelling Water Storage Tank with borated water as and when required.

Fuel Pool Cooling (and Purification) System [PTR]: This system is divided into two sub-systems, the Fuel Pool Cooling System and the Fuel Pool Purification System. The Fuel Pool Cooling System cools water of the spent fuel pool. The Fuel Pool Purification System purifies water of the spent fuel pool. There is one purification circuit for the Reactor Building pool and the In-Containment Refuelling Water Storage Tank pool. The Fuel Pool Purification System also enables skimming of the spent fuel and Reactor Building pools.

In-Containment Refuelling Water Storage Tank (IRWST): The IRWST performs several functions, including:

- provision of borated water required to fill the reactor cavity and ensure biological shielding (radiation protection) during refuelling periods; and
- assurance of the water supply for the Chemical and Volume Control System charging pumps in the event of a low level in the volume control tank and after isolation of this tank on receipt of a boron dilution signal.

The water in the In-Containment Refuelling Water Storage Tank may contain low levels of activity which can be treated by the Fuel Pool Purification System. The boron concentration is managed through the Reactor Boron Water Make-up System via the Fuel Pool Purification System.

Gaseous Waste Processing System [TEG]: This system treats the gaseous effluents from the various tanks and systems serving the primary circuit in the UK EPR^{TM} unit. This system treats gaseous effluent prior to transfer to the Nuclear Auxiliary Building Ventilation System and Stack. The Gaseous Waste Processing System is the principal abatement system for gaseous wastes. Condensate from the Gaseous Waste Processing System is transferred to the Reactor Coolant Storage and Treatment System; and

Effluent Treatment Building Sampling System [TEN]: This system takes samples from the Liquid Waste Processing System to determine the most appropriate treatment technique to minimise radiological discharges.

2.3.4 Secondary system

The heat transfer, steam production and condensate return (secondary circuit)

The heat produced inside the reactor core is transferred by the primary circuit to the steam generators. The steam generators are heat exchangers which use boiler tubes to allow heat to be transferred from the primary circuit and the secondary circuit used to feed the steam turbine.

On the secondary side of the steam generators, feedwater absorbs the heat transferred from the primary side and evaporates to produce saturated steam. The steam is dried inside the steam generators then delivered to the turbine. After exiting the turbine, the steam is returned to its liquid state (condensed) and returned as feedwater to the steam generators.

Need for steam generator blowdown

A small proportion of the condensed water is bled continuously from the secondary circuit and replaced with fresh demineralised water. This is to prevent saturation of the secondary circuit with dissolved salts and to prevent the formation of foams or solids in the system that would make it difficult to dry the steam before it enters the turbine, which is required to prevent damage to the turbine. The water bled out of the system is known as blowdown.

Sources of non-radioactive and radioactive contaminants

Blowdown water from the steam generators is largely made up of demineralised feedwater. Chemicals, including hydrazine, ammonia, morpholine and ethanolamine, are added to the secondary circuit to prevent corrosion and to control pH. There is a potential for the discharge of radioactive liquid effluent from the secondary circuit, including low levels of tritium as a result of migration between the primary and secondary circuits[4]. Radioactive discharges will be covered under the Radioactive Substances Regulations permit and is mentioned here to aid understanding of the system.

Treatment systems to remove contaminants

The blowdown from the steam generators is processed by the Steam Generator Blowdown System [APG], which includes a treatment system. The primary purpose of this system is to remove non-radioactive corrosion products and dissolved salts before the water is recycled in the secondary circuit. Treatment will involve filtration and the use of ion exchange resins.

The non-recyclable blowdown from the Steam Generator Blowdown System is sent to the Nuclear Island Waste Monitoring and Discharge System [KER], for monitoring and discharge on a batch basis in admixture with Stream B and if necessary hydrazine destruction to an acceptable level. The method for hydrazine destruction will be determined during detailed design of the plant.

After purification, the blowdown is sent to the main turbine condenser circuit where it is recycled. If analysis shows that it remains unsuitable for re-use (for example the tritium is too high) or the secondary circuit is not available, the treated effluents from the blowdown system is sent to storage tanks [KER] after passing through a 5µm filter, to await monitoring and discharge. This is the source of Effluent Stream C.

[4] The discharge of radioactive liquid effluent, including tritium, is covered in the Radioactive Substances Regulation environmental permit and therefore not covered by this environmental permit application.

Appendix A, Figure 2.3.3 Effluent Stream C summarises the effluent collection, processing and storage techniques that will be applied before Effluent Stream C is transferred to the Outfall Pond, from the Discharge Tanks of the Nuclear Island Waste Monitoring and Discharge System [KER] prior to release to the GSB via the common Outfall Tunnel.

The discharge tanks of Effluent Streams B and C

Each of the UK EPR TM units will be provided with a dedicated liquid radwaste system for the transfer and treatment of the effluent streams outlined above. Effluent will be held and monitored in the Nuclear Island waste monitoring and discharge system [KER] tanks (3 x 750m^3 capacity), serving both units, before discharge intermittently on a batch basis if monitoring confirms compliance with permitted limits. Discharge of a [KER] tank will take approximately three hours. If the quality is not satisfactory, the effluent will be transferred to additional holding tanks [TER] for return to the liquid waste treatment system [TEU] for further treatment before discharge to the [KER] tanks for re-testing.

Discharge from the [KER] tanks are to the unit 1 Outfall Pond [HCA] and Long Sea-Outfall [HCT]. Discharges will be through unit 2 infrequently as operational requirements dictate during maintenance activities.

Potential contaminants of the Turbine Hall

When the steam in the secondary circuit enters the steam turbine, it is allowed to expand, which creates dynamic pressure and turns the blades of the turbine. The rotational energy of the turbine is converted to electrical energy in a generator, which exploits the relative motion between a magnetic field and a conductor. The turbine system requires a range of oils, greases and lubricants to operate at maximum efficiency. Water is also collected in the Turbine Hall [HM] as a result of leakage from and draining/emptying of the secondary circuit (excluding blowdown from the steam generators). This may contain corrosion inhibitors hydrazine, morpholine, ethanolamine, ammonia and phosphates (used to inhibit corrosion in circuits in contact with air, where volatile inhibitors cannot be used) and metals arising from corrosion. The effluent stream also has the potential to become contaminated with oils used in the Turbine Hall [HM], and so is treated by the oil-water interceptor system in the Conventional Island Liquid Waste Discharge System network and tanks [SEK]. Hydrazine present in the effluent will be destroyed to an acceptable level by treatment before discharge of the effluent. The method for this will be confirmed at a later date and will be progressed through the forward action plan using information from Hinkley Point C.

Floor drains collecting uncontaminated fluid from leaks, floor washing, and drainage of equipment in uncontrolled areas (called Floor Drains 3) are routed to the Conventional Island Liquid Waste Discharge System.

The sources of Effluent Stream D are shown in Appendix A, **Figure 2.3.4** Effluent Stream D

The discharge tanks of Effluent Stream D

The effluent outlined above will be held within 2x 750m^3 storage tanks in the Conventional Island Liquid Waste Discharge System [SEK] for monitoring before being discharged intermittently to the Outfall Pond [HCA] of unit 1 on a batch basis if monitoring confirms compliance with permitted limits. If the [SEK] tank contents do not meet specifications, for example due to radioactive contamination, the effluent will be directed to additional tanks [TER] provided for the liquid (rad)waste treatment system [TEU] and the effluent will be treated before discharge via the [KER] as part of Effluent Stream B.

2.3.5 Site drainage system

The Site Drainage Network [SEO-EP] has evolved from the original Hinkley Point C design. Whilst the Hinkley Point C design and lessons learnt will be replicated to maximum effect for Sizewell C some degree of change could be required or will be beneficial in the future (see FAP **Section 7.3.1** Action 1: Design description).

The drainage from the road and roof surface as well the drainage from transformers, electrical substations and fuel and oil off-loading areas will flow to localised full retention oil/ water separators. The external drainage from workshops and chemical storage areas will be controlled with a 3-way valve. The uncontaminated water from both systems will then flow to an oil/ water by-pass separator. The small volume of uncontaminated condensate from the condensers will also flow to this by-pass separator. Any oil residues will be sent for offsite disposal at a licensed waste management facility. Both bypass and full retention separators will be Class 1 separators (BS-EN-858), designed to achieve a discharge concentration of less than 5mg/litre of oil. The combined flow will then be transferred to the Forebay [HPF] along with the abstracted sea water (feeding the cooling water systems) pending discharge principally with spent cooling water (Stream A) via the common Outfall Pond [HCA] and Long Sea Outfall [HCT]. The Fish Recovery and Return System [HCF] is also fed downstream of the Forebay [HPF], a small proportion of Stream E will be discharged via Stream H and the dedicated Fish Recovery and Return System outfalls.

This is the source of Effluent Stream E.

Penstock valves will be installed to contain polluted effluent (including firewater) arising from unplanned and emergency situations within the drainage system, to enable such wastewater to be diverted, isolated, sampled, treated or removed as necessary. The system will be sized and specified to meet design criteria that reflect environmental and operational requirements, together with measures to mitigate against flood risk.

Figure 2.3.5 Effluent Stream E summarises the effluent collection, processing and storage techniques that will be applied before Waste Stream E is transferred to the Outfall Pond [HCA] prior to release to the GSB via the common Outfall Tunnel.

2.3.6 Production of demineralised water

The primary and secondary circuits both require a feed of fresh demineralised water. In variance to the GDA, demineralised water will be produced from mains water using a combination of self-cleaning filters, pass reverse osmosis and ion exchange resins. This process will be undertaken in the Demineralisation Plant [SDA] which is located within the Demineralised Water Production Building [HY]. This process will generate non-radioactive effluents characterised by either high acidity or alkalinity as a result of the use of sulphuric acid and sodium hydroxide to regenerate the resins and membranes; this is Effluent Stream F. Batch treatment of these effluents using acids and alkalis will result in a neutral pH.

No further treatment of demineralisation effluents is proposed and the discharge will contain dissolved solids removed from the mains water as well as substances such as sulphates, sodium and chlorides. The exact design of this system is site specific and is yet to be finalised (see FAP **Section 7.3.4**, Action 4: Environmental performance)

Appendix A, **Figure 2.3.6** Effluent Stream F summarises the effluent collection, processing and storage techniques that will be applied before Effluent Stream F is transferred to the [SEK] tanks and then to the Outfall Pond prior to release to the GSB via the common Outfall Tunnel. No oil interceptors are anticipated downstream of the neutralisation pit.

2.3.7 Sanitary effluent treatment

The on-site workforce will generate sanitary effluent from offices, site restaurant and mess facilities, which is transferred to the foul sewer network [SEO-EU/EV] and treated in a Sewage Treatment Plant [HXE] serving both units before being released through dual outlets to either outfall pond, as required, and on to the marine environment as a continuous discharge; this is Effluent Stream G.

The Sewage Treatment Plant will be designed and sized to accommodate peak numbers of people on-site, for example during a major outage (shutdown for maintenance purposes), as well as operating effectively to treat effluent from the lower numbers of people expected during normal operations. The detailed design and expected performance of the Single Package Sewage Treatment Plant and foul drainage network will take place as part of the detailed design process and will be confirmed to the Environment Agency as described in the FAP (see **Section 7.3.1** Action 1: Design description).

Appendix A, **Figure 2.3.7**. Effluent Stream G summarises the effluent collection, processing and storage techniques that will be applied before Effluent Stream G is transferred to the Outfall Pond [HCA] prior to release to the GSB via the common Outfall Tunnel.

2.3.8 Fish recovery and return system

During operation, a fish recovery and return system will be in place to minimise impacts on impinged fish. Abstracted water will be transported along the intake tunnels through the station forebay to the pumping station where larger biota (including fish and crustaceans) will be impinged on the drum and band screens. Impinged biota will be washed off the drum screens and returned to the marine environment via the fish recovery and return system. Not all impinged biota will survive so dead and moribund material will also be returned to sea via the fish recovery and return system and, as a result, the contribution to nutrients, un-ionised ammonia and deoxygenation that may be contributed by decaying fish has been assessed. Effluent Stream H comprises water used to operate the Fish Recovery and Return System that is discharged via the dedicated fish return outfalls, one for each EPR^{TM} unit.

The fish recovery and return system is described further in **Section 2.5. Figure 2.3.8** Effluent Stream H- fish recovery and return system summarises the process flow associated with the fish recovery and return system.

2.4 Summary of plant items and structures from which discharges will arise

2.4.1 Key buildings / facilities / structures identified for a UK EPR^{TM} unit

The GDA presents the design for one UK EPR^{TM} unit. The typical layout is shown in Appendix A, **Figure 2.4.1.**

At Sizewell C it is proposed to build two UK EPR^{TM} units. In general, this means there will be two each of the main plant buildings (i.e. four diesel buildings, two per UK EPR unit). The two UK EPR^{TM} units will however also share some supporting facilities at Sizewell C**.**

Table 2.4.1 shows the grouping of relevant UK EPR structures and whether they are shared or non-shared at Sizewell C.

Table 2.4.1 Grouping of relevant main standard and site specific structures

Main Structures	Code	Hinkley Point C Standard Structures	Sizewell C Site Specific Structures	Shared Facilities
Nuclear Island and Extensions (NI)				
Reactor Building	**HR**	✓		
Safeguard Buildings	**HL**	✓		
Fuel Building	**HK**	✓		
Boron Storage Building	**HKB**	✓		
Nuclear Auxiliary Building	**HN**	✓		
Radioactive Waste Treatment Building of Unit 2 (transfer of radioactive waste from Unit 2 to Effluent Treatment Building)	**HQC**	✓		
Access Tower	**HW**	✓		
Emergency Diesel Generator Buildings	**HD**	✓		
Effluent Treatment Building (for radioactive waste treatment of Units 1 and 2)	**HQ**	✓		✓
Effluent Tanks (KER, TER, SEK) & Refuelling Water Storage Tanks (PTR)	**HXA**	✓		✓

Main Structures	Code	Hinkley Point C Standard Structures	Sizewell C Site Specific Structures	Shared Facilities
Hot Laundry	**HVL**	✓		✓
Hot Workshop, Hot Warehouse and Facilities for Decontamination	**HVD**	✓		✓
Nuclear Island Demineralised Water Tank	**HYB**	✓		✓
Conventional Island (CI)				
Turbine Hall	**HM**		✓	
Conventional Island Electrical Building	**HF**	✓		
Main Transformer Platform	**HTP**	✓		
Unit Transformer Platform	**HTS**	✓		
Auxiliary Transformer Platform	**HJA**	✓		
Conventional Island Demineralised Water Tank (SER)	**HYA**	✓		✓
Balance of Plant (BOP)				
Cooling Water Pump House	**HP**		✓	
Intake Tunnel Heads	**HPT**		✓	
Forebay	**HPF**		✓	
Forebay Liasion Galleries	**HPL**		✓	✓
Fish Recovery and Return Outfall	**HCF**		✓	
Outfall Pond Building	**HCA**		✓	
Outfall Tunnel Heads	**HCT**	✓		✓
Filtering Debris Recovery Building	**HCB**		✓	
Demineralisation Station	**HY**		✓	✓
Fire-Fighting Water Distribution Building	**HOJ**	✓		
Gas Storage (Hydrogen, Nitrogen and Oxygen)	**HZH/ HZO**	✓		✓
Hydrazine Storage	**HZN**	✓		
Raw & Potable Water Storage/Supply	**HOR**	✓		✓
Marine Works Outfall Structure	**HCT**		✓	✓
Sodium Hypochlorite Treatment Plant	**CTE**		✓	✓
Buildings related to spent fuel and ILW storage				
Interim Storage Facility for Spent Fuel	**HHK**		✓	✓
Interim Storage Facility for Intermediate Level Waste	**HHI**		✓	✓

Main Structures	Code	Hinkley Point C Standard Structures	Sizewell C Site Specific Structures	Shared Facilities
Ancillary Storage Buildings / Garages				
Chemical Products Storage	**HZC**	✓		✓
Garage for Handling Facilities	**HHG**	✓		✓
Oil and Grease Storage	**HZG**	✓		✓
Other Buildings				
By-Pass Separator	**SEO-EP Tank**		✓	✓
Sewage Treatment Plant	**HXE**		✓	✓

A simple description of the structures listed above is provided in **Section 2.3** under the relevant effluent stream. **Table 2.4.2** shows the location of systems and the associated effluent streams.

Table 2.4.2 Location of main systems and effluent streams

Main Systems	Acronym	Effluent Stream	Location of System
Seawater Cooling System	CRF	A	Intake Tunnel, Forebay, Condenser, Outfall Building, Outfall Tunnel
Chlorination Plant	CTE	A	Pre-condenser
Fish Recovery and Return system	FRR	H	Across the Forebay, Pumping Station, Filtering Debris Recovery Building, Fish Recovery and Return tunnel and outfall
Reactor Coolant System	RCP	B	Reactor Building
Nuclear Steam Supply System	NSSS	B	Reactor Building
Chemical and Volume Control System	RCV	B	Across the Reactor Building, Fuel Building and Nuclear Auxiliary Building.
Nuclear Island Sampling System	REN/RES	B	Across the Reactor Building, Fuel Building and Nuclear Auxiliary Building.
Steam Generator Blowdown System	APG	C	Across the Reactor Building, Safeguard Building, Nuclear Auxiliary Building and Turbine Hall.
Nuclear Vent and Drain System	RPE	B	Nuclear Island and relevant site buildings

Main Systems	Acronym	Effluent Stream	Location of System
Coolant Storage and Treatment System	TEP	B	Across the Fuel Building and Nuclear Auxiliary Building.
Reactor Boron Water Make-up System	REA	B	Across the Fuel Building and Nuclear Auxiliary Building.
Fuel Pool Cooling (and Purification) System	PTR	B	Across the Reactor Building, Safeguard Building and Fuel Building.
In-Containment Refuelling Water Storage Tank	IRWST	B	Reactor Building
Gaseous Waste Processing System	TEG	B	Mainly located in the Nuclear Auxiliary Building.
Liquid Waste Processing System	TEU	B	Effluent Treatment Building
Effluent Treatment Building Sampling System	HQ	B	Effluent Treatment Building
Condenser Vacuum	CVI	D	Turbine Hall
Demineralisation Plant	SDA	F	Demineralisation Station
Nuclear Island Waste Monitoring and Discharge System	KER	B, C	Discharge Tanks Building
Liquid Radwaste Discharge System	KER	B, C	Discharge Tanks Building
Conventional Island Liquid Waste Discharge System	SEK	D	Turbine Hall
Site Liquid Waste Discharge System	KER/SEK	B and D	Discharge Tanks Building
Site Oily Water Drainage System (Collection of Oils and Hydrocarbon Effluents (including storage))	SEO/SEH	E	Site wide
Sewage Treatment Plant	HXE	G	Sewage Treatment Plant
Foul Water Drainage Network	SEO-EU/EV	G	Site wide

2.5 Summary of plant and infrastructure for handling the cooling water and effluent

2.5.1 Seawater cooling plant and infrastructure

Like other coastal power stations with open cooling systems, Sizewell C will abstract a significant volume of seawater to condense the turbine steam. Following an options appraisal (see **Section 3.1**) it was decided that at an open circuit cooling system was the preferred option for two UK EPR^{TM} units as described in the GDA. The system has been designed to comprise an open circuit (once-through) system that extracts water through two offshore intake tunnels. The intakes will be located approximately 500m apart approximately 3km offshore.

A schematic of the water intake arrangements is presented in Appendix A, **Figure 2.5.1.**

The principal components of the system include:

- The seawater intake;
- Transfer system of seawater to the filtration and pumping arrangements;
- Filtration and transfer of seawater for cooling;
- Main condensers and heat exchangers
- Fish recovery and return system; and
- Discharge of the cooling water and other effluent streams.

Details of these stages of the process are summarised below.

Seawater intake

Each of the two UK EPR^{TM} units at Sizewell C will be installed with a separate cooling water intake system. Each can draw water from the opposing system under diversification for maintenance and emergencies. Seawater is drawn into the intake heads, with two heads being installed for each intake tunnel to enable a contingent head to be available in the event of loss of availability of one of the systems, and to enable a consistent flow of intake water to the tunnel.

The intake head is designed so that it:

- does not create a surface vortex;
- is orthogonal to tidal flows to prevent fish being transported by the tide being ‘forced’ into the intake

- is large so that velocity of water being drawn is reduced to enable fish a better opportunity to escape being drawn
- has an entrance protected by bars to prevent entry by large objects; and
- maintains velocities across the face of the bars that will not pin a swimmer or diver to the bars.

Transfer system of seawater to filtration and pumping arrangements

Each intake tunnel is configured to transfer the abstracted seawater into designated reservoirs which are known as Forebays when associated with seawater cooling systems. The length and orientation of the intake tunnels are designed with reference to the Environment Agency evidence regarding cooling water options for the new generation of nuclear power station [52], which include the following requirements:

- There should be a sufficient depth of water at the intake heads to protect against low water conditions;
- The intake heads should not be close to shallow water where young fish and shellfish are most concentrated;
- The intake heads should not be close to areas of the seabed having fine loose sediment which could be shifted by tidal currents or drawn into the intakes;
- The intake heads should be sufficiently distant from the discharge heads, and/ or in deep enough water, to ensure that discharged heat is not recycled into the intake system; and
- There should be significant separation between the intake heads on one tunnel and the intake heads on the other tunnel in order to provide segregation to protect against external hazards. The distance between the intake heads on one tunnel and the intake heads on the other tunnel will be about 500m. This separation is great enough to provide effective segregation in the unlikely event of aircraft impact and to provide a significant degree of segregation against ship impact and most blocking hazards.

Each intake tunnel increases its incline to meet its Forebay unit, which receives the intake water before it is drawn into the associated Pumping Station. Each UK EPR^{TM} unit is allocated an individual Forebay, filtering unit including Fish Recovery and Returnsystem and Pumping Station Systems. Two tunnels are installed to link the Forebays together, to ensure the supply of cooling water to both units in the event one of the intake tunnels is unavailable, e.g. for maintenance. In normal operation, one link tunnel is kept open and the other is kept closed.

The open-topped Forebays are also designed to dissipate pressure effects in the intake tunnels and to accommodate changing water levels associated with pump start-up and shutdown transients. The design aims to promote self-cleaning and to minimise the amount of entrained sediment which settles out of suspension.

Filtration and transfer of seawater for cooling

The cooling water is transferred from the Pumping Station to the Turbine Hall [HM] and Nuclear Island via underground pipework. Each Pumping Station draws water from its adjoining Forebay to supply the cooling water.

The Pumping Stations house the pumps for all the cooling water systems and the pumping arrangements are installed with pre-filtration (trash racks) and filtration systems (drum and band screens). Larger fish and marine debris are removed through impingement on the trash racks. An automated raking system (timed and pressure triggered) will rake the bars from bottom to top, collecting debris (and any large fish) that are impinged on the racks. Material removed from the racks is placed in a gutter for onward transmittal to the filtering Debris Recovery Building [HCB]. On entering the filtering debris recovery building, this material passes through another trash rack with wider bar spacing: debris and fish that are impinged on this rack are removed and deposited at a licensed waste disposal facility; all material that passes through this secondary trash rack will be discharged back to sea via the Fish Recovery and Return tunnel.

Rotating,10mm fine-mesh drum screens (which protect the main cooling water supply to the station condensers) and band screens (that protect the auxiliary [SEN], essential [SEC] and, ultimate [SRU] cooling water systems) will remove organisms and debris. Smaller organisms (mostly fish eggs and larvae and other plankton) that pass through the drum and band screens are entrained and pass through the power station cooling system without causing blockages.

Fish recovery and return system

Historically, all material removed from the filtration systems at direct-cooled power stations would be removed from the station and discarded at a licensed facility (e.g. landfill or incinerator). However, many fish and invertebrate species survive impingement on the filtration screens detailed above and from an environmental perspective it is better to return these fish to sea. It is also generally better from an environmental perspective to return fish that are injured or killed during the impingement process because this returns the biomass to the system and makes it available for other organisms. the fish recovery and return system is designed to recover and return as many fish as it can without injury, but regardless it will return all impinged biomass back to sea (other than material so large that it might block the fish recovery and return tunnel). Optimisation of this system is described in more detail in **Section 3.1.3** Pollution control measures.

Main condensers and heat exchangers

For the operational phase, seawater is abstracted for cooling the steam turbine condenser [CRF] and plant auxiliary and safety systems [SEN, SEC and SRU]. The seawater pumps are installed in the Pumping Station. The flow rate value must be large enough to cool the secondary water at the condenser level but must also be such that the temperature increase at the discharge point is acceptable. It is also important to be able to protect this system against the potential growth of biofilm and biological fouling by injecting sodium hypochlorite into the circulating water.

Discharge of cooling water and other aqueous effluent streams

Once the cooling water has passed through the condensers or other heat exchangers, and served its heat removal function, it is channelled to the Outfall Ponds (one installed per UK EPR^{TM} unit). The ponds enable the operator to regulate the water level and control the pressure head on the discharge side of the system. The Outfall Ponds are reinforced concrete basin structures which are set into the ground.

The discharge ponds also provide a stand-by supply to the Essential Service Water System and the Ultimate Cooling Water System diversification links.

The offshore discharge tunnel is to be bored beneath the seabed to a length of approximately 3.5km. The tunnel length and orientation is driven by the following constraints affecting the location of the discharge heads:

- There should be a sufficient depth of water at the discharge heads to encourage the thermally buoyant plume to stratify and dissipate the heat to the atmosphere.
- The discharge heads should not be in shallow water, to minimise the impact on tidal habitats close to the shoreline where young fish and shellfish are most concentrated.
- The discharge heads should be sufficiently distant from the intake heads and/or in sufficiently deep water, to ensure that discharged heat is not recycled into the intake system.

At Sizewell there is a very large sandbank complex offshore and the outfall (and intake) heads need to be positioned to the east of this, hence the long tunnel lengths. A vertical shaft will connect each discharge head to the common Outfall Tunnel.

Outfall design

The single common Outfall Tunnel will have an internal diameter of 8m, sized to generate a sufficient flow-rate to promote self-cleaning and to minimise the amount of entrained sediment which settles out of suspension, as well as ensuring frictional forces are not too high (affecting head loss pressure). The Outfall Tunnel will be bored at depth under the shore and seabed from landward by a Tunnel Boring Machine (TBM), before rising to two seabed-mounted discharge heads (diffusers). This enables the flow of the discharge water from the tunnel to be maintained in the event that one discharge head is unavailable (e.g. due to maintenance). The diffusers, which will be aligned in series offshore, will each discharge a proportion of the outgoing cooling water, directing this horizontally and offshore, at right angles to the prevailing tidal currents. These discharges will occur in the lower third of the water column towards the time of low tide and in the lower quarter of the water column towards the time of high tide. The discharge heads will be covered by about 6.3m of water at Lowest Astronomical Tide.

The outfall structures will be mounted directly on the steel lining of the vertical shafts which will have an internal diameter of 4.6m. Each of these structures will have two outlet orifices on the seaward face of the outfall head, that seaward face being 3.95m x 8.65m. Illustrative detail of the outfall head is provided in Appendix A, **Figure 2.5.2**.

2.5.2 Biological fouling (micro and macroorganisms)

The abstraction of seawater provides the potential for biofouling and subsequent blockage of the abstraction systems. In the event of a significant blockage affecting the filters, the following measures will be taken to preserve the supply of cooling water to the Essential Service Water System [SEC] and the Ultimate Cooling Water System [SRU]:

- The circulating water system pumps will be tripped manually or automatically to:
    - Protect the mechanical integrity of the filters;
    - Minimise the further accumulation of blockage material on the filters; and
    - Preserve the clear area of the filters for flow to the essential service water systems.
- Headers on the suction side of the essential service water supply pumps and ultimate cooling water system pumps may be opened by local operator action to allow water supply to be re-instated to a pump whose normal filter train is unavailable (e.g. blocked, damaged or undergoing maintenance).

A 10mm mesh is proposed for the drum screens at Sizewell C due to the high numbers of ctenophores present at certain times of the year. Operational experience at Sizewell B has identified that blockages caused by ctenophores have been effectively reduced by the use of a 10mm mesh.

Seawater used as cooling water for power plant cooling systems contains micro and macro-organisms that can thrive in a range of environmental conditions provided by cooling water systems.

Sizewell B is currently assessed as subject to a high risk of biofouling. EDF Energy’s policy for its existing UK fleet is that stations exposed to a high biofouling risk should have the capability of maintaining continuous, year-round chlorination. This approach will also apply at Sizewell C although seasonal dosing is likely to be sufficient to meet operational requirements. Details of the proposed arrangements for chemical dosing are provided in **Section 3.7**.

Control of marine fouling will be achieved in compliance with the requirements of the EDF Energy document BEOM 006: Control of marine fouling [53]. The document specifies the mandatory requirements for the control of marine fouling due to sessile organisms (such as mussels).

The main systems at risk of biological fouling include the intake heads, filtration equipment, main condensers and auxiliary coolers. In addition to macrofouling, growth of microbial films on heat transfer surfaces. The low thermal conductivity of a biofilm can impair the plant thermal efficiency, resulting in reduced power output.

Another problem is the colonisation of culverts, condensers and coolers by larger organisms, which can restrict cooling water flows thus also resulting in the impairment of the thermal efficiency of the plant. In cooling water piping, the settlement of macro-organisms can lead to the constriction of the diameter of pipelines resulting in higher pumping costs and extended plant outage to enable removal.

The minimum effective level for long term treatment of mussels in cooling water circuits is 0.15mg/l Total Residual Oxidant (TRO). Operational control is generally found to be insensitive at the +/- 0.05 mg/l level hence the normal practice of setting a target residual of 0.2mg/l TRO. It should be noted that this low dosing regime is to prevent settlement (and for biofilm control) as opposed to curing established fouls. The intention is to prevent fouls from occurring as treating established fouls can cause large organisms to be dislodged and block the pipework.

Potential chlorination strategies have been assessed for Sizewell C in order to meet the required biofouling control of critical plant whilst minimising both operational risks and toxicological effects on non-target species. The proposed strategy for chlorination at Sizewell C is to only chlorinate downstream of the drum and band screens. Dosing at the intake heads is not feasible and the sheer size of the cooling water tunnel would allow for a degree of fouling, even though the fast flow rates (ca 2.3m/s) will also mitigate fouling. Chlorination downstream of the filtration screens will mitigate potential impacts on fish in the Fish Recovery and Return, but should it be necessary to chlorinate at the screens for operational and/or safety reasons SZC Co. would provide a reasoned case and environmental assessment to the Environment Agency. To mitigate environmental impacts from the discharge, chlorination would only occur when sea temperatures are 10°C or more as this corresponds to the period when planktonic stages of fouling organisms are typically present. The risk based preventive seasonal dosing regime will however balance the operational needs of the plant with mitigation of environmental impacts. As the design develops more information on the chlorination strategy will become available, see FAP **Section 7.3.4** Action 4: Environmental performance.

As chlorination of the intake heads themselves is not feasible there remains a risk of fouling at the intakes. It is therefore proposed that, consistent with the requirements of Environment Agency science report SC030231: Screening for intake and outfalls: a best practice guide [54], the bars located in the intake heads will be constructed of a biological resistant material, such as cupro-nickel and that the bar profiles will be designed to impede marine growth by species including *Sabellaria* (the reef worm).

2.6 Abnormal / emergency sources of discharges

2.6.1 Accident management plan

Abnormal discharges are those that are:

- planned but not typical; for example, during a major outage (shutdown for maintenance purposes) there will be a change in the characteristics of the trade effluent generated and the number of people on-site will rise from 900 up to a maximum of 1,900 which will increase significantly the amount of sanitary effluent that is generated; and
- unplanned but not unexpected; for example, the high levels of surface water run-off that would be generated during a thunderstorm.

Emergency discharges are those arising from an unplanned event, such as water from firefighting or uncontained hydrocarbon or chemical spillages.

Identification of the full range of abnormal and emergency non-radioactive discharges and the proposed techniques to minimise their impacts is being carried out as part of the on-going design of the Sizewell C site, and as such the full drainage system for the Sizewell C site has not yet been designed. One of the key actions for the FAP will be to provide a demonstration that the drainage systems are designed so that abnormal and emergency discharges can be managed in a way that minimises the impact on the environment (see **Section 7.3.1**, Action 1: Design description). These measures are closely connected to accident management planning, and further details on this are provided in **Section 6**.

2.6.2 Prevention of unplanned emissions of oils from heat exchangers

Past operational experience of the use of oil coolers (heat exchangers filled with oil and directly cooled by seawater) has shown that over time these systems become vulnerable to corrosion and subsequent losses of oil to the seawater cooling system. Such occurrences at Sizewell C are not considered possible because the UK EPR™ design does not use oil coolers that come into direct contact with the seawater cooling circuit.

2.7 Commissioning of Sizewell C

In order to safely operate Sizewell C in line with the design specification, the plant must be conditioned and tested in line with the operational envelope.

The commissioning of Sizewell C can be broken down into two distinct phases:

- Cold testing.

- Hot Functional Testing (HFT).

2.7.1 Cold testing

This activity involves the cleaning and initial preparation of various plant components. The main activity in this phase is cold flushing of pipe work (using demineralised water) to remove surface deposits and residual debris

The discharges from this phase will be formed primarily of water containing suspended solids and iron oxide (rust) and small quantities of conditioning chemical s (e.g. ammonia, ethanolamine, and hydrazine).

During this phase of commissioning, the cooling water pumps will not have been commissioned therefore the cooling water system will not be available as a discharge route of these effluents. The cooling water system will be static (no significant flow) and unsuitable for receiving effluent for discharge through the cooling water outfall. Cold commissioning discharges will be made via a construction discharge route following appropriate treatment to ensure suspended solid and chemical (including hydrazine) discharges are at levels where they will not have an unacceptable impact on water quality or marine ecology.

Cold commissioning effluents discharged through the construction discharge route will be consented via the Sizewell C construction water discharge activity environmental permit and are therefore not described further in this permit application.

2.7.2 Hot functional testing

HFT is a process whereby the UK EPR^{TM} is tested prior to operation under normal operating temperature and pressure conditions. HFT occurs before fuel is loaded into the reactor and therefore there are no radioactive effluents. The HFT phase of commissioning begins following the successful completion of the cleaning/flushing and cold performance tests and when the required equipment and functional units are deemed to be available.

HFT is split into five key activities:

- Increasing the temperature and pressure in the circuits.
- Regulation of the settings of the steam generator security valves.
- Once the system is under nominal temperature and pressure:
    - Set and calibrate the lines of the primary temperature and core thermocouples.
    - Testing the operation of the steam generators and associated auxiliary systems.

- Passivation[5] of the Reactor Coolant System internals.
- A cooling period.

The key point to note here is that ultimately, HFT can be considered as running the systems under normal operating conditions with the exception that nuclear fuel has not been loaded into the reactor. This means that the chemical effluents discharged during the HFT phase of commissioning will be the similar to and bounded by the discharges made during the normal operation of Hinkley Point C.

Once HFT has been completed the primary circuit must be fully drained prior to refuelling with borated water. The steam generators are then either drained and placed in dry lay-up or wet lay-up (depending on the duration of preservation required).

HFT will be deemed to be complete if:

- results of the tests carried out are satisfactory;
- the reactor pressure vessel endurance tests are successful; and
- the reactor pressure vessel is available for preparation for loading of nuclear fuel.

It is important to note that during the HFT phase, the cooling water system will be operational and therefore available to receive effluents and apply typical operational dilutions.

The only part of HFT that will be outside the normal operating envelope will during the draining of the primary circuit prior to refilling with borated water. During this period, operational discharge limits will be respected and adhered to. This will involve careful planning to ensure that the effluent drained from the primary circuit is:

- Directed to appropriate storage tanks;
- Sampled and subjected to appropriate analysis; and
- Subject to satisfactory analysis, discharged to the cooling water system (in a manner that does not exceed the operational discharge limits).

If analysis shows that discharge of this effluent would cause operational discharge limits to be exceeded, appropriate treatment will be applied to bring the effluent within specified limits. If this is not possible, disposal through an appropriately permitted offsite method will be arranged.

[5] Passivation is a physico-chemical process designed to remove impurities in the primary circuit which could become undesirable activation products during normal operation (after loading of nuclear fuel).

Notably, there will be extra temporary storage tanks on site, required as part of the cold flush phase of commissioning, which ensure there is sufficient capacity to store, sample and, if needed, retain for further treatment, prior to discharge via the cooling water outfall.

It is anticipated that there will be an overlap between the construction and commissioning phases of the project. However, given the current stage of the project and the long time period until commissioning actually takes place the amount of detail available on the commissioning sequence and the associated discharges is currently limited. In time, SZC Co. will draw on the experiences at Hinkley Point C through the replication strategy. Importantly, the commissioning discharges covered under this permit application will be bounded by the operational discharges described in this report. A commitment is made through the FAP (see **Section 7.3.3** Action 3: Development of the operational management plans) to provide a comprehensive commissioning discharges management plan prior to commissioning which will describe the process and management techniques in more detail.

3 Pollution Control Measures and Application of Best Available Techniques

This section demonstrates the use of appropriate pollution control measures for water discharge activities and the application of BAT for cooling water abstraction. It is structured as follows:

- The selection of an open cycle cooling water system and the main cooling water return (Effluent Stream A) is discussed in **Section 3.1**.
- All other aqueous effluent streams have been considered in **Section 3.2** to **3.9** against the following general criteria:
  - Trade effluent discharge options: consideration of whether discharge can be avoided by discharging the effluent to sewer.
  - Process design and effluent treatment.
  - Re-use of water.
  - Selection of raw materials.
  - Minimising use of materials.
  - Prevention contamination of effluents and surface water run-off.
- A section has also been included considering how impacts on the environment are minimised by maximising diffusion through the discharge heads.

3.1 Justification for the cooling water system design

3.1.1 Selection of open circuit cooling system

There are two key documents that identify the BAT for cooling systems at power stations. The first document [55], known as the Industrial Cooling BREF note, was published by the European Commission in December 2001 and sets out the standards expected for cooling at conventional power stations regulated under Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) [56]. The Industrial Cooling BREF note considers direct cooling to be the preferred option for large combustion plant in coastal locations, provided that the aquatic environment is not adversely impacted, because of the overall reduction in emissions of greenhouse gases that can be achieved. Whilst nuclear power stations are not within the scope of the Integrated Pollution Prevention and Control (IPPC) Directive the Industrial Cooling BREF note is useful source of information.

Historically, the identification of direct cooling as BAT came under challenge, specifically:

- As a result of legal action in the USA closed cycle cooling systems (i.e. wet or dry cooling towers) were identified as Best Technology Available for new power plant cooling facilities; and

- The validity of direct cooling as BAT for a new 2,000MWe combined cycle gas turbine power station using direct cooling in European Natura 2000 site was investigated on behalf of the Countryside Council for Wales. A key conclusion of this was that the Industrial Cooling BREF note was out of date.

The Environment Agency therefore commissioned an Evidence Report [52] to consider cooling water options for the new generation of nuclear power stations in the UK. This report is considered to be the most relevant guidance available. **Section 7** of the report compares the advantages and disadvantages of the different cooling options. **Section 7** of the report also recommends that the following factors should be considered to select the most suitable type of cooling system:

- The sensitivity of the source waters to abstraction impacts (entrainment and impingement); indirect cooling methods require less water and therefore reduce these types of impacts;

- The heat sink capacity of the receiving water, with lower capacities favouring indirect cooling methods;

- Planning limitations on the use of cooling towers (aesthetics, visible plumes, fog formation); and

- Comparative lower thermal efficiencies of indirect cooling methods, therefore increasing carbon emissions per unit of electricity produced.

The first two factors favour indirect cooling, the second two direct cooling. Further factors that need to be considered are whether:

- Predicted thermal and chemical related impacts exceed an acceptable level; and

- Impacts can be mitigated by use of available techniques or compensated for, e.g. by provision of replacement habitat.

The cooling system of the UK EPR™ is required to provide cooling to both the condenser [CRF] and auxiliary [SEN] cooling systems as well as to plant supporting nuclear safety, specifically the Essential Service Water System [SEC] and the Ultimate Cooling Water System [SRU]. The design of the system has considered site specific aspects relating to conditions both on and offshore, external hazards and environmental constraints.

Cooling water options were considered and the relative merits of open and closed-circuit cooling water systems (and a combination of these) were explored for Hinkley Point C. The outcome of this assessment was that the preferred option for the Hinkley Point C cooling water system would be an open circuit system drawing water through long offshore intake tunnels into one Forebay per UK EPR™ unit. The same assessment is applicable for Sizewell C and is discussed under the options assessment.

Options assessment

A safety assessment was undertaken that considered both open and closed-circuit systems and combinations of these systems. This assessment reinforced the findings of earlier studies and concluded that an entirely open circuit system with shared screening was the preferred option.

The safety assessment assessed six open and closed-circuit systems and concluded that an open circuit system was a well proven technology with recognised operating experience in the existing UK fleet. The Sizewell B PWR, Flamanville EPR in France and Hinkley Point C EPR currently use or have been authorised to use direct cooling with seawater. In addition, direct cooling with sea water was expected to be the most appropriate technology for the cooling of the Sizewell C Power Station, given its location on the coast adjacent to the North Sea.

There is no significant visual impact associated with the open circuit system, given that there are no cooling towers and the system is less vulnerable to extreme weather effects.

Clogging is a potential risk to both open and closed loop cooling systems. There is a possibility of marine clogging in an open system, but this is slightly reduced by the shared filtration with the safety systems and the cooling water system which benefits from the ‘over-sized’ filtering arrangement. There is the also the potential for marine hazards such as ship collision, however, the likelihood of this would be extremely low.

There is a potential environmental impact due to polluting matter from dead fish via the Fish Recovery and Return and thermal and chemical discharges from the main outfalls. These environmental impacts are further discussed in **Section 5** and are considered to have a minor impact on the environment.

The open circuit system is the preferred option as it meets the technical feasibility and safety requirements. In addition, an open circuit system cooled with seawater is in line with the cooling water guidance presented by the Environment Agency [52] and is also supported by the EC which states that, for major cooling loads such as power plants, direct cooling is an option [55]. An open circuit system is also described within the GDA for the EPR.

Summary of preferred option justification

The use of direct cooling at Sizewell C would be the most appropriate technique. In summary, direct cooling is considered to be BAT for the proposed Sizewell C power station because of the following:

- The use of direct cooling is a fundamental part of the nuclear safety case for Sizewell C. In particular, there is considerably more UK operating experience for open circuits compared to closed circuit cooling systems, meaning that potential issues associated with operating the plant are well understood and such systems can be run in a way that ensures nuclear safety and minimises environmental impacts.
- Direct cooling is the most energy efficient cooling technique and minimises the following potential environmental impacts at Sizewell C:
    - Minimises the generation of radioactive waste per unit of electricity exported.
    - Avoids impacts associated with a closed-circuit design with cooling towers, which would tend to have significant visual and noise impact.
- The North Sea at the point of discharge has the thermal capacity to enable direct cooling.
- Discharges of potentially polluting matter associated with the abstraction of cooling water will be minimised by using best practice (see **Section 3.1.3**).
- Extension of the heat plume principally in the surface water layers leaves adequate cross-section for unimpeded passage of migrating fish.
- There would be significant disadvantages of using large cooling towers with turbid, salty water. A water treatment plant would be required to process the make-up water leading to increased land-take, a reduction in power output and the generation of significant amounts of waste requiring disposal. Further disadvantages of the closed-circuit option are the major land-take (at Sizewell C there is not enough room to accommodate these large towers) and the visual impact. The potential vulnerability of cooling towers to extreme weather hazards is an additional factor which favours an open circuit solution.

Further details on the composition of the main cooling water can be found in **Section 4.1.2**.

3.1.2 Selection of intake location

The selection of the intake location has been optimised to minimise sediment intake, the entrapment of fish and other marine objects and minimise the risk of external hazards by considering the Environment Agency evidence regarding cooling water options for the new generation of nuclear power station [52], which includes the following criteria:

- The intake heads should be sufficiently distant from the discharge heads (or other local thermal discharges), and in deep enough water, to ensure that discharged heat is not recirculated into the intake system.
- The intake heads and shafts should be sited in an area with competent and stable ground conditions.
- There should be significant separation between the intake heads on one tunnel and the intake heads on the other tunnel in order to provide segregation to protect against localised external hazards. The distance between the intake heads on one tunnel and the intake heads on the other tunnel will be about 500 m. This separation is great enough to provide effective segregation against aircraft impact and to provide a significant degree of segregation against ship impact and most clogging hazards.
- At Sizewell specifically the intakes are located to the east of the large Sizewell-Dunwich Bank to avoid being smothered by the sand bank which is gradually migrating westwards.
- There should be a sufficient depth of water at the intake heads to protect against low water conditions.
- The intake heads should not be close to the inter-tidal zone where young fish and shellfish are most concentrated.
- The orientation of the intake screens on the intake heads is selected so that the inflow direction is perpendicular to the main tidal currents.
- The intake heads should not be close to areas of the seabed having deep deposits of fine loose sediment which could be shifted by tidal currents or drawn into the intakes.

In addition, the last four points above will also reduce the amount of potentially *"polluting matter"* that could be discharged from the system.

3.1.3 Pollution control measures

The optimisation of the design of the intake head, plant and the Fish Recovery and Return system at Sizewell C will reduce potentially polluting matter arising through the death of impinged marine organisms. A multi-stage approach has been adopted with measures including:

- A capped intake head eliminates vertical water movement which in turn is expected to help fish avoid entrapment into the intakes, because fish are ill-equipped to respond to vertical water movements.

- The Low Velocity Side Entry style intake head is orthogonal to the tidal flow to remove effect of tidal current forcing fish into the head.

- The velocity at the intake will be optimised to as low as possible whilst not causing a fouling risk.

- Optimised fish recovery and return system within the Filtration System.

In accordance with the requirements of the two Environment Agency Science Reports [52] and [54] the fish recovery and return system enables the return of fish to the marine environment. In accordance with the best practice requirements the following techniques will be employed:

- Very low-pressure wash sprays (1 bar) shall be used for biota removal from the screens in order to minimise the potential for harm and abrasion of the biota.

- The geometry of the collection hoppers is designed to minimise the escape of fish and return into the screen well.

- The screen buckets are designed to retain water. The contents of the bucket will then be channelled via a wash water gully to the sea under gravity flow via a dedicated pipeline, separate to the cooling water outflow channel.

- Fish gullies will be smooth.

- Swept bends of radius >3m will be used.

- Dedicated fish return tunnels will be used.

- A wash water supply will be provided to ensure the fish are immersed as they move along the return line.

- Minimal use of chemicals for intake water pre-treatment.

- The fish recovery and return outfalls have been chosen to avoid live fish being immediately entrapped in the Sizewell B intake and, therefore, being returned to sea dead and moribund.

Most existing power plants do not have a fish recovery and return system. The application of these measures will help to ensure that as many fish as possible are returned to the sea alive therefore reducing the amount of dead and moribund fish being discharged, which could constitute polluting matter. It will also reduce the amount of trash being directed to landfill. Only the material that is impinged on the course screens at the Debris Recovery Building [HCB] will require disposal at a licensed waste disposal facility. The Sizewell C Fish Recovery and Return will replicate the Hinkley Point C design where possible and appropriate, although it is worth noting that Sizewell C site specific requirements mean the complexity is reduced, leading to reduced handling of the fish also.

Behavioural deterrents

The design of the intake heads, together with their location to the seaward side of the Sizewell-Dunwich Bank approximately 3km offshore in relatively deep water, is designed to substantially reduce the impingement of abundant pelagic species such as sprat and herring and also of such species as sea bass.

Studies have concluded that, with the modified intake head design and Fish Recovery and Return system, potential environmental impacts from impingement and subsequent discharge of dead and moribund fish from the Fish Recovery and Return as potentially polluting matter would not have a significant effect on the water quality and ecology of the GSB.

The possibility of installing biota exclusion techniques at the offshore intakes (e.g. bubble curtain or acoustic fish deterrent) to potentially further reduce fish impingement presents significant technical and safety challenges to designing, installing and maintaining such a system approximately 3km offshore. Commercially available systems proven to work in offshore locations and at the required scale do not exist. Installing and maintaining such a system also gives rise to significant safety risks. It is therefore not considered BAT to install biota exclusion techniques at the intakes for the modest reduction of polluting matter.

3.1.4 Minimisation of silt accumulation

At Hinkley Point C, the design of the forebay has been modified to minimise silt accumulation in a particularly turbid environment and consequently the need to de-silt. At Sizewell C the build-up of sediment is not predicted to be as high as at Hinkley Point C but the optimised design will be replicated. The water intake system is therefore designed to:

- reduce the ingress of sediment by the location the intake heads to avoid areas of sediment settlement (accretion);
- achieve a flow velocity in the intake tunnels of 2.3 m/s, in order to promote self-cleaning and to minimise the amount of entrained sediment that settles out of suspension;
- accommodate instrumentation to monitor the flow rate, water level and head loss; and,
- enable the periodic draining and inspection of the tunnel.

Desilting

At this stage in the design of the heat sink it is not possible to provide a precise methodology for the desilting of the forebays. It is likely that the desilting of the forebays will involve the re-suspension of the silt within the forebays and cooling water system with the silt subsequently being discharged along with the spent cooling water to the outfall pond. The choice of method depends on several factors that have not yet been finalised including the detailed design of the heat sink and the Forebay maintenance strategy for Sizewell C.

The potential for contamination of the sediments in the forebay is considered negligible. The forebay only receives the main cooling water drawn from the sea, roof and road drainage, uncontaminated chiller condensate and oily water drainage which has passed through oil/water separators. No other effluents are discharged to the forebays.

During the de-silting operations there may be potential changes to the properties of the water in the forebays, which are thought to be associated with a potential decrease in the dissolved oxygen content and the potential generation of hydrogen sulphide gas (due to anaerobic degradation of organic matter in the accumulated sediments). These changes are not expected to result in any adverse environmental impact due to the low quantities of hydrogen sulphide (these levels will be low due to the low quantities of organic matter present in the water abstracted from the GSB area) released and the subsequent re-suspension and subsequent re-aeration of the sediments in the cooling water system.

Once the design of the heat sink and the forebay maintenance strategy have been finalised, the impact assessment findings will be verified and a suitably detailed methodology for undertaking the de-silting activity will be developed and agreed with the Environment Agency (also subject to marine licensing), see FAP **Section 7.3.3** Action 3: Development of the operational management plans.

3.1.5 Thermal plume

Section 5.9.5 discusses the results of thermal modelling undertaken to assess the impact of waste heat being discharged to the GSB. In summary, the resulting thermal plume will not prevent the passage or feeding of the marine mammals, the harbour porpoise associated to the Southern North Sea SAC, the harbour seals associated to the Wash and North Norfolk Coast Special Area of Conservation (SAC) and grey seals associated with the Humber estuary SAC. Overlap of thermal plumes at levels predicted to influence foraging areas of three key Special Protection Area (SPA) bird species are also predicted to be limited in extent.

3.2 Trade and sanitary effluent discharge options

The preferred option for these Effluent Streams (B to G) is to apply appropriate treatment prior to discharging into the GSB. This effluent could theoretically be discharged to public sewer and treated at a local Water Recycling Centre (WRC) however, there is no suitable connection to the foul sewer in the immediate vicinity of Sizewell C. This is reflected in the current arrangements at Sizewell B, which uses an on-site Sewage Treatment Plant (STP) before discharging treated wastewater via the cooling tunnel into the GSB.

The nearest large publicly available WRC to Sizewell C is located in Leiston in the Leiston Valley Rd catchment. The pre-planning assessment report [57]undertaken by Anglian Water has concluded that the Water Recycling Centre is at capacity and would require a costly and time consuming upgrade in order to accept trade effluent. Whilst the foul drainage could be accepted, Anglian Water cannot reserve capacity and the available capacity can be reduced at any time due to growth, environmental and regulation driven changes.

There are other Sewage Treatment Works (STW) in Suffolk:

- AWS Lowestoft STW, 29 miles from Sizewell C
- Stowmarket Anglian Works, 32 miles from Sizewell C

Providing suitable pipelines and pumping small volumes of treated wastewater, both trade and sanitary effluent, via the public sewerage network to one of the above STW would be prohibitively expensive. The impact of discharging into the GSB would be the same regardless of whether the wastewater is treated at a STW or treated at an on-site STP at Sizewell C before discharging directly into the GSB.

3.3 Nuclear island trade effluents

The following aspects of the Nuclear Island trade effluent streams are considered to reduce emissions and associated impacts:

- The water in the pressurised primary cooling circuit is used in a closed system with a recycling plant to maximise the re-use of water, which minimises water consumption and the generation of effluent. The recycling system also reduces consumption of boric acid, thereby minimising mass emissions of boron;
- The water in the primary cooling circuit is dosed with chemicals which prevent corrosion of the plant and therefore minimises emissions of radioactive and non-radioactive metals;
- Effluent streams on the nuclear island are managed to prevent contamination of clean effluent streams prior to and after treatment; and
- Treatment of effluents from the Nuclear Island are optimised according to their source to remove radioactive contaminants (see **Section 2.3.3**), which in turn also removes non-radiological contaminants.

Further details on the composition of this effluent can be found in **Section 4.1.3**.

3.4 Steam generator blowdown effluent trade effluent

3.4.1 Plant design and effluent treatment

The following aspects of the steam generator blowdown trade effluent stream are considered to reduce emissions and associated impacts:

- The water in the secondary circuit is used in a closed system. The Steam Generator Blowdown System maximises the use of this water, which minimises water consumption and the generation of effluent.
- The water in the secondary circuit is dosed with chemicals which prevent corrosion of the plant and therefore minimises emissions of non-radioactive metals.
- The steam generator blowdown is treated using filtration and demineralisation to maximise recycling of water to the secondary circuit and also produces a high-quality effluent stream.
- The steam generator blowdown effluent may be contaminated with small amounts of tritium but is unlikely to contain other types of radioactive contaminants. The effluent discharged from the Steam Generator Blowdown System will be segregated from other effluent streams potentially containing other radioactive substances to prevent its contamination both prior to and after treatment.
- The Steam Generator Blowdown System effluent will be sent to the discharge storage tanks (Liquid Radwaste Monitoring and Discharge System tanks), when analysis indicates that it is unsuitable for reuse, so that, if necessary, hydrazine destruction can be applied to reduce the concentration before the effluent is discharged.

Further details on the composition of this effluent can be found in **Section 4.1.4**.

3.4.2 Selection of raw materials

The secondary steam system will be dosed with morpholine, ammonia and ethanolamine to control pH, which helps to prevent corrosion. Corrosion is undesirable because:

- It reduces the efficiency of the plant, ultimately meaning there is more impact on the environment for each unit of electricity exported to the grid;
- Reliability impacts;
- It results in increased discharges of corrosion products (metals); and
- It results in a decrease in the design life expectancy of plant items leading to early replacement and increased waste production.

The feedwater to the system will also be dosed with hydrazine, which is a very effective oxygen scavenger. This prevents corrosion associated with oxidation of metals in the steam generator (i.e. rusting). Whilst hydrazine is a toxic substance and a carcinogen it does not readily bio-accumulate and tends to decompose in the aquatic environment, mainly under cold conditions and under atmospheric pressure, through oxidation and molecular gaseous nitrogen biodegradation. The decomposition products are not toxic, being water and dissolved nitrogen gas.

Other oxygen scavengers are available, but they either reduce the efficiency of the power station or are more harmful to the environment than hydrazine. Considerable work has been undertaken for the EDF Energy Nuclear Generation Limited fleet in the UK looking at the use of alternatives to hydrazine, specifically:

- Carbohydrazide;
- Diethyl hydroxylamine;
- Methyl ethyl ketone;
- Hydroquinone; and
- Erythorbic acid

Of the alternatives tested, none removed oxygen from high temperature and pressure boilers as efficiently as hydrazine. It is therefore concluded that hydrazine represents the most appropriate oxygen scavenger for Sizewell C.

In selecting hydrazine, careful consideration has been given to its potential behaviour in the environment. Laboratory studies have been carried out to identify how quickly hydrazine decomposes in the environment to help assess the potential impacts. Hydrazine time to 50% degradation in seawater collected at Sizewell was shown to be ca. 38 minutes for hydrazine concentrations in the range 30 – 3000ng/l. These studies provided the source data in support of the operational discharge modelling of hydrazine. The detailed dispersion modelling and assessment are described in more detail in **Section 5**.

It should also be noted that the Liquid Radwaste Monitoring and Discharge System will incorporate hydrazine destruction technology (specification of which will be determined during detailed design) which can be utilised to lower hydrazine concentrations in the primary and secondary circuit effluents if they are found to be elevated prior to discharge.

An optioneering study looking at further optimisation of hydrazine discharges will be developed and communicated to the Environment Agency as described in the FAP (see **Section 7.3.3** Action 3: Development of the operational management plans). This will utilise studies from Hinkley Point C as they become available.

3.5 Oily water treatment

The following aspects of the oily water trade effluent stream are considered to reduce emissions and associated impacts:

- Drainage from plant areas where there is the potential for contamination with oils will be segregated from other drainage, preventing the contamination of other effluents and clean surface water run-off; and

- Oily water will pass through an oil-water interceptor before being discharged.

The design of the site oil-water interceptors has yet to be confirmed. Drainage from the oily water network will however flow either to full retention oil/water separators or bypass separators, which will be Class 1 separators designed to be compliant with BS-EN-858 Separator Systems for Light Liquids and achieve a discharge concentration of less than 5 mg/litre of oil.

The Environment Agency guidance on pollution prevention for businesses (2016) [41] sets out the main principles for oil separators including the type, class, size and use of oil separators for any sites with a risk of oil contamination including car parks, roads, and fuel off-loading facilities.

Further details on the composition of this effluent can be found in **Section 4.1.5.**

3.6 Production of demineralised water trade effluent

3.6.1 Plant design

As a variation to the approach proposed in the GDA, demineralised water will be produced from mains water in a plant using a combination of membrane (e.g. reverse osmosis) and ion exchange technology, which is considered to reduce emissions and associated impacts.

Table 3.6.1 below presents the process steps and emissions described in the GDA which are not applicable to Sizewell C.

Table 3.6.1 Processes identified in the GDA that will not be applied at Sizewell C

Aspect of Demineralised Water Production	Emissions Avoided
Filtration of seawater to remove sediment	Suspended solids from the sediment
Coagulation and precipitation of substances in the water using ferric chloride	Iron in the coagulant
Sand filtration	Iron and suspended solids when the filters are backwashed
Desalination	Concentrated brines

Using a combined technology system adequately balances the advantages and disadvantages of each technology type (summarised in **Table 3.6.2**) to reliably provide large quantities of demineralised water.

Table 3.6.2 Comparison of ion exchange and reverse osmosis production of demineralised water

Aspect of demineralised water production	Comparison of ion exchange and reverse osmosis
Reliability	Both ion exchange and reverse osmosis are well established reliable technologies with a good track of performance worldwide. Future technical developments are not expected to have a major influence on plant and process costs.
Feed water pre-treatment required	Both processes require pre-treatment to remove suspended solids to a low level to avoid fouling. However, ion exchange is more tolerant of suspended solids and reverse osmosis requires additional pre-treatment by micro-filtration. Membranes are also subject to scaling by hardness present in the feed water and require either a softening plant as part of the feed water pre-treatment or the addition of anti-scaling chemicals.
Quality of treated water	Even the best performing reverse osmosis plants cannot meet the treated water quality of a simple ion exchange plant and a subsequent ion exchange unit is required to achieve boiler feed water quality.
Flexibility	Ion exchange plants tend to be more flexible than reverse osmosis, for example in terms of performance over a wider range of temperature variations and the ability to recover from high suspended solids in the feed.
Fouling by organics	Both ion exchange resins and reverse osmosis membranes can be fouled by organics present in the feed water. Ion exchange resins are much more easily cleaned than reverse osmosis membranes without long plant shutdown and use cheap cleaning chemicals; salt and sodium hydroxide. However reverse osmosis can have a place in producing demineralised water and when used in combination with ion exchange can produce the highest quality boiler feed water.
Plant size and/or feed flow-rate	The capital cost of a reverse osmosis plant is generally higher than that of an ion exchange plant and is relatively insensitive to scale.

Aspect of demineralised water production	Comparison of ion exchange and reverse osmosis
Operating costs	Power costs for reverse osmosis are the most significant contributors to operating costs. Variation in power and chemicals costs from region to region can significantly influence the operating costs for both types of plant.
Membrane and resin replacement costs	The cost of membrane plus resin replacement in a combined reverse osmosis/ion exchange system is significantly higher than the cost of resin replacement in an ion exchange system and this is very little affected by the ionic load and scale of operation.
Plant maintenance	Reverse osmosis plants have higher maintenance costs than ion exchange plants owing to the more complex nature of reverse osmosis plants.
Manpower	Manpower costs are similar in both cases.
Costs of feed water and waste treatment	In all cases the sum of water costs and waste treatment is greater for reverse osmosis/ion exchange plants than for ion exchange plants. The lower water recovery for reverse osmosis/ion exchange systems results in a higher cost contribution of feed water to treated water cost.

The main emissions from the plant will be from:

- membrane and ion exchange treatment, which results in discharges of sulphates, sodium and chlorides when the resins and membranes are regenerated and/or treated with sulphuric acid and sodium hydroxide; and
- neutralisation of effluent with either sulphuric acid or sodium hydroxide, which results in discharges of sulphates and sodium.

Further details on the composition of this effluent can be found in **Section 4.1.6.**

3.6.2 Selection of raw materials

Water treatment chemicals such as sodium hydroxide, hydrochloric acid and sulphuric acid contain traces of substances such as cadmium and mercury, which are priority substances listed by the Water Framework Directive. The potential impact of these trace contaminants is discussed below.

As part of the H1 assessment there are specific requirements for the minimisation of the discharge of annual loads of the priority hazardous substances. Of the substances identified for consideration of significant load for coastal waters and estuaries, cadmium and mercury were identified as potential trace contaminants that may be present in raw materials. To ensure this target is met it is necessary to determine that the annual limit of priority pollutants discharged is not more than a defined significant load limit (an annual load limit that has been set for priority hazardous pollutants). In addition to various organic chemicals significant load limits are set for cadmium and mercury. Based on operational experience and feedback from EDF's French fleet of nuclear power stations. **Table 3.6.3** contains the estimated annual and 24 hour loadings for cadmium and mercury. Both these annual (and the daily worst case if scaled over a year) load figures meet the requirement to not exceed a significant annual load of 1kg for mercury or 5kg for cadmium.

Table 3.6.3 Discharge loadings for cadmium and mercury

Trace metal	Discharge loading	
	Annual (kg/y)	**24-hr (kg/day)**
Cadmium	0.37	0.005
Mercury	0.099	0.0011

Potential discharges to the marine environment have been assessed for the operational phase of the planned Sizewell C development. For large cooling water discharges that are discharged to estuaries or coastal waters after checks for load of priority hazardous pollutants as described above specific screening assessment recommended by DEFRA and Environment Agency, (Clearing the Waters for All, 2017 [25] is applied).

Substances likely to be discharged in the cooling water are assessed as follows:

(i) Average background concentration for substance multiplied by average cooling water flow (to determine background load).

(ii) Average load of substance in process stream added to above load.

(iii) Divide previous step (ii) result by total of average cooling water discharge volume and average process stream volume combined.

(iv) Compare result of above to the Environmental Quality Standard (EQS) Annual Average (AA).
A second assessment makes a comparison to the relevant EQS Maximum Allowable Concentration (MAC).

(v) Maximum background concentration for substance multiplied by minimum cooling water flow (to determine background load).

(vi) Maximum load of substance in process stream added to above load.

(vii) Divide step (vi) result by total of minimum cooling water discharge volume and average process stream volume combined.

(viii) Divide step (vi) result by total of minimum cooling water discharge volume and average process stream volume combined.

(ix) Compare result of above to the EQS MAC.

The aim of the process is to identify components of discharges that may contribute to the deterioration of a waterbody and so prevent achievement of target standards such as status objectives under the Water Framework Directive. The guidance applies to continuous discharges and variable process discharges to freshwater and coastal water ("surface waters")

Environmental quality standards

Mercury and cadmium are among the priority hazardous substances, listed in Annex X of the Water Framework Directive (2000/60/EC) [7] , and are strictly regulated with low EQS values and objectives for the elimination of these discharges in the future. The EQS values for estuarine and coastal waters for each of these metals potentially present in trace amounts in bulk chemicals is presented below in **Table 3.6.4.**

Table 3.6.4 EQS for selected metals potentially present in Sizewell C process chemicals

Metal[1]	Classification	EQS AA (µg/l)	EQS MAC (µg/l)	EQS MAC biota (µg/kg)	EU Directive
Cadmium	Priority hazardous substance.	0.2	1.5	-	EQS directive 2008/105/EC
Mercury	Priority hazardous substance.	0.05	0.07	20	

[1] EQS values are for the dissolved portion of each metal listed.

H1 assessment results

For this assessment, it is assumed that the discharge loadings are entirely in the dissolved state (as EQS values are for the dissolved fraction only). The H1 assessments of cadmium and mercury discharges are presented in **Table 3.6.5** and **Table 3.6.6**.

Table 3.6.5 H1 assessment of cadmium discharges

Discharge scenario	Cadmium discharge loading (kg)	Cooling water flow (m^3/s)	DC[1] (µg/l)	BC[2] (µg/l)	Discharge Load (µg/sec) mean or 95%	DC (µg/l) mean or 95% +background	Mean or 95% DC+BC over EQS (%)
Annual	0.37	116	1.0E-04	0.05	11.73	0.05	0.25

24 hour	0.005	66	9.0E-04	0.13	57.87	0.13	0.09

[1] DC - Discharge Concentration.
[2] BC - Background Concentration (derived from British Energy Estuarine and Marine Studies (BEEMS) TR314).

Table 3.6.6 H1 assessment of mercury discharges

Discharge scenario	Mercury discharge loading (kg)	Cooling water flow (m^3/s)	DC (µg/l)	BC[1] (µg/l)	Discharge Load (µg/sec) mean or 95%	DC (µg/l) mean or 95% +background	Mean or 95% DC+BC over EQS (%)
Annual	0.099	116	2.7E-05	0.02	3.14	0.02[2]	0.29
24 hour	0.0011	66	2.0E-04	0.02	12.73	0.02	0.29

[1] BC - background Concentration.
[2] The mean and 95% background for mercury is same value due to large number of less than detection values in the dataset (these were set to face value detection limit).

H1 assessment conclusions – trace metals

Potential metal contaminants in process chemicals are present in only trace amounts, as is reflected in the low discharge loading values determined for cadmium and mercury. The calculated discharge concentration for cadmium is several orders of magnitude below the AA-EQS and MAC-EQS and is also below method detection limits. The situation is similar for the calculated mercury discharge. In all cases, the calculated discharge concentration is less than 1% of the relevant EQS and it is only the inclusion of site background concentrations which elevates the total discharge concentration to around 25 to 29% of the respective EQS values, which negates the need for further detailed assessment of these metals under the H1 methodology.

Based on the analysis and arguments presented above, the proposed use of the process chemicals in question (sodium hydroxide and hydrochloric acid) and the associated discharges of trace metal contaminants are considered to have a negligible impact on the receiving environment and is therefore justified.

3.7 Dosing of cooling water with sodium hypochlorite

3.7.1 Need for chlorination

Biofouling of the cooling water system, in particular the condensers, by bacteria, fungi or macrofauna such as *Sabellaria sp.* Or *Mytilus sp* can reduce the overall efficiency of the power station, which is undesirable as it has the potential to increase environmental impacts (e.g. generation of radioactive waste) for every unit of electricity exported. There are only a limited number of options available to prevent biofouling of the cooling system, including:

- Use of anti-fouling paints and coatings.
- Copper-nickel self-cleaning bar screens.
- Chemical dosing, usually with sodium hypochlorite.

The main disadvantage of using paints or coatings is that many of the more effective types contain substances such as tributyl tin which are widely recognised as being particularly hazardous to the environment. The preferred option described in the GDA is therefore to select an approach based on self-cleaning bar screens at the intake and chlorination of the cooling water prior to the condensers.

Based upon the known risk of biofouling at Sizewell, it would be necessary to dose critical plant at Sizewell C (the condensers and essential cooling water systems) during the growing season when seawater temperatures exceed 10 °C and also to have the flexibility to dose those systems at other times of the year based upon operational need. The chlorination policy for the other parts of the cooling water (CW) system has to be effective against any biofouling risk that would threaten the operation of the station whilst minimising toxicological effects on non-target species. In particular, Sizewell C will be fitted with a fish recovery and return system to reduce the mortality of impinged fish and the Environment Agency best practice screening guidelines are that, wherever possible, chlorination should be avoided before the fish recovery and return so as to minimise any loss of fitness for those fish returned to the marine environment.

3.7.2 Sources of chlorine

The options available for supplying chlorine are to:

- Produce sodium hypochlorite in an on-site production plant and store it for dosing purposes, as described in the GDA;
- Undertake in-situ sodium hypochlorite production at the dosing location; and
- Import and store sodium hypochlorite for dosing.

Production of sodium hypochlorite through electrolysis is widely used in both the French and UK fleet, including Flamanville and Sizewell B. The option that will be applied at Sizewell C will be confirmed once the chlorination strategy has been developed as described in the FAP (see **Section 7.3.4** Action 4: Environmental performance). The assumption is that no additional emissions will be made from any associated processes such as cleaning and regeneration.

3.7.3 Strategy for minimising chlorination

The GDA for the EPR design identifies that under normal conditions worst case chlorination will involve injecting 0.5mg/l of active chlorine, applied sequentially once every 30 minutes per cooling channel to achieve 0.2mg/l residual oxidants. In variance to the GDA, at Sizewell C there will need to be the ability to chlorinate in front of the condensers such that the TRO level at the condensers for both UK EPR units is maintained at a continuous level of 0.2mg l^{-1} throughout the year. The following proven approach will be adopted to minimise the amount of chlorination required:

- A strategy will be implemented based on 'Cooling Water Management in European Power Stations: Biology and Control of Fouling' and best practice used by EDF Energy Nuclear Generation (formally British Energy) for the existing fleet of nuclear power stations as set out in their strategy document BEOM 006 [53], which involves developing a site specific risk based protocol to prevent biofouling. This is an important difference from the general approach described in the GDA.

- The strategy based on BEOM 006 [53] involves screening, cleaning and dosing in that order of preference. Effective screening and cleaning are the first lines of defence, so appropriate plant and practices will be put in place at Sizewell C to achieve these. Screening and filtration help prevent systems becoming fouled but eventually the systems will need to be cleaned. Chemical dosing is a means of limiting fouling but is only carried out in conjunction with screening and cleaning and will not be relied on as the sole means of preventing fouling.

- Identifying the need for chlorination will also be closely linked to monitoring protocols for fouling, including monitoring of the condenser efficiency, examination of growth in circuits and monitoring populations of organisms in the surrounding sea.

Ultimately, the strategy to be developed will be a risk based intermittent dosing regime that will respect the operational needs of the plant, the EQSs and the Habitats Regulations thresholds. The strategy for control of biofouling is considered further in the FAP (see **Section 7.3.4**, Action 4: Environmental performance).

Further details on the composition of the main cooling water can be found in **Section 4.1.2**.

3.8 Sanitary effluent

Treatment of sanitary effluent will be undertaken in a Sewage Treatment Plant that will be designed and sized to accommodate peak numbers of people on-site, for example during a major outage, as well as operating effectively to treat effluent from the lower numbers of people expected during normal operations.

The system will be designed taking into account the principles below, which are reflected in the FAP (see **Section 7.3.1**, Action 1: Design description):

- Use of techniques appropriate and proportionate to the risk presented by the sanitary effluent.
- Application of the waste hierarchy, in particular segregating drainage systems so that the plant does not treat uncontaminated surface water run-off.
- Use of appropriate monitoring, control and maintenance systems to ensure that the plant operates effectively.

Further details on the composition of the sanitary effluent can be found in **Section 4.1.7**.

3.9 Segregated surface water drainage system

Sizewell C will be provided with its own separate surface water drainage network which will discharge to the forebays, mix with cooling water and ultimately discharge to sea. Full details of the drainage strategy for the water discharge activity will be developed at the detailed design phase including the interface with Sizewell B. The finalised drainage drawings with detail on the drainage routes and emission points from the site will be supplied to the Environment Agency prior to commissioning of the water discharge activity as part of the FAP (see **Section 7.3.1**, Action 1: Design description).

The surface water drainage network will be designed to be compliant with all, currently applicable British/European Standards (BS Ens) and Practices. The design shall provide compliance with statutory regulation and the requirements of National and/or Local Authorities and Drainage/Environmental Regulators.

The following guidance documents from the Environment Agency set out the main principles that should be applied when designing a surface water drainage system for a site:

- Environment Agency guidance to control and monitor emissions for your environmental permit (2016) [28];
- Environment Agency guidance on Oil Storage Regulations for businesses (2018) [37];
- Environment Agency guidance on pollution prevention for businesses (2016) [30] ; and
- EA guidance for fire prevention plans: environmental permits (2018) [38].

The key design principles from the above guidance documents that will be applied at Sizewell C are described within **Table 3.9.1**, which summarises the information currently available on the design of the surface water drainage system that will be developed at Sizewell C and identifies why these measures are considered to reduce emissions and associated impacts.

It should be noted that uncontaminated surface water runoff from the segregated drainage system will not require treatment before joining the main discharge. In the event that the surface water run-off does become contaminated appropriate measures will be included in the plant design so that it can be isolated to prevent discharge to the environment and stored for appropriate disposal.

Table 3.9.1 Surface water drainage system – general principles of design

Source	Design Principle	Application of BAT design principles at Sizewell C
Surfacing		
EA guidance to control and monitor emissions for your environmental permit (2016)	• Ensure surfaces, including roofs, hard standing, working areas, any containment structures required by your permit, such as bunds or other secondary containment measures, and your site drainage infrastructure will prevent pollution to surface water and groundwater. • Consider collection capacities, surface thicknesses, strength and reinforcement, falls, materials of construction and permeability. • Rainfall collection systems are kept separate from areas of the site which are or may be contaminated. • Surfaces and containment or drainage facilities are resistant to spilled chemicals. Your management system must include a plan about how you will inspect and maintain your surfaces and containment facilities. • The following are needed to prevent contaminated run off polluting groundwater or surface waters: - A waterproof surface. - Spill containment kerbs. - Sealed construction joints. • A sealed drainage system prevents water escaping from your operational area, and means any liquid used in your process will be stored in the system and collected for disposal elsewhere.	Surface water will be handled using dedicated drainage systems. The drainage system design will be highly integrated with assessments of potential risks associated with the storage, use and handling of hazardous materials and wastes, including containment techniques such as bunding and kerbing. These measures are closely connected to planning, and further details on this are provided in **Section 6**. Design of the drainage system will also consider the important relationship with areas of hardstanding, including construction method, materials and joints. The drainage system will be designed in such a way as to allow easy maintenance and inspection of surface structures and will part of the site's planned preventative maintenance programme.

Source	**Design Principle**	**Application of BAT design principles at Sizewell C**
Drainage		
EA guidance for pollution prevention for businesses (2016)	• Paint your manhole covers according to the standard code: - Blue for surface water. - Red for foul water. - Red 'C' for a combined system where all water goes to a treatment plant. • Show the direction of flow with a painted arrow on the manhole cover. • Check your drains regularly for: - blockages or leaks – clear or repair them to prevent pollution; and - misconnections, where your drains have been connected to the wrong part of the sewer network – you must fix any mis-connections or you could be fined.	Manholes and other features of the drainage system will be colour coded, or use other similar techniques, so enable the appropriate response in the event of loss of containment of polluting materials such as hydrocarbons. The drainage system will be designed in such a way as to allow easy maintenance and inspection and will be part of the site's planned preventative maintenance programme.
Sub-surface Structures		
EA guidance to control and monitor emissions for your environmental permit (2016)	• You must design your site so that leaks from underground structures are prevented and any leaks can be detected quickly. • You must keep a record of the route of any underground drains or pipework on your site.	Requirement has been communicated to system designers and will be addressed during detailed design.
Oil-water separators/interceptors		
EA guidance for pollution prevention for businesses (2016)	• Install an oil separator (interceptor) or other device to remove oil from water that drains off hard surfaces. Typically, a separator is needed for any site with a risk of oil contamination, such as: - Car parks larger than 800m² or for 50 or more parking spaces. - Smaller car parks that discharge to a sensitive environment, such as a marsh that has been designated as a nature reserve. - Vehicle maintenance areas. - Roads. - Refuelling facilities. • The type and class of separator you need will depend on the activity and where the discharge is directed to. - Ensure that the oil separator is correctly sized.	Surface water run-off from areas where materials such as oils are used will pass through an oil-water interceptor or appropriate treatment process to minimise the potential for hydrocarbon emissions.

Source	Design Principle	Application of BAT design principles at Sizewell C
EA guidance to control and monitor emissions for your environmental permit (2016)	If you use oil in your operations, you must fit and maintain oil separators to surface water drainage systems to prevent discharges being contaminated by oil.	Surface water run-off from areas where materials such as oils are used will pass through an oil-water interceptor or appropriate treatment process to minimise the potential for hydrocarbon emissions.
Bunding & Containment		

Source	Design Principle	Application of BAT design principles at Sizewell C
EA guidance to control and monitor emissions for your environmental permit (2016)	You must provide containment (bunding) for underground pipework, sumps and storage vessels. You may also need to fit a leak detection system, for example if you're carrying out your activity in a groundwater Source Protection Zone. You must keep a list of any underground sumps or storage vessels. Your sumps and bunds must be: • Waterproof; and, • resistant to any materials you're going to store in them. You must make sure sumps and bunds do not become contaminated or blocked as this may cause them to leak. You must: • check that sumps and bunds are working correctly, for example that there are no cracks; • hydraulically test any sump or bund if you're worried it is not working correctly; and • fit a high-level probe to any sumps or bunds that you cannot check with an alarm to alert you before waste begins to escape containment. Your bunds must also have a capacity larger than both of the following: • 110% of the largest tank the bund is protecting. • 25% of the combined volume of all the tanks the bund is protecting. Use the maximum volume that a tank can physically hold when calculating capacity. Do not use the volume a tank is designed to hold. Your bunds must also: • have no outlets (for example drains or taps); • drain to a blind (completely enclosed) collection point; and • have self-contained pipework that is separate from the container pipework. Your bunds must have tanker connection points within the bund. If that's not possible, the tanker connections points must be contained to capture any leaks. If you need to use your bund to contain a leak you must make sure it's emptied to restore maximum capacity.	Requirement will be communicated to system designers and will be addressed during detailed design.

Source	Design Principle	Application of BAT design principles at Sizewell C
EA guidance for Oil Storage Regulations for businesses (2018)	Bunds can either be: • manufactured as part of a tank system – tanks that are 'pre-bunded' by the manufacturer in this way are known as 'integrally bunded' tanks; and, • constructed from masonry or concrete. For bunds of either variety you must make sure: • the bund is impermeable to oil and water – oil and water cannot pass through; • the base or walls of the bund does not have a pipe, valve or opening that allows the bund to be drained; • any fill pipe or draw off pipe that passes through the bund base or wall is sealed to stop oil getting out of the bund; • the bund contains every part of the container and its associated equipment (such as valves) unless the oil being stored has a flash point of less than 32℃ (such as ethanol), in which case filters, sight gauges, valves and other equipment can sit outside the bund; • hold 110% of the capacity of the container; and, • fixed tanks must be bunded. Bunds constructed from masonry and concrete are likely to need a rendering or coating on the internal surfaces of the base and walls to make them impermeable.	The design will be highly integrated with assessments of potential risks associated with the storage, use and handling of hazardous materials and wastes, including containment techniques such as bunding and kerbing; these measures are closely connected to incident management planning, and further details on this are provided in **Section 6**.

Source	**Design Principle**	**Application of BAT design principles at Sizewell C**
Storage areas for (Intermediate Bulk Containers (IBCs), drums, bags etc.		
EA guidance for pollution prevention for businesses (2016)	Hazardous and non-hazardous waste must be stored separately. This reduces the risk of fire and means that if there is an incident – such as a spill – the substances cannot mix. Provide secondary containment for your containers, for example a drip tray or 'bund' with an impermeable base and walls to contain or catch leaks or spills with the following capacities for secondary containment: • At least 25% of the capacity of storage containers up to 205 litres capacity. • At least 110% of the capacity of storage containers over 205 litres capacity. Ensure secondary containment is suitable for the substances you store, including its size and construction. Do not store other materials within a bund and make sure you remove accumulated rainwater regularly. You must not allow the contents of containers to get into surface water or groundwater. Storage should be at least 10m from watercourses, open drains, gullies, unsurfaced areas or porous surfaces and 50m from wells, springs or boreholes.	The design will be highly integrated with assessments of potential risks associated with the storage, use and handling of hazardous materials and wastes, including containment techniques such as bunding and kerbing; these measures are closely connected to incident management planning, and further details on this are provided in **Section 6**.

Source	Design Principle	Application of BAT design principles at Sizewell C
EA guidance to control and monitor emissions for your environmental permit (2016)	You must bund or kerb any area where environmentally harmful substances are stored (for example coolants, chemical solvents, lubricating oils). You must store substances separately if it may be risky to store them too near each other, for example because they're flammable or if 2 substances spilled and mixed could cause an explosion or harmful fumes. Do not use plastic intermediate bulk containers (medium-sized containers that can be moved easily and are made out of plastic or metal) to store flammable materials. You must also: • locate storage areas away from watercourses, sensitive groundwater areas such as Source Protection Zone 1, unprotected drainage systems and sensitive boundaries, for example near areas where people live or nature reserves; • clearly mark your storage areas, and any containers and packages in them; • define the maximum storage capacities for each of your storage areas and containers and stick to them; • store containers, including empty containers, with lids, caps and valves secured and in place; and, • inspect your containers, drums and small packages at least once a week to check they're not damaged or leaking and put a procedure in place to replace or repair damaged or leaking containers.	The design will be highly integrated with assessments of potential risks associated with the storage, use and handling of hazardous materials and wastes, including containment techniques such as bunding and kerbing; these measures are closely connected to incident management planning, and further details on this are provided in **Section 6**.

Source	Design Principle	Application of BAT design principles at Sizewell C
EA guidance for Oil Storage Regulations for businesses (2018)	Containers positioned to minimise the risk of them being damaged by impact, for example away from driveways, tanker turning circles and fork lift truck routes. Make sure that any impact will not damage the container, for example by placing barriers or bollards around the tank. If you fill your container via a remote fill pipe you must use a drip tray to catch any oil that may be spilled during the delivery. You must install secondary containment around your container to catch any oil that leaks. For fixed tanks, mobile bowsers, IBCs and other single containers, the secondary containment must have capacity to hold 110% of the capacity of the container. The secondary containment for a drum (usually a drip tray) must have a capacity equal to or more than one quarter of the drum it's holding and if the drip tray can hold more than one drum, it must be able to hold one quarter of the combined capacity of the drums it can hold. For fixed tanks, mobile bowsers, IBCs and other single containers, the secondary containment must have capacity to hold 110% of the capacity of the container. Secondary containment that contains multiple fixed tanks, mobile bowsers or IBCs, must have a capacity that is equal to whichever is the greater of these 2 measurements: • One quarter of the combined capacity of all the containers. • 110% of the capacity of the largest container. If the containers are hydraulically linked, they should be treated as a single container, so the secondary containment must have a capacity of 110% of the combined capacity. If the containers are hydraulically linked, but have separate secondary containment, each separate secondary bund or drip tray must have a capacity of at least 110% of the combined capacity of all the containers.	The design will be highly integrated with assessments of potential risks associated with the storage, use and handling of hazardous materials and wastes, including containment techniques such as bunding and kerbing; these measures are closely connected to incident management planning, and further details on this are provided in **Section 6**.

Table 3.9.3 identifies the pollution prevention measures that will be applied at Sizewell C to prevent polluting materials entering the drainage system and using it as a pathway to sensitive surface waters, aquatic ecosystems, groundwater and soil. These measures will be incorporated in to the procedures of the integrated management system, see FAP **Section 7.3.2**, Action 2: Development of the integrated management system.

Table 3.9.2 Surface Water Drainage System – Pollution Prevention and Control

Source	Indicative BAT	Application of BAT for pollution prevention and control at Hinkley Point C
Drainage		
EA guidance for pollution prevention for businesses (2016)	Ensure only clean water drains into the surface water drain or soakaway Contaminated water drains into the foul water drain connected to a foul sewer Do not put fats, oil, grease or solid items down drains.	The surface water drainage system will be segregated to prevent pollution of clean run-off with hydrocarbons and other substances. Segregation of this drainage will be such that it does not pass through the Sewage Treatment Plant, which is an important measure for ensuring that sewage treatment is not adversely affected during periods of high rainfall; Although the site drainage system has not yet been designed, there will be segregation of the following individual wastewater streams, reflecting different management approaches: • Oily water run-off from areas where there is the potential for chemical contamination will pass through an oil-water interceptor before being discharged. • Uncontaminated surface water run-off will not pass through the plants identified above. Sanitary effluent from administrative buildings and mess areas will be passed through a Sewage Treatment Plant before being discharged; the plant will be designed and sized to accommodate peak numbers of people on-site.
Unloading and moving potential pollutants		

Source	Indicative BAT	Application of BAT for pollution prevention and control at Hinkley Point C
EA guidance for pollution prevention for businesses (2016)	Procedures to prevent pollutants from spilling or leaking when they're being delivered, loaded or moved around your premises. Before you order new supplies, check the quantity in your containers – only order what can safely fit in the containers so you do not overfill. Load and unload in suitable places on your site – make sure there are no open drains to surface water and carry out a risk assessment. Use pre-arranged routes for deliveries and movements. Have a spill kit, suitable to the products on your site, available near storage, loading areas and transfer routes. Supervise deliveries, and make sure the people involved know what to do if there's a spill and how to use the spill kit safely and effectively.	The design will be highly integrated with assessments of potential risks associated with the storage, use and handling of hazardous materials and wastes, including containment techniques such as bunding and kerbing; these measures are closely connected to incident management planning, and further details on this are provided in **Section 6**.
Storage and containment		
EA guidance to control and monitor emissions for your environmental permit (2016)	Prevent leaks or accidental release of liquids that could cause pollution from tanks, sumps, containers and bunds. Provide secondary containment for your containers. You must provide containment (bunding) for underground pipework, sumps and storage vessels. Bund or kerb any area where environmentally harmful substances are stored.	The design will be highly integrated with assessments of potential risks associated with the storage, use and handling of hazardous materials and wastes, including containment techniques such as bunding and kerbing; these measures are closely connected to incident management planning, and further details on this are provided in **Section 6**.
EA guidance for pollution prevention for businesses (2016)	Containers containing liquids, chemicals or waste which may pollute the environment, should be: • in good condition, including any pipework and valves, and you have an inspection and maintenance programme; • protected against theft and vandalism; • protected if they're in a flood risk area – for example, moved to another location, secured so they cannot float (ask the manufacturer how to do this) or protected by flood barriers; and, • clearly marked so people know what's in them and about any risks or hazards. Ensure used containers are stored so it does not cause pollution or disposed of appropriately.	The design will be highly integrated with assessments of potential risks associated with the storage, use and handling of hazardous materials and wastes, including containment techniques such as bunding and kerbing; these measures are closely connected to incident management planning, and further details on this are provided in **Section 6**.

Source	Indicative BAT	Application of BAT for pollution prevention and control at Hinkley Point C
Maintenance		
EA guidance for pollution prevention for businesses (2016)	Check your drains regularly for: • blockages or leaks – clear or repair them to prevent pollution; and • misconnections, where your drains have been connected to the wrong part of the sewer network, you must fix any misconnections, or you could be fined. Any oil separator has to be maintained and any trapped oil or sediment has to be disposed of to a suitably permitted facility.	The drainage system will be designed in such a way as to allow easy maintenance and inspection and will be part of the site's planned preventative maintenance programme.
Incidents and emergencies		
EA guidance for pollution prevention for businesses (2016)	Develop an environmental management system to help avoid pollution and act appropriately if an incident does occur using a pollution incident response plan. The pollution incident response plan should include: • Emergency contact details. • A product inventory, including a product safety data sheet. • A site layout plan. • A plan of the drainage arrangements on the site. • Details of the location of emergency response equipment. • Your emergency procedure. • How you report incidents. Have a drainage plan which shows: • Where the drains are. • The types of drains – surface water, foul water, or combined. • Direction of flow. • Where drains leave your property. • Where they discharge into, for example, a watercourse, clean-water soakaway or sewage treatment works.	An integrated management system will be in place which will incorporate a pollution incident response plan and drainage plan to minimise pollution.

Source	Indicative BAT	Application of BAT for pollution prevention and control at Hinkley Point C
EA guidance for Oil Storage Regulations for businesses (2018)	Develop a pollution incident response plan to minimise pollution if there's a leak, spill or fire.	An integrated management system will be in place which will incorporate a pollution incident response plan to minimise pollution.
EA guidance for fire prevention plans: environmental permits (2018)	Contain the run-off from fire water to prevent pollution of the environment. Prevent fire water entering: • surface waters, for example rivers, streams, estuaries, lakes, canals or coastal waters; and, • into the ground.	An integrated management system will be in place which will incorporate a fire water management plan to ensure that firewater can be collected and contained in the event of an emergency.

Further details on the composition of the surface water drainage system can be found in **Section 4.1.5**.

3.10 Outfall design

Main outfall

The single common Outfall Tunnel will have an internal diameter of 8m, sized to generate a sufficient flow-rate to promote self-cleaning and to minimise the amount of entrained sediment which settles out of suspension, as well as ensuring frictional forces are not too high (affecting head loss pressure). The Outfall Tunnel. Will be bored at depth under the shore and seabed from landward by TBM before rising to two seabed-mounted discharge heads (diffusers). This enables the flow of the discharge water from the tunnel to be maintained in the event that one discharge head is unavailable (e.g. due to maintenance). The diffusers, which will be aligned in series offshore, will each discharge a proportion of the outgoing cooling water, directing this horizontally and offshore, at right angles to the prevailing tidal currents. These discharges will occur in the lower third of the water column towards the time of low tide and in the lower quarter of the water column towards the time of high tide. The discharge heads will be covered by about 6.3m of water at Lowest Astronomical Tide.

The outfall structures will be mounted directly on the steel lining of the vertical shafts which will have an internal diameter of 4.6m. Each of these structures will have two outlet orifices on the seaward face of the outfall head, that seaward face being 3.95m x 8.65m. Illustrative detail of the outfall head is provided in Appendix A, **Figure 2.5.2**.

Fish recovery and return

Each of the two fish recovery and return outfall headworks (one for each UK EPR^{TM} would comprise a concrete block approximately 4.5m (height) x 3m (width) x 3m (depth). It would be buried approximately 2m into the sediment. The internal diameter of the fish recovery and return tunnel would be ca. 0.65m and this would terminate in a simple discharge point from the outfall headwork. The headworks would be located below the Lowest Astronomical tide (LAT) mark so that fish would be returned to sea at all states of the tide and in a location so as to avoid immediate re-entrapment into Sizewell B.

4 Emissions and Monitoring

4.1 Emissions

4.1.1 Introduction

The WDA Permit (operational) will place controls on the discharge of a range of effluents generated at Sizewell C arising from activities undertaken during the hot functional testing stage of the commissioning phase and the operational phase.

Effluents associated with the operational phase include those arising from the operation of the seawater cooling systems, operational and maintenance activities undertaken on the Nuclear Island, Conventional Island and sanitary facilities, together with management of storm water run-off. These effluents will be combined before release to the marine environment (the final effluent) via a single sea outfall serving both UK EPR^{TM} units at Sizewell C. Greater detail on the origination of these effluents is provided in **Section 2**.

Sea water abstracted with the cooling water flow will also be used as a carrier for the transfer of fish and other marine biota retrieved from the fish recovery and return system. This will be returned to the marine environment via a separate outfall for each of the UK EPR^{TM} units.

A summary of these effluent streams contributing to non-radioactive effluent discharges covered by the WDA permit is provided in **Table 2.2.1**. An overview of the relationships between the effluent streams is provided in Appendix A, **Figure 2.2.2** Simplified Overview of Effluents Contributing to the Surface Water Discharge.

This section will look at the operating scenarios of the plant, the basis of information presented on flow and dilution as well as quantifying emissions associated with each effluent stream.

Operating scenarios

During the operational phase of Sizewell C the plant, systems and processes outlined in section may be operated at any time, generating discharges to the GSB. The nature of the releases will depend on the operating mode of each of the reactors. The reactors may operate under different conditions: normal, abnormal and emergency conditions. This application relates to the release of effluents to the marine environment under normal conditions during the hot functional testing and operational phases. Normal operation includes the scenarios described below, which are routine and anticipated:

- **Standard Operation.** Electricity generation based on nuclear fission with both of the UK EPR^{TM} units operating at their full capacity with power changes in line with operational requirements;

- **Outage.** One reactor on outage and not operating due to scheduled maintenance activities and refuelling.
- **Maintenance.** Includes planned outages of a Circulating Water System [CRF] pump for maintenance with both reactors continuing to operate.

It is currently anticipated that Unit 1 will not have a refuelling outage until completion of commissioning of Unit 2. Typically, outages will last about 2 weeks and are expected to occur every 18 to 22 months.

Sizewell C will release effluent continuously to the GSB area during all scenarios, though the flow rate and composition of the effluents will vary according to the activities being undertaken.

The relative effects of these operating modes on the composition of the final effluent are summarised in **Table 4.1.1** The variances will arise from the release of chemicals associated with operational and refuelling/ maintenance activities being undertaken and the level of dilution available from the cooling sea water. During outages, the workforce present on-site will also increase, giving rise to increased flows to the foul sewer network and the sewage treatment plant.

Shutdowns resulting from unforeseen and/ or abnormal operating scenarios may take place and as such will not be representative of normal operations. On this basis, these scenarios are not discussed further here.

Table 4.1.1 Normal operating scenarios and effects on composition of combined effluent

Normal Operating Scenario	EPR Unit 1	EPR Unit 2	Description	Comments
	Number of CRF Pumps running			
Standard operation	2	2	This refers to the situation when both units are operating normally at their full capacity, that is 100 per cent load, with all four CRF pumps operational. The reactors may be subject to power changes within this scenario from time to time in line with operational requirements, but the default is for operation at full capacity.	Chemicals are associated with standard activities and cooling water pumps for both UK EPR™ units are all in operation, providing substantial dilution of contaminants before release to the environment.
Outage	0	2	This refers to the situation when one UK EPR™ unit is shut down for planned routine maintenance and/or refuelling. Typically, maintenance would be made to a	Reduced dilution overall arises as a result of operating only two out of four [CRF] pumps being operational. Given the reduced dilution available, additional discharges arising from

	1	1	CRF pump or to an element of the filter train. During an outage neither CRF pump on the shutdown unit is operational. The smaller pumps continue to feed cooling water to the auxiliary systems. The other reactor unit would continue to operate as per standard operation. An outage would be expected to take place every 18-22 months and typically last for about two weeks	the outage (for example treatments applied to primary and secondary circuits during shut-down and start-up, as well as drain-down after lay-up or cleaning during maintenance) will be managed to ensure compliance with permitted limits during the short periods of planned outages by; • treatment of the effluent where facilities exist (e.g. for hydrazine destruction); • recycling within the effluent systems (where appropriate); • retention of effluents in the appropriate available tanks (until the [CRF] system has been returned to normal flow rate); • discharge from the effluent tanks at a restricted rate (which would be calculated so as to remain within the permitted limits); and, • the details of how outage discharges will be managed will be confirmed following the completion of the detailed design of the relevant systems. It is proposed that this will be delivered through the WDA permit application Forward Action Plan (see **Section 7** of this application report).
Maintenance test (RF2) (worst case)	1	1	This refers to a theoretical situation where both UK EPRTM units are operating at 100%load, with only a single CRF pump serving each unit, that is with only 50% cooling water capacity. If this situation occurred in practice, this would likely result in the plant being shut down. Having more than one CRF pump out of operation at any one time would not be considered to be part of normal operations. However, this situation represents a useful worst case in terms of cooling water and provides a useful reference	For temperature the worst-case scenario is when 2 out of 4 pumps are under maintenance the flow of cooling water would be halved but the heat content of 2 full power reactors would remain approximately the same raising the excess temperature at the outfall from 11.6°C to 23.2°C. It should be noted that the hotter plume near to the discharge point transfers heat to the atmosphere much more efficiently than the normal cooler plume. This means that there is less heat to mix down into the water column, resulting in a smaller plume at the surface and at

			short-term or 24-hour discharge scenario.	the bed. Whilst the excess temperature plume area is smaller for the maintenance run, the increased temperatures within Sizewell C would cause more entrainment mortality to planktonic organisms
Maintenance test (RF3)	2	1	This refers to the situation when both reactor units are operational, one on 100% load with two CRF pumps running, and the other unit on 90% load with only a single CRF pump in operation. The plant could be operated under this configuration as a result of both planned and unplanned situations. The remaining CRF pump would be subject to maintenance during this period. Normally, pump maintenance of this type would be planned to coincide with an outage as described above. It is not unknown for unexpected failures to occur while the unit is operating at full power, for example, pump or drum screen failure. If this unplanned situation were to occur, the load on the unit would be reduced to a maximum of around 90% rated thermal power to compensate for the loss, and would remain in this configuration until the fault is rectified, which would be expected to take no longer than one month. Even when routine pump maintenance is scheduled to coincide with an outage, it may be necessary to operate the plant in the RF3 configuration for up to a month. This is because the time to complete the required maintenance work is going to take longer than the critical tasks normally associated with an outage, for example, refuelling of the UK EPR unit. In this planned situation, the CRF pump would either be taken off line before the outage begins or it could remain	Cooling water outlet temperature and concentration of discharged contaminants during normal power operation increases due to reduction in dilution before discharge by [CRF] flows with one pump on outage. Given the reduced dilution available, effluents will be managed to ensure compliance with permitted limits during the short periods of planned outages by: • treatment of the effluent where facilities exist (e.g. for hydrazine destruction); • recycling within the effluent systems (where appropriate); • retention of effluents in the appropriate available tanks (until the [CRF] system has been returned to normal flow rate); • discharge from the effluent tanks at a restricted rate (which would be calculated so as to remain within the permitted limits); • the details of how outage discharges will be managed will be confirmed following the completion of the detailed design of the relevant systems. It is proposed that this will be delivered through the WDA permit application Forward Action Plan (see **Section 7** of this application report).

			off line after the critical outage tasks have been completed and the UK EPR unit has been brought back up to power.	

Basis of information presented on flow

The flow of cooling seawater will be continuous and substantial, relative to all other effluent streams. All calculations related to flow from the two Outfall Ponds [HCA] pending transfer via the sea outfall [HCT] are therefore based on the flows of cooling water that are presented for Stream A in **Table 4.1.2**.

Effluent Streams B/C, D and F from the two UK EPR^{TM} units will be routed through the Nuclear Island waste monitoring and discharge system [KER] or Conventional Island liquid waste discharge system [SEK] tanks, as appropriate (see **Sections 2.3.3** and **2.3.4**), prior to discharge via the Outfall Pond [HCA] of unit 1. There is also availability to discharge these effluent streams to unit 2 if necessary, for example during maintenance. The maximum flow rates for effluent Streams B/C, D and F are specified based on the ratings of the pumps used to transfer the discrete effluent streams to the outfall pond from these holding tanks on a batch basis.

Effluent Stream G will be from a single Sewage Treatment Plant [HXE] serving both EPR^{TM} units. The discharge can also be sent to either unit 1 or unit 2 outfall pond dependant on operational requirements.

More information on flow rates for all the discrete effluent streams (including Streams E and H) are provided in **Sections 4.1.2 – 4.1.8**.

The cooling water flow rates and dilution with dispersion scenarios used in the H1 assessment (Appendix B), are summarised below in **Table 4.1.2**. This is based on the lowest volume of water through the system to represent a worst-case scenario in terms of dilution of contaminants. For substances not screened out for the H1 assessment (**Section 5.8**) more detailed modelling is required. The specific details for the setup of the hydrodynamic modelling for these discharge assessments is provided for thermal assessment in **Section 5.9.5** and for chemical discharges in **Sections 5.9.8** and **5.9.9**.

For the H1 screening assessment the annual scenario is based on the maximum annual discharge of $116m^3sec^{-1}$ based on a single EPR unit having a minimal operational cooling water flow of $58m^3sec^{-1}$ under low tide conditions (worst-case scenario within ‘standard operation’). The 24-hour scenario represents the scenario described as RF2 in **Table 4.1.1** with operation of two EPRs with only a single pump providing half the cooling water flow (based on maximum flow for 2 EPRs of $132m^3sec^{-1}$). For screening, these scenarios present a conservative assessment in terms of chemical dilution.

Table 4.1.2 Dilution and dispersion scenarios used in the H1 screening assessment

Discharge scenario	CW flow (m^3/s)
Annual (Standard Operation)	116
24hour (Maintenance- RF2)	66[1]

[1] This is a worst-case scenario used for the screening assessment with only half the cooling water flow as described for the RF2 operating scenario.

Basis of information presented on emissions

Operational experience, information obtained from other nuclear power stations operated by EDF and studies and assessments undertaken to support characterisation of effluents for Hinkley Point C and Sizewell C have informed characterisation of the operational phase effluent streams arising at Sizewell C.

Where practicable, the characterisation data have been presented as the following measurement statistics are considered representative of normal operating conditions. These all relate to individual effluent steams before dilution with cooling water in the outfall pond. It is anticipated, based on the WDA permit issued for Hinkley Point C (HP3228XT), that limits on annual loads will be set for individual effluent streams for Sizewell C. Therefore, the values in this report would be expected to inform the limits established in the Sizewell C WDA permit.

- **Annual load.** This is the maximum total quantity of a contaminant expected to be discharged over a year.
- **Daily load.** This is the maximum total quantity of a contaminant expected to be discharged over a day.

Total loads and concentrations of contaminants in the final effluent from the long sea-outfall are calculated as part of the environmental risk assessment described in **Section 5**.

Basis of information presented on temperature

The proposed Sizewell C power station would comprise a twin-unit EPR^{TM}, with a design cooling water outfall rate of $132m^3s^{-1}$ (2 x $65.9m^3s^{-1}$ during standard operation). A maximum of 8.6% of the total cooling water flow would supply the essential and auxiliary cooling water systems via band screens and the remaining 91.4% ($120m^3s^{-1}$) would supply the main cooling water systems [CRF] via the station drum screens. The thermal uplift of the $12m^3s^{-1}$ that supplies the essential and auxiliary cooling water systems would be 6.6°C ΔT. In the absence of full details on the design of the Sizewell C cooling water system, thermal modelling in 2015 assumed a total discharge of $125m^3s^{-1}$ would be discharged at 11.6°C ΔT. This is within 1.4% of the total heat flux of the estimated cooling water discharge of

$131.8 m^3 s^{-1}$ at a net 11.15°C thermal uplift and the modelling reported is, therefore, considered enough accuracy for thermal assessment purposes.

Basis of information presented on background concentration

Summaries of the analytical results of the monitoring surveys described in this section are provided in **Section 5.4.1** and the details of the surveys are provided in relevant monitoring reports as referenced. Environment Agency monitoring data are available for dissolved metals 1989 to 2006 for various monitoring sites from off Felixstowe to just off the river Yare however only five of the nine sites identified are within the Suffolk waterbody (see **Figure 5.4.2**). For nutrients and inorganic chemicals sample sets were identified through to 2014 and six locations were monitored within the Suffolk coastal waterbody. For the concentrations of metals in seawater from various sites within the Suffolk Waterbody only zinc exceeded the EQS off the Alde/Ore although high values were also measured in samples off Dunwich and off the mouth of the Orwell. There is no clear trend in zinc concentrations measured with values below detection interspersed with high values. For the nutrients and inorganics, the mean Ammonium ion concentrations measured are similar at all the sampling sites and are relatively low ($24 \mu g l^{-1}$) [58] . For dissolved inorganic nitrogen the data from the Environment Agency surveys indicate concentrations measured were at or below Good/Moderate status equivalent values.

Marine monitoring surveys were conducted in February 2010 to February 2011 [59]. A spatial survey was conducted at twelve sampling stations centred upon the existing cooling water outfall for the Sizewell B, at station 5 (see **Figure 5.4.1**). Further samples for selected determinands were collected and analysed during 2014 and extending into the beginning of February 2015 additional water samples were collected monthly from up to four locations (representing Sizewell B outfall and intake, Sizewell C planned outfall location and a Centre for Environmental, Fisheries and Aquaculture Science (Cefas) reference site (~2k south of Dunwich and ~1.2k offshore) [60].

The collected samples have been analysed for the range of parameters that describe general offshore water quality conditions and are also targeted specific chemicals that will be present in the surface water discharges from the proposed development during the construction, commissioning and operational phases. Justification for the siting of the monitoring points and a summary of the results are provided in BEEMS [59] and [60].

The area sampled for marine water quality for the Sizewell C studies falls within the Suffolk Coastal Water Framework Directive waterbody which is classed as a coastal waterbody. The waterbody is currently indicated to have a Moderate overall quality with the objective of reaching ‘Good Status’ by 2027. The Suffolk coastal waterbody has been classified as of moderate status for Dissolved Inorganic Nitrogen (DIN) (2013-2016, Environment Agency Catchment data explorer, 2019). However, regional sea area 2, the Southern North Sea within which the area off Sizewell is included is not considered a problem area for eutrophication under the OSPAR common procedure (UK National Report, 2017).

The key findings from the non-radiochemical water quality monitoring work are:

- In the 2010/11 survey concentrations of dissolved copper, arsenic, zinc, mercury and cadmium exceeded EQS levels on occasions. Some exceedance of the EQS concentrations for these metal and metalloid substances was detected at all stations except for stations 2 and 6. A small number of samples with concentrations in excess of their EQS were recorded for some polycyclic aromatic hydrocarbons (PAHs), biphenyl and bis (2-ethylhexyl) phthalate, though the majority of analyses for these compounds were negative. Exceedances of EQS concentrations for these organic compounds were detected at stations 1, 5, 9 and 12. All of these exceedances of organic EQSs were observed in samples acquired on three sampling dates: 7th and 8th April and the 19th May 2010.

- In the survey conducted in in 2014/15 which repeated the metals analysis, and for which improved detection limits were available for copper, zinc, mercury and cadmium, copper was detected above its EQS on 4/57 samples occasions across the four locations surveyed and zinc was above its EQS for 44/57 samples. In this more recent survey chromium (analytical method not specific for chromium VI but worst-case assumption made that 100% contribution to measured value is the more toxic chromium VI for which the EQS is established) was above detection in 10/57 samples with the remainder below detection (<0.5μg l^{-1}). Annual average values for chromium and copper were below their respective annual average EQS values.

- In 2010/11 chlorine produced TRO varied between 10 – 160μg l^{-1}. The EQS for TRO is 10μg l^{-1}. The mean of all TRO measurements (n=725) was 40 μg l^{-1}. Slight localised elevation of TRO was observed near the cooling water outfall and was below the level of detection within 2.4km to the north and 500m to the south. Elevated TRO was observed at the southern extremity of the survey area (at stations 9 and 12, see **Figure 5.4.1**) but there was no spatial pattern to indicate that this elevation was connected to the power station outfall at Sizewell B.

- Bromoform was detected at Station 5 (near the cooling water outfall of Sizewell B) at concentrations of 2 -10µg l^{-1}

- Of the 81 water samples acquired at Stations 1 to 12, 78 gave negative results for morpholine. The three positive results (all obtained from surface-water samples) were measured in two samples from Station 5 (Sizewell B outfall) and one further offshore (Station 11). Morpholine is not used by Sizewell power station as a conditioning product and does not occur naturally. The reason for these analysis results is therefore uncertain.

- Another conditioning product potentially used in UK EPRs for pH control, ethanolamine, was not detected in any of the samples acquired.

- Nutrients analysis conducted in the 2014/15 survey confirmed a low background concentration of total ammonia with a mean across all sampling locations of 11.38μg l^{-1}. The average phosphorus concentration was 33.4 μg l^{-1}. Under the Water

Framework Directive, the assessment of dissolved inorganic nitrogen status requires a mean winter concentration in micromoles per litre (µM/l) to be calculated for samples collected between the 1st November and the 28th February. Nutrient status of waterbodies references winter DIN and the level of Suspended Particulate Matter (SPM) as this affects light penetration and therefore also affects the growth of phytoplankton in response to DIN concentration. There are four waterbody types defined in terms of annual mean SPM and the waters off Sizewell would be considered of intermediate turbidity (10 -100mg l^{-1}). Within this turbidity range 99 percentile DIN of 980 and 1470µg l^{-1} would be classed as Good or Moderate. Sampling during 2014/15 for measurement of DIN from each of four sample locations between November and February confirmed a background winter DIN 99 percentile of 425µg l^{-1} for Sizewell, indicating High to Good status. However, it is noted that based on the Environment Agency assessment the Water Framework Directive (WFD) waterbody Suffolk coastal is classified as of moderate status for DIN.

- The marine waters off Sizewell are characterised by intermediate concentrations of SPM. Survey work at Sizewell carried out in 2009 – 2010 show Seasonally, inshore (Station 5, TR189 [59], 2010/11) SPM 1 m above the seabed ranged between 15 - 144 (April – August) and 9 – 426 (September – February). Additional sampling in 2016 on three occasions over a tidal cycle showed an SPM mean (and range) for July of 25.2 (8.65 – 68.35) mg l^{-1}, 16.67 (7.21 – 38.38) mg l^{-1} August and 10.61 (5.20 – 16.98) mg l^{-1} for September. Satellite data was also used to describe spatial and temporal patterns of turbidity at Sizewell. The data had previously been compared with measurements of turbidity from research cruises and the Cefas SmartBuoy network for several UK coastal and offshore sites and showed a good correlation. Satellite data for Sizewell for suspended particulate matter showed average mean and maximum SPM values from April to August of 30.6 and 80.8 mg l^{-1} and during September to March 72.7 and 180.4mg l^{-1}.

- pH values were typical of seawater with a mean overall value of 8.02 and 95th percentile of 8.2pH units [59].

- Salinity varied slightly between the sampling programmes in 2010/11 and 2014/15 the overall mean value was 33.1 and the 95th percentile was 34.5 which is in the normal range for full strength seawater.

- During the survey period 2014/15 dissolved oxygen concentrations were between 6.96 and 11mg l^{-1} which was well above the requirement for High status (5.7mg l^{-1}). Lowest measured values were in summer with the lowest values of 6.96 -7.04mg l^{-1} recorded in July 2015.

- Conductivity, temperature and depth sensor profiles showed that the waters sampled were well mixed for salinity. The temperature profiles indicated the presence of a thermally buoyant plume of water at the sea surface. Many of the chemical analyses gave negative results, indicating that the analytes were either absent or present at concentrations below the limits of detection. Few differences between results from inshore of Sizewell Bank and offshore were noted.

The results of this programme show that the concentrations of many elements and compounds are relatively uniform in the programme area. A small percentage of the samples acquired indicated that EQSs may occasionally be exceeded, though there is no indication that this is caused by Sizewell B power station.

Explanation of derivation of loadings - Proportion of un-ionised ammonia

A full assessment of the potential impact of ammoniacal nitrogen discharges requires an assessment of the relative contribution to the un-ionised ammonia concentration. A further calculation is required to derive the un-ionised ammonia contribution as it is influenced by the physicochemical character of the water and this is explained in the following below.

Total ammonia concentrations from operational inputs (sanitary plus other inputs i.e. circuit conditioning) and the existing site background values are combined. Both an average annual loading and maximum 24-hour loading are considered. For the annual assessment the annual ammonia value for combined operational sources plus background for the site are used with average pH, salinity and temperature in the Environment Agency calculator to derive the annual un-ionised ammonia concentration. To derive the 24-hour maximum loading of un-ionised ammonia, extreme values for temperature, pH and salinity that maximise the proportion of un-ionised ammonia are used in the Environment Agency un-ionised ammonia calculator with the 24-hour loading of ammoniacal nitrogen and site background ammonia to derive the maximum un-ionised ammonia value.

The ammonia background concentration in the seawater is based on monitoring data from BEEMS Technical Report TR314 [60]. The physicochemical data for the site are derived from BEEMS report TR189 [59]. Comparable summary statistics for physicochemical parameters were derived for surveys from 2010/11 and 2014/15 for pH and salinity (i.e. from 2010 as a 50th percentile pH 8.05 compared to 8.01 and salinity 33.3 compared to 33.7) the slightly more precautionary values for 2010 are used for these parameters. These values were also used for the in combination thermal assessment, so this provides a consistent approach. However, the more reliable data for ammonia background from the 2014 survey was used.

The un-ionised ammonia loadings were calculated using the Environment Agency calculator which requires input data for temperature, salinity, pH and total ammonia and takes account of typical and worst-case temperature uplift. All these source data were specific to the Sizewell site. The data recorded during the 2010 monitoring survey at Sizewell and for the historic temperature record for the site were the reference source for the relevant physicochemical data used to derive un-ionised ammonia values for screening. For the annual assessment the 98th percentile temperature (19.4°C), the 50th percentile pH (8.05) and the 50th percentile salinity (33.3) were used to calculate un-ionised ammonia concentration. These values together with the typical uplift of 11.6°C for the cooling water from Sizewell C provided the input parameters for the Environment Agency calculator together with the total ammonia concentration to derive the maximum annual loading of un-ionised ammonia. In a worst-case scenario when 2 out of 4 pumps are under maintenance the flow of cooling water would be halved but the heat content of 2 full power reactors would remain approximately the same raising the excess temperature at the outfall from 11.6°C to 23.2°C. Hence a value of 23.2°C together with the 98th percentile temperature (19.4°C) 95th percentile pH (8.2) and 5 percentile salinity (31.7) was used to derive the maximum 24h loading for un-ionised ammonia. This latter assessment is very precautionary as instead of taking "mean" values for the parameters influencing ammonia speciation, it has used extreme values which maximise the proportion of un-ionised ammonia. This approach was adopted as un-ionised ammonia concentrations are a particularly sensitive issue (e.g. in some cases as a potential barrier to fish migration).

The maximum 24-hour and annual discharge loadings for total ammonia for 2 EPR units are the following (including all sources of nitrogen, including sanitary waste):

- Maximum Annual total ammonia discharge loading = 14396kg / year (combined waste streams 13009kg + sanitary 1387kg.
- Maximum 24-hour total ammonia discharge loading = 77kg / day (combined waste streams 73.13kg + sanitary 3.8 kg).

Using the Environment Agency calculator for un-ionised ammonia with the above load input data and relevant physicochemical parameters the maximum un-ionized ammonia discharge loadings for 2 EPR units the following un-ionised ammonia loads are calculated:

- Maximum 24-hour un-ionised ammonia discharge loading = 28kg / day (combined waste streams 95% contribution + sanitary 5% contribution).
- Maximum Annual total ammonia discharge loading = 958kg / year (combined waste streams 90.4% contribution + sanitary 9.6% contribution).

4.1.2 Effluent Stream A: Main cooling water return

Sources of emissions associated with Effluent Stream A

The main purpose of the open circuit cooling water systems is to remove waste heat from the operational systems in the power station and discharge it to the sea for dissipation into the environment in a way that avoids significant adverse environmental effects. The heat content is a major component of the spent cooling water discharge that has potential to cause thermal pollution of the environment.

The chlorination (through dosing with sodium hypochlorite) of the seawater to control biofouling will give rise to the presence in Effluent Stream A of hypochlorous acid and hypochlorite ions as well as a range of chlorinated and brominated chlorination by-products. Those with oxidising properties (and thus effective in varying degrees in restricting biofouling) are referred to as TRO and concentrations are expressed in terms of the equivalent concentration of chlorine.

Sources of pollutants present in effluent discharge Stream A are summarised in **Table 4.1.3**. The arrangements of this system are set out in Appendix A **Figure 2.3.1** from abstraction of the sea water to its discharge at a higher temperature after use for cooling.

Table 4.1.3 Sources of emissions associated with the sea water cooling systems

Descriptor	Pollutants present in the effluent stream
Use of sea water for cooling	Use of the sea water for cooling will result in a discharge of heat to the marine environment. Under normal power operation, the discharged cooling water (Stream A) will have a temperature of 11.6°C above the sea water temperature at the intake.
Chlorination of the sea water cooling systems	Chlorine will be dosed as sodium hypochlorite solution in sea water (generated by electrolysis or by addition as solution tankered to site) to provide a target concentration of total residual oxidants (as chorine) of 0.2 mg/l at the condensers. This would be <0.2mg/l at the Outfall Pond [HCA] and estimated to result in a TRO concentration of <0.15mg/l at entry to the sea at the end of the sea-outfall [HCT].

Flow characteristics of Effluent Stream A

Table 4.1.4 summarises the flow characteristics of the cooling water systems. During normal power generating operation, Stream A comprises a continuous discharge, with flows varying slightly with tidal water level.

Table 4.1.4 Flow rates of discharges from the cooling water system (Stream A)

Descriptor	Flow rate of Effluent Stream A (abstracted flow will vary with tidal water level)
Effluent discharged from each EPR unit during normal power operation	During normal operation, the sea water pumping stations nominal intake for a single EPR unit, at mean tidal water level, is distributed as follows: • 61m^3/s for [CRF] via 2 pumps each 30.5m^3/s nominal flow; • 2.8m^3/s for the [SEN] via 4 pumps (2 in operation at any time) each 1.4 m^3/s nominal flow; • 2.0m^3/s for the [SEC] via 4 pumps (2 normally in operation at any time) each 1.0 m^3/s nominal flow; • 0.14m^3/s for the [SRU] via one pump of 0.14m^3/s nominal flow; • 0.04m^3/s for the electro-chlorination system [CTE] via one pump of 0.04m^3/s nominal flow; • 0.56m^3/s for wash water for the drum screens and band screens [CFI] via 2 pumps for drum screens and 2 pumps for band screens. Thus, the maximum abstracted flow at mean tidal water level, which will be the same as the tidally averaged flow rate, will be 66.54m^3/s. Of this, 0.3m^3/s will be discharged through the fish recovery and return system outfall. Therefore, the net discharge per EPR unit of Stream A at mean tidal level (= tidally averaged flow) will be 66.25m^3/s
Combined effluent discharged from both EPR units at Sizewell C during normal power operation	For both EPR units the discharge rate (as a tidal mean) will be 132m^3/s. For both EPR units the minimum discharge rate (instantaneous) at low tide will be 116m^3/s.
Combined effluent discharged from both EPR units at Sizewell C during outage of one EPR unit	For both EPR units the discharge rate (as a tidal mean) will be 71.5m^3/s ([CRF] pumps for one unit not operating)
Combined effluent discharged from both EPR units at Sizewell C during normal power operation but with outage of one [CRF] pump	For both EPR units the discharge rate (as a tidal mean) will be 102 m^3/s (one [CRF] pump not operating)

Physical and chemical characteristics of Effluent Stream A

Table 4.1.5 shows physical and chemical characteristics of cooling water Effluent Stream A, identifying pollutants predicted to be present. EQS are included, where established for sea water, to provide a comparative value. Monitoring surveys at Sizewell [59] and [60] established background concentrations for various physicochemical parameters and these were used in assessment of additional inputs from Stream A (for background concentrations for various substances determined during several monitoring campaigns see **Section 5.4**).

Table 4.1.5 Characteristics of discharges from the cooling water system (Stream A)

Substance	EQS for sea water	Mean	Maximum	Annual load	Note
Total residual oxidants	10 µg/l (as Cl) (as 95%ile)	200 µg/l (as Cl)	200 µg/l (as Cl)	N/A	Target value at outfall pond. Predicted discharge concentration = 0.15 mg/l
pH	-	6-9	-	N/A	Limits of range of pH
Oil and grease	-	-	None visible	N/A	

Temperature characteristics of Effluent Stream A

Table 4.1.6 shows temperature characteristics of cooling water Effluent Stream A.

Table 4.1.6 Temperature characteristics of cooling water discharges (Stream A)

Temperature Parameter	Temperature
Maximum temperature of Effluent Stream A.	35°C (as a 95th percentile)
Maximum temperature increase between sea water inlet (forebay) and outfall pond during normal power operation including outage of one EPR unit.	11.6°C (as a tidal mean)
Maximum temperature increase between sea water inlet (forebay) and outfall pond during an outage of one [CRF] pump for maintenance, the minimum likely cooling water flow (combined flow from both EPR units) corresponds to operation of three out of the four [CRF] pumps, with all other cooling water pumps [SEN], [SEC] and [SRU] operating normally.	23.2°C. (as a tidal mean)

4.1.3 Effluent Streams B and C: Main cooling water return

This section considers the following effluent streams associated with chemical constituents of the emissions of effluents potentially containing radioactivity:

- A block flow diagram for discharge of waste from the Nuclear Island is given in Appendix A, **Figure 2.3.2**.
- A block flow diagram of the Steam Generator and Blowdown System is given in Appendix A, **Figure 2.3.3**.

It is important to note that this section does not include an assessment of the discharges of any radionuclides (which is covered under the Sizewell C RSR Permit application [51]. Please see **Section 2.3.3** of this report for a basic description of radioactive discharges and treatment techniques.

Sources of emissions associated with Effluent Streams B and C

Effluent Streams B and C will be discharged together from the [KER] tanks and have been considered together from here onwards in this report.

The contaminants associated with the liquid radioactive effluent arisings derive from various chemical dosing processes within the primary circuit, the secondary circuit and a number of nuclear and conventional auxiliary circuits. For various operational and maintenance reasons, these chemicals and their breakdown products cannot be retained within those systems. Contaminants can also arise from wear and corrosion within the systems. A brief summary of contributions to Effluent Streams B and C is given in **Table 4.1.7**.

Table 4.1.7 Sources of emissions associated with Effluent Streams B and C

Activities	Components of the effluent
Dosing the primary circuit	The primary circuit will be treated with the following chemicals, which may be present in reactor let-down discharged to the radwaste system: • boric acid for its neutron-absorbing properties. Throughout the fuel cycle, increased volumes of borated water will be let down (removed) from the reactor coolant system and replaced by water or boric acid at lower concentrations. As the fuel burn-up increases during the fuel cycle and less boron is required in the reactor cooling water (primary system). A larger volume of borated water will need to be let down each month progressively through the fuel cycle. Currently there are no proposals to recycle boron at Sizewell C; • lithium hydroxide, to offset the acidity of the boric acid, to keep the pH slightly alkaline and prevent equipment corrosion; • zinc acetate to inhibit corrosion; • hydrogen peroxide during shutdown to produce an oxidising environment; and • hydrazine during start up to eliminate oxygen from the reactor coolant to minimise corrosion. Any hydrazine present in the effluent will be treated in the [KER] tanks before discharge of the effluent at an agreed limit.

Activities	Components of the effluent
Dosing the secondary circuit	In order to obtain a pH where minimum levels of corrosion occur, a basic compound must be injected into the secondary circuit. Compounds that can be used for this dosing include ammonia, morpholine and ethanolamine. Whichever dosing compound is used to maintain the pH for minimum corrosion, ammonia will always be present in the secondary circuit. Dosing will be supplemented with hydrazine to eliminate oxygen in the feedwater to prevent fouling of the steam generators caused by corrosion products (mainly iron oxides). Hydrazine decomposes when heated to produce ammonia. Where the conditioning uses ammonia, the quantity of ammonia produced by the decomposition of hydrazine is not sufficient to maintain the pH for minimum corrosion, and therefore additional ammonia needs to be added. Where the conditioning uses morpholine or ethanolamine, the thermal decomposition of hydrazine means that ammonia is also present in the secondary circuit.
Dosing of the circuits during shutdown/ Maintenance of steam generators	The feedwater plant for the secondary circuit is kept dry during shutdown. To minimise corrosion, the steam generators will potentially be filled with demineralised water treated during shutdown with: • hydrazine; and • morpholine, ammonia or ethanolamine. Once the outage is over, the solution used for wet lay-up may be either drained into the [KER] tanks as Effluent Stream C or directly heated in the steam generators as the installation restarts. Any hydrazine present in the effluent will be treated in the [KER] tanks before discharge of the effluent at an agreed limit, see FAP **Section 7.3.3**, Action 3: Development of the operational management plans (Hydrazine Management Plan).
Dosing in the auxiliary nuclear and conventional circuits	Trisodium phosphate will be dosed to the cooling and heating circuits to inhibit corrosion in circuits in contact with air, where an all-volatile treatment cannot be used, and may be discharged into the environment during the plant operation.
Decontamination of tools and parts used during unit outage	Chemicals will be used in the decontamination workshop. The effluent generated will be filtered, sampled and sent either to the Liquid Waste Processing System for further treatment or to the Liquid Radwaste Monitoring and Discharge System tanks.
Wear in the circuits	Metals arising from wear in the circuits will be found in the discharged liquids associated with radioactive effluent. These metals will be those used to manufacture either the circuits or some of the equipment (aluminium, copper, chromium, iron, lead, manganese, nickel and zinc). Appropriate chemical conditioning and operation during hot functional testing is a major factor in limiting the amount produced. Although the effluent will be filtered and treated with ion exchange resins, small quantities of these metals will be released the discharge tanks.

Activities	Components of the effluent
Miscellaneous contaminants	Floor and equipment drains may be contaminated with cement dust (calcium compounds), possibly small concentrations of soaps and detergents, chemicals from closed cooling systems leaks or spills, decontamination water and other sources. The floor drains may also be high in dissolved organic materials and salts. The radioactive chemistry laboratory sink drains will give rise to releases of mixed hazardous/radioactive wastes or other radioactive wastes with a high dissolved solids content Suspended solids will arise from collected effluent that may be polluted either by dust. There will only be limited suspended solids in the Liquid Radwaste Monitoring and Discharge System storage tanks, because the effluent will be filtered. The effluent will also include chemical oxygen demand (COD), which will come from the organic compounds (particularly detergents) to be used and also from oxidisable mineral salts in the water used. Potential metal contaminants in process chemicals are present in only trace amounts, as is reflected in the low discharge loading values determined for cadmium and mercury, even after applying conservative and bounding assumptions.

Flow characteristics of Effluent Streams B and C

Once the contents of the [KER] tanks have been approved for discharge, the effluent will be pumped at a rate limited by the maximum pump capacity of 250m^3/h to the Outfall Pond [HCA] until the tank is empty. Thus, discharges will be intermittent, with flows discharged for approximately three hours at a time during emptying of a [KER] tank. Flow characteristics are summarised in **Table 4.1.8**.

Table 4.1.8 Flow rates of discharges from the radwaste system (Streams B and C combined)

Descriptor	Flow rate
Maximum volume of effluent discharged per day from [KER] tanks	1,500m^3/d
Maximum rate of discharge from a single [KER] tank	0.08m^3/s (83.3 litres/s)[1]

[1] based on a maximum pump capacity of 300m^3/h

Physical and chemical characteristics of Effluent Streams B and C

Table 4.1.9 summarises the chemical characteristics of effluents released from the Nuclear Island and the steam generator blowdown system. EQS are included, where established for sea water, to provide a comparative value (see environmental risk assessment in **Section 5** for detailed assessment).

Table 4.1.9 Characteristics of discharges from the radwaste system for 2 EPR units (Streams B and C combined)

Substance	EQS for sea water	Daily load kg/day	Annual load kg/year	Maximum Pre-dilution concentration mg/l	Note
Boron	AA – 7mg/l	984	2448	656	Environment Agency operational EQS.
Lithium (as LiOH)	-	4.4	8.8	2.93	
Hydrazine [1]	Probable no-effect concentration (PNEC) (AA) – 0.4ng/l PNEC (MAC) – 4ng/l	1.00	3.00	0.67	Optimisation of hydrazine destruction and system to be developed. See FAP **Section 7.3.3**, Action 3: Development of the operational management plans. PNEC based on EDF R&D review.
Morpholine	PNEC (AA) – 17µg/l PNEC (MAC) – 28µg/l	75.00	210	50.0	PNEC based on EDF R&D review.
Ethanolamine	PNEC (AA) – 160µg/l PNEC (MAC) – 160µg/l	15.00	65	10.0	PNEC based on EDF R&D review.
Nitrogen (as N) [2]	Loading assessed against natural background using modelling	8.2	253.25	5.33	Assessment made using combined phytoplankton macroalgal modelling **Section 5.**
Nitrogen (in terms of ammonia ions NH_4)	AA – 21µg/l (un-ionised)	1.83	325.2	0.95	
Phosphate (as P)	-	150.00	602.5	100	
Suspended solids	-	20.24	135	13.5	

Chemical oxygen demand (COD)	-	39.27	601	26.2	
Aluminium	-	0.09	0.41	0.06	
Copper	MAC – 3.76µg/l where DOC ≤1mg/l (dissolved)	0.01	0.03	<0.01	Where dissolved organic carbon (DOC) concentration exceeds 1 mg/l: EQS is 3.76+(2.677x((DOC/2)-0.5)).
Chromium	Cr^{VI} only AA – 0.6µg/l MAC – 32µg/l	0.14	0.65	0.09	
Iron	AA – 1 mg/l (dissolved)	0.60	2.70	0.40	
Manganese	-	0.06	0.26	0.04	
Nickel	AA – 8.6µg/l MAC – 34µg/l	0.01	0.03	0.01	
Lead	AA- 1.3 µg/l MAC – 14µg/l	0.01	0.02	<0.01	
Zinc	AA- 6.8µg/l plus ambient	0.10	0.46	0.07	

PNEC – predicted no-effect concentration

[1] Effluent streams B+C are fed from the primary circuit and so the hydrazine loads are not factored into daily and annual discharge calculations as they have no daily discharge and only apply during start up or shut down periods. The worst-case daily hydrazine discharge would be after wet lay-up of steam generators. The assumption is that this would be treated until the hydrazine concentration falls below a level that is acceptable for a batch discharge. Wet lay-up is not expected in a normal refuelling outage (i.e. for Sizewell B this was ~15 years after first operation). Only emissions which are derived from the secondary circuit (Effluent Stream D) daily loads are therefore used in the environmental impact assessment.

[2] excluding hydrazine, morpholine and ethanolamine – further discussion of the potential influence of these nitrogen inputs of this is provided in **Section 5.**

Temperature characteristics of Effluent Streams B and C

Table 4.1.10 summarises the temperature characteristics of effluents released from the Nuclear Island and the steam generator blowdown system.

Table 4.1.10 Temperature characteristics of discharges from the radwaste system (Streams B and C combined)

Temperature Parameter	Temperature
Maximum temperature of Effluent Stream B + C	Ambient, no greater than 25°C

4.1.4 Effluent Stream D: Trade effluents from the conventional island

This section considers effluents generated by activities undertaken at the Conventional Island (incorporating the Turbine Hall [HM]) (Stream D). The effluents arise from the following activities in each EPR unit:

- water drained from the Turbine Hall [HM] from leakage;
- drainage of the secondary circuits (excluding blowdown from the steam generators - Effluent Stream C);
- floor drains from the uncontrolled area of the Nuclear Island (floor drains 3 [FD3]).

A block flow diagram for discharge of effluent from the Conventional Island is given in Appendix A **Figure 2.3.4**.

Sources of emissions associated with Effluent streams D

Effluents from the Conventional Island may contain corrosion inhibitors (hydrazine, morpholine, ethanolamine, tri-sodium phosphate) and metals arising from corrosion. Floor drains collecting uncontaminated fluid from leaks, floor washing, and drainage of equipment in uncontrolled areas of the Nuclear Island (called Floor Drains 3) are also routed to the Conventional Island liquid waste discharge system [SEK].

A summary of sources of pollutants associated with Effluent Stream D is given in **Table 4.1.11**.

Table 4.1.11 Sources of emissions associated with releases from the Conventional Island (Stream D)

Activities	Components of the effluents
Dosing the secondary circuit	In order to obtain a pH where minimum levels of corrosion occur, a basic compound must be injected into the secondary circuit. Compounds that can be used for this dosing include ammonia, morpholine and ethanolamine. Whichever dosing compound is used to maintain the pH for minimum corrosion, ammonia will always be present in the secondary circuit. Dosing will be supplemented with hydrazine to eliminate oxygen in the feedwater to prevent fouling of the steam generators caused by corrosion products (mainly iron oxides). Hydrazine decomposes when heated to produce ammonia. Where the conditioning uses ammonia, the quantity of ammonia produced by the decomposition of hydrazine is not sufficient to maintain the pH for minimum corrosion, and it is therefore additional ammonia needs to be added. Where the conditioning uses morpholine or ethanolamine, the thermal decomposition of hydrazine means that ammonia is also present in the secondary circuit. Additional ammonia will also be injected to ensure sufficient conditioning in the vapour and liquid phases of the secondary circuit.

Activities	Components of the effluents
Dosing in the conventional circuits	Trisodium phosphate will be dosed to the cooling and heating circuits to inhibit corrosion in circuits in contact with air, where an all-volatile treatment cannot be used, and may be discharged into the environment during the plant operation.
Wear in the circuits	Metals arising from wear in the secondary circuits will be found in the discharged liquids. These metals will be those used to manufacture either the circuits or some of the equipment (aluminium, copper, chromium, iron, lead, manganese, nickel and zinc).
Miscellaneous	Potential metal contaminants in process chemicals are present in only trace amounts, as is reflected in the low discharge loading values determined for cadmium and mercury, even after applying conservative and bounding assumptions.
Miscellaneous contaminants	Floor and equipment drains may be contaminated with cement dust (calcium compounds), possibly small concentrations of soaps and detergents, chemicals from closed cooling systems leaks or spills, decontamination water and other sources. The floor drains may also be high in dissolved organic materials and salts. Corrosion products associated with the metallurgy of the systems and will also be present in the effluent. Suspended solids will arise from collected effluent that may be polluted either by dust. The effluent will also include COD, which will come from the organic compounds (particularly detergents) to be used and also from oxidisable mineral salts in the water used.

Flow characteristics of Effluent Stream D

Once the contents of the [SEK] tanks have been approved for discharge, the effluent will be pumped at a rate limited by the maximum pump capacity of 300m^3/h to the Outfall Pond [HCA] until the tank is empty. Thus, discharges will be intermittent, with flows discharged for approximately two to three hours at a time during emptying of a [SEK] tank. Flow characteristics are summarised in **Table 4.1.12**.

Table 4.1.12 Flow rates of discharges from the Conventional Island (Stream D)

Descriptor	Flow rate
Maximum volume of effluent discharged per day from [SEK] tanks	1,500m3/d
Maximum rate of discharge from a single [SEK] tank	0.08m3/s (83.3 litres/s)[1]

[1] based on a maximum pump capacity of 300m^3/h

Physical and chemical characteristics of Effluent Stream D

Table 4.1.13 summarises the chemical characteristics associated with the effluent discharged from the Conventional Island [SEK] tanks (Stream D). These receive effluents arising from the Conventional Island.

Table 4.1.13 Characteristics of discharges from the Conventional Island [SEK] tanks for 2 EPR units combined (Stream D)

Substance	EQS for sea water	Daily load kg/day	Annual load kg/year	Maximum Pre-dilution concentration mg/l	Note
Hydrazine	PNEC (AA) – 0.4ng/l PNEC (MAC) – 4ng/l	3.0	24.3	2.0	Optimisation of hydrazine destruction and system to be developed. See FAP relating to discharge of hydrazine. PNEC based on EDF R&D review
Morpholine	PNEC (AA) – 17µg/l PNEC (MAC) – 28µg/l	17.25	1464	11.5	PNEC based on EDF R&D review
Ethanolamine	PNEC (AA) – 160µg/l PNEC (MAC) – 160µg/l	9.75	854	6.5	PNEC based on EDF R&D review
Nitrogen (as N) [1]	Loading assessed against natural background using modelling	319.8	9876.7	8.0	Assessment made using combined phytoplankton macroalgal modelling **Section 5**
Nitrogen (in terms of ammonia ions NH_4)	AA - 21µg/l (un-ionised)	71.3	12683.7	47.53	
Phosphate (as P)	-	202.5	187.5	135.0	
Suspended solids	-	399.8	2665	267	
Chemical oxygen demand (COD)	-	290.7	4449	194	
Aluminium	-	1.01	4.85	0.67	

Substance	EQS for sea water	Daily load kg/day	Annual load kg/year	Maximum Pre-dilution concentration mg/l	Note
Copper	MAC – 3.76µg/l where DOC ≤1mg/l (dissolved)	0.074	0.39	0.05	Where DOC concentration exceeds 1mg/l: EQS is 3.76+(2.677*((DOC/2)-0.5))
Chromium	CrVI only AA – 0.6µg/l MAC – 32µg/l	1.56	7.72	1.04	
Iron	AA - 1mg/l (dissolved)	6.55	32.27	4.37	
Manganese	-	0.61	3.07	0.41	
Nickel	AA – 8.6µg/l MAC – 34µg/l	0.083	0.41	0.06	
Lead	AA- 1.3µg/l MAC – 14µg/l	0.055	0.28	0.04	
Zinc	AA- 6.8µg/l plus ambient	1.10	5.54	0.73	

[1] excluding hydrazine, morpholine and ethanolamine

Temperature characteristics of Effluent Stream D

Table 4.1.14 summarises the temperature characteristics of effluents released from the Nuclear Island and the steam generator blowdown system.

Table 4.1.14 Temperature characteristics of discharges from the Conventional Island (Stream D)

Temperature Parameter	Temperature
Maximum temperature of Effluent Stream D	Ambient, no greater than 25°C

4.1.5 Effluent Stream E: Site drainage system

Sources of emissions associated with the site drainage system (Stream E)

The site drainage network [SEO EP] (Stream E) receives releases arising from:

- road and roof drainage;

- drainage from the oily water network [SEH] subject to potential hydrocarbon contamination including transformers and electrical equipment areas, diesel fuel storage, diesel generators, workshops and chemical storage; and,
- condensate from chillers.

A flow diagram of Effluent stream E is presented in Appendix A, **Figure 2.3.5.**

Table 4.1.15 summarises the chemical characteristics associated with the effluent arising from the Site Drainage Network.

Table 4.1.15 Sources of emissions associated with releases from the site drainage system (Stream E)

Activities	Components of the effluent
Transfer of solid and liquid contaminants to the site drainage network	Hydrocarbons will be present in run off from operational areas. Silt and suspended solids will also be released into the system. The oil/water separators will be specified to the meet the requirements of the BS-EN-858 Class 1 standard to provide effective treatment for hydrocarbons. The by-pass oil/water separator will reduce hydrocarbon concentrations in the effluent discharged to the forebay to less than 5mg/l. Hydrocarbons retained in the oil/water separator together with the resultant sludge will be disposed of off-site at an appropriately licensed waste management facility.
Pollutants associated with condensate	Although chiller condensate is essentially generated as distilled water it may contain low levels of metals from corrosion of metal equipment.

Flow characteristics of Effluent Stream E

The design of the oil/water separators and site drainage system is a site specific design which is yet to be determined. The flows will vary according to operational arrangements and prevailing meteorological conditions. The maximum volume @ 30 YR + 40% CC for 24-hour winter storm is anticipated to be circa 35,000m^3. This assumes the following:

- The site is fully impermeable.
- No water is collected for re-use.
- All discharges are disposed of through the main outfall
- Climate change of 40% has been allowed for in accordance with current Environment Agency guidance for climate change.
- A 30-year storm event has been allowed for.

- The site area is approximately 40ha. This may change in the future should the surface water be managed differently long term.

With the above information, and a rainfall depth of approximately 3.57mm/hour over a 24-hour storm, the 35,000m^3 figure has been calculated. The l/s discharge rate will be determined during the design process.

Physical and chemical characteristics of Effluent Stream E

A summary of the physical and chemical characteristics of effluent released from the site drainage network is provided in **Table 4.1.16**.

Table 4.1.16 Characteristics of discharges from the site drainage network (Stream E)

Substance	EQS for sea water	Mean	Maximum	Annual load	Note
Petroleum hydrocarbons	-	-	5 mg/l	N/A	Concentration limited by use of Class 1 oil/water separators to BS-EN-858
Oil and grease	-	-	None visible	-	

Temperature characteristics of Effluent Stream E

Table 4.1.17 summarises the temperature characteristics of effluents released from the Nuclear Island and the steam generator blowdown system.

Table 4.1.17 Temperature characteristics discharges from the site drainage network (Stream E)

Temperature Parameter	Temperature
Maximum temperature of Effluent Stream E (including demineralisation pit flows from Stream F)	Ambient, no greater than 25°C

4.1.6 Effluent Stream F: Demineralised water production trade effluent

Sources of emissions from the demineralisation process

Discharges from the process carried out in the demineralisation plant for production of high purity water will contain a range of substances, as discussed below:

- There will be emissions of iron and suspended solids associated with preliminary treatment of raw water. However, Sizewell C will use mains water for the production of demineralised water and as such Effluent Stream F will not be a significant source of iron or suspended solids.

- Sulphates will be introduced when the demineralisation resins and membranes are cleaned with sulphuric acid or when basic effluent is neutralised with sulphuric acid.
- Sodium will be introduced to Effluent Stream F when the demineralisation resins and membranes are cleaned with sodium hydroxide and when effluent is treated with sodium hydroxide in the neutralisation pit.
- Sizewell C will use mains water for the production of demineralised water and as such Effluent Stream F will not be a significant source of chlorides.

Table 4.1.18 shows the sources of emissions associated with releases from water demineralisation. A flow diagram of Effluent Stream F is presented in Appendix A, **Figure 2.3.6**.

Table 4.1.18 Sources of emissions associated with releases from water demineralisation (Stream F)

Activities	Components of the effluents
Treatment of potable water	The effluent released from the demineralised water plant will be characterised by the quality of potable water.
Miscellaneous	Potential metal contaminants in process chemicals are present in only trace amounts, as is reflected in the low discharge loading values determined for cadmium and mercury, even after applying conservative and bounding assumptions.
Increasing the solubility of salts to decrease scale formation on reverse osmosis membranes	Sequestering agents are used in the desalination plant to prevent mineral deposits forming on the reverse osmosis membranes. Use of such chemicals would result in additional components released in the reject water.
Filter washing. Regeneration of mixed bed ion exchange resins. Cleaning in place (CIP) of reverse osmosis membranes	Self-cleaning filter washing would involve use of additional water and result in an increase of suspended solids. CIP and ion exchange bed regeneration will involve use of sulphuric acid and sodium hydroxide. Effluent from these processes as well as reverse osmosis reject water will pass to the neutralisation pit for pH balancing and effluent will be released after testing to the Outfall Pond [HCA]. After neutralisation the effluent will comprise sodium and sulphate ions at a pH within the acceptable range. These are not regarded as polluting materials when discharged to sea water. Use of additional chemicals would result in additional contaminants in the neutralisation pit effluent.

Flow characteristics of Effluent Stream F

Table 4.1.19 below outlines the flow characteristics of the trade effluent from demineralised water production.

Table 4.1.19 Flow rates of discharges associated with Effluent Stream F

Flow Characteristics	Demineralised Water Production Trade Effluent
Maximum volume of effluent discharged per day (m^3/day)	4000
Maximum rate of discharge (l/s)	46

Physical and chemical characteristics of Effluent Stream F

Current estimations of discharge loadings from the demineralisation plant are largely based on extrapolation of information from the Flamanville 3 site (combined desalination and demineralisation plant) and local sea water quality. The proposal for Sizewell C is that demineralised water would be generated from a mains water supply rather than through use of desalination. There are no discharge loading data currently available for only demineralisation of the mains water supply. Therefore, the assessment has adopted the discharge loading values for a combined desalination and demineralisation plant. This is considered to provide bounding conditions of a worst-case discharge scenario. The expected effluents from a combined desalination and demineralised plant are presented in **Table 4.1.20**. The values presented are based on the production of water for two EPR units. These maximum discharge values assume the desalination units run continuously and that the demineralisation unit runs for several hours each day with a regeneration cycle occurring every 30 days.

Table 4.1.20 Characteristics the demin system (Stream F)

Substance	EQS for sea water	Daily load kg/day	Annual load kg/year
Detergents	-	-	624
Suspended solids	-	450	88000
Iron	AA - 1 mg/l (dissolved)	250	46000
Chloride	-	450	87100
Sulphates	-	2000	98400
Sodium	-	855	52400

Amino tri-methylene phosphonic acid	-	45	9100
HEDP	-	4.5	890
Acetic acid	-	0.1	14
Phosphoric acid	-	0.1	12
Sodium polyacrylate	-	40	8030
Acrylic acid	-	1	165

Sequestering agents

Sequestering agents are used in the demineralisation plant to prevent mineral deposits forming on the reverse osmosis membranes. For the Sizewell C demineralisation plant one of two sequestering agents will be used i.e. either Amino tri-methylene phosphonic acid (ATMP) or a sodium polymer sequestering agent.

Amino tri-methylene phosphonic acid based sequestering agent

ATMP is the active ingredient in the commercial ATMP based sequestering agent. The discharge loading values for constituent chemicals and by-products associated with use of an ATMP sequestering agent are presented in **Table 4.1.21**.

Table 4.1.21 Constituent chemicals and by-products for an ATMP sequestering agent

Constituent chemicals	Proportion of commercial solution	24-hour loading (kg d^{-1})	Annual loading (kg yr^{-1})
ATMP[1]	100	45	9100
Sodium	100	45	9100

[1] ATMP = Amino Trimethylene Phosphonic Acid CAS No: 6419-19-8

Sodium polymer based sequestering agent

The commercially available product comprises 10% alky-phosphonic acid, which on use degrades into several potentially toxic by-products and 90% sodium polyacrylate, which is also potentially toxic. Details on the calculations of the loading values in discharges are presented in **Table 4.1.22.**

Table 4.1.22 Constituent chemicals and by-products for a sodium polymer sequestering agent

Constituent chemicals	By-Products	Proportion of commercial solution	24-hour loading (kg d-1)	Annual loading (kg yr-1)
Alkyl phosphonic acid (10%)	HEDP	9.75	4.5	890
	Acetic acid	0.15	0.1	14
	Phosphoric acid	0.13	0.1	12
Sodium polyacrylate (90%)	Sodium polyacrylate (polymer)	88.2	40	8030
	Acrylic acid (residual monomer)	1.8	1	165
Total		100%	45	9100

Temperature characteristics of Effluent Stream F

Table 4.1.23 summarises the temperature characteristics of released effluent from the demineralisation system.

Table 4.1.23 Temperature characteristics discharges from sewage treatment plant (Stream G)

Temperature Parameter	Temperature
Maximum temperature of Effluent Stream G	Ambient, no greater than 25°C

4.1.7 Effluent Stream G: Sanitary effluent

Source of Emissions from sewage treatment works

The sewage system will typically collect black and grey wastewater from lavatories and welfare facilities, after treatment in the Sewage Treatment Plant [HXE]; the discharge will typically be characterised by a relatively high five-day biochemical oxygen demand (BOD_5) when compared to the other effluent streams expected at the site.

There are no connections from the primary or secondary circuits to the sewage treatment system, therefore there will be no additional sources of phosphates or nitrogenous substances other than those arising from wastewater effluent discharged into the sewage system. A flow diagram of Effluent Stream G is presented in Appendix A, **Figure 2.3.7**.

Table 4.1.24 summarises sources of chemical pollutants from the sanitary effluent.

Table 4.1.24 Sources of emissions associated with releases from the sewage treatment plant (Stream G)

Activities	Components of the effluents
Releases from the Foul Sewer Network	The sewage treatment plant will be designed to achieve the following treatment specification: • biochemical oxygen demand ($BOD_{5\text{-}atu}$) concentration of 20mg/l; • ammoniacal nitrogen 20mg/l (as N); • total suspended solids of 30mg/l.

Flow characteristics of Effluent Stream G

Table 4.1.25 below outlines the flow characteristics of intermittent releases of reject water from the water demineralisation plant.

Table 4.1.25 Flow rates of discharges from the sewage treatment plant (Stream G)

Descriptor	Flow rate
Normal flow based on population equivalent of 900 using 100 litres/day (combined flow for two EPR units)	90 m^3/day
Maximum flow during an outage based on population equivalent of 1,900 using 100 litres/day (combined flow for two EPR units)	190 m^3/day

Physical and chemical characteristics of Effluent Stream G

A summary of the physical and chemical characteristics of effluent released from the site drainage network is provided in **Table 4.1.26.**

Table 4.1.26 Characteristics the sewage treatment plant (Stream G)

Substance	Maximum	Annual load
Biochemical oxygen demand (BOD5 -atu)	20mg/l	1387kg/y
Suspended solids	30 mg/l	2080kg/y
Total ammonia	20mg/l	1387kg/y[1]
Total nitrogen (as N)	23mg/l	1595 kg/y[1]

[1] Based on estimated 1900 staff on site and water volume 100l/head/day

Temperature characteristics of Effluent Stream G

Table 4.1.27 summarises the temperature characteristics of effluents discharged from the sewage treatment plant

Table 4.1.27 Temperature characteristics discharges from sewage treatment plant (Stream G)

Temperature Parameter	Temperature
Maximum temperature of Effluent Stream G	Ambient, no greater than 25°C

4.1.8 Effluent Stream H: Fish recovery and return system effluent

Source of Emissions from fish recovery and return system

A fish recovery and return system is planned to provide a safe return of the more robust organisms directly into the marine environment. A flow diagram of Effluent Stream H is presented in Appendix A, **Figure 2.3.8**. Some less robust species will suffer mortalities and so dead fish would be discharged from the fish recovery and return. The influence of the decay of the predicted biomass loading of dead fish upon several water quality parameters is considered in **Section 5**. Other than the input of live and a proportion of dead fish the discharge is a low volume seawater discharge characterised by the parameters described in the following Tables.

Flow characteristics of Effluent Stream H

Table 4.1.28 below outlines the flow characteristics of the Fish Recovery and Return system.

Table 4.1.28 Flow rates of discharges from the fish recovery and return systems (Stream H)

Descriptor	Flow rate
Discharge from fish recovery and return system outfall for one EPR unit	$0.3m^3/s$
Combined discharge from fish recovery and return system outfalls at Sizewell C power station	$0.6m^3/s$
Annual volume discharged from fish recovery and return system outfalls at Sizewell C power station	$189\ 000\ 000m^3/y$

Temperature characteristics of Effluent Stream H

Table 4.1.29 summarises the temperature characteristics of effluents discharged from the fish recovery and return system

Table 4.1.29 Temperature characteristics discharges from the fish recovery and return system (Stream H)

Temperature Parameter	Temperature
Maximum temperature of Effluent Stream H	Ambient, no greater than 25°C

4.2 Monitoring

4.2.1 Principles

This section of the report presents proposals for monitoring for the purpose of demonstrating compliance with the WDA permit (operational). It is anticipated that these requirements will be incorporated into the permit. A significant amount of additional monitoring will need to be undertaken for operational management purposes within the various processes that take place within the power station and this aspect is not addressed here.

The design of the monitoring systems for non-radiological discharges to the GSB is yet to be confirmed. It is therefore not possible at this stage to identify the location for the inlet sampling point for Effluent Stream A (cooling water inlet temperature) or the detailed design and location within the EPR unit or power station of flow and chemical monitoring points for all of the discharges. However, it can be confirmed that the water discharge monitoring locations will be selected to:

- enable monitoring to be undertaken so that representative measurements or samples can be made and/or taken; and
- ensure locations can be designed so that they can be safely used and inspected by SZC Co. and the Environment Agency's representatives.

Furthermore, the water discharge monitoring systems will be developed according to the design principles outlined in the Environment Agency's guidance document *Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer*, Version 6, September 2017 and all monitoring will meet MCERTS requirements where such equipment is available.

In addition to the discharge monitoring infrastructure, the integrated management system will incorporate aspects to ensure the quality and reliability of the monitoring data obtained.

Decisions for the arrangements for sampling, measurement and assessment of discharges to surface water will also be informed by recent operational experience and knowledge, particularly in relation to the identification of available techniques for sampling, measurement and assessment of the key processing stages to support evaluation of compliance with the conditions included in the WDA permit. This information will also inform the design of infrastructure, plant and equipment. This will ensure that no option is unreasonably foreclosed and allow decision making based on up-to-date information. The location of sampling and measurement points will take account of access requirements and the need for obtaining representative samples and will be addressed during detailed design, see FAP **Section 7.3.4** Action 4: Environmental performance (NGR monitoring points).

A description of both the monitoring infrastructure and management systems will be provided to the Environment Agency as an Effluent Monitoring Plan, which SZC Co. anticipates will be included as a pre-operational measure in the WDA Permit (operational), see FAP **Section 7.3.3** Action 3: Development of the operational management plans.

Proposed indicative locations for sampling are presented in this section, see Appendix A, **Figure 4.2.1**. Whilst the exact details of the proposed monitoring techniques are not yet available, for practicality it is proposed that the effluent streams are monitored at the outlet from the individual effluent streams rather than at the final discharge, as the latter is likely to be impracticable. Exact locations for the cooling water sampling in particular will depend on providing sampling points on very large pipework operating at considerable pressure and this is likely to limit engineering options.

This section provides an indication of the monitoring points and techniques that are proposed for each effluent stream. The proposed outline monitoring points for each waste stream are:

- Effluent Stream A - upon entry to the condensers and auxiliary systems and upon exit to the Outfall Pond [HCA] (four sampling points for each EPR unit).

- Effluent Stream B and C - within [KER] tanks of the Nuclear Island waste monitoring and discharge system or immediately after discharge from the [KER] tanks, depending upon parameter (in effect one sampling point for each EPR unit).
- Effluent Stream D - within [SEK] tanks of the Conventional Island liquid discharge system or immediately after discharge from the [SEK] tanks, depending upon parameter.
- Effluent Stream E - downstream of the final oil/water separator before discharge to the Forebay [HPF] (one sampling point for each EPR unit).
- Effluent Stream F - immediately downstream of the neutralisation pit of the water demineralisation plant and immediately downstream of the reverse osmosis back wash water (two sampling points for each EPR unit).
- Effluent Stream G - at the discharge of final treated effluent from the sewage treatment plant (one sampling point for the Sizewell C power station) before discharge to the outfall pond.
- Effluent Stream H - Monitoring of fish would occur at filtering Debris Recovery Building [HCB] immediately prior to discharge to sea as part of a routine impingement monitoring programme. Water samples would also be collected close to the fish recovery and return outfalls for assessing water quality.

4.2.2 Methods

Sampling may be undertaken by removal of an aliquot of wastewater for laboratory analysis or by continuous measurement of parameters for which this is practicable (for example pH). Aliquot samples may be collected manually as spot samples or using an automatic sampler programmed to collect sampled on a timed basis or a flow-proportional basis. Details of methods to be used for sample collection will be included in the Effluent Monitoring Plan, see FAP **Section 7.3.3**, Action 3: Development of the operational management plans, which will be developed when sufficient detailed design information is available.

All of the aliquot samples taken from storage tanks or discharge points will be analysed at the onsite laboratory. Where required by the Environment Agency, the staff and techniques used by the effluent laboratory will be MCERTS accredited. For samples of contents of tanks collected in advance of discharge to ascertain that the tank contents are suitable for discharge, contents of the tank will first be homogenised using an installed sparging system to ensure that the sample is representative

All sampling and monitoring equipment will be subject to a programme of preventive maintenance, involving a periodic check of their operation and periodic calibration. Records of all maintenance and calibration will be kept secure and made available to the Environment Agency when required.

Analytical methods envisaged at present are listed in **Table 4.2.1**. These are considered to be appropriate for the processes and emissions investigated. This list will be kept under review to ensure that advances in analytical techniques are taken into account in the Environmental Monitoring Plan. Monitoring will be undertaken in accordance with the relevant standards. The specification and performance of the proposed techniques will be defined during detailed design.

In calculating annual or daily loads, concentrations which are measured below the limit of detection, as agreed with the Environment Agency, will be considered to be zero for the substances concerned.

For ammonia note that the sea water EQS is for un-ionised ammonia, whose concentration is dependent on the equilibrium between ammonium ions and un-ionised ammonia. The equilibrium position (and thus the concentration of un-ionised ammonia) depends on temperature, pH and salinity. Therefore, concentrations of un-ionised ammonia cannot be assessed by dilution calculations as with most other parameters and will be calculated after dilution of relevant effluent streams with sea water taking account of temperature, pH and salinity. This forms part of the ERA ('H1 assessment' in **Section 5**) and calculation of un-ionised ammonia concentrations is not included here under monitoring of individual effluent streams, as the equilibrium position will change when diluted with sea water.

Further details of standards for sampling and analysis methods are given in the Environment Agency's guidance document Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer, Version 6, September 2017, and its requirements will be followed in developing the Environmental Monitoring Plan.

Table 4.2.1 Analytical methods for water samples

Determinand	Measurement Method
Flow rates	Continuous measurement using ultrasonic or magnetic flow measuring methods
pH	pH electrode
Temperature	Electrical temperature probe
Total residual oxidant	Colorimetry
Boron (in boric acid)	Molecular absorption spectrometry Inductively Coupled Plasma (ICP) Mass Spectrometry
Hydrazine (N_2H_4)	Molecular absorption spectrometry
Morpholine ($O(CH_2CH_2)_2NH$)	Capillary electrophoresis
Ethanolamine ($HOC_2H_4NH_2$)	Capillary electrophoresis

Determinand	Measurement Method
Ammoniacal nitrogen	Molecular absorption spectrometry Capillary electrophoresis
Nitrite	Molecular absorption spectrometry Ionic chromatography
Nitrate	Ionic chromatography Flow analysis and spectrometric detection
Phosphate	Molecular absorption spectrometry with bismuth phosphomolybdate Molecular absorption spectrometry with ammonium molybdate Ionic chromatography
Detergents	Molecular absorption spectrometry
Metals (Al, Cd, Cu, Cr, Fe, Hg, Mn, Ni, Pb, Zn)	Ionic chromatography ICP Mass Spectrometry
Total petroleum hydrocarbons	Gas chromatography
Total suspended solids	Filtration through glass fibre filters and drying at 105°C
Biochemical oxygen demand ($BOD_{5\text{-atu}}$)	Dissolved oxygen metering, with addition of allyl thiourea
Chemical oxygen demand	Molecular absorption spectrometry

Calculation Procedures

The composition calculations for the analysis of each "tank" and "aliquot" will be carried out with the following provision: for all of the flow calculations (periodic) and cumulative totals for quantities discharged, the concentrations which are measured below the detection limit are considered to be zero for all of the substances concerned.

4.2.3 Monitoring of cooling water systems

The temperature and flow rate of each of the three cooling water return flows to the outfall pond will be monitored in each EPR to inform operational decisions and to ensure compliance with the conditions of the WDA permit (operational). As the permit is expected to place a limit on temperature rise across the cooling systems, inlet sea water temperature will also need to be measured. The design of the monitoring systems is specific to Sizewell C and is still under development. Monitoring techniques will be developed as part of the detailed design process and will be included in the Environmental Monitoring Plan which is detailed on the Forward Action Plan in **Section 7**.

The cooling water will be dosed with chlorine in solution in sea water (as hypochlorite), generated by electrolysis of sea water, to protect the systems against biofouling. The addition of chlorine produces a number of chlorination by-products and measurement of disinfectant chemicals in the discharge is normally of total residual oxidants (TRO), expressed as an equivalent chlorine concentration.

The chlorine concentration required to be dosed in the cooling systems is dependent on the size of the installations and the chlorine demand of the sea water. Dosing will be managed according to the measured TRO at the outlets from the condensers and other cooling systems. This measurement, together with the volume of water discharged, allows the load of residual oxidants discharged to sea to be calculated.

The compliance monitoring proposed for monitoring substances associated with chlorination in the cooling water return flows is presented in **Table 4.2.2**. These sampling requirements apply to each EPR unit.

Table 4.2.2 Monitoring of cooling water systems (Stream A)

Location	Determinant	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Methods[1]
Sea water inlet to condensers and auxiliary systems [SEN], [CFR], [SEC] and [SRU].	Temperature (absolute)	Used for temperature rise calculation	Continuous	Temperature – To Be Confirmed (TBC) (MCERTS not available).
Outlet from auxiliary cooling water system [SEN] to Outfall Pond [HCA].	Discharge rate Temperature (absolute) Temperature (rise) Total residual oxidant	Mean & 98%ile 99.5%ile Maximum Maximum	Continuous Continuous Continuous Hourly	Flow - MCERTS certified flow meter Temperature - TBC (MCERTS not available) Total Residual Oxidant - TBC (MCERTS not available)
Outlet from circulating water system [CRF] to Outfall Pond [HCA].	Discharge rate Temperature (absolute) Temperature (rise) Total residual oxidant	Mean & 98%ile 99.5%ile Maximum Maximum	Continuous Continuous Continuous Hourly	Flow - MCERTS certified flow meter Temperature - TBC (MCERTS not available) Total Residual Oxidant - TBC (MCERTS not available)

Location	Determinant	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Methods[1]
Combined outlet from essential service water system [SEC] and ultimate cooling water system [SRU] to Outfall Pond [HCA].	Discharge rate Temperature (absolute) Temperature (rise) Total residual oxidant	Mean & 98%ile 99.5%ile Maximum Maximum	Continuous Continuous Continuous Hourly	Flow - MCERTS certified flow meter Temperature - TBC (MCERTS not available) Total Residual Oxidant - TBC (MCERTS not available)

[1] Methods will be consistent with Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer, Version 6, September 2017.

4.2.4 Monitoring of trade effluent discharges associated with liquid radioactive effluent

Anticipated requirements for WDA permit compliance monitoring of batch discharges from the Nuclear Island waste monitoring and discharge system [KER] are summarised in **Table 4.2.3**. Additional monitoring is likely to be required for operational purposes of any effluent transferred to the liquid radwaste discharge system additional tanks [TER] for further treatment.

Sampling frequency will be determined by the pattern of tank emptying, in that the contents of every tank to be discharged need to be examined before discharge for radioactive substances (covered by the RSR permit) and for parameters indicated in **Table 4.2.3**, to confirm acceptability for discharge. If the contents are not acceptable, they will be transferred to the [TER] tanks to await further treatment in the liquid waste treatment systems [TEU] and the same effluent will then need to be re-tested in the [KER] tanks to check acceptability before discharge.

Sampling tank contents before discharge will involve collection of a single sample after using the sparging system to ensure tank contents are fully mixed and the sample is therefore representative of the tank contents. Laboratory analysis will be undertaken prior to any effluent being discharged from the [KER] tank.

In addition to analysis for radioactive components (not covered under the WDA permit), pre-discharge analysis will include determination of concentrations of the following non-radiological parameters:

- Boric acid from reactor coolant let-down.
- Hydrazine from secondary circuits and primary circuits during an outage.
- Morpholine (only analysed if this has been dosed to secondary circuits).

- Ethanolamine (only analysed if this has been dosed to secondary circuits).

Discharge parameters will be stipulated during the WDA operational permit application determination by the Environment Agency.

If any hydrazine is detected in a [KER] tank above limits deemed to have an environmental impact, the effluent will be treated in line with the process agreed with the Environment Agency through the Forward Action Plan for hydrazine before final discharge.

The parameters listed in **Table 4.2.3** will be analysed in samples collected from the KER tanks and their outlets. Full details will be agreed with the Environment Agency and included in the Environmental Monitoring Plan. The sampling may involve manual collection of individual samples or could be automated using flow-proportional automatic samplers which would be activated at commencement of discharge.

These sampling requirements apply to each EPR unit.

Table 4.2.3 Monitoring of trade effluent discharges from the Nuclear Island ([KER] tanks)

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Method[1]
Nuclear Island waste monitoring and discharge system [KER] – samples from [KER] tanks	Boric acid (as boron)	Concentration Annual load	Aliquot from each [KER] tank before discharge Resample after return via [TER] tanks and treatment in [TEU], if this is required	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Hydrazine (N_2H_4)	Confirm acceptable concentration for discharge	Aliquot from each [KER] tank before discharge Resample after treatment to confirm hydrazine destruction	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Method[1]
before discharge	Morpholine ($O(CH_2CH_2)_2NH$)	Concentration Annual load	Aliquot from each [KER] tank before discharge Resample after return via [TER] tanks and treatment in [TEU], if this is required Only measured in tanks receiving conditioned water from the steam generators in the case where morpholine has been used for conditioning the water.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Ethanolamine ($HOC_2H_4NH_2$)	Concentration Annual load	Aliquot from each [KER] tank before discharge Resample after return via [TER] tanks and treatment in [TEU], if this is required Only measured in tanks receiving conditioned water from the steam generators in the case where ethanolamine has been used for conditioning the water.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
Outlet from Nuclear Island waste monitoring and discharge system [KER] to Outfall Pond [HCA]	Daily discharge volume	Maximum volume	Calculated from maximum number of tanks emptied per day and tank volume	MCERTS certified flow meter
	Discharge flow rate (instantaneous)	Mean flow rate	Flow measured continuously during discharge of each [KER] tank that is discharged to the outfall pond	MCERTS certified flow meter
	Lithium	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Method[1]
	Boric acid (H_3BO_3) (as boron)	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Morpholine ($O(CH_2CH_2)_2NH$)	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Ethanolamine ($HOC_2H_4NH_2$)	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Ammoniacal nitrogen (as N)	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either BS EN ISO 11732, BS 6068-2.11 ISO 7150-1, BS 6068-2.7, ISO 5664 BS 6068-2.10, ISO 6778 or BS ISO 15923–1.
	Nitrite (as N)	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard BS EN ISO 13395, BS EN 26777 and ISO 6777.
	Nitrate (as N)	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard BS EN ISO 13395, BS EN 26777 and ISO 6777.

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Method[1]
	Total dissolved inorganic nitrogen (as N)	Concentration Annual load	By calculation from ammoniacal nitrogen, nitrite, nitrate, morpholine and ethanolamine results from sampling during discharge of each [KER] tank discharged	Grab sample (not MCERTS) Monitoring Standards BS EN ISO 11905-1, BS EN 12260 or BS ISO 29441.
	Phosphate (as P)	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standards either BS EN ISO 15681-1, BS EN ISO 15681-2, or BS EN ISO 6878.
	Detergents	Concentration Annual load	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Metals (Al, Cd, Cu, Cr, Fe, Hg, Mn, Ni, Pb, Zn)	Concentration (each metal) Annual load (each metal)	Sampled during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Methods Various Trace Metals either BS EN ISO 11885, BS EN ISO 17294-1, BS EN ISO 17294-2, or BS EN ISO 15586
	Chemical oxygen demand	Concentration Annual load	Sampled once during discharge of each [KER] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard SCA blue book 215.

[1] Methods will be consistent with Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer, Version 6, September 2017.

4.2.5 Monitoring of trade effluent from the conventional island liquid waste system

As discharges from the Conventional Island liquid waste system (Stream D) are made on a batch basis from the [SEK] tanks, the monitoring approach mirrors that described in **Section 2** for the Nuclear Island waste monitoring and discharge system [KER]. Contents of each [SEK] tanks will be monitored before discharge for radioactive substances (covered by the RSR permit) and for hydrazine.

If radioactivity above acceptable limits is detected in an [SEK] tank, its contents will be transferred to the liquid radwaste system additional tanks [TER] for treatment in the liquid waste treatment systems [TEU] and discharge with Steam B and C via the [KER] tanks as described in **Section 2.3.4**.

If any hydrazine is detected in a [SEK] tank (above a limit agreed with the Environment Agency based on environmental impact studies), the effluent will be reprocessed with an appropriate technique as confirmed in the Forward Action Plan. The tank of effluent will then be retested to ensure any hydrazine is below levels that would cause an environmental impact before the tank is discharged.

Parameters to be analysed in samples from the Conventional Island liquid waste system are shown in **Table 4.2.4** The approach to monitoring will be the same as described for the Nuclear Island waste monitoring and discharge system [KER]. Note that boric acid, morpholine and ethanolamine are only analysed if they have been used in the secondary system.

These sampling requirements apply to each EPR unit.

Table 4.2.4 Monitoring of trade effluent discharges from the Conventional Island ([SEK] tanks)

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Method[1]
Conventional Island liquid waste system [SEK] – samples from [SEK] tanks before discharge	Hydrazine (N_2H_4)	Confirm not present. Confirm destruction by appropriate technique	Aliquot from each [SEK] tank before discharge Resample after treatment to destroy hydrazine if hydrazine is detected by the initial sampling	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
Outlet from Conventional Island liquid waste system [SEK] to Outfall Pond [HCA]	Daily discharge volume	Maximum volume	Calculated from maximum number of [SEK] tanks emptied per day and tank volume	MCERTS certified flow meter.
	Discharge flow rate (instantaneous)	Mean flow rate	Flow measured continuously during discharge of each [SEK] tank that is discharged to the outfall pond	MCERTS certified flow meter.

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Method[1]
	Boric acid (H_3BO_3) (as boron)	Concentration Annual load	Sampled during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Morpholine ($O(CH_2CH_2)_2NH$)	Concentration Annual load	Sampled during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Ethanolamine ($HOC_2H_4NH_2$)	Concentration Annual load	Sampled during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either CEN, ISO or British Standards.
	Ammoniacal nitrogen (as N)	Concentration Annual load	Sampled during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either BS EN ISO 11732, BS 6068-2.11 ISO 7150-1, BS 6068-2.7, ISO 5664 BS 6068-2.10, ISO 6778 or BS ISO 15923–1.
	Nitrite (as N)	Concentration Annual load	Sampled during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either BS EN ISO 13395, BS EN 26777 and ISO 6777.
	Nitrate (as N)	Concentration Annual load	Sampled during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either BS EN ISO 13395, BS EN 26777 and ISO 6777.

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Method[1]
	Total dissolved inorganic nitrogen (as N)	Concentration Annual load	By calculation from ammoniacal nitrogen, nitrite, nitrate, morpholine and ethanolamine results from sampling during discharge of each [SEK] tank discharged	Grab sample (not MCERTS) Monitoring Standard either BS EN ISO 11905-1, BS EN 12260 or BS ISO 29441.
	Phosphate (as P)	Concentration Annual load	Sampled during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard either BS EN ISO 15681-1, BS EN ISO 15681-2, or BS EN ISO 6878.
	Metals (Al, Cd, Cu, Cr, Fe, Hg, Mn, Ni, Pb, Zn)	Concentration (each metal) Annual load (each metal)	Sampled during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standards Various. Trace Metals either BS EN ISO 11885, BS EN ISO 17294-1, BS EN ISO 17294-2, or BS EN ISO 15586.
	Chemical oxygen demand	Concentration Annual load	Sampled once during discharge of each [SEK] tank that is discharged to the outfall pond.	Grab sample (not MCERTS) Monitoring Standard SCA blue book 215

[1] Methods will be consistent with Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer, Version 6, September 2017

4.2.6 Monitoring of oily water trade effluent

Oily water trade effluent (Stream E) will be treated by Class 1 oil/water separators before discharge to the Forebay [HPF]. This effluent stream will potentially be contaminated with hydrocarbons and will be monitored at the drainage system outfall. A summary of the monitoring proposed is given in **Table 4.2.5**. These sampling requirements apply to each EPR unit.

Table 4.2.5 Monitoring of oily water trade effluent discharges from the site drainage network (Stream E)

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Method[1]
Discharge from site drainage network [SEO EP] to Forebay [HPF]	Daily discharge volume	Maximum volume	N/A	MCERTS certified flow meter
	Visible oil or grease	No significant trace present	Daily	Grab sample (not MCERTS) Monitoring Standard either BS EN ISO 9377-2 or SCA blue book 77

[1] Methods will be consistent with Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer, Version 6, September 2017.

4.2.7 Monitoring of demineralised water production trade effluent

In variance from the GDA it is not proposed that effluents from the production of demineralised water will be monitored for iron and suspended solids as Sizewell C will use mains water for the production of demineralised water and as such Effluent Stream F will not be a significant source of these substances.

Effluents from cleaning the reverse osmosis membranes and regeneration of the ion exchange resins are neutralised in the neutralisation pit by using sulphuric acid and sodium hydroxide. The neutralisation process results in discharges of:

- sulphates;
- pH (acids/alkali); and
- sodium.

Sulphates

With respect to sulphates, periodic sampling will be carried out at the demineralisation station outlet. It allows the sulphate concentration to be determined before dilution and the corresponding flow assessed.

The methods for proposed for measuring sulphate are presented in **Table 4.2.6.**

Table 4.2.6 Measurement Method for Sulphate Concentration at the Demineralisation Station Outlet

Parameter	Requirement	Sampling Location	Measurement Method	Measurement Method[1]
Sulphates	Maximum concentration at the demineralisation station outlet before dilution	Demineralisation station outlet	Molecular absorption spectrometry with barium chloride	Grab Sample (not Grab sample (not MCERTS) Monitoring Standard molecular absorption spectrometry with barium chloride. Alternatively CEN, ISO or British Standards.

[1] Methods will be consistent with Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer, Version 6, September 2017.

pH

Due to the alkalinity and/or acidity of the reagents present in the neutralisation pit, pH will be measured prior to draining the pit. Details of the pH monitoring system are not currently available, but will be developed as part of the detailed design process and will be demonstrated via the FAP (see **Section 7.3.4**, Action 4: Environmental performance).

Sodium

Due to the low quantities of discharged sodium, and the background concentrations in seawater, it is considered that an emission limit value and monitoring requirements would be unnecessary.

4.2.8 Monitoring of sanitary effluent

Treated effluent from the site Sewage Treatment Plant [HXE] will be monitored at entry to the outfall from the works to the outfall pond. This effluent (Stream G) will be subjected to a programme of self-monitoring allowing the efficiency of the drainage system and compliance with emission limit values to be checked. The parameters monitored are likely to include pH, flow rate, $BOD_{5\text{-atu}}$, COD and Total Suspended Solids. The proposed measurement methods are presented in **Table 4.2.7**.

Details of sampling arrangements will be determined when final design details are available and included in the Environmental Monitoring Plan. Sampling may be undertaken by automatic samplers.

These sampling requirements apply to a single sewage treatment works serving both EPR units.

Table 4.2.7 Monitoring of effluent from the sewage treatment works (Stream G)

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Methods[1]
Discharge from the site Sewage Treatment Works [HXE] to the Outfall Pond [HCA]	Daily discharge volume	Maximum volume	Calculated from flow meter data	MCERTS certified flow meter.
	Discharge flow rate (instantaneous)	Mean flow rate	Continuous (flow meter)	MCERTS certified flow meter.
	Biochemical oxygen demand ($BOD_{5\text{-atu}}$)	Maximum	To be confirmed	Grab sample (not MCERTS) Monitoring Standard either BS EN 1899-1 or BS EN 1899-2.
	Total suspended solids	Maximum	To be confirmed	Grab sample (not MCERTS) Monitoring Standard either BS EN 872 or SCA blue book 105.
	Ammoniacal nitrogen (as N)	Maximum	To be confirmed	Grab sample (not MCERTS) Monitoring Standard either BS EN ISO 11732, BS 6068-2.11 ISO 7150-1, BS 6068-2.7, ISO 5664 BS 6068-2.10, ISO 6778 or BS ISO 15923–1.
	pH	Within range	To be confirmed	Grab sample (not MCERTS) Monitoring Standard BS ISO 10523.

[1] Methods will be consistent with Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer, Version 6, September 2017

4.2.9 Monitoring within the fish recovery and return

Effluent released from the fish recovery and return system will be monitored at the fish sampling culvert in the filtering Debris Recovery Building [HCB] to ensure flows are maintained. The proposed measurement are presented in **Table 4.2.8**.

Discharges of dead and moribund biota from the fish recovery and return system have the potential to locally effect water quality parameters whilst some taxa, are expected to respond positively to exploit the increased food supply as dead and moribund biota would be discharged from the fish recovery and return system outfalls. These effects are likely to be minor and localised within the vicinity of the outfall, where organic loading would be concentrated. Nevertheless, operational safety constraints, preventing deployment of benthic sampling equipment close to the fish recovery and return system outfall, would likely limit the ability to detect localised changes in abundance/populations size. Monitoring should therefore consider the potential for water quality issues.

Water quality samples would be collected throughout the water column at sites as close to the fish recovery and return system headworks as operationally feasible and at control sites. Samples would be collected quarterly for one year to capture seasonal variation in fish recovery and return system discharges and ambient water quality. Sampling should focus on periods of full operational power once both systems are commissioned to determine the potential worst-case seasonal scenarios. Should reductions in water quality be identified monitoring may be extended, however, monitoring near the existing Sizewell B outfalls has not detected significant changes in the parameters described.

Table 4.2.8 Monitoring of effluent from the fish recovery and return (Stream H)

Location	Determinand	Compliance parameter calculated/recorded	Sampling frequency	Monitoring Methods[1]
Discharge from Fish Recovery and Return Outfalls	Daily discharge volume	Maximum volume	Calculated from flow meter data	MCERTS certified flow meter.
	Discharge flow rate (instantaneous)	Mean flow rate	Continuous (flow meter)	MCERTS certified flow meter.

[1] Methods will be consistent with Technical Guidance Note (Monitoring) M18: Monitoring of discharges to water and sewer, Version 6, September 2017.

5 Environmental Risk Assessment

5.1 Introduction

The environmental risk assessment included in this section for the proposed water discharge activity during operation of Sizewell C has been prepared in parallel with the EIA that supports the applications being made to the Planning Inspectorate.

The proposed surface water discharge will occur approximately 3km offshore on the eastern flank of the Sizewell-Dunwich Bank via two outfall structures. Within the Habitats Regulations Assessment (HRA) evidence plan and following consultation on the Likely Significant Effects (LSE) Report the following sites and features were identified as having the potential for marine water quality effects from the operation phase of Sizewell C:

- Alde-Ore and Butley Estuaries SAC – Estuaries, Mudflats and sandflats not covered by seawater at low tide and Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*).
- Alde-Ore Estuary SPA - Supporting habitat to SPA designated interest, Breeding Little Tern Sterna albifrons, Breeding Sandwich Tern *Sterna sandvicensis*, Breeding Lesser black-backed gull *Larus fuscus* and assemblage qualification: a seabird assemblage of international importance.
- Alde-Ore Estuary RAMSAR - Ramsar criterion 2 (Nationally-scarce plant species and British Red Data Book invertebrates), Ramsar criterion 3 (The site supports a notable assemblage of breeding and wintering wetland birds) and Ramsar criterion 6 (species/populations occurring at levels of international importance).
- Benacre to Easton Bavents Lagoons SAC - Coastal lagoons Priority feature.
- Benacre to Easton Bavents SPA - Supporting habitat to SPA designated interests and Breeding Little Tern *Sterna albifrons*.
- Minsmere to Walberswick Heaths and Marshes SAC - Annual vegetation of drift lines and Perennial vegetation of stony banks.
- Minsmere to Walberswick SPA - Supporting habitat to SPA designated interests and Breeding Little Tern *Sterna albifrons*.
- Minsmere to Walberswick RAMSAR - Ramsar criterion 1 (Mosaic of marine, freshwater, marshland and associated habitats) and Ramsar criterion 2 (Supports 9 nationally scarce plants and at least 26 red data book invertebrates).
- Orford Ness to Shingle Street SAC - Coastal lagoons Priority feature and Annual vegetation of drift lines.

- Outer Thames Estuary SPA - Supporting habitat to SPA designated interests, Wintering /passage Red-throated diver *Gavia stellata*, Breeding Little Tern *Sterna albifrons* and Breeding Common Tern *Sterna hirundo*.
- Humber Estuary SAC – grey seal *Halichoerus grypus.*
- The Wash and Norfolk coast SAC – Harbour seal *Phoca vitulina.*
- Southern North Sea SAC (designated in 2019) – Harbour porpoise (*Phocoena phocoena*).

This section of the report is intended to help the Environment Agency to understand the predicted effects of the discharge on the receiving environment, with reference to effects on designated/classified/listed interest features of internationally protected wildlife sites. In relation to the European sites (the SAC and SPA and UK policy is to apply the same assessment requirements to Ramsar Sites), the Environment Agency, as a competent authority in relation to the environmental permit for the water discharge activity, will be required to undertake an assessment in accordance with the Conservation of Habitats and Species Regulations 2017 [61], to determine whether there is a likely significant effect and, if so, to carry out an appropriate assessment of the effects on the integrity of the site. Regulation 67 of the Conservation of Habitats and Species Regulations 2017 does not require a competent authority to assess any plan or project that would more appropriately be assessed by another competent authority and in this case the Secretary of State will be the competent authority for the DCO application. However, the Environment Agency will still need to undertake the assessment of likely significant effect for the parts of the project not covered by the planning permission and which it authorises, such as the environmental permit. This section provides information to support the Shadow Habitats Regulations Assessment, which is presented in a separate report covering those aspects of relevance to the operational WDA permit (Appendix C).

The section has been prepared considering the assessment criteria set out in the Habitats Directive guidance [62], Environment Agency's advice on nuclear new build [63], [64], and its H1 guidance on environmental risk assessment and adopts the following structure:

- Identification of target EQS for the waters off Sizewell including Sizewell Bay.
- Description of the water quality baseline for the receiving water and comparison with environmental standards.
- Description of the physical and sediment baseline, including habitat classification.
- Identification of sensitive biological receptors and fish of commercial value.
- Modelling of the plume from the water discharge activity.
- H1 impact assessment for substances discharged.

- Impact assessment, including impacts of discharged biota due to abstraction of cooling water and assessment of in-combination affects with cooling water discharges from Sizewell B power station.

- Supporting information for the Habitats Regulations Assessment.

5.2 Target environmental water quality standards

5.2.1 Introduction

This section relates to environmental water quality (chemical, thermal and microbiological) standards as well as ecological targets.

5.2.2 EC Directives affecting water quality

Much of the water quality legislation in the UK derives from European Directives that have been transposed into national law. Some of the Directives set water quality standards specific to the 'use' of the receiving water body (e.g. bathing water, potable abstraction, freshwater fish, shellfish waters, etc.), while others apply to all surface water discharges and aim to provide general environmental protection. The standards define limits for concentrations of substances in the water which ensure that no undesirable effects occur. Such concentration limits are called EQS. Where no statutory EQS exists, the Environment Agency has in some cases defined values used as operational EQS or as environmental assessment levels (EAL).

The following Directives are relevant to consideration of chemical and microbiological standards for the receiving waters for the proposed water discharge activity.

Water Framework Directive

The EC WFD (2000/60/EC), which came into force on 22 December 2000, and is transposed into law in England and Wales by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017, establishes a new, integrated approach to the protection, improvement and sustainable use of Europe's rivers, lakes, estuaries, coastal waters and groundwater, and includes the following aims relevant to this permit application:

- To enhance the status and prevent further deterioration of aquatic ecosystems, as well as associated wetlands which depend on the aquatic ecosystems;

- To promote the sustainable use of water;

- To reduce pollution of water, especially by 'priority' substances listed in Annex X (this list later replaced by annex II see priority substances); and

- The cessation or phasing-out of discharges, emissions and losses of priority hazardous substances to surface water bodies.

The Dangerous Substances Directive and the Shellfish Waters and Freshwater Fish Directive were revoked by the WFD in 2013.

Amongst other measures, the WFD [7] and associated 'Daughter Directive' [8] set EQS to protect specific uses of the water environment from the effects of pollution and to protect the water environment itself from especially harmful chemical substances.

Through a process of river basin management planning, the Directive includes the aim of achieving 'good chemical status' and 'good ecological status' (GES) for surface water bodies by specific target dates. Where water bodies are unable to meet GES due to other uses, such as modification for flood protection or navigation, the water body may be designated as a heavily modified water body and is then required to meet 'good ecological potential' (GEP). Tidal water bodies are divided into 'coastal waters' and 'transitional waters' (estuaries), collectively referred to as transitional and coastal (TRaC) waters.

Certain types of water body are defined under the Directive as 'protected areas'. This includes waters protected under other Directives, such as the Bathing Water Directive and the Habitats Directive (see below). Where environmental quality standards established for such protected areas are more stringent than the general standards set under the WFD, the more stringent standards prevail and override the general standards.

Priority Substances Directive

Under the WFD, certain substances that are regarded as the most polluting were identified in 2001 as Priority Hazardous Substances by a Decision of the European Parliament and the Council of Ministers (Decision 2455/2001/EC). This first list of substances became Annex X of the WFD. This first list was replaced by Annex II of the Directive on Environmental Quality Standards (Directive 2008/105/EC), also known as the Priority Substances Directive and this was further updated in 2013, Directive 2013/39/EU [9] For Sizewell the relevant priority substances are cadmium, lead, mercury and nickel for these substances EQS are determined at the European level, and these apply to all Member States.

For other substances, standards may be derived by each Member State, and they should lay down, where necessary, rules for their management. This list of compounds or Specific Pollutants is defined as substances that can have a harmful effect on biological quality, and which may be identified by Member States as being discharged to water in "*significant quantities*".

Bathing Waters

A proposal for a revised Bathing Waters Directive (2006/7/EC) was adopted in 2002 and came into force in 2006, eventually replacing the 1976 BWD in 2014 (76/160/EEC). The Bathing Waters Regulations 2013 came into force 31st July 2013 [14] to protect the quality of bathing waters used by bathers. The new Directive requires sampling and analysis for bacteriological parameters *Escherichia coli* and intestinal enterococci, as well as requiring better arrangements for management of bathing water quality.

The Directive applies only to designated bathing waters, which are classed as protected areas. Bathing waters in the vicinity of the proposed discharge are at:

- Southwold the Denes (latitude 52.32º N, longitude 1.679º E), about 18km North from the proposed discharge point;
- Felixstowe North (latitude 51.96º N, longitude 1.355º E) approximately 35km South from the proposed discharge.

The revised Directive was fully implemented in 2015 when the first report on compliance under the new standards was produced, based on 4 years of data from 2012, and any new discharge potentially affecting the quality of a bathing water has to be designed to ensure that compliance is not compromised.

The Directive is relevant to the proposed water discharge only in relation to the microbiological content of discharges of treated sewage from the power station site.

Shellfish Waters

The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulations 2016 amended the Water Framework Directive Regulations 2003 to provide specific powers for the designation of transitional and coastal waters where shellfish are harvested to contribute to a high-quality shellfish product for human consumption. The Shellfish Waters Directive sets environmental standards for the quality of the waters where shellfish live in order to promote healthy shellfish growth. The quality of commercially harvested shellfish intended for human consumption must comply with the EU Food Hygiene Regulations [65].

The Directive sets physical, chemical and microbiological water quality requirements that designated shellfish waters must either comply with ('mandatory' standards) or endeavour to meet ('guideline' standards). The Directive is designed to protect the aquatic habitat of bivalve and gastropod molluscs, including oysters, mussels, cockles, scallops and clams. It does not cover shellfish crustaceans such as crabs, crayfish and lobsters. However, the nearest designated shellfish water is in the Butley Creek about 44km South, well outside any possible zone of influence (ZOI) of the proposed water discharge. As the Directive only applies in designated shellfish waters, it does not therefore provide any statutory standards that are relevant in the risk assessment for the proposed water discharge activity at Sizewell C power station (see **Section 5.9.** regarding predicted ZOI for thermal influence, chemical discharges and microbiological inputs from Sizewell C). However, the standards for maximum temperature rise set under the Directive are the same as those used for assessments of the impact of thermal discharges on European Marine Sites.

Shellfish waters in the vicinity of the proposed discharge are at:

- Butley Shellfish, Butley Creek (latitude 52.077º N, longitude 0.966º E), about 44km South from the proposed discharge point.
- The River Deben (latitude 52.037º N, longitude 1.348º E) approximately 63km South from the proposed discharge.
- Blakeney Shellfish (latitude 52.969º N, longitude 1.355º E) approximately 195km North from the proposed discharge.

Marine Strategy Framework Directive

In 2008 the European Union adopted Directive 2008/56/EC on establishing a framework for community action in the field of marine environmental policy. Known as the Marine Strategy Framework Directive, the Directive aims to implement an effective mechanism to protect the marine environment across Europe and achieve 'Good Environmental Status' by 2020. Achieving Good Environmental Status will be managed through an ecosystem-based approach for the sustainable use of marine goods and services and human activities. Member States are required to develop a marine strategy to achieve GES and establish a network of Marine Protected Areas. Annex I of the Directive outlines 11 high-level descriptors of Good Environmental Status.

Marine and Coastal Access Act 2009 (as amended)

The Orford Inshore Marine Conservation Zone (MCZ) was part of the third tranche of MCZs that was formally designated in May 2019. Located approximately 14km offshore from the Alde Ore Estuary, the site is composed of subtidal mixed sediments that form important nursery and spawning grounds for some species of fish, including Dover sole, lemon sole and sand eels. Burrowing anemones, sea cucumbers, urchins, starfish and nationally important shark species are found at the site. The area is an important foraging area for seabirds. Harbour porpoise pass through the site. The protected features at the site a 'subtidal mixed sediments. The general management approach is to 'recover to a favourable condition' [66].

The Orford Inshore MCZ is beyond the ZOI (see **Section 5.9**) of the primary impacts associated with the proposed development including the thermal plume, suspended sediment plumes from dredging activities and underwater noise effect zones for fish. The potential for the proposed development to effect fish species utilising the MCZ, primarily through entrapment, is considered.

Habitats and Birds

The Habitats regulations of relevance to the Sizewell C project are transposed into English law by both 'The Conservation of Habitats and Species Regulations 2017' (for sites within 12nm) and 'The Conservation of Offshore Marine Habitats and Species Regulations 2017' (for sites within 12nm).

The area of open sea adjacent to the eastern boundary of the Main Development Site is part of the Southern North Sea SAC. The SAC was formally designated in February 2019 for Annex II species harbour porpoise (*Phocoena phocoena).* The ES considers the conservation objectives of the SAC when determining the significance of effects arising from development impacts.

Implications of the proposed development specifically regarding designated sites is considered in the HRA (Appendix C). Protected SAC areas relevant for the Marine Ecology and Fisheries ES chapter are provided in **Table 4.1** Appendix C.

Birds Directive

The conservation and management of wild bird populations across Europe is underpinned by Directive 2009/147/EC on the conservation of wild birds, the Birds Directive. The Birds Directive is the means by which the UK and the European Union meet the objectives of the Bonn Convention of migratory species and the Bern Convention of conservation of wild species. Vulnerable and rare species listed on Annex I are afforded protection under the Natura network of protected areas through designated SPAs. Migratory species and internationally important wetlands are also protected with SPA designations.

Ramsar Convention

The Ramsar Convention on the conservation of wetlands was accepted in 1971 and was ratified into UK law in 1976. Wetlands of international importance are designated Ramsar sites and are afforded the same level of protection as SPAs under the EC Birds Directive.

The Oslo and Paris convention for the protection of the marine environment of the north-east Atlantic

The The Oslo and Paris convention for the protection of the marine environment of the north-east Atlantic (OSPAR) Convention (1992) seeks to protect the marine environment of the north-east Atlantic through international co-operation. Part of its focus complements ongoing work under the EU Habitats Directive and other international agreements by establishing a list of species, habitats and ecological processes that are threatened and/or declining.

Conservation of Migratory Species of Wild Animals: Bonn 1979

The Bonn Convention on the Conservation of Migratory Species of Wild Animals (CMS) is a multi-governmental agreement for the conservation of species and habitats when migratory routes cross international boundaries. Member countries afford stringent protection measures for endangered migratory species listed in Appendix I of the Convention, and intergovernmental conservation, management and research activities were established to benefit migratory species listed on Appendix II.

CMS was implemented in the UK in 1985 with legal protection for Appendix I species provided by the Wildlife and Countryside Act (1981 as amended). Within the framework of CMS the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) was agreed. In 2009 the Countryside and Rights of Way Act came into force in England and Wales to enhance protection for threatened cetacean species.

Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas

The ASCOBANS was implemented under the auspices of the Convention of Migratory Species in 1994. ASCOBANS provides a means of promoting cooperation across signatory members with the overriding aim of providing Favourable Conservation Status for small cetaceans. The harbour porpoise (*Phocoena phocoena*) is considered a flagship species of the ASCOBANS programme.

The Bern Convention of the Conservation of Wildlife and Natural Habitats (1979) aims to conserve and protect the wild animal and plant species and their natural habitats listed in Appendix I and II of the Convention. Increased cooperation between signatory members is further aimed to mitigate the exploitation of species listed in Appendix III, which includes migratory species. The Bern Convention is implemented in UK law through the Wildlife and Countryside Act (1981) and the obligations of the Convention are achieved through the EC Habitats Directive.

The Convention on Biological Diversity

The Convention on Biological Diversity (CBD) is a multilateral treaty aiming to develop national strategies for the conservation and sustainable use of biological diversity. The UK Government's first response to the CBD was to compile lists of Biodiversity Action Plan (BAP) species and habitats. These action plans sought to ensure that priority species or habitats were conserved or enhanced.

The UK Post-2010 Biodiversity Framework, published in 2012 shifted priorities from BAP to other regulatory and conservation frameworks. BAP lists have been superseded by statutory lists of priority species and habitats under the Natural Environment and Rural Communities (NERC) Act 2006.

Others

The Urban Wastewater Treatment Directive is also considered. Council Directive 91/271/EEC concerning urban wastewater treatment was adopted on 21 May 1991 to protect the water environment from the adverse effects of discharges of urban wastewater and from certain industrial discharges. On 27 February 1998 the Commission issued Directive 98/15/EC amending Directive 91/271/EEC to clarify the requirements of the Directive in relation to discharges from urban wastewater treatment plants to sensitive areas which are subject to eutrophication.

5.2.3 EQS for water quality

The following section describes EQS applicable to the TRaC waters to which the proposed water discharge will be made and which are relevant to the substances, microbiological and thermal loads that will be discharged, as described earlier.

The EQS relevant to this permit application have been identified from the following sources:

- EQS covered by Annex II of the Directive on Environmental Quality Standards (Directive 2008/105/EC) and further updated in 2013, Directive 2013/39/EU [7].
- Water Framework Directive (Standards and Classification) Directions (England and Wales, 2015) [8].
- EQS set under the Bathing Waters Regulations 2013 [14].
- Guidance from Water Quality Technical Advisory Group (WQTAG)[6] on assessments for water quality and European wildlife sites (see later).
- PNEC values from independent toxicity testing undertaken by EDF.

Table 5.2.1 shows target general environmental standards for achievement of 'good' chemical status under the WFD. **Table 5.2.2** shows EQS for priority substances and other pollutants in the receiving TRaC waters set under the WFD for achievement of 'good' chemical status

The receiving waters in this case are TRaC water bodies and, therefore, TRaC standards apply where these have been set. Although the latest guidance from the Environment Agency[7] recommends following UKTAG guidance and using temperature standards derived for freshwaters and shellfish waters for TraC waters, as no generally applicable temperature standards for TRaC waters have yet been developed, in this case, the proposed discharge is into TraC waters which form part of European wildlife sites for which decisions have been made to set more stringent standards (see [67]) therefore these more stringent standards have been applied.

In a review of temperature standards [67] it was recommended that, in order to minimise temperature increases that affect migratory fish species, in a river or estuarine channel of high ecological status, the plume mixing zone for a maximum 2°C uplift in temperature should not occupy more than a 25% of the channel cross section for more than 5% of the time. Based upon these recommendations an assessment for the Alde-Ore/Blyth estuary would test if there would be a thermal barrier to fish migration by assessing if the cross-sectional area of the estuary was affected by a temperature increase of > 2°C across >25%

[6] WQTAG is the Group set up to advise on compliance with the Habitats Directive.

[7] Environment Agency (2010) Nuclear New Build – Guidance on Temperature Standards and Environmental Permit Requirements.

of a cross section for > 5% of the time. There are no thermal standards to assess potential migration barriers for fish in coastal waters. However, if fish have to pass through a coastal plume on their migration route to or from an estuary there remains the possibility of the plume acting as a barrier to migration so this was also given consideration.

Where no standards are available proxy standards EALs have been developed. For the following compounds of concern, EDF proposed PNEC values which were subsequently validated by external experts:

- Hydrazine
- Morpholine
- Ethanolamine

Table 5.2.1 Target Environmental Standards under the WFD for coastal and transitional waters off Sizewell C

Parameter	High status		Good status		Source
Dissolved oxygen	5.7 mg/l	P_5	4.0 mg/l	P_5	[10]
Dissolved inorganic nitrogen (as nitrogen)	0.168 mg/l	P_{99}	0.98 mg/l	P_{99}	[10] Unpublished draft guidance cites SPM and nitrogen relationships to allow derivation of specific waterbody nitrogen reference value. However, this value is used for screening but a full assessment using an combined phytoplankton and macroalgal model is undertaken to account for nutrient limited period in summer.

Table 5.2.2 EQS values for 'good status' and for Habitats Directive sites in coastal and transitional waters for substances of concern in relation to proposed water discharges from Sizewell C.

Parameter	Long term EQS or EAL		Short term EQS or EAL		Source
Temperature - ΔT (rise above ambient)	-	-	3°C	MAC	[67]: BEEMS Scientific Advisory Report: Thermal standards for cooling water from new nuclear power stations, for standards recommended for Good Status under WFD
Temperature	-	-	23°C	P_{98}	
Temperature - ΔT (rise above ambient)	-	-	2°C	MAC	[67]: SAC (any designated for estuary or embayment habitat and/or salmonid species)
Temperature	-	-	21.5°C	P_{98}	

Parameter	Long term EQS or EAL		Short term EQS or EAL		Source
Temperature - ΔT (rise above ambient)	-	-	2°C	MAC	[67]: SPAs
Temperature	-	-	28°C	P_{98}	
Aluminium	-	-	-	-	No EQS set for seawater
Arsenic (dissolved)	25 µg/l	AA	-	-	[10]
Boron (total)	7 mg/l	AA	-	-	[68]
Cadmium (dissolved)	0.2 µg/l	AA	1.5 µg/l	MAC	[10]
Chromium VI (dissolved)	0.6 µg/l	AA	32 µg/l	MAC	[10]
Copper (dissolved)	3.76 µg/l	AA	-	-	[10]
Iron (dissolved)	1 mg/l	AA	-	-	[10]
Lithium	-	-	-	-	No EQS set for seawater
Lead (dissolved)	1.3 µg/l	AA	14 µg/l	MAC	[10]
Manganese	-	-	-	-	No EQS set for seawater
Mercury (dissolved)	-	-	0.07 µg/l	MAC	[10]
Nickel (dissolved)	8.6 µg/l	AA	34 µg/l	MAC	[10]
Zinc (dissolved)	6.8 µg/l	AA	-	-	[10]
pH	-	-	6-9	P_{95}	[14]
BOD	-	-	-	-	No EQS set for seawater but effects of BOD assessed through monitoring dissolved oxygen against EQS
Un-ionised ammonia (as N)	21	AA	-	-	[10]
Phosphate (as P)	-	-	-	-	No EQS set for seawater
Sulphate	-	-	-	-	No EQS set for seawater
Total residual oxidants (as chlorine)	-	-	10 µg/l	P_{95}	[10]
Tribromomethane (bromoform) (CBP)	-	-	5 µg/l	-	PNEC derived [69]
Non-ionic detergents	0.83µg/l	PNEC	-	-	[70]
Hydrazine	0.4 ng/l	PNEC	4 ng/l	PNEC	EDF commissioned studies [70]
Ethanolamine	160 µg/l	PNEC	160 µg/l	PNEC	[70]

Parameter	Long term EQS or EAL		Short term EQS or EAL		Source
Morpholine	17 µg/l	PNEC	28 µg/l	PNEC	[70]
Amino tri-methylene phosphonic acid (ATMP)	74µg/l	PNEC	74µg/l	PNEC	[70]
Hydoxyethylidene Diphosphonic Acid (HEDP)	13µg/l	PNEC	13µg/l	PNEC	[70]
Acetic acid	62.8µg/l	PNEC	301µg/l	PNEC	[70]
Phosphoric acid	20µg/l	PNEC	200µg/l	PNEC	[70]
Sodium polyacrylate	11.2µg/l	PNEC	180µg/l	PNEC	[70]
Acrylic acid	0.34µg/l	PNEC	1.70µg/l	PNEC	[70]
Escherichia coli (cells)	-	-	500 cfu/ 100 ml	P_{95}	[14]
Intestinal enterococci (cells)	-	-	200 cfu/ 100 ml	P_{95}	[14]
Escherichia coli (cells)	-	-	500 cfu/ 100 ml	P_{90}	[14]
Intestinal enterococci (cells)	-	-	185 cfu/ 100 ml	P_{90}	[14]

AA – AA- Annual Average, MAC- maximum allowable concentration, cfu- colony forming unit, P5-5%, P95-95%ile and son on, PNEC- predicted no-effect concentration CBP- chlorination by-product

5.2.4 Sediment quality standards

There are no quantified Environmental Quality Standards for in-situ marine sediment quality in the UK but two sets of criteria are widely used against which to assess sediment contamination. These are:

- Cefas guideline action levels for the disposal of dredged material; and
- Canadian Sediment Quality Guidelines for the Protection of Aquatic Life [71].

The Cefas guidelines have been specifically developed to be used as part of a 'weight of evidence' approach to assessing the suitability of dredged material for deposition in the sea as a means of disposal. Current Action Levels are set out in **Table 5.2.4.**

In general, contaminant levels in dredged material below Action Level 1 are of no concern and are unlikely to influence a licensing decision to approve sea disposal, while dredged material with contaminant levels above Action Level 2 is generally considered unsuitable for disposal/placement at sea and such material will usually need to be disposed of by a land-based route. Where contaminant concentrations fall between the two levels, further consideration will usually be required before a decision can be made about the suitability of the sea disposal route. The standards should not be viewed, therefore, as directly comparable to EQS.

The Canadian Interim Sediment Quality Guidelines (ISQGs) were developed by the Canadian Council of Ministers of the Environment for evaluating the potential for observing adverse biological effects in aquatic systems from available toxicological information. The guidelines are presented in **Table 5.2.4**. Again these provide two levels, the lower ISQG based on the Threshold Effect Level (TEL), below which adverse biological effects are expected to occur only rarely, and a higher level based on the probable effects level (PEL), above which adverse effects are expected to occur in a wider range of organisms. Although these guidelines were developed specifically for Canada and are based on protection of pristine environments they are widely used in the UK as one part of the 'weight of evidence' approach used by several regulatory and statutory bodies.

Table 5.2.4 Marine sediment quality standards (all as mg/kg dry weight)

Contaminant	Cefas action levels (MMO 2015 [72]		Canadian sediment quality guidelines [71]	
	Action Level 1	Action Level 2	ISQG/TEL	PEL
Arsenic [As]	20	100	7.24	41.6
Cadmium [Cd]	0.4	5	0.7	4.2
Chromium [Cr]	40	400	52.3	160
Copper [Cu]	40	400	18.7	108
Lead [Pb]	50	500	30.2	112
Mercury [Hg]	0.3	3	0.13	0.7
Nickel [Ni]	20	200	-	-
Zinc [Zn]	130	800	124	271
Tributyltin [TBT]	0.1	1	-	-
Dibutyltin [DBT]	0.1	1	-	-
Monobutyltin [MBT]	0.1	1	-	-
Polychlorinated biphenyls [PCBs], sum of ICES 7 congeners	0.01	None	-	-
Polychlorinated biphenyls [PCBs], sum of 25 congeners	0.02	0.2	0.0215	0.189
PAHs	0.1	None		

Contaminant	Cefas action levels (MMO 2015 [72]		Canadian sediment quality guidelines [71]	
	Action Level 1	Action Level 2	ISQG/TEL	PEL
Dichlorodiphenyldichloroethene [DDE]	-	-	0.00207	0.374
Dichlorodiphenyltrichloroethane [DDT]	0.001	-	0.00119	0.00477
γ-hexachlorocyclohexane [lindane]	-	-	0.00032	0.00099
Dieldrin	0.005	-	0.00071	0.0043

Table 5.2.5 Canadian sediment quality standards for individual PAHs (all as µg /kg dry weight)

Contaminant	Canadian sediment quality guidelines	
	ISQG/TEL	PEL
Acenaphthene	6.71	88.9
Acenaphthylene	5.87	128
Anthracene	46.9	245
Benz(a)anthracene	74.8	693
Benzo(a)pyrene	88.8	763
Chrysene	108	846
Dibenz(a,h)anthracene	6.22	6.22
Fluoranthrene	113	1494
Fluorene	21.2	144
2-Methylnaphthalene	20.2	201
Naphthalene	34.6	391
Phenanthrene	86.7	544
Pyrene	153	1398

5.2.5 Water Framework Directives targets

Waterbodies

Under the WFD, default objectives for surface water bodies are to meet ‘good chemical status’ and GES. Under certain defined circumstances, these can be modified for individual water bodies. Local surface water bodies that are scoped in for assessment are shown in **Table 5.2.3** and Appendix A, **Figure 5.2.1**. The objectives are set out in the River Basin Management Plan [73], as described below.

Table 5.2.3 Summary of Sizewell C WFD Compliance Assessment TraC waterbodies that have been scoped in

Name of Water Body	Water body ID	Hydro morphological Designation	Reasons for Designation as Heavily Modified Water Body (HMWB)	Current Overall Status	Proposed Status
Coastal					
Suffolk	GB650503520002	HMWB	Coastal Protection Flood Protection	Moderate potential	GEP by 2027
Walberswick Marshes	GB610050076000	HMWB	Flood Protection	Good potential	Remain at GEP
Transitional					
Blyth (S)	GB510503503700	HMWB	Coastal Protection Flood Protection	Moderate potential	GEP by 2027
Alde & Ore	GB520503503800	HMWB	Flood Protection	Moderate potential	GEP by 2027

The following information from the Suffolk operational catchments are taken from the Environment Agency catchment data explorer:

- Suffolk - The Suffolk Coastal operational catchment includes the natural surface water catchments of the rivers: Lothingland, Easton Broad, Wang, Blyth, Leiston Beck & Minsmere Old River, Fromus, Hundred and Alde & Ore, Butley, Tang, and Black Ditch. The catchment is mainly rural with numerous small towns and villages scattered throughout the area. It is one of the driest parts of the country, with local rainfall typically only two-thirds of the national average. The importance of this coastal catchment for biodiversity is recognised by its many wildlife designations including Ramsar sites, SPAs, SACs, National Nature Reserve and Sites of Special Scientific Interest.

- Suffolk TraC - There are five estuaries along the Suffolk coast (the Stour, Orwell, Deben, Alde/Ore and Blyth) with extensive wildlife-rich intertidal areas of mudflat and salt marsh the importance of which is recognised by their designation as sites of European/National importance. In places, old river mouths have become enclosed by sand and shingle bars, creating large areas of freshwater marshland, much of which is managed as nature reserves. Reclaimed estuarine intertidal areas bounded by river walls are now important agricultural areas. The shoreline consists of predominantly shingle beaches as well as important geomorphological features including shingle structures, such as Orford Ness.

The status of each waterbodies classifying elements along with information on sensitive habitats is found in the WFD waterbody summary **Table 5.2.4** and **Table 5.2.5**.

Other water bodies

The water quality and thermal plume modelling undertaken (see **Section 5.8**) shows that mixing zones associated with the discharges from the cooling water outfall will not extend outside the water bodies listed above.

Protected areas

Protected areas defined under the WFD and those relevant to assessing the environmental risk of the water discharge activity are the European wildlife sites and the designated bathing waters. The following objectives for these areas are in addition to the requirements for chemical and ecological status detailed above.

The objective for Natura 2000 Protected Areas, identified in relation to relevant areas designated under the Habitats Directive, is to protect and where necessary improve the status of the water environment to the extent necessary to achieve the conservation objectives established for the protection or improvement of the site’s natural habitat types and species of Community importance, in order to ensure the site contributes the maintenance of, or restoration to, favourable conservation status.

The objective for Natura 2000 Protected Areas identified in relation to relevant areas classified under the Birds Directive is to protect and where necessary improve the water environment to the extent necessary to achieve the conservation objectives that have been established for the protection or improvement of the site in order to ensure that the site contributes to the conservation (survival and reproduction in their area of distribution) of rare or vulnerable birds species as well as for regularly occurring migratory species listed in Annex I of the Birds Directive.

The objective, from the end of 2014, for bathing waters designated under the revised Bathing Waters Directive is to preserve, protect and improve the quality of the environment and to protect human health by complementing the WFD. This objective will be achieved by meeting the ‘sufficient’ quality standards of the revised Bathing Waters Directive; and by taking such realistic and proportionate measures considered appropriate with a view to increasing the number of bathing waters classified as ‘excellent’ or ‘good’.

Table 5.2.4 Sizewell C WFD Compliance Assessment TraC waterbodies classifying elements and sensitive habitats

Waterbody summary Table					**Current status**			**Target status**	**Waterbody**	**Hydromorphology**				
WFD water body name	**WFD water body ID**	**River basin district name**	**Water body type**	**Water body total area (ha)**	**Overall water body status**	**Ecological status**	**Chemical status**	**Target water body status**	**Deadline (year)**		**Hydro-morphology status**	**Is the water body heavily modified (HMWB)?**	**Use (reason for HMWB designation): coastal protection**	**Use: flood protection**
Alde & Ore	GB52 05035 03800	Anglian	Estuarine	1086.8 1	Moderate	Moderate	Good	Moderate	2015	Supports Good	Yes	No	Yes	No
Blyth (S)	GB51 05035 03700	Anglian	Estuarine	260.60	Moderate	Moderate	Good	Moderate	2015	Supports Good	Yes	Yes	Yes	No
Suffolk	GB65 05035 20002	Anglian	Coastal	14653. 27	Moderate	Moderate	Good	Moderate	2015	Not assessed	Yes	Yes	Yes	No
Walberswick Marshes	GB61 00500 76000	Anglian	Coastal	25.66	Good	Good	Good	Good	2015	Not assessed	Yes	No	Yes	No

Table 5.2.5 Sizewell C WFD Compliance Assessment TraC waterbodies classifying elements and sensitive habitats

Biology higher sensitivity habitats				Biology lower sensitivity habitat				bivalve mollusc production areas	Water quality: phytoplankton and harmful algae	
WFD water body name	**Mussel beds, including blue and horse mussel (ha)**	**Polychaete reef (ha)**	**Saltmarsh (ha)**	**Cobbles, gravel and shingle (ha)**	**Intertidal soft sediment (ha)**	**Rocky shore (ha)**	**Subtidal soft sediments (ha)**	**Bivalve mollusc production area name**	**WFD phyto-plankton classification**	**History of harmful algae**
Alde & Ore	1.38	-	390.82	219.22	817.54	0.29	320.56	Butley	-	Yes
Blyth (S)	-	-	93.02	-	200.46	-	-	-	-	Not Monitored
Suffolk	-	11.57	197.49	1929.57	816.46	1.78	10568.96	-	Good	Not Monitored
Walberswick Marshes	-	-	-	-	-	-	-	-	-	Not Monitored

5.3 European site standards

The European wildlife sites Alde-Ore and Butley estuaries SAC, Alde-Ore Estuary SPA, Alde-Ore Estuary Ramsar site, Benacre to Easton Bavents Lagoon SAC, Benacre to Easton Bavents SPA, Humber Estuary SAC, Minsmere Walberswick Heaths and Marshes SAC, Walberswick Heaths and Marshes SPA, Minsmere to Walberswick Ramsar site, Ofordness Shingle Street SAC, Outer Thames Estuary SPA, Southern North Sea SAC, the Wash and Norfolk coast SAC are required to comply with the conservation objectives set by Natural England and the Countryside Council for Wales under the provisions of Regulation 35(3)(a) of the Conservation of Habitats and Species Regulations 2017. This also covers objectives for the Ramsar Sites. These objectives are to achieve 'favourable conservation status', which is defined mainly in terms of:

- Limits of change in extent, physical characteristics and biological communities of relevant habitats from a defined baseline;
- The water quality standards established under the WFD and the Environment Agency's Review of Consents[8] process;
- Absence of toxic contaminants that would affect relevant species;
- For the SPA, numbers of birds;
- For the Ramsar Site, limits on obstruction of fish migration; and
- Adequacy of the supply of prey.

These objectives are therefore closely linked to water quality standards for aquatic designated sites.

5.3.1 Requirements under the Eels Regulations

The European Regulation for Establishing Measures for the Recovery of the Stock of European Eel (No 1100/2007 of 18 September 2007) [12] was introduced in response to concerns about the decline in populations of European eel and the requirement to prepare Eel Management Plans.

The Eels (England & Wales) Regulations 2009 (S.I. 2009 No. 3344) (as amended) [11] provide for regulation of eel fisheries and provision of eel passes.

[8] A requirement of the former Conservation (Natural Habitats &c) Regulations 1994, now replaced by Regulations 63 and 64 of the Conservation of Habitats and Species Regulations 2010, is for the Environment Agency (and other regulators) to review existing consents and determine if the consent can be affirmed or whether modification or revocation is required to avoid adverse effects on the integrity of the European site. A number of water quality targets were established as part of this process.

The UK produced a National Overview Report on Eel Management Plans and a series of regional plans based on River Basin Districts (RBDs). The Anglian RBD Eel Management Plan (DEFRA, 2010b) [74] concluded that the RBD probably did not comply with the 40% escarpment target for silver eel and therefore the Environment Agency are implementing a series of measures to enhance eel production in the RBD.

The WDA environmental permit will only cover discharges from the Outfalls and the Fish Recovery and Return. The design aspects of the Intakes and Fish Recovery and Return system including abstraction and impingement are discussed within the DCO Application.

5.4 Water quality baseline

5.4.1 Water quality data available

Historic data

Any development at Sizewell that may affect freshwater and/or estuarine and coastal water quality must be considered in relation to the WFD designations associated with the site which is in East Suffolk Zone of the Anglian RBD. In this RBD, only 5% of rivers (by length) meet the requirements for GES or GEP. In total, 15% of all surface waters are designated as artificial and 56% of all surface waters are designated as heavily modified. Currently none of the estuaries and transitional and coastal waters meets the requirements for GES or GEP. The nearest designated bathing waters immediately north and south of Sizewell are Southwold the Denes (and Southwold the Pier) and Felixstowe North (and Felixstowe south).

Metals enter the aquatic environment as a result of various processes. On the East coast of the UK the main sources are geological weathering, leaching of fertilizers, atmospheric deposition, animal excretion and the discharge of human sewage. Other sources include leaching from dumps and surface runoff e.g. from roads which contain metals that are present as a result of the abrasion of metal in the road surface and from vehicle lubricants and components. Metals enter estuaries both from feeder rivers and from direct discharges. These metals tend to be trapped in estuaries and accumulate in sediments. Physical disturbance and changes in physicochemical processes may make the metals in sediments available for accumulation by marine organisms.

The concentration of contaminants within the RBD is relatively low by comparison to levels present in estuaries and coastal waters associated with more industrialised areas although port activities on the Orwell have probably contributed to increased metal inputs to sediments.

Shipping and boating activity have resulted in contamination from antifouling compounds particularly tributyltins in sediments and currently to the input of copper and zinc which are again localised to areas of highest activity. It is likely that this contribution is responsible for the elevated concentration close to and in a few cases for zinc (mouth of the Orwell and off the Alde/Ore) exceeding respective EQS for these metals in seawater samples collected for compliance monitoring by the Environment Agency from a range of sites on the Suffolk coast from 1989-2006. The cadmium EQS was exceeded for the mouth of the Orwell and this was potentially linked to sewage works inputs. Upgrades to sewage works that discharge to the Orwell were however due to completed by 2005 so improvement in this parameter would be expected.

Other compounds of relevance to power station operation are generally not measured routinely and therefore data on levels within the area are limited to historic studies on power station discharges. These studies indicate relatively low and localised inputs of chlorine produced oxidants and bromoform from the exiting Sizewell B not exceeding current or indicative standards beyond 1-2km of the point of discharge.

The thermal input from the power station cooling water discharge is one of the more significant potential affects upon the marine environment off Sizewell. The data for temperature for four sites across the Suffolk Waterbody indicate that there is likely to be sufficient margin between the derived 98 percentile baseline temperature for the waterbody (19.4°C) to not result in major areas failing to meet the temperature boundary for Good/Moderate status (20 - 23°C). The boundary value for the Outer Thames Estuary SPA for the Habitats Directive criteria (28°C as a 98 percentile) is also likely to be met with only small areas of exceedance likely within the immediate mixing zone.

This location is relatively free of major industrial operations and emissions, but agriculture does have a significant influence on water quality and has contributed to the elevation of nutrient concentrations in rivers and estuaries in the region.

The coastal waters of East Anglia are enriched by nutrients derived from several sources including Urban Wastewater discharges but predominantly from riverine inputs which include agricultural sources. While the wider marine waters of the southern North Sea have been assessed as non-problem areas (Oslo-Paris Convention; OSPAR) for eutrophication there are coastal water bodies (within the 1nm of WFD) that are assessed as moderate status resulting from the level of nutrients. The Suffolk Coastal water body is Moderate status for DIN and High Status for the biological quality element phytoplankton.

Recent surveys

A marine water quality monitoring programme was established off the Suffolk coast in Sizewell Bay to assess the concentrations of many elements and compounds and their variation over a range of time scales. The initial programme ran from February 2010 to February 2011, and the results are presented [59]. Further monitoring surveys were conducted in 2014-2015 [60]. This latter survey allowed more reliable data to be collected for nutrients and some metals (for which detection limits were not adequate for these parameters in earlier work). However, the tidal cycle surveys in the earlier work in 2010 and 2011 provide a useful perspective of daily variation in physicochemical parameters in the marine environment off Sizewell. Sampling sites during both periods are shown in **Figures 5.4.1** and **5.4.2**. **Table 5.4.1** and **5.4.2** summarise the data obtained in 2010/2011 and 2014/15, as data averages and ranges. This provides a reasonable indication of the background water quality and represents the current 'baseline' situation with Sizewell B power station in operation. The coastal waters within the survey area were found to be fully mixed vertically, with no evidence of thermal or salinity stratification.

Table 5.4.1 2014/15 Survey mean and standard deviation of priority analytes at SZ3 (Cefas reference site), Sizewell C intake/outfall and Sizewell B outfall (see Figure 5.4.2).

Analyte	*Units*	EQS	All sites	SZ3		Sizewell C intake/outfall		Sizewell B Outfall	
		Annual average	Annual average	Mean	St dev	Mean	St dev	Mean	St dev
Arsenic Dissolved	µg l^{-1}	25	1.07	1.1	0.32	1.11	0.3	0.99	0.32
Cadmium, Dissolved	µg l^{-1}	0.2(1.5)[1]	0.05	0.03	0.03	0.05	0.03	0.08	0.10
Copper, Dissolved	µg l^{-1}	3.76	2.15	2.00	1.29	1.90	0.94	2.58	2.58
Nickel, Dissolved	µg l^{-1}	8.6(34)[1]	0.79	0.69	0.14	0.78	0.20	0.90	0.38
Zinc, Dissolved	µg l^{-1}	6.8	15.12	11.21	7.76	14.36	11.51	20.44	13.96
Iron, Dissolved	µg l^{-1}	1000	<100	<100	-	<100	-	203	446
Mercury, Dissolved	µg l^{-1}	(0.07)[1]	0.02(0.02) [1]	0.01	0.01	<0.01	-	0.03	0.12
Chromium VI Dissolved	µg l^{-1}	0.6(32) [1]	0.57	0.4	0.49	0.88	1.72	0.44	0.51

[1] These values in brackets are MACs set as a 95 percentile EQS, for mercury there is only a 95th percentile defined

Table 5.4.2 2014/15 Survey mean and standard deviation of environmental parameters SZ3, Sizewell C intake/outfall and Sizewell B outfall (see Figure 5.4.2)

Analyte	*Units*	SZ3		Sizewell C intake/outfall		Sizewell B Outfall	
		Mean	St dev	Mean	St dev	Mean	St dev
BOD 5 Day ATU	mg l^{-1}	1.02	0.41	1.04	0.51	1.31	0.55
Chloride	mg l^{-1}	18476.19	605.73	18572.22	507.36	18516.67	499.71
Carbon, Organic, Dissolved as C {DOC}	mg l^{-1}	1.07	0.21	1.04	0.21	1.15	0.26
Fluoride	mg l^{-1}	1.26	0.08	1.25	0.09	1.24	0.08
pH	pH Units	8.01	0.06	8.01	0.07	8.01	0.07
Bromide	mg l^{-1}	63.59	1.94	64.28	1.39	64.08	1.52
Solids, Suspended at 105 C	mg l^{-1}	52.43	46.53	55.50	39.77	90.56	72.98

5.4.2 Assessment of whether receiving water body meets the target standards

The ecological status of a surface water body is assessed according to:

- the condition of relevant biological elements, for example fish, benthic invertebrates, phytoplankton and other aquatic flora;
- the condition of supporting physico-chemical elements, for example temperature, pH, oxygenation salinity and concentrations of nutrients;
- the concentrations of specific pollutants; and
- the condition of the hydromorphological quality elements, including morphological condition, hydrological regime and tidal regime

The WFD water body most likely to be affected by the proposed discharge activity is the Suffolk Coastal WFD water body (GB650503520002).

Coastal water body (Suffolk) (HMWB)

This water body is currently estimated to be at moderate ecological status with an overall status of moderate (2016). Biological indicators based on phytoplankton are at good status. Physicochemical quality elements – dissolved inorganic nitrogen are at moderate status, dissolved oxygen is at high status, specific pollutants are high status and chemical status is good. Target waterbody status is Moderate by2027. (EA: https://environment.data.gov.uk/catchment-planning/WaterBody/GB650503520002, accessed on 22 January 2019).

Walberswick Marshes

Walberswick Marshes GB610050076000 Coastal water body – this water body is located to the north of the outfall and adjoins the Suffolk Coastal water body. This water body is currently estimated to be at good ecological status with an overall status of good (2016). Chemical status is good. Target waterbody status and deadline remains at Good ecological potential. (EA: https://environment.data.gov.uk/catchment-planning/WaterBody/GB650503520002, accessed on 22 January 2019).

Blyth (S)

Blyth GB510503503700 Transitional water body – this water body is located to the north of the outfall and adjoins the Suffolk Coastal water body. Target waterbody status and deadline are Good ecological potential (by 2027). (EA: https://environment.data.gov.uk/catchment-planning/WaterBody/GB650503520002, accessed on 22 January 2019).

Alde-Ore Estuary

Alde and Ore GB520503503800 Transitional water body – this water body is located to the south of the outfall and adjoins the Suffolk Coastal water body. This water body is currently estimated to be at moderate ecological status with an overall status of moderate (2016). Biological indicators based on macroalgae are at high status. Physicochemical quality elements – dissolved inorganic nitrogen are at moderate status, dissolved oxygen is at high status, specific pollutants are high status and chemical status is good. Target waterbody status and deadline are Good Ecological Potential (by 2027). (EA: https://environment.data.gov.uk/catchment-planning/WaterBody/GB650503520002, accessed on 22 January 2019).

Protected areas

The nearest designated bathing waters are Southwold the Denes (latitude 52.32º N, longitude 1.679º E) and Felixstowe North (latitude 51.96º N, longitude 1.355º E) and are approximately 10km and 35km distant, respectively. Of these bathing waters, Southwold the Denes is of sufficient quality (2018) and Felixstowe North is of Good quality (2018).

The European wildlife sites (Alde-Ore and Butley SAC, Benacre to Easton Bavents Lagoons SAC and Alde-Ore Estuary SPA; Minsmere to Walberswick SPA; Outer Thames Estuary SPA; Benacre to Easton Bavents SPA; Humber Estuary SAC; Minsmere to Walberswick Marshes SAC; Orfordness to Shingle Street SAC; Southern North Sea SAC; Wash and Norfolk Coast SAC) are required to comply with the Conservation of Habitats and Species Regulations 2017. In terms of water quality, this is achieved by compliance with the water quality EQS and sediment guidelines detailed above, including water quality EQS set for

European wildlife sites as part of the Review of Consents process. Thus, the discussions on compliance above have already taken account of the requirements for this type of protected site.

5.4.3 Future trends in water quality

The assessment start date for constructing the proposed development is 2021. The construction phase is anticipated to last nine to 12 years before the station becomes fully operational. The current baseline is considered appropriate for the duration of the construction and commissioning phases. The effects of operational impacts on water quality and sediment are considered against well-established current baselines. The extended lifecycle of the proposed development (60-years) means that some impacts must be considered in relation to potential shifts in future baselines due to climate change.

The water quality and sediment future baseline in this section is primarily taken from the Marine Climate Change Impacts Partnership (MCCIP) [75], the most comprehensive and up to date reviews of climate change impacts on the UK marine environment. The following summarises the MCCIP [75] findings of relevance to water quality and sediment.

Sea temperature rises

The southern North Sea is shallower with a faster warming rate than other areas of the UK. Climate predictions assume a linear increase in temperature which will be subject to increased uncertainty further into the future.

Thermal discharges and entrainment predictions are assessed against a baseline of elevated ambient temperature. However, Sizewell B is predicted to cease operation by 2055 at the latest. Thus, reducing the thermal footprint within the GSB.

Ocean acidification

Towards the end of the 21st century, ocean acidification may become an environmental concern around the UK for marine ecology. Decreasing pH will influence chemical speciation and e.g. partitioning of ionised and un-ionised ammonia favouring the less toxic ionised form.

5.5 Physical and sediment baseline, including habitat classification

5.5.1 Physical characteristics

The GSB is anchored in the north by the Blyth river jetties and in the south by the Thorpeness Headland and underlying erosion-resistant Coralline Crag, which outcrops sub-tidally. The main morphological features of the Bay are:

- the shingle beach;
- two sandy, shore-parallel longshore bars;

- the Sizewell–Dunwich Bank; and
- the Coralline Crag ridges that outcrop sub-tidally and extend to the north-east from Thorpeness.

The intertidal beach is primarily comprised of shingle (i.e. gravel-sized material) with a smaller sand-fraction that is either mixed with shingle or exists as surface, or sub-surface, veneers. The seaward limit of the shingle beach is an abrupt beach-step that meets a sub-tidal, low sloping, sandy bed. This boundary demarcates the seaward limit of the shingle beach and indicates that cross-shore exchange of shingle occurs almost exclusively landward of the low-tide beach step.

Landward of the continuous shingle beach are cliffs (Dunwich – Minsmere and Sizewell – Thorpeness) or low-lying hinterlands (Walberswick Marshes and the Minsmere Levels). A shingle barrier/dune with crest elevations ranging 2.4 – 7.2m Ordnance Datum Newlyn (ODN)) separates the Minsmere Levels (c. 0.26m ODN) from the sea along that frontage.

The subtidal beach is sandy and features an inner longshore bar 5-150m from shore of -1.2 to -3 m ODN elevation, as well as a larger outer bar 200 – 400m from shore of -2.5 to -4.5m ODN elevation. The bars are approximately shore-parallel and play an important role in dissipating wave energy (through wave breaking) and reducing wave angle at the shore/bar line (which controls longshore transport). During larger storms, when both bars are part of the surf zone, high suspended sand concentrations will fuel transport along the bar crests and troughs. That is, the bars are a sand transport corridor during storms.

Seaward of the bars, a 1200m-wide channel (up to 9m deep) separates the coast from the Sizewell – Dunwich Bank. Whilst primarily sandy, muds [76] are found in a narrow stretch just landward of the bank. Muddy sediments dominate the area to the north of the Dunwich end of the bank, whilst the bank itself is comprised of well-sorted fine-sands.

The tidal currents in the region are semi diurnal constituents and highly rectilinear (i.e., North – South). Typical spring tidal velocities near Sizewell are 1.2m/s. The tidal range increases from North to South across the region with spring tides from 1.9m at Lowestoft, 2.2m at Sizewell and to 3.5m at Felixstowe. Water movement is dominated by tidal currents that flow south for most of the rising (flood) tide (1.14m/s; peak) seaward of Sizewell Bank) and flow north for most of the falling (ebb) tide (1.08m/s). The strong tides and generally shallow bathymetry combine so that the water column is thermally well mixed throughout the year. The only exception to this being in the vicinity of the Sizewell B discharge plume but this is of insufficient spatial extent to affect the flow regime. As expected, tidal currents reduce close to shore and are about 0.2m/s (peak) within 50m of the coast [77].

Suspended sediments

Sediment suspended in sea water is the result of both natural processes and anthropogenic activities. The Suspended Sediment Concentration (SSC) is depth dependent, highly seasonal, and varies throughout the tidal cycle due to processes of deposition and resuspension. The SSC environment is an important factor determining ecological processes.

SSC from a sampling instrument (minilander) deployed 500m off the coast adjacent to the proposed Sizewell C station recorded the daily minimum, mean and maximum SSCs (Table 5.5.1). High levels of SSC are driven by both high wave energy events and peak spring tidal currents. Minimum observations are observed when neap tides coincide with low wave energy. The difference between daily maximum and minimum suspended load is approximately 300mg/l at 1m above the seabed and 500mg/l at 0.3m above the seabed.

Table 5.5.1 Suspended sediment concentration 500m from Sizewell C

Statistic	SSC at 0.3 m above the bed (mg/l)	SSC at 1 m above the bed (mg/l)
Daily minimum	24-28	15-19
Daily mean	103 – 161	72 – 105
Daily maximum	357 – 609	266 – 459

Further sampling was conducted inside of the Sizewell - Dunwich Bank looking at seasonal variation [61]. Samples 1m above the bed, near the existing Sizewell B outfall (Station 5, 52° 12.73’ N, 001° 37.77’ E), are summarised in **Table 5.5.2**.

Table 5.5.2 Inshore suspended sediment concentrations 1m above bed, Station 5

Sample Date	SSC at 1m above the bed (mg/l)
April to August (2010/11)	15 – 144
September to February (2010/11)	9 – 426
July 2016	8.65 – 68.35
August 2016	7.21 – 38.38
September 2016	5.20 – 16.98

SPM data, which is analogous to SSC at the surface, was also gathered from MODIS satellite database [59]. Satellite data for suspended particulate matter showed average mean SPM values at Sizewell during April to August of 31mg/l and average monthly maximum values of 80mg/l. Between September to March mean SPM values of 73mg/l were recorded in the surface waters at Sizewell with average monthly maximum values of 180mg/l (**Table 5.5.3**).

Table 5.5.3 Surface mean and maximum suspended particulate matter from MODIS satellite database.

Assessment period	Mean SPM (mg/l)	Maximum SPM (mg/l)
April – August	31	80
September – March	73	180

Suspended matter is an important driver for ecological functioning of coastal systems. The WFD DIN standards for coastal waterbodies account for turbidity within the system as phytoplankton are less able to utilise nutrients in turbid systems. DIN standards are based on the annual mean concentration of SPM (Water Framework Directive, 2015). Based on the satellite data the surface waters at Sizewell are classed as 'intermediate turbidity' (10-100mg/l).

Climate change

There are several issues that may need to be considered for future climate change relative to the sensitivity of the receiving environment for the proposed water discharge activity. The main factors influenced by climate change that could affect the geomorphology or hydrodynamics of the GSB are:

- Increased relative sea level, which is likely to increase breaching, beach/cliff erosion and may increase rates of longshore transport.
- A different wave climatology, which has relevance to longshore sediment transport.
- An altered sediment supply regime into, or out of, the GSB, which could be caused by climate change or changes in regional coastal management practices (defined through shoreline management plans).

These changes may result in undermining and/or overtopping of sea defences, and an increase and/or change in sediment loads in the water at the intake structure.

5.5.2 Sediment quality

SZC Co. commissioned a survey in 2015 in order to acquire seabed and sub seabed data, to provide sediment data relating to the defined site areas intended for construction of the Beach Landing facility and offshore tunnels and shafts. The investigation was designed to confirm the stratigraphy and horizons of the ground layers, the geotechnical properties and assess any contamination within the marine sediments.

As part of the geotechnical survey carried out between 02/02/2015 and 30/04/2015, 30 Vibrocores (VC) were acquired (**Figure 5.5.1**) [78]. The VC were carried out using Fugro's High Performance Corer (Hinkley Point C). The corer has a 6m barrel and uses a motor to generate optimum excitation frequency and vibration amplitude. Immediately after recovery, the VC were cut into 1m sections. The sections of core were sealed using plastic caps and adhesive PVC tape, and stored vertically in a core transport crate located on deck. Sample quality was good, with penetration ranging from 0.62m to 6.22m and an average recovery ratio of 92%. Insufficient water depth prevented cores at the proposed locations VC20 and VC25.

Sediment processing

Samples were taken from 14 cores and were analysed for organic chemical and heavy metal contaminants; 5 of those cores were also sampled for radionuclide composition. Samples were taken from the sediment surface and then at 1m intervals down to the Crag. Samples were representative of the material at the sampling depth. Samples were placed into chemically clean sample containers which were taken promptly from the cores before samples were exposed to air and sunlight for an extended period. Samples were protected from contamination from vessel exhaust, winch grease and smoking. Samples were then uniquely labelled, stored and transported at below 4ºC in the dark. Laboratory testing of samples was conducted by Fugro Alluvial Offshore Ltd (FAOL), National Laboratory Service and Cefas. Geotechnical samples were sent to the relevant laboratories for further analysis which included chemical, heavy metal contaminants and radionuclide composition.

Sediment analysis

The marine sediment at Sizewell has been characterised with respect to sediment quality in keeping with OSPAR requirements for dredged material for which 7 – 15 sample stations are required for plans requiring dredge volumes of for 100,000 – 500,000m^3

Sediment samples from the VC were analysed for the following contaminants between 25/05/2015 and 23/07/2015:

- National Laboratory Service – Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Zinc, Dichlorodiphenyltrichloroethane and Dieldrin.
- FAOL – Monobutyl-tin, Dibutyl-tin, Tributyl-tin and Particle Size Analysis (PSA).
- Cefas – PAHs, Total Hydrocarbon Content (THC) and Polychlorinated biphenyls (PCBs).
- Cefas – Radionuclides.

The metal analysis method for Arsenic, Cadmium, Chromium, Copper, Lead, Nickel and Zinc was sediment microwave aqua regia digest, determined by ICP mass spectrometry. Samples were sieved to 2000 µm. The metal analysis method for Mercury was sediment microwave aqua regia digested, acidic SnC12 reduced determined by cold vapour atomic fluorescence spectroscopy. Samples were sieved to 2000µm.

The organotin analysis method for Monobutyl-tin, Dibutyl-tin and Tributyl-tin was acidic solvent extraction of the sample followed by analysis by gas chromatography mass spectrometry.

The PAH analysis method was sulphur removal followed by analysis by gas chromatography mass spectrometry. The THC analysis method was solvent extraction followed by analysis by gas chromatography flame ionisation detector. THC includes all dichloromethane extractable hydrocarbons between nC_{10} to nC_{40}.

The PCB analysis method was sulphur removal followed by analysis by gas chromatography mass spectrometry. PCB ICES 7 is the sum of the following congeners: PCB#28; PCB#52; PCB#101; PCB#118; PCB#138; PCB#153; and PCB#180. PCB 25 congeners is the sum of all 25 PCB congeners.

The Dichlorodiphenyltrichloroethane (DDT) and Dieldrin analysis method was solvent extraction followed by analysis by gas chromatography mass spectrometry.

The PSA method was by dry sieving (63000 – 1000µm) at 0.5 Phi intervals and laser diffraction (<1000 - <3.91µm) at 0.5 and 1 Phi intervals.

The radionuclide analysis method was high resolution gamma spectrometry.

Each analysis method, apart from the organotin analysis method is United Kingdom Accreditation Service (UKAS) accredited.

Analysis results and interpretation

The sediment samples collected at Sizewell indicate that PCB's, organotin and some heavy metals were below Cefas Action Level 1 and pose no environmental concern. Nickel and Chromium exceeded Cefas Action Level 1 but the highest concentrations reported were less than 25% of Cefas Action Level 2 concentrations and below ISQG PEL concentrations. Arsenic exceeded Cefas Action Level 1 concentrations in six of the samples at different locations and depth profiles. Two samples from the inshore areas (VC18 and VC30) at a sediment depth of 2-2.2m and 5-5.2m showed the highest levels of arsenic, close to, but not exceeding the Cefas Action Level 2 of 100 mg/kg (measurements of 84.7mg/kg and 91.5mg/kg). Three other sample locations with one at two depths sampled exceeded AL1 but the highest exceedance was <25% above AL1. High levels of arsenic have been reported in the region under similar studies (for example see Galloper Wind Farm Limited 2015). The elevated levels of arsenic at location VC18 and VC30 are not associated with any other elevated contaminants of anthropogenic origin and are found only sub-surface, and as such are representative of the natural geology and not anthropogenic contamination.

PAH and THC exceeded Cefas Action Level 1 for some determinants (no Cefas Action Level 2 exists for hydrocarbons). However, only for the PAH dimethyl naphthalene were concentrations elevated above the PEL and this was the case in eleven samples. All other determinants were below PEL limits. A further method to examine PAHs in marine sediments involves assessing levels of grouped PAHs based on their origin and effects characteristics, to published effects ranges. Hydrocarbons can be grouped into low molecular weight (LMW) and high molecular weight compounds (HMW); LMW are typically from oil (termed 'petrogenic') sources, are highly volatile so evaporate quickly, have high solubility and are easily absorbed across cell membranes and are acutely toxic and carcinogenic. HMW are typically derived from 'pyrolytic' sources (e.g. burning of fossil fuels) they are more pervasive with low volatility, are often bound to particulates in air or sediment and are more persistent in the environment. Effects ranges typically used for assessment include the 'effect range low' (ERL) and the 'effects range medium' (ERM). Effects on biota at concentrations below the ERL are rarely observed however at levels above the ERM effects are generally or always observed. The ERL and ERM values for LMW and HMW PAHs are given in (Buchman, 2008) as; 552ng/g (ERL) and 3,160ng/g (ERM) for LWM and 1,700ng/g (ERL) and 9,600 (ERM) for HWM. All values for the sediment samples were below the relative ERM values and all expect two samples were below the ERM values. Samples VC10 (surface) and VC24 (surface) marginally exceed the ERL for LMW PAHs (levels of 725ng/g and 793 ng/g respectively), however these exceedances are marginal and the ERL should be considered a low point on a continuum of possible effects, furthermore these two locations represent the highest proportions of fines in the surface sediments and therefore can be expected to adsorb relatively higher levels of organic compounds compared to coarser sediments.

The analysis of contaminants from the core samples indicates surface sediments are at, or close to, background levels (i.e. Cefas Action Level 1) or are shown to be considerably below the levels at which biological effects could be anticipated. Elevated arsenic levels, although still below Cefas Action Level 2, are observed in sub-surface samples from >2m below the seabed. The only pathway for disturbance of these sub-surface sediments would be dredging or drilling. The locations of elevated arsenic are >160m from the currently proposed dredging site (Fish Recovery Return 2), dredging at this site is expected to cover a footprint of 9m by 23m, and therefore it is currently considered unlikely that these sediments would be disturbed by the proposed works. Furthermore, the acceptability of material for dredging and disposal will require a contemporary assessment at the time of dredging which will consider the specific details of the dredging requirement and, if necessary, obtain and interpret new sediment samples

The sediments are therefore considered to be uncontaminated and the effects of resuspension of contaminants on marine ecology receptors is not considered further.

PSA indicated that most of the samples consisted of sandy material with low organic carbon content (0.08 – 0.1 OC % inshore and 0.58 – 0.82 % further offshore).

5.6 Sensitive receptors

5.6.1 Scope

The aim of this section is to describe briefly the aquatic ecological baseline of the Sizewell C area, with emphasis on receptors sensitive to the proposed water discharge activity.

5.6.2 Biotopes

The intertidal beaches within the GSB are predominantly coarse sediment with ephemeral sand veneers, harbouring sediment-dwelling organisms. However, the beaches of the area cannot be considered particularly diverse compared with other intertidal beaches in Europe. Intertidal surveys of the area show little evidence of spatially distinct assemblages and no benthic invertebrate species found in the intertidal zone of the GSB are of conservation importance.

In the subtidal area, the same broad infaunal and epifaunal benthic community - including the infauna (organisms living in the seabed) and epifauna (organisms living on or just above the seabed) - spans most of the GSB. Both the infauna and epifauna communities are common in a regional context as they are part of a larger community distributed across the south of the North Sea 'infralittoral region', corresponding to subtidal areas within 50m depth.

The European Nature Information System (EUNIS) brings together European data from several databases and organisations into three interlinked modules on sites, species and habitat types. The EUNIS habitats classification is a means of standardising habitat types for conservation objectives using a hierarchical classification system.

Seabed habitats, classified to EUNIS Level 4 show spatial variation in the GSB (see **Figure 5.2** Appendix D). The following section considers the habitats of relevance to Sizewell and references them with EUNIS codes and descriptions:

- Infralittoral fine sand (A5.23) is found in the north of the survey area, covering both Dunwich and Sizewell Bank, as well as along the coast from Aldeburgh to Dunwich. These two areas are interspaced with circalittoral muddy sand (A5.26) and infralittoral sandy mud (A5.33) in the deeper parts of the Bay.

- Along the shoreline, in the shallow subtidal zone, habitats alternate between infralittoral fine sand (A5.23) and infralittoral coarse sediments (A5.13).

- Larger patches of infralittoral coarse sediments are be found off Minsmere and Orford (A5.13).

- The area off Sizewell and Thorpness are classified as hard substrates including circalittoral rock (A4.13) and infralittoral mixed sediment (A5.43) where coralline crag (hard sediment characterised by biogenic debris) is exposed on the seabed.

Two habitats have been identified for their potential conservation and ecological importance in the GSB:

- The coralline crag hard substrate is locally unusual among the sands and gravels of the GSB. Surveys on the coralline crag indicate the presence of *Sabellaria spinulosa* reefs [79]. When in reef aggregations, *S. spinulosa* is an Annex I habitat under the EU Habitats Directive and listed under Section 41 of the NERC Act as a habitat of conservation importance.

- Seasonally high abundance of benthic invertebrate taxa following recruitment events on the Sizewell-Dunwich Bank suggests the sandbank may provide feeding grounds for higher trophic levels (fish, seals, seabirds). The Sizewell-Dunwich Bank is not an Annex I designated sandbank habitat; however, the feature appears to have an important ecological role influencing benthic community composition of the GSB. Except for the single occurrence of *G. insensibilis* in low densities in June 2010, no species of conservation importance are known to occur on the sandbank.

The benthic habitats in the GSB, unless formed by live organisms, are not treated as receptors in the benthic ecology assessments but rather are considered in terms of their role in determining the sensitivity of benthic invertebrates to pressures associated with the proposed development.

5.6.3 Designated wildlife sites

EDF Energy first undertook a European site scoping exercise for the Sizewell C Project between 2012 and 2014; this was updated in 2018-2019. The first scoping exercise built upon the Nuclear National Policy Statement European site scoping undertaken [80]. This scoping exercise identified (“scoped in”) all European sites within a 20 km range of the Sizewell C Project.

In 2018 and 2019 this exercise was updated for the entire Sizewell C Project, based on the most up to date project proposals and consultation with the HRA Working Group.

In relation to the activities that are the subject of the Operational Water Discharge environmental permit application, the HRA scoping exercise identified 13 relevant European sites based on the predicted ZOI of the Sizewell C Project’s discharge activities. In order to determine if any European sites outside the ZOI may also be affected by the proposed WDA, evidence must be gathered to determine the use of the ZOI by mobile qualifying features from these sites, i.e. marine mammals, migratory fish and birds. Such species may use the area within the ZOI for foraging and migration routes. These European sites are listed in the following sections which also set out the qualifying interest features for each of these sites. More detail is provided including on connectivity between SACs for marine mammals and i.e. breeding seabird SPAs/Ramsar sites that are distant from the Sizewell C Project (i.e. beyond 20km) in Appendix C SIZEWELL C Shadow HRA Report -Operational Water Discharge environmental permit application.

Alde-Ore and Butley Estuaries (SAC) (distance from main development site 5km)

The SAC covers an area of 1,633ha and is made up of three rivers. It is the only bar-built estuary in the UK with a shingle bar. Annex 1 habitats that are a primary reason for selection of the site:

- Estuaries

Annex 1 habitats present as a qualifying feature, but not a primary reason for selection of this site:

- Mudflats and sandflats not covered by seawater at low tide.
- Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*).

Alde-Ore Estuary (SPA)

The SPA is located on the Suffolk coast between Aldeburgh to the North and Bawdsey to the South. The site includes Havergate Island and Orford Ness, as well as the estuaries of the rivers Alde, Butley and Ore.

The SPA is composed of Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*), intertidal mudflats, shingle, coastal lagoons and estuarine fish communities. Bird usage of habitats within the SPA varies seasonally, with different areas being utilised for nesting and feeding at different times of the year.

This site qualifies under Article 4.1 of the Birds Directive (2009/147/EC) by supporting populations of European importance of a range of bird species listed on Annex I of the Directive:

These include species present during the breeding season and those that over winter (see Table 4.1 Appendix C)

Alde-Ore Estuary Ramsar Site

The site comprises the estuary complex of the rivers Alde, Butley and Ore, including Havergate Island and Orfordness. There are a variety of habitats including, intertidal mudflats, saltmarsh, vegetated shingle. The site qualifies as a Ramsar for the following reasons:

- Ramsar criterion 2 - the site supports a number of nationally-scarce plant species and British Red Data Book invertebrates.
- Ramsar criterion 3 - the site supports a notable assemblage of breeding and wintering wetland birds.
- Ramsar criterion 6 - species/populations) occurring at levels of international importance. Qualifying Species/populations (as identified at designation).

A range of bird species are regularly supported during the breeding season (Table 4.1 Appendix C).

Benacre to Easton Bavents Lagoons SAC (distance from main development site 15.5km)

This SAC is a series of percolation lagoons on the east coast of England. The lagoons (the Denes, Benacre Broad, Covehithe Broad and Easton Broad) have formed behind shingle barriers and are a feature of a geomorphologically dynamic system. Annex 1 habitats that are a primary reason for selection of the site:

- Coastal lagoons.

Benacre to Easton Bavents SPA

The SPA is located on the North Sea coast of East Suffolk, between the coastal towns of Kessingland (to the north) and Southwold (to the south). The coast here is low-lying and consists of shingle beach in the northern part and low cliffs around Easton Bavents and Covehithe. Benacre Broad is a natural brackish lagoon separated from the sea by a shingle bar, reed-fringed on the landward side and then grading into deciduous woodland on the rising ground behind. This site qualifies under Article 4.1 of the Birds Directive (2009/147/EC) by supporting populations of European importance of the following species listed on Annex I of the Directive:

During the breeding season;

- Bittern *Botaurus stellaris*
- Little tern *Sternula albifrons*
- Marsh harrier *Circus aeruginosus*

Humber Estuary SAC (distance from main development site 220km)

The Humber is the second largest coastal plain Estuary in the UK, and the largest coastal plain estuary on the east coast of Britain. The estuary supports a full range of saline conditions from the open coast to the limit of saline intrusion on the tidal rivers of the Ouse and Trent.

Annex 1 habitats that are a primary reason for selection of the site:

- Estuaries.
- Mudflats and sandflats not covered by seawater at low tide.
- Annex 1 habitats present as a qualifying feature but not a primary reason for selection of this site as detailed Appendix C (**Table 4.1**).

Minsmere to Walberswick Heaths and Marshes SAC (Adjacent to main development site)

This site is one of two representatives of annual vegetation of drift lines on the east coast of England. It occurs on a well-developed beach strandline of mixed sand and shingle and is the best and most extensive example of this restricted geographical type. The site is designated as a SAC for the following features:

Annex 1 habitats that are a primary reason for selection of this site:

- Annual vegetation of drift lines.
- European dry heaths.

Annex 1 habitats present as a qualifying feature, but not a primary reason for selection of this site:

- Perennial vegetation of stony banks.

Minsmere Walberswick SPA

The site comprises two large marshes, the tidal Blyth estuary and associated habitats. This composite coastal site contains a complex mosaic of habitats, notably areas of marsh with dykes, extensive reedbeds, mud-flats, lagoons, shingle, woodland and areas of lowland heath.

The site qualifies under Article 4.1 of the Birds Directive (2009/147/EC) by supporting populations of European importance of the following species listed on Annex 1 of the Directive:

- During the breeding season;
- Avocet *Recurvirostra avosetta*
- Bittern *Botaurus stellaris*
- Little tern *Sternula albifrons*
- Marsh harrier *Circus aeruginosus*
- Nightjar *Caprimulgus europaeus*

Over winter;

- Hen harrier *Circus cyaneus*

This site also qualifies under Article 4.2 of the Birds Directive (2009/147/EC) by supporting populations of European importance of the following migratory species:

During the breeding season;

- Shoveler *Anas clypeata*
- Teal *Anas crecca*
- Gadwall *Anas strepera*

Over winter;

- Gadwall *Anas strepera*
- Shoveler *Anas clypeata*
- White fronted goose Anser *albifrons albifrons*

Minsmere Walberswick RAMSAR site (Adjacent to main development site)

This Suffolk coastal site contains a complex mosaic of habitats, notably, areas of marsh with dykes, extensive reedbeds, mudflats, lagoons, shingle and driftline, woodland and areas of lowland heath.

The site qualifies as a Ramsar under the following criteria:

- Ramsar criterion 1 - the site contains a mosaic of marine, freshwater, marshland and associated habitats.
- Ramsar criterion 2 - this site supports nine nationally scarce plants and at least 26 red data book invertebrates.
- Ramsar criterion 2 – this site also supports an important assemblage of rare breeding birds associated with marshland and reedbeds.

Orfordness Shingle Street SAC (Distance to main development site 8km)

Orfordness is an extensive shingle structure and consists of a foreland, a 15 km-long spit and a series of recurves running from north to south on the Suffolk coast.

The site is designated as an SAC for the following features: Annex 1 habitats which are a primary reason for site selection:

- Coastal Lagoons
- Annual vegetation of drift lines
- Perennial vegetation of stony banks

Outer Thames Estuary SPA (Main development site within and adjacent)

The Outer Thames Estuary SPA consists of areas of shallow and deeper water, high tidal current streams and a range of mobile sediments. The site qualifies under Article 4.1 of the Birds Directive (2009/147/EC) as it is used regularly by 1% or more of the Great Britain population of the following species listed in Annex I in any season: During the breeding season;

- Little tern *Sternula albifrons*, representing 19.64% of the Great Britain population (2011 – 2015).
- Common tern *Sterna hirundo* representing 2.66% of the Great Britain population (2011 – 2015).

Over winter;

- Red-throated diver *Gavia stellata*, 6,466 individuals representing 38% of the Great Britain population (1989 – 2006/07).

Southern North Sea SAC (Main development site within and adjacent)

The Southern North Sea SCI lies along the east coast of England, predominantly in the offshore waters of the central and southern North Sea, from north of Dogger Bank to the Straits of Dover in the south.

The qualifying feature of the site is the Annex II species:

- Harbour porpoise *Phocoena phocoena*

The Wash and Norfolk Coast SAC (distance from main development site 120km)

The Wash is the largest embayment in the UK. It is connected via sediment transfer systems to the north Norfolk coast. Annex 1 habitats that are a primary reason for selection of the site:

- Sandbanks which are slightly covered by sea water all the time
- Mudflats and sandflats not covered by seawater at low tide
- Large shallow inlets and bays
- Reefs
- Salicornia and other annuals colonizing mud and sand
- Atlantic salt meadows (*Glauco-Puccineolietalia maritimae*)

Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticose*) Annex 1 habitats present as a qualifying feature, but not a primary reason for selection of this site:

Coastal lagoons Annex II species that are a primary reason for selection of this site:

- Harbour seal Phoca vitulina

Annex II species present as a qualifying feature, but not a primary selection:

- Otter Lutra lutra

5.6.4 Key species and habitats

Phytoplankton

Data to inform the phytoplankton baseline has been compiled from surveys undertaken as part of the BEEMS monitoring programme in 2012 and 2014, the Environment Agency WFD data from the Sizewell area, from the Cefas West Gabbard site and information from remote sensing of the wider region [76].

Additional monthly surveys were completed as part of the BEEMS monitoring programme between March 2014 and January 2017 [81]. These surveys included sampling sites at the location of the current Sizewell B intakes, the Sizewell B outfalls and the proposed location of the Sizewell C cooling water infrastructure, approximately 3km offshore. A references site (SZ3), 5.8km to the north of Sizewell was also sampled. The survey objectives were to determine the temporal and spatial variability in phytoplankton communities within the GSB.

Phytoplankton cells numbers and biomass (chlorophyll a) is highest during the “spring bloom” in May. A seasonal succession occurs in community composition; however, the system is heavily dominated by diatoms (2-500µm) year-round. Diatom relative abundance peaks at >99% in May and June and dips to 54% in September. Microflagellates (2-20µm) become more abundant in mid-Summer to Autumn. Dinoflagellates are present but typically accounted for less than 13% of the community composition during their peak abundance in August and September.

No detectable differences in phytoplankton taxon distribution were observed between sampling sites within the GSB, and the community is representative of the wider region (represented by the Suffolk Environment Agency and Cefas West Gabbard data).

Zooplankton

Zooplankton include the early life stages of fish (ichthyoplankton), benthic organisms and invertebrates that are planktonic throughout their life cycle (holoplankton). Zooplankton feed on phytoplankton, detritus and other smaller zooplankton and form an important food source for higher trophic levels. Zooplankton are a core component of marine ecosystems.

The zooplankton community has been characterised for the marine waters adjacent to the proposed development. Ichthyoplankton sampling began in 2008 and invertebrate zooplankton collection and analysis commenced in June 2009.

Of the larger size fraction zooplankton, characteristic taxa include mysids, ctenophores, gammarid amphipods, polychaete larvae, hooded shrimps (cumacea), jellyfish, *Crangon* spp., decapods, nematodes, isopods and krill.

Bentho-pelagic mysids were both the most common and abundant group. In the 2009-2012 data set mysids were identified in 97% of samples and accounted for nearly 77% of the total abundance of the larger size fraction zooplankton individuals analysed. Four species of mysid have been identified at Sizewell including *Schistomysis spiritus*, *Siriella sp*., *Mesopodopsis sp*. and *Schistomysis sp*., of which *Schistomysis spiritus* was the most abundant. Mysids peak in abundance off Sizewell in May-June.

Ctenophores were the second most common and abundant group occurring in 59% of the samples and accounting for over 10% of the total abundance in the February to July data set between 2009 and 2012. The species observed off Sizewell primarily included the ctenophores *Pleurobrachia pileus* (sea gooseberry) and *Beroe Cucumis.* Jellyfish also occur in the plankton off Sizewell and include unidentified medusae, the crystal jellyfish (*Aequorea victoria*), the compass jellyfish (*Chrysaora hysoscella*) and the moon jellyfish (*Aurelia aurita*). Abundance is low throughout most of the year but increases in August and September.

The smaller size fraction zooplankton represented by far the most numerically abundant zooplankton group. The peak abundance for most taxa occurs in May. A total of 60 taxonomic groups were identified in the 2014-2017 surveys. The smaller size fraction zooplankton was characterised by invertebrate eggs, foraminifers, copepod juveniles and adult stages, bivalves, polychaetes, bryozoans, appendicularians, rotifers, gastropod larvae, echinoderms, gelatinous zooplankton, cirripedia (barnacle) larvae, nematodes, arachnids and protozoans.

Copepod are a highly diverse group of holoplankton. Copepods were ever-present in zooplankton samples and accounted for over 28% of the total abundance of the smaller size fraction zooplankton (2009-2012 data). Copepods include the adult and juvenile stages of harpacticoids, cyclopoids and the numerically dominant calanoid orders. Acartia spp and *Temora longicornis* are the most dominant calanoid copepod taxa.

Zooplankton entrainment

Comprehensive Entrainment Monitoring Programme (CEMP) surveys at Sizewell B determined the zooplankton taxa entrained in the cooling water flow. Forty-nine invertebrate zooplankton taxa were encountered in the Sizewell B cooling water. Based on scaled numbers an estimated 294.5×10^9 individual invertebrate zooplankton are entrained annually. Copepods made up over 72% of the total zooplankton entrained with the Centropages, Temora, and Acartia the most commonly observed. Bentho-pelagic taxa (mainly gammarids 8.7% and mysids 3.4%) and benthic taxa and their larvae (mostly barnacles 3.4%) comprised a further 18.0 %.

Key zooplankton taxa

Based on the in-situ sampling programmes and CEMP, the key zooplankton taxa for assessment purposed include:

- mysids;
- amphipods;
- gelatinous zooplankton and;
- copepods.

These species are common and abundant in the coastal waters off Sizewell and are considered to be ecologically important components of the food-web. Gelatinous zooplankton are both abundant and important for the EIA due to their potential socio-economic importance. Gelatinous zooplankton are an important consideration for power plants, due to their gelatinous nature and propensity for populations to expand exponentially (i.e. to from “blooms”). In certain circumstances, gelatinous zooplankton blooms have the potential to cause reductions in efficiency or blockages of the cooling water intake filters of power stations, which in severe cases can lead to station shutdown.

Benthic biota

The benthic biota of the GSB has been characterised based on a series of onshore and offshore surveys implemented between 2008 and 2017.

Onshore surveys include comprehensive fortnightly impingement sampling at Sizewell B, with a total of 202 samples collected between 2009-2017 and invertebrate abundance recorded. An intertidal survey of the beaches in the GSB was implemented in 2011 and involved 12 quadrat samples across the shore.

Offshore surveys included:

- Eleven subtidal surveys, comprising a total of 890 grab samples (0.1m^2) from 88 stations.
- A shallow subtidal survey, comprising 17 grab samples (0.025m^2) in 2011.
- A total of 295 2m beam trawl samples from 84 stations and 64 commercial otter trawl samples from 11 stations, collected quarterly to annually during 2008-2014.

As it is unfeasible to consider the effect of each pressure associated with the proposed development on each species, assessments are focused on twenty key taxa belonging to the five broad taxonomic groups (molluscs, crabs and lobsters, shrimps and prawns, polychaetes and echinoderms). These taxa are selected due to their ecological importance (i.e. they are widespread and abundant), conservation importance (i.e. they have national or international conservation status) and/or socio-economic importance (i.e. they are commercially exploited locally or targeted by recreational fishers).

Species and habitats listed under Section 41 of the NERC Act (2006) are identified as being ‘high value’ receptors. The lagoon sand shrimp *Gammarus insensibilis* is typically associated with saline lagoons but was observed outside of this habitat in the GSB, occurring at low abundance in the subtidal zone in June 2010. The ross worm Sabellaria spinulosa is listed under Section 41 of the NERC Act (2006) when it forms biogenic reefs. Under these circumstances it is also a habitat of international conservation importance under the EU Habitats Directive of 1992. *Sabellaria spinulosa* is considered a high value receptor here as the formation of a habitat of conservation importance requires its presence.

As species-specific assessments are limited to a subset of key taxa, a biological traits-based approach is used to describe the full infaunal and epifaunal assemblages in terms of a suite of organismal characteristics that determine biotic response to environmental changes. This way, assessments of ecological effects can be made at the community level using shared traits that are most relevant for the pressures to which benthic invertebrates would be exposed.

Migratory fish

Within the GSB, migratory fish recorded in the Comprehensive Impingement Monitoring Programme dataset as well as the juvenile European eels survey and smelt survey are as follows:

- Smelt *Osmerus eperlanus*
- European eel *Anguilla anguilla*
- Allis shad *Alosa alosa*
- Twaite shad *Alosa fallax*
- River lamprey *Lampetra fluviatilis*
- Sea lamprey *Petromyzon marinus*
- Sea trout *Salmo trutta*
- Atlantic salmon *Salmo salar*

Smelt is listed as a Priority Species in Section 41 of the NERC Act 2006. In 2016, surveys were undertaken to determine whether the River Blyth supports a spawning population of Smelt and whether the fish impinged at Sizewell are from a specific river stock or a pan-East Anglian or a wider east coast stock. The sampling period coincided with the main spawning migration of smelt in the adjacent rivers Yare, Wensum, Bure, Waveney and Cambridge Ouse.

The nearest estuary to the northern smelt migration rivers of East Anglia is the Blyth, approximately 12km away. Surveying using fyke nets and kick sampling methods was carried out in the tidal and estuarine areas of the Blyth in April and May 2016. No smelt were found in the area and there was an absence of suitable spawning substrate.

No eels were found in the BEEMS coastal trawl surveys. In April/May 2015, an additional survey was undertaken targeted towards glass eels in the area of the proposed Development cooling water infrastructure. Only one glass eel was captured from the 105 valid hauls and it was concluded that this lack of glass eels at Sizewell was indicative of the extremely low local abundance and high level of dispersal of this particular life stage in this open coastal area of the North Sea.

For Twaite shad the species has declined substantially across Europe and in the UK. It is now known to breed only in the Severn River Basin District in the Severn, the Wye, the Usk and the Tywi) and in the Solway Firth. There are also non-breeding populations in the UK off the southern and eastern coasts, at Looe Bay, Hastings and Sizewell.

Allis shad *Alosa alosa* are rare in the UK. Although formerly known to spawn in several British river systems, there is inconclusive evidence of spawning activityin the Tamar Estuary (Plymouth Sound and Estuaries cSAC).

River and sea lamprey occur in estuarine/coastal environments. Sea lamprey is uncommon in the UK and the main population centre, concentrated on the Bristol Channel, is distant from the proposed Development site.

For Atlantic salmon and sea trout based on the data gathered from BEEMS surveys, neither species is present to any appreciable degree, nor has been seen in the GSB.

Marine fish

The current baseline for fish of the GSB area have been characterised from coastal demersal and pelagic trawl surveys; entrainment and impingement monitoring at Sizewell B; ichthyoplankton sampling; and international stock assessments. The use of multiple sampling methods or gears allowed a comprehensive description of the area to be produced, since a single gear or sampling method was unable to fully sample the entire community.

Demersal fish and elasmobranchs

During the coastal surveys, Dover sole was the most commonly occurring species, present in 68% of beam trawls and all the otter trawl samples. Whiting was found in a third of the beam trawls and 60% of the otter trawls. Gobies, dab and flounder were also generally common. Dab were recorded in two thirds of otter trawls and 13% of beam trawls, gobies in nearly half of the beam trawls and flounder in 75% of the otter trawls. Thornback rays were common in the otter trawls, being found in 75%, though they were rarely captured in the beam trawls. Many of the remaining species were reasonably rare; 26 of the 40 taxa caught in the 2m beam trawl were present in less than 10% of tows, with 11 recorded only once, seven of the 25 species in the otter trawls were recorded only once.

Pelagic fish

The 2m beam trawl and commercial otter trawl may catch pelagic fish during deployment and retrieval, although neither is specifically designed for this purpose. Herring, sprat and anchovy were caught in the coastal demersal surveys by the 2m beam trawl and herring by the otter trawl. No mackerel or horse mackerel were caught in the BEEMS coastal sampling but were detected during the 2009-2013 impingement sampling. Anchovy and small sprat were also captured in the ground-truthing trawls carried out for the June 2015 acoustic survey. From the acoustic data, pelagic fish were more abundant in waters further north off Minsmere than around Sizewell itself, although good numbers were found at Sizewell throughout the year. Six pelagic species were recorded during surveys including; Atlantic herring, European sprat, anchovy, mackerel, horse mackerel (scad) and pilchard, with sprat being the most abundant.

CEMP fish survey

Over the 2010-11 twelve-month CEMP surveys, 23 fish taxa were recorded as present, as either eggs, larvae, and/or small juveniles. Although some witch (*Glyptocephalus cynoglossus*) larvae were entrained, there are no self-sustaining witch stocks in the southern North Sea. The larvae are vagrant larvae that have drifted from more distant populations and are not part of any southern North Sea witch stock. It is also noted that sandeel (*Ammodytidae*) usually attach their eggs to the substrate, so any sandeel eggs drifting in the plankton are unlikely to be viable.

Ichthyoplankton survey

Results of the zooplankton surveys (2008-2012 and 2014-2017) provide an indication of the presence of the eggs and larvae in the GSB. During 2008-2012, anchovy, Dover sole, and sprat were the most dominant species accounting for over 95% of the total egg abundance across the full sampling period. Rockling and seabass eggs also accounted for over 1% of the total abundance. Solenette, unidentified specimens, lesser weever, pilchard, and mackerel all contributed to the top ten most abundant species (99.84% of total egg abundance). Rockling and sprat eggs started to appear in March, followed by Dover sole eggs in April and seabass eggs in May. The highest number of fish eggs was found in June-July and mostly comprised of anchovy.

5.6.5 Commercial fisheries

Commercial fishing activity is informed by landings data submitted to the MMO by commercial fishing vessels. Commercial landings are partitioned into ICES statistical rectangles. ICES rectangle 33F1 is located off the Suffolk coast and covers an area from Lowestoft in the north to Orford in the south, thereby encompassing the GSB. Landings figures are based on data obtained from the MMO for ICES rectangle 33F1 for the year 2017.

During 2017, 58 vessels operated near the GSB area, most of these were less than 10m in length. Most of the catches were landed into Lowestoft, Aldeburgh, Orford, and Southwold, along with minor landings to Sizewell beach and Great Yarmouth. The larger vessels predominantly landed into Lowestoft, with minor landings to West Mersea, Wells-next-the-Sea and Ipswich.

5.7 Modelling of Water Discharge Plume

5.7.1 Models used

For the development of new nuclear build (NNB) power stations that use and discharge cooling water to the environment it is necessary to establish hydrodynamic models to predict the impact of the discharged thermal and chemical plumes on a variety of sensitive ecological receptors. The Environment Agency has produced draft guidelines[9] which are complemented by the independent BEEMS Expert Panel guidance.

Models are required to study construction, commissioning and operational discharges but thermal modelling will only be required for the operational discharges. The hydrodynamic models are also used for several other studies including dredge disposal studies, impacts of coastal structures and to support flood risk assessment. Thermal plume assessments include the in combination influence of Sizewell B and for chemical plume studies of chlorine produced oxidants and chlorination byproducts the in combination influence of the discharge plumes from Sizewell B and Sizewell C are also assessed.

To meet Environment Agency guidelines two different hydrodynamic models (Delft3D and General Estuarine Transport Model (GETM)) setup by two independent subcontractors Bolding and Burchard (GETM) and ABPmer (Delft3D) were used to predict the temperature changes off Sizewell that may result from different SIZEWELL C power station cooling water intake and outfall combinations [77]. Evaluation and quality assurance of the modelling results is performed at each stage of the process before the next stage is undertaken. Both models were successfully used for modelling of the proposed Hinkley Point C power station. The relative strengths and limitations of these models are well understood and the respective model performances were subject to regulatory scrutiny as part of the consultation on the Hinkley Point C planning and permit applications.

The two models are different in many ways; the principle differences being the heat loss schemes. The Delft3D model uses an excess temperature model, where the heat loss is primarily a function of the initial temperature rise and the wind speed. The GETM model uses meteorological forcing to consider total heat loss and gain and a reference run without the power station is subtracted from the original run with the power station to calculate excess temperatures in the plume.

The Delft3D model, is not able to simulate long runs nor variable meteorology and thus shorter runs, over neap and spring tidal periods with selected, fixed meteorological conditions have been performed. These data have been averaged to investigate mean plume properties over a spring – neap cycle.

[9] Environment Agency, Nuclear New Build – Guidance on Hydrodynamic Modelling Requirements, 2010

The GETM model has been implemented to run on a mutli-processor parallel cluster and because it is using hindcast meteorological forcing it is able to simulate real weather events which means that it can be used to test scenarios incorporating meterological extremes that can have a significant influence upon the model predictions.

The Environment Agency guidelines suggest that a representative year should be modelled. Selection of the year was made by examination of the inshore temperature network data [82] for Sizewell. The data are supplied by EDF (historically British Energy and CEGB) and are recorded at the inlet to the Sizewell B condensers. The year 2009 was chosen to be modelled because:

- the mean annual temperature in 2009 was very close to the mean annual temperature since 1967; 11.9 °C compared to 11.8°C;
- for the whole year each monthly temperature was within one standard deviation of the 44 year mean (no data are available for 1997); thus,
- in relation to temperature, 2009 is an average a year.

The Environment Agency guidelines also suggest that the modelling year should be representative of the last 10 years. The mean annual temperature in the period 2003-2012 at Sizewell was 11.9°C, the same as the 2009 average. However, January and February 2009 were cooler (i.e. > 1sd) than the 10 year average.

Several other differences exist between the two models, the most significant being the initial selection of the modelling grid. The GETM grid is curvilinear which enables high accuracy in the vicinity of the intake and outfall. The model has 21 layers in the vertical and at highest resolution of approximately 20m. The Delft3D model is also setup on a curvilinear grid but with a maximum resolution of 25m around the intakes and outfalls with 8 layers in the vertical.

SZC Co. decided that on risk management grounds that the intakes of Sizewell C should be offshore of the Sizewell-Dunwich Bank which has historically been migrating shoreward. The purpose of the model review then became:

- To determine the accuracy of the excess temperature predictions from the 2 models and which one should be used as the primary tool for assessment purposes.
- To determine the preferred Sizewell C cooling water outfall location on environmental, recirculation and engineering grounds in collaboration with EDF Energy engineers.

Sizewell B will be operational until at least 2035 and therefore the modelling undertaken in this study was of the in combination impact of Sizewell B and Sizewell C.

To use the models for assessment of thermal recirculation and potential environmental impacts it is important to derive a numerical estimate of the accuracy of the 2 models. The best datasets with which to make such an estimate were the 5-minute inlet temperature record at Sizewell B and the temperature data gathered during the September/October 2009 Sizewell B outage in which it was possible to directly follow the thermal impact of Sizewell B from no power to full power in a period of stable weather conditions and to compare these results with modelling.

In conclusion:

- The predicted Delft3D excess temperatures due to Sizewell B alone were lower than the excess temperatures measured at the station.
- For the Delft3D combined Sizewell B and Sizewell C modelling runs the predicted relative increase in excess temperatures over those predicted due to Sizewell B alone appear reasonable. The predicted values for excess temperatures are, however, significantly underestimated compared with measurements made at the existing Sizewell B station and from considerations of the increase in discharged heat energy.
- The GETM excess temperature predictions for Sizewell B alone were higher than those measured at the station but were closer to the measured values than the Delft3D results. The combined Sizewell B and Sizewell C excess temperature predictions appear reasonable compared with measurements made at the existing Sizewell B station and from considerations of the increase in discharged heat energy.

It was therefore considered that the GETM model was more suitable as the primary tool for plume modelling at Sizewell and that its use would be conservative but not overly so.

5.7.2 Compliance with Environment Agency Guidance

Following discussion with the Environment Agency **Table 5.7.1** provides demonstration that the Environment Agency guidance on hydrodynamic modelling have all been met.

Table 5.7.1 Demonstration of Compliance with Environment Agency Modelling Requirements

Environment Agency Requirement	Compliance statement
Modelled output to provide information in 3-D	Met using 3-D models
Model(s) must be suitable for the application(s)	Met (as demonstrated by the validation reports)
Not limited to the use of one model – different model types can support and complement each other, for example an excess temperature model looking at different discharge temperature elevations, run over relatively short periods for a number of different scenarios, and a long-term absolute temperature model	Met – 2 models produced (using Delft3D and GETM), results compared and inconsistencies investigated and resolved.
Model(s) must be demonstrated to be suitably calibrated and validated – validation against existing thermal plumes if possible, including the use of aerial or satellite imaging	Met - comprehensive validation reports provided

Environment Agency Requirement	Compliance statement
Model(s) to comply with Agency standards for hydrodynamic model calibration/validation	Met - comprehensive validation reports provided
Model(s) to be independently audited – audit report(s) to be provided	Met- Independent audit reviews of model performance provided
Model(s) to be available for use over period of (a) at least 10 years from date of commissioning of the power station, and (b) beyond that for as long as there is(are) no suitable alternative(s) available	a. Yes b. To be discussed as part of permit conditions dependent on perceived need at time. If required dependent upon need at time additional modelling tools would be provided
Agency will require access to the model(s) over the lifetime of the power stations	Access will be possible on contractor premises if the Agency does not have the required IT infrastructure.
Output to represent both absolute temperature and excess temperature above background, both in the near/mid-field and in the far-field	Met reports provided
Results to include the effects of tidal currents, residual currents, wind driven currents, turbidity, solar insolation, cloud cover, air temperature, surface cooling including the effect of wind, river flows, river temperature, thermal and saline stratification, seasonal effects (including short-term extreme temperature events), and sedimentation and erosion	Met. Geomorphic change scenarios will be included where appropriate (i.e. bathymetric change scenarios) rather than including sedimentation and erosion in the plume models.
Results to cover a range of plausible scenarios of climate-change driven rises in air and sea temperatures and sea-levels over the planned life-time of the station	Met. Climatic and Geomorphic change scenarios will be included where appropriate.
Results from alternative abstraction and discharge locations, including options to discharge near-bed, mid-water-column, or near-surface, and utilising different outfall designs, as appropriate	Met. Results from a full range of CW configuration options provided.
Maps to show locations of designations, sensitive waters, relevant sensitive receptors, etc.	Met
Mixing Zones appropriate to the various thermal standards to be presented in 3-D, based on the statistics of the standard (e.g. annual average, maximum, 98%ile)	Met
Where a Mixing Zone relates to an instantaneous statistic (such as maximum value), then as far as is practicable, some indication of the variation of the duration of exceedance over the Mixing Zone	Met. Plume contour plots of annual maximum temperature and annual maximum and mean excess temperatures at the surface and the seabed provided. Model outputs can be interrogated to provide any additional information upon request

Environment Agency Requirement	Compliance statement
In addition to the presentation of the overall Mixing Zones, various instantaneous representations of the temperature field are needed to enable an understanding of typical conditions	Met; such information is available at any location/ depth on request
Detailed impact assessment inside the Mixing Zones (and outside if considered appropriate) for all relevant receptors (flora and fauna throughout the water column, on and within the sea bed, and in the inter-tidal zone) to be assessed and discussed	Met - Provided as part of the ecological assessment not in modelling results reports.
Relevant statistics of the mixing zones: e.g. area, volume, proportion of estuarine cross-section, proportion of time threshold value exceeded	Met
Post-scheme appraisal within 5 years of commissioning to validate (or not) the model predictions – based on field observations, satellite or aerial imaging, etc.	Details to be agreed, but will be met
If necessary, the re-calibration and validation of the model(s) following post-scheme appraisal.	Will be met if required
Any models used will need to incorporate water quality modules suitable for the processes being modelled	Met

5.7.3 Recirculation

The thermal impact of the Sizewell C discharge falls predominantly upon Sizewell B as an increase in intake temperatures and in the extent of the Sizewell B discharge plume. For any of the Sizewell C discharge locations studied the amount of recirculation into Sizewell C is minimal. The mean and maximum excess temperatures at the Sizewell B intake decreases as the Sizewell C discharge is moved eastwards.

5.8 H1 Impact Assessment for Substances

5.8.1 Methodology

Environmental Statement

In addition to applications to the Environment Agency for environmental permits required under the EP Regulations, applications are also being made for development consent under the planning regime. As part of this, an ES has been prepared which includes a detailed assessment of the potential impact of discharges to surface water during commissioning and operation of the new Sizewell C power station.

The information provided in **Section 5.9** therefore reflects that provided in Volume 2, Chapter 21, of the ES on Marine Water Quality and Sediment and the terms used to describe the significance of effects on ecological receptors are referenced from Volume 2 Chapter 22 of the ES on Marine Ecology.

5.8.2 Approach

In December 2016, the Environment Agency released new guidance on how to assess the impact of any activity in transitional and coastal waters, "Clearing the Waters for All" [25]. The process consists of three stages (screening, scoping and impact assessment). In addition, guidance for a surface water pollution risk assessment for permitting (based on the approach applied in the original H1 process) is also referenced. For the planned Sizewell C this report considers three assessment stages for the discharges to the marine environment during operation. In the screening stage those discharges and substances that are evaluated as having negligible likely effects are excluded from further scoping.

To assess the significance of specific chemical discharges the screening methodology applies existing EQSs. Where no EQS is available approaches are described for derivation of an alternative reference value or PNEC.

The focus here is the potential impact of activities upon water quality. Where relevant, more detailed chemical modelling of discharges is used to determine total areas of exceedance for those substances not screened out by preliminary assessment. For large cooling water discharges that are discharged to estuaries or coastal waters there is a required screening approach as described in the following section.

Substances likely to be discharged in the cooling water are assessed as follows:

(i) Average background concentration for substance multiplied by average cooling water flow (to determine background load).

(ii) Average load of substance in process stream added to above load.

(iii) Divide step (ii) result by total of average cooling water discharge volume and average process stream volume combined.

(iv) Compare result of above to the EQS AA.

A second assessment makes a comparison to the relevant EQS MAC.

(v) Maximum background concentration for substance multiplied by minimum cooling water flow (to determine background load).

(vi) Maximum load of substance in process stream added to above load.

(vii) Divide step (vi) result by total of minimum cooling water discharge volume and average process stream volume combined.

(viii) Compare result of above to the EQS MAC.

The aim of the process is to identify components of discharges that may contribute to the deterioration of a waterbody and so prevent achievement of target standards such as status objectives under the Water Framework Directive. The guidance applies to continuous discharges and variable process discharges to freshwater and coastal waters ("surface waters"). More detailed modelling is required if the concentration of the pollutant in the cooling water is more than the relevant EQS AA or MAC.

Assumptions and limitations

Several assumptions were made to conduct the calculations for EQS AA and EQS MAC assessment for large cooling water discharges:

- The discharge loadings used are included in **Table 5.8.1** to **Table 5.8.2**.
- The maximum daily and annual loading values have been adopted to provide a worst-case scenario in terms of contaminant loadings in the discharge. The use of daily chemical loading values needs to be treated with caution as the H1 methodology is developed for the assessment of long-term discharges. These discharge values are compared to EQS values which are normally based on annual average concentrations.
- For chemicals in the discharge that do not have an EQS Predicted No Effect Concentrations are derived if enough toxicity data are available. Comparisons are made to any acute toxicity values where ecotoxicological data are limited and where no toxicity data are available comparisons are made to site background levels for the relevant chemical [70].
- For substances subject to intermittent release which is considered appropriate for 24-hour discharge assessments a factor of 100 would normally be applied to the lowest $L(E)C_{50}$ of at least three short term tests for species from three taxonomic groups to derive a short term PNEC [70].
- For annual discharge assessments where two long term test No observed effect concentrations (NOECs) are available the lowest has a factor of 500 applied to derive a chronic NOEC for marine data and where three are available a factor of 100 is appropriate [70].
- The maximum annual loadings are assumed to be discharged at a constant rate over the course of a year and to be mixed in the cooling water flows prior to discharge to the environment. It is assumed within the presented H1 calculations that for average annual concentrations the cooling water discharge flow, into which all discharges are mixed, is $116 m^3 sec^{-1}$ as a worst case under normal operational flow.
- For 24 hour discharges the assessment has been made for a discharge flow of $66 m^3 sec^{-1}$ to provide a worst-case "incidental" dilution scenario. This discharge volume assumes that only a single cooling water pump is operating for each EPR

unit during a low water period. However, it should be noted that 24-hour discharges are unlikely to occur exclusively under low tide conditions and when only one cooling water pump is functioning normally (and is therefore particularly conservative).

- For metals it is assumed that annual loading figures relate entirely to metals in the dissolved phase. As dissolved metals are in a biologically available form, this assumption allows for assessment of a worst-case potential impact scenario.
- The chemical discharge values consider any initial dilution in process flows routed to holding tanks and degradation is accounted for if this is part of an intended treatment process to meet permit needs.
- Mean background concentrations are used in place of EQS values for those substances which have no EQS and for which there is no or insufficient toxicity data to derive a predicted no effect concentration. Mean background concentrations are based on the results for the monitoring programme conducted in 2010 as reported in [59] and in Sizewell 2014/15 supplementary monitoring report [60].
- For inorganic nitrogen initial screening references a generic 99th percentile but inputs are more fully assessed using a combined phytoplankton/macroalgal model
- Discharge loadings have been used for both desalination and demineralisation processes. For Sizewell C it is proposed that only a demineralisation plant will be used and therefore loadings from these sources represent a worst-case scenario.
- The degradation products from ethanolamine and morpholine include a range of amines for which the toxicity is not above that for the parent compounds and quantities discharges are lower so these are covered by the discharge risk assessment for the parent compound. Contributions of the additional nitrogen and ammonia loads from these sources are however accounted for [70]

5.8.3 Initial screening out of insignificant effluent components

The site will be managed to avoid contamination of surface drainage therefore the variable natural surface drainage from the site would not be assessed. The discharges from surface drainage systems will be highly variable in both chemical quality and volume. As such it is not appropriate to model such discharges using the screening methodology. Groundwater discharges from the operational site would be made at a maximum rate of 15 l/s [70]. The final discharge point for groundwater during operation is not confirmed, but if they pass the assessment for discharge via the CDO or have limited areas of exceedance then if they are routed via the cooling water discharge, they are unlikely to be of concern.

Expected discharges to local marine waters from Sizewell C during the operational phase may be broadly characterised as:

- Discharges associated with chlorination.

- Chemicals discharged during the operation of the units;
- Surface drainage from across the developed site;
- Effluent from demineralisation plant; and
- Sanitary wastewater from on-site purification plants;
- Operational low level groundwater discharges.

The data for chemical discharges during the operational phase are mainly provided as maximum loading rates over annual and 24-hour periods for most chemicals within the waste water effluent. Source term calculations for nitrogen and hydrazine which are included in the chemical discharges to the marine environment during the operational phase are discussed in the following sections.

Concentration of a substance in the cooling water discharge together with any background concentration of the same substance in the cooling water effluent that exceed the EQS or equivalent assessment level value (see **Section 5.8.4**) are given further consideration (**Section 5.8.5**) to determine whether more detailed modelling is required for a full assessment.

5.8.4 Identification of whether further assessment is required

Results- calculation of discharges

The following tables show the results from the emissions considered in the Water Quality Technical Note [83] (note that desalination is allowed for in the calculations). Data are set out in two tables for clarity there is no significance to the grouping of substances in each table:

- Table 5.8.1 and 5.8.2 Operational impacts – 24-hour discharges (short term) (for cooling water flow = 66 m^3/s).
- Table 5.8.3 and 5.8.4 Operational impacts – annual discharges (long term) (for cooling water flow = 66 m^3/s.

Table 5.8.1 Operational impacts(a) – 24-hour discharges (short term) (for cooling water flow = 66 m3/s)

Substance	**EQS or surrogate value µgl^{-1}**	**Derivation of surrogate**	**Maximum 24-hour loading (kg d^{-1})**	**Discharge + background (µgl^{-1})[1]**	**Max discharge /EQS <1**
Boric acid (H_3BO_3)[1]	-	-	5625	-	-
Boron[1]	7000	Pre WFD EQS	984	4656	0.67
Lithium hydroxide	65[2]	Mean background	4.4	0.22[2]	**1.39**[3]
Hydrazine	0.004	Acute PNEC	3[4]	0.53[5]	**131.5**
Morpholine	28	Acute PNEC	92.3	16.18[5]	0.58
Ethanolamine	160	Acute PNEC	25	4.34[5]	0.03
Nitrogen as N	980[6]	WFD 99%	332[7]	484.3	0.49
Un-ionised Ammonia (NH_3-N)	21	WFD AA-EQS	27[8]	7.34	0.35
Phosphates (PO_4-P)	33.5	Mean background	352.5	127	**3.79**
Suspended solids	74000	Mean background	875	153[5]	0.002
BOD	2000	Mean background	3.8	0.67[5,9]	0.0003
COD	239000	Mean background	330	57.87[5]	0.0002

[1] Variable dissociation products of Boric acid and other boron compounds in seawater so assessment focuses on equivalent boron concentration.

[2] Expressed as lithium.

[3] Figures in bold exceed the EQS or reference value.

[4] This loading does not include hydrazine from stream B+C because this would not be discharged except during start up and shutdown when hydrazine from stream D would not be discharged.

[5] Discharge only does not include background or no background either measured or detected

[6] It should be noted that a more specific methodology for deriving 99th percentile values based on a relationship between SPM and DIN is recommended in draft unpublished Environment Agency guidance and for an annual average SPM of 55.2mgl-1 would give a slightly lower value of 952µgl-1 as a 99th percentile but the screening here would only slightly change.

[7] This figure includes a calculated 4.4kg day from sanitary effluent derived by calculation from permitted 23mg/l N from STW discharge – stream G.

[8] These figures are back calculated from the un-ionised ammonia concentration derived from the un-ionised ammonia calculator using the total Ammonia concentration that results from the combined sanitary and conditioning inputs [70]

[9] The BOD value is derived from stream G based on a BOD5-atu concentration of 20 mg/l and the derived concentration due to the discharge (0.67µgl-1) is negligible relative to the site background (2mgl-1) and not significant in terms of impact on dissolved oxygen when oxygen flux for vertically well mixed water column at site is considered. Figures in bold exceed the EQS or reference value.

Table 5.8.2 Operational impacts(b) – 24-hour discharges (short term) (for cooling water flow = 66 m3/s)

Substance	**EQS or surrogate value µgl^{-1}**	**Derivation of surrogate**	**Maximum 24-hour loading (kg d^{-1})**	**Discharge + background (µgl^{-1})[1]**	**Max discharge /EQS <1**
Aluminium	12	Mean background	1.1	20.19	**1.68**[1]
Cadmium[2]	1.5	WFD MAC-EQS	0.005	0.13	**0.09**
Copper	3.76	WFD AA-EQS	0.08	4.76	**1.27**
Chromium	32	WFD MAC-EQS	1.7	2.48	0.08
Iron	1000	WFD AA-EQS	257	302	0.3
Manganese	2	Mean background	0.67	-	-
Mercury[2]	0.07	WFD MAC-EQS	0.001	0.02	0.29
Nickel	34	WFD MAC-EQS	0.09	1.17	0.03
Lead	14	WFD MAC-EQS	0.07	3.94	0.28
Zinc	6.8	WFD AA-EQS	1.2	46	**6.77**
Chloride	14128000	Mean background	450	78.9[3]	0.00
Sulphates	2778000	Mean background	2000	350.7[3]	0.00
Sodium	10400000	Mean background	855	150[3]	0.00
ATMP	74	NOEC (96h fw algae)	45	7.89[3]	0.11
HEDP	13	EC_{50} (96 h fw algae)	4.5	0.79[3]	0.06
Acetic Acid	301	LC_{50} 48h fw crust	0.1	0.02[3]	0.00006
Phosphoric acid	200	LC_{50} 72h fw algae	0.1	0.02[3]	0.0001
Sodium polyacrylate	180	LC_{50} 96h fw fish	40	7.01[3]	0.04
Acrylic acid	1.7	EC_{50} 96h fw algae	1	0.18[3]	0.1
Chlorine (TRO) bromoform	(10) 5	MAC-EQS	-	(150), 190	(15)38

[1] Figures in bold exceed the EQS or reference value.

[2] Cadmium and mercury loadings are derived from trace contamination of raw materials see **Section 3.6.2**.

[3] Predicted concentrations in the discharge not including background or no background either measured or detected.

Table 5.8.3 Operational impacts – annual discharges (long term)

Substance	EQS/surrogate value μg l^{-1}	Derivation of surrogate	Maximum annual loading (kg yr^{-1})	Discharge concentration including background (μg l^{-1})	Annual Discharge/EQS <1
Boric acid (H_3BO_3)	-	-	14000	--	-
Boron[1]	7000	Pre WFD EQS	2448	4145.67	0.59
Lithium hydroxide	65	Mean background	8.8	0.0007[2]	1.00[3]
Hydrazine	0.0004	Chronic PNEC	24.3[4]	0.01	16.6
Morpholine	17	Chronic PNEC	1674	0.46[5]	0.03
Ethanolamine	160	Acute PNEC	919	24.75[5]	0.001
Nitrogen as N	980[6]	WFD 99%	11725	360.12	0.37
Un-ionised Ammonia (NH_3-N)	21	WFD AA-EQS	958[7,8]	0.96	0.05
Phosphates	33	Mean background	790	33.57	1.00
Detergents	-	Chronic PNEC	624	0.17[5]	0.2
Suspended solids	74000	Mean background	92879	25.39[5]	0.00035
BOD	2000	Mean background	1387	0.38[5,9]	0.00019
COD	239000	Mean background	5050	1.38[5]	0.00001

[1] Variable dissociation products of Boric acid and other boron compounds in seawater so assessment focuses on equivalent boron concentration.

[2] Expressed as lithium.

[3] Figures in bold exceed the EQS or reference value.

[4] This loading does not include hydrazine from Stream B+C because this would not be discharged except during start up and shutdown when hydrazine from Stream D would not be discharged.

[5] Discharge only does not include background or no background either measured or detected.

[6] It should be noted that a more specific methodology for deriving 99th percentile values based on a relationship between SPM and DIN is recommended in draft unpublished Environment Agency guidance and for an annual average SPM of 55.2mgl-1 would give a slightly lower value of 952µgl-1 as a 99th percentile but the screening here would only slightly change.

[7] This figure includes a calculated 4.4kg day from sanitary effluent derived by calculation from permitted 23mg/l N from STW discharge – Stream G.

[8] These figures are back calculated from the un-ionised ammonia concentration derived from the un-ionised ammonia calculator using the total Ammonia concentration that results from the combined sanitary and conditioning inputs [70].

[9] The calculated BOD is derived from Stream G based on a BOD5-atu concentration of 20mg/l and the derived concentration in the discharge (0.38µgl-1) is negligible relative to the site background (2mgl-1) and not significant in terms of impact on dissolved oxygen when oxygen flux for vertically well mixed water column at site is considered. Figures in bold exceed the EQS or reference value.

Table 5.8.4 (b) Operational impacts – annual discharges (long term)

Substance	**EQS/surrogate value μg l^{-1}**	**Derivation of surrogate**	**Maximum annual loading (kg yr^{-1})**	**Discharge concentration including background (μg l^{-1})**	**Annual Discharge/EQS <1**
Aluminium	12	Mean background	5.26	12	**1.00**[1]
Cadmium[2]	0.2	WFD AA-EQS	0.37	0.05	0.25
Copper	3.76	WFD AA-EQS	0.42	2.15	0.57
Chromium	0.6	WFD AA-EQS	8.37	0.57	0.95
Iron	1000	WFD AA-EQS	46035	132.58	0.13
Manganese	2	Mean background	3.33	-	0.00
Nickel	48.6	WFD AA-EQS	0.44	0.79	0.09
Lead	1.3	WFD AA-EQS	0.3	1.0	0.76
Mercury[2]	0.07	WFD MAC-EQS	0.0011	0.02	0.29
Zinc	6.8	WFD AA-EQS	6.0	14.7	**2.16**
Chloride	14128000	Mean background	87100	23.81[3]	-
Sulphates	2778000	Mean background	98400	26.90[3]	-
Sodium	10400000	Mean background	52400	14.32[3]	-
ATMP	74	NOEC 96h fw algae	9100	2.49	0.03
HEDP	13	NOEC 96h algae	890	0.24[3]	0.02
Acetic Acid	62.8	NOEC 21d fw crust	14	0.004[3]	0.0001
Phosphoric acid	20	LC_{50} 72h algae	12	0.003[3]	0.0002
Sodium polyacrylate	11.2	NOEC 72h fw crust	8030	2.20[3]	0.20
Acrylic acid	0.34	NOEC 72 h fw algae	165	0.05[3]	0.13

[1] Figures in bold exceed the EQS or reference value.

[2] Cadmium and mercury loadings are derived from trace contamination of raw materials see **Section 3.6.2 3** predicted concentrations in the discharge not including background or no background either measured or detected

5.8.5 Assessment of the acceptability of the proposed emissions against EQS

Following the calculation of the long- and short-term discharge plus background concentrations the next stage in the assessment process is to identify which chemical components warrant further investigation.

This is done by screening out those which are discharged at such low concentrations that they are unlikely to cause significant impact to the receiving coastal waters by:

Comparing the discharge plus background concentration of each chemical within the effluent against relevant benchmark values such as EQSs;

Screening out as insignificant those where the estimated concentration for a cooling water discharge:

- <MAC value for short-term releases (e.g. 24-hour discharges); or
- <AA EQS value for long-term releases (e.g. annual discharges).

The results provided indicate that all discharge parameters, based on the assumptions made, are below the EQS or environmental benchmark except for those discussed below.

24-hour discharge assessment

Reference to **Table 5.8.3** and **Table 5.8.4** show that for the 24-hour discharge assessment, hydrazine, chlorine produced TRO’s and bromoform concentrations in the discharge during the operational phase will exceed the acute PNEC and so will be taken forward for more detailed modelling.

Discharge concentrations for copper and zinc also exceed EQS assessment criteria but, in each case, actual discharge concentrations are at least 30 times below the relevant AA EQS and are below their respective detection limits for analysis. It is the high derived 95 percentile background loadings that are responsible for this exceedance therefore no measurable exceedance resulting from the discharge itself would be detectable and so further assessment will not be conducted.

Lithium hydroxide, phosphate and aluminium do not have EQS or PNEC values but instead reference site mean backgrounds and so the 95 percentile load calculations which use site background 95 percentile values will invariably result in an exceedance. In the case of aluminium, the actual discharge contributes a sixtieth of the background and for lithium hydroxide the equivalent lithium input from the discharge is almost 300 times below the background in neither case are these inputs considered of significance. The phosphate input is several times above background (3.79) and as phosphate can contribute to nutrient status it will be given further consideration in **Section 5.10.7**.

Concentrations of other substances for which the discharge 24-hour loading concentration are present in the operational discharge at >40% of their EQS or equivalent reference value are also considered here, and these are boron (boric acid), morpholine, DIN, un-ionised ammonia and acrylic acid.

The boron background concentration in Sizewell seawater as a 95th percentile (as used in the 24h discharge calculation) is around 4564µgl^{-1} and as the estimated discharge concentration of boron represents around one twentieth of this value so it is the background concentration that has the most influence on the scale of the cooling water discharge concentration relative to the EQS. The elevation of boron above the seawater background is relatively small and any influence will be localised to the area around the immediate discharge. As an essential element for many marine algal species the low elevation of boron concentration expected in short term discharges and small extent of elevation above background is likely to have negligible effects.

Morpholine was 58% of its derived PNEC for 24-hour discharges but is a readily degradable chemical and has a low likelihood of bioconcentration this coupled with its low toxicity indicates it would have negligible effects on marine species under this discharge scenario.

Un-ionised ammonia was 35% of its derived PNEC. As temperature may influence the relative amount of un-ionised ammonia the operational discharge has been further assessed considering temperature elevation and this modelling is described in **Section 5.10.7.** Additional sources of un-ionised ammonia are hydrazine, ethanolamine and morpholine. Contributions from these sources may vary dependent on the degradation process during operation. Based on an estimated maximum contribution from these sources the un-ionised ammonia contribution would increase by 4% to 39% of the EQS. This elevation does not change the assessment [70].

The 24-hour discharge concentration of dissolved inorganic nitrogen was 49% of the site 99% winter standard for water bodies of intermediate turbidity. As the loading of DIN may influence algal growth this is further assessed in **Section 5.10.7**.

The 24-hour discharge concentration of acrylic acid is 52% of the PNEC. The bioconcentration factor for acrylic acid is estimated at 1.0 and so is very low and it is readily degradable [70]. Acrylic acid is therefore likely to have negligible effects at the predicted discharge concentration.

Annual discharge assessment

For annual loadings in the operational cooling water discharge hydrazine exceeds relevant PNEC or EQS values in the screening assessment and so more detailed modelling will also consider this discharge scenario. An annual average assessment is modelled for chlorine and bromoform although the standards for each are set as 95th percentiles and they do not have annual average standards). Discharges during the operational phase would also just exceed or equal the annual average PNEC for lithium hydroxide (assessed as lithium), phosphates, aluminium, zinc and acrylic acid (**Table 5.8.5)**.

All method detection limits are provided in [70]. Lithium hydroxide, phosphate and aluminium do not have EQS or PNEC values but instead reference site mean backgrounds and so the mean load calculations which use site background mean values will invariably result in an exceedance. In the case of aluminium and lithium hydroxide, the actual discharge concentrations are below the method detection limit and are several orders of magnitude below the site background so the discharge contributions would have negligible effects. The phosphate discharge concentration is also below the method detection limit and although the discharge concentration is very low the input can contribute to nutrient status so it will be given further consideration in **Section 5.10.11**.

Zinc fails the annual assessment. However, it is the high background loading that is responsible for this exceedance and the actual discharge concentration would be below detection therefore this input is considered to have negligible effects.

The annual discharge concentration of acrylic acid is 13% over the chronic PNEC but as bioconcentration is low, estimated at 1.0 and it is readily degradable [70] it is considered to have negligible effects at the predicted discharge concentration.

In screening copper and chromium were 57 and 95% of their respective annual average EQS values but for both the predicted discharge concentrations are below method detection limits and are several orders of magnitude below their respective EQS (i.e. site backgrounds are not included) therefore negligible likely effects are predicted.

As was the case for the 24-hour screening assessment elevation of boron above the seawater background is relatively small and so any influence will be localised to the area around the immediate discharge. As an essential element for many marine algal species the low elevation of boron concentration is likely to have negligible effects and therefore this is screened out of further assessment.

For the annual discharge screening assessment as DIN at 37% of its background reference can contribute to nutrient status it is given consideration in **Section 5.9.6**. Un-ionised ammonia concentration was low at 0.05% of its EQS but is also given further consideration in **Section 5.9.7** in relation to the influence of temperature elevation on the percentage of un-ionised ammonia. Additional sources of un-ionised ammonia are hydrazine, ethanolamine and morpholine. Contributions from these sources may vary dependent on the degradation process during operation. Based on an estimated maximum contribution from these sources the un-ionised ammonia contribution would not change the assessment as the percentage of the EQS remains at 5% [70].

Table 5.8.5 Discharges parameters with a concentration plus background estimated at greater than the EQS or environmental benchmark or with other properties that warrant further assessment

Substance	Discharge type 24 hour or annual	EQS/surrogate value µg l^{-1}	Discharge concentration including background (µg l^{-1})	Annual Discharge and background/EQS <1
Hydrazine	24 hour	0.004	0.53	**131.5**
Chlorine	24 hour	10	150	15
Bromoform	24 hour	5	190	38
Phosphate	24 hour	33	127	3.79
Un-ionised ammonia (NH3)	24 hour	21	7.34	0.35
DIN	24 hour	958	484.3	0.49
Hydrazine	Annual	0.0004	0.01	16.6
Phosphate	Annual	33	33.57	1.00
Un-ionised ammonia (NH3)	Annual	21	0.96	0.05
DIN	Annual	958	360.12	0.37

5.9 Impact Assessment

This summary of the impact assessment is based on key parts of **Chapters 21** and **22** of Volume 2 of the ES.

5.9.1 Scale of effects

The plume is buoyant in the near field so effects on receptors on or near the seabed (benthic and epibenthic organisms and demersal fish) will be minimised. The main concern will be potential effects in the water column, particularly in relation to planktonic organisms and fish prey species.

5.9.2 Mixing zones

Guidance has been produced on the use of the mixing zone concept in the application of the Habitats Regulations in relation to thermal discharges [67] and in relation to discharges of toxic materials [84]. Further guidance has been provided in the Environment Agency's guidance on nuclear new build [16] and considers that:

The mixing zone can be defined as the area of water (around a discharge) within which exceedance of EQS is acceptable. This is sometimes defined in terms of the zone within which initial dilution takes place as a buoyant effluent rises to the surface or it may be larger.

A ‘mixing zone’ is that part of a body of surface water within which a standard is exceeded. In tidal waters this can be temporally and spatially variable e.g. for a maximum elevation of temperature of no more than 2°C above ambient, then the mixing zone is the volume of water, in 3-D, within which the water temperature can reasonably be expected to be 2 or more degrees above ambient at some time during the lifetime of the plant.

Alternatively, if the standard under consideration is a 98 percentile temperature of 23°C over a year, then the mixing zone is the 3-D envelope around the discharge point encompassing all locations where the temperature is predicted to exceed 23°C for more than 2% of the time. The size of this mixing zone may be small when compared to the worst-case instantaneous impact of the discharge.

Clearly, the zone of influence (of elevated temperature) will extend beyond the mixing zone as it is defined here.

Thus, in tidal waters, the zone where initial dilution occurs will move with the tide, raising the issue as to how to define the mixing zone laterally from the discharge point, while the buoyant nature of most cooling water discharges raises the question as to whether the zone should be defined on a depth axis as well. This makes application of EQS which are based on annual averages particularly complex and EQS based on MAC are simpler to define.

For thermal discharges, the basic principles set out are that the zone should not extend so far as to inhibit fish migration. Definition of acceptability will need to take account of migration behaviour within a waterbody (spatially and seasonally).

5.9.3 Zone of influence for discharge assessment

The GSB is considered as the initial reference area for the study site. For the purposes of the EIA, the GSB extends to Walberswick in the north with the southerly extent bound by the geomorphic Coralline Crag formation at the apex of the Thorpeness headland in the south. The seaward boundary extends to the eastern flank of the Sizewell-Dunwich Bank and includes the proposed cooling water infrastructure on the east side of the bank. The landward limit of the marine study area is delineated by MHWS. However, the GSB is not a closed system and water exchanges with the rest of the Southern-North Sea. The ZoI for development impacts is therefore dependent on hydrodynamic processes. The ZoI’s have been informed by the largest-scale potential impacts associated with the proposed development, which include:

- Thermal plume modelling of the in-combination impacts of Sizewell B and Sizewell C cooling water discharges (applying the 2°C mean excess temperature contour at the seabed).

Operational discharges are predicted to occur from different point sources and may act cumulatively with discharges from Sizewell B, as is the case for thermal inputs. Therefore, the ZoI provides an initial reference point for considering the spatial and temporal area of impacts. Assessments will account for these factors and determine the absolute area of impact.

Sizewell B intakes and outfalls are located within the Sizewell-Dunwich Bank and discharge into the receiving waters of the GSB. Sizewell C site discharges from the Fish Recovery and Returns would also occur within the GSB and would be transported throughout the inner tidal excursion within the Sizewell-Dunwich Bank

Approximate surface area and volume for zones of influence for operation discharges were calculated and are described in more detail in [70]. The GSB and tidal excursion used for assessment for water quality is 9906.7ha.

5.9.4 Approach to Impact Assessment

The significance of impacts has been assessed taking account of the value of each receptor (for example whether it is internationally significant, nationally significant and so on), its sensitivity (in terms of its capacity to adapt to or recover from changes from the baseline conditions) and the magnitude of the impact (for example in terms of area affected compared with total area of the resource, as well as the certainty and expected frequency of the effect, where relevant).

5.9.5 Thermal discharges – including secondary effects

The primary change to the characteristics of discharged cooling water will be an increase in temperature. The main concerns over the thermal plume generation are related specifically to impacts upon species in the water including those that are prey species.

Modelling was undertaken using the validated Sizewell GETM and looked at indicative locations for the outfall to determine the worst case scenario for thermal effects [77]. The modelling also assumed that Sizewell B would be operational until at least 2035 and, therefore, this is accounted for (as part of the baseline) in the results of the assessment. Four intake heads and two outfall heads were included in the model as a realistic representation of the final design. The GETM set up used for calculating the thermal plumes of Sizewell C only is the same set up as the Configuration 12 Sizewell B and Sizewell C model runs, as detailed [85]. The only difference between the two set ups is the exclusion of the thermal discharge of Sizewell B in the Sizewell C only model run. The model runs used for calculating the mean and 98th percentile thermal excess are the ReferenceV2-annual (baseline) and Conf12_Sizewell C-annual (Sizewell C only).

Under the Habitats and Water Framework Directives, thermal boundaries have been established to protect sensitive taxa. These guidelines, or criteria, outline the upper limits of thermal increase and maximum temperature that the receiving waters can handle with minimal impacts caused to thermal-sensitive receptors. **Section 5.2.3** in this report outlines the guidelines set under the WFD. Appendix C outlines the guidelines set by the Habitats

Directive. Using these guidelines five different assessments are identified against each temperature criteria for Habitats Directive and WFD. These are summarised in **Figure 5.9.1**. Each 'row' represents one assessment using a specific criterion from either the guidance for Habitats Directive designated sites or draft standards proposed for assessing status under the WFD.

Modelling results for thermal effects on water quality in relation to standards set for SAC/SPA habitats

An initial assessment of discharges or other activities on water quality considers the extent of mixing zones within which there is exceedance of relevant water quality criteria. Dependent on the scale of these areas further assessment may be indicated to determine the potential for ecological effects on specific receptors [67]. The absolute areas of exceedance for each standard for the SPA thermal standards are shown in **Table 5.9.1**.

The 2°C uplift threshold is exceeded over a minimum of 5,219ha at the seabed for Sizewell B to 22,464ha at the surface for Sizewell B and Sizewell C. The corresponding maps are shown in Appendix C **Figure 5.1** to **5.3**. According to [67] the exceedance of the threshold requires further evaluation of the potential environmental impact with respect to ecological receptors within that area and this is considered in the Marine Ecology section of the ES.

Table 5.9.1 Total area where the Habitat temperature standards are exceeded.

Model run	Position	Unit	Max excess temp. >2°C (100%ile)	98th percentile >28°C. Calculated from mean excess temp. >8.6°C	98th percentile >28°C Calculated using GETM absolute temperatures (GETM absolute temperatures are over estimates)
ReferenceV2 annual Sizewell B	Surface	ha	9,375	0	0.78
	Seabed	ha	5,219	0	0
Conf12 annual Sizewell B and Sizewell C	Surface	ha	22,463	0.11	4.15
	Seabed	ha	16,451	0	1.57
Conf12 annual Sizewell C only	Surface	ha	16,777	0	0
	Seabed	ha	12,244	0	0

Note: BEEMS Technical Report TR301 [86] has demonstrated GETM absolute temperature predictions are overestimates (last column above).

There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters. To be protective of the most sensitive species, thermal standards have, therefore, been set on an indicative basis. As such, they act as triggers for further investigation of potential ecological effects. Thermal standards include criteria for absolute temperature and thermal uplifts to determine the potential for acute and chronic effects and behavioural responses. Recommended thermal standards exist for SACs, SPAs and WFD waterbodies. The receiving waters adjacent to the proposed development are within the southern North Sea SAC designated for harbour porpoise. Accordingly, SAC thermal standards are considered in the first instance. SAC thermal recommendations include a maximum allowable 2ºC thermal uplift (100th percentile) above ambient at the edge of the mixing zone. Furthermore, SACs designated for estuarine or embayment habitat and/or cold-water salmonid species, apply absolute temperature thresholds of 21.5ºC as a 98th percentile [67]. These criteria are not applicable to the southern North Sea SAC designated for harbour porpoise. The uplift criterion is defined as a Maximum Allowed Concentration. In ecotoxicity studies MACs are normally defined as 95 or 98 percentiles but the SPA uplift threshold is specified as a 100th percentile i.e. a maximum temperature value. This metric is, therefore, very dependent on how the observations or model simulations are done and the time period considered. Using the GETM model the maximum taken from instantaneous temperature fields, saved every hour over a one-year simulation, provides data on the area that exceeds 2°C excess temperature for at least 1 hour per year i.e. for 1h in 8760h per annum. At this temperature threshold, this metric is not considered to have any link to specific ecological effects, and it serves as a precautionary threshold to trigger further ecological investigation.

Modelling results for thermal effects on water quality in relation to standards set for WFD waterbodies

To undertake the compliance assessment, guidance issued [87] (and [88]) recommends that maximum temperatures at the edge of the mixing zone should not exceed 23°C and, that outside the mixing zone, temperature rises above ambient should be limited to 3°C.

Hydrodynamic modelling was undertaken to calculate the area over which the values set out above would be exceeded. The water to be discharged back to the marine environment was assumed to be 11.6°C above ambient temperatures with a flow of 125m^3s^{-1} for the operational scenario and 23.2°C above ambient temperatures with a flow of 62.5m^3s^{-1} for the maintenance scenario. For chemical assessments a discharge rate of 66m^3s^{-1} is applied as this provides the most conservative assessment.

Modelling was undertaken using the validated Sizewell GETM. The modelling assumed that Sizewell B would be operational until at least 2035 and, therefore, this is accounted for (as part of the baseline) in the results of the assessment. Four intake heads and two outfall heads were included in the model as a realistic representation of the final design.

Four scenarios were considered; the first with no power stations present, the second with only Sizewell B operating, the third with both Sizewell C and B operating simultaneously and the fourth with Sizewell C under maintenance.

The effect of the power stations was evaluated by calculating the difference in temperature between the station(s) operating runs and the run which had no power station discharge.

The difference was calculated for each hourly snapshot and the annual mean and the 98th percentile were calculated from the difference. For assessment against absolute thermal standards, it was determined that the GETM model overestimates absolute temperatures and, therefore, a more reliable prediction of the 98th percentile is derived by adding the predicted mean temperature uplift due to the plume (i.e. the annual mean excess plume temperature) to the observed 98th percentile seawater background temperature (19.4°C).

The Sizewell C and Sizewell B plumes are separate at high plume temperatures but at lower temperatures the Sizewell C plume increases the size and temperature of the Sizewell B plume at the surface and seabed.

Table 5.9.2 and **Table 5.9.3** show the areas over which the relevant WFD absolute and uplift thermal standards are exceeded.

Table 5.9.2 Total areas over which the WFD absolute temperature standard for Good status are predicted to be exceeded

Model run	Position	Unit	98th percentile >23°C. Calculated from mean excess temp.>3.6°C (Area at GOOD or below threshold)
ReferenceV2 annual Sizewell B	Surface	ha	44.86
	Seabed	ha	8.75
Conf12 annual Sizewell B and Sizewell C	Surface	ha	89.60
	Seabed	ha	25.57
Conf12 annual Sizewell C only	Surface	ha	0[1]
	Seabed	ha	0

[1]Mean exceedance temperatures were 3.52°C marginally below the 3.6°C threshold.

Table 5.9.3 Total areas over which the WFD uplift temperature standards are predicted to be exceeded

Model run	Position		Excess temp. >2°C as a 98th percentile Area at GOOD	Excess temp. >3°C as a 98th percentile Area at MODERATE or below
Reference V2 annual Sizewell B	Surface	ha	2,433.30	1262.57
	Seabed	ha	2126.71	667.67
Conf12 annual Sizewell B and Sizewell C	Surface	ha	7899.17	2200.05
	Seabed	ha	6240.64	1,552.56
Conf12 annual Sizewell C only	Surface	ha	1,551	170.6
	Seabed	ha	305.7	0.0

Sizewell C would increase the area of exceedance of the Good Status threshold from 44.86ha to 89.60ha at the surface and from 8.75ha to 25.57ha at the seabed within the WFD water body.

In relation to the excess temperatures, the area below Good Status increases from 2433 ha for Sizewell B alone to 7899ha at the surface and from 2127ha to 6241ha at the seabed with Sizewell C added. For the Moderate Status threshold both the seabed and surface areas increase by approximately 900 ha when Sizewell C is added to the Sizewell B plume.

Thermal changes in waterbodies are an important quality element and affect the tolerance of exposed organisms both to the thermal changes and to their influence on the fate and behaviour of other chemical and physical parameters. However, the sensitivity of water quality overall in terms of the amount of temperature change described is evaluated as low but the magnitude of change is evaluated as high therefore the significance of any impact is evaluated as moderate. Further ecological assessment is therefore required.

It is important to note that, due to plume buoyancy, seabed temperature elevations are over much smaller areas than predicted at the surface. Given that the thermal standards outlined above are not evidence based in relation to biological effects, interpretation as to whether the predictions outlined above could cause a deterioration the water body is also undertaken for parameters that can respond to changes in seawater temperature. These are as follows:

- physico-chemical parameters (ammonia and dissolved oxygen);
- biology (habitats and fish); and
- phytoplankton.

Each of these areas is briefly considered in **Section 5.10.6**. The following sections consider the influence of the thermal plume on ecological and fishery receptors.

Phytoplankton sensitivity to thermal influence

The impact magnitude is precautionarily assessed as High and the sensitivity of phytoplankton biomass at Sizewell to thermal discharges is predicted to be Low resulting in an overall assessment of minor effects with effects not judged as significant in relation to natural variability.

Zooplankton sensitivity to thermal influence

For zooplankton thermal discharges are predicted to have minor effects at the population level. Changes in zooplankton abundance is not significant and would be within the bounds of natural variability.

Benthic species sensitivity to thermal influence

This section considers the impact of thermal discharges on benthic species. The limited sensitivity of benthic species to temperature increases associated with the proposed development, the likelihood of recruitment from source populations outside the zone of influence of the thermal plume, and the precautionary nature of the thermal standards used to inform impact magnitude mean that effects of the thermal plume on benthic invertebrates are predicted to be minor effects. The effect is not significant. Thermal discharges are predicted to have a minor effect on the planktonic stages of benthic receptors. Effects are not significant relative to natural variability.

Fish Receptors sensitivity to thermal influence

The absolute temperature and thermal uplift thresholds were applied to trigger further ecological investigation for the potential for effect on fish receptors. In addition, the potential for thermal plumes to cause barriers to migratory species was considered in relation to local estuaries. It is known from laboratory thermal preference experiments, that fish species can choose to avoid areas of high temperature and so there is a possibility that thermal plumes could act as barriers to migration; principally in transitional waters.

At the mouth of the Alde-Ore Estuary, excess temperatures in the order of 0°C to 1°C occur as 98 percentiles. As such, no occlusion effects are predicted. The thermal plume intersects the Blyth estuary at 98 percentile temperatures of 2-3°C for less than 5% of the annual simulation (307 hours per annum). During this time there was no period when the thermal barrier lasted for more than 1 day. No thermal barriers are predicted for migratory species in the Blyth estuary [89].

No regulatory standards apply for coastal waters. An assessment has been made of the potential for the thermal plume to act as barrier to migration for those species moving between coastal and transitional waters. The assessment applied a similar approach to transitional waters and was applied to the cross-section of water running from the coast to

3km offshore. The threshold applied is that the offshore cross-section (running from the coast to 3km offshore), should not have an area larger than 25% with a temperature uplift above 2°C, for more than 5% of the time [67].

Potential effects of temperature increases are assessed for cold-water species and warm-water species. Cold-water species are typically of an Arctic-Boreal zoogeographic distribution, encompassing species with an Arctic distribution (>60°N), and Arctic–Boreal distribution (from the Arctic Circle through the northern temperate zone to the southern United Kingdom. Temperature increases due to the plume may particularly affect Arctic-Boreal species where the southern, warmer limit is reached and hence species may be near to the limits of their thermal niche. Warm-water species typically have Boreal–Lusitanian distributions (north of the United Kingdom down to Iberia) [90].

The assessments specifically consider potential effects to species and respective life history stage(s), that were recorded in abundance within the coastal trawl surveys, zooplankton surveys, impingement and/or entrainment monitoring programmes. The species assessed include commercially and ecologically important species.

The potential interaction of fish receptors has been considered in relation to the seabed and surface plumes. Effects from temperature increases can be grouped into effects that are acute or chronic. Acute effects are lethal effects where temperatures approach the species' critical threshold. Chronic effects are long-term effects to biological processes related to an elevation in mean temperature [90].

Cold water ichthyoplankton sensitivity to thermal influence (uplift and absolute temperatures)

Applying the >23ºC threshold for the absolute water temperature, the area of exceedance at the surface and seabed, as a 98th percentile, would be small; 89.6ha and 25.6ha, respectively. This means that ichthyoplankton would experience limited exposure to acute (lethal) effects in a tidal environment.

The timing of the interaction may influence the likelihood of acute effects. For example, the highest larvae abundances of herring are noted in the area during May. Ichthyoplankton abundances in the area would be influenced by a range of factors, like the survival of the eggs to the stage of larvae hatching, the availability of food and predation during larval development as well as ambient environmental conditions e.g. salinity.

There is the possibility of physiological changes and/or behavioural responses and the possibility of acute (lethal) and chronic (sub-lethal) effects. While localised egg/larvae mortality may occur, no decline in the stock/regional population viability is predicted. The sensitivity of cold-water ichthyoplankton to temperature changes, due to thermal discharges from the cooling water outfalls, is predicted to be not sensitive.

The impact of thermal discharges from the cooling water outfalls, is predicted to have a minor negative effect on cold-water ichthyoplankton. Effects are not significant at the sea area and regional stock/population levels. Ichthyoplankton typically experience high natural mortality and so potential losses are considered negligible relative to ichthyoplankton abundance, that are produced by stocks/populations occurring outside the GSB.

Cold water juvenile and adult sensitivity to thermal influence (uplift and absolute temperatures)

In terms of absolute temperatures change influenced by the thermal plume exposure of juveniles and adults to lethal temperatures could be minimised by species movement vertically and/or horizontally in the water column as well as accessing alternative areas within and beyond the GSB, that are within the preferred temperature range. Some of the species also occur seasonally and so this may limit potential for interaction with the thermal plume.

The impact of thermal discharges from the cooling water outfalls, is predicted to have a minor effect on cold-water juvenile and adult fish. There is potential for avoiding the lethal temperatures and the availability of alternative habitat within and outside the GSB for fish to shelter, forage and for use during reproduction. Effects are not significant at the sea area and regional stock/population levels.

Warm water ichthyoplankton and egg cases sensitivity to thermal influence (uplift and absolute temperatures)

The sensitivity of warm-water ichthyoplankton and egg cases to temperature changes, due to thermal discharges from the cooling water outfalls, is predicted to be not sensitive.

The impact of thermal discharges from the cooling water outfalls, is predicted to have a minor effect on warm-water ichthyoplankton and egg cases. Effects are not significant at the sea area and regional stock/population levels. The limited magnitude of the plumes, with tidal mixing, limits potential for lethal and sub-lethal effects.

Warm water juvenile and adult sensitivity to thermal influence (uplift and absolute temperatures)

There is the potential for tolerance in species where the uplift falls within the preferred temperature range, and some life stages may even exploit the warmer waters. Given the range of species in the group, a precautionary approach is that the sensitivity of warm-water juveniles and adults to temperature changes, due to thermal discharges from the cooling water outfalls, is Low.

The impact of thermal discharges from the cooling water outfalls, is predicted to have a minor effect on warm-water juvenile and adult fish. There is potential for avoidance of lethal temperatures and the availability of alternative habitat within and outside the GSB for fish to shelter, forage and for use during reproduction. However, there is also the potential for a minor effect for some of the species, such as seabass, capable of exploiting the heated cooling water. Effects are not significant at the sea area and regional stock/population levels.

Migratory fish sensitivity to thermal uplift

Using the SAC Estuary criteria (25% cross-section >2°C for 5% of the time), modelling indicates no occlusion of the Blyth or Alde-Ore Estuaries [89]. Since there would be migration route available for all migratory species, no decline in the wider sea area/regional stock/population viability is expected. Migratory fish are considered not sensitive to temperature changes from the operational thermal discharge.

Given the medium magnitude assigned to the thermal plume, precautionary approach is that the impact of thermal discharges from the cooling water outfalls, is predicted to have a minor effect on migratory fish. No barriers to migration are predicted. Effects are not considered significant at the sea area and regional stock/population levels.

Commercial fisheries sensitivity to thermal influence

For commercial fisheries the magnitude of impact of the thermal plume on both cold and warm-water species is likely to be *Low*, given that the area of the plume represents a minor proportion of the fishing area and stock area of commercially exploited species. In general, the commercially exploited species are also highly mobile and able to move either to or from the influence of the plume, and their sensitivity has been assessed as low.

The impact of the thermal plume for both cold and warm-water species is considered minor and effects are not conserved significant.

5.9.6 Thermal Discharges- secondary effects on dissolved oxygen

Elevated temperature discharges have the potential to impact upon water quality status in several ways. Water temperature and dissolved oxygen concentration have a close relationship – warmer water holds less oxygen (at any given pressure) than it would at lower temperature (at the same air pressure).

Fish are highly sensitive to changes in oxygen levels, particularly those that need high levels of oxygen such as certain migratory fish. Drops in oxygen levels can cause behavioural changes in fish if they are unable to move away from the low oxygen waters. Such changes range from an increase in ventilation, decrease in activity, or swimming close to the surface where the water-air interface is richer in oxygen. This, however, makes the fish more vulnerable to predators.

With dissolved oxygen the issue is to avoid low values, the WFD threshold for dissolved oxygen is the 5th percentile i.e. that concentration which will be exceeded 95 per cent of the time. In relation to the effect of the thermal plume, it is the temperature that directly determines the dissolved oxygen concentration in an inverse relationship, high temperatures lead to low dissolved oxygen concentration. The calculation method used in this report is therefore to use the 95th temperature fields derived from the model to generate the dissolved oxygen concentration that would be expected at 100% saturation, which gives the 5th percentile dissolved oxygen field across the whole domain.

The WFD applies to 1 nautical mile from the coast (approx. 1852m) and from 2016 the Marine Strategy Framework Directive applies to the UK boundary. Both standards use the same criteria for defining permissible dissolved oxygen (DO) concentrations, 4 – 5.7mgl^{-1} being good status and above 5.7mgl^{-1} is high status.

The average DO concentration over the model domain for both scenarios is >7mgl^{-1} as a 5th percentile which is above the WFD threshold for High Status of 5.7mgl^{-1}. Therefore all areas are predicted to meet High status in terms of DO concentration (**Table 5.10.4**). The thermal discharge from Sizewell B and Sizewell C are therefore evaluated as having negligible effects for levels of dissolved oxygen at Sizewell.

Table 5.9.4 Areas where the WFD dissolved oxygen standards are predicted to be exceeded within the Suffolk Coastal water body.

DO concentration as a 5th percentile (mg l^{-1}) Normalised to salinity 35	**Sizewell B + C (ha)**		**Sizewell B only (ha)**	
	Surface	Bed	Surface	Bed
4.47 (Boundary at Good status)	0	0	0	0
5.77 (1%)(Boundary of high status)	106	8	52	5
5.97 (5%)	631	279	234	104
6.19 (50%)	7,064	6,053	2,453	2,401
6.39 (95%)	108,437	108,045	102,068	105,808
6.43 (99%)	124,345	124,152	119,048	123,681

Discussion of temperature interactions with ammonia concentrations are discussed in the **Section 5.9.7** below as loadings of ammonia are expected with operation of the EPR units.

5.9.7 Secondary effects of thermal elevation on proportion of un-ionised ammonia

In the operational phase Sizewell C will discharge ammonia from plant conditioning chemicals and the on-site sewage treatment plant. The maximum annual discharge of nitrogen (as ammonia ions) from circuit conditioning for two EPRs is 13,009kg and the worst case sanitary loading during an outage is calculated to be 1,387kg giving a total ammonia discharge of 14,396kg [70] which gives a calculated mean ammonia discharge concentration of 3.06µg/l NH_4-N at the outfall assuming a worst case cooling water discharge rate of 116m^3/s (this is a potential minimal discharge rate and would lead to a worst case in terms of process chemical dilution). As a conservative assumption this value has been added to the regional background mean and 95th percentile values for relevant physicochemical parameters and used temperature fields generated by GETM and the relevant physicochemical data and total ammonia concentration for each scenario to derive the un-ionised ammonia calculation. A summary of the annual mean increases in un-ionised ammonia concentration predicted at the surface for Sizewell Bay is shown in **Table 5.10.5**. All cases (including worst cases) for un-ionised ammonia show that no areas exceed the EQS of 21µg/l as an annual mean and the predicted mean increase in un-ionised ammonia was at maximum 13 times below the EQS of 21µg/l.

The overall effect of the thermal discharge from Sizewell B and Sizewell C is therefore evaluated as having negligible effects in terms of its influence on the proportion of un-ionised ammonia derived from the total ammonia present in the operational cooling water discharge from Sizewell C and including the local total ammonia background (which reflects current inputs from Sizewell B).

In the marine environment the toxicity of ionised ammonia should be considered. In waters, particularly at higher salinities, it has been shown that the ammonium ion can also permeate the gills, and so the concentration of total ammonia can also be toxicologically significant. Total ammonia values of 1100 (annual average) and 8000µg/l NH_4-N (Maximum allowable concentration) have been suggested as guideline values for likely significant effects on habitats [70]. For the operational discharge the predicted maximum daily concentration of ammonia is low at 13.49µg/l NH_4-N and the annual avergae is lower at 3.06µg/l NH_4-N. These inputs are considerably below guideline values for habitats.

Table 5.9.5 Summary of the surface un-ionised ammonia concentration (EQS is 21µg/l as an annual mean) for Sizewell Bay

Un-ionised ammonia for mean temp, mean pH, ammonia and salinity (The regulatory standard)		
	Sizewell B + Sizewell C	Sizewell B only
50th centile	0.25	0.25
95th centile	0.27	0.26
99th centile	0.29	0.27
Maximum	0.52	0.50
Un-ionised ammonia for 95th centile temperature, mean ammonia, salinity, pH.		
	Sizewell B + Sizewell C	Sizewell B only
50th centile	0.8	0.46
95th centile	0.8	0.47
99th centile	0.9	0.52
Maximum	1.2	0.91
Un-ionised ammonia for mean temp, 95th centile pH, ammonia, 5th percentile salinity		
	Sizewell B + Sizewell C	Sizewell B only
50th centile	0.8	0.81
95th centile	0.8	0.83

99th centile	0.9	0.88
Maximum	1.61	1.55

5.9.8 Hydrazine

A seasonal survey [59] acquired surface water samples at intervals of every two weeks at the Sizewell B cooling water outfall (Station 5) and at reference site (ca., 6k offshore from Sizewell B outfall, Station 11, **Figure 5.4.1**) Samples were analysed for hydrazine using a gas chromatography mass spectrometry (GC-MS) technique. The analysis indicated that hydrazine concentrations were below the detection limit (10ng/l).

There is no established EQS for hydrazine and so a chronic PNEC of 0.4ng/l has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4ng/l for short term discharges (represented by the 95th percentile). As some hydrazine process discharges are recycled the worst case daily discharges from the Turbine Hall [HM] have been modelled corresponding to an annual hydrazine discharge of 24kg per annum into the cooling water flow [89]. Hydrazine would be diverted to the [KER] tanks (**Section 4.1.3**) before treatment if required and discharge. Based on an annual loading of 24kg hydrazine and a daily load of 66.6g a concentration of 89µg/l hydrazine is estimated based on dilution in the 750m^3 [KER] tanks. Treatment would be required for hydrazine concentrations above this level to achieve the final discharge concentrations modelled here. To understand the impact of different discharge rates from the treatment tanks two discharge scenarios were studied for Sizewell C: the first one considering a hydrazine discharge of 69ng/l in daily pulses of 2.32h starting at 12pm, and the second one of 34.5ng/l of hydrazine discharged in daily pulses of 4.63h duration starting at 12pm. For each model run 28 days were analysed (two tidal cycles) and the mean and 95th percentile of the hydrazine concentrations was extracted.

Total areas of hydrazine PNEC exceedance

The plume simulations showed that both strategies gave similar results. The hydrazine plume follows a narrow trajectory parallel to the shore. At the seabed, less than 1ha exceeds the chronic PNEC, irrespective of the release strategy.

The hydrazine plume areas at the chronic PNEC (0.4ng/l as an average) and the acute PNEC (4ngl^{-1} as the 95th percentile) have been calculated (**Table 5.10.6**). The chronic PNEC is exceeded at the surface by approximately 158ha for both discharge scenarios and at the seabed by less than 1ha for both discharge scenarios. The acute PNEC is exceeded at the surface (less than 18ha) and at the seabed, but only in the case of the 69ng/l release for an area of 0.22ha.

[89] presents the predicted plume plots at the surface and the seabed from model runs of daily hydrazine discharges from Sizewell C. The magnitude of change in terms of the hydrazine operational discharge is evaluated as having a low spatial extent but high duration

and amount of change giving an overall magnitude of medium. Laboratory studies have shown hydrazine to have a half-life in seawater of around 38 minutes and at the point of discharge the water column is well mixed, so sensitivity is evaluated as low. The operational hydrazine discharge is therefore evaluated as having a minor impact on marine water quality.

Table 5.9.6 Absolute areas exceeding the Hydrazine PNEC.

Model	PNEC	Unit	Absolute area of exceedance	
			surface	seabed
Hydrazine_Sizewell C_69ng_May mean	Chronic 0.4ng/l	ha	158.11	0.56
Hydrazine_Sizewell C_34ng_May mean	Chronic 0.4ng/l	ha	156.88	0.336
Hydrazine_Sizewell C_69ng_May 95th percentile	Acute 4ng/l	ha	1.00	0.22
Hydrazine_Sizewell C_34ng_May 95th percentile	Acute 4ng/l	ha	17.38	0.00

As there is evidence that hydrazine is harmful to aquatic organisms at low concentrations [70] and although exceedance is predominantly at the surface over relatively small areas, further consideration will be given to potential impacts on marine ecology. The results of the modelling show that there is no interaction between the hydrazine plume and the Suffolk Coastal waterbody but this is further discussed in **Section 5.10.14** in this application and for supporting information for habitats assessment (marine mammals, and the prey species of marine feeding birds with terrestrial breeding colonies) see **Section 5.10.15** (this application).

Phytoplankton sensitivity to hydrazine

There is no established EQS thresholds for hydrazine. The marine chlorophyte *Dunaliella tertiolecta* has been shown to have the lowest acute toxicity to hydrazine with a six-day EC50 for growth inhibition of 0.4µg/l [70]. These results form the basis for precautionary PNEC thresholds. A chronic PNEC of 0.4 ng/l has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4 ng/l for short term discharges (represented by the 95th percentile). These thresholds are considered as precautionary triggers for further ecological investigation.

Assessments used in support of Canadian Federal Water Quality Guidelines for hydrazine indicate concentrations below 0.2µg/l (200ng/l) have a low probability of adverse effects for marine life. In the freshwater environment, where more data is available, a threshold of 2.6 µg/l has been applied [91].

The concentrations observed to induce growth inhibition are higher than the discharge concentration. Therefore, phytoplankton in the receiving waters are likely to incur minimal effects from daily operational hydrazine discharges.

Phytoplankton in the receiving waters are predicted to be Not Sensitive to hydrazine discharges. Cross-tabulation of the impact magnitude (Medium) and sensitivity (Not Sensitive) results in a score of Minor effects. Due to the highly precautionary applied PNEC for assessing impact magnitude the effects have been down weighted based on the predicted sensitivity of phytoplankton and zooplankton to hydrazine discharges.

Hydrazine discharges would have a negligible effect on phytoplankton receptors.

Zooplankton sensitivity to hydrazine

Limited data exists on the toxicity of marine invertebrates to hydrazine. However, 48-hour exposures of the marine copepod *A. tonsa* demonstrated NOEC for hydrazine of 50µg/l [92]. Similar results have been observed in freshwater crustaceans, with examples of 48-hour exposure concentrations of 160µg/l for *Daphnia pulex* [93], and 40µg/l for the amphipod *Hyallela azteca* [94]. These concentrations are considerably higher than those experienced by zooplankton in the receiving waters. Zooplankton in the receiving waters are predicted to be not sensitive to hydrazine discharges.

Hydrazine discharges are predicted to have negligible effects on zooplankton populations.

Benthic species sensitivity to hydrazine

The spatial extent of the hydrazine plume in exceedance of the applied EQS (chronic predicted no-effect concentration, PNEC at the seabed is very low (less than 1ha) although the daily discharges of hydrazine would occur throughout the lifetime of the power station. Overall, discharges of hydrazine are assessed as having a Low impact magnitude on the seabed. At the surface exceedance of the PNEC is predicted over a larger area which may have more influence for eggs and larvae of benthic species.

A limited number of ecotoxicology studies are available on the sensitivity of benthic invertebrate larvae and eggs to hydrazine. Larvae or eggs are expected to be most sensitive stages. Toxicity tests on larval oysters demonstrated toxicity below concentrations of 6 µg/l of hydrazine for exposure periods up to 48 h. The most sensitive crustacean species (freshwater amphipod) reported at a LC_{50}-48 h of 40µg/l hydrazine [91]. Discharge concentrations are considerably below effects levels shown for available short-term acute exposure studies.

As no mortality is expected in the limited area under the influence of the hydrazine plume on the seabed, and considering their naturally high fecundity in the GSB, benthic taxa are assessed as not sensitive to the pressure.

The impact of daily hydrazine discharges during the operation phase is predicted to have a negligible (seabed) to minor (water column) effect on benthic receptors.

Fish Receptors sensitivity to hydrazine

This section considers the impact of hydrazine on Fish Receptors at Sizewell.

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to hydrazine discharges

In the near-field of the hydrazine plume, exposure could result in acute effects (lethal) over very spatially restricted areas, for life stages and species unable to avoid the plume. In the wider field area where the hydrazine plume occurs, there is potential for chronic effects (sublethal).

Exposure of eggs/larvae could result in morphological abnormalities, altered growth and hatching and ultimately, survival of the eggs and larvae. But losses are considered negligible relative to natural mortality. Also, the likelihood of mortality is minimised where species and seasonal eggs/larvae may have minimal interaction with the plume in a given year.

The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive.

The impact of hydrazine discharges is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are not significant at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to hydrazine discharges

Juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while less mobile species e.g. gobies and juvenile stages may remain. There is potential for sublethal physical and physiological effects. However, a very small extent of the GSB seabed is likely to be exposed to the hydrazine plume compared with foraging habitat and spawning/nursery habitat.

The sensitivity of demersal fish and elasmobranchs to hydrazine discharges is predicted to be not sensitive.

The impact of hydrazine discharges is predicted to have a negligible effect on demersal fish and elasmobranchs. Effects are not significant at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to hydrazine discharges

As per the assessment for demersal fish and elasmobranch eggs/cases and larvae, the sensitivity of pelagic fish eggs and larvae, to hydrazine discharges from the cooling water outfalls, is predicted to be *Not Sensitive.*

The impact of hydrazine discharges is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are not significant at the sea area and regional stock/population levels.

Pelagic fish juveniles and adults: sensitivity to hydrazine discharges arm water juvenile and adult sensitivity to hydrazine

As per the assessment for demersal fish and elasmobranchs, the sensitivity of pelagic fish to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive to this pressure.

The impact of hydrazine discharges is predicted to have a negligible effect on pelagic fish. Effects are not significant at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to hydrazine discharges

Given the limited persistence of the hydrazine plume, no barrier to migration is predicted.

Migratory fish may choose to avoid the area and move elsewhere in the GSB, though some may remain. The location of parasitic lamprey would, however, be dictated by the host's movements. Lethal effects are unlikely given the ability of fish to avoid the plume and in view of the very limited area of the surface plume, where the acute threshold would be exceeded for the 69ng/l release strategy.

The sensitivity of migratory fish to hydrazine from the cooling water outfalls, is predicted to be not sensitive to this pressure.

The impact of hydrazine is predicted to have a negligible effect on migratory fish juveniles and adults. Effects are not significant at the sea area and regional stock/population levels. As per the assessment for demersal fish and elasmobranchs, the sensitive of pelagic fish to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive to this pressure.

Some species may be temporarily displaced from the area of the plume through avoidance behaviour. Or individual fitness compromised by sublethal or lethal effects, if unable to move away from the decaying hydrazine. As such, minor changes in localised abundance and distribution could occur. However, given the limited magnitude of the hydrazine surface plume and acknowledging the seasonal presence of some of the species, there are unlikely to be substantial changes in availability of fish prey items for designated features and fisheries resources. Therefore, localised displacement of fish receptors, due to the hydrazine surface plume, is predicted to have a minor but not significant effect.

Commercial fisheries sensitivity to hydrazine discharges

This section considers Development activities and associated pressure with the potential to effect commercial and recreational fisheries during the operational phase of the proposed development. Activities are informed by the results of direct effects on commercially targeted fish and shellfish species described. The thermally buoyant nature of the plumes means there is minimal interaction of chemical discharges with the seabed with negligible effects for the shellfishery.

Chemical discharges 3km offshore may cause localised avoidance near the outfalls however no significant changes in species distribution and therefore availability of target species to the fishery are predicted. No further assessment is made.

5.9.9 Total residual oxidants and chlorination by-products

Coastal power stations require a means of chlorine dosing for biofouling control. Based upon the known risk of biofouling at Sizewell, EDF Energy would need to chlorinate the Sizewell C CW system to maintain control over biofouling of critical plant. At those sites where chlorination is required, EDF Energy's operational policy for its existing UK fleet (based upon experiments and operational experience) is to continuously dose during the growing season to achieve a minimum TRO dose of 200µg/l in critical sections of the CW plant and at the inlet to the condensers. For Sizewell C the TRO concentration at the outfall would depend on the chlorination strategy applied within the power station, however a worst-case TRO concentration of 150µg/l at the outfalls has been used for plume modelling purposes [89].

Chlorine-produced oxidants which provide the required anti-fouling action are a group of unstable, short-lived oxidising agents collectively measured as TRO, with hypobromous acid/hypobromite the dominant species.

Other non-oxidising compounds are formed by the interaction of chlorine with sea water and these are known collectively as chlorination by-products. Bromoform and other trihalomethanes are the most prevalent.

To assess the spatial extent of a TRO plume from the proposed Sizewell C development, experimental evidence was used to generate coefficients for chemical decay equations for input into a full hydrodynamic model. As with temperature, the GETM was used to predict the TRO plume behaviour. The year 2009 was chosen to be modelled in keeping with the selection made for the thermal assessment. The potential effects of the chemical plume are on the local biology and so modelling studies have been focused on the period of the year of highest biological productivity. The month of May was chosen due to having the highest phytoplankton growth which drives the whole marine ecosystem. Two scenarios were considered: chlorination of Sizewell B plus Sizewell C operating in combination, and chlorination of Sizewell B only. For each model run a month-long simulation was analysed and the mean and 95th percentile of the TRO concentration extracted. For both the Habitats Regulations Assessment and WFD assessment, the same standard is used, the saltwater EQS (expressed as a maximum allowable concentration) of TRO (expressed as chlorine) is set as 10µg/l at the edge of the defined mixing zone. **Table 5.10.7** shows the calculated total area of plume within the model domain where it exceeds the EQS of 10µg/l as 95th percentile.

Table 5.9.7 Total area of the plume modelled by GETM that exceeds the TRO EQS in the model domain.

Model	Unit	TRO =10µg/l as a 95th percentile	
		surface	**seabed**
Sizewell B + Sizewell C	ha	726.21	167.08
Sizewell B only	ha	388.56	164.95
Sizewell C only	ha	337.65	2.13

Sizewell C Marine Water and Sediment Quality Synthesis [89] presents the predicted plume plots at the surface and the seabed from model runs of daily TRO discharges from Sizewell C. The magnitude of change in terms of the TRO operational discharge is evaluated as having a low spatial extent but high duration and amount of change giving an overall magnitude of medium. Chlorine produced oxidants rapidly decay when mixed with seawater and as the water column at Sizewell is well mixed sensitivity is evaluated as low. The operational TRO discharge is therefore evaluated as having a ***minor*** impact on marine water quality.

Phytoplankton sensitivity to total residual oxidants

Concentrations of TRO of 50µg/l are predicted to occur over a sea surface area of <9ha as a 95 percentile. Therefore, a very small proportion of phytoplankton within the tidal excursion are predicted to be exposed to concentrations at a level shown to cause reductions in cell abundance or changes in species diversity and any reductions in cell abundance or species composition are predicted to be highly localised. Furthermore, recovery of phytoplankton exposed to the greater effects of primary entrainment following mixing in the receiving waters have been observed [95], [96], [97].

The sensitivity of phytoplankton to TRO discharges is predicted to be Low. TRO discharges are predicted to have minor but not significant effects on phytoplankton in the receiving waters.

Zooplankton sensitivity to total residual oxidants

In crustaceans the primary influence of TROs is to impair osmoregulation, which eventually disrupts neural activity and causes death following prolonged exposures [97]. Limited long-term data on the chronic toxicity of chlorine on marine organisms exists [98] with much of the focus on acute toxic effects. The most sensitive marine species show acute toxicity at TRO concentrations between 10 and 100µg/l [99]].

The toxicity to low level TRO dosing was tested in the dominant mysid species at Sizewell (*Schistomysis spiritus*). No significant mortality occurred at any of the concentrations tested (mean 15, 43 and 101µg/l TRO) following 48-hour exposure [89]. The lowest reported LC50 value for 96-hour chlorine exposure on the copepod *Acartia tonsa* is 29µg/l [100]. The survival and growth of the juvenile amphipod *Melita palmata* was studied over a 28-day period. Exposure to 20µg/l TRO resulted in an additional 10% mortality in comparison to controls. Growth rates were not significantly affected [89].

Concentrations above 20µg/l are predicted to occur over a surface area of 98ha as a 95 percentile and 0.34ha at the seabed. In the tidal environment a very small proportion of the zooplankton community would be exposed to concentrations that could cause mortality and exposure times would be limited.

Sub-lethal effects of chlorination may consist of damage to eggs, reduced hatching success, delayed larval development, gill damage and reduced respiration [99]. Laboratory experiments have shown reduced egg production rates in the copepod A. tonsa following chlorine additions but at higher concentration than that predicted in the receiving waters [101]. Reductions in feeding rates of *S. spiritus* were observed following 48-h expose to 50 and 100µg/l TRO [67]. Avoidance behaviour has been observed in response to chlorinated discharges at concentrations of 20µg/l in the amphipod *Gammarus daiberi* [102].

Sub-lethal effects reducing zooplankton fitness are possible in the vicinity of the outfall. However, a small proportion of the population would be affected and high natural fecundity and recruitment from the wider area result in Low sensitivity of zooplankton to TRO discharges. TRO discharges are therefore predicted to have minor but not significant on zooplankton in the receiving waters at the population level.

Benthic species sensitivity to total residual oxidants

This section considers the impact of TRO discharges on benthic species.

Discharge plume modelling for Sizewell C suggests that sessile benthic organisms would be exposed to TRO concentrations exceeding the EQS (10µg/l) in a small area in the immediate vicinity of the outfall (2ha). The key sessile invertebrate taxa in this area are bivalves, amphipods and polychaetes, and their resistance to TRO effects vary.

Acute effects (mortality) are expected to be minimal as a result of the concentration range and extent of the TRO plume. However, the fitness of benthic sessile taxa is predicted to be affected in proximity to the outfall. Based on these observations, the sessile/low mobility invertebrate have a Low sensitivity to the pressure.

The key mobile invertebrate species in this area are decapods (shrimp, prawns, crabs and lobsters) and echinoderms (ophiuroids). Although toxicity data are limited, they indicate relative resistance to exposure to TRO at the discharge concentration. Therefore, no mortality is expected in the area under the influence of the chemical plume and all the key mobile taxa are present across most of the unaffected areas of the GSB and in the wider region therefore, the mobile macroinvertebrates are assessed as Not sensitive to the pressure.

A great majority of the invertebrate taxa present in the GSB have planktonic stages before adopting a benthic lifestyle. The surface plume model suggests that planktonic larval stages of benthic invertebrate would be exposed to TRO concentrations exceeding the EQS (10µg/l) across a total area of 338 ha within the GSB. As the taxa present in the GSB have a high fecundity and potential to recruit from source populations inside and outside the zone of influence, the planktonic invertebrate larvae and eggs are assessed as having Low sensitivity.

The impact of TRO discharge during the operation phase is predicted to have a minor but not significant effect on benthic receptors.

Fish Receptors sensitivity to total residual oxidants

The impact magnitude for TRO discharges has been assessed as Medium. This section considers the impact of TRO on Fish Receptors at Sizewell.

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to total residual oxidants discharges

The potential exists for acute effects in the near-field of the plume. But given the limited magnitude of the TRO surface and seabed plumes, potential losses of eggs and larvae are considered minimal. This is when compared to the loss of eggs/larvae due to natural mortality, and in view of the abundances of eggs/larvae occurring within the extensive spawning and nursery grounds. Sand gobies are abundant within the GSB area and wider area of the North Sea. No declines in abundance and distribution of the respective stocks/populations is expected despite possible egg and larvae mortality. The sensitivity of demersal fish and elasmobranch eggs /cases and larvae, to TRO is not significant.

The impact of TRO discharges is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are not significant at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to total residual oxidants discharges

Except for seabass and tope, most species in this sub-group live on the seabed, atop the seabed or just several metres above the seabed. Consequently, exposure to a buoyant surface plume would be limited but exposure to the seabed plume may occur.

There may be very localised acute effects in the near-field of the plume for less mobile species e.g. gobies and potentially juvenile seabass. However, there is predicted to be a rapid dilution of the plumes and there would be TRO surface and seabed plumes of a limited magnitude.

The sensitivity of demersal fish and elasmobranchs to TRO discharges from the cooling water outfalls, is predicted to be Medium.

The impact of TRO discharges from the cooling water outfalls is predicted to have a minor effect on demersal fish and elasmobranchs. Effects are not significant at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to total residual oxidants discharges

Eggs and larvae drift inshore into the GSB area and consequently, could be exposed to the buoyant surface plume, though this would depend on the timing of the eggs and larvae relative to the plume.

Assuming herring larvae/post larvae were in proximity of the seabed plume, herring larvae survival is likely. For anchovy, sprat and mackerel, the exposure of eggs and larvae to the seabed plume is unlikely given the pelagic nature of the life history stage for these species. However, no decline in the stock/regional population viability, due to mortality, is expected. The sensitivity of pelagic fish eggs and larvae to TRO discharges from the cooling water outfalls, is predicted to be not sensitive.

The impact of TRO discharges from the cooling water outfalls, is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are not significant at the sea area and regional stock/population levels.

Pelagic fish juveniles and adults: sensitivity to total residual oxidants discharges

There may be very localised acute effects in the near-field of the plume; however, there is predicted to be a rapid dilution of the plumes and there would be TRO surface and seabed plumes of a limited magnitude. There is the potential for sub-lethal effects in the far-field of the plume, with effects on juvenile and adult physiology, behaviour and thus fitness.

For mobile juveniles and adults, avoidance behaviour may mitigate exposure to toxic effects from the TROs. The TRO concentrations initiating an avoidance response are likely to vary between species and life history stages. Juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while others may remain and acclimate to decaying TRO concentration.

The TRO seabed plume covers a very small extent of seabed in the GSB potentially used as herring nursery grounds. The pelagic nature of other taxa such as sprat, limits potential for exposure to the seabed plume. The TRO surface plume is also a very small extent of water column habitat in the GSB.

The sensitivity of pelagic fish juveniles and adults to TRO discharges from the cooling water outfalls, is predicted to be Low.

The impact of TRO discharges from the cooling water outfalls is predicted to have a minor effect on pelagic fish juveniles and adults. Effects are not significant at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to total residual oxidants discharges

Exposure of migratory fish in the near-field of the plume is unlikely to result in mortality to individuals. Avoidance behaviour could mitigate exposure to toxic effects, but the TRO concentrations initiating an avoidance response are likely to vary between species.

The sensitivity of migratory fish juveniles and adults to TRO discharges from the cooling water outfalls, is predicted to be not sensitive to this pressure.

The impact of TRO discharges from the cooling water outfalls is predicted to have a negligible effect on migratory fish juveniles and adults. Effects are not significant at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: total residual oxidants

Some species may be temporarily displaced from the area of the plume through avoidance behaviour. Or individual fitness compromised by sublethal or lethal effects, if unable to move away from the TRO plume. As such, minor changes in localised abundance and distribution could occur. However, with the seasonal chlorination and resulting TRO plumes, and acknowledging the seasonal presence of some of the species, there are unlikely to be substantial changes in availability of fish prey items for designated features and fisheries resources. Therefore, localised displacement of fish receptors, due to the TRO sea surface, is predicted to have a minor but not significant effect at the sea area and regional stock/population levels.

Commercial fisheries sensitivity to total residual oxidants discharges

This section considers Development activities and associated pressure with the potential to effect commercial and recreational fisheries during the operational phase of the proposed development. Activities are informed by the results of direct effects on commercially targeted fish and shellfish species described. The thermally buoyant nature of the plumes mean there is minimal interaction of chemical discharges with the seabed with negligible knock-on effects for the shellfishery.

Chemical discharges 3km offshore may cause localised avoidance near the outfalls however significant changes in species distribution and therefore availability of target species to the fishery is not predicted. No further assessment is made.

Chlorination by-products (bromoform) modelling assessment

Another consequence of the chlorination of the power station is the formation of chlorination by-products (CBPs) as a result of complex chemical reactions in seawater. Many products are formed, the number and type being dependent on the composition and physical parameters of the seawater. The dominant CBP's are, in order, bromoform, dibromochloromethane (DBCM), bromodichloromethane (BDCM), monobromaceitic acid, dibromoaceitic acid (DBAA), dibromoacetonitrile (DBAN) and 2,4,6 tribromophenol. Laboratory studies carried out with chlorinated Sizewell seawater only detected bromoform [89]. Bromoform has the highest (or same level) derived PNEC relative to the other dominant CBPs and the latter if measurable in cooling water discharges from UK and European power stations have been reported at levels below PNEC at the point of discharge [89]. Bromoform is lost through volatilization to the atmosphere, with the loss rate a function of the thermal stratification and values obtained from the literature [69] and coupled into the GETM Sizewell model.

Since bromoform is a product of chlorination, the same scenarios as for TRO were considered: chlorination of Sizewell B plus Sizewell C operating in combination and chlorination of Sizewell B only. For each model run a month-long simulation was analysed and the 95th percentile of the bromoform concentrations was extracted. There is no published EQS for bromoform and so a calculated PNEC of 5µg/l as a 95th percentile has been used [69]. This value was predicted based on the results of a toxicological review and the application of Quantitative Structure Activity Relationships (the same figure was used in the Hinkley Point C WDA permit application). Additional information is provided in BEEMS technical report TR193 [70] and shows the area of the plume that exceeds the relevant concentration threshold.

The amount of bromoform that is discharged mainly depends on the amount of chlorine that is added, but as bromoform is relatively volatile, also on the amount of mixing/turbulence of the water. In laboratory experiments [89], different concentrations of bromoform are obtained from the same initial concentration when samples are stirred or not. Evident from these studies is that stirring, as might be expected in a turbulent discharge appears to reduce bromoform concentration through loss to air. Unstirred replicate samples following addition of 0.5mg/l Cl_2 had 19 µg/l of bromoform compared to the much higher value of 29µg/l that was reported for unstirred replicate samples.

Like the TRO plume, the bromoform plume is a long, narrow feature parallel to the coast. Also, the Sizewell B plume is always within the channel inshore of the Sizewell-Dunwich Bank and does not c with the Sizewell C plume that is outside the Bank. The Bromoform plume areas that exceed the PNEC (5µg/l as a 95th percentile) have been calculated and are shown in **Table 5.10.8**. For Sizewell C only, the total area in the model domain exceeding the applied EQS at the seabed is 0.67ha and 52.14ha at the sea surface.

The magnitude of change in terms of the predicted bromoform concentration resulting from chlorination of the operational discharge is evaluated as having a low spatial extent but high duration and amount of change giving an overall magnitude of medium. Bromoform concentrations rapidly decay with mixing and aeration of the receiving water and as the water column at Sizewell is well mixed sensitivity is evaluated as low. The operational bromoform (CBP) discharge is therefore evaluated as having a minor impact on marine water quality.

Table 5.9.8 Total area of the plume modelled by GETM that exceeds the bromoform EQS in the model domain.

Model	Unit	PNEC = 5µg/l as a 95th percentile	
		surface	seabed
Sizewell B + Sizewell C	ha	357.94	130.19
Sizewell B only	ha	305.80	129.52
Sizewell C only	ha	52.14	0.67

Plankton sensitivity to chlorination by-products (Bromoform)

The average bromoform concentration within the discharge plumes of ten European power stations, including Sizewell A, has been shown to be 16.3µg/l [103] and outfall concentrations range from 1-43 µg/l [69]. CBPs associated with chlorination are predicted to have very limited toxicity once in the receiving waters [69].

Few studies have specifically looked at bromoform in isolation from other chlorination products and plankton receptors are considered together. NOEC for bromoform on a range of marine organisms including bivalve gill tissue and larvae, echinoderm larvae and bacteria ranged from 0.5 to 3.4mg/l [104]. The 96-h LC50 for mysid (24.4mg/l) and diatom mortality (11.5-12.3mg/l) are orders of magnitude above concentrations observed in the field [104].

Plankton are predicted to be not sensitive to bromoform and so discharges of CBP (bromoform) are predicted to have negligible additional effects on plankton communities in the receiving waters beyond the wider effects of TROs.

Indirect Effects of chlorinated discharges

Chlorine species are rapidly degraded in the marine environment and bioaccumulation is not an important consideration [103]. Bromoform is the most abundant CBP and has a low bioconcentration factor (BCF). The BCF ranges from 1-4 in most species except for shrimps where values of >8 have been reported in the literature. However, following cessation of chlorination depuration of bromoform was completed after two days from mussels [104].

Limited environmental persistence of chlorine species, and the low BCF of bromoform indicate that indirect effects due to bioaccumulation in the food-web is expected to be limited.

Benthic species sensitivity to chlorination by-products (Bromoform)

This section considers the impact of chlorination byproducts (bromoform) discharges on benthic species.

There is limited literature on the sensitivity to bromoform of sessile/low mobility benthic invertebrate living on the seabed. Some studies on the American oyster *Crassostrea virginica* showed no mortality after 48 h exposure at concentration of 2 µg/l and some sublethal effect such as increased respiration and decrease in gonad condition after 32 days exposure at 20 µg/l [105]. This species is known to be one of the most sensitive to TRO toxicity so its Low sensitivity to concentration in Bromoform expected to be discharge in the GSB indicate that benthic invertebrates may be evaluated as of Low sensitivity to the effects of Bromoform from the Sizewell C chemical plume. Bioaccumulation of bromoform in bivalve has been shown to be limited as depuration is relatively rapid, within days of being returned to clean waters ([106], [107]). Bromoform is not persistent and decreases in concentration due to anaerobic degradation and volatilization; and exposure is limited temporally and spatially (worst-case of 0.67 ha for Sizewell C). As no mortality is expected in the area under the influence of the bromoform plume on the seabed, and considering their naturally high fecundity in the GSB, the sessile/low mobility taxa are assessed to not be sensitive to the pressure.

The key mobile invertebrate taxa in the GSB are decapods (shrimp, prawns, crabs and lobsters) and echinoderms (ophiuroids). There is limited relevant toxicological data for this group. Juveniles and adults of mobile species have the potential to move elsewhere in the GSB. Lethal effects are unlikely as exposure to bromoform would be limited temporally and spatially due to the relatively low predicted discharge concentration and the limited persistence of bromoform. All key mobile taxa are present across most of the GSB and in the wider region. As no mortality is expected and due to their naturally high fecundity, the mobile macroinvertebrates are assessed to not be sensitive to the pressure. Benthic larvae and eggs are also assessed as not sensitive to the pressure due to the large numbers produced both within the influence of the plume and in the wider area and the low likelihood of exposure to bromoform.

Bromoform exposure in the cooling water discharge during the operation phase is predicted have negligible effects at the seabed to minor effects in the water column for benthic receptors.

Fish Receptors sensitivity to chlorination by-products (Bromoform)

The impact magnitude for bromoform discharges has been assessed as Medium. This section considers potential impacts on fish receptors and are summarised below.

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to chlorination by-product (bromoform)

There is limited published literature on the ecotoxicity of bromoform to ichthyoplankton. A study of freshwater carp embryo exposure to a range of CBPs, including bromoform, determined that the LC50 after 96 hours from the time of exposure was 52 mg/l [108]. This lethal concentration is substantially greater than the target 5µg/l EQS for the proposed development, which is exceeded over a very limited (52ha at the surface and 0.15ha at the seabed).

The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to bromoform from the cooling water outfalls, is predicted to not be sensitive.

The impact of bromoform is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are considered significant at the sea area and regional stock/population levels.

Demersal fish and elasmobranch: sensitivity to bromoform chlorination by-product

NOEC for bromoform on a range of marine organisms range from 0.5 to 3.4mg/l [104]. Lethal effects are unlikely given the limited persistence of bromoform, which is expected to diminish over time because of anaerobic degradation and volatilization. As such, the nature of exposure would be limited temporally and spatially. No decline in the stock/regional population viability, due to mortality, is expected.

The sensitivity of demersal fish and elasmobranchs to bromoform from the cooling water outfalls, is predicted to be not sensitive.

The impact of bromoform is predicted to have a negligible effect on demersal fish and elasmobranchs. Effects are not considered to be significant at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to bromoform chlorination by-product

There is a low likelihood of chronic effects such as altered growth and potentially the survival of eggs and hatched larvae/post larvae. No decline in the stock/regional population viability, due to mortality, is expected.

The sensitivity of pelagic fish eggs and larvae to bromoform from the cooling water outfalls, is predicted to be not sensitive.

The impact of bromoform chlorination by-product is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are not significant at the sea area and regional stock/population levels.

Pelagic fish juveniles and adults: sensitivity to bromoform chlorination by-product

Published literature on the ecotoxicity of bromoform and pelagic fish is limited in availability. The pelagic nature of the species in the water column minimises potential interaction with the seabed bromoform plume. Juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while others may remain. Lethal effects are unlikely given the limited persistence of bromoform, which is expected to diminish over time because of anaerobic degradation and volatilization.

The sensitivity of pelagic fish juveniles and adults to bromoform from the cooling water outfalls, is predicted to be not sensitive.

The impact of bromoform is predicted to have a negligible effect on pelagic fish juveniles and adults. Effects are not considered significant at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to bromoform chlorination by-product

Given the limited persistence of the bromoform plume, no barrier to migration is predicted.

Migratory fish may choose to avoid the area and move elsewhere in the GSB, though some may remain. Parasitic lamprey would be associated with the host's movements. Lethal effects are unlikely given the limited persistence of bromoform, which is expected to diminish over time because of limited persistence. As such, the nature of exposure would be limited temporally and spatially.

The sensitivity of migratory fish to bromoform from the cooling water outfalls, is predicted to be not sensitive.

The impact of bromoform chlorination by-product is predicted to have a negligible effect on migratory fish juveniles and adults. Effects are not considered significant at the sea area and regional stock/population levels.

Assessments of effects of localised displacement

Some species may be temporarily displaced from the area of the plume through avoidance behaviour. Or individual fitness compromised by sublethal or lethal effects, if unable to move away from the decaying bromoform. As such, minor changes in localised abundance and distribution could occur. However, given the limited magnitude of the bromoform seabed plume, the seasonal chlorination presence, and acknowledging the seasonal presence of some of the species, there are unlikely to be substantial changes in availability of fish prey items for designated features and fisheries resources. Therefore, localised displacement of fish receptors, due to the bromoform plume, is predicted to have a negligible effect which is not significant. Given the limited persistence of the bromoform plume, no barrier to migration is predicted.

Commercial fisheries sensitivity to CBPs (Bromoform)

This section considers development activities and associated pressure with the potential to effect commercial and recreational fisheries during the operational phase of the proposed development. Activities are informed by the results of direct effects on commercially targeted fish and shellfish species described. The thermally buoyant nature of the plumes means there is minimal interaction of chemical discharges with the seabed with negligible knock-on effects for the shellfishery.

Chemical discharges 3km offshore may cause localised avoidance near the outfalls however significant changes in species distribution and therefore availability of target species to the fishery is not predicted. No further assessment is made.

5.9.10 Dissolved inorganic nitrogen inputs during operation

During operation, the maximum number of people on site occurs when there are refuelling outages, during this time nitrate and phosphate loads are increased above background concentrations. The refuelling outages typically last four to six weeks but can occur at any time of year. During the winter period light is limiting and there is no effect resulting from the additional supply of nutrients. It is only in summer that the discharge needs to be considered. During operation the maximum 24-hour loading of nitrogen from all sources is 332 kg and the maximum annual loading 11725kg per year (daily equivalent 32.12kg). During the operational phase, maximum daily loading for nitrogen therefore reach approximately 2% of the nitrogen loading in the daily exchange for Sizewell Bay (based on annual average background nitrogen concentration), but the average daily value is low at 0.2% of that present in the daily exchange (again indistinguishable from background levels) [109]. The effect of Sizewell B and the proposed Sizewell C on phytoplankton that pass through the power station has been simulated using a phytoplankton box model [109]. The observed cycle of plankton production has been simulated with emphasis on the spring bloom and summertime production. During operation the power stations discharge nutrients in the form of phosphate and nitrates resulting from the use of conditioning chemicals and the discharge of treated sewage. The influence of power station chlorination upon phytoplankton survival is also incorporated into the model. For much of the year light availability limits phytoplankton growth and the addition of relatively small quantities of nutrients has no effect. In the summer, nitrate is a limiting nutrient (when light is not limiting) and is consumed rapidly. However, the exchange with the wider environment is much greater than the maximum proposed discharges, during operation so that no change in phytoplankton growth beyond natural variability would be observed. The phytoplankton growth Box model run over an annual cycle (that incorporated both nitrogen and phosphorus inputs showed an insignificant increase in carbon levels (phytoplankton biomass) of 0.1%. Therefore, the discharge loading of nitrogen from operational input is predicted to have a negligible effect on water quality which is not significant.

During operation the use of hydrazine, morpholine and/or ethanolamine have the potential to contribute to the nitrogen input to the marine environment. Hydrazine breakdown during operation or subsequently during holding and potentially treatment before discharge may result in nitrogen loss to the atmosphere however estimated maximum nitrogen inputs from combined loadings of hydrazine, ethanolamine and morpholine not accounting for atmospheric losses could contribute 1.3 kg/day. This additional potential loading is small relative to the 32kg from other sources and would be insignificant relative to the mass present in the daily exchange and would not be expected to significantly influence phytoplankton growth above that predicted for other operational inputs of nitrogen.

5.9.11 Dissolved inorganic phosphorus inputs during operation

Phosphorus also passed the screening assessment but had one of the higher values based on 24-hour loadings (352kg as PO_4). Converting this loading to PO_4-P gives a value of 114.8kg. A predicted PO_4-P daily exchange in summer between Sizewell Bay and outer tidal excursion and the wider area is 2440kg [109] therefore the planned maximum daily PO_4-P loading from Sizewell C would represent ~5% of this value. The maximum daily discharge concentration is 11.58µg/l PO_4-P and is below the site background value of 33.5µg/l. However, the average daily operational discharge would be 0.7kg PO_4-P and this represents 0.03% of the daily exchange. There is no equivalent EQS value for phosphorus and it is not normally the limiting nutrient in marine waters, and the discharge concentration is also below background concentrations for offshore waters based on mean winter nutrient concentrations in Atlantic seawater [110]. Incorporation of the operational phosphorus load together with that of the DIN was modelled in [109] as described in **Section 5.10.10** above and showed a negligible increase in carbon levels at 0.1%. Therefore, the discharge loading of phosphorus from operational input is predicted to have a negligible effect on water quality which is not significant.

5.9.12 Inputs influencing biological demand during operation

BOD loadings assessed during operation take account of maximum staff numbers on site during an outage based on Hinkley Point C this is estimated as 1900 staff. The waters off Sizewell are well mixed vertically. Draw down of oxygen will only occur if the rate of consumption due to BOD is greater than the oxygen transfer across the water surface. Typical values of oxygen flux are 100mmol m^2 d^{-1} [111] or 3.2gm^2 d^{-1}. The maximum daily BOD loading based on 1900 staff on site is 3.85kg. This amount of oxygen would be transferred across just over 1000m^2 in a day. After mixing in the cooling water this loading is not expected to show measurable change in BOD background. Therefore, DO is likely to remain at high status. The discharge of BOD during operation is therefore considered to be of negligible significance for dissolved oxygen modification and associated water quality.

5.9.13 Assessment of inputs contributing to coliforms and intestinal enterococci for operational discharges

This assessment is based on the Bathing Water Regulations [14] for coastal and transitional waters for which Good status requires that the colony forming unit (cfu) counts for intestinal enterococci are ≤200 cfu/100ml and for Escherichia coli are ≤500 cfu/100ml.

The nearest designated bathing waters are Southwold the Denes (latitude 52.32º N, longitude 1.679º E) and Felixstowe North (latitude 51.96º N, longitude 1.355º E) and are approximately 10km and 35km distant, respectively. To ensure that there is no impact on compliance at these locations it is necessary to confirm that treatment and dilution of the sewage effluents produced during the operation meets the required standard.

Based on data in support of the Hinkley Point C development, estimates were provided for maximum levels of faecal indicator organisms for the raw sewage input to the treatment plant. Secondary treatment implies a 100 factor (2 log) reduction in Coliforms and enterococci. If tertiary treatment is also applied a 5.4 log reduction is assumed. Following application of these different levels of treatment reduction the dilution factor required to reduce the coliforms to levels that would comply with bathing water standards and the distance from the point of discharge at which this would be achieved has been derived.

During operation the maximum number of staff on site is estimated at 1900 (with 100l^{-1} per head per day effluent production) based on Hinkley Point C and on numbers present during an outage. Mixing of the treated sewage effluent volume with the cooling water flow (66m^3 s^{-1}) for one EPR (a worst case) will achieve a dilution of ~33000. Assuming treatment reductions of 2 log and 5.4 log for secondary and including tertiary treatment then compliance with the bathing water standards would be achieved at the point of cooling water discharge with secondary treatment only as well as with tertiary treatment.

The discharge of treated sewage influence on the bathing water standards during operation is therefore considered to be of negligible significance.

5.9.14 Potential interaction of chemical and physical parameters during operation

The influence of thermal uplift upon un-ionised ammonia proportion and dissolved oxygen concentration is considered for the cooling water discharge in sections 5.9.5 to 5.9.7. Other chemical and thermal interactions are considered here.

Chemical parameters as influenced by temperature

Increase in temperature is known to increase chemical toxicity including that of chlorine. For example, a 5°C increase in temperature more than halved the effect concentration of free chlorine and chloramine for various marine species. The main potential for synergistic effects of temperature and toxicity of the chlorinated seawater is to species experiencing entrainment. The acute effects of this exposure would be expected to diminish rapidly upon discharge of the cooling water with rapid loss of temperature and reduction in oxidant concentration as the plume mixes and reaches the sea surface. The thermal uplift in combination with the toxicological effects of chlorination is therefore not expected to change the assessment of the chlorination discharge or thermal plume alone.

Synergistic effects of chlorinated discharges and ammonia from treated sewage

Seawater chlorination with the ammonia present is likely to form different residual oxidants dependent on the ammonia to chlorine ratio. Dibromamine is one of the primary formation products and has a generally higher toxicity than uncombined oxidants of chlorine or bromine although it is of very low persistence. However, as total ammonia is very low and only around one third of the background ammonia, any increase in toxicity above that due to chlorination alone is expected to be very small. As a result, additional water quality effects are not predicted.

5.9.15 Water Framework Assessment

A detailed Water Framework Assessment considering the specific WFD elements is provided in Appendix D. The following section considers areas of exceedance only for the Suffolk Coastal Waterbody for specific discharges.

Thermal Modelling results for WFD water bodies

To undertake the compliance assessment, guidance issued recommends that maximum temperatures at the edge of the mixing zone should not exceed 23°C and, that outside the mixing zone, temperature rises above ambient should be limited to 3°C [67].

Hydrodynamic modelling was undertaken to calculate the area over which the values set out above would be exceeded [77] and [85]. The water to be discharged back to the marine environment was assumed to be 11.6^{o}C above ambient temperatures with a flow of 125m^3s^{-1} for the operational scenario and 23.2^{o}C above ambient temperatures with a flow of 62.5m^3s^{-1} maintenance scenario (a value of 66m^3s^{-1} was used for chemical discharges as this represented a potential maximum case).

Modelling was undertaken using the validated Sizewell GETM. The modelling assumed that Sizewell B would be operational until at least 2035 and, therefore, this is accounted for (as part of the baseline) in the results of the assessment. Four intake heads and two outfall heads were included in the model as a realistic representation of the final design.

Four scenarios were considered; the first with no power stations present (zero reference) which enables the thermal influence of Sizewell B to be discriminated from the natural background temperatures without the influence of a power station. This scenario was derived from an outage period when Sizewell B was not generating a thermal input. The second scenario with only Sizewell B operating, enables the influence of this input relative to reference conditions, the third with both Sizewell C and B operating simultaneously allows the additional thermal influence of Sizewell C to be determined. The fourth scenario with Sizewell C under maintenance is the worst-case scenario for temperature when 2 out of 4 pumps are under maintenance the flow of cooling water would be halved but the heat content of 2 full power reactors would remain approximately the same raising the excess temperature at the outfall from 11.6°C to 23.2°C. This latter scenario represents a useful worst case in terms of cooling water and provides a useful reference short-term or 24-hour discharge scenario.

The effect of the power stations was evaluated by calculating the difference in temperature between the station(s) operating runs and the run which had no power station discharge. The difference was calculated for each hourly snapshot and the annual mean and the 98th percentile were calculated from the difference. For assessment against absolute thermal standards, it was determined that the GETM overestimates absolute temperatures and, therefore, a more reliable prediction of the 98th percentile is derived by adding the predicted mean temperature uplift due to the plume (i.e. the annual mean excess plume temperature) to the observed 98th percentile seawater background temperature (19.4^{o}C).

The Sizewell C and Sizewell B plumes are separate at high plume temperatures but at lower temperatures the Sizewell C plume increases the size and temperature of the Sizewell B plume at the surface and seabed. Table 5.10.9 provides the assessment for the three scenarios considered.

In combination Sizewell C would increase the area of exceedance of the Good Status threshold from 43.77ha to 87.66ha at the surface and from 8.63ha to 23.81ha at the seabed within the WFD water body. However, when Sizewell C is modelled separately there is no exceedance for the Suffolk Coastal waterbody at either 28 or 23°C 98th percentiles.

In relation to the excess temperatures (**Table 5.10.10**), the area below Good Status increases from 2428ha for Sizewell B alone to 4123ha at the surface and from 2121ha to 3758ha at the seabed with Sizewell C added. For Sizewell C only there is no area of intersection with 98th percentiles for 2 and 3°C uplift.

Table 5.9.9 Areas where the WFD temperature standards are predicted to be exceeded within the Suffolk Coastal water body.

Model run	Position	Unit	98th percentile >23°C (area below 'Good' threshold) hectares	98th percentile >28°C (area below 'Moderate' threshold) hectares
Sizewell B	Surface	ha	43.77	0
		%	0.3	0
	Seabed	ha	8.63	0
		%	0.06	0
Sizewell B + Sizewell C	Surface	ha	87.66	0.11
		%	0.6	<0.01
	Seabed	ha	23.81	0
		%	0.16	0
Sizewell C	Surface	ha	0	0
		%	0	0
	Seabed	ha	0	0
		%	0	0

Table 5.9.10 Areas where the WFD temperature standards are predicted to be exceeded within the Suffolk Coastal water body.

Model run	Position	Unit	Excess temperature >2°C <3°C as a 98th percentile (area at 'Good') hectares	Excess temperature >3°C as a 98th percentile (area at 'Moderate') hectares
Sizewell B	Surface	ha	2428	1260
		%	17	8
	Seabed	ha	2121	665
		%	15	5
Sizewell B + Sizewell C	Surface	ha	4123	1859
		%	28	13
	Seabed	ha	3758	1550
		%	26	11
Sizewell C	Surface	ha	0	0

		%	0	0
	Seabed	ha	0	0
		%	0	0

Thermal Secondary Effects Modelling results for WFD water bodies

Section 5.10.6 considered the effect of thermal elevation upon dissolved oxygen concentration in the cooling water discharge. Elevated temperature discharges will hold less oxygen (at any given pressure) than would be the case at lower temperature (at the same air pressure). The waters off Sizewell are well mixed and retain a high level of oxygenation. Modelling of the oxygen level changes in the thermal discharge from Sizewell B and Sizewell C showed no significant reduction to reduce oxygen levels to below High status across the entire model domain including the intersection with the WFD Suffolk Waterbody.

The influence of the thermal discharge on the proportion of un-ionised ammonia was also assessed as un-ionised ammonia has a low annual average EQS of 21 µg/l. In **Section 5.10.6** the un-ionised ammonia concentration as influenced by the thermal discharge over the model domain was assessed and found to be very low (at least 13 times below the EQS). The thermal discharge from Sizewell C and Sizewell B is therefore unlikely to impact the Suffolk Coastal waterbody through influence of other chemical/physical parameters. Given that the thermal influence on other parameters is very limited with respect to the Suffolk Coastal waterbody the effects on adjoining waterbodies is insignificant.

Hydrazine Effects Modelling results for WFD water bodies

The results of the modelling show that there is no interaction between the hydrazine plume and the Suffolk Coastal waterbody. Effects on adjoining WFD waterbodies would be negligible.

Chlorine total residual oxidants and bromoform plume effects modelling results for WFD water bodies

Chlorination of the power station cooling water system occurs to avoid bio-fouling. The TRO resulting from the combination of chorine and organic material in the water are modelled using an empirical demand/decay formulation derived from experiments with Sizewell seawater and coupled into the GETM Sizewell model [89]. For Sizewell C the TRO concentration at the outfall will depend on the chlorination strategy applied within the power station, however a worst-case TRO concentration of 0.15mg/l at the outfalls has been used for plume modelling purposes [89].

The TRO plume areas at the EQS (10µg/l as a 95% percentile) in the WFD Suffolk waterbody have been calculated and are shown in **Table 5.10.11**. The results only show an interaction with Sizewell B but no interaction between the Sizewell C TRO plume (above the EQS) and the WFD Suffolk waterbody. A similar situation occurs for the bromoform plume for which there is no intersection between the predicted bromoform plume from Sizewell C and the Suffolk coastal waterbody. Adjoining waterbodies are also not predicted to be affected by the TRO or bromform plumes from Sizewell C

Table 5.9.11 Area of interaction of the TRO plume modelled by GETM for areas exceeding the TRO EQS in the WFD Suffolk Waterbody

Model	**TRO =10µg/l as a 95th percentile**	**WFD (Suffolk Coastal Waters 14653.59 ha)**	
		surface	**seabed**
Sizewell B only	ha	386.28	162.95
	% of designated area	2.64%	1.11%

5.9.16 Information to support Habitats Regulations Assessment

Thermal modelling results for SAC/SPA habitats

The shadow habitats regulations assessment is provided in Appendix C and provides details of baseline conditions, specific habitats/receptors and assessment. The following sections provide summary points but reference to the full assessment in Appendix C should be made. There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters [67]. To be protective of the most sensitive species, thermal standards have, therefore, been set on an indicative basis. As such, they act as triggers for further investigation of potential ecological effects. Thermal standards include criteria for absolute temperature and thermal uplifts to determine the potential for acute and chronic effects and behavioural responses. Recommended thermal standards exist for SACs, SPAs and WFD waterbodies (**Table 5.9.12**). The receiving waters adjacent to the proposed development are within the Southern North Sea SAC designated for harbour porpoise. Accordingly, SAC thermal standards are considered in the first instance. SAC thermal recommendations include a maximum allowable 2ºC thermal uplift (100th percentile) above ambient at the edge of the mixing zone. Furthermore, SACs designated for estuarine or embayment habitat and/or cold-water salmonid species, apply absolute temperature thresholds of 21.5ºC as a 98th percentile [67]. The latter of these criteria is not considered applicable to the Southern North Sea SAC designated for harbour porpoise or to the harbour seal (also known as common seal) and grey seal which are also present within the GSB. The Wash and North Norfolk Coast SAC is the closest SAC site designated for harbour seals. The nearest SAC to the proposed development that includes grey seal as a qualifying feature is the Humber Estuary, approximately 220km to the north. The uplift criterion is defined as a Maximum Allowed Concentration. In ecotoxicity studies MACs are normally defined as 95th or 98th percentiles but the SPA uplift threshold is specified as a 100 percentile i.e. a maximum temperature value. This metric is, therefore, very dependent on how the observations or model simulations are done and the time period considered. Using the GETM model the maximum taken from instantaneous temperature fields, saved every hour over a one-year simulation, provides data on the area that exceeds 2°C excess temperature for at least 1 hour per year i.e. for 1h in 8760h per annum. At this temperature threshold, this metric is not considered to have any link to specific ecological effects, and it serves as a precautionary threshold to trigger further ecological investigation.

Table 5.9.12 Area of interaction of the plume modelled by GETM with the designated regions under different scenarios against the Habitats and WFD Directive criteria

Threshold	Criteria	Designated site thermal standard.	Area of exceedance (Sizewell B only).	Area of exceedance (Sizewell B + Sizewell C).	Area of exceedance (Sizewell C only)
2ºC uplift as a 100th percentile.	Thermal uplift.	SAC[10]	Surface 9,370ha.	Surface 22,464ha.	Surface 16,775ha.
			Seabed 5,214ha.	Seabed 16,451ha.	Seabed 12,244ha.
3ºC uplift as a 98th percentile.	Thermal uplift.	WFD	Surface 1,263ha.	Surface 2,200ha.	Surface 305.7ha.
			Seabed 668ha.	Seabed 1,553ha.	Seabed 0ha.
> 28ºC.	Absolute temperature.	SPA	Surface 0ha.	Surface 0.11ha.	Surface 0ha.
			Seabed 0ha.	Seabed 0ha.	Seabed 0ha.

WQTAG (2006) [67] also presents threshold values for maximum acceptable temperature uplift in the SPA, i.e. an increase in temperature above background as opposed to a maximum temperature. This threshold for both SAC and SPA is 2°C. Therefore, the area of plume that exceeded this 2°C threshold, at the surface and bed, was calculated. This area of exceedance is compared to the area of the SPA and the results are also in **Table 5.9.12**.

For Sizewell C only there is no intersection at >2°C as 100th percentile or 28°C as a 98th percentile standards for either the SAC or SPA

Thermal and chemical modelling results for marine mammals

Marine mammals can regulate body temperature during periods of high activity and they are well accustomed to change in water temperature as they dive. Due to the evolved ability of marine mammals to naturally regulate their body temperature, it is concluded that the

[10] It is worth noting that the absolute area of exceedance extends beyond Southern North Sea (SNS) SAC and is considered here. The area relevant to SNS SAC will be addressed within the shadow HRA Appendix C.

change in ambient temperature due to the operational thermal plume would have no direct impact on marine mammal species and no effect on foraging grey seal in the area. However, a precautionary assessment was made (Appendix C **Section 6.4**)

Table 5.5 in **Section 5.3d** of **Appendix C** lists the SACs with marine mammal qualifying features considered in the Appropriate Assessment and further details of the approach are provided. In summary effects were predicted due to the discharge of the thermal and chemical plumes on grey seal, harbour porpoise and harbour seal, and their prey species on the following European sites:

- Humber Estuary SAC;
- Southern North Sea SAC; and
- Wash and North Norfolk Coast SAC.

The assessment of potential effects on marine mammal populations was based on a prediction of the number of individuals present within the ZOI of the Sizewell C Project in the context of the relevant Management Unit (MU) for the population in question (Appendix C **Section 6.4**).

The assessment of the Humber Estuary SAC (for grey seals), the Southern North Sea SAC (for harbour porpoise) and The Wash and North Norfolk Coast SAC (for harbour seals) (based on the proportion of the MU population potentially affected) concludes that there would be no adverse effect on the integrity of the above SACs. The in-combination assessment also concluded that there would be no adverse effect on integrity when the Sizewell C Project is assessed in-combination with other plans and projects.

Thermal and chemical modelling results for fish prey species of birds

Water discharge activities have the potential to affect marine or piscivorous birds, mainly through secondary effects on their prey species, i.e. fish. From the European sites scoped into the screening process, the following qualifying features can be classified as marine birds:

- Little tern *Sternula albifrons*
- Sandwich tern *Thalasseus sandvicensis*
- Common tern *Sterna hirundo*
- Lesser black-backed gull *Larus fuscus*
- Red-throated diver *Gavia stellate*

Table 5.4 in **Section 5.3c** in Appendix C lists the SACs and Ramsar sites, and their qualifying features, for which LSE could not be discounted and, therefore, considered in the Appropriate Assessment for birds: features can be classified as marine birds:

- Alde-Ore Estuary SPA;
- Alde-Ore Estuary Ramsar site;
- Benacre to Easton Bavents SPA;
- Minsmere-Walberswick SPA;
- Minsmere-Walberswick Ramsar site; and
- Outer Thames Estuary SPA.

Details of the assessments are provided in Appendix C, but a summary is provided here. Of the area that is potentially 'lost' to birds foraging in the marine environment the period from April to August during the breeding season is considered as most important. For each of the bird species assessments are made based on absolute areas of exceedance and in addition for thermal elevation in terms of the extent of overlap of the instantaneous plumes (as calculated at hourly intervals from April to August).

The assessment of potential effects on prey species for birds in the marine environment was undertaken based on the exclusion of foraging within the ZOI of the chemical and thermal discharges; this represents a highly precautionary approach. Such effects cover the largest zone of influence in the marine environment during the operational phase and, therefore, consideration of any combined effect with other effect pathways does not change the outcome of the alone assessment.

For the screened-in SPA and Ramsar qualifying features it is concluded that water discharge activities would not have an adverse effect on the integrity of the European sites, either alone or in-combination with other plans and projects.

5.9.17 Fish recovery and return system

During the abstraction process, finfish and shellfish will be drawn into the cooling water systems. These will be removed by drum or band screens and returned to the GSB via a fish recovery and return system (alternative head designs are being evaluated and these would reduce impingement numbers so the present assessment is very conservative). The fish recovery and return wash water would not be chlorinated. Therefore, impinged biota would not be subjected to chlorination.

This section describes the impacts associated with the operation of the unmitigated fish recovery and return. The fish recovery and return system is designed to minimise impacts on impinged fish and invertebrate populations. However, some species such as clupeids are highly sensitive to mechanical damage caused during passage through the cooling water intakes, drum screens and fish recovery and return channels and incur high mortality rates. The return of dead and moribund biota retains biomass within the system but represents a source of organic carbon with the potential to enhance secondary production of carnivorous zooplankton and through the detrital pathways. In addition to organic loading, the potential for increases in nutrients, and reductions in un-ionised ammonia and dissolved oxygen are considered.

Calculation of moribund biomass fish recovery and return and potential nutrient input and influence on un-ionised ammonia and dissolved oxygen levels

The total biomass of moribund biota that potentially may be discharged from the fish recovery and return has been estimated based on the level of abstraction (pump rates) for the planned Sizewell C intakes and the information on seasonal distribution of species and length weight distribution of the species impinged for the existing Sizewell B [70] . The derived Sizewell C data indicate that the highest biomass discharged occurs during the months December to April. An average derived mean daily biomass for the year of 1065.5 kg per day is predicted to be discharged from the fish recovery and returns. Between April to September a period more critical for potential nutrient enrichment the average daily biomass is much lower at 405.2kg per day.

The recycling of nutrients from decaying fish biomass has been more frequently considered for freshwater systems e.g. decay of salmon carcasses in headwater streams. Several studies on salmonids indicate on a wet weight basis a phosphorus content of around 0.5% and nitrogen content of around 3.5% [70] . The April to September period represents a time when sea temperatures and light levels at depth are increasing and phytoplankton growth is also increasing. At this time nutrients start to become less available and become a limiting factor for algal growth.

The potential decaying biomass between April to September has a mean value of 405.2 kg per day during this more critical spring/summer period. Based on the percentage of nitrogen and phosphorus released per unit quantity of tissue with values derived from several studies, a maximum daily loading of ca., 14kg N and ca., 2kg P is indicated. Average daily nitrogen loading from operational inputs at Sizewell C is 32kg which represents 0.2% of the mass of nitrogen (based on background annual mean concentration) present in the daily exchange for Sizewell Bay. The additional inputs of N from decaying biomass represent an increase to a value of 0.3% of the mass present in the daily exchange. The daily average operational phosphorus loading is low at ca., 0.03% of the mass present in the daily exchange for Sizewell Bay and the biomass input from the fish recovery and return represents a relatively high addition to this. Nevertheless, the P value only increases to ca., 0.1% of the equivalent mass present in the daily exchange value for combined operational and fish recovery and return inputs.

Highest biomass discharge is predicted from January to March with lowest values during the spring summer period. However, nutrients derived from biomass during the winter period would not directly contribute to phytoplankton growth due to light limitation and lower temperatures. However, to provide a conservative assessment of potential nutrient inputs, values were derived based on the annual average biomass (1065.5kg). The predicted nitrogen and phosphorus loadings were 37.3kg per day N and 5.3kg per day P. These derived annual values for the fish recovery and return system were combined with the predicted daily inputs during operation and used as source values in the Combined Phytoplankton and Macroalgae Model. A model run over an annual cycle predicts a less than 0.29% difference in annual gross production [109] of carbon and this level of change would not be discriminated above natural background variation. The additional inputs of N and P from decaying biomass represent an increase to a value of 0.4% and 0.3% of the daily exchange, respectively.

This basic assessment is a worst case as it assumes that the fish are not consumed by other species and that the tissue nutrient content makes a direct contribution to nutrient levels when in fact it will take several days for the tissue to decay and to release nutrients. This assessment is conservative assuming rapid release of nutrients from the total biomass, therefore the nitrogen and phosphorus increase and potential contribution to phytoplankton growth is evaluated as negligible. The input loading of phosphorus and nitrogen from biomass discharged from the fish recovery and return system is predicted to have a negligible effect on water quality.

Consideration is also made of the un-ionised ammonia contribution from decaying biomass. Studies on tissue of cod show ammonia contribution of 125mg kg^{-1} NH_4-N [70] . This value is used as a proxy in the un-ionised ammonia calculator (along with relevant site background conditions for pH, temperature and salinity) to indicate the potential un-ionised ammonia contribution from decaying biomass at Sizewell. Based on the daily average biomass of fish discharged during the period April to September (and average pH, salinity and temperature) the estimated Ammonia loading could be at or above the EQS (NH_3-N, 21µgl^{-1}) over an area of 1.2ha around the fish recovery and return system (including natural background and maximum predicted NH_3-N background from Sizewell C operation with thermal elevation, 1.61µgl^{-1}, **Section 5.10.6**). If the calculator input values are adjusted to consider 95th percentile temperature and pH which may occur during the summer period, the area of exceedance increases to 3.8ha. Considering maximum predicted daily biomass from the fish recovery and return system during March (3442kg) adjusted for an average March temperature (6.09°C, Cefas, 2013 and [58]) an area of 6.7ha would exceed the EQS. The input loading of un-ionised ammonia from biomass discharged from the fish recovery and return system is predicted to have a negligible effect on water quality which is not considered significant.

The decaying fish biomass will also contribute to the BOD. An estimate of BOD loading of 3.5g/g dry mass is derived based on BOD loadings from a study of particulate organic matter from fish cages. The source BOD value is used to derive estimates of the BOD contribution from the daily average biomass (Based on annual mean biomass, 1065.5kg). The estimate is 1342.5kg BOD/day for the biomass of fish discharged from the fish recovery and return system.

Any area that exceeds 1.5mgl^{-1} deviation in BOD from background is expected to generate less than 0.5mgl^{-1} impact/reduction on dissolved oxygen. Dividing the BOD loadings by 1.5 and multiplying by 0.5 produces an estimate of the total oxygen reduction potential due to the BOD input of which is 447.5kg/day. Based on a background concentration of 6.96mg/l dissolved oxygen for GSB the calculated O_2 demand requirement (447.5kg) is equivalent to oxygen available in 64,297m^3. This volume represents 0.2% of the mass present daily exchange for GSB (based on annual average background levels) [70].

Reaeration at the sea surface would also replenish oxygen levels. Typical values of oxygen flux are 100mmol m-2d^{-1} [111] or 3.2$gm^{-2}d^{-1}$ therefore reaeration across 14ha would be expected to compensate for the daily oxygen consumption by decaying fish biomass.

During March when the highest daily biomass discharge would be predicted to occur via the fish recovery and return system (3442kg) oxygen demand would increase to 0.6% of that available from daily exchange and would be equivalent to reaeration over 45.2ha.

This assessment assumes direct breakdown of material and no losses through predation. Reduction of oxygen concentration will only occur if the rate of oxygen use due to BOD is greater than the oxygen transfer across the water surface. Therefore as waters off Sizewell are well mixed vertically facilitating reaeration at the surface and the water exchange rate of the GSB is enough to limit the extent and duration of any oxygen reduction, the input loading of BOD from biomass discharged from the fish recovery and return system is predicted to have a negligible effect on water quality. which is not. Average background BOD is 2mgl^{-1} and this is assumed to include the influence from Sizewell B.

Calculation of moribund biomass fish recovery and return system and influence on organic carbon loading

Biota that suffer mortality as a result of the impingement process would be discharged into the receiving waters via the fish recovery and return system. This activity has the potential to affect benthic ecology receptors by increasing the availability of food to scavengers/opportunists.

The total biomass of dead and moribund biota to be discharged from the fish recovery and return system has been estimated based on abstraction rates and information on the seasonal abundance of species along with length-to-weight distributions of the species impinged at the existing Sizewell B station. The data show seasonal variation in discharges. The highest discharge biomass would occur in March, when clupeids are most abundant. During March, a mean daily discharge biomass of 3,442kg is predicted, representing the worst-case scenario. Between April to September, a lower mean daily discharge biomass of 405.2kg is expected [69]. The annual average daily biomass discharge is 1065.5kg. These values are based on rates of impingement at Sizewell B and extrapolated to account for abstraction volumes. They do not account for headwork designs and should be considered as highly precautionary.

Modelling indicates that 88% of dead and moribund biota discharged from the fish recovery and return system would primarily settle onto the seabed in the vicinity of the two fish recovery and return system outfalls. The remaining 12% would mostly be widely distributed by tidal processes, throughout the GSB with a proportion being consumed by seabirds. Discharges are expected throughout the year, in seasonally variable quantities, for the duration of the operation phase.

The are no established regulatory standards for assessing organic loading to benthic systems. In the absence of established standards, pressure benchmarks proposed as a starting point to establish the potential for effects [70]. For organic carbon deposition the appropriate benchmark is defined as 100g organic carbon/m^2/year.

The area in the vicinity of the two fish recovery and return system outfalls predicted to be impacted by organic carbon above benchmark levels was estimated based on the estimated discharge rate and carbon content of fish. The carbon content of fish biomass was derived based on carbon composition of fish processing waste being 64.7% of the dry weight and a wet weight to dry weight conversion factor of 0.48 [70]. Equivalent areas above the benchmark are then estimated.

An annual average area of approximately 40.7ha may be exposed to organic carbon loading above benchmark values. The area effected reduces to approximately 15.5ha from April to September. Peak biomass events, occurring in March, would result in an equivalent area of 131.5ha above the benchmark. It should be noted that the assessments of the spatial area effected is considered precautionary based on the following conservative assumptions:

- Modelling of the distribution of dead and moribund fish assumes that 88% of fish would sink immediately, remaining in-situ. Tidal and wave driven processes in the shallow subtidal environment near the fish recovery and return system headworks would prompt resuspension and thereby wider distribution of the biomass (diluting the impact).
- The assessment of impacts assumes all biomass is directly converted to organic carbon deposits. Piscivorous birds, fish and benthic invertebrates would consume a considerable proportion of the biomass.
- The assessments consider discharges of dead and moribund biota form a single point source. This adds a further precautionary factor to the assessment as the two fish recovery and return system units, located approximately 300m apart, would allow a greater level of initial dilution with discharges split between two spatially separated point sources.
- The impact on benthic species is expected to be limited as in general there is a low sensitivity to the pressure of organic loading and so minor effects are predicted.

Modelling the distribution of dead fish released from the fish recovery and return system using particle tracking

The Sizewell C fish recovery and return system is designed to return as many impinged fish as possible safely to sea. The system is expected to work well for robust species such as eel, lamprey, flatfish and crustacea with survival rates greater than 80%. However, the system is not effective for more delicate pelagic species such as sprat and herring where the expected survival rate for impinged fish is zero. Some dead fish will, therefore, be discharged from the fish recovery and return system outfall throughout the year and there is a concern that if these fish come ashore in large numbers they could represent a nuisance on public beaches. To assess the potential for such an impact, a worst-case modelling study has been undertaken.

The particle tracking study was conducted using the validated Sizewell 3D curvilinear GETM model that was used for thermal plume and chemical discharge studies as described [77] and [85] .

The most numerically dominant species, sprat is present in the largest numbers during January so this month was selected for modelling to provide a conservative assessment. Sprat are expected to have 100% mortality within the fish recovery and return system. Discharged dead fish will be passively transported from the fish recovery and return system outfall and due to the tidal currents at Sizewell, there is a potential for some fish to wash up on surrounding beaches and become a visual nuisance. In practice the discharged dead fish will have a more varied fate. Some will sink to the seabed before reaching land and be consumed by benthic organisms, some will be consumed by foraging piscivorous birds (either whilst the fish are floating and once any fish beach).

It was assumed that all of the sprat discharged from the fish recovery and return system outfall were dead and their fate was modelled via particle tracking over a spring neap cycle using 31 days of January 2009 (the year selected as the representative year for modelling in Sizewell C studies) with a time interval of 1 hour. The buoyancy (sinking behaviour) of impinged sprat was assessed during field studies and the data derived was used to refine the model. Assessment was made of in combination releases from both Sizewell B and the Sizewell C fish recovery and return system. There were three processes modelled in which a particle is removed from the system: beaching, sinking and predation by seabirds. Predation of fish on the seabed by benthic species is not included in the model.

For Sizewell B only the results show that over the spring-neap cycle, the particles follow a trajectory parallel to the coastline, moving north-south, with sprat beaching up to 1km north of Aldeburgh to Southwold. There is limited movement of particles to the east (approximately 1.75 km east of release), with the particles remaining inside of the Sizewell-Dunwich bank. The total extent of the beached particles was 18.4 km, with particles beaching 5.9 km south of the Sizewell B outfall and 12.5 km north. Over a 30-day period only 0.3% of fish are predicted to beach the majority sinking immediately with the remainder sinking within 24 hours, and others being predated at sea or following beaching.

Beaching occurred predominantly during the night as during daylight hours the modelled fish were consumed within 3.75 hours of daybreak. The maximum instantaneous number of particles on the beach over the 30-day simulation was 1,341, at daybreak on 12th January, however, within 10 hours of daybreak, all those beached particles had been eaten by birds. The 1,341 particles covered a maximum total length of 10.6 km, with an average linear distribution of one sprat every 7.9 m. The average daily rate of beaching was 209.23 sprat per 24 hours. The mean instantaneous number of beached particles over the 30-day simulation during daylight hours was 26.38 fish.

For Sizewell B and C in combination particles in the model follow the same trajectory to that for Sizewell B alone. The in combination modelling was precautionary in that it assumed identical impingement patterns at both stations (correlation factor of 1) whereas in practice due to the spatial separation of the Sizewell B and Sizewell C intakes and the patchy spatial distribution of sprat shoals, the impingement would not be correlated. A peak in sprat impingement at Sizewell B would not correspond to a peak at Sizewell C and therefore the predicted peak impingement rates are considered to have been over estimated. The percentage of fish predicted to be beached after 30 days of Sizewell B and C was also similar to that for Sizewell B alone although now based on higher starting numbers. As before beaching occurred predominantly at night with particles eaten within approximately 4.3 hours of daybreak. The maximum instantaneous number of particles on the beach over the 30-day simulation was 4,786, at daybreak on 12th January. However, unlike the Sizewell B only simulation some particles remained uneaten after 24 hours on the first day. It takes 4.3 days from the time of the largest beaching event for the number of particles to all be eaten by birds, including new particles over those 4.3 days. The 4,786 particles covered a maximum total length of 12.0km, with an average linear distribution of one sprat every 2.5m. The average daily rate of beaching was 678.53 sprat per 24 hours. The mean instantaneous number of beached particles over the 30-day simulation during daylight hours was 79.95 fish.

5.9.18 Future trends in water quality

For the assessment a start date for constructing the proposed development of 2022 is assumed. The construction phase is anticipated to last for an indicative period of 9 to 12 years before the station becomes fully operational. The current baseline is considered appropriate for the duration of the construction and commissioning phases. The effects of operational impacts on water quality and sediment are considered against well-established current baselines. The extended life-cycle of the proposed development (60-years) means that some impacts must be considered in relation to potential shifts in future baselines due to climate change.

The water quality and sediment future baseline in this section is primarily taken from the MCCIP [75], the most comprehensive and up to date reviews of climate change impacts on the UK marine environment. The following summarises the MCCIP [75] findings of relevance to water quality and sediment.

Sea temperature rises

The southern North Sea is shallower with a faster warming rate than other areas of the UK. Climate predictions assume a linear increase in temperature which will be subject to increased uncertainty further into the future.

Thermal discharges and entrainment predictions are assessed against a baseline of elevated ambient temperature. However, Sizewell B is expected to operate until 2035, with the potential for an extension of its lifetime of 20 years to 2055. Thus, reducing the thermal footprint within the GSB.

Ocean acidification

Towards the end of the 21st century, ocean acidification may become an environmental concern around the UK for marine ecology. Decreasing pH will influence chemical speciation and e.g. partitioning of ionised and un-ionised ammonia favouring the less toxic ionised form.

Thermal impacts of Climate Change

Climate change is expected to lead, over time, to increases in water temperature in the receiving waters, which may lead to exceedance of the EQS for absolute temperature. This will increase the maximum temperatures to which biological receptors are exposed as a result of the proposed cooling water discharge and will affect other parameters, such as oxygen solubility and ionisation of ammonia. In Appendix F of [89] an assessment is made of the influence of climate change on future thermal parameters in relation to the operation of Sizewell C and Sizewell B. Future temperature estimates are used to consider the following parameters:

- Intake temperatures at Sizewell B and Sizewell C for the full operational life-cycle of the power stations accounting for recirculation and climate change;
- Entrainment temperatures at Sizewell B and Sizewell C accounting for recirculation and climate change;
- Implications of climate on chlorination strategy;
- The influence of future climate change on (contemporary) thermal standards.

To account for the effects of the power stations operating on intake temperatures, recirculation of thermal discharges at the point of the Sizewell B and Sizewell C intakes was incorporated into the predictions based on outputs from GETM thermal plume modelling [85].

To incorporate a range of future intake temperatures the following scenarios were investigated:

- 2030: The decade during which the Proposed Development is expected to be operational, with operation likely to be from 2034. The scenario includes both stations running simultaneously.
- 2055: The hypothetical last likely date for Sizewell B to be operational. The scenario includes both stations running simultaneously and Sizewell C running in isolation.
- 2085: Towards the end of the operational life of Sizewell C.
- 2110: A hypothetical extreme date for Sizewell C to remain operational prior to decommissioning.

By assuming the last likely date of station operation, these scenarios are precautionary in terms of the effects of long-term climate change. However, it should be noted that extreme scenarios are subject to increased uncertainty.

Intake temperatures peak in August at 20.4ºCat Sizewell B in 2030 with slightly lower temperature of 19.4ºC predicted at the more offshore Sizewell C intakes. By 2055, the last likely operational date for Sizewell B, mean August temperatures are predicted to be 21.9ºCat Sizewell B and 20.2ºC at Sizewell C. By the year 2110, August temperatures at Sizewell C are predicted to be 21.7ºC, corresponding to a 2.3ºC increase from 2030.

To account for the worst-case temperature predictions for each month, the maximum of daily temperatures for a given month was applied to the data. Scenarios were developed using UKCP09 predictions as future sea temperatures are not included in the current UKCP18 marine climate change predictions. Maximum intake temperatures at the inshore Sizewell B site are predicted to occur in July and peak at 24.7ºC in 2030 and 25.5 ºC in 2055. At the offshore Sizewell C intakes maximum temperatures are predicted later in the year in September peaking at 23.4 ºC in 2030 and 26.2 ºC by 2110

Experimental work indicates that mortality due to temperature shock for the egg and larval life stages of many fish and zooplankton species increases rapidly once maximum temperatures exceed 30°C. Mean daily entrainment temperatures are predicted to exceed 30ºC for 57 days in July-September by 2030, temperatures peak in early August reaching 31.3 ºC. By 2055, entrainment temperatures exceed 30 ºC for 100 days in much of July, August and September and continue into October. Entrainment temperatures exceed 33 ºC for 13 days in August and September. Following the end of the operational life of Sizewell B (after 2055 at the latest), entrainment temperatures exceeding 30 ºC occur for fewer days; 92 in 2085 and maximum temperatures remain below 33 ºC. By, 2110 the extreme of the operational life-cycle of Sizewell C, entrainment temperatures are predicted to exceed 30 ºC for 105 days per annum between the beginning of July and mid-October.

Whilst it is likely that high mortality rates will be observed for longer periods of time during the summer months with future climate change, thermal lethality is species specific and adaptation to future climate conditions and potential species distribution shifts may influence the ability to tolerate thermal stress and determine survival following entrainment.

The spread of invasive non-native species (INNS) with preferences for warmer water may also be encouraged where introduction has already occurred. Only one INNS was recorded during the Sizewell C benthic baseline surveys, the American jacknife *Ensis leei* which was found in a single grab sample. In the North Sea, 274 INNS and cryptogenic (of uncertain origin) have been recorded. The main vector for primary introduction is vessels (ballast of hull fouling). This burrowing species is thought to have been introduced to Europe at a similar latitude (German Bight) to the GSB, within the cooler part of its thermal niche. The distribution of *E. leei* in the North Sea (and the north-west Europe) is predicted to expand this century due to an increase in sea temperature. Therefore, it is possible that the cooling water discharge would hasten its climate change-induced geographic spread. It should be noted, however, that this species has been recorded in the UK at sites north of the GSB, therefore this species has already reached areas to which the GSB could act as a steppingstone. As a result, the effect of the thermal plume on this species is unlikely to significantly affect its spread over and above that anticipated to be due to climate change

The seasonal chlorination strategy for the proposed development involves chlorination during the period of the year when water temperatures exceed 10ºC. At the start of the decade when operation of the proposed development is predicted (2030), predicted water temperatures at the Sizewell C intakes would exceed 10ºC for 219 days per annum from the beginning of May until the start of December. By the year 2085, climate change is predicted to result in temperatures exceeding 10ºC from late April until late December for a total of 244 days per annum. However, in the coastal waters at Sizewell, high levels of turbidity in the winter and early spring limit biological production and increases in the duration of annual chlorination is likely to be in the order of weeks at most.

Thermal standards for TraC waterbodies are detailed in **Section 5.10.5.** Thermal standards relate to maximum absolute temperature thresholds and thermal uplifts above ambient. Determining the influence of future climate change on contemporary regulatory standards is flawed as baseline conditions are inherently predicted to change and standards would be expected to respond to such changes in the baseline.

Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature [85]. Therefore, thermal uplift areas predicted for in **Section 5.10.5** would remain largely unchanged under future climate scenarios.

To calculate future absolute exceedances for relevant standards the influence of climate change is added to the thermal uplifts to ascertain absolute temperatures in the future. The results indicate that future climate change is not predicted to significantly increase the absolute areas in exceedance of 28°C, which remain under 1 ha for all scenarios tested.

Following the decommissioning of Sizewell B, 28°C as an absolute temperature is not predicted to be exceeded as a 98th percentile even under the extreme climate case of operations in 2110. During the operation of both stations, absolute temperatures of 23°C increase from 198.2ha at the surface in 2030 to 506.2ha at the surface in 2055. At the seabed absolute temperatures of 23°C are 92.3ha and 264.4ha in 2030 and 2055, respectively.

In the likely event Sizewell B is decommissioned prior to 2055, leaving Sizewell C operating alone, the exceedance of the absolute 23°C threshold is predicted to be just 5.38ha at the surface and 0ha at the seabed.

In the likely event Sizewell B is decommissioned prior to 2055, leaving Sizewell C operating alone, the exceedance of the absolute 23°C threshold is predicted to be just 5.38ha at the surface and 0 ha at the seabed. Warming effects mean that by the extreme operational scenario of 2110 large areas are predicted to exceed 23°C as a 98th percentile (7,080 ha at the surface, and 6,540 ha at the seabed). However, in 2085, towards the end of the likely operational life-cycle, seabed areas in exceedance of 23°C are predicted to occur over just 0.22 ha, whereas surface exceedance occurs over an area of 69.1 ha. The total area of the thermal plume above 23°C in 2085 is therefore smaller and further offshore than the contemporary predictions for the two power stations. Furthermore, the offshore location of the outfalls would mean no intersection of the Sizewell C plume with the WFD water body (extending to 1nm) under the current standards.

Thermal elevation influence on chlorination

Although the rate of TRO decay would increase at elevated temperatures, dosing would be adjusted to ensure that the target TRO of 0.2mg l^{-1} is achieved in critical sections of the CW plant. The relative temperature increase under future climate change would not necessitate significantly higher chlorination to achieve target TRO values therefore the associated chlorination by-product concentration would not be significantly elevated relative to the present conditions. The relative increase in temperature background in the wider environment is also unlikely to significantly increase TRO decay upon discharge and consequently a conservative assessment is that the discharge plume size and magnitude are likely to be comparable to those predicted under the current baseline.

Reduced pH levels influence on chlorination

Several Oceanic Global Circulation Models (OGCMs) have projected a pH reduction of 0.3 -0.4 units by the end of the century [89]. Assuming atmospheric CO_2 increases by 500ppm by 2050 a decrease of ca., 0.1 pH unit is predicted over most of the North Sea area. Other projections suggest a reduction 0.14 units below present values by 2050 and 0.3–0.4 below present units in 2100.

The ratio of oxidant chemicals formed upon chlorination of seawater is influenced by pH: the percentage of hypochlorous acid is likely to increase relative to hypobromous acid following a pH reduction from a present baseline mean of 8.0 to around 7.8 to 7.6 for future projected baselines at 2055 to 2085. Although there may be some differences in the toxicity of the different oxidants this difference in relative proportions is unlikely to be significant for the present impact assessment.

The formation and types of other chlorination byproducts that occur during seawater chlorination is also influenced by aspects of seawater quality including pH. The most abundant CBP in discharges from coastal power stations, and the only one detected in recent CBP decay studies using Sizewell seawater is bromoform [89].

For bromoform, the dominant CBP at Sizewell, the primary fate process is volatilisation with biodegradation having relatively little influence on reducing environmental concentrations. Increased temperatures are therefore expected to have minimal influence on bromoform decay and consequently the discharge plume magnitude and extent are conservatively assessed to be like those predicted for the current baseline.

Bromoform is likely to occur at similar concentrations or possibly slightly reduce following a pH reduction from a present baseline mean of 8.0 to around 7.8 to 7.6 for future baselines at 2055 to 2085. For other CBPs there may be a small relative increase with lowering pH. The difference in terms of the extent and magnitude of any effects is likely to be negligible

Climate change influences on other operational discharges

For hydrazine, the primary fate processes in water are oxygen dependent chemical breakdown and biological breakdown.

The former is dependent on the presence in water of appropriate catalysts and other factors such as ionic strength, temperature and pH. Biodegradation is also influenced by temperature. Hydrazine half-life (time for concentration to reduce by 50% of its starting concentration) in natural seawater from Sizewell is very short ca. 38 minutes therefore increasing seawater temperatures is likely to reduce the discharge plume magnitude and extent, but a conservative assessment is that they remain comparable to those predicted for the current baseline. Reducing pH is also likely to reduce the degradation time for hydrazine but the degree of this change is expected to be small under future ocean acidification predictions. Hydrazine decay rate is only shown to significantly increase at values below pH 4 and future climate baseline predictions for regions such as the North Sea are ca., 7.8 - 7.6.

The thermal influence of the plume upon the proportion of un-ionised ammonia is considered in sections 5.9.5 to 5.9.7 but under future climate change the background temperatures would be elevated. However, 24-hour cooling water discharge assessments already take account of thermal extremes that occur within the cooling water system and even under these extreme elevated temperatures the proportion of un-ionised ammonia when accounting for background, increases within the cooling water system to ca., one third of the EQS. In the wider discharge plume temperature uplift would be more modest and even during peak predicted future summer temperatures based on the maximum ammonium input via the cooling water system the un-ionised ammonia would be low and equivalent to ca., 11% of the EQS [89].

5.9.19 European eel assessment

An Eels Regulations Compliance Assessment [112] was carried out to support the WDA environmental permit for Sizewell C. The elements that could affect Eels are impingement & entrainment, structures that affect the passage of eels and the quality of the water discharge. As discussed in **Section 5.4.1**, the WDA environmental permit will only cover discharges from the Outfalls and the fish recovery and return system . The design aspects of the Intakes and fish recovery and return system including abstraction and impingement are discussed within the DCO Application.

European eel has been recorded in low numbers in the surveys carried out in the GSB and along the Suffolk Coast [112]. Glass eels generally arrive in the North Sea in January to February and would transit past Sizewell C on their passage to river estuaries from February to April and it is reasonable to assume that adult silver eels would transit past Sizewell C on their return migration to the Sargasso Sea from November to February [112].

As discussed in the Eels Regulations Compliance Assessment [112] , migratory species such as eels can be sensitive to power station discharges if avoidance of the discharge plume impacts on their migratory pathways. The modelling of temperature and thermal uplift concluded that the Sizewell C thermal plumes are not predicted to present a barrier to the migration of eels.

The chemical plumes from Sizewell C may alter water quality properties and cause fish species to avoid an area due to the potential for a reduction in water quality. Modelling of the chemical discharge from the Outfalls was undertaken and the assessment concluded that the impact from the chemical discharges would not impact the passage of eels or eel populations given that the headworks are located 3km offshore in deep water which will allow for initial mixing and minimise intersection with the Suffolk Coast coastline [112]. The operational discharge of polluting matter from the fish recovery and return system concluded that the effects are very small scale and localised to the fish recovery and return system outfall location.

The cooling water system will be designed to increase the momentum of discharge and promote the mixing and dispersal of heated water and chemicals (thus reducing the area of impact). Discharges will be managed effectively and minimised where possible. Additional pollution control measures will be in place to safeguard the water quality including physical controls such as secondary containment and segregation, treatment and monitoring.

Therefore, it can be concluded that the water discharge activities from the operation of Sizewell C will comply with the Eels (England & Wales) Regulations 2009 [11] and the Anglian RBD Eel Management Plan [74].

6 Managing the Water Discharge Activity

6.1 Management systems

6.1.1 Approach

As discussed in Section 2.1.1 the approach for the design of the plant is based on the strategy for replication of HPC. This is aligned to the overall project strategy; to maximise the opportunity to derive value from a 'Next of a Kind' effect, duplicating the HPC detailed design and adopting a systematic approach to capturing, quantifying and applying lessons learned to SZC Co. The replication strategy also extends to the adoption of management arrangements from the HPC project.

The Sizewell C Management Systems Manual [113] explains how the management processes for SZC Co. are to be implemented. It describes the IMS which is the tool used to ensure SZC Co. can act as an Intelligent Customer to design, procure, construct, commission, operate and eventually decommission the Sizewell C nuclear power plant. This will be executed safely and reliably to quality, time and cost in accordance with the Company Manual and the Nuclear Baseline statement [2] and the company Quality Policy [114].

In order for SZC Co. to demonstrate that it is a competent licensee, staff within the Sizewell C team will be nominated as counterparts, and provide Intelligent Customer 'ownership' of the process on behalf of the Sizewell C team and be a 'shadow' of the author and owner within the Hinkley Point C team. No divergence of process will normally be allowed.

The IMS will cover all on-site activities to ensure a holistic and consistent approach is taken; the IMS will also cover off-site activities where applicable (e.g. design, supply chain management etc.).

SZC Co. recognises that the development of effective management arrangements, integrated in the company management systems, are key to ensuring a high standard of environmental performance and ensuring regulatory compliance. In order to reflect the complexity of regulating sites with environmental permits, the Environment Agency has produced specific guidance on developing a management system [40]. The guidance recommends that management systems are based on a recognised standard such as ISO 14001:2015 [115], or BS 8555 [116] and independently checked by an accredited body such as UKAS.

SZC Co. will make every effort to ensure that the strategy for management systems fulfils the requirements laid down in these documents and guidance. Appropriate systems will be put in place for the construction, commissioning, operation and decommissioning phases, recognising the differences in systems necessary to manage environmental performance. A phased implementation of the systems will account for the development and maturity of the organisation and allow for the arrangements to remain proportional to the risk profile of the site. The process will include a period of testing and ensure users are appropriately trained.

The approach to the development of suitable management arrangements will be supported by the company's drive towards certification to a UKAS accredited environmental standard, once the management systems are mature.

Due to the long construction time associated with the building of the plant, it is feasible that certification may be obtained before the plant becomes operational. The systems implemented will be project wide and will include operations at Sizewell C during the construction, commissioning, operations and decommissioning phases, recognising proportionality of arrangements for future phases. The environmental aspects will be part of a full IMS covering environment, health, safety and security arrangements.

The management systems and management arrangements will be developed in a phased manner according to the life cycle milestones of the project development (refer to **Section 7.3.2**, Action 2: Development of the integrated management system). Specific management controls including procedures and instructions associated with managing the permitted water discharge will be developed at the relevant project phase. All parties undertaking activities on behalf of the site licensee will be already qualified with recognised qualifications, before they undertake any activities. Management arrangements and capabilities will be defined and implemented at the most appropriate time in the project's development so that they are fit for purpose and SZC Co. is fully capable of complying with the relevant permit conditions at the appropriate time.

SZC Co. will adopt the EDF Energy Environmental Policy, as signed by the Chief Executive Officer, and all those working on behalf of the company will be required to comply with the environmental policy.

Arrangements will be in place for the identification and evaluation of the environmental aspects and impacts of SZC Co.'s project as well as compliance with legal and other requirements.

Objectives and targets will be set to ensure regulatory compliance and continual improvement in environmental performance. Sizewell C's procedures will be developed and will include details for the applicable responsible personnel on site, and their roles and responsibilities. This will take into full consideration all of the regulatory and other requirements applicable to the business activities, which will be controlled through the company formal management of change arrangements and will be undertaken in consultation with the Environment Agency. All personnel on site will be competent for the activities, which they carry out. Records will be kept including security arrangements and management control of documentation will be developed.

Changes made to the Sizewell C design configuration (RC0) will be managed through the SZC Co. 'No Change Committee' (refer to **Section 7** – FAP Ref. 2). This will protect the replication benefits between the Sizewell C and Hinkley Point C projects whilst maximizing the scope of common documentation and data and minimising the risk or rework and schedule over run. The 'No Change Committee' will screen and assess the significance of any design changes including site specific adaptation, procurement change, construction change and regulatory change on the Sizewell C project to ensure that the design and activities are consistent with the environmental permits and the incorporation of BAT formally into the design process. Arrangements will be developed for the identification of changes to legal requirements in a timely manner to enable SZC Co. to plan for any changes to compliance arrangements required.

SZC Co. will ensure that there are effective communications internally and externally to ensure compliance with permit conditions.

As part of the development of suitable integrated management arrangements a set of strategies and actions has been produced by SZC Co. which includes requirements for water discharges. The actions will include:

- A review of relevant technical guidance notes provided by the Environment Agency, such as those in draft/consultation form at the time of writing;
- A review of existing EDF Energy documentation to understand the procedures and processes currently used at the existing sites;
- A specific review of NNB GenCo (Hinkley Point C) Ltd documentation and the procedures and processes being developed and implemented;
- Consultation with the key stakeholders within EDF Energy to gain an appreciation of their expectations for an integrated management system and ensure early engagement;
- Consultation with key stakeholders regarding the key organisational roles and responsibilities required to ensure compliance and ensure consistency with the organisation baseline;
- A review of the applicable EDF Energy and SZC Co. documentation, to identify procedures already developed that can be used to support the development of the integrated management system;
- Communication with all the parties involved in the development of the integrated management system; and
- A final review of the legislation and guidance to ensure compliance with the applicable regulations.

In addition, the lessons learnt from other EDF nuclear power stations and from bringing the first unit into operation will be recorded and used when undertaking activities for the second unit (refer to **Section 7.3.2**, Action 2: Development of the integrated management system).

At this stage in the development of the IMS, the operational organisational structure has not been defined. The management arrangements and structure of the company will be reviewed and revised at key points later in the project lifecycle to ensure SZC Co. have sufficient control of the water discharge activities.

6.1.2 Management system requirements

The Environment Agency develop a management system: environmental permits guidance note [40] requires consideration of the proposed management systems for the following aspects:

- Site operations.
- Site and equipment maintenance.
- Contingency plans.
- Accident prevention and management plan.
- A changing climate.
- Complaints procedure.
- Competence and training.
- Keeping records.
- Management system review.
- Site closure.

6.1.3 Site operations

An IMS, which includes arrangements for compliance with environmental permits and legislation, will be produced which will cover all on-site activities and relevant off-site activities. This will include the environmental policy, management arrangements, technical specifications as well as working instructions. The technical specifications will include operating parameters to ensure that plant or processes are kept in a safe condition with optimal environmental performance and that waste and emissions are minimised through the application of BAT. These arrangements will also ensure that the plant is operated in accordance with the manufacturers operating manual.

To ensure that the arrangements are appropriate to the nature and scale of the activities being undertaken, as well as the regulatory requirements, they will be formally documented and advised by a controlled environmental aspects assessment process. The basis of this process is likely to build on the present arrangements that are in place at the UK EDF Energy sites, the arrangements will be amended to ensure that they take full account of SZC Co. and the information and data that have been produced during impact assessments undertaken for the regulatory application processes.

For the development of the arrangements, consideration is being given to the approach that was taken for the Sizewell B PWR and to approaches being taken at other EPR™ units under construction, such as Hinkley Point C, which includes utilisation of the MERITS methodology (Methodically Engineered Restructured and Improved Technical Specifications). From an environmental perspective, all guidance available to date and made available before the finalisation of the arrangements will be consulted and will underpin the development of management arrangements.

For the purposes of commissioning there are specific requirements under the NSL to ensure that the licensee has adequate arrangements to control all the testing, inactive and active commissioning of plant and systems that may affect safety on the nuclear licenced site. These will be developed to ensure appropriate environmental controls are in place as required under other permits and authorisations. The SZC Co. key stakeholders that will be consulted as appropriate during the production of all documentation and other supporting arrangements will include the Head of Environment. The commissioning documentation will ensure that environmental impacts are fully documented, taken into account and that there are appropriate arrangements, including suitably qualified personnel in place to ensure safe operation and appropriate environmental performance.

6.1.4 Site and equipment maintenance

Maintenance systems will be developed as part of appropriate operational management arrangements. A bespoke maintenance management platform will be used to manage maintenance and will be integrated into the SZC Co. management systems. The experiences of the EDF Energy Existing Nuclear sites will be important in developing suitable management arrangements for maintenance. Expertise of the parent company and plant vendors will also be key to developing appropriate maintenance management arrangements. Maintenance records will be held including testing, calibration, and planned preventative maintenance records (this is discussed further in **Section 6.1.10**).

Environmentally significant equipment will be identified and is recorded within the Environmental Protection Function Register. This will implement a three tiered system, where equipment is designated as Key Environment Protection Equipment, Environment Protection Equipment or No Environmental Protection Function. The maintenance schedule will take into consideration the designation of equipment within the register and apply more or less stringent requirements as appropriate.

Management arrangements will be developed to ensure that safety and environmental performance will be maintained during shutdown for maintenance or any other reason. The key aims of these maintenance management arrangements are as follows:

- To ensure that all maintenance schedule activities that require unavailability of any plant or process to allow any examination, maintenance, inspection or testing to be performed are identified, planned, actioned, reviewed and recorded; and
- To ensure that procedures are in place to enable the safe shutdown, and subsequent safe re-start, of any plant or process to allow any examination, maintenance, inspection or testing to be performed.

6.1.5 Contingency plans

SZC Co. will minimise the impact on the environment of any breakdowns, enforced shutdowns and any other changes in normal operation, for example due to flooding or other extreme weather. These requirements are both embedded in the design as a principle and contained within the arrangements established at a local level (e.g. Risk Assessment Methodology Statements, maintenance schedules and re-fuelling procedures).

A Flood Risk Assessment scoping exercise has been undertaken and the Flood Risk Assessment is to be completed to confirm any adverse flood risk impact of Sizewell C development at the time of submission of the Sizewell C DCO application.

6.1.6 Incident prevention and management plan

Accident and incident management plan

As part of the FAP (see **Section 7.3.3**, Action 3: Development of the operational management plans), an Accident and Incident Management Plan will be developed (this is discussed further in **Section 6.2**).

A quantitative environmental risk assessment will be developed as part of the FAP and will provide details of the types of measures that may be implemented at the site to control and mitigate such events to achieve BAT (this is discussed in **Section 6.2**).

In addition to this, SZC Co. will generate a Major Accident Prevention Policy (MAPP) which will ensure that all measures necessary are implemented to prevent major accidents at Sizewell C and limit any consequences to persons and the environment (this is discussed further in **Section 6.2**).

Incidents and non-conformances

Licence Condition 11 of the NSL, when granted, will require SZC Co. to have adequate arrangements in place for managing incidents and emergencies. This includes consideration of incidents that could lead to an environmental impact.

A full set of management arrangements for the management of incidents and non-conformances will be in place at the latest 9 months prior to the commencement of the phase (i.e. construction, commissioning, operation and decommissioning). Management arrangements for incidents and non-conformances are to ensure adequate response and reporting at this stage in the project. These arrangements are as follows:

- Procedure to prevent and react to incidents and non-conformances.
- Procedure for notification, recording, investigation and reporting of incidents.
- Identification of incidents that are to be reported to the regulator.
- Roles and responsibilities of those involved.

- Learning and improvements.
- Mitigation measures.
- Training.
- Reporting to management.

This system will be developed in line with the key stages of the development of the nuclear power station. This means that suitable systems will be in place prior to the construction phase as well as prior to the commissioning phases. At the construction stage, detailed coverage for direct 'nuclear' incidents is not required; however, robust emergency arrangements will be put in place to prevent and react to any conventional industrial incidents, such as security, fire or medical, as well as specific plans to react to an Off-Site Nuclear Emergency from Sizewell B. This will involve the creation of an evolving emergency response structure supported by an on-site command and control function to co-ordinate any required response and follow-on actions. Additional support will be provided by an off-site Incident Management Team made up of appropriate specialists who will be available to support the site's long-term recovery efforts.

In terms of operations, a system will be developed for notification, recording, investigation and reporting of incidents. This will include initial registration of incidents, their classification and investigation (with associated actions).

As with most of the management arrangements that will be in place at Sizewell C it is intended to follow ONR and Environment Agency guidance and the practical experience of other licensees. There will be a single system for incidents and for unexpected or unusual occurrences.

The arrangements involving response to incidents will be part of a comprehensive system of management arrangements that includes:

- Document control.
- Communications with the Regulatory Authorities.
- Examination, Maintenance, Inspection and Testing (i.e. in the case of deficiency).
- Leakage and Escape of Waste (i.e. in the case of loss of containment).
- System for capturing and disseminating operating experience.
- Documents, Records, Authorities and Certificates.
- Organisational Learning.
- Quality Assurance.

6.1.7 A changing climate

During the GDA process, SZC Co. undertook due consideration of how operations could be affected by a changing climate and thus mitigations were included within the UK EPR™ design to accommodate such changes. This included conditions such as rainfall, snow, wind, low and high ambient temperatures, frazil ice and freeze up, flooding, drought and rising sea levels.

Sizewell C site data for external hazards that could affect Nuclear Safety is being reviewed further to support the Sizewell C NSL application. This includes an assessment of the climate change projections aligned with UK Climate Projections 2018 (UKCP18). This data will be collected, consolidated and summarised within a Site Data Summary Report specific to Sizewell C site. Ultimately, this work will review and assess the adequacy of the Hinkley Point C RC2 design against the Sizewell C site requirements and will make up part of the Sizewell C Pre-Construction Safety Report justification.

Given that Sizewell C is anticipated to be operated for approximately 60 years it is considered likely to be risk from the impacts of climate change. A climate change risk assessment is provided below aligned with the Environment Agency guidance 'Adapting to Climate Change: Risk Assessment for your Environmental Permit [42].

Table 6.1.1 Ranking matrix for risk assessment

Potential changing climate variable	A - Impact	B - Likelihood	C - Severity	D - Risk (B x C)	E - Mitigation (what will you do to mitigate this risk)	F - Likelihood (after mitigation)	G - Severity (after mitigation)	H - Residual risk (F x G)
1. Summer daily maximum temperature may be around 7°C higher compared to average summer temperatures now.	Failure of ventilation system	3	3	9	Consider additional cooling systems and building insulation at design stage.	3	1	3
2. Winter daily maximum temperature could be 4°C more than the current average.	No negative impact expected.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3. The biggest rainfall events are up to 20% more intense than current extremes (peak rainfall intensity).	Surface water drainage system overloaded.	3	2	6	Consider surface falls at design stage.	2	2	4

Potential changing climate variable	A - Impact	B - Likelihood	C - Severity	D - Risk (B x C)	E - Mitigation (what will you do to mitigate this risk)	F - Likelihood (after mitigation)	G - Severity (after mitigation)	H - Residual risk (F x G)
4. Average winter rainfall may increase by 35% on today's averages.	Surface water drainage system overloaded.	3	2	6	Increase surface water storage capacity and consider surface falls at design stage.	2	2	4
5. Sea level could be as much as 0.6m higher compared to today's level.	Flooding of site	4	3	12	Flood Risk Assessment and plan for sea defence as appropriate	3	2	6
6. Drier summers, potentially up to 39% less rain than now.	No negative impact expected.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7. At its peak, the flow in watercourses could be 35% more than now, and at its lowest it could be 80% less than now.	No negative impact expected.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8. Increase in temperature in receiving water	Increased temperature exposure to organisms from cooling water	4	2	8	Future Thermal Parameters Assessment	4	1	4

6.1.8 Complaints procedure

SZC Co. will develop a procedure to manage enquiries and complaints received in relation to activities on the Sizewell C Main Development Site and its associated developments. This will include activities which have a permit, or another permission, associated with them. The procedure ensures that SZC Co. will investigate and provide a considerate, informed response within a reasonable time-period to contact from local residents, occupiers and other interested parties.

The procedure activities include:

- supporting the SZC Co. commitment to communicate openly and transparently with local communities and other interested parties;
- ensuring that SZC Co. manage enquiries and complaints appropriately, helping to build trust with those local communities and facilitate SZC Co. management to respond and take appropriate action; and
- ensuring that complaints are managed in a compliant way with PW18 Residential Amenity: Information Dissemination and Complaints Handling.

6.1.9 Competence and training

A major part of the IMS development programme is to provide assurance that all staff, contractors and any other personnel who control supervise and/or carry out work associated with the project are fully trained for the tasks that they carry out. They need to be fully aware of the potential environmental issues associated with the activities that they carry out and they are fully competent for the roles that they undertake. This therefore applies to all duly authorised persons and other suitably qualified and experienced persons.

The Operator will provide adequate instructions to all persons allowed on the site so they are aware of the risks and hazards associated with the plant and its operations, the precautions that must be taken to minimise the risks the environment, to themselves and others and the actions to be taken in the event of accident or emergency. Detail of the Compliance Arrangements and supporting documentation for instructions to persons on site are expected to change during the Station lifecycle, particularly at changeover points from construction, to commissioning, into operation and close of operations.

To this end, the Operator is progressively developing a system of procedures which will encompass:

- an integrated company policy which summarises how training arrangements will be implemented;
- a summary of environmental and safety roles and responsibilities;
- organisational arrangements and responsibilities;
- procedural documentation;
- standards, manuals and guidance; and
- a fully developed compliance matrix.

Training arrangements that have been demonstrated to comply with required regulations are already implemented on UK operating (EDF Energy) sites. These will form the basis of training arrangements developed in subsequent life cycle phases. A review of these arrangements will be performed to determine whether they are appropriate for SZC Co. and to identify any gaps against operational and regulatory requirements. It has been noted that there will be aspects of these arrangements that will not be applicable on SZC Co. sites due to the different training requirements for new build sites. Conversely, the Operator recognises that since this is a new build site there are additional requirements which may not be relevant or are less relevant to established sites. The Operator will ensure that all those people on the project who carry out activities during design, construction, manufacture, commissioning, operation or decommissioning of the nuclear installation, WDA permit related plant or who have responsibility for any action which may affect environmental performance or safety are adequately trained for that purpose. Assurance procedures are being developed so that the necessary training requirements are identified for each activity that individuals who carry out these activities can demonstrate that they have received such training. Records are kept to demonstrate that individuals have been trained.

It is envisaged that the system will be based on top down arrangements of which the requirements for training under the environmental permit for the water discharge activity will be a part. The upper tier of these arrangements will be an overall integrated policy for training for activities that may impact on plant environmental performance and safety. The arrangements that will be developed will require the production of a comprehensive schedule or programme for each person or group of persons on the site, in which the training requirements for each role are specified and the training requirements of an individual are identified. However, responsibility for ensuring that persons are trained lies with their Manager.

The Head of Training is responsible for defining SZC Co.'s approach to compliance and has overall responsibility for the SZC Co. management arrangements related to training and competency management. The responsibility for implementing the requirements will lie with Department Managers and Heads of Section.

As part of every individual's annual appraisal, a review of training needs will be carried out and where an individual has an environmental responsibility, appropriate training will be provided. All needs including environmental ones will be recorded and appropriate measures taken to deliver the required training. This will be managed through the central training/HR process and is also applicable for contractors.

6.1.10 Keeping records

SZC Co. will ensure that all documents and records are managed through a defined life cycle from creation, use and maintenance through to completion and disposal such that documents and records. These will be readily available to team members with legitimate business requirements including during the design, construction, commissioning, operation and decommissioning of the plant.

SZC Co. will keep records to demonstrate the IMS is being implemented in line with the requirements of the developing project and the WDA permit and all documentation will be kept within the project's Electronic Document and Records Management System. The Hinkley Point C project document management procedure will be further developed for Sizewell C, and will include details of the documentation to be kept and for how long.

Records will be kept of:

- environmental permits;
- legal requirements;
- risk assessment;
- management system plans;
- plans and drawings;
- management plans required by the permit;
- design information
- Operating procedures;
- staff competence and training;
- emissions and any other monitoring records;
- compliance checks, findings of investigations and actions taken;
- complaints made, findings of investigation and actions taken;
- audits of management system, findings (reports) and actions taken;
- management reviews and changes made to the management system; and
- where applicable, certification audit reports and any actions carried out.

6.1.11 Regulatory interaction, notification and reporting

The IMS will clearly define the requirements for regulatory interaction, reporting and notification.

Arrangements will be developed for the interaction between SZC Co. and the Environment Agency and other regulatory stakeholders. It will guide the interfaces between SZC Co. and the Environment Agency to ensure they are professional, controlled, consistent and appropriately documented.

Event categorisation and offsite reporting and notification guidance will be defined identifying how reportable incidents are notified and recorded in the Regulatory Correspondence log.

6.1.12 Management system review

SZC Co. will implement a procedure for checking compliance with the permit, procedures and management system.

SZC Co. will review and update the management system:

- within defined review periods as appropriate;
- when changes are made to the site, operations or equipment that affect the activities covered by the permit;
- when a permit variation application is made;
- after any accident, complaint or breach of the permit; and
- whenever a new environmental problem or issue arises, and new control measures to control it have been implemented.

Changes made to the management system will be recorded, such as implementation of new control systems.

Suitable management review will also be undertaken on a higher level, whereby the effectiveness of arrangements and performance will be reviewed.

Monitoring and measurement will be carried out of the key operational characteristics that can have significant impact(s) on the environment.

Audits and inspections will be carried out to ensure that permit activities are managed to meet the conditions of the environmental permit. In addition, audits will also take place of contractors and/or contractors will be required to share the results of their audits and inspections.

6.1.13 Site closure

The site will be decommissioned in a sensitive manner, in order to minimise the potential for environmental impacts associated with the decommissioning, dismantling and demolition of the plant.

The nuclear power station will be designed and built for a 60-year operation period. Although it is not practicable to develop a precise decommissioning plan at this time, the plant has been designed to minimise environmental impacts associated with the decommissioning and dismantling activities.

Accordingly, arrangements for the shutting down and decommissioning of the water discharge activities will be incorporated into the Sizewell C Decommissioning Plan for the whole site. When developed, appropriate information will be provided to the Environment Agency and management arrangements will be altered accordingly.

The Operator will also develop a Decommissioning Waste Management Plan during detailed design stage, as required by the Energy Act [117]. An EIA will be undertaken closer to Decommissioning, in line with the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations [118].

6.2 Incident management plan

This section will describe the mechanisms developed by the Operator to enable the identification, assessment, management and mitigation of hazards associated with the activities undertaken at Sizewell C under normal operation and abnormal operating conditions.

The Control of Major Accident Hazards Regulations requirements are dealt with in a separate site specific application.

As part of the operational incident management system, SZC Co. will generate a MAPP which will ensure that all measures necessary are implemented to prevent major accidents at Sizewell C and limit any consequences to persons and the environment. The MAPP will detail:

- Roles and responsibilities of those involved in the management of major hazards at all levels in the organization will be defined and training needs will be identified and provided. Co-operation of employees will be encouraged and contractors will be selected to ensure that they are competent.

- Arrangements to identify and evaluate the potential for major hazards to arise from site activities and to prepare, test and review emergency plans in response to such emergencies. A management of change process will exist for the planning, design of new installation, processes and storages to ensure all health, safety & environmental requirements and BAT is met. Operating and maintenance procedures will be in place and procedures will be reviewed and revised whenever a change occurs or as required. The integrity of safety and environmental equipment will be maintained through examination and planned preventative maintenance. Contractors will be managed and monitored to ensure an adequate standard of safe working.

- Arrangements for the investigation and corrective action in the event of failure to achieve the stated objectives, aims and standards. Procedures will be in place for the reporting of unsafe or hazardous conditions and for corrective action to correct these conditions and to follow up on the basis of lessons learnt.

Sizewell C will implement a well-developed hazard and risk management systems and a philosophy of safe working practices to minimise the potential for environmental impacts as part of the IMS.

This section of the application requires a detailed quantified risk assessment of feasible incidents that can have an environmental impact. This analysis should cover accidents and their consequences, including spills and abnormal operation, taking into consideration the advice provided within the Environment Agency develop a management system guidance [40] and the Environment Agency risk assessments for your environmental permit guidance [26].

Due to the development of the overall programme of work, the detailed site design and layout has not yet been finalised and any procedural mitigation has not been produced.

Therefore, this section of the submission follows the overall approach taken to describe how the IMS will be developed and implemented to provide evidence that the Operator has adopted a robust approach to the identification, management and mitigation of environmental impacts. This section also provides details where appropriate, of the potential hazards that will be addressed in the Accident and Incident Management Plans. The Incident Management Plan will be developed in accordance with Environment Agency guidance and other relevant guidance as part of the IMS. In time, this will also operate to identify the roles and responsibilities of personnel in the management of accidents, arrangements for communication in such an event, how such incidents should be managed in the event of occurrence and an assessment of causes of event and changes to operations/procedures to prevent recurrence.

This section discusses the approach to be taken and highlight the main risks identified (based on the current design and experience from other sites). This section of the application therefore currently comprises a relatively high level environmental risk assessment. As part of the FAP (see **Section 7.3.3**, Action 3: Development of the operational management plans), a detailed Accident and Incident Management Plan will be provided.

The analysis already performed in the PCER (Sub-chapter 3.3) [119] includes the following events:

- Fire.
- On-site explosion (overpressure).
- Toxic cloud derivative.
- Explosive cloud derivative (overpressure).
- Toxic cloud derivative following a fire.
- Liquid chemical pollution.
- Projectile ejection.

Based on operating and permitting experience across the UK, typical abnormal / emergency events that will be addressed as the site design is developed are:

- Significant loss of fuel oil or chemicals during delivery.

- Damage to the fuel oil and chemical tanks and bunds through accidental rupture or spontaneous failure of tank, leading to loss of the tank contents.
- Loss of fuel oil and chemicals from distribution system during transfer from the bulk storage tanks to the day storage tanks.
- Loss of fuel oil and chemicals from distribution system during transfer from the day storage tanks to the burner.
- Fire/explosion of combustible materials.
- Flooding of the site and associated contamination of flood waters with chemicals/fuel stored on site.
- Vandalism to plant, equipment and infrastructure and associated loss of fuel / chemicals from site.

Other scenarios may be identified as the design of the plant develops, together with the assessment of the associated environmental impacts.

6.2.1 Identification of hazards

The identification of environmental hazards associated with the operation of the plant has informed the development of the PCER in the GDA, with further developments captured within the Hinkley Point C Safety Report (PCSR3) and environmental permits applications.

When implemented, the management system will enable the identification of potentially adverse environmental impacts arising from operations under normal and abnormal conditions, by virtue of the following:

- developments incorporated into the Hinkley Point C RC2 design, where applicable;
- plant risk assessments;
- the Schedule for the assessment and maintenance of plant and machinery that are identified as presenting a risk of potentially adverse environmental impacts;
- operating procedures and work instructions, including training on use of spill kits;
- plant modification/change management procedures; and
- the Environmental Aspects Register.

The development of these documents and compliance with the periodic review of the environmental aspects register and records of non-conformances with the management system and operational requirements, enables the Operator to characterise the significance and probability of potential adverse environmental impacts, and to implement, and where appropriate, to review the efficiency of the accident mitigation and management measures.

Details of the documentation referenced above are provided in the following sections.

Environmental risk assessment

A preliminary risk assessment carried out for the environmental permit application (and reflecting the level of detail available) has identified a number of typical hazardous events (accident scenarios) as listed above. These will be discussed further in **Section 6.2.3**.

Schedule of inspections and environmental maintenance

A schedule of Inspections and Environmental Maintenance has not yet been developed. Once the detailed design of the plant has been finalised, a preliminary schedule can be prepared. This will be a dynamic document influenced by the commissioning process and ongoing operations. Where equipment is identified has having an environmental protection role, this will be recorded and appropriate maintenance and inspection will be carried out. This will be recorded as a procedure within the site management system.

Operating procedures/job instructions

Procedures will be developed to cover key operations at Sizewell C. These will include the water discharge operations and the delivery/refilling of fuel and/or chemicals and will incorporate any actions required for environmental protection.

6.2.2 Environmental risk assessment

This section of the submission will provide a description of the procedures/methodology for identifying and assessing environmental risk. A quantified risk assessment has not been provided as the processes and mitigations are not sufficiently developed to either reflect the protection measures in place or to commit to specific measures. A full quantified risk assessment will be provided as part of the IMS.

The approach to the assessment of hazards with the potential for environmental impacts will be in accordance with the requirements of the Environment Agency risk assessments for your environmental permit guidance (January 2019) [26].

The identified hazards will be reviewed in accordance with the approach provided by the Environment Agency guidance [26] (along with any additional risks identified). To enable an accurate and meaningful quantitative assessment of the likelihood and environmental significance of the identified accident scenarios the quantitative values and definitions of their meaning that will be applied are provided in the ranking matrix given in **Table 6.2.3**.

Table 6.2.1 Ranking matrix for risk assessment

"S" Severity of environmental impact	
1. Minor	Nuisance onsite only (no off-site effects). No outside complaint.
2. Noticeable	Noticeable nuisance offsite, e.g. discernable odours.

"S" Severity of environmental impact	
	Minor breach of permitted emissions, but no environmental harm. One or two complaints from the public.
3. Significant	Severe and sustained nuisance, e.g. strong offensive odour or noise disturbance. Major breach of permitted emissions with possibility of prosecution. Numerous public complaints.
4. Severe	Hospital treatment required. Public warning & off-site emergency plan invoked. Hazardous substance releases into water course with ½-mile effect.
5. Major	Evacuation of local populace. Temporary disabling and hospitalisation. Serious toxic effect on beneficial or protected species. Widespread by not persistent damage to land. Significant fish kill over 5 mile range.
6. Catastrophic	Major airborne release with serious offsite effects. Site shutdown. Serious contamination of groundwater or watercourse with extensive loss of aquatic life.
"L" Likelihood of event	
1. Extremely unlikely	Incident occurs less than once in a million years.
2. Very unlikely	Incident occurs between once per million and once every 10,000 years.
3. Unlikely	Incident occurs between once per 10,000 years and once every 100 years.
4. Somewhat unlikely	Incident occurs between once per hundred and once every 10 years.
5. Fairly probable	Incident occurs between once per 10 years and once per year.
6. Probable	Incident occurs at least once per year.

This assessment methodology is presented in **Table 6.2.2**.

Table 6.2.2 Calibration of risk assessment outputs 1 – banded

Likelihood of Event		Severity of Environmental Impact					
		Minor	**Noticeable**	**Significant**	**Severe**	**Major**	**Catastrophic**
		1	2	3	4	5	6
Extremely Unlikely	1	1	2	3	4	5	6
Very Unlikely	2	2	4	6	8	10	12
Unlikely	3	3	6	9	12	15	18
Somewhat Unlikely	4	4	8	12	16	20	24
Fairly Probably	5	5	10	15	20	25	30
Probable	6	6	12	18	24	30	36

An inventory of the potential hazardous events has been developed by identifying scenarios for different events and activities on the site and recording the likelihood and the environmental significance of these events, should they occur.

The worst possible or maximum ‘Environmental Consequence’ by media of each event is listed, and the consequence has then been considered and allocated the appropriate numerical value (from **Table 6.2.1**) shown under ‘S’ for the severity of any outcome, and ‘L’ for the likelihood of the event occurring. The risk is then calculated by multiplying the severity and likelihood numbers. The results of this are shown under the column ‘R’.

S = Severity, L = Likelihood, R = Risk, (S x L = R)

Interpretation of the risk scores are provided at Table 6.2.3, which provides comments on the severity/acceptability of the hazard.

Table 6.2.3 Calibration of risk assessment outputs 2 – descriptive

Risk Score	Magnitude of Risk	Consideration
6 or less	Insignificant	Low or negligible levels of risk, low or negligible impacts. Adherence to good operational practices will adequately control these risks.

Risk Score	Magnitude of Risk	Consideration
8 – 12	Acceptable	Lower level of possible impact, but major severity or high likelihood would require consideration of further actions to reduce risk.
15 - 20	Unacceptable	Combination of high likelihood or major impact would require further assessment and possible actions to reduce risk.
24 or more	Severe	Risk is unacceptable, immediate resolution required.

6.2.3 Quantitative risk assessment

Table 6.2.4 provides an example of environmental risk assessment for the accidents identified in the hazard assessments for the water discharge activity. The table does not provide a quantitative assessment of the hazards associated with the activities undertaken at Sizewell C; this will be provided when detailed design data is available and will be calculated in accordance with the methodology described above. **Table 6.2.4** also provides details of the types of measures that may be implemented at the site to control and mitigate such events to achieve BAT.

The final column in **Table 6.2.4** contains a comment on the controls applied; it should be noted that the cause of the events has not necessarily been identified (e.g. for a fire, the specific source of ignition has not always been considered, rather a general assessment of the likelihood of the event and the types of precautions to be applied).

Table 6.2.4 Example assessment of accidents identified and their environmental consequences at Sizewell C

Hazardous Event	Potential Environmental Consequences by Media	Risk Assessment			Comments/Controls
		S	L	R	
Raw Material Delivery					
Significant loss of oils or chemicals during delivery (tankers) or transfer (by bowser, IBC or drum).	Air: Short term localised air impact, some odour. Water: Spillage likely to be contained on site. Land: Unlikely impact on ground as operational area of site is likely to be new hard standing and all drains will be new. Key receptor: North Sea Pathway: Still to be determined but likely to be site drains.	TBC	TBC	TBC	Transfers of oils and chemicals by tanker, bowser, IBC, drum and container have sound primary containment; the need for secondary containment will be assessed as a part of the design risk assessment. Risks will be reduced by the design of the surface water system. Procedures requiring spill mats to be placed over any local surface water drains. Forecourt separators are to be provided at all locations where fuel handling takes place. Penstock valves are provided at the point of discharge to all fore bays. Procedures will also be developed for filling of main oil tanks, chemical deliveries, emergency and spill response. Training will be provided for relevant personnel All operations will comply with the Oil Storage Regulations, Environment Agency guidance on Oil Storage Regulations for businesses, BS 5410 Code of Practice for Oil Firing and the Construction Industry Research and Information Association advice where relevant. Transfers will be supervised by appropriately trained and supervised site personnel (in addition to the vehicle drivers). Tanks will be checked for capacity before filling to prevent over filling and will have level indication/alarms and emergency cut-off switches. Any small spillage contained in delivery pipework will be managed through local containment. The site drainage system has still to be developed (as part of the FAP, see **Section 7.3.1** Action 1: Design description) and this process will consider the risks of tanker failure or IBC, drum or container Vehicle speeds will be controlled by site speed limits and all plant will be housed within the diesel building providing protection against vehicle damage.

Raw Material Storage					
Oil/chemical storage Damage to tanks, IBCs, drums, containers and bunds through accidental impact, rupture or spontaneous failure of tank leading to loss of all tank contents.	Air: Short term localised air impact, some odour. Water: Spillage would be contained within the diesel building, secondary containment or the drainage system. Land: Unlikely as any spillage would be contained within the diesel building, secondary containment or the drainage system.	TBC	TBC	TBC	Tanks, IBCs, drums, containers and associated pipework will be located within appropriate secondary containment. Any leaks or spills would be captured in sumps or holding tanks and pumped out and removed from site by tanker for offsite treatment and disposal. Any loss would be fully contained. Damage from accidental impacts (e.g. vehicles) is unlikely with the tanks being indoors and IBCs, drums and containers stored with collision protection. Tanks, IBCs, drums, containers, valves, pipework and flange points will be inspected as part of the IMS. Emergency and spill response plans will be developed and training provided to relevant personnel.
Movement of Process Fluids					
Loss of integrity of pipework Damage to pipework through accidental impact, rupture or spontaneous failure	Air: Short term localised air impact, some odour from building ventilation, minor for smaller spills and unlikely to be noticeable off site. Water: Spillage would be contained within the diesel building, within secondary containment or the drainage system. Land: Unlikely as any spillage would be contained within the diesel building, secondary containment or the drainage system.	TBC	TBC	TBC	All of the pipework is fully contained. Any leaks or spills would be captured in sumps or holding tanks and pumped out and removed from site by tanker for off-site treatment and disposal. Any leaks (minor or major) would be fully contained. Pipework, valves and flange points will be inspected as part of the IMS. Emergency and spill response plans will be developed and training provided to relevant personnel.

Discharge of Effluents into the Environment					
Discharge of effluent above permitted concentration levels	Air: None Water: Discharges of process effluents above the permitted concentrations could have an adverse impact on the water quality (chemical and ecological) of the North Sea. Land: None Key receptor: North Sea. Pathway: Permitted discharge routes (ultimately through cooling water system).	TBC	TBC	TBC	Unauthorised discharge via the cooling water system, site drainage system and fish recovery and return system discharge. Penstock valves are provided at the point of discharge to all fore bays. Procedures will also be developed for filling of main oil tanks, chemical deliveries, emergency and spill response. Training will be provided for relevant personnel Failure or rupture of valves, pipelines, secondary containment, effluent tanks, containers, drums, IBCs and could lead to an unauthorised discharge of process effluents (via permitted discharge routes). The risk of this occurring will be mitigated through a programme of planned, preventative maintenance and the implementation of a rigorous inspection and testing schedule. Failure to undertake appropriate sampling and/or analyses could lead to discharge of effluents above permitted limits. The risk of this occurring will be mitigated through a series of engineering training and management arrangements. These mitigation measures will be developed as part of the FAP (see S**ection 7.3.1**, Action 1: Design description.
Fire					
Major fire and/or explosion of incompatible materials, combustible materials.	Air: Significant local air quality impact from combustion products/ dust/ smoke, etc. Water: Fire water would be contained within buildings and/or overflow into the site drainage system. Land: Unlikely impact on ground due to the extensive hardstanding and new	TBC	TBC	TBC	Although possible, fire/explosion is not likely (based on operational experience). Areas, which pose a significant threat of fire, will be protected by dedicated installed fire prevention and mitigation systems. Extensive controls will be incorporated into the plant design to both prevent explosions and fires (‘zoned’ electrical equipment, alarms, automatic fire systems etc.) and minimise impact. A fire water management plan is to be completed to ensure that firewater can be collected and contained in the event of an emergency. The station may operate a fire team and (if so) will develop and maintain a fire plan to deal with minor incidents.

	drainage system installed across the site.				More significant fires will be dealt with in collaboration with Suffolk Fire Brigade.
Flooding					
Flooding of the site and associated contamination of flood waters with chemicals/fuel stored on site	Air: No impact. Water: Floodwater would be contained within buildings and/or the drainage system. Land: Floodwater would be contained within buildings and/or enter the groundwater via unsurfaced areas. Pathway: Flow by gravity/drainage systems/unsurfaced areas	TBC	TBC	TBC	Flood Risk Assessment is to be completed to confirm any adverse flood risk impact of Sizewell C development.
Vandalism					
Vandalism to plant, equipment and infrastructure and associated loss of oil / chemicals from site	Negligible. Appropriate design and management action should prevent vandalism happening.	TBC	TBC	TBC	The site will be protected by high level security systems.

Indicative best available techniques requirements for accidents

Table 6.2.5 details the indicative BAT requirements from the Environment Agency guidance for Risk Assessments for your Environmental Permit and provides a commentary on the proposed approach for Sizewell C. This recognises the limitations of the approach taken and the proposal to provide further data through the accident and incident management plan, see FAP **Section 7.3.3** Action 3: Development of the operational management plans.

Table 6.2.5 Indicative best available techniques requirements for accidents

Indicative BAT from Guidance	How the Activities Address Indicative BAT
EA guidance for risk assessments for your EP: develop an accident risk assessment - "Risk assessments for your EP" identifies the type of accidents which should be considered:	Adequate arrangements in relation to Other Than Normal Operating Conditions will be developed as part of the Integrated Management System.
Transferring substances, for example loading or unloading vessels	**Table 6.2.4** identifies the likely hazards associated with operations associated with the water discharge.
Overfilling vessels	**Table 6.2.4** identifies the likely hazards associated with operations associated with the water discharge.
Plant or equipment failure	When determined, compliance with the site inspection and plant maintenance and testing schedules are considered to mitigate these hazards. Appropriate alarms to reduce the likelihood of overfilling or over pressurisation will be considered in the Procurement Phase. **Table 6.2.4** identifies the likely hazards associated with operations associated with the water discharge.
Releasing an effluent before checking its composition	Appropriate management arrangements will be in place including competent and trained personnel. Operating procedures will be available and compliance checks will ensure the quality of the effluent. **Table 6.2.4** identifies the likely hazards associated with operations associated with the water discharge.
Vandalism	The site will be protected by high level security systems. **Table 6.2.4** identifies the likely hazards associated with operations associated with the water discharge.
Flooding	The site and installations are located within an area at risk of flooding (Flood Risk 3) as a result of rivers or seas without defences. There is a small sacrificial bund present along the eastern boundary of the site and an additional higher bund running along the north and east of the site, which will be raised to 10m above ground level as part of the Sizewell C development.

Indicative BAT from Guidance	How the Activities Address Indicative BAT
	Table 6.2.4 identifies the likely hazards associated with operations associated with the water discharge.
Inadequate bunding around tanks	The oil and chemical storage tanks will be designed to protect the environmental and will be housed within secondary containment. Actual tank specifications are not yet known but will be designed and specified in accordance with appropriate requirements and practice at the time e.g. tank material and manufacturers testing regime). **Table 6.2.4** identifies the likely hazards associated with operations associated with the water discharge.

6.3 Emissions of substances management plan

The emissions of substances management plan will be developed alongside the other power station management systems. The purpose of this plan is to show how appropriate measures will be taken to prevent, or where that is not practicable, to minimise emissions not covered by emission limit values in the permit.

An emission of substances management plan will be developed as part of normal business development and will be provided to the communicated to the Environment Agency when completed (as discussed in the FAP, **Section 7.3.3**, Action 3: Development of the operational management plans).

7 Forward Action Plan

7.1 Introduction

SZC Co. is planning to build and operate the proposed new Sizewell C nuclear power station, adjacent to the existing Sizewell A and Sizewell B Power Stations near Leiston, Suffolk. SZC Co. are applying for a number of consents, licences and permits, including the water discharge activity environmental permit to allow discharge of non-radiological aqueous wastes to the GSB.

SZC Co. has developed this submission so that it can be considered in parallel with the application to the PINS for a DCO. The information presented in this submission is consistent with that required by the Environment Agency for determining the application for a water discharge activity environmental permit and outlines operational plant, management and controls that will deliver a good standard of environmental protection. The application is being made significantly in advance of the first permitted activities being undertaken.

On receipt of this application the Environment Agency, having assessed it to ensure it is complete, that it is duly made and having placed it on the public register, will invite comments as part of the consultation process. The Environment Agency may engage in additional consultation activities including consultation on the draft water discharge activity environmental permit and the decision document.

7.2 Reference plant

As discussed in **Section 1.6.1**, the ONR and Environment Agency granted DAC and SoDA for the for the UK^{EPR} reactor design. Much of the information submitted to the regulators as part of the GDA process has been made accessible to the public via various websites.

The information provided in the GDA was used to support the Water Discharge permit application for Hinkley Point C which was duly made in September 2011 (Hinkley Point C EPR/HP3228XT/A001). Additional information was received and through the Environment Agencies Decision Document the Hinkley Point C WDA permit was determined in March 2013.

As discussed in Section 2.1.1, the design of the SZC diesel generators is based on the SZC replication strategy. The replication strategy is based on the replication of the final HPC design used for construction and erection activities (HPC Reference Configuration 2 (HPC RC2.0). The design configuration will be managed through the SZC No Change Committee in order to maximize the scope of common documentation and data which will be applicable on both sites without any changes.

7.3 Forward action plan

Given the current stage of development of the project, this section includes a FAP. This defines the activities necessary to achieve compliance with all of the WDA environmental permit conditions prior to commissioning of the power station at Sizewell C. The FAP provides a route map of how SZC Co. will develop from a competent applicant to a competent water discharge activity environmental permit holder and Operator in a timely fashion. This recognises the various stages of development of the project and the evolution of the organisation through design, construction, commissioning and operation. It is understood that these stages can occur in parallel (e.g. construction and commissioning of each UK EPR™ unit). The lessons learnt from other EDF nuclear power stations and from bringing the first unit into operation will be recorded and used when undertaking activities for the second unit.

SZC Co. will have a number of hold points as part of its management of the process of building and commissioning Sizewell C. These hold points include a number of actions and requirements that must be satisfied in order for SZC Co. to proceed to the next phase of the project. These may be linked to certain regulatory, organisational or commercial requirements that must be completed prior to commencing to the next stage. Therefore, the development of the project is controlled and co-ordinated. It is recognised that the Environment Agency may decide to implement pre-operational conditions as part of its WDA environmental permit determination. These could impose requirements that would necessitate the completion of specific activities prior to operation. This ensures that the necessary checks and balances are in place prior to commissioning and operation of the water discharge activity.

SZC Co. recognises that many of the other permitting, consenting and licensing applications (including marine licences) it plans to make over the next few years will require similar FAP commitments, and that these will need to be managed. SZC Co. is therefore developing a FAP and supporting processes to manage the delivery of all FAP elements (including the FAPs from the environmental permits for the combustion activities, water discharge activity, radioactive substances regulation activity and construction water discharge activity), and recognises that some commitments may be needed to address the requirements of one or more of these permits or permissions.

The FAP provides a clear summary of the commitments SZC Co. is making as part of this application. These commitments below have been proposed based upon learning from Hinkley Point C and recognising cross cutting topics listed within the Hinkley Point C Operational Water Discharge permit improvement programme and pre-operational measures. There are four of these high level actions that cover a variety of topics that need to be delivered on different timescales: some relatively early on in the project phase, others that are required much later, including after several operational cycles. These high level actions reflect topics considered important by SZC Co. as part of the progression towards being a competent Operator.

7.3.1 Action 1: Design description

Confirmation of final design

This application is based upon the generic design within the GDA and development in design at FA3 and Hinkley Point C. It is recognised that in some areas there is further detailed design to be undertaken as part of the normal engineering, procurement and construction process. Given the early delivery of this application, in part to support the planning process, the procurement of these turnkey contracts (which include detailed design within their scope) has not yet started as it is many years until the systems will be installed. Therefore prior to hot functional testing of the power station, SZC Co. will provide a completed, as-built description of the plant and infrastructure, including a justification of how the final design prevents or minimises impacts on the environment. It is not possible to provide this level of detail earlier because during the course of large engineering projects it is possible that through design evolution and learning any relevant lessons from other EPR projects under construction that some further opportunities for optimisation may become apparent and these should be incorporated. Should the final design vary from that described in the permit application, the report shall include as appropriate, a risk assessment to demonstrate how the changes will prevent or minimise impacts on the receiving water environment. Any significant changes following submission of this application could result in the requirement to vary the application and/or re-consult. SZC Co. will ensure early engagement with the Environment Agency regarding any proposed changes.

Specific information will be provided on:

- Buildings and associated containment systems including:
  - Design of buildings to contain fire water from emergency incidents/response.
  - Design of tanks, bunds, pipework, sumps and drainage systems.
  - Equipment for handling any spilled hazardous liquids.
  - Specific details of the preventative maintenance programme to prevent loss of containment of hazardous materials.
- Site drainage systems including:
  - The final specification of surface water systems.
  - The final specification of the sanitary effluent system.
  - The final specification of the oil-water interceptor system.
  - Arrangements to prevent hazardous materials contaminating the marine environment in the event of loss of containment.

Location of the main cooling water and fish recovery and return outfalls confirmation.

7.3.2 Action 2: Development of the integrated management system

Development of the integrated management system

SZC Co. will undertake a period of trial working to demonstrate that the necessary management arrangements for the control and disposal of liquid effluent wastes are adequately tested to the satisfaction of the Environment Agency prior to hot functional testing.

SZC Co. is a developing organisation with arrangements that are fit-for-purpose for the project phase. A description of how the management system will be developed is provided in **Section 6**. This includes, but is not limited to:

- Arrangements to manage environmental permit requirements including improvement and/or pre-operational conditions.
- Assessment of design changes through the company's modifications assessment process.
- Arrangements to manage lessons learnt

The arrangements for some topics within the management system are required early in the project, for example: training and competence from when the environmental permit is issued, whilst others are required later as the organisation develops and approaches the point of effluents requiring disposal. The development of the management arrangements will reflect this evolution. This is consistent with the approach reflected in the development of management arrangements for other environmental permits and the NSL application.

7.3.3 Action 3: Development of the operational management plans

Prior to the discharge of liquid effluents under this permit a number of specific operational management plans will need to be developed. These will underpin the relevant management arrangements. In order to ensure these plans are tested prior to use SZC Co. will produce the relevant operational management plans prior to commissioning. This will include the following plans.

Accident and incident management plan

A detailed accident and incident management plan will augment the information proved in **Section 6** and will:

- Provide a quantified risk assessment of hazards that take into account the engineering and procedural mitigation measures that will be in place before operation commences.

- Address how environmental risks will be prevented and mitigated during operation, and in particular will address the storage and handling of hazardous materials during operation.

Emission of substances management plan

An emission of substances management plan will be developed alongside the other power station management systems which will include:

- Identification of emissions not covered by limit values in the permit.
- Consideration of impacts associated with such emissions.
- Identification of appropriate measures to be taken to prevent, or where that is not practicable, to minimise such emissions.

Effluent monitoring plan

SZC Co. will specify relevant monitoring techniques and assessments to be used for monitoring of effluent. SZC Co. has described a generic approach in this submission building on the information presented in the GDA and Hinkley Point C current design information. There are a number of drivers that mean that early definition of the monitoring requirements could foreclose options that would be available later. For these reasons it is difficult to predict what will be considered the best techniques in the future. Therefore, SZC Co. commits to make the appropriate decisions in a timely fashion. This will include consideration of MCERTS and other relevant standards, reviewing relevant techniques in light of developments and ensuring the design integrity of the sampling systems. SZC Co. will submit an Effluent Monitoring Plan to the Environment Agency including the procedures and quality assurance that will be in place. This action will be completed prior to hot functional testing with sufficient time to enable the testing and demonstration of arrangements. Early engagement with the Environment Agency is essential to avoid delays to the schedule. It is recognised that SZC Co. needs to have access to competent persons for advice throughout the process.

Environmental monitoring plan

SZC Co. will submit to the Environment Agency for approval an environmental monitoring plan for the Sites and Features (SAC, SPA and Ramsar) having the potential for marine water quality effects from the operation phase of Sizewell C for the purpose of post-scheme appraisal.

The plan will propose monitoring methods to determine the physical, chemical and biological characteristics of the area potentially affected by the water discharge activity and monitoring locations and frequencies. It shall also include the procedures for assessing any effects and reporting the results of the monitoring and assessment to the Environment Agency. The plan shall include, but not be restricted to the following aspects:

- Thermal plume monitoring.
- Subtidal and intertidal benthic ecology monitoring.
- Water quality monitoring.
- Sediment quality monitoring.
- The quality assurance procedures in place.
- Limit of Detection of monitoring technique.
- Fish monitoring as a source of polluting matter.

Commissioning discharges management plan

SZC Co. as part of its submission has presented a bounding envelope of the expected discharges arising from commissioning activities, the impacts of which are presented in this submission. Given the length of time until commissioning is expected it would be premature to produce a refined Commissioning Discharges Management Plan. SZC Co. recognises the importance of such a plan and therefore prior to commencement of Hot Functional Testing of Sizewell C, SZC Co. will produce a detailed Commissioning Discharges Management Plan. This plan will build on the commissioning discharge information provided within this application as well as information available from Hinkley Point C and will demonstrate how management and engineering controls will be applied to ensure that environmental impacts are minimised and that the discharges remain within the bounding envelope for all waste streams.

The plan shall include, but not be restricted to the following:

- A timetable for HFT of both UK EPR™ units.
- A description of the HFT process.
- A description of associated effluent treatment measures.
- Confirmation of the expected thermal loading, including the expected temperature of the discharge.
- Proposals for effluent monitoring during the HFT process.
- Demonstration that environmental impacts will be prevented or minimized.
- Demonstration of how compliance with the permit will be achieved.

Forebay de-silting plan

Prior to the commencement of the Hot Functional Testing phase of commissioning the Operator will submit to the Environment Agency for approval a Forebay de-silting Plan for the removal of accumulated silt from within the cooling water forebays. The Plan will include:

- Verification of the initial impact assessment findings detailed in the permit application.
- Clarification of the preferred approach for sediment management.
- A Method Statement for undertaking the de-silting activity.

Priority hazardous substances management plan

SZC Co. will submit to the Environment Agency for approval a Priority Hazardous Substances Management Plan. The Plan shall describe how the Operator intends to manage the use of chemicals so as to gradually cease or phase out discharging Priority Hazardous Substances, in accordance with the objectives set out under the Water Framework Directive.

The Plan will make reference to amongst other things, the cadmium and mercury which is present as trace contaminants in bulk raw materials and will propose a timetable for the gradual phasing out of the use of such chemicals.

Hydrazine management plan

SZC Co. as part of its submission has presented a bounding envelope of the expected hydrazine discharges under the WDA permit, the impacts of which are presented in this submission and deemed acceptable. SZC Co. will however review the lessons learnt from the experience of the EPR in France and Hinkley Point C to ensure that discharges of hydrazine are minimised as far as possible. Therefore, prior to commissioning of the power station, SZC Co. will conduct an optioneering exercise into the feasibility of further minimising hydrazine prior to discharge at levels below those given in this application. This exercise will balance potential environmental benefit, technical feasibility and the costs associated with implementing various engineering or management options. The results of this exercise will be made available to the Environment Agency.

7.3.4 Action 4: Environmental performance

NGR monitoring points

Recognising more information will become available during the design phase of the development, prior to the commencement of the Hot Functional Testing phase of commissioning, SZC Co. shall submit to the Environment Agency:

- Confirmation of the NGR‟s for the compliance monitoring points associated with each waste stream.
- Confirmation of the monitoring point references.
- Detailed site plan(s) showing the exact location of the waste stream compliance monitoring points.

Validation of strategy for control of biofouling

SZC Co. as part of its submission has presented a bounding envelope of the expected chlorine discharges under the WDA permit, the impacts of which are presented in this submission and are consistent with those presented in the Habitats Regulations Assessment. Through design evolution and lessons learnt from the commissioning and operation of the EPR unit in France, Hinkley point C and Sizewell B the operational strategy for chlorination will be finalised. Therefore, prior to commissioning of Sizewell C, SZC Co. will provide the Environment Agency with further information on the environmental impacts of the use of the chlorination regime described in this Application. This will include validation of the impacts of the proposed regime based on numerical modelling and eco-toxicological studies where appropriate.

Hydrodynamic modelling

SZC Co. will review their hydrodynamic modelling for the purpose of post-scheme appraisal to validate modelling predictions described in this permit application. The review shall include re-calibration and validation of the hydrodynamic model(s) if necessary, as well as a reassessment of the assumptions concerning the near-field behaviour of the discharges. This shall include:

- best available climate change projections;
- operational performance of the power station; and
- the output from post scheme appraisal studies;

Review of emissions loading

Prior to Hot functional Testing SZC Co. will review the substance loadings and emissions to surface water described in this application as well as any mitigation measures.

This will include:

- Information form designers and suppliers which has influenced the design with respect to flow and composition of effluents; and
- Confirmation of the demineralisation system outputs.

7.3.5 Summary of high level forward action plan

Table 7.3.1 below, presents a summary of the high level FAP described above by SZC Co. for this Sizewell C submission. The use of a FAP, as used in other regulatory regimes, does not preclude the Environment Agency developing additional requirements and using any of the available mechanisms, such as Pre-operational conditions, within the water discharge activity environmental permit to ensure SZC Co. achieves the requirements necessary prior to operation. SZC Co., as part of the demonstration of being a competent applicant and a responsible Operator feels it is important to recognise those areas that require further attention and to provide a clear path of how and when we will deliver these. The FAP, along with the appropriate procedures and processes to manage it are the means by which SZC Co. will meet these obligations.

Table 7.3.1 Water discharge activity high forward action plan

Ref.	Action	Timing
1	**Design description** SZC Co. will: • Provide a completed, as-built description of the plant and infrastructure relevant to the water discharge activity including a justification of how the final design prevents or minimises impacts on the environment. Specific information will be provided regarding the relevant buildings, containment systems and site drainage systems. Should the final design vary from that described in the permit application, the report shall include as appropriate, a risk assessment to demonstrate how the changes will prevent or minimise impacts on the receiving water environment. • Submit confirmation of the final NGR's for the cooling water and the fish recovery and return outfalls.	Prior to Hot Functional Testing phase of commissioning

Ref.	Action	Timing
2	**Integrated management system** SZC Co. will: • develop an IMS to ensure that the environmental permit requirements are met. The IMS shall be developed in line with Environment Agency guidance Develop a Management System: Environmental Permits. The documents and procedures set out in the IMS shall form the written management system; • carry out a review of the IMS to demonstrate that suitable management arrangements are in place for the relevant project phase; • develop arrangements to manage improvement and/or pre-operational conditions as the requirements may be across one or more permits. Actions taken to address the improvement and/or pre-operational conditions will be provided to the Environment Agency; • fully assess design changes through the company's modifications assessment process; and, • develop arrangements to manage lessons learnt from other EDF nuclear power stations and from bringing the first unit into operation will be recorded and used when undertaking activities for the second unit.	Prior to Hot Functional Testing phase of commissioning

Ref.	Action	Timing
3	**Operational management plans** SZC Co. will produce the relevant operational management plans prior to commissioning. This includes: • a detailed accident and incident management plan for surface water discharge activities including a quantified hazard risk assessment incorporating engineering and procedural mitigation measures that will be in place before operation commences and how environmental risks will be prevented and mitigated during operation; • an emission of substances management plan will be developed alongside the other power station management systems including identification of emissions not covered by limit valves in the permit, consideration of impacts associated with such emissions and information on how emissions are prevented or minimised; • an Effluent Monitoring Plan which specifies the monitoring techniques and assessments to be used for monitoring of effluents and the procedures and quality assurance that will be in place; • an Environmental Monitoring Plan which proposes monitoring methods to determine the physical, chemical and biological characteristics of the area potentially affected by the water discharge activity and monitoring locations and frequencies; • a Commissioning Discharges Management Plan describing how SZC Co. intends to undertake HFT including a HFT timetable, HFT process description and associated effluent treatment measures, thermal loading confirmation and prevention or minimisation of environmental impacts to ensure compliance with the Permit; • a Forebay de-silting Plan for the removal of accumulated silt from within the cooling water forebays including verification of the initial assessment detailed in the permit application and a method statement for undertaking the de-silting activity; • a Priority Hazardous Substances Management Plan describing how priority hazardous substances will be ceased or phased out; and • a Hydrazine Management Plan which assesses the feasibility of further minimising hydrazine prior to discharge at levels below those given in the permit application.	Prior to Hot Functional Testing phase of commissioning

Ref.	Action	Timing
4	**Environmental Performance** SZC Co. will: • provide final confirmation of the NGR"s for the compliance monitoring points, monitoring point references and detailed site plan showing the exact location of the waste stream compliance monitoring points; • provide further information on the environmental impacts of the use of the intermittent chlorination regime including validation of any relevant modelling and eco-toxicological studies; • review the hydrodynamic modelling to validate modelling predictions including re-calibration and validation of the hydrodynamic model(s) if necessary, as well as a re-assessment of the assumptions concerning the near-field behaviour of the discharge; and • review of the substance loadings and emissions composition to surface water and any mitigation measures. Confirmation will also be provided of the demineralisation system outputs.	To be confirmed

7.4 Conclusions

SZC Co. believes this document contains sufficient information to enable the Environment Agency to determine whether a WDA environmental permit can be granted.

SZC Co. believes it has demonstrated that the proposed water discharge system at Sizewell C represents the application of BAT and that impacts on the environment are minimised. SZC Co. undertakes regular reviews of technology and guidance so as to demonstrate the ongoing application of BAT.

SZC Co. is submitting this document to the Environment Agency for it to undertake a determination of this WDA environmental permit application, including a consultation on SZC Co.'s submission. SZC Co. will respond to any requests for clarification and information from the Environment Agency in a timely and efficient manner to enable it to complete its process.

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8.2 Acronyms / Glossary

Acronym/Abbreviation/Codes	Definition
AA	Annual Average
APG	Steam Generator Blowdown System
ATMP	Amino Tri-Methylene Phosphoric Acid
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
BAP	Best Available Technique
BAT	Best Available Techniques
BC	Background Concentration
BCF	Bioconcentration Factor
BEEMS	British Energy Estuarine and Marine Studies
BOD / BOD_5	Biochemical Oxygen Demand / 5 Day Biochemical Oxygen Demand
BS ENs	British/European Standards
CBD	Convention on Biological Diversity
CBP	Chlorination By-Products
CDO	Combined Drainage Oufalls
CEFAS	Centre for Environmental, Fisheries and Aquaculture Science
CEMP	Comprehensive Entrainment Monitoring Programme
[CFI]	Drum Screens and Band Screens
CIP	Cleaning in Place
CMS	Conservation of Migratory Species of Wild Animals: Bonn 1979
COD	Chemical Oxygen Demand
[CRF]	Circulating Water System
CTE	Electro-Chlorination System
CWDA	Construction Water Discharge Activity
DEFRA	The Department for Environment, Food and Rural Affairs
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EC	European Commission
EIA	Environmental Impact Assessment
EMS	Environmental Management System
EPR	European Pressurised Reactor
EP Regulations	Environmental Permitting Regulations 2010

Acronym/Abbreviation/Codes	Definition
EQS	Environmental Quality Standard
ERL	Effect Range Low
ERM	Effects Range Medium
ES	Environmental Statement
EUNIS	European Nature Information System
FAOL	Fugro Alluvial Offshore Ltd
FAP	Forward Action Plan
FID	Financial Investment Decision
GDA	Generic Design Assessment
GEP	Good Ecological Potential
GES	Good Ecological Status
GETM	General Estuarine Transport Model
GSB	Greater Sizewell Bay
[HCA]	Outfall Pond (Discharge Pond)
[HCB]	Debris Recovery Building
[HCF]	Fish Recovery and Return System
[HCT]	Outfall Tunnel
HFT	Hot Functional Testing
HMWB	Heavily Modified Water Body
[HP]	Pumping Station
[HPF]	Forebay
[HPT]	Cooling Water Intake Tunnel
[HVL]	Hot Laundry
[HXE]	Site Sewage Treatment Plant
[HY]	Demineralised Water Production Building
IBC	Intermediate Bulk Container
ICP	Inductively Coupled Plasma
ILW	Intermediate Level Waste
IMS	Integrated Management System
IPPC	Integrated Pollution Prevention and Control
IRWST	In-Containment Refuelling Water Storage Tank
ISGQ	Interim Sediment Quality Guidelines
ISO	International Organisation for Standardisation
[KER]	Nuclear Island Waste Monitoring and Discharge System

Acronym/Abbreviation/Codes	Definition
LAT	Low Astronomical Tide
LSE	Likely Significant Effects
LWM	Low Molecular Weight
MAC	Maximum Allowable Concentration
MAPP	Major Accident Prevention Policy
MCAA	Marine and Coastal Access Act 2009
MCCIP	Marine Climate Change Impacts Partnership
MCERTS / MCERTs	Monitoring Certification Scheme
MCZ	Marine Conservation Zone
MERITS	Methodically Engineered Restructured and Improved Technical Specifications
MHWS	Mean High Water Spring
MMO	Marine Management Organisation
NERC	Natural Environment and Rural Communities (Act 2006)
NGR	National Grid Reference
NNB GenCo	NNB Generation Company Limited
NOEC	No Observed Effect Concentration
ODN	Ordnance Datum Newlyn
ONR	Office for Nuclear Regulation
PAH	Polycyclic Aromatic Hydrocarbon
PCER	Pre-Construction Environmental Report
PEL	Probable Effects Level
PCB	Polychlorinated Biphenyls
PNEC	Probable No-Effect Concentration
PSA	Particle Size Analysis
[PTR]	Fuel Pool Cooling (And Purification) System
PWR	Pressurised Water Reactor
Ramsar	The Convention on Wetlands (Ramsar, Iran, 1971)
RBD	River Basin District
[RCV]	Chemical and Volume Control System
[REA]	Reactor Boron Water Make-Up System
[REN/RES]	Nuclear Island Sampling System
RSR	Radioactive Substances Regulation
SAC	Special Area of Conservation
[SBE]	Laundry, Maintenance and Decontamination Services

Acronym/Abbreviation/Codes	Definition
[SDA]	Demineralisation Processes
[SEC]	Essential Service Water System
[SHE]	Oily Water Network
[SEK]	Conventional Island Liquid Waste Discharge System
[SEN]	Auxiliary Cooling Systems
[SEO-EP]	Site Drainage Network
SoDA	Statement Of Design Acceptability
SPA	Special Protection Area
SPM	Suspended Particulate Matter
[SRU]	Ultimate Cooling Water System
SSC	Suspended Sediment Concentration
STW	Sewage Treatment Works
TBC	To Be Confirmed
TBM	Tunnel Boring Machine
[TEG]	Gaseous Waste Processing System
TEL	Threshold Effect Level
[TEN]	Effluent Treatment Building Sampling System
[TER]	Holding Tanks
[TEU]	Liquid (Rad)Waste Treatment System
[TEP]	Coolant Storage and Treatment System
THC	Total Hydrocarbon Content
TRaC	Transitional and Coastal
TRO	Total Residual Oxidants
UKAS	United Kingdom Accreditation Service
VC	Vibrocores
WDA	Water Discharge Activity
WFD	Water Framework Directive
WFD-UKTAG	United Kingdom Technical Advisory Group (UKTAG) supporting the implementation of the Water Framework Directive
WQTAG	Water Quality Technical Advisory Group
WRC	Water Recycling Centre
ZOI	Zone of Influence

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Appendix A
Site Maps, Plans and Drawings

Figure 1.4.1 Location of site

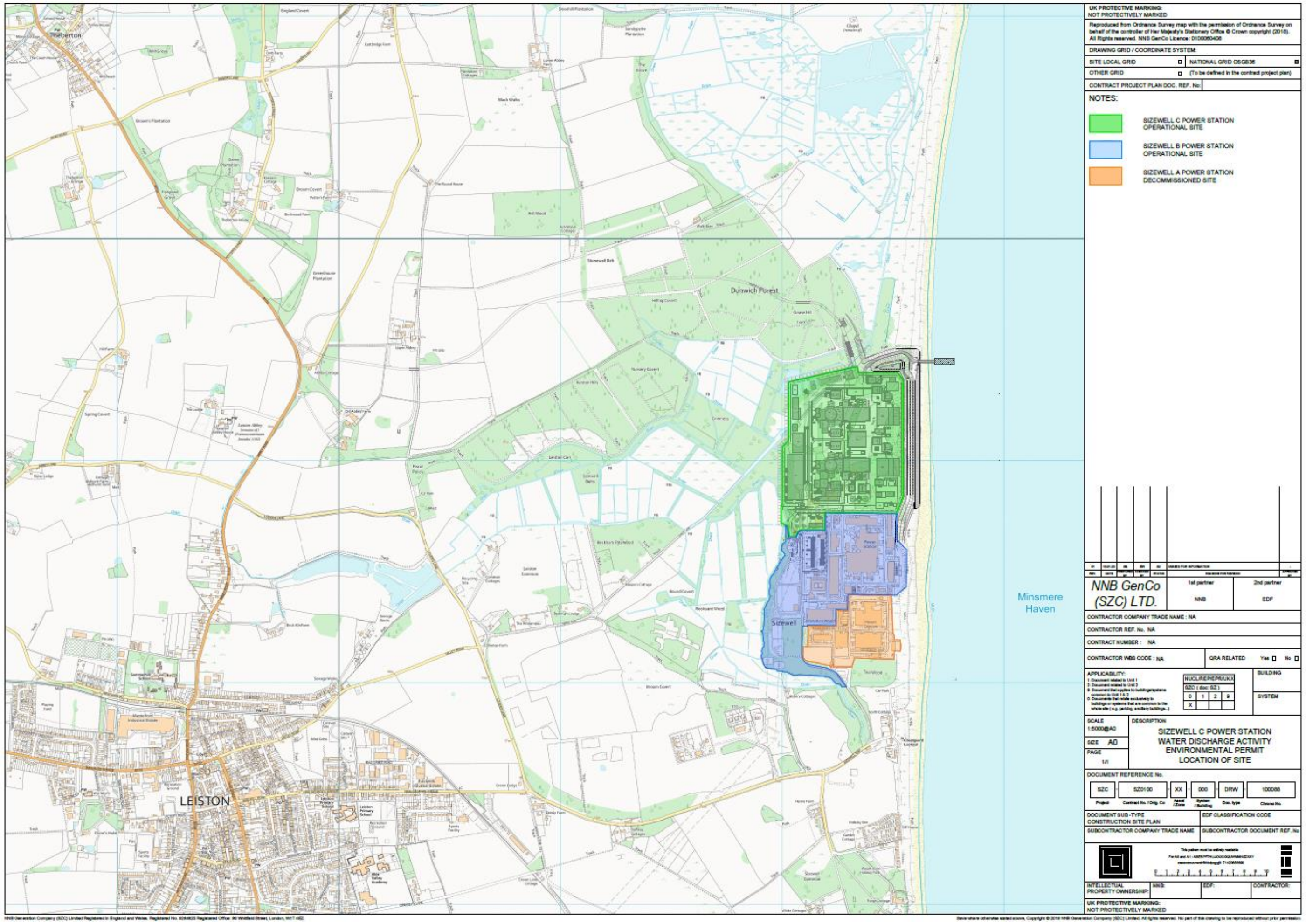


Figure 1.4.2 Location of the proposed cooling water inlets (A) and discharge outfall (B) (Interim)

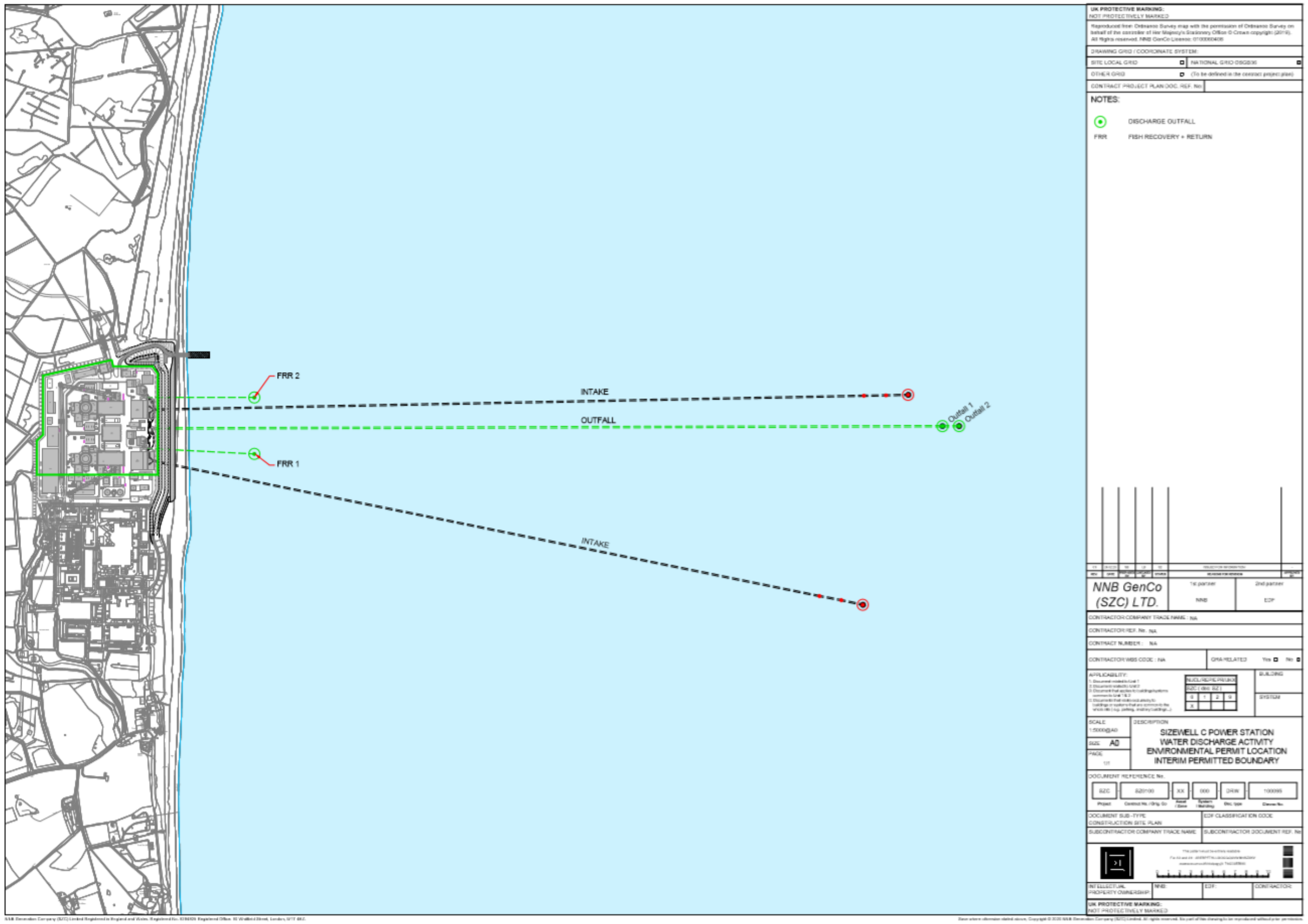


Figure 1.4.3 Location of the proposed cooling water inlets (A) and discharge outfall (B) (Final)

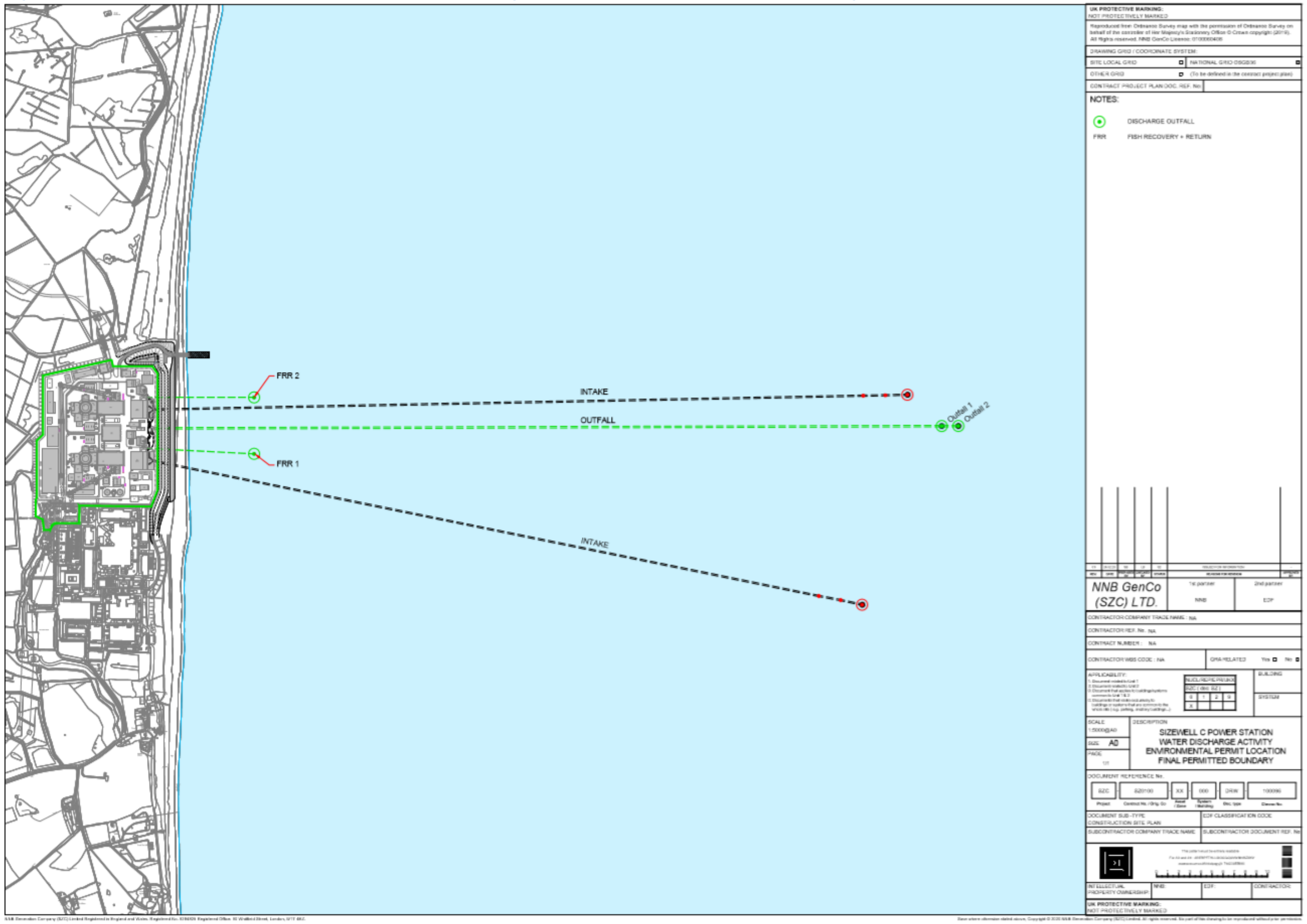


Figure 2.1.1 Conceptual diagram of the proposed Sizewell C power station

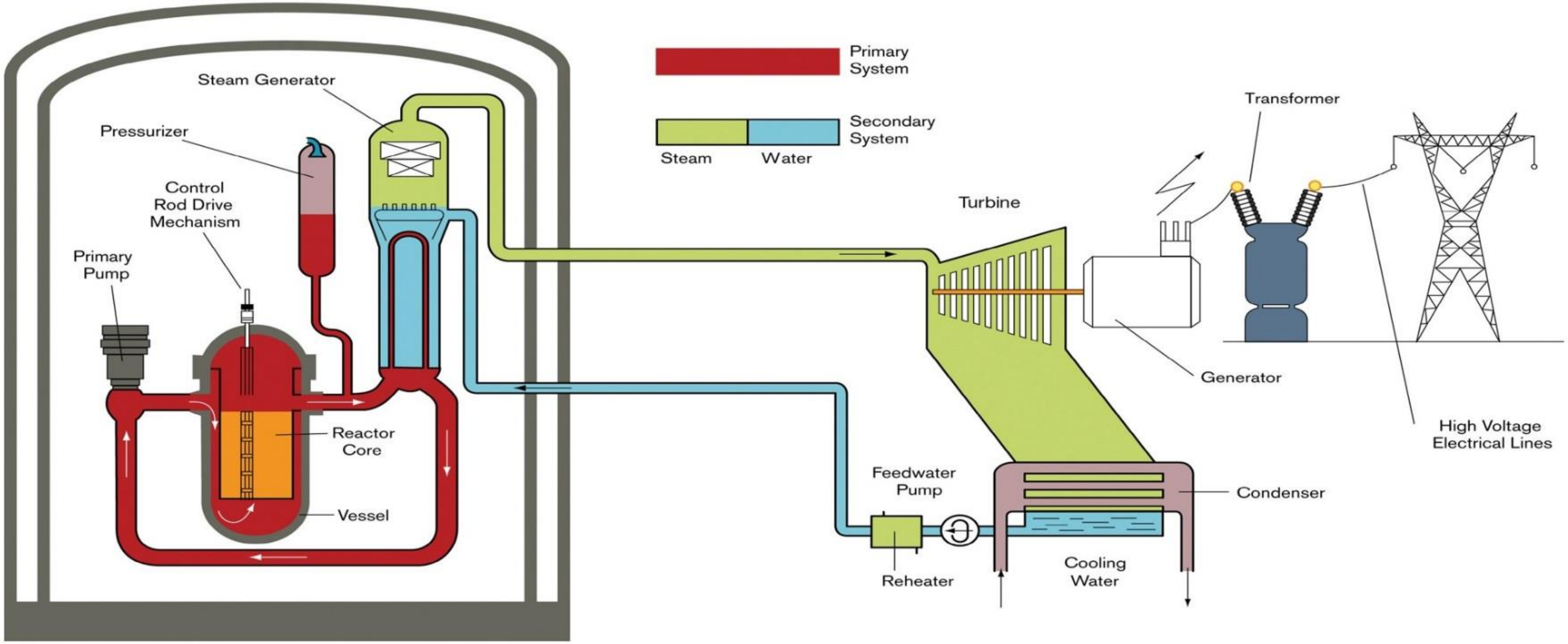
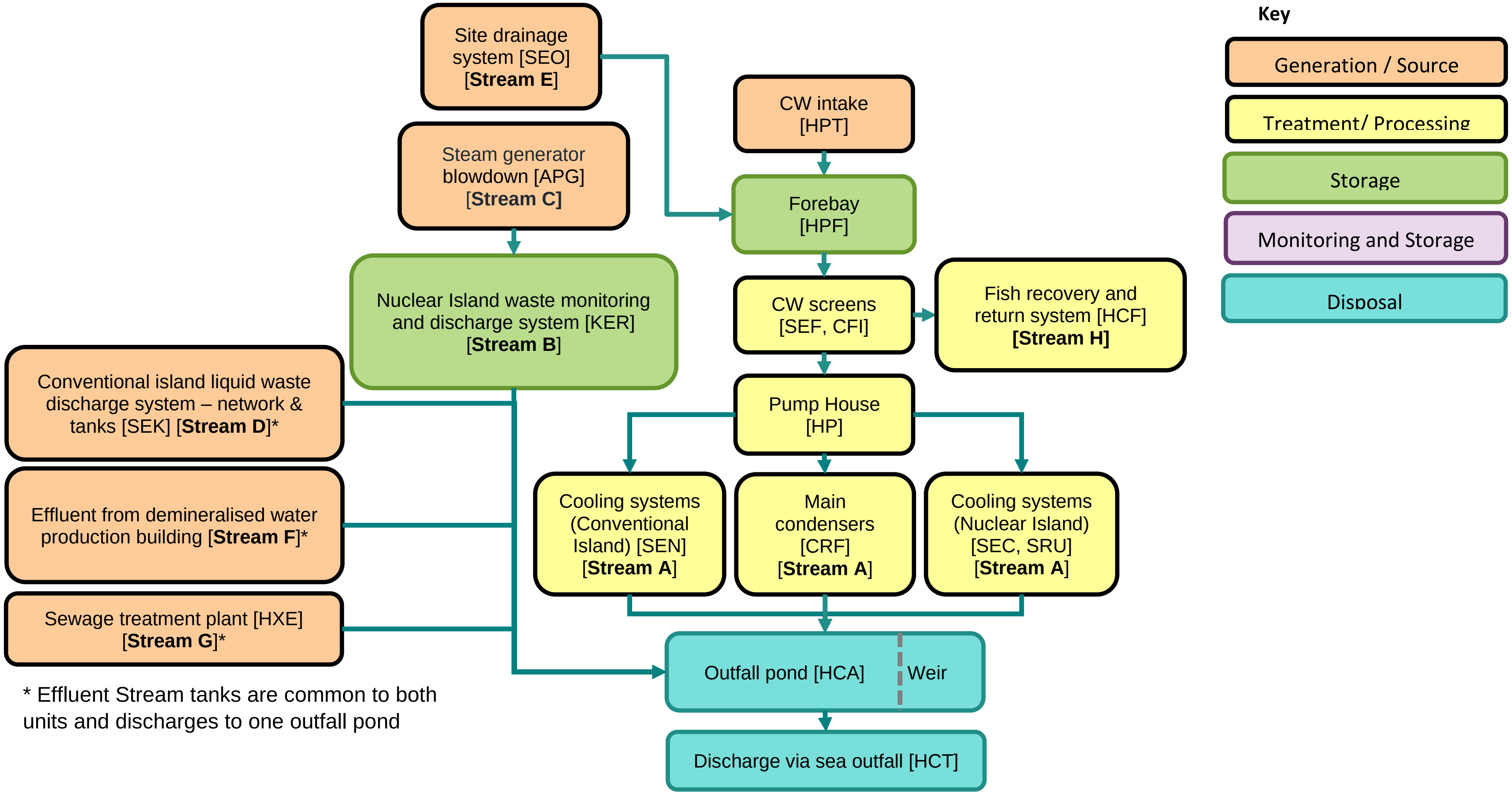


Figure 2.2.2 Simplified overview diagram of effluents contributing to the surface water discharge



* Effluent Stream tanks are common to both units and discharges to one outfall pond

Figure 2.3.1 Effluent Stream A- Cooling seawater

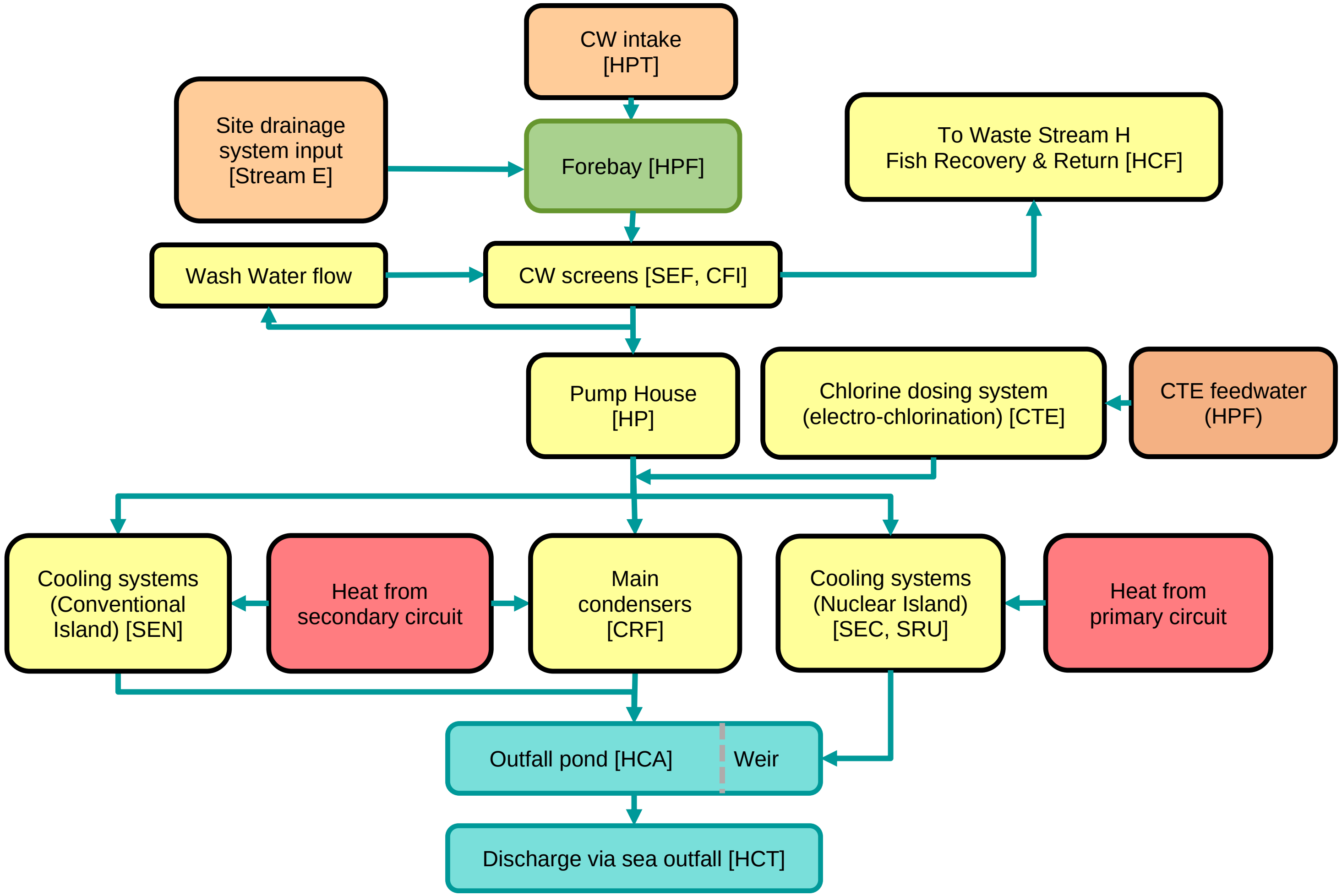


Figure 2.3.2 Effluent Stream B- Nuclear island

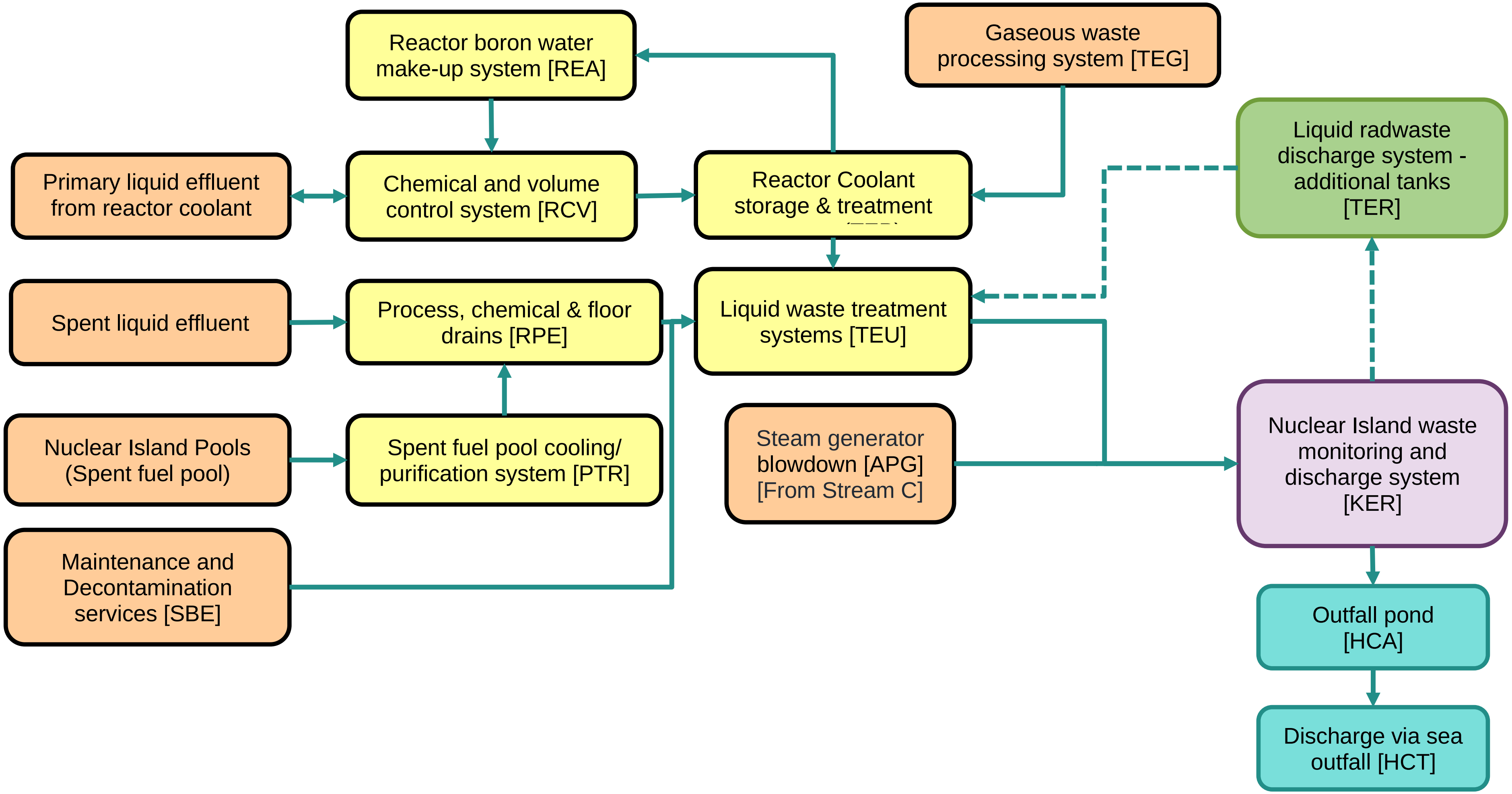


Figure 2.3.3 Effluent Stream C- Steam generator blowdown [APG]

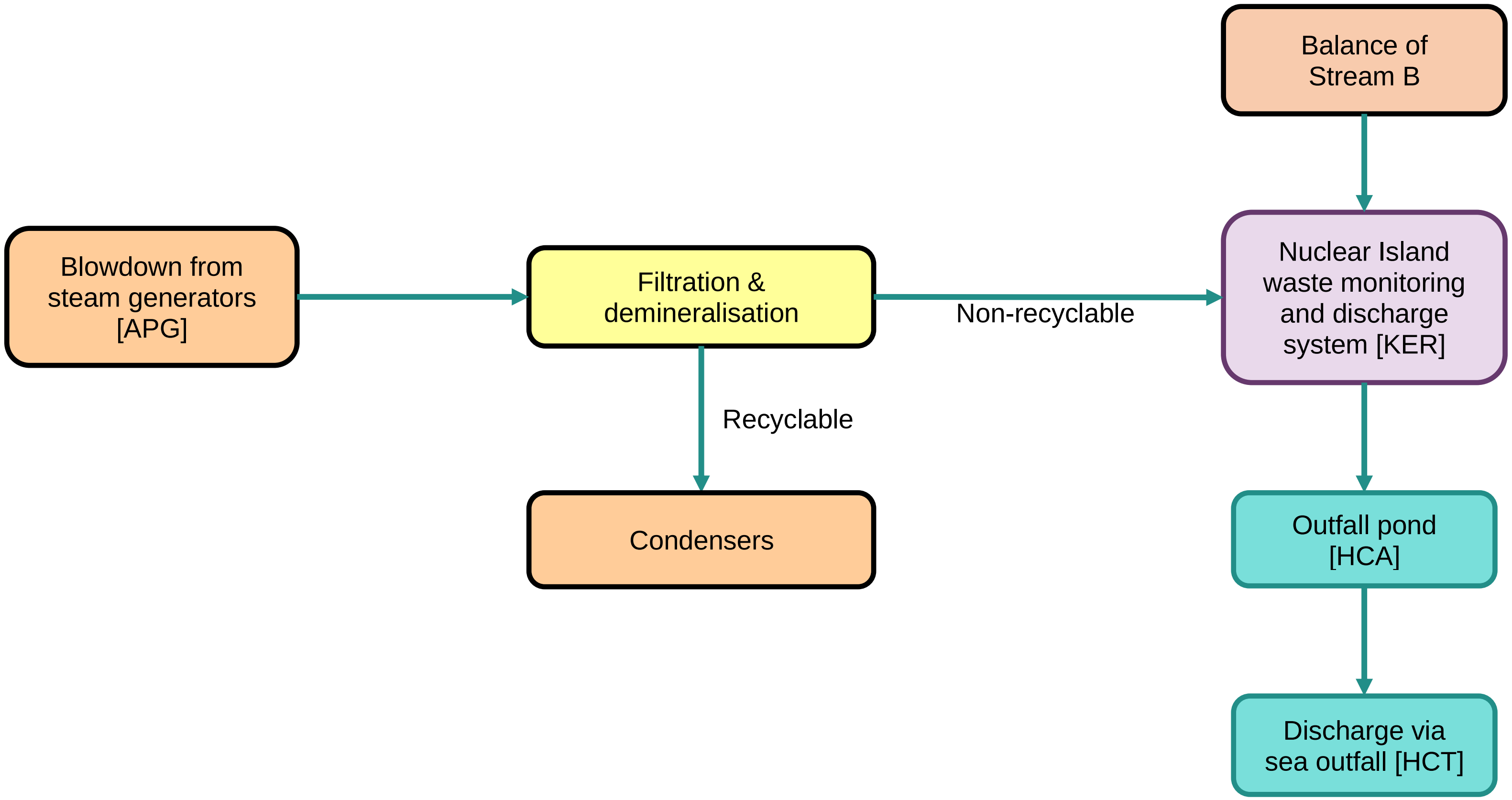


Figure 2.3.4 Effluent Stream D- Conventional island

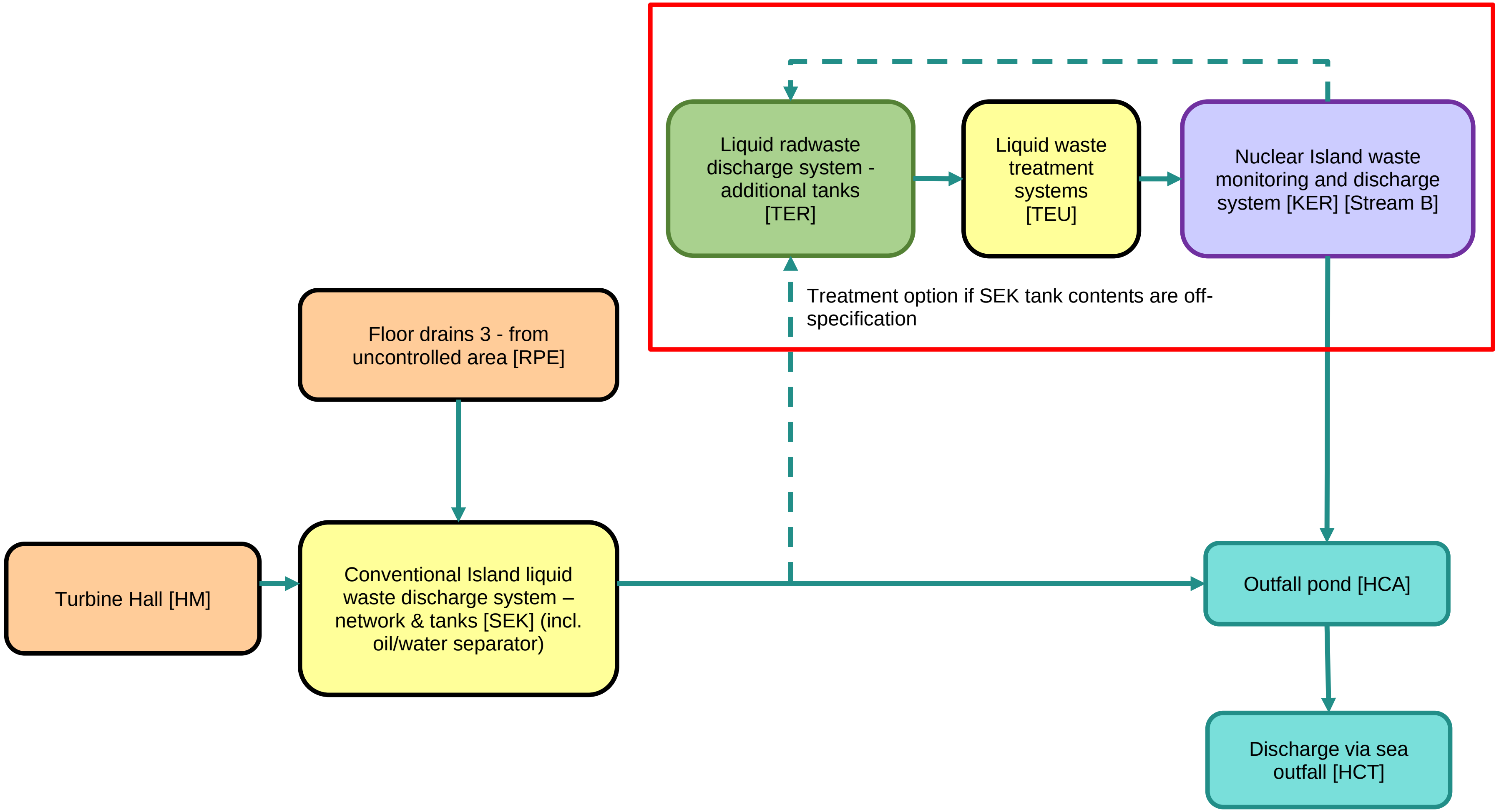


Figure 2.3.5 Effluent Stream E- Site drainage network [SEO EP]

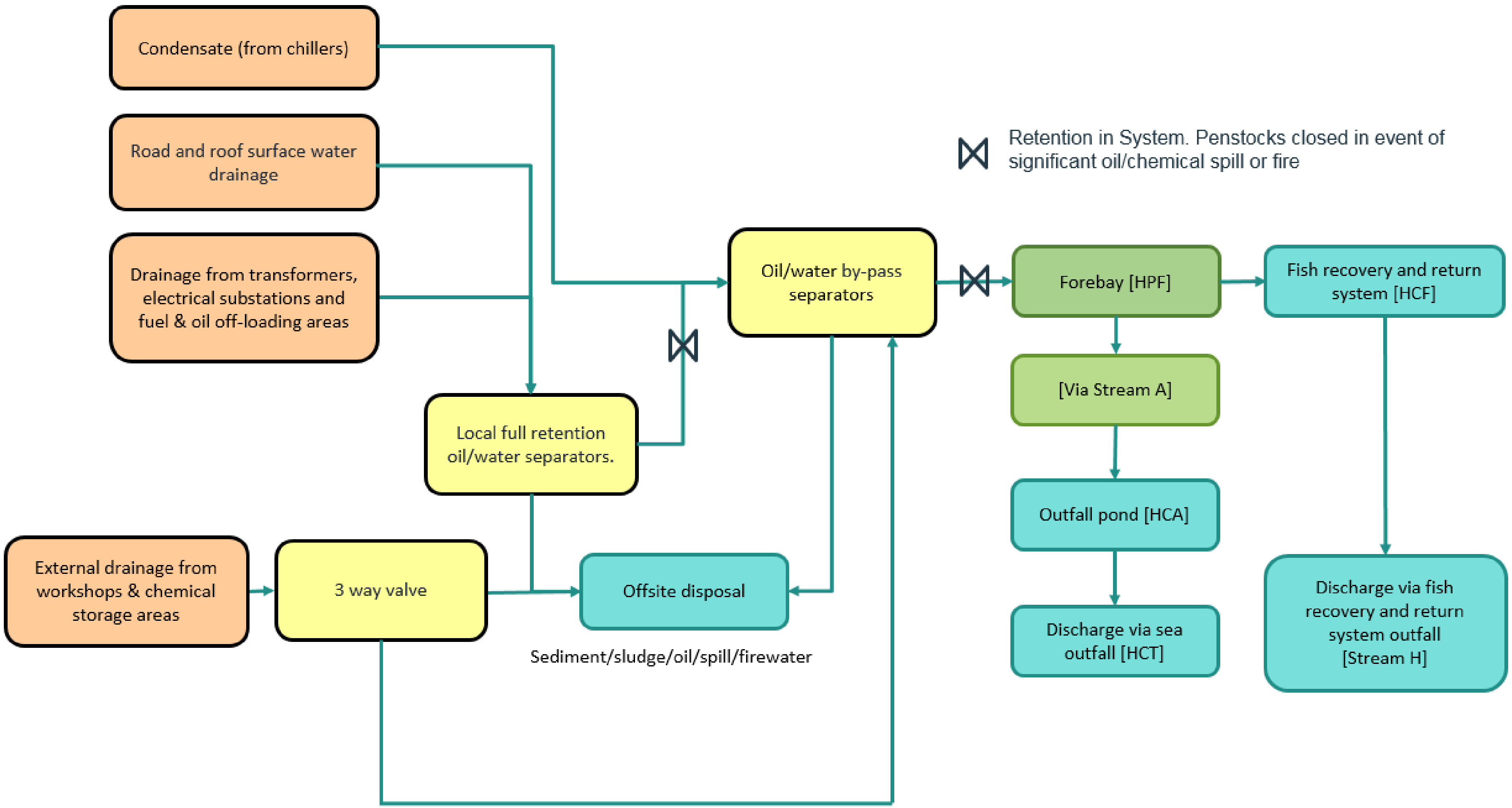


Figure 2.3.6 Effluent Stream F- Demineralisation plant

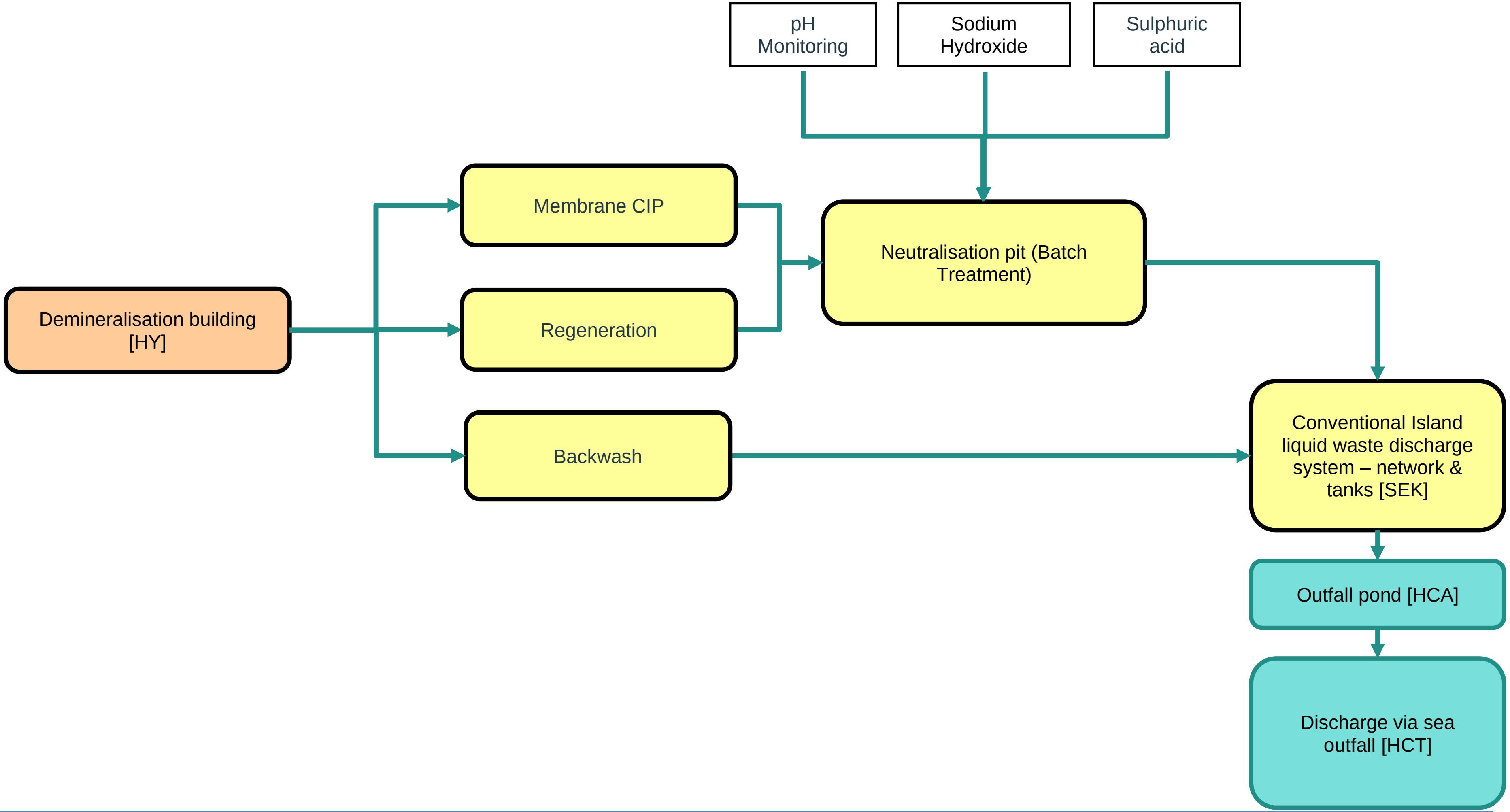


Figure 2.3.7 Effluent Stream G- Domestic sewage

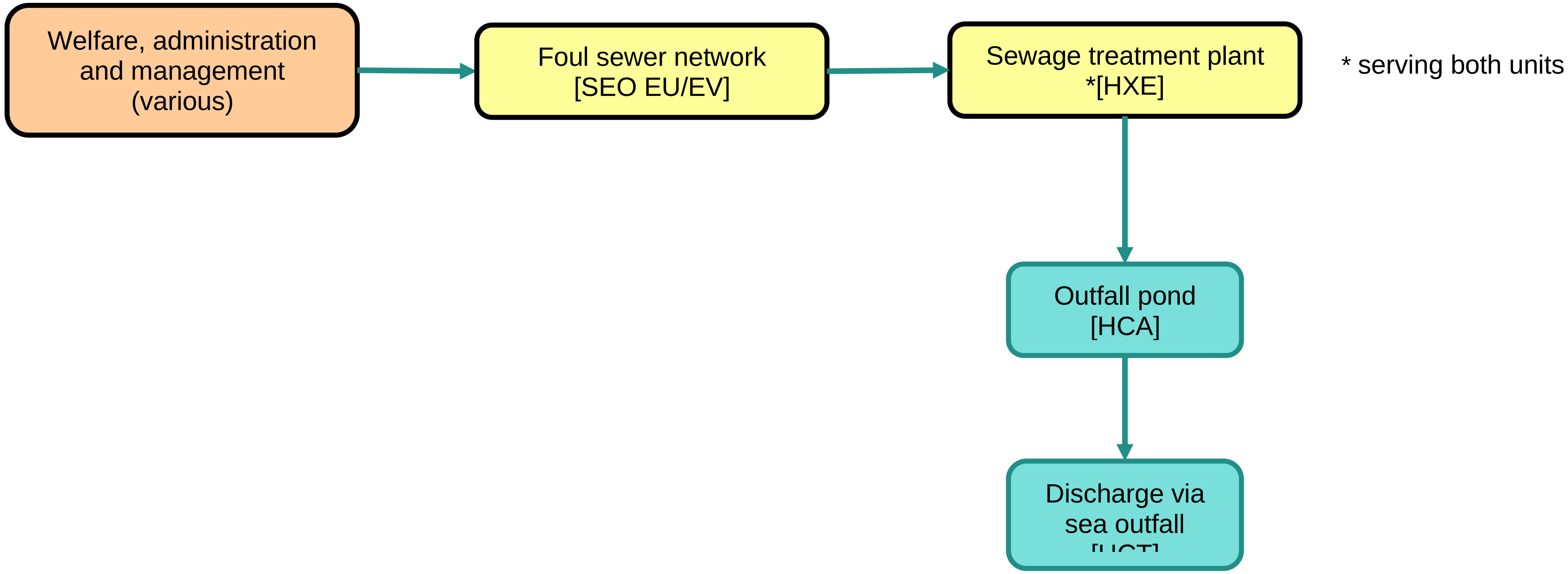


Figure 2.3.8 Effluent Stream H- Fish recovery and return system

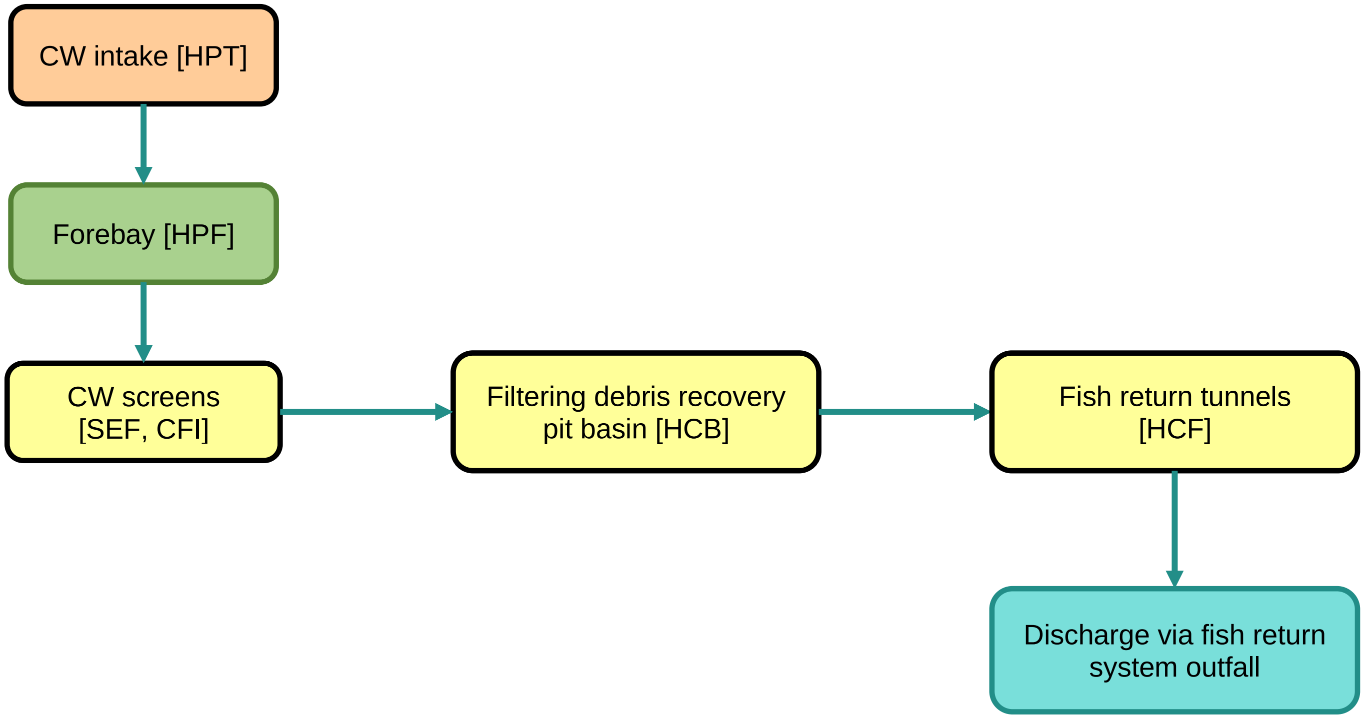


Figure 2.4.1 Typical EPR™ unit

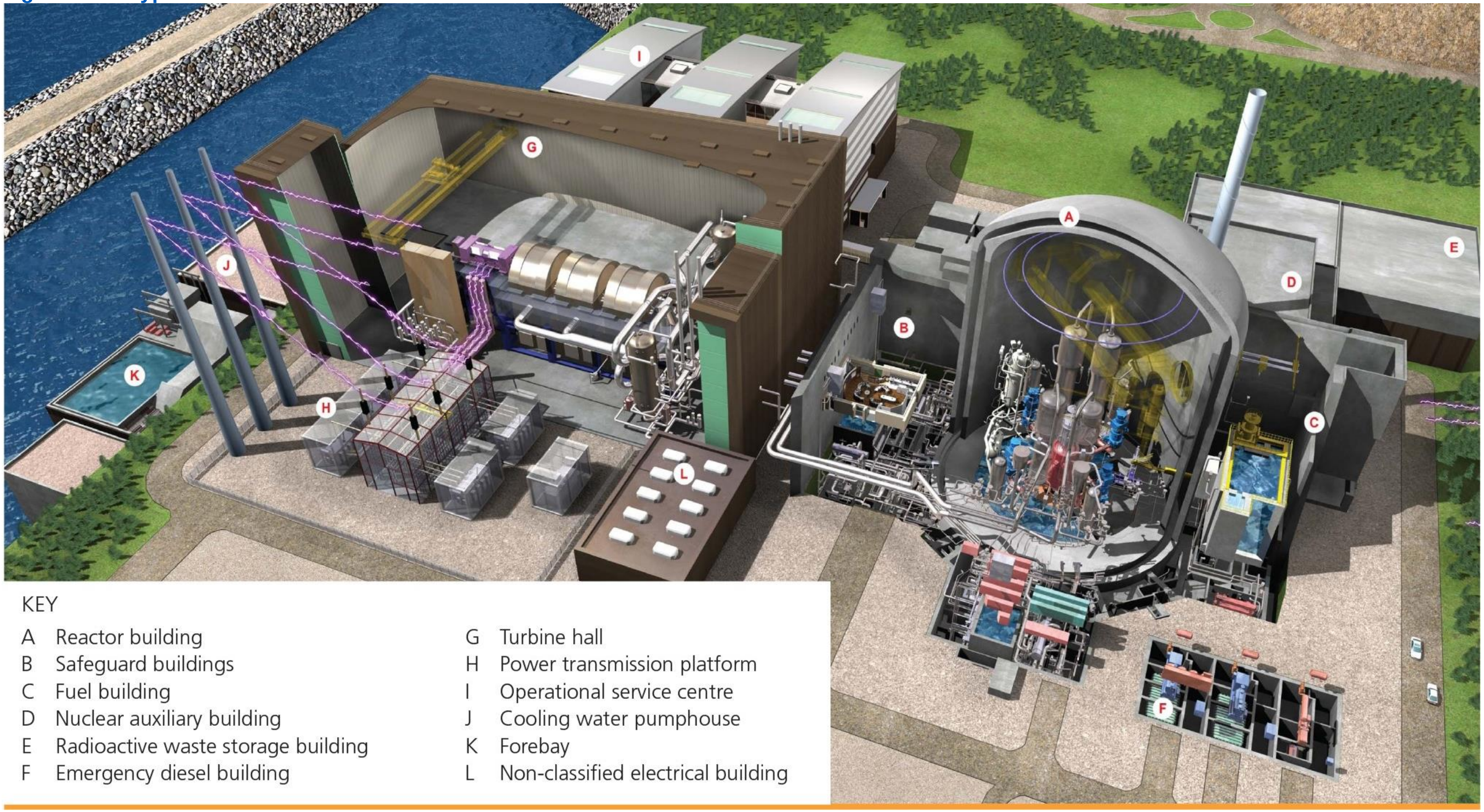


Figure 2.5.1 Schematic of water intake and outfall arrangements

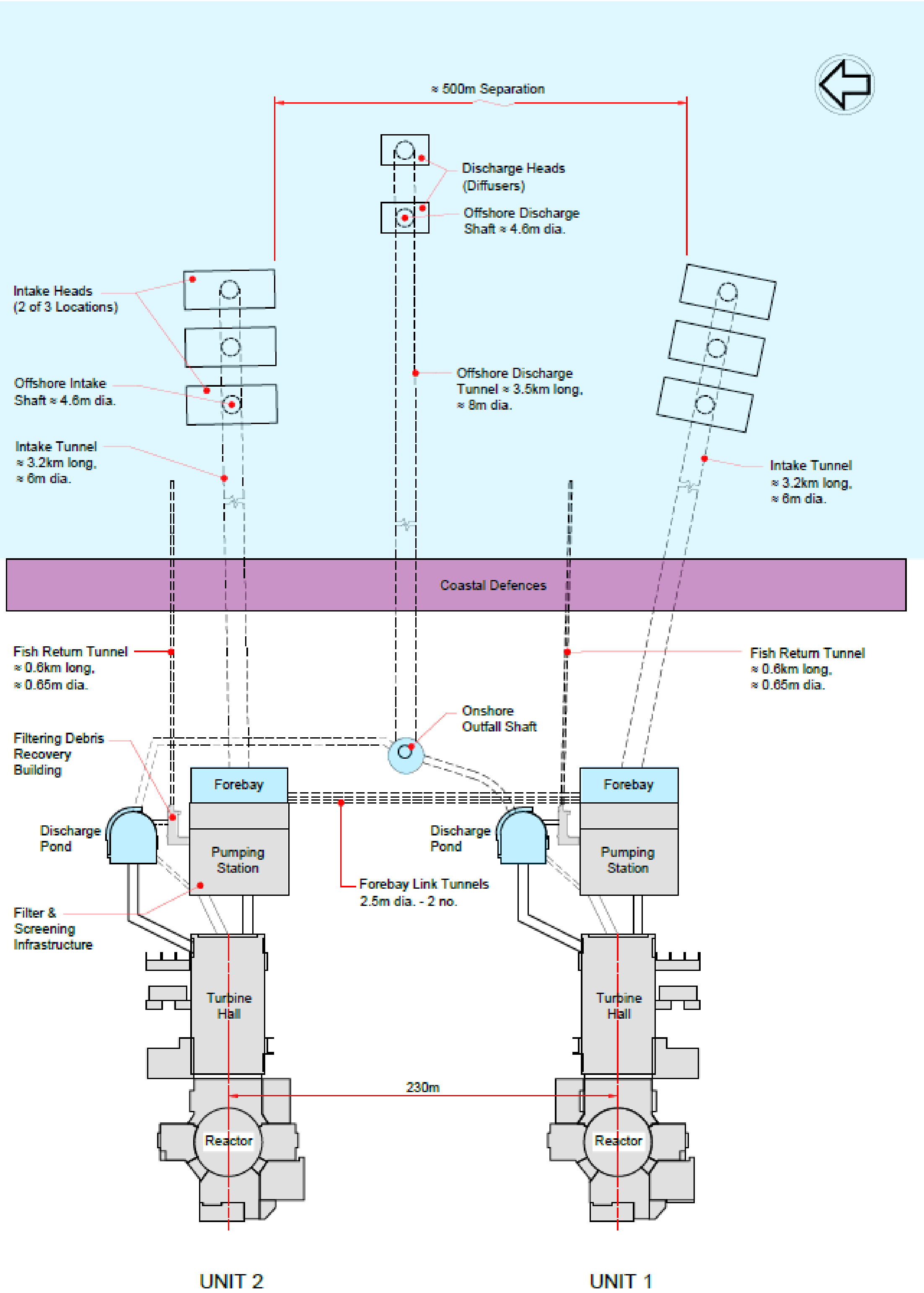


Figure 2.5.2 Cross section of water outfall structure

Figure 4.2.1 Indicative positions of proposed monitoring points

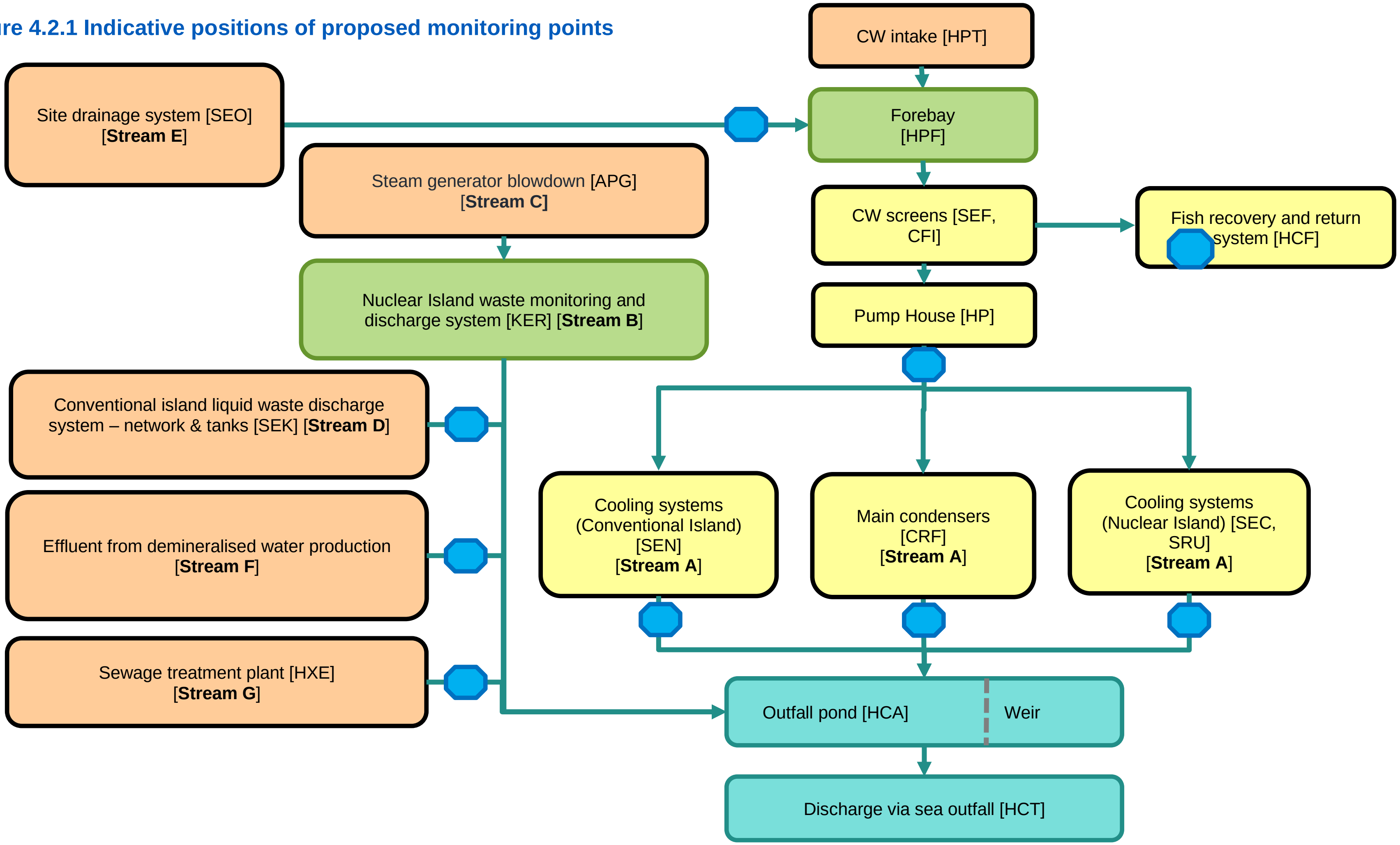


Figure 5.2.1 Location of designated sites in relation to Sizewell C development

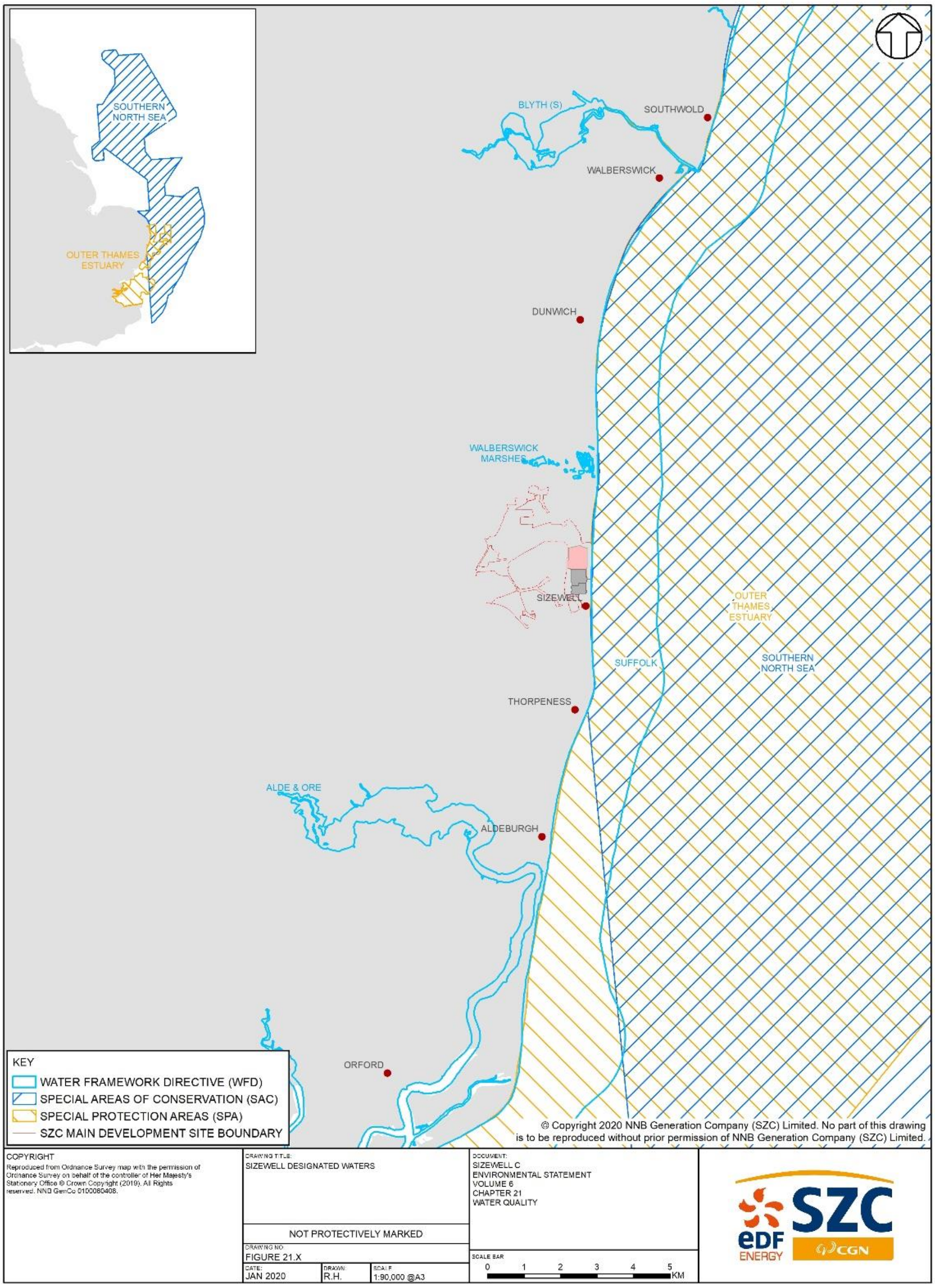


Figure 5.4.1 Location of the BEEMS sampling sites in the 2010 Sizewell water quality monitoring programme.

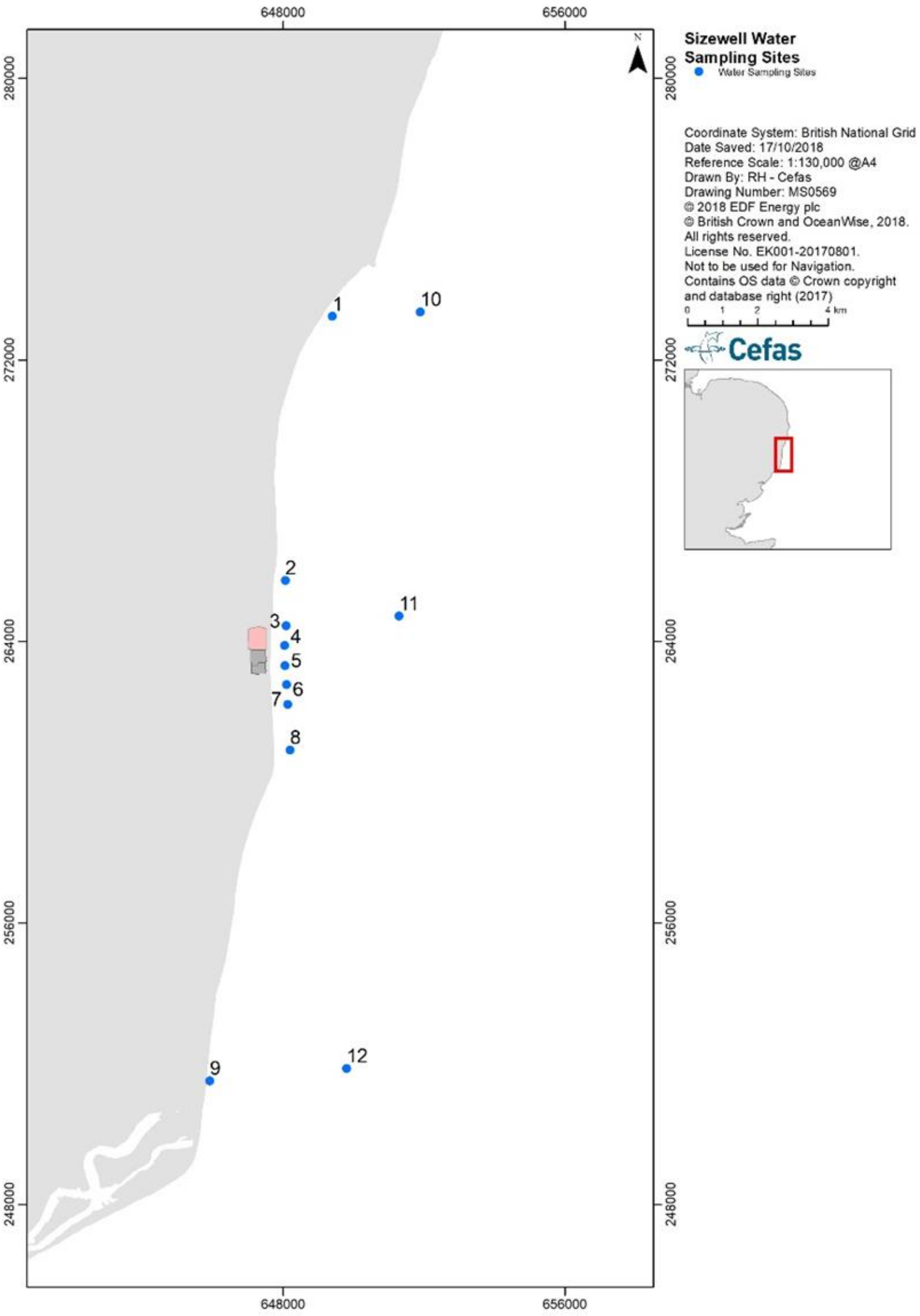
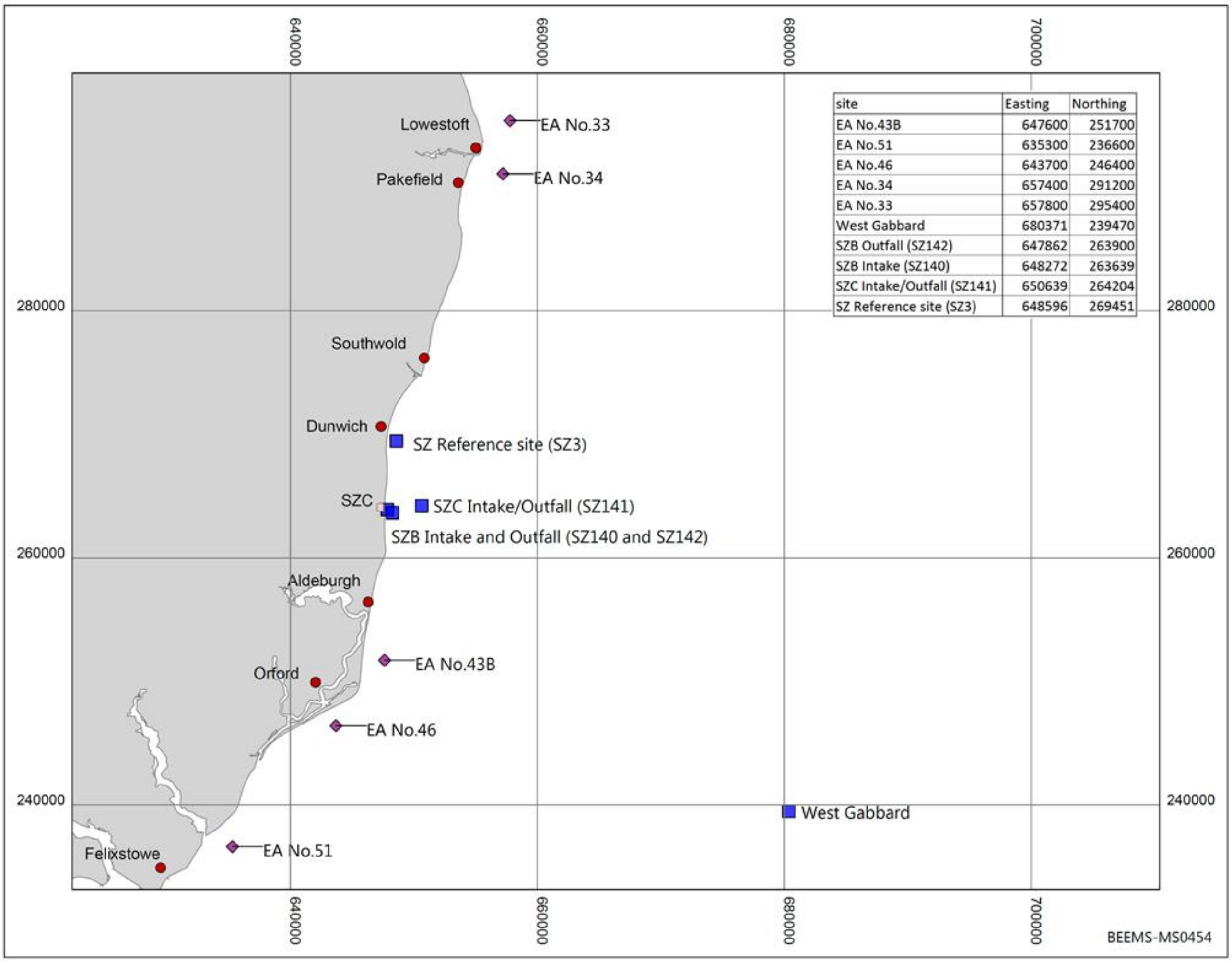


Figure 5.4.2 Location of sampling sites for water quality monitoring 2014/15 Sizewell sampling stations in 2014 and 2014 (SZ), Environment Agency WFD monitoring sites (Environment Agency), and the West Gabbard mooring site.



site	Easting	Northing
EA No.43B	647600	251700
EA No.51	635300	236600
EA No.46	643700	246400
EA No.34	657400	291200
EA No.33	657800	295400
West Gabbard	680371	239470
SZB Outfall (SZ142)	647862	263900
SZB Intake (SZ140)	648272	263639
SZC Intake/Outfall (SZ141)	650639	264204
SZ Reference site (SZ3)	648596	269451

Figure 5.5.1 Position of Sizewell C 2015 vibrocore sampling stations from the geotechnical survey and selected cores from which samples were taken for chemical analysis in relation to Sizewell C infrastructure.

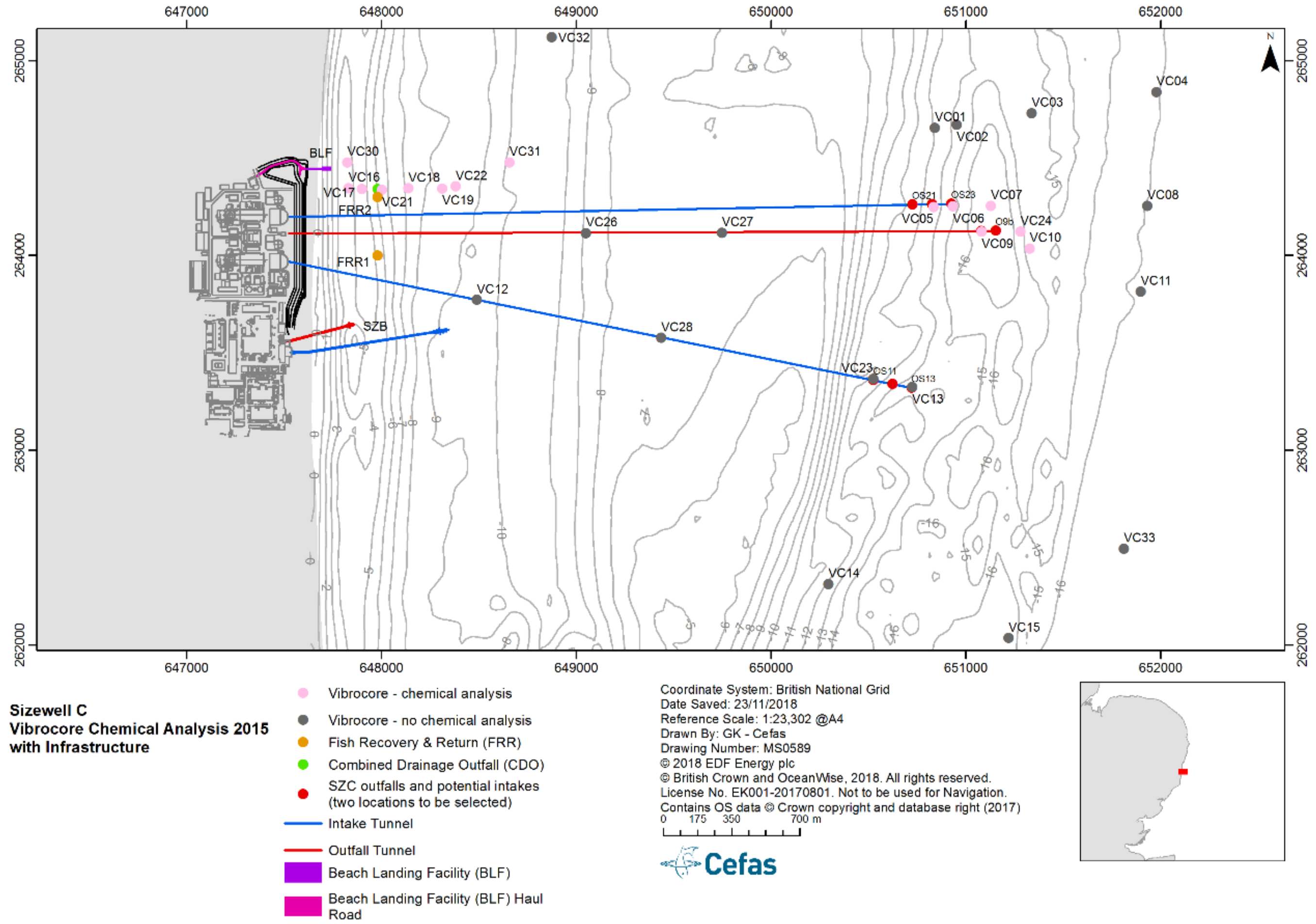
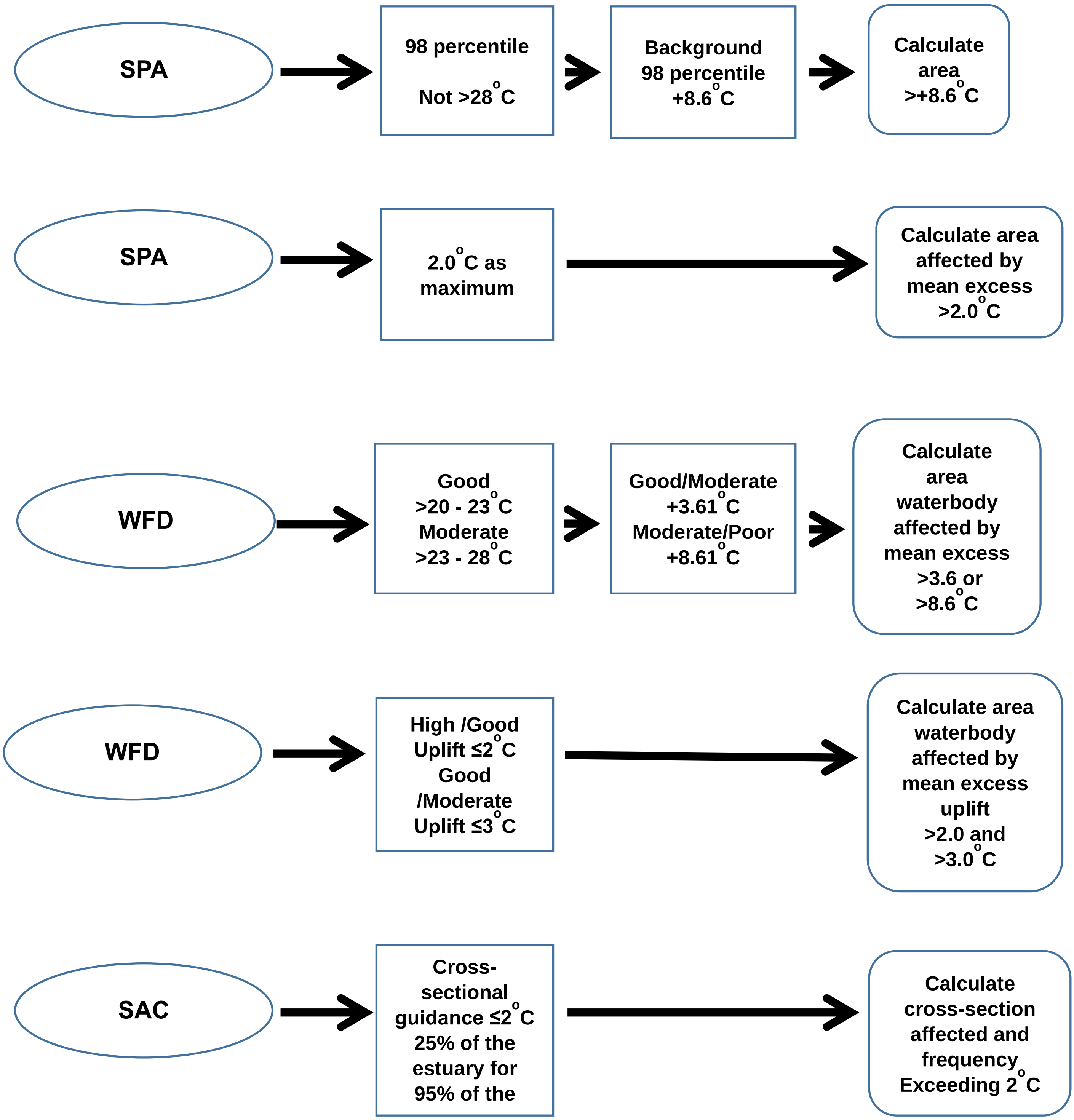


Figure 5.9.1 Assessments made against temperature standards using both models



Appendix B H1 Screening Assessment

Appendix C Information for the Habitats Regulations Assessment

Appendix D WFD Compliance Assessment

Appendix E Supporting Information

A list of documents to support this Water Discharge Activity Application can be found in the following references:

- [2] NNB Generation Company (SZC) Ltd, Company Manual.
- [53] EDF BEOM 006 Control of Marine Fouling.
- [57] Anglian Water Pre-Planning Assessment Report PPE-0074925.
- [58] BEEMS TR131 Water Quality Literature.
- [59] BEEMS TR189 Marine Water Quality.
- [60] BEEMS TR314 Marine Water Quality (Supplementary Water Quality Monitoring Data 2014/2015).
- [76] BEEMS TR346 Sizewell Characterisation Report – Phytoplankton.
- [77] BEEMS TR311 Ed.4. Sizewell Coastal Geomorphology and Hydrodynamics: Synthesis for Environmental Impact Assessment (MSR1/4). 2020.
- [79] BEEMS TR473 Coralline Crag Characterisation. Cefas. Lowestoft.
- [81] BEEMS TR431 SPA/SAC Features and Marine Prey.
- [83] Review of Maximum Chemical and Radiochemical Discharge and their Limits During Operation.
- [85] BEEMS TR302 Thermal Plume Modelling: GETM Stage 3.
- [86] BEEMS TR301 Sizewell Thermal Plume Modelling: GETM Stage 2 (Model Results with Initial Cooling Water Configurations, Suitable Reference or Comparison of Hydrodynamic Models).
- [89] BEEMS TR306 Marine Synthesis MSR2/2.
- [92] BEEMS TR387 Investigation of Hydrazine Toxicity.
- [109] BEEMS TR385 Modelling Effects of Phytoplankton.
- [112] RHDHV Sizewell C Eels Regulation Assessment.

- [113] NNB Generation Company (SZC) Ltd, Management System Manual.
- [114] NNB Generation Company (SZC) Ltd, Quality Policy.

Appendix F Application Forms